

### III. AUTONOMOUS BODIES

#### III-A. COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH

##### 1. INTRODUCTION

During the Tenth Five Year Plan (TFYP), CSIR experimented a model in which resources available with various laboratories were pooled together to achieve technological excellence. CSIR conceptualized and implemented 56 such network projects during Tenth Plan. Being the terminal year of TFYP, majority of the network projects have been completed successfully however some projects are permitted to spill over for a year or two into the Eleventh Five Year Plan for their completion.

Research on the fundamental or basic aspects of science is not only the major source of advancement of knowledge in science but it also provides the building blocks for development of newer generic technologies for the future. CSIR continuously upgrades its core competencies and plans new research areas to lead the S&T developments primarily within the country and occasionally abroad. Its area of influence encompasses aerospace science & technology, modern biology and biotechnology, chemistry, geophysics, oceanography, materials science, etc.

CSIR is not only the flag bearer of India's S&T processes but contributes significantly in developing research manpower through inducting thousands of young students to carryout their research programmes in its laboratories. Many of its scientists have continued to contribute in shaping India's S&T policy initiatives in diverse science domains.

The following sections record some of the significant achievements of CSIR during the

year. Many achievements have resulted from the projects carried out under 'network' mode which essentially means a group of three or more synergistically linked laboratories working on one single R&D projects having shared or common objective or outcome.

##### 2. S&T CONTRIBUTIONS

###### 2.1 AEROSPACE SCIENCE & TECHNOLOGY

CSIR is a major player in India's aerospace programmes. Its constituent laboratory, NAL, Bangalore has developed a world class capacity for design, development and fabrication of large components of advanced composites for civilian and combat aircraft, structural testing and analysis, aerospace electronics and systems, innovative capabilities in surface engineering etc. The activities are focused on design, development, fabrication and airworthiness, testing of small civilian aircraft and on creating, maintaining and providing expertise and test and certification facilities.

###### Scientific & Technological achievements

###### *Flight Testing of SARAS Aircraft*

The first SARAS prototype aircraft (PT1) VT-XSD completed 56 test flights during the year (total 106 successful test flights so far). Basic handling qualities, Pressure Error Correction (PEC) test data, Parameter Identification Data (PID) test data, climb performance data etc., have been obtained and evaluated.



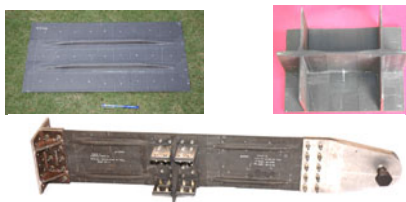
*100<sup>th</sup> flight of SARAS(PT1)*

The second SARAS prototype aircraft (PT2) VT-XRM has been fully integrated and has successfully completed low speed and high speed taxi trials. 100<sup>th</sup> flight of SARAS (PT1) at the AeroIndia 2007

### ***Vacuum Enhanced Resin Infusion Technology***

NAL has developed a Vacuum Enhanced Resin Infusion Technology (VERITY) process for advanced composites manufacturing. An aircraft wing using this new process would result in a weight saving of about 10% on the optimized metallic wing with a cost reduction of about 20%. Some of the advantages of the VERITY process are: relatively low cost for low volume production (significant reduction in cost when compared to autoclave-moulding cost), eliminates the need for clean rooms and expensive cold storage facilities (-18°C).

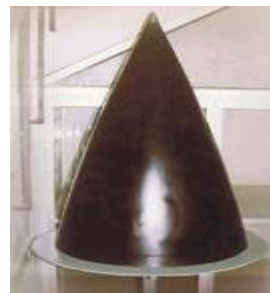
A Test box (2.3mx1.2m) has been designed to prove the VERITY process and testing the skin and spar splices with closely simulated conditions as well as to verify the adequacy of the sealing mechanism for the inter spar box joints (integral fuel tank area) and access covers. Some of the components made out of VERITY process are displayed below.



*Skin Splice Parts and Assembly*

### ***Rapid resin injection moulding technology***

Another novel and cost effective technology developed by NAL is for the rapid resin injection moulding process. Flight-worthy nose radomes for Jaguar fighter aircraft have been designed, developed and fabricated by NAL for Hindustan Aeronautics Ltd. (HAL) / Indian Air Force (IAF) incorporating the above technology. These radomes are further qualified to the stringent military specifications and have been cleared as flightworthy. This has given an insight into the intricacies of composite radome engineering and has created base for indigenizing the requirements of IAF for other fighter aircrafts. This competence is being used to propose development of an indigenous radome for SU 30 fighter aircraft.



*Nose Radome for Jaguar Aircraft*

### ***Ceramic thermal barrier linings***

For providing ceramic thermal barrier lining for strategic applications on axi-symmetric metal components NAL has developed a novel technique using exothermic reactions under the effect of centrifugal force. This process makes the material immune to corrosion and erosion. The lining helps the material to withstand high temperatures of the order of 3000K. Another spin-off of the technique is the zirconia based ceramic insert, which has been developed for rocket thrusters. This near-net shaped casting has good thermal shock resistance & high temperature hardness. This technology is of a great strategic value for rocket and missile applications.



*Thermal barrier lining to steel pipe*

### ***NAL Visualization and Animation Software (NALVAS) software***

Another notable achievement from NAL is a software for incident and accident analysis of aircrafts along with the routine flight data analysis, which is a mandatory activity as per Director General of Civil Aviation for every scheduled airline. The tool unfolds the actual behavior of aircraft during flight in terms of events, exceedances and limits visually instead of numbers and figures. The use of this software greatly enhances the air safety and mandatory quality assurance requirements. NALVAS is a configurable windows concept which can be configured the way user would like to see the windows during operation.



***NALVAS showing the capability for aircraft models with ILS operation***

## **Progress made under Network projects**

Some of the significant achievements detailed project-wise are:

### **I. Catering to specialised aerospace materials**

The objective of the project is to formulate and execute a structured programme on development and characterization of different specialized aerospace materials and to provide materials related technological services to aerospace organizations.

Convergent-Divergent nozzles used in strategic application have been lined with ceramics capable of withstanding temperature of 1600 to 1800°C. The nozzles have been tested in the Defence R&D Laboratory (DRDL) test bed and the performance of the coated nozzles was excellent. The nozzle did not show any damage even after 22 seconds of firing (against a target of 20 sec) and there was no significant pressure loss for the entire duration of the firing. Pressure sensitive paints for measurement of the air pressure distribution over models during wind tunnel testing developed by NAL have successfully withstood endurance of over 50 blowdowns without any change in their sensitivity.

Billets of Mg-Al-Zn (AZ31) and Mg-Re-Zn-Zr (L126) alloys with size of 70mm dia and 50 mm height were fabricated using spray forming technique. These billets have shown excellent compositional uniformity, low porosity and good mechanical properties.

A major development is the establishment of a state-of-the-art failure analysis laboratory which facilitates failure investigations for IAF, Aerospace industries and Defence R&D labs. It has helped in providing critical data on failure investigations and courts of enquiry. Incidentally NAL has completed the

1000<sup>th</sup> failure investigation during the current year.

## II. High science & technology for national aerospace programmes

The main objectives of this programme are to enhance the capabilities for generating crucial design and certification data for aerospace systems; to enhance the knowledge base through R&D activity for increased self-reliance and freedom; and build up new and critical facilities in the area to minimize dependence on foreign test facilities.

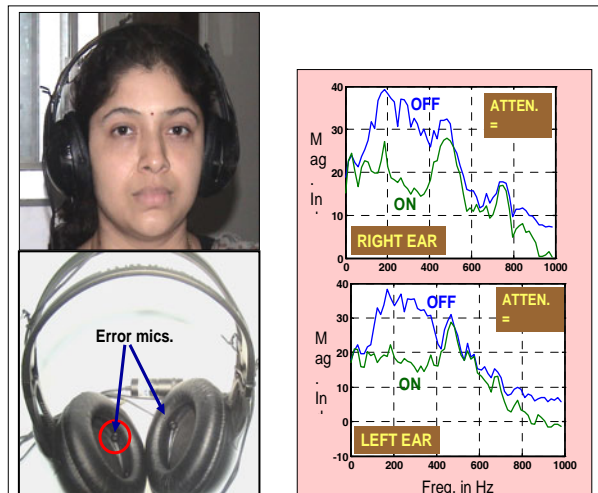
**Aerodynamics:** Aerodynamic data has been generated on hypersonic research vehicle / its components. The most significant achievement is development of hardware for study of multi jet interaction on after-body drag. The readiness for tethered flight of Remote Controlled (RC) Blimp at Aerial Delivery Research and Development Establishment, Agra has been tested.

**Aerospace propulsion and energy Systems:** Detailed component drawings/manufacture of components and critical design review for Wankel engine has been carried out. components have been designed and fabricated for 10 kW gas turbine. A national Test Facility for Rolling Element Bearings is being setup.

**Aerospace structures and materials:** Sources have been located for manufacture of components for autoclaves and related accessories for demonstration of adaptive wing technology. A customised un-balanced magnetron sputtering system has been commissioned. Hard nano layer coatings were done on sample cutting tools.

**Aerospace electronics, controls and systems:** Active Noise Control (ANC) for *Tejas* combat aircraft cockpit has been developed.

The *Tejas* aircraft cockpit and the helicopter cabins have serious problem of high noise levels. It affects health of the pilot and also causes inconvenience in communication. Algorithms, used for the active noise control, play a very crucial role reducing the noise level in the active noise control systems used. NAL has designed and developed hardware and software (algorithms) for addressing this problem and noise reduction of 15 dB has been successfully achieved in the head phones of pilots. This work is being attempted to a full aircraft and active noise control is being attempted for the fighter aircraft cockpits and helicopter cabins.



*Head set with active adaptive noise control for broadband noise*

## III. Spearheading small civilian aircraft design, development & manufacture

The main objectives of the project are to design and develop stretched HANSA; civil aircraft R&D; indigenous development of critical Line Replaceable Units (LRUs) with particular relevance to small aircraft; and weight optimization and other improvements of SARAS to production standards.

An MoU has been signed with M/s Mahindra Plexion Technologies, Bangalore for joint development of 4-seater HANSA aircraft.



Also a contract has been signed with M/s. Honeywell Technologies, Bangalore for the joint development of digital autopilot for the SARAS aircraft.

The design review for nose and main landing gears for the production version of SARAS have been carried out. A number of components were manufactured for the landing gear actuators.



*Parts manufactured for the landing gear actuators*

The first phase of optimization of nacelle, stub wing and engine mount has resulted in a weight reduction of around 30kg

Three engines (PT6A-67A) with a power rating of 1200 SHP at 1700 RPM have been procured from M/s. Pratt and Whitney, Canada. In addition, four pusher propellers rated at 1200 SHP at 1700 RPM were procured from M/s. MT Propeller, Germany. The 120 hrs of endurance tests for this Propeller-Engine combination, for certification as per JAR-33 regulations, were completed successfully in an engine ground test bed located at NAL. A flow computational programme for a transport aircraft in flight has been jointly worked out by NAL and the Cambridge University.



*Head set with active adaptive noise control for broadband noise*

## 2.2 Biology & Biotechnology

CSIR has emerged as a leading public funded R&D agency with many of its laboratories contributing significant R&D outputs and technologies in the areas of genomics, proteomics, molecular biology, immunology, bio markers, bio molecules etc. Some of the major accomplishments are provided below.

### Scientific & Technological Achievements

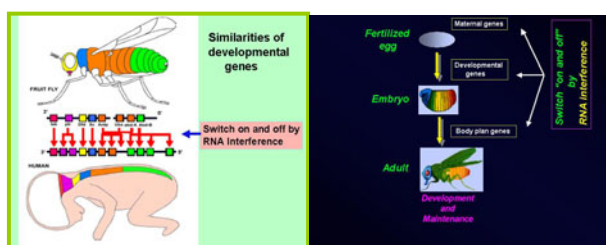
#### *Engineering of host-defense antibacterial peptides as therapeutic agents*

CCMB has investigated the antibacterial activities of synthetic human  $\beta$ -defensin analogs, constrained by a single disulfide bridge and in the reduced form. The peptides span the carboxy-terminal region of human  $\beta$ -defensins HBD-1-3, which have a majority of cationic residues present in the native defensins. The disulfide constrained peptides exhibited activity against *Escherichia coli* and *Staphylococcus aureus*, whereas the reduced forms were active only against *Escherichia coli*. The antibacterial activities were attenuated in the presence of increasing concentrations of NaCl and divalent cations such as  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ . The site of action was the bacterial membrane. A 13-residue peptide present in mammalian neutrophils, which has both antibacterial and hemolytic activities, has been engineered so that only antibacterial activity is exhibited by the modified peptides.. Since this research has important impact in the development of antibacterial peptides as therapeutic agents, a US patent has been secured.

#### *Role of RNAi for animal development*

CCMB & IICT has, jointly, unraveled the molecular mechanism associated with developmental abnormality in *Drosophila*, which is required for dynamic chromosome

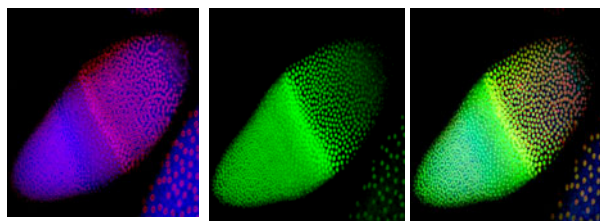
movement. This abnormality causes various birth defects and most common cancer including brain tumor and other fatal neuro-degenerative diseases. The normal function of several genes eliminates irreparable abnormalities. A genetically well-developed model system- fruit fly- was compared to understand the fundamental relationship of different developmental and segmentation genes which are conserved in all animals including mice, flies and human. It has been demonstrated that RNAi-based silencing machinery is required for establishment and maintenance of silencing state of different segmentation genes and developmental regulators. It is proposed that RNAi plays an immense and novel role in guiding complex animal formation during development and eliminate several fatal diseases in embryo. Further results show that preferential switch “on and off” of different developmental genes is controlled by RNAi machinery. In future, this might help to repair different birth defects by controlling the RNAi machinery. It paves a new beginning for generating different types of RNAi-based therapies for birth defects.



### ***Genomic packaging and nuclear architecture***

Eukaryotic genomes carry complex set of regulatory elements that control the genes to allow developing and functioning of such organisms. A key feature of this regulatory process is that packaging of the genome itself has influence on expression of genes. CCMB has characterized components of nuclear matrix at molecular level. Among the proteins of the nuclear matrix a protein has been

identified, known as boundary- element-associated factor (BEAF) earlier known to be the component of chromatin domain boundary. One of the major unsolved problems in this field is how genome is repackaged after every cell cycle in such a way that global expression state is maintained and how cells remember the epigenetic state in absence of early developmental regulators? It has been shown that BEAF remains associated with the genome even after the nuclear envelop has disintegrated. Further it has been shown that BEAF remained associated with various mitotic components suggesting a link between genomic packaging and nuclear architecture that can serve as structural platform for epigenetic memory. It is known that loss of such memory can lead to variety of disease situations, including cancer.



Early *Drosophila* embryo stained for genome packaging protein, BEAF (green), DNA (blue) and nuclear envelop component, lamin (red). The embryo shows mitotic wave going from left to right showing that in the regions where lamin has disappeared, BEAF still remains associated with the genome. Left picture shows DNA and lamin, middle one shows BEAF and the right one shows a merged image of embryo

### ***Unprecedented SnCl<sub>2</sub>-mediated cyclization of Nitro Arenes via N-N bond formation***

CDRI has developed a mild, efficient, and one-pot protocol for the intramolecular cyclization of nitro arene substrates using SnCl<sub>2</sub>. The mechanistic course suggests involvement of a hydroxylamine intermediate for cyclization via N-N bond formation. The

versatility of the methodology has been demonstrated by using two nitro arene substrates derived from dihydroisoquinolines and dihydro-beta-carbolines. The intramolecular cyclization led to the formation of indazoles in high yields and purity. The methodology may find wide application in synthesis of heterocyclic compounds using a suitable molecular framework.

#### ***CLIV-92, the hepatoprotective phytochemical***

CIMAP has tested CLIV-92 a hepatoprotective molecule, for its effect on the pro and anti-inflammatory cytokines. Pro-inflammatory mediators (IL-6, TNF- $\alpha$  and nitric oxide) were significantly inhibited in dose dependent manner when compared with macrophages stimulated with LPS alone ( $P < 0.05$ ). Whereas, the anti-inflammatory cytokine (IL-4) productions from splenic lymphocytes culture supernatant were found to be enhanced in mice administered with CLIV-92 when compared with Con-A alone ( $P < 0.05$ ). These results suggest that CLIV-92 can augment the protection of liver stressed by the intake of chemotherapeutic agents by inhibiting the expression of pro-inflammatory cytokines.

#### ***CIM-Sujal: high yielding variety of fennel***

CIMAP has developed the cultivar CIM-Sujal of fennel *Foeniculum vulgare* through intensive breeding efforts for high yield of seeds and essential oil of better quality. Fennel family 'Apiaceae' is important for its seeds and essential oil. Seeds are used to flavour liquors, vinegars, breads, pastries, candies and pickles. Leaves and stems serve as vegetable, salad or potherb. Essential oil is used in culinary articles, cordials and toilet articles. Besides above, it is also used in Indian, Folk and Unani systems of medicine as abortifacient, carminative, cardio tonic,

stimulant, vermicide, lactagogue, etc. The seeds are also regarded as aromatic, carminative, emmenagogue, and stimulant and stomachic almost anywhere the spices are encountered. Variety CIM-Sujal consistently shows high seed and oil yield in all field evaluation yield trials. The average seed and oil yield of this variety is about 9.73 quintal and 22.87 kg/ hectare respectively with high t-anethole content (75-80 %) and low fenchone content (8.08 %), respectively. The variety will find direct utility in herbal preparations and nutraceuticals in addition to its spice value and also as a source of anethole for industrial cultivation.

#### ***Aloe vera based all-purpose cream***

An effective all purpose skin care cream formulation named H Aloe Skin developed and released by CIMAP. The cream possesses wound healing and anti fungal properties and can also be used to cure cracks in heels, chapped hands and dry skin. It is a herbal formulation, derived from age-old traditional skin recipe from a plant extract that is known for its healing activity and an essential oil, which has shown a promising anti fungal activity. The cream is pharmaceutically more elegant because it contains water washable cream base in order to give a smooth and soft feeling on application. The technology is available to industry for its commercial exploitation.

#### ***Effect of altitude on primary products of photosynthesis***

IHBT has reported for the first time a change in primary products of photosynthesis and the associated enzymes with change in altitudes that could have functional advantages at high altitude (HA). There is not much information available on the primary products of photosynthesis and the change in the activity of the associated enzymes with altitude.

Varieties of barley and wheat grown at 1300m (low altitude, LA) and 4200m (HA) elevations above mean sea level in the western Himalayas were studied. Plants at both the locations had similar photosynthetic rates, leaf water potential and the chlorophyll fluorescence kinetics. The short-term radio-labelling experiments in leaves showed appearance of  $^{14}\text{CO}_2$  in phosphoglyceric acid and sugar phosphates in plants at both the LA and HA, suggesting a major role of ribulose-1,5-bisphosphate carboxylase/oxygenase (Rubisco) in  $\text{CO}_2$  fixation in the plants at two altitudes, whereas the appearance of labelled carbon in *aspartate* (*Asp*) and *glutamate* (*Glu*) at HA suggested a role of *phosphoenolpyruvate carboxylase* (PEPCase) in photosynthesis metabolism. Plants at HA had significantly higher activities of PEPCase, carboxylase and oxygenase activity of Rubisco, *aspartate aminotransferase* (*AspAT*), and *glutamine synthetase* (*GS*). However, the activities of *malate dehydrogenase*, NAD-malic enzyme and citrate synthase were similar at the two locations. Such an altered metabolism at HA suggested that PEPCase probably captured  $\text{CO}_2$  directly from the atmosphere and/or that generated metabolically e.g. from photorespiration at HA.

#### ***New cultivar of Curcuma aromatica (HIMHALDI)***

Yet another development of significance for hilly regions is the development of a new cultivar of *Curcuma aromatica* "HIMHALDI" by IHBT suitable for cultivation in western Himalaya at locations above 1300m altitude. The rhizome is light yellow (internally orange red) in colour and possesses a camphoraceous odour. *C. aromatica* is some times used as substitute of turmeric but not as a condiment. *Curcuma aromatica* has vast ethnobotanical value, already known in India as tonic, carminative,

antidote to snake bite, astringent and used for bruises, corns and sprains. HIMHALDI is raised by planting rhizomes. Plant is distributed in the Himalaya at 1000-2500 m altitude. On an average 200 kg oil/ha is produced from 60 ton raw material (fresh rhizomes) after two years. Total cost of production/ ha (for two years) is Rs.70,000 – 1,00,000 / ha. Net returns per ha (after two years) are in the range of Rs.35,000 – 45,000/ ha. Benefit cost ratio (BCR) is 1.39.



#### ***Popularization of Alstroemeria***

*Alstroemeria (Alstroemeria hybrida)* is an exotic high value cut flower crop. IHBT has standardized agrotechniques including nutrition requirement, plant spacing, time of planting, method of propagation, method of planting, impact of shoot thinning, irrigation etc. for flower production for Himachal Pradesh and other hill states. Agrotechnologies for cut flower as well as planting material production have been transferred to growers through training and demonstration plots. Three demonstration plots were set up, each at Kangra and Kullu district and IHBT. Growers are earning good returns by sale of alstroemeria flowers in domestic flower markets.

#### ***LeishMan topoisomerase I - an unusual enzyme***

The active site tyrosine residue of all monomeric type IB topoisomerases resides in the C-terminal domain of the enzyme.



*Leishmania donovani*, possesses unusual heterodimeric type IB topoisomerase. The small subunit harbors the catalytic tyrosine within the SKXXY motif. To explore the functional relationship between the two subunits, IICB has replaced the small subunit of *L. donovani* topoisomerase I with a C-terminal fragment of human topoisomerase I (HTOP14). The purified LdTOP1L (large subunit of *L. donovani* topoisomerase I) and HTOP14 were able to reconstitute topoisomerase I activity when mixed in vitro. This unusual enzyme, 'LeishMan' topoisomerase I (Leish for *Leishmania* and Man for human) exhibits less efficiency in DNA binding and strand passage compared with LdTOP1L/S. Fusion of LdTOP1L with HTOP14 yielded a more efficient enzyme with greater affinity for DNA and faster strand passage ability. Both the chimeric enzymes are less sensitive to camptothecin than LdTOP1L/S. Restoration of topoisomerase I activity by LdTOP1L and HTOP14 suggests that the small subunit of *L. donovani* topoisomerase I is primarily required for supplying the catalytic tyrosine. Moreover, changes in the enzyme properties due to substitution of LdTOP1S with HTOP14 indicate that the small subunit contributes to subunit interaction and catalytic efficiency of the enzyme. Engineering of a hybrid 'LeishMan' topoisomerase I, from *Leishmania* and human is an ideal chimera for drug development.

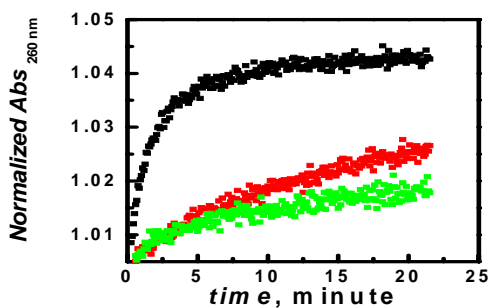
#### ***Interaction between IL1B gene promoter polymorphisms***

It has been speculated that IL-1 genes play a crucial role in the genetic predisposition to duodenal ulcer upon *H. pylori* infection by

modulating the host immune response. IICB has studied 310 individuals from Eastern India to determine the IL1B and IL1RN risk genotypes to *H. pylori* mediated duodenal ulcer. An analysis of genotype frequency revealed a significantly higher frequency of genotypes in *H. pylori*-infected individuals with duodenal ulcer compared to infected individuals with normal mucosa. Quantitative analysis of the mucosal IL1B mRNA revealed that among *H. pylori*-infected individuals, carriers of the -31CC genotype had significantly lower IL1B transcript levels than carriers of the CT (P<0.001) and TT (P<0.001) genotypes, independently of disease status. The results also show that *H. pylori*-infected individuals with the -31CC genotype secrete less IL1B and are susceptible to duodenal ulcers. It has been further suggested that the allelic interaction between the -511 and -31 polymorphic sites determines the overall strength of the IL1B promoter.

#### ***Water soluble nanoparticles from PEG-based cationic hyper branched polymer***

The research involving RNA molecules faces a practical limitation, since RNA is highly labile. IGIB has developed a novel method to protect RNA from cleavage by complexing it with a hyper branched cationic polymer. The property of total cellular RNA isolated from yeast to form a spherical nano particle morphology was used. This interaction protects the RNA against enzymatic degradation, and hence can be easily adapted for long-term storage of RNA, long distance transfer of RNA, and genetic engineering using RNA as a building block.



*RNase digestion assays for native RNA (black), HP/RNA complexes at Z<sup>±</sup> 3 (red) and 5 (green).*

### ***Genome-wide prediction of G4 DNA as regulatory motifs: Role in Escherichia coli global regulation***

IGIB has established the role of DNA structure in transcription on a genome-wide scale using the *G-quadruplex* (G4 DNA) motifs as a model. Analysis of more than 61,000 open reading frames (ORFs) across 18 prokaryotes have shown the enrichment of G4 motifs in regulatory regions and indicates its predominance within promoters of genes pertaining to transcription, secondary metabolite biosynthesis, and signal transduction. Therefore, it has been predicted that G4 DNA may present regulatory signals, and induce the super coiling sensitivity for >30 operons in *E. coli*, implicating G4 DNA in DNA-topology-mediated global gene regulation in *E. coli*.

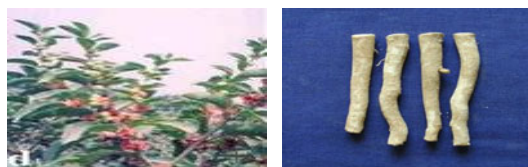
### ***Recombinant human epidermal growth factor: from bench to bedside***

A renaissance in the study of biology of wound-care by IGIB has led to the development of a range of advanced genetically tailored therapeutic products like growth factors. The epidermal growth factor, produced by salivary glands, enhances healing of diabetic foot ulcer, which is a major complication of diabetes. People with diabetes show a 5 to 50 fold higher risk of non-traumatic amputation compared with non-diabetics. In general, diabetic foot ulcers are

difficult to heal, become readily infected & gangrenous and frequently lead to amputation. Through a public-private partnership between IGIB, Delhi and BBIL, Hyderabad, two important formulations have been commercialized: one as a brand name Regen-D™ -60 for skin graft and burn injuries, while the other, Regen-D™ -150, for diabetic foot ulcer.

### ***New variety of withania somnifera***

A new variety of *Withania somnifera* designated as NMITLI 002 which is both genetically and chemically stable has been developed by IIIM. The root and leaf biomass produced by this high yielding variety is 8-10q/ha and 16-17q/ha, respectively. From multilocational trials at two varied locations that is Jammu and Bhopal, it has been established that this variety can adapt to varied environmental conditions and is stable in terms of both root yield as well as *withaferin A* content. Chemical consistency of the genetically pure lines developed from this variety has been established on the basis of ten bioactive markers. Pharmacological activities (Immunomodulatory and anticancer) of roots and leaves of this variety indicate high promises of yield.



*Leaf and root of new variety of Withania somnifera*

### ***Piperine, a phytochemical potentiator of ciprofloxacin against staphylococcus aureus***

In a trial conducted at IIIM, piperine which was earlier reported, as *P-glycoprotein* inhibitor has been found to act as bacterial efflux pump inhibitor also. Piperine, when used in combination with ciprofloxacin, increases the activity of the drug by reducing

its Minimum Inhibitory Concentration (MIC). This combination also decreases the frequency of mutation thereby decreasing the mutation prevention concentration. The inhibition of accumulation and efflux of ethidium bromide by piperine in the ciprofloxacin resistant mutant confirms its role as inhibitor of bacterial efflux. Several analogues have been prepared. One of the molecules thus developed is 4 times as potent as piperine and is inhibiting several bacterial efflux pumps. It is a significant step towards the development of combination therapy of anti infectives to prevent the emergence of resistance.

***Rapid plant regeneration of chlorophytum arundinaceum baker - an endangered medicinal herb***

An efficient *in-vitro* multiplication system via multiple shoot bud induction and regeneration in *Chlorophytum arundinaceum* using shoot crown explants has been developed at IIM. Optimum regeneration frequency (87%) and desirable organogenetic response in the form of de novo organized multiple shoot buds without an intervening callus phase was obtained on MS minimal organics medium. Axenic secondary explants with multiple shoot buds on subculturing elicited best response with  $1 \times 10^{-5}$  M Kn and  $5 \times 10^{-6}$  M IBA giving rise to an average of 18.74 shoots per culture with mean shoot length of 7.6 cm $\pm$ 1.73. Varying molar ratios of either Kn/IBA or Kn/NAA revealed statistically significant differences in regeneration frequencies among the phytohormone treatments. It has been observed that shoot bud differentiation and regeneration was influenced by molar ratios of cytokinin / auxin rather than their relative concentrations. Genetic fidelity was assessed using Randomly Amplified Polymorphic DNA (RAPD), karyotype analysis and meiotic behaviour of *in-vitro* and *in-vivo* plants. Five arbitrary

decamers displayed same banding profile within all the micropropagated plants and in vivo explant donor. The cytological and molecular analysis complemented and compared well and showed no genomic alterations in the plants regenerated through shoot bud differentiation. High multiplication frequency, molecular, cytological and phenotypic stability ensures the efficacy of the protocol developed for the production and conservation of this important endangered medicinal herb.



*Multiple shoot bud induction and regeneration in Chlorophytum arundinaceum*

***Extension of carvomint in South India***

A new improved alternative potential source of l-carvone rich strain (carvone 65-73%) CARVOMINT (*Mentha longifolia* L.) Hudson var. *incana*, developed by IIM has been extended to the farmer’s fields in South India. The genetic stability and consistency of the essential oil production and desired quality of this strain has been proved over a period of three years while the high adaptive value, faster regeneration and early maturation 100-110 (DAP) are added attributes of Carvomint. Under north Indian conditions, the yield patterns / economic returns of this new strain are quite promising with 40-45 tonnes of fresh herbage/ha and 160-170 kg of essential oil/ha. This strain also exhibits a significant increase of essential oil production (37%) over spearmint (*Mentha spicata*) which is a known commercial source of l-carvone. Technology package and guidelines for cultivation,

essential oil extraction and market potential has been provided to M/s South Indian Mint & Aromatic Products, Tirunelveli (Tamil Nadu). Approximately 10,000 kg planting material has been supplied to the party to cover 20ha of land in Tamil Nadu during the year. The crop has performed well in terms of essential oil production and its quality characteristics.



*Anant Carvone mint growing in fields*

### ***Staphylokinase – potent clot dissolving agent***

Staphylokinase (SAK), a clot-dissolving agent, has potential clinical application as a thrombolytic agent for the treatment of myocardial infarction and ischemic strokes. Its ability to display profibrinolytic activity in a fibrin selective manner is beneficial for thrombolytic therapy. As an extracellular bacterial protein, it is produced by several strains of *Staphylococcus aureus*. In its native host, SAK is produced in very small amount along with other toxic proteins; therefore, highly purified preparation of SAK from its native host is difficult to obtain for clinical use. A recombinant system for high level production of this clot-dissolving agent was developed by IMTECH where staphylokinase encoding gene was genetically engineered to overproduce SAK as a soluble cytoplasmic protein in *E. coli*. The technology for high yield production of SAK has been developed to produce this thrombolytic agent in grams quantities at fed-batch fermentation. Two-step chromatography was standardized to obtain highly purified preparation of recombinant staphylokinase displaying specific activity for

plasminogen activation. Using this technology, large amount of this thrombolytic agent can be obtained in pure form that may be useful for clinical application for thrombolytic therapy.

### ***Alternative pathway of glutathione degradation in *Saccharomyces cerevisiae****

Glutathione biosynthesis and metabolism proceeds through the  $\gamma$ -glutamyl cycle. The degradation of glutathione is usually initiated by the action of  $\gamma$ -glutamyl transpeptidase. IMTECH has provided a genetic evidence for the existence of an alternative pathway for GSH degradation independent of  $\gamma$ -GT. This was demonstrated through the use of cells disrupted in the ECM38 gene encoding the  $\gamma$ -GT enzyme. *S. cerevisiae* encodes a single enzyme for  $\gamma$ -GT. These cells retained the ability to utilize glutathione as a sulphur source demonstrating that an alternate pathway for GSH degradation exists in yeast cells. Using a genetic approach, participants in this novel pathway for the degradation of GSH have been identified. This pathway requires the participation of 3 previously uncharacterized genes in *S. cerevisiae* viz. DUG1 (YFR044c), DUG2 (YBR281c) and DUG3 (YNL191w). Although dipeptides and tripeptides with a normal peptide bond such as cys-gly or glu-cys-gly required the presence of only a functional DUG1 gene that encoded a protein belonging to the M20A metallohydrolase family, the presence of an unusual peptide bond such as in the dipeptide,  $\gamma$ -glu-cys, or in GSH, requires the participation of the DUG2 and DUG3 gene products as well. The Dug1p, Dug2p and Dug3p proteins were found to form a degradosomal complex, through Dug1p-Dug2p and Dug2p-Dug3p interactions. A model has been proposed for the functioning of the Dug1p/Dug2p/Dug3p proteins as a specific GSH degradosomal complex.



### ***Macrophage cell surface Glyceraldehyde-3-phosphate dehydrogenase: A Novel Transferrin Receptor***

Glyceraldehyde-3-phosphate dehydrogenase (GAPDH) is known primarily as a cytosolic protein. IMTECH has demonstrated for the very first time that GAPDH has a novel cell surface localization in mammalian cells. The studies reveal the presence of an entirely new uptake mechanism for the iron transport protein transferrin into mammalian macrophages, wherein these cells utilize the ubiquitous moonlighting protein GAPDH as a receptor. This mechanism provides an elegant method by which this abundant cellular protein is relocated to the membrane for this additional role. It has been proposed that mammalian cell surface GAPDH represents a primitive mechanism for the uptake of iron transport proteins that has been conserved in cells. Since GAPDH is a ubiquitous protein, the broader implications of this finding are that in addition to macrophages, this may be an alternative mechanism for iron acquisition in other mammalian cells and tissues. The discovery identifies a new type of ubiquitously expressed Transferrin receptor that bears no homology to the two previously known receptors. It has also been established that this receptor is regulated by the levels of extracellular iron.

### ***Collection and compilation of small antigenic molecules***

Infectious diseases, tuberculosis in particular, remain the leading cause of human mortality. IMTECH has developed a database for hapten (small molecules) and anti-hapten antibodies. The database would be of great help in identifying functional group(s) in smaller molecules using antibodies as well as for the development of immunodiagnosics / therapeutics by providing data and procedures

available so far for the generation of specific or cross reactive antibodies.

### ***Novel rhizosphere competent high temperature/drought tolerant bacteria***

A novel rhizosphere competent high temperature/drought tolerant *Pseudomonas putida* strain, MTCC 5279, which has a very good potential for commercialization due to its ability to survive at high temperature has been isolated at NBRI. This strain will be used to identify and isolate high temperature/drought tolerant gene(s).

### ***Functional genomics of *Withania somnifera* for gene discovery and drug development***

Scientists from NBRI have cloned and sequenced seven full-length genes from *Withania somnifera* gene family of sterol glucosyltransferase. One of the genes from the family has been cloned and expressed in *E. coli*. Isoenzymes of SGT were purified from membrane and cytosolic fractions of *Withania somnifera* leaves. Characterization of these enzymes reveals their role in various biotic, abiotic stresses and withanolide production.

### ***Post harvest biotechnology for prolonged shelf life of fruit, flower and vegetables***

Several genes from banana, mango, rose and gladiolus have been cloned and characterized by NBRI, which are thought to be responsible for ripening and softening in fruits and abscission and senescence in flowers. Some of the important genes identified as candidates for future biotechnological uses to improve shelf life of fruits and vegetables are: genes for ethylene biosynthesis, ACC oxidase and ACC synthase; MaMADS, a homologue of tomato MADSRIN, an important developmental regulator of ripening in tomato; eIF1A, a translational initiation factor; a SIN3 like transcriptional co-

repressor and expansins and pectate lyase that are known to participate in fruit softening. AP2/ERF domain transcription factors that are differentially regulated during ripening and abiotic stresses have been isolated and characterized. An increment of almost ten days in the shelf life of transgenic tomato carrying an antisense gene of ACC oxidase from banana has been confirmed with second generation of the transgenic tomato variety. Same construct has been introduced in banana in order to achieve transgenic banana with higher shelf life.

#### ***Phytoremediation of metal contaminated environment***

Plants of *Bacopa monnieri*, *Ceratophyllum demersum* and *Hydrilla verticillata* could be useful for phytoremediation of metals and metalloids (arsenic, cadmium and lead) from polluted aquatic bodies as significant accumulation of metals and metalloid was observed in both the plant species without any significant effect on their growth. NBRI scientists have characterized and cloned the gene, *Phytochelatase synthase* gene responsible for the synthesis of phytochelatin from *C. demersum*. *Vetiveria zizanioides* (khus khus) and lemongrass (*Citronella flexuosus*) were found effective in removing metals thereby improving the physico-chemical properties of the contaminated soil. *Sida acuta*, *Cassia fistula*, *Spinacea oleracea* and *Chenopodium album* were found suitable for the decontamination of most of the metals from tannery waste contaminated sites. Vegetables like, spinach (*Spinacea oleracea*) and Bathua (*Chenopodium album*) grown on tannery waste contaminated soil are, however, unfit for edible purpose due to accumulation of toxic metals above prescribed levels.

#### ***Synergistic Bioinoculant Composition***

A synergistic bioinoculant composition comprising bacterial strains of accession

Nos.- NRRL B-30486, NRRL B-30487, and NRRL B-30488 has been developed at NBRI which is useful as individual and also in several possible combinations with each of the strains showing plant growth promotory and phytopathogenic fungi controlling activity, abiotic stress conditions tolerating and phosphate solubilization capabilities under abiotic stress conditions. Further, a method of producing said composition and isolating said bacterial strains from cow 'Sahiwal' has also been developed. This being the first report of the isolation of plant growth promoting bacteria from milk, a USA patent (7,097,830 B2) has been obtained for this work.

#### ***Improved strain of Lemon grass BLI-Arun through hybridization***

A new clone of lemon grass developed at NEIST records very good herb yield (ca 35 to 39 t/ha) and 0.8 to 1.12% essential oil on Fresh Weight Basis (FWB). The major constituents of the oil were geraniol (30.5 to 30.8%), citronellol (24.1 to 24.3%), Geraniol (13.0 to 13.6%) and neral (10.1 to 10.3%). Lemon grass (*cymbopogon*) is an important genus of aromatic grasses with about 120 species yielding varied combination of terpenes and non-terpenic phenolic compounds. Lemongrass oil is used in perfumery, cosmetic and pharmaceutical industries and India happens to be the major producer and exporter of lemon grass oil. However, has declined considerably due to low production and competition from other countries. The reason for low production of Lemon grass oil in India was due to non-availability of strain with high biomass yield, oil and citral content.

#### ***New and superior source of cinnamomum***

*Cinnamomum verum* and *C. cassia* are used as sources of Cinnamon spice. NEIST has

identified *Cinnamomum pauciflorum*, an indigenous species of Meghalaya having qualities superior to the former. The essential oil/content of leaves varied from 3.5 to 4.0%. Twenty five components representing 98.8% of the total oil were identified. The main constituent is Cinnamaldehyde (89.85%). The composition of the oil is different from essential oils of existing Cinnamon sources by the presence of 3 components (one aldehyde & two diterpene), constituting only 0.3% of the total oil.

### **Progress made under Network projects**

Network mode of working, wherein several groups of scientists across various CSIR laboratories, working on commonly identified research problems has gained acceptance and admiration of scientists, leading to mutually beneficially synergistic linkages.

Some of the significant achievements, project-wise, are:

#### **I Exploration and exploitation of microbial wealth of India for novel compounds and biotransformation process**

The project envisages to exploit microbial diversity of the country using both culture dependent and culture independent methods, with ultimate goal of its commercial exploitation as a major source of biotechnological products and processes.

##### **(a) Culture dependent approach**

Some leads obtained earlier have been actively pursued. Nearly 1200 bacterial isolates have been collected from different ecological niches of the Western Ghats. An armory of well characterized biocatalysts (like *lipases/esterases*, *oxidoreductases*, *monooxygenases*, *hydantoinases* and *glycosidases*) which are adapted to work at variety of pH and temperature has been

prepared. These are useful biotransformation solutions to pharmaceutical, agrochemical and fine chemical industry.

Further, twelve new taxa including two new genera and twelve species from different regions of India have been discovered and published.

In addition, two microbial consortia developed earlier for biofertilizer (phosphate solubilisation, desiccation resistance and nitrogen fixation) have been exchanged between two labs for testing under field conditions in two different parts of the country. Another microbial consortium was developed for wastewater and poultry waste treatment and tested at pilot scale level.

##### **(b) Culture independent approach**

In order to exploit the gene pool of uncultured bacteria, 25 metagenomic libraries of different environmental samples were made. Two libraries have been screened using both function based and sequence based methods for unique esterases and resistance to salt and arsenic. Few unique genes are being investigated now.

#### **II Molecular biology of selected pathogens for developing drug targets**

The project envisages in-depth study of molecular biology of a few pathogens for developing drug targets, namely for *Mycobacterium tuberculosis*, *Plasmodium falciparum*, *Leishmania Donovanii*, *Fungal pathogens* (*C. albicans* and *A. fumigatus*), *Enteric pathogens* (*V. cholerae*, *S. dysenteriae* and *H. pylori*).

*Mycobacterium tuberculosis*: Polypeptide deformylase, nucleoside diphosphate kinase A, peptidyl tRNA hydrolase, enhanced intracellular survival proteins from *M. tuberculosis* were cloned, over expressed,

purified and their biological activity confirmed. Crystal structure of the adenylation domain of NAD dependent DNA ligase were used for designing inhibitors of the enzyme. Further, robust DNA microarray and proteome analysis protocols were developed.

*Plasmodium falciparum*: Enzymatic properties of Choline kinase, a putative drug target have been elucidated and a screening assay developed. Three proteins coded by apicoplast genome were identified during the year.

*Leishmania donovani*: Mitochondrial tRNA binding protein, actin binding proteins were cloned, over expressed, purified and their biological activity confirmed. Some natural products (dihydrobetulinic acid, luteolin, diospyrin and indolyl quinolines) were identified as inhibitors of leishmanial topoisomerases.

### III Developing cell & tissue engineering

The project targets to develop methodologies for growing cells and tissues (of animal origin) *in-vitro* and induce them to perform differentiated functions; to develop biomedical devices as substitutes for a defective organ or its parts; to develop methodologies for the transplantation of cells and tissues grown *in-vitro* into hosts including humans; and *in-vitro* production of pancreatic  $\beta$ -Cells for transplantation in type I diabetic patients.

*Plants*: Candidate vaccine protein has been produced in the tobacco plant for immunization against rabies.

*Animals*: A new culture system for growth of limbal cells has been developed from the human eye.

### IV Toxicogenomics of polymorphism in Indian population to industrial chemicals for development of biomarkers

The project aims to understand the molecular basis of the toxic response, identify the biomarkers for toxic exposure, and screen the individuals in the population that are genetically predisposed for differential toxic response. It will help to design suitable strategies for reducing the risk of the chemicals, mitigation and treatment of the toxic response, and adoption of preventive methods for the susceptible individuals.

Polymorphism in the DNA repair enzyme ERCC2 codon 751 is associated with arsenic-induced pre-malignant skin lesions. Specific polymorphisms of gene p53 associated with keratosis in individuals were exposed to arsenic through drinking water. Single Nucleotide Polymorphisms (SNPs) in the gene for epoxide hydrolase showed significant polymorphism (>5%) in Exons 3, 4, 6 and 8. Most notably, a significant association of polymorphism was observed in favor of lung cancer development. 2D-gel electrophoresis of the blood plasma samples from control and lead exposed rats revealed the proteins that are differentially present in lead-exposed animals. Thus, levels of three proteins, identified as different forms of J-chain of immunoglobulins decreased after lead treatment. Another protein, identified as 'alpha-chain of Haptoglobin', was found to increase by 2 folds in lead-exposed animals.

### V Designing animals and plants as bio-reactors for proteins & other products

The project envisages designing of transgenic plant, animal, and yeast bioreactors, to develop genetic transformation technology in novel hyper expression systems, to exploit cells as bioreactors for production of high value biopharmaceuticals and to construct



Gtases library for biotransformation (glucosylation) of natural products.

Human AAT gene and Cecropin gene from *Drosophila melanogaster* has been isolated, cloned into TOPO vector and *E. coli* transformants selected. Processes for purification of AAT and cecropin like proteins from plant tissue matrices have been developed. Chloroplast transformation for potato has been initiated as replication from the technology developed and optimized on Tobacco. Also productivity of laccase has been optimized at a 5 L fermentor scale. The system is to be employed for the target transgene (therapeutic proteins- AAT, SOD etc.). Collagen producing sponges have been identified out of the collected germplasm and putative alpha chain of collagen has been demonstrated by SDS-PAGE electrophoresis and Western blotting.

#### **VI Medicinal plant chemotypes for enhanced marker and value added compounds**

The project envisages to enhance the production of around 20 commercially important high value drug molecules present in medicinal plants viz. *Artemisia annua*, *Acorus calamus*, *Bicopa monnieri*, *Cathranthus roseus*, *Picrorrhiza kurroa* etc.

Protocols for Poly (A) +mRNA construction of cDNA libraries of leaf and root tissues, subtractive hybridization and sequencing of ESTs have been developed. A total of 150 ESTs were sequenced. Gene hunting based on EST analyses has led to the isolation of a pathway related gene namely Strictosidine  $\beta$ -D-glucosidase (sg) from alkaloid rich chemovar *Dhawal*. The full length sg gene has been successfully cloned on pUC19 vector and the construct has been named as pCRSG1702.

In another study of *Picrorrhiza kurroa*, seven genes of the irridoid pathway have been successfully cloned using differential display and degenerate primer approaches. Internal control gene primers have been developed for expression analyses of cloned genes.

In addition, agrotechnology packages in terms of seed rate, cultivation practices, fertilizer requirements, spacing, harvest management, intercropping patterns etc have been developed for newly developed chemovars/ chemotypes of *Andrographis*, *Catharanthus*, *Bacopa*, *Artemisia*, *Chlorophytum* and *Acorus*.

#### **VII Development and commercial-ization of new bioactives and traditional preparation**

The objectives of the project are to discover new single molecules as drugs and take them to the IND stage for diseases of concern to India and to the international community; discover and develop herbals which function through different mechanisms including metabolic activation and are based on synergism; introduce combination drugs including the use of bioenhancers which themselves are not drugs but increase the effectiveness of the drug; introduce formulations and novel delivery systems which may be target specific; and discover and develop new herbal pest management agents which influence the pests in the desired fashion but are safe for humans.

The identified promising leads for various disease conditions such as cancer, ulcer, dementia, anti psychotic, leishmania etc. are under different stages of developments. An agreement has been signed with M/s Nicholas Piramal for joint development of one herbal formulation for immunostimulatory conditions.

## 2.3 Chemical Science & Technology

CSIR enjoys immense credibility with the chemical industry especially in the areas of agrochemicals, catalysts, and chemical intermediates-subsectors characterized by high level of innovativeness. During the year, its chemical domain laboratories continued to work on projects having significant importance for niche sector. Some of the significant achievements of the period under report are presented below:

### Scientific & Technological Achievements

#### *Computing shapes of nanocrystals from X-ray diffraction data*

CECRI developed an elegant mathematical technique and tested it for computing the shapes of nanocrystals from X-ray diffraction (XRD) data. The shapes/ habits/ morphologies of the crystals present in the material specimen can be generated from the XRD of the specimen. X-ray diffractometer, alone can be used to generate both the internal structure and the external shape of crystals. The invented algorithm provides quantitative information, while art Transmission Electron Microscope (TEM) and High Resolution Transmission Electron Microscope (RTEM) yield only visual images. The algorithm is superbly suited to find the crystal shapes of nano-crystal and materials. Crystal shapes can be viewed from arbitrary angles. The invention assigns unique miller indices (hkl) to each of the crystal faces identified.

#### *Novel hexaborides by molten salt technology*

Novel rare earth hexaborides have attracted attention because of their interesting physical properties like high electrical conductivity, valence fluctuations and high magnetic ordering. These are promising materials in various engineering applications because of

their high melting point, strength and stability. Their high thermal conductivity, ionic bombardment resistance and low work function makes them suitable materials as electron emitters in thermal emission cathodes. The electron emitters made up of these compounds are much more desirable as cathodes for higher current density applications.

CECRI has used molten salt technique to produce high purity materials (samarium and Neodymium) with precision stoichiometry. Characterization of above materials reveals that 1:6 (Nd: B) composition is more suitable for producing high purity crystals and the remaining molar ratios namely 1:8, 1:10, 1:12 are fairly good to produce crystals of NdB<sub>6</sub>. The influence of current density has been evaluated and it is found that 1.3 & 2.3 A/Cm<sup>2</sup> produces good quality crystals with maximum yield.



*Deposited SmB<sub>6</sub>*

*NdB<sub>6</sub> Deposit*

#### *Electrolytic production of Ti metal from TiO<sub>2</sub> using molten CaCl<sub>2</sub> electrolyte*

A process based on electrolytic reduction of TiO<sub>2</sub> to obtain Ti metal using CaCl<sub>2</sub> melt by electro-deoxygenation process has been reported by CECRI. The electrolytic cell was designed and operated at 50A capacity. After a predetermined duration of electrolysis, the cathode was removed and analysed. The cell consists of inconel retort where the reduction process was carried out. Sintered TiO<sub>2</sub> serves as cathode whereas circular graphite tube as

anode. The cell operates at 650-700°C with molten CaCl<sub>2</sub> as the reductant as well as the electrolyte. The final product serves as intermediate compounds of Ti as magneli phases.

### ***Surface acidity of activated acid montmorillonite***

Scientist from CSMCRI studied the surface acidity of montmorillonite treated by conventional hydrothermal reaction with acids as well as ultrasonic- and microwave-assisted acid digestion using diffuse reflectance FT-IR (DRIFT) spectroscopy of adsorbed pyridine molecules. An attempt for semi-quantitative measurement of Brønsted acidity generated during the acid digestion was also carried out. The conventional hydrothermal, ultrasonic- and microwave-assisted acid digestion yields strong Brønsted acid sites of similar nature and strength, which retained pyridine up to 400–450°C. Strong Lewis acid sites have also been developed at higher temperature (>300°C), which were able to retain pyridine at 450 °C. The results show that surface acidity of similar strength can be generated with conventional hydrothermal treatment at 80°C for 4 hrs. or ultrasonic-treatment at room temperature for 1 h or microwave-assisted acid digestion for 10 min using 3N concentration of H<sub>2</sub>SO<sub>4</sub>. Therefore, microwave- and ultrasonic-assisted acid digestions are potential and rapid alternative methods to conventional hydrothermal acid digestion for preparing acid-activated clays. The technique offers an alternative method for preparing acid treated clays which finds extensive applications in industry.

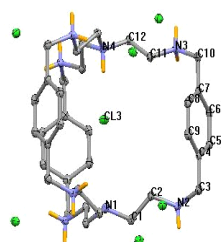
### ***Covalently bonded chiral Mn(III) salen complexes as efficient catalysts***

Another notable development from CSMCRI has been the preparation of Chiral Mn(III)

salen complex supported onto modified mesoporous supports (MCM-41 and SBA-15) using 3-aminopropyltriethoxysilane as a reactive surface modifier by a covalent grafting method. The supported catalysts shows higher chiral induction (ee, 71%) for enantioselective epoxidation of styrene and 4-chlorostyrene in presence of pyridine N-oxide (PyNO) as axial base using aqueous NaOCl (12%) as an oxidant than seen in its homogeneous counterpart 1 (ee, 48%). SBA-15-based catalyst 3, with a larger pore diameter, was found to be more active than MCM-41-supported catalyst. In addition, bulkier alkenes like indene, 1,2-dihydronaphthalene, and 2,2-dimethylchromene were efficiently epoxidized with these supported catalysts (ee up to 96%), and the results were comparable to those for the homogeneous system. It is a novel approach for the heterogenization of chiral Mn(III) salen complex where the performance of the chiral catalyst was improved for the epoxidation of styrene as compared to homogeneous system. Epoxides in high chiral purity are required as intermediates for the synthesis of various chiral drugs.

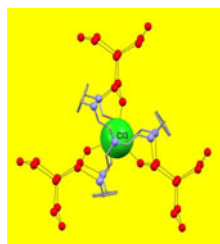
### ***Discrete propeller - shaped undecameric water cluster***

Heptahydrochloride salt of cryptand encapsulates one chloride inside the proton cage. Crystallographic analysis shows that the cage stabilized the structure of discrete propeller-shaped tricyclic water [(H<sub>2</sub>O)<sub>11</sub>] clusters. This is the first ever report by IICT of a “discrete” propeller-shaped undecameric water cluster. This water cluster, oriented symmetrically around the cryptand moiety, interacts with the encapsulated chloride inside the cryptand cavity.



(a)

(a) ORTEP diagram of heptahydrochloride salt of octaamino cryptand;



(b)

(b) encapsulated chloride and its interaction with the discrete  $(\text{H}_2\text{O})_{11}$  cluster.

Studies on water clusters in host lattice have shown that “discrete” even-membered water ring morphologies such as  $(\text{H}_2\text{O})_n$  ( $n = 4, 6, 8, 10, 12, 14$  &  $16$ ) are common within the lattice of crystal host. Curiously, little is known of the structural constraints required in stabilizing “discrete” odd-membered water cluster morphologies of “higher nuclearity” though trimers and pentamers are familiar in crystal hydrates.

### ***Solar power operated community reverse osmosis desalination unit***

The social work and research center (Barefoot college) Tilonia, Rajasthan and CSMCRI, Bhavnagar have jointly developed a solar powered community scale RO desalination unit which has been installed in the Sambhar Lake area of Rajasthan. The unit is producing 700 liters per hour drinking water from brackish water containing excess fluoride and catering to the requirement of the entire area.



***First solar power operated community scale reverse osmosis desalination plant installed in the country***

The electricity to power the unit is generated by 2.5KW solar panels. This is the first community scale solar powered unit set up in India. Efforts are under way to raise the output of the unit to 1000LPH. The people in the rural areas where electricity is not available are expected to be benefited the most.

### ***Cultivation of Gracilaria edulis in Andaman and Nicobar Islands***

CSMCRI has transferred technical know how for cultivation of *Gracilaria edulis* and extraction of agar therefrom to Community Enterprise Forum International (CEFI) who is actively engaged in empowerment of coastal communities in Andaman and Nicobar Islands through development of sustainable community enterprise for livelihood security and poverty alleviation. CSMCRI with CEFI demonstrated cultivation using raft method and imparted training to end-users in seaweed cultivation, farm maintenance, post harvesting practices in Andaman and Nicobar, who are farming this alga successfully in Andamans. The geographical conditions are conducive for the growth and the seaweed cultivators can directly reap the benefit.



***Cultivation of Gracilaria edulis by coastal communities in Andaman islands***

### ***Improved process for Heptafluoropropane***

An important contribution from CSIR towards mitigating the Ozone layer depletion efforts,



has been the development by IICT of an improved process for Heptafluoropropane (FM-200) at 70gm/hour scale and release of the same to Centre for Environment and Explosive Safety (CEES/DRDO). The technology has been commercialized by M/s Mechvac Fabricators (I) Pvt Ltd., Mumbai. Other than India, the technology for making Heptafluoropropane is available only with the USA. FM-200 is a halon substitute used in fire fighting systems. As per the Montreal Protocol, halons should be phased out as they cause depletion of Ozone layer. The company has already received advance orders for 500 tonnes of FM-200 and is considering to set up three more facilities to meet the demand. The annual domestic requirement of the gas is around 750 tonnes. M/s Mechvac will be able to provide about 300 tonnes during the first year of operation set up at an initial cost of Rs.10 crore. The market size for this halon substitute is about Rs.150 crore per annum.



*Heptafluoropropane plant*

### ***Synthesis of SBS triblock copolymers***

Thermoplastic elastomers take an intermediate position between rubbers which are soft, flexible and elastic and thermoplastics which are rigid. These materials are used as specialty elastomers in adhesives, noise reduction applications, production of foams, films, tapes, and cable sheathing. NCL in collaboration with

University of Bordeaux, France have discovered a new dicarbanionic initiator by lithium-halogen exchange reaction of dibromo compound with sec-butyllithium. This dilithiated initiator is totally soluble in hydrocarbons in the absence of any additive and efficiently generates well-defined polybutadiene telechelics and poly(styrene-b-diene-b-styrene) triblock copolymers with high 1,4-units in the polybutadiene segment. The dibromo compound viz; 1-bromo-4-(4'-bromophenoxy)-2-pentadecyl benzene used for synthesis for dicarbanionic initiator was derived from 3-pentadecyl phenol which in turn is obtained from cashew nut shell liquid (CNSL), a naturally occurring plant derived material. This dicarbanionic initiator is totally soluble in non-polar media without any additives, which allowed synthesis of well-defined polybutadiene telechelics with a high percentage of 1,4-PB units (91%). This initiator proved to be very efficient in providing SBS triblock copolymers containing 91% 1,4-microstructure polybutadiene segment with good mechanical properties (ultimate tensile strength higher than 30 MPa and elongation at break of 1000%).

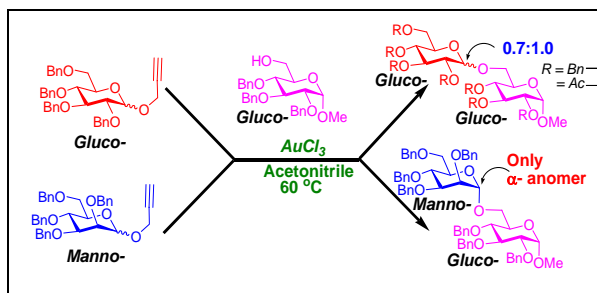
### ***Beating the ferroelectricity limit in barium titanate nanoparticles***

Among the ferroelectric oxides, barium titanate has been studied in detail both in bulk as well as in nano-size but it showed the absence of ferroelectric-tetragonal phase at room temperature when the particle size is reduced below few tens of nanometer. NCL has synthesized barium titanate particles (5 nm) using a room-temperature fungus-mediated technique in a proper crystalline phase. These particles and their composites in polymethyl methacrylate (PMMA) were investigated for the structural and dielectric properties and demonstrated that it is indeed possible to store electrical information in tiny

barium titanate particles as small as 5 nm by polarizing them at will (in reverse directions) by using atomic force microscopy probes. The electrical information thus written was directly imaged using Kelvin probe microscopy technique. This is a direct evidence of a clear ferroelectric to paraelectric (tetragonal to cubic) phase transition across the Curie temperature that could be shown at such small size in any ferroelectric material.

### ***Synthesis of oligosaccharides and glycoconjugates***

Isolation of oligosaccharides and glycoconjugates biomolecules from natural sources is a complicated task and often laborious and time consuming; hence, chemical synthesis of oligosaccharides is the most sought after technique. NCL has developed a novel transglycosylation methodology for the synthesis of these biomolecules exploiting gold catalyst. A competing reaction in diversity oriented syntheses pathway development programme enabled them to identify the peculiar behaviour of propargyl group in the presence of Au(III) salts. Extrapolation of this observation led to a novel transglycosylation protocol for the glycoside and disaccharide synthesis. The procedure developed at NCL enabled conversion of stable propargyl glycosides to transglycosylated products in the presence of catalytic quantity of AuCl<sub>3</sub> in acetonitrile. Utility and efficacy of the transglycosylation was demonstrated using various aglycones and synthesized respective glycosides and disaccharides. It can be envisioned that transition metal mediated activation of propargyl glycosides would be advantageous as propargyl glycosides can be (i) synthesized from aldoses by modified Fisher glycosidation, (ii) stable to diverse chemical manipulations, (iii) directly used for saccharide coupling, and (iv) chemo-selectively activated.



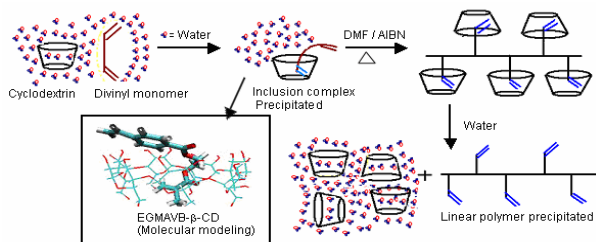
### ***Conversion of methane and methanol into gasoline***

A process having significant commercial outlook, for conversion of methane to gasoline through non-oxidative activation of methane and its simultaneous conversion with methanol into gasoline-range hydrocarbons over bifunctional ZSM-5 type zeolites has been developed by NCL. It has also been shown that the amount of methane converted could be equimolar to the amount of methanol converted in this novel process, depending on the specific conditions. Conversion of methane to higher hydrocarbons was confirmed by using carbon labeled methanol and analysis of the reaction products. In this process, methane is converted at low temperature (<600 °C) over bifunctional zeolite catalysts. Simultaneous conversion of methane and methanol results in a significant change in the hydrocarbon product distribution. The formation of benzene was very small. In the absence of methane, an appreciable amount of benzene is produced in the aromatization of methanol. Therefore, the presence of methane as a co-reactant in this process is beneficial, as the aromatization of methanol results in no net formation of benzene. The required methanol itself can be produced from methane through a well-established technology (CH<sub>4</sub>→syngas →methanol).

### ***Functional polymers from divinyl monomers via cyclodextrin host guest chemistry***

Crosslinked polymers find a wide range of applications such as ion exchange resins,

adsorbents, molecularly imprinted polymers, supports for reagents in organic synthesis, enzyme immobilization and drug delivery systems. A sequential multistep approach, wherein, a soluble linear polymer is first synthesized, isolated and then crosslinked offers significant advantages in most applications. NCL in collaboration with IICT has developed a methodology for selective polymerization of divinyl monomers such as ethylene glycol dimethacrylate and ethylene glycol methacrylate 4-vinyl benzoate by exploiting the principles of host-guest chemistry. In the methodology developed at NCL/IICT, the water insoluble divinyl monomers form an inclusion complex with  $\beta$ -cyclodextrin and its derivatives such as dimethyl  $\beta$ -cyclodextrin. The vinyl group included in the cavity of  $\beta$ -cyclodextrin does not participate in polymerization. As a result, a divinyl monomer behaves as a monovinyl monomer. The polymerization results in a solvent soluble linear polymer containing one vinyl double bond per repeat unit.

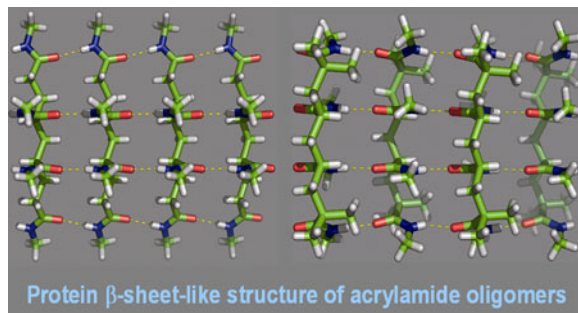


#### ***Biotransformation of amorphous silica in rice husk to nanocrystalline silica***

An exciting futuristic biomedical application has been reported by NCL scientists wherein the use of silica nanoparticles can enhance the image quality of tumour cells, making it possible for an ultrasound device to track them and thereby detect cancers. Using the fungus *Fusarium oxysporum*, commonly found in garden soil, NCL has demonstrated that almost the entire silica present in rice husk (up to 97%) can be converted to high value nanocrystals of 2-6 nanometres in size.

More importantly, the entire operation takes place at room temperatures.

#### ***Protein $\beta$ -sheet-like structure of acrylamide oligomers***

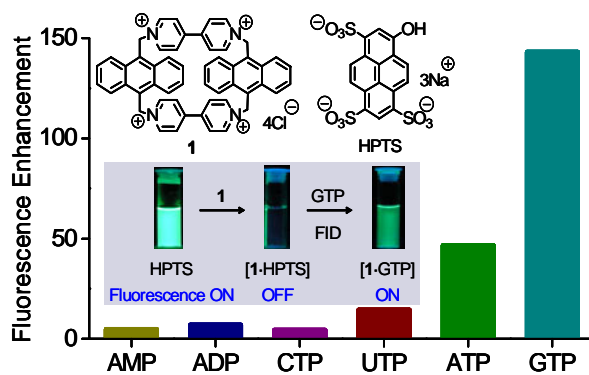


Poly-N-alkyl acrylamides are polymers formed by the polymerization of acrylamide monomer units. As a class of functional materials, these synthetic polymers are gaining prominence, primarily, due to their enormous potential for applications in various fields, from disposable nappies to micro fluidic devices and from advanced drug delivery materials to high-tech materials. NCL demonstrated that acrylamide chains form sheet-like structures similar to protein  $\beta$ -sheets. Isotactic acrylamide tetramers were synthesized and crystallized using a method usually used for protein crystallization. Conformation of these oligomers was investigated by single crystal X-ray and two-dimensional NMR studies, and a layered structure was found held together by hydrogen bonds “reminiscent of protein  $\beta$ -sheets”. This insight should help in understanding how the spatial arrangement of atoms and groups in the monomers (i.e. the stereochemistry) translates into final macromolecular shapes.

#### ***Novel cyclic conjugate for selective recognition of purine nucleotides in aqueous medium***

Detection of nucleosides and nucleotides has paramount importance as they form the fundamental units of all the life forms. Of all nucleotides, the recognition of adenosine

5'-triphosphate (ATP) and guanosine 5'-triphosphate (GTP) is vital, since ATP plays an important role in energy transduction in organisms and controls several metabolic processes, whereas GTP is involved in RNA synthesis, citric acid cycle and acts as an energy source for protein synthesis. Available sensors do not work in aqueous medium since it involves multiple hydrogen bonding. NIIST has developed a highly sensitive fluorescence assay for GTP, which makes use of the beneficial non-fluorescent and selective binding properties of the receptor, highly fluorescent properties of the indicator, 8-hydroxy-1,3,6-pyrene trisulfonate (HPTS;  $F = 0.7$ ). The system is unique in the sense that it differentiates between ATP and GTP involving synergistic effects of electronic,  $\pi$ -stacking and electrostatic interactions inside the cavity and recognizes micromolar quantities of GTP in buffer and biological fluids through a visual "turn on" fluorescence mechanism. The findings are useful in developing sensor for biologically important molecules.



### *Metal ion imprinted polymers*

Thiruanathapuram NIIST is pioneer in trapping-based ion imprinted polymers (IIPs). IIPs have many important applications and perhaps the most important one is detoxification of synthetic nuclear power reactor effluents containing uranium - an

emerging pollutant. Imprinted polymer inclusion membrane sensors have been fabricated by dispersing atrazine and dysprosium imprinted polymer materials in polyvinyl chloride matrix. The resulting devices enable highly selective and sensitive detection of atrazine/dysprosium. An on-line flow injection preconcentration-FAAS methodology were developed in analysis of dust and rock samples for palladium(II) using exfoliated graphite/inorganic or inorganic-organic hybrid materials and soils and sediment samples for cobalt using dihaloquinoline-8-ol embedded polymeric materials.

## **Progress Made under Network Projects**

### **I. Development of catalysis and catalysts**

The project envisages development and standardization of novel mesoporous materials that include Nano tubes and Nano particles and evaluation in catalytic oxidations.

Under this project being coordinated by NCL, several related developments have been place. the scale-up of the mesoporus materials (MCM-41 and MCM-48) up to 1 Kg level has been successfully achieved. A lab scale twin-process for the conversion of carbon dioxide and olefins/epoxides to cyclic carbonate and transesterification of organic carbonates with various alcohols has also been developed where the catalyst as well as reaction conditions are optimized. Non-noble metal based catalyst has been synthesized and found to be active for removal of  $\text{NO}_x$  from automobile engine exhaust under lean burn conditions. The catalyst (Co based) has been identified for indirect route of nitrogen utilization. Chiral ligands, their anchoring on porous support and catalytic application for asymmetric reactions has been prepared. Asymmetric hydrogenation of various

substrates like ketones, olefins, imines, enamines etc is important for the synthesis of enantiomerically pure pharmaceuticals / intermediates.

## II. Developing green technologies for organic chemicals

The project being led by IICT targets to develop good processes for bioactives from medicinal plants, value-added organic chemicals from biomass and agro industrial wastes, alkylation and oxidation of aromatic compounds, fluoroorganics by chemical/electrochemical methods and novel mesoporous nanomaterials.

Several processes for the production of medicinally important products and intermediates have been developed such as: artemesinin in batch of 5Kg; pheromone components IV (E11-hexadecene-1-ol) and V (E11-hexadecenyl acetate) (25g batch); process for Trifluoroethanol 1,1,1-trifluoro-2,2-dichloroethane (HFCFC-123) & Heptafluoropropane (FM200); and novel mesoporous materials for gas storage.

Ruthenium based complexes were used for catalytic oxidation of methane by molecular oxygen under moderate conditions of pressure and ambient temperature. The catalyst is being investigated in detail for oxidation of methane by molecular oxygen to study the effect of various parameters on the formation of the oxidation product.

Nanocrystalline  $\text{TiO}_2$  prepared by sol-gel method was calcined at 583, 683, 753, 833, 913, and 1023 K under airflow. The photocatalytic activities of these catalysts were tested for degradation of nitrobenzene under UV light irradiation for 1-8 hours. It was found that the catalyst calcined at higher temperature showed highest rate of degradation of nitrobenzene.

## III. Globally competitive chemicals, processes and products

This network project with IICT as the lead laboratory aims to develop new generation technologies for high demand chemicals and strategically important chemicals for the country, e.g. novel bioactives, alternative fuels, new natural functional dyes etc.

- Tissue culture and processing of natural dyes Calli formation with respect to its proliferation/growth medium has been optimized. Also fresh *T. erecta* flowers (10 Kg) were produced in an experimental farm.
- Towards the development of functional dyes dipotassium rhodizonate, dipotassium croconate, barium croconate, croconic acid have been prepared at gram level. Further new homogeneous and supported catalysts on biopolymer were synthesized and evaluated for Heck reaction. Titanium Oxide electrodes have been prepared from chemical grade  $\text{TiO}_2$  and are being characterized.
- Zeolite Molecular Sieves A and  $\text{BiCl}_3$  catalyse and excellent yield of the nucleophilic ring opening of epoxides in solvent free conditions to give the corresponding  $\beta$ -amino alcohols.  $\text{BiCl}_3$  also catalyses the nucleophilic ring opening of epoxides of styrene, substituted styrenes, 1-propene, 1-hexene, 1-octene, cyclohexene, cis- $\beta$ -methylstyrene and allyl chloride by aliphatic and aromatic amines under solvent free conditions to give the corresponding  $\beta$ -amino alcohols in excellent yield and regioselectivity within 1.5 to 6 h.



#### **IV Development of novel polymeric materials**

The project being coordinated by NCL aims to use sustainable raw materials for the preparation of specialty polymers such as Organic-Inorganic hybrids and nanocomposites, UV/E-beam curable coatings and adhesives, functional polymers for chiral separations specialty polymers for petroleum industry and specialty polymers from renewable resources. So far highly luminescent bulky-conjugated liquid crystalline poly(p-phenylenevinylene)s and perylenebisimide derivatives materials have been developed for applications in opto-electronics.

#### **2.4 Earth Resources & Natural Hazards Assessment**

CSIR laboratories NGRI, NIO and NEIST are primarily devoted to R&D on earth resources. These laboratories continued to work during the year on R&D programmes, both through Network and Non-network modes on new hydrocarbon resource location, estimation of recharge of ground water systems, coastal and ocean science mineral explorations, seismic studies etc. as under:

##### **Scientific & Technological Achievements**

##### ***Shillong plateau earthquakes in Northeast India region***

Jorhat based NEIST has examined the complex tectonic model of the Shillong Plateau, the source area of the 1897 great earthquake in the northeast India region using the high precision data of a 20-station digital seismic network that is in operation in the Plateau since 2001. The dominating thrust/strike-slip faulting earthquakes in the western Plateau although could be explained by the 'pop-up' tectonic model, the

seismological data, however, shows that the north dipping Dapsi and the south dipping Brahmaputra faults are the possible boundary faults, not the Dauki and Oldham faults as were proposed in the model. The more intense normal/strike-slip faulting earthquakes in the eastern Plateau (Mikir massif), on the other hand, are generated by a long and deep rooted Kopili fault by transverse tectonics, and this could be the more vulnerable source area for an impending large/great earthquake in the region. The study has generated some seismological data which might be useful for earthquake prediction related studies.

##### ***Prediction of water table variation***

A mathematical model using approximation scheme to predict water table variation in an unconfined aquifer induced by time-varying recharge and/or withdrawal from any number of recharge basins, pumping wells and leakage sites of different dimensions has been developed by NGRI. Advantage of this approximation scheme is that any complex nature of recharge and/or withdrawal rates for any number of recharge basins, pumping wells and leakage sites and for any number of these operations can be approximated with more accuracy.

##### ***Deep Seismic Sounding refraction profile of Vattalkundu to Kanyakumari***

Using wide angle seismic refraction data, NGRI has derived upper crustal velocity image from tomographic inversion and its relation with compositions of different rock assemblages from the study of  $V_p/V_s$  and poisson's ratio respectively. The tomographic study, for the first time, clearly reveals these aspects by imaging shallow (8km) anomalous high  $V_p/V_s$  ratio ( $>1.75$ ), large variation of poisson's ratio (0.25-0.29) in upper crust of Southern Granulite Terrain representing numerous shear zones cutting across south

block with major compositional boundaries. The dominant metamorphic event of southernmost block is ~550 Ma.

### ***Paleo-seismological Investigations***

Palaeo-seismological investigations conducted by NGRI in Upper Assam and Arunachal Pradesh, which are the meizoseismal areas of 1950 earthquake, name led to the identification of number of liquefaction features were identified along the banks of Burhi Dihing river near Dibrugarh and Duliajan areas in upper Assam. The timing of the causative earthquake was constrained through the radiocarbon and optically simulated luminescence dating of liquefaction features. About 30 OSL and 16 radiocarbon ages were obtained from various liquefaction features. The radiocarbon ages of the lower bound varied between  $870 \pm 80$  to modern (about 50yrs); apart from one sample indicated the lower bound as  $5080 \pm 130$  yrs.

### ***Relevance of biofilm bacteria in modulating the larval metamorphosis of *Balanus amphitrite****

Natural microbial communities found on different substrata exposed to the marine environment, including barnacle shell surfaces, are reported to have varying influences on the settlement and metamorphosis of competent cypris larvae. NIO has carried out experiments to compare the influence of settlement inducing compounds from the bacteria isolated from the shell surface of *Balanus amphitrite* on its larval metamorphosis. The effect of multispecies bacterial film was also assessed. The production of different molecules by the bacteria was influenced by the nutrient media under which they were grown. It was observed that the promontory multispecies bacterial film turned to inhibition mode in the

presence of the adult extract of the barnacle, indicating that bacteria–adult extract interactions alter the synthesis of different compounds produced by bacteria. The studies also show that the waterborne and the surface-associated cues from the bacteria function differentially in mediating larval metamorphosis.

### ***Glycolipids from the red alga *Chondria armata* (Kütz.) Okamura***

NIO has isolated three distinct fractions containing polar glycolipids (PF<sub>1-3</sub>) from the chloroform soluble fraction of crude methanolic extract of red alga *Chondria armata* (Kütz.) *okamura*. The coupling constant of the anomeric proton in <sup>1</sup>H NMR spectrum and sign of rotation indicate an exclusive configuration of the sugar molecules in the glycerolipids. Major glycolipids were identified as (2R)-2-*O*-(5,8,11,14-eicosatetraenoyl)-3-*O*- $\alpha$ -D galactopyranosyl-sn-glycerol (GL<sub>2</sub>), its pentacetate (GL<sub>1</sub>), and (2R)-1-*O*-(palmitoyl)-2-*O*-(5,8,11,14,17 - eicosapentanoyl) - 3 - *O*- $\beta$ -D-galactopyranosyl-sn-glycerol (GL<sub>3</sub>). Each one was methanolysed to give the same galactosylglycerol which on ESI-MS provided a pseudomolecular ion at *m/z* 309 representing deacylated glycolipid with the sodiated sugar moiety. Additionally, six minor glycolipids were also identified on the basis of ESI-MS. These include a 1,2-di-*O*-acyl-3-*O*-(acyl-6'-galactosyl) glycerol (GL<sub>1a</sub>), sulfonoglycolipids 2-*O*-palmitoyl-3-*O*-(6'-sulfoquinovopyranosyl)- glycerol (GL<sub>2a</sub>) and its ethyl ether derivative (GL<sub>2b</sub>), 1-oleoyl-2-palmitoyl-3-*O*-galactosyl glycerol (GL<sub>3a</sub>), and 1,2 diacyl phosphatidyl glycerol (GL<sub>3b</sub>). GL<sub>1</sub>, GL<sub>1a</sub>, and GL<sub>2b</sub> are new to the literature. The novelty of the remaining identified compounds lies in the diversity of their fatty acid composition. Antimicrobial properties of these glycolipids against pathogens were evaluated. The yeast *Candida albicans* and

the bacteria *Klebsiella sp.* were as sensitive as the standard Nystatin and antibiotic Streptomycin against PF<sub>3</sub>. Considerable activity was expressed by the same metabolite against the fungus *Cryptococcus neoformans* as compared to the control. Antimicrobial activity of glycolipids is being reported for the first time.

#### ***Formation of genotoxic nitro-PAH compounds in fish exposed to ambient nitrite and PAH***

Mutagenic nitrated polycyclic aromatic hydrocarbons (nitro-PAHs) have been known to arise in the environment through direct emissions from combustion sources and nitration of PAHs, primarily in the atmosphere. NIO has reported the formation of nitro-PAH compounds in fish contaminated with PAH and exposed to nitrite (NO<sub>2</sub><sup>-</sup>) in the ambient water. Electrospray ionization mass spectrometric analysis of the bile of the euryhaline fish *Oreochromis mossambicus* exposed simultaneously to field relevant, sublethal concentrations of phenanthrene NO<sub>2</sub><sup>-</sup> and collision-induced dissociation of selected ions revealed the presence of two strongly genotoxic nitro-PAH metabolites, namely phenanthrene-6-nitro-1, 2-dihydrodiol-3, 4-epoxide and dihydrodihydroxy acetylamino nitrophenanthrene. These two metabolite peaks present only in the bile of fish exposed simultaneously to phenanthrene and NO<sub>2</sub><sup>-</sup> constituted, respectively, about 3.1 and 2.7% of the highest peak among the putative unconjugated phenanthrene metabolites in the mass spectrum. The presence of the oxidized phenanthrene metabolite dihydroxy-phenanthrene (m/z 233) in fish exposed to phenanthrene alone as well as phenanthrene plus NO<sub>2</sub><sup>-</sup> suggested that oxidation of phenanthrene precedes nitration in the sequence of reactions leading to the formation of the observed nitrophenanthrene metabolites. However, the route of PAH

administration seems to determine the nature of metabolites formed. Nearly 92% of the hepatic cells of the fish exposed to phenanthrene in the presence of NO<sub>2</sub><sup>-</sup> were found to have suffered extensive DNA fragmentation on comet assay.

#### ***Biological indicators in relation to coastal pollution along Karnataka coast***

NIO has examined marine pollutants in relation to planktonic and benthic at two locations along Karnataka coast, one at Kulai (74°47.74"E and 12°55.16"N) receiving huge amount of industrial effluents from fertilizer, petroleum and chemical plants along with the sewage discharges. The other site Padubidri (74°45.74"E and 13°10"N) is located 20 km away, which is a typically agricultural and fishing village having no stress of industrial discharges. Although the concentrations of dissolved oxygen, nutrients and trace metals in water and sediment showed marginal differences at these two locations, the concentration of petroleum hydrocarbon (PHC) remained exceptionally high with a maximum of 1523 mg/l at Kulai which is 10 times higher than that at Padubidri (144 mg/l). Biomass and population of phytoplankton and zooplankton showed that the seasonal differences were more conspicuous rather than the regional changes. Macro and meiobenthic population remained high at both the locations during the two seasons. Phytoplankton species indicated that centric diatoms such as *Rhizosolenia*, *Leptocylindricus*, *Chaetoceros*, *Thalassiosira* and *Coscinodiscus* contributed to 490% of population in May and 470% in January at Kulai. While mixed population of centric, pennate, cyanophycean and dinoflagellates prevailed at Padubidri in January. The results suggest that although Kulai receives large quantities of industrial and sewage effluents responsible for alteration of the ecosystem structure, the excellent wind-driven mixing

and tidal flushing keep the waters well aerated thus reducing the severe pollution stress by dispersing the organic and other pollutants. Direct relationship of PHC with Cd and Pb as contaminants, NO<sub>3</sub> and PO<sub>4</sub> as oxidants of excess PHC further suggest that these biological parameters could serve as indicators for detecting moderately high environmental stress at Kulai, compared to Padubidri.

### ***Methane from Sea-bed***

NIO participation in the drilling and coring operations carried out by 'JOIDES Resolution', an American drill ship, in the Exclusive Economic Zone of India has opened up doors to new areas of exploration in the field of microbiology, geochemistry and sedimentology of gas hydrate bearing sediments. It was found that methane is available in the form of solid crystalline structures in the organic rich sediments. The methane hydrate structure is composed of methane and water molecules in a cage (clathrate) like pattern. The hydrate structure, which is otherwise stable within the *in situ* temperature-pressure conditions, rapidly destabilizes into methane gas and fresh water by the time it is brought on-board. This may be due to evaporation of hydrate when the cores were brought to the water column having higher temperature and lower pressure. A suitable technology has to be developed to harvest the existing resources.

## **Progress made under Network Projects**

### **I. Study of mesozoic sediments for hydrocarbon exploration**

The objectives of the project are application of new strategies of integrated geophysical studies of seismic refraction, gravity, magnetotellurics and deep resistivity sounding for the delineation of mesozoics

basins in areas covered by Deccan Traps which are likely to contain oil and gas; investigation of unexplored areas for hidden Mesozoic sediments for oil and gas; and location of prospective hydrocarbon potential structures in the study area.

During the year 160 km seismic line of Umapur-Hewarkhed-Assegaon-Saur- Shirala-Brahmandwadi (W-E) has been profiled. 181 stations have been surveyed for Magneto telluric: studies. Preliminary results of 61 soundings indicate large thickness (>1.5km) of Mesozoic sediments under trap in the Burhanpur, Amravati and Jamner regions. 6000 gravity stations with zero grid interval have been surveyed for gravity studies. Topographical correction was applied to the acquired data. Bouguer and Free air anomaly maps of acquired data have been prepared.

### **II. Development of techniques and methodologies for exploration, assessment and management of ground water**

The project aims at development of techniques and methodologies and integration of the available advanced geophysical and hydrogeochemical data to thoroughly investigate various aquifer systems in hard rocks, delineation and characterization of the fractured and Island aquifer systems to understand the recharge mechanism as well as geochemical contamination and simulation of flow and mass transport and development of techniques to simulate the process of artificial recharge and test their effectiveness for a value added groundwater management in hard rocks.

Fracture Delineation: Groundwater potential zone has been delineated through the integration of hydrogeological and geophysical data. Artificial tritium experiments reveals that secondary recharge

in granitic terrain is most significant. Source well, capture well, subsurface barrier and check dams have been constructed to ensure sustainable fluoride free drinking water supply to villages in Wailapalli watershed (A.P.). Suitable structures for groundwater augmentation have been constructed. Groundwater flow and mass transport model have been used to assess the pollution due to fertilizer in alluvial terrain and due to industry in basaltic terrain. Its impact on groundwater regime has also been studied for better management of pollutants. Another method of Soil gas radon studies helped in delineation of good potential zones as the Rn concentration was detected as high as 50000 cpm. This has led to drilling of successful bore well.

**Anthropogenic Pollution :** In order to assess the contamination migration, groundwater flow and Mass Transport Models of Loninala watershed, covering Unnao CETP Tannery Cluster has been simulated through development of 4 layer model in the alluvial terrain of Ganga plain. Visualization of contaminant migration (TDS plume) has been shown for next 20 years. TDS, Sulphates, chlorides and Sodium have been found exceeding the WHO limits in groundwater samples. Heavy metal concentrations are also found elevated particularly chromium, arsenic and lead in groundwater. Similarly, groundwater flow and Mass transport modeling of Chambal river sub-basin have been completed and prediction of contaminant transport for next 20 years has been made in the mass transport model.

**Assessment of utilizable fresh groundwater potential on islands:** Detailed hydrogeological, geophysical and chemical analysis has been carried out on Androthi island to delineate area of island vulnerable to sea water ingress. The study suggests seawater ingress during non-monsoon period

in the western as well as eastern part of the Androth island. The western and eastern parts of the island where groundwater quality begins to deteriorate during the non-monsoon period, the aquifer system becomes more vulnerable to seawater ingress. It is suggested to minimize the groundwater abstraction in these zones and implement rainwater harvesting measures to augment groundwater resources.

### **III. Tectonic and oceanic processes along the Indian Ridge system and back arc basins**

The project proposes to concentrate on Carlsberg ridge (CR)- Central Indian ridge (CIR) and Andaman backarc spreading system to understand the tectonic and oceanic processes that are occurring at these dynamic plate boundaries.

Multi-disciplinary investigations have been conducted along the Carlsberg and Central Indian Ridge segments in the Indian Ocean by undertaking cruises onboard ORV Sagar Kanya. During these oceanographic expeditions mid-ocean ridge segments along the CR and CIR have been explored. Extraction of Helium from water samples and analysis for  $^3\text{He}/^4\text{He}$  ratio were attempted for the first time on especially collected samples. Based on the analysis of the data acquired, two potential sites have been identified on CR and CIR for detailed investigations to locate active hydrothermal vent sites. Manganese-oxidizing bacteria have been encountered in the CR and NCIR segments in abundance during recent findings. These bacteria are distinguished by the formation of dark brown colonies with Mn-oxide precipitate around them. The relatively high specific activity of these mixotrophic bacteria under relatively oligotrophic conditions suggests that they may be responsible for scavenging dissolved



Mn from the Carlsberg Ridge waters and could potentially participate in oxidation.

The shipboard gravity, bathymetry and seismic data across the West Andaman Fault (WAF), a major tectonic feature in the Andaman Sea, have been analysed to infer the crustal structure and to examine the influence of WAF in controlling the aftershock pattern of December 2004 and March 2005 megathrust events. The two-megathrust earthquakes of 26 December 2004 (Mw=9.3) and the 28 March 2005 (Mw=8.6) in the Andaman-Sumatra region exhibited distinct and divergent rupture patterns, controlled by the WAF lithospheric boundary. It is suggested that the active strike-slip motion along the WAF, presence of backarc spreading coupled with increased obliquity of subduction in the Andaman Sector reduce the probability of occurrence of major or great earthquakes north of 10°N.

It is proposed to investigate these areas with high-end exploration tools such as deep-tow and ROV during the second phase of field work on chartered vessel.

## **2.5 ECOLOGY & ENVIRONMENT**

CSIR contributes significantly in providing S&T inputs to evolve national policies and to ameliorate environmental problems. A few of its laboratories has developed expertise in air, water and soil quality management, near space environment, ionospheric chemistry, stratosphere – mesosphere coupling, ‘toxic & hazardous’ waste management etc. CSIR is achieving these goals both through network and non-network programmes. Significant scientific achievements are outlined below.

### **Scientific & Technological achievements**

#### ***Drishti-Kuha***

CSIR has initiated a comprehensive programme to develop a multi-scale

environmental modelling and forecast platform specially calibrated for India with special concern towards high-impact weather events like episodes of extreme rainfall and fog. As a part of this programme, CSIR has christened the forecast platform 'Drishti-Kuha', to emphasize forecast based vision to manage fog. The fog forecast platform, developed and calibrated by CMMACS, has a built-in Flight Schedule Decision Support System that allows flight rescheduling based on fog forecast and management parameters. This is India's first and only Flight Schedule Decision Support System with high-resolution, long-range dynamical forecasts, developed completely in-house. CMMACS is currently involved in the implementation of 'High-Resolution Regional Atmospheric Analysis (HiRRAA) through Meso-scale Observation Network for Urban System (MONUS)'. The purpose of HiRRAA-MONUS is to develop a high-resolution data set over select vulnerable locations for model calibration and model validation. MONUS will be initially a pentad of observation stations with meteorological towers over Delhi, with subsequent expansion to other cities.

#### ***Interaction of lead with some essential trace metals in the blood of anemic children***

The effects of lead on the hematological system result in inhibition of heme synthesis and anemia. ITRC has correlated the association of elevated blood lead levels ( $\geq 10\mu\text{g/dL}$ ), with anemia, and some essential trace metals (iron, copper, zinc, & calcium) in children. Results indicate that elevated blood lead levels were significantly associated with risk of anemia. In addition, blood lead levels also influenced the status of essential trace metals. The correlation as established in the above study gave new insight into understanding the phenomenon of causation of anemia in children. Also the regulatory

agencies are required to control overall lead emissions after even phasing out of leaded petrol in the region.

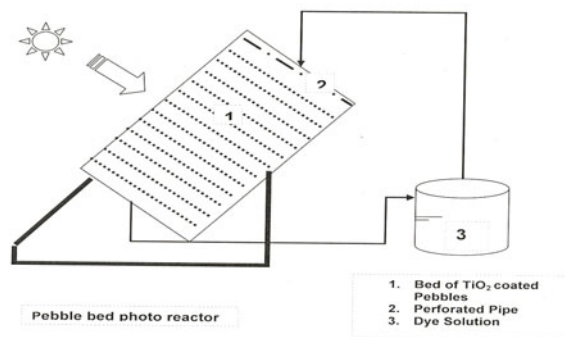
### ***Antimicrobial, antioxidant capacity and chemical fingerprint profile of Zingiber officinale from different ecological zones of India***

*Zingiber officinale* (*Zingiberaceae*) is one of the most utilized herbal drugs in traditional system of medicine. Its therapeutic uses include protection against throat ailments, bronchitis, dyspepsia, colic and as stimulant. ITRC has studied variation in their chemical fingerprint profile and biological activity. Camphene and Geraniol, two important constituent of the drug were found to be maximum i.e 98% & 40% respectively in sample from Madurai representing southern region. Madurai sample was also found to have highest superoxide scavenging capacity. Antimicrobial activity of these extracts was tested against seven gram +ve and gram -ve test bacteria. All the extracts showed strong to moderate antimicrobial activities against *B.cereus*, *B. subtilis*, *S.typhi*, *S.flexneri*, *S.sonnei*, *S.auerus*, *P.aeruginosa* and *E.coli*. The MIC values of *B.cereus* and *P.aeruginosa* ranged from 0.01 mg/ml to 10 mg/ml indicating strong activity against these bacteria, which was again highest in Madurai sample. Results confirm that *Z. officinale* obtained from the Madurai region of India has higher antioxidant, antimicrobial activities and bioactive constituents. The information can be useful while procuring the raw material for preparation of therapeutic formulations.

### ***Solar photocatalytic treatment of textile wastewater***

A novel bench scale pebble bed photo reactor has been fabricated by NEERI for its applicability to treat aqueous dye solutions

and synthetic textile wastewater under solar illumination. Silica rich white pebbles coated with Degussa P-25 TiO<sub>2</sub> catalyst were used for fabrication of photocatalyst bed surface. The pebbles used as a support for TiO<sub>2</sub> and a pebble bed reactor have been used for first time for the treatment of aqueous dye solutions. Various experiments for optimization of parameters viz. dye concentration, pH and flow rate on the performance of reactor were conducted using artificial UV light and Reactive Black dye. The results indicate that PBPR can be successfully used for the decolorization of dyes from dye wastewater under sunlight.



***Schematic diagram of solar photocatalytic treatment plant***

### ***“NEERI-Zar” portable instant water filter***

NEERI has developed a water purification system ‘NEERI-Zar’ suitable for potable water supply particularly during floods. A typical unit, with two 100 L vessels, can serve about 20-30 persons, when operated for 10 hours a day, on the basis of 6-10 liters per capita/day for drinking and cooking purposes. It brings down the turbidity of filtered water to less than 3 NTU from raw water with 100-300 NTU. It is based on the principles of oxidation of organic matter in water, using the oxidizing chemical agent to remove organisms, and filtration through a sand bed to remove turbidity and suspended matter as well as to bring down the micro-organisms, including bacteria and zooplankton. A typical

unit comprises two plastic containers of 100 L capacity placed at elevation difference to manage gravity flow. The top container contains raw water. The oxidizing chemical solution is mixed into the raw water container placed on top. The water flows by gravity into the second container, passes through the filter bed and gets accumulated. The water coming out from the second container is collected in the third container. The disinfectant solution is added to this treated water. In usual circumstances safe potable water is ready for use after half an hour.



*NEERI Zar*

## **Progress made under Network projects**

### **I. Pollution monitoring, mitigation systems and devices with applications to environmental assimilative capacity in select regions**

The project envisages developing innovative sensors, indicators and instruments for pollution monitoring and study of assimilative capacity of environmental media for pollution mitigation. During the year under report tin oxide and ceria thick films as leak detecting sensors of SO<sub>2</sub> (with sensitivity down to 5 ppm) were developed, fabricated & tested. Two machines were designed and developed for automation of critical sensor assembly. Nano-crystalline polymer thin films for detection of Carbon Monoxide, HCl & NO<sub>x</sub> have been prepared. BOD sensors

(software, membrane and bioseed) for beverage and dairy waste have also been developed.

### **II. Industrial waste minimization and clean up**

Under this project it is proposed to dematerialize the resource intensive activities of industries into more appropriate environmental technological solutions aimed at waste minimization, cleanup and remediation. It is also envisaged to go in for development of futuristic, niche and cost-effective technological interventions for at least ten highly polluting categories of industries. The work carried out has resulted in the development of several process technologies at lab scale; such as BFBR technology for insoluble COD removal; blue dust recycling from lance based smelters; microbial deodourisation for pulp & paper wastewater; photocatalytic colour removal for textile wastewaters and recycling of MnO<sub>2</sub> from secondary zinc industry. Enzymatic bioreactor system for pharmaceutical wastes was developed at bench scale.

### **III. Impact of anthropogenic perturbations on oceanographic-atmospheric processes in and around India in the context of global change**

The major objective of this project is to improve understanding of natural variability (from Diurnal to decadal) and to develop the capability to differentiate anthropogenic influence through long-term time series measurements. As a network project, the result obtained during the year indicated occurrence of alkyl halides in coastal waters of the Candolim time-series section (CaTS) in Goa where their abundance varies with oxygen deficient conditions. Experiments reveal that biological processes significantly

contribute to the formation of chloroform in seawater. Atmospheric measurement laboratory is being set up at NIO, Goa. Continuous and high quality carbon dioxide measurement facility is being installed to facilitate monitoring the air quality in the central west coast of India with particular reference to changing environment and climate.

## 2.6 Electronics & Instrumentation

CSIR laboratories of this sector have reported the development of several specialized products, notable among them are power quality analyzer, trace moisture analyzer FBG sensor etc. Additionally, a knowledge base exists in microwave & traveling wave tubes and klystrons & magnetrons. Its capabilities in semiconductors have provided tailor-made hybrid microcircuits for the Indian space programme and other applications. CSIR's achievements are highlighted in following subsections:

### Scientific & Technological achievements

#### *Silicon carbide Schottky diode*

Silicon carbide is a wide band gap semiconductor material with higher thermal conductivity, making it viable for high power and high frequency device applications. Among more than two hundreds polytypes of SiC crystal structures, 4H-SiC is the most appropriate for devices, which is available commercially with uniformly low doped epitaxy layers of not more than 50 microns. The quality of the SiC substrate is limited by the presence of unavoidable micropipes. CEERI has developed SiC Schottky diode technology for the first time in the country, by fabricating diodes of varying diameters from 1.2 mm to 2.0 mm and packaged in TO-8 headers for direct applications. Breakdown voltage of more than 700 Volts and reverse leakage currents of 1.0-5.0 nA at 200 Volts are salient specifications of all the diodes.

Ideality factor and the barrier height of the Schottky diodes have been evaluated using forward I-V data giving rise to 1.2 and 1.25 eV respectively. Nickel has been used for the realization of Schottky contact on si-face of the wafer carrying about 50.0  $\mu\text{m}$  thick epitaxy layer with a doping concentration of  $9 \times 10^{-14} \text{ cm}^{-3}$ . The c-face of the wafer of 0.020  $\Omega\text{-cm}$  resistivity has been deposited with Ti/Pt/Au for ohmic contact metallization. The technology thus developed has novelty in thermal oxidation and subsequent vacuum annealing of grown oxide and the metal films for proper adhesion to the respective faces of SiC substrate. Application of PECVD oxide for passivation and capping of grown oxide on si-face is an additional uniqueness for improved device characteristics. Field ring and field plate termination techniques have been incorporated in the diode structure to minimize multi-dimensional effect.



*Packaged SiC Schottky Diode array chip in TO-8 header for detector purposes*



*4H-SiC Schottky Diode Detectors ready for delivery*

#### *High k HfO<sub>2</sub> dielectric thin film*

Hafnium oxide (HfO<sub>2</sub>) has emerged as the most promising high k dielectric for Metaloxide semiconductor (MOS) devices. As deposited sputtered HfO<sub>2</sub> thin films have large number of defects resulting in increased oxide charge and leakage current. CEERI has

investigated the effect of sputtering voltage, bias sputtering and post deposition thermal annealing. It is found that oxide charge increases with increasing sputtering voltage. Thermal annealing in oxygen reduces the interface/oxide charges and leakage current. It is shown that applying substrate bias during film deposition leakage current is further reduced by an order of magnitude. The microstructure of thin film is examined by Atomic Force Microscopy (AFM). The development of high k dielectric material is a step forward towards advanced gate technology for scaled MOSFET and provides an understanding of the effect of material technology on interface charges and improvement in MIM and MOS device performance.

#### ***Smart materials for temperature-sensitive applications***

CEERI has developed alumina based temperature-sensitive smart materials with conductor terminations. These are based primarily on the combination of one or more of the following constituents: piezoelectric materials, glass, conducting oxides, organic binders and minor impurities in different proportions to control the resistivity, viscosity and hardness of the material. The process for development of temperature sensitive smart materials has been evolved and samples have been fabricated accordingly.

The fabricated samples are characterized with respect to temperature. They are subjected to different temperatures and the electrical resistance is measured in each case. The initial resistance of fabricated material is in the range of few M $\Omega$  and decreases drastically by several folds with the increase in temperature. Thus indicating, fast switching action in the device parameters with temperature. One curve indicates the variation in resistance with the increase in

temperature while the other is with the decrease in temperature. The variation of resistance approximately follows the same path in both the cases. The change in the electrical properties with change in temperature of the developed material leading to fast switching action is being examined and could be broadly attributed to phase transformations in the material.

#### ***Paper dirt speck analyzer***

a paper dirt speck analyzer has been designed and developed at CEERI using image-processing technique. As paper dirt measurement is an important parameter of the paper quality for the pulp and paper industry. The main components of the system are a PC, monitor, illumination system and image processing software for computation of dirt speck in paper. The indigenously developed instrument, using the latest available image analysis techniques, helps the paper maker in analyzing dirt specks in paper, based on physical area as well as EBA computation of the captured image of the sample paper. The instrument has field of View 40 mm x 30 mm sample area with accuracy of 0.002 mm resolution.

#### ***Optoelectronic instrument for the determination of sulphite in beverages***

An instrument to measure the sulphite concentration in beverages has been designed and developed at CSIO. This selective and sensitive method for determination of sulphite is based on the reaction of pararosaniline acid bleached dye with formaldehyde solution, which gives violet colored complex having absorption maxima at 560 nm. High intensity green light emitting diode (LED) of wavelength 565 nm is used as light source. BPW21 photodiode having the relative spectral sensitivity above 90% in the range of 500-600 nm has been used as a detector, for



the determination of sulphite concentration. These will lead to the development of portable device for Sulphite measurement in beverages. Instrument can be used in the field and the results are directly displayed on the LCD. There is no interference of various other cations and anions in the test solution.

### ***Optical fiber temperature switching technique***

An optical fiber switching technique for in-situ monitoring of point temperature of a process remotely developed at CSIO, is very useful for monitoring temperature in applications involving a harsh environment which could be corrosive, electromagnetically noisy, chemically explosive and hazardous. It works on the principle of guiding light by means of total internal reflection occurring in a right angled micro prism mounted on a glass capillary tube that contains a liquid in a bulb attached at the bottom.

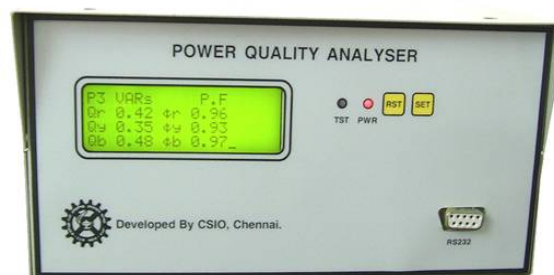
### ***Monitoring of railway tracks and acceleration of railway vehicles for safety determination***

A team of CSIO scientists has developed Oscillation Monitoring System which is an advanced portable instrument to monitor, detect and record the horizontal and vertical acceleration of the railway vehicles (railway coaches, wagons and locomotives, etc.) as well as of the railway tracks. The instrument uses 89C52 low power Micro-controller as a main component. The system continuously measures vertical and lateral accelerations at any desired location on the floor of a railway vehicle and simultaneously measures distance from fixed points of track on real time basis. The system is capable of working in non air-conditioned, harsh environment and withstands vibration of '1 g' in all three orthogonal axes. The system is designed with large storage capacity and displays locations

of bad spots along with other required information. The system has been field tried in association with Research Design and Standards Organisation, Lucknow. The instrument has been installed in Track Recording Coach on the routes from Kalka to Ambala & from Ambala to Jalandhar.

### ***Low cost power quality analyser for industrial and commercial applications***

For most of the power intensive industries, quality of power is important. To meet such a need, CSIO has developed a low-cost power quality analyser (PQA) based on the state-of-the-art digital signal processor. It measures the power quality events along with basic electrical parameters in a three-phase four-wire star connected system. It detects the impulse transients, swells & sags, harmonics, phase sequence, unbalance along with basic electrical parameters like voltage, current, power factor, powers & energies.



## **Progress made under Network Projects**

### **I. Special electron tube technologies for large scale applications**

This ambitious project being coordinated by CEERI aims at technology development for fabrication and characterization of high power electron tubes, their components like RF windows, multistage depressed collectors, high current density cathodes and other components, plasma devices and integrated pulse power systems.

Dispenser Cathodes: Technology of graphite to graphite and graphite to alumina brazing has been developed using active alloy brazing. Dispenser Cathodes have been developed and are currently undergoing life tests at accelerated temperature. One of the cathodes has logged more than 27,000 hrs. of life without any degradation in emission. A prototype thermionic emission microscope has been developed to study the spatial emission distribution. The performance is satisfactory.

Multi stage depressed collector: An accurate micro-alignment set-up for electrodes in multi-stage depressed collector, to enhance the efficiency of space borne 140 watt  $K_u$  band Traveling Wave Tube has been developed. It embarks upon development of a generic technology for axial alignment of the four stage sub-assemblies, each containing one hollow conical poco-graphite electrode, an alumina insulator and a monel outer shell, within  $\pm 10 \mu\text{m}$  which will give enhanced collector efficiency, better than 60%, the present state-of-the-art available in India. A design of high precision mechanical fixture device has been developed for aligning the electrodes at different stages using He-Ne laser source for its coherent and stabilized characteristics in the field of Metrology. The main thrust of the work lies in accurate alignment of the annular hollow conical shaped four sub-assemblies into the MDC.



*Complete Alignment Set-Up*

## II. Development of key technologies for photonics and opto electronics

It is proposed to develop indigenous technology and packaged products for a number of key components and devices, which play vital role in future communication technology and have enormous market potential such as Optical amplifiers, In-fibre Bragg grating, Arrayed planar waveguide components and Organic light emitting diodes (OLED).

This project has shown a commercial promise as 40 amplifier modules of C-band optical amplifier for telecom application each costing around Rs.2.0 lakh for applications in Cable TV (CATV) network have, so far, been sold in the national and international markets. 16 of them have been exported to USA after obtaining the qualification certificate from the competent authority. A few more orders are awaiting delivery.



*EDFA module in the main studio of Cable Comm, Saltlake, Kolkata*



*FBG sensor mounted on a simulated HT (High Tension) line*

A unique facility for writing Fibre Bragg Grating and Long Period Grating has been set up to cater to the needs of both strategic and

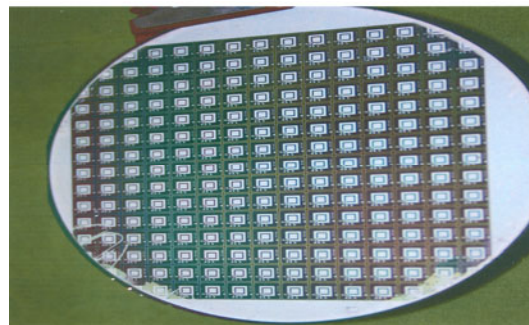
civilian sectors of the country. The set up is now being used for producing number of Fibre Bragg grating sensors and filters on a regular basis for supplying to the users. As an off-shoot of this network activity, a sensor has been developed to measure temperature and strain of high tension transmission lines erected by M/s Power Grid Corporation of India. One such sensor has been installed at a testing site in West Bengal. This has been developed under a collaborative project with SINTEF, Norway under an Indo-Norwegian collaboration programme.

### III. Developing capabilities and facilities for micro-electromechanical systems (MEMS) and sensors

The project aims at development of MEMS based chemical and biosensors, microstructures for Lab-on-a-chip type application in different chemical and biological fields, and micro-cantilever beam array biosensors. These developments are to be transferred to industry for commercial exploitation.

Fabrication of Zinc oxide based piezoelectric acoustic sensor using MEMS technology of bulk micromachined (100) silicon diaphragm could be completed at CEERI. The sensor is a sandwich structure consisting of two concentric metal electrodes, sputtered zinc oxide layer and a top metal electrode. Two capacitors, formed by the concentric electrodes, when connected in parallel, cancel the pyro-electric response. The device was fabricated on one side of the 4" diameter silicon wafer and an acoustic tunnel was made on the other side of the sensor to maintain sound pressure level inside the cavity below the silicon diaphragm. A Pyrex glass base was bonded on the backside of the device. The acoustic sensor having 5 x 5 mm<sup>2</sup> area, 25 μm thick silicon diaphragm and 3 μm thick ZnO layer, showed an average sensitivity of

50 μV rms/Pa over a frequency range of 31.5 Hz to 8 kHz.



*Acoustic sensors on 4" silicon wafer*

### IV. Electronics for societal purposes

The project with CSIO is the nodal laboratory aims to develop electro-optic systems for sorting, grading, packaging & storage of agricultural products, prosthetic instrumentation and medical instruments calibration and natural hazards mitigation.

During the year work on several applications continued space Controlled atmosphere system has been developed integrated with sensors, solenoid valves, nitrogen generator and scrubbers to maintain the level of required parameters. The system is computer controlled, operated with Lab-View Software. The five parameters - temperature, humidity, oxygen, carbon dioxide and ethylene concentration levels are displayed on the computer monitor and controlled through computer. Performance testing of the system has been checked with different gas concentrations. The system is under performance trial with different fruits and vegetables. An Off-Line non destructive quality assessment system based on selective absorption of IR for fingerprinting of different attributes for apples using fiber optic probe with interference IR filters has also been developed.

Complete system has been developed at selected field site near Haridwar (Mansa

Devi). System is operational round the clock & is under observation and field data is being collected for further analysis. Test & Calibration Centers for Seismic Instruments & Networks has been setup.

## 2.7 Energy

In the early years CSIR played a major role in the establishment of the coal washeries in the country. It has been working on developing new approaches to coal fines beneficiation and recovery from the washeries, design of mini flotation plants etc. It has assisted the steel industry to decide on coke blends; the power industry in evolving washing strategies and the myriad of small and medium sized beehive coke units in the coal belt of India to produce coke efficiently with minimum pollution from inferior coals. It has been a pioneer in the developmental efforts in coal gasification and conversion of coal to liquid fuels. CSIR is synergising its strengths existing in different laboratories by networking to develop technologies/products required by the Indian industry. Some of the achievements are outlined below:

### Scientific & Technological achievements

#### *Sol-gel synthesis of lithium silicate nanoparticles: Scope for CO<sub>2</sub> sequestration*

Synthesis of nanocrystalline lithium silicate by coupling of sol-gel method in reverse microemulsion has been reported by CFRI wherein the samples calcined at 800°C give pure phase lithium metasilicate nanocrystallites. X-ray diffraction and transmission electron microscopy confirms the formation of nanocrystalline lithium silicate particles with a narrow size distribution. The nanoparticle prepared in the microemulsion shows enhanced CO<sub>2</sub> sorption capacity and shorter retention times at higher

temperature (~131 ml/g at STP at 610<sup>0</sup> C) which are better than the best known results.

#### *Estimation of gross calorific value of coals using Artificial Neural Network*

The gross calorific value (GCV) is an important property defining the energy content and thereby efficiency of fuels, such as coals. There exist a number of correlations for estimating the GCV of a coal sample based upon its proximate and/or ultimate analyses. These correlations are mainly linear in character although there are indications that the relationship between the GCV and a few constituents of the proximate and ultimate analyses could be nonlinear. Using this approach CFRI has developed a total of seven nonlinear models using the artificial neural networks (ANN) methodology for the estimation of GCV with a special focus on Indian coals. The comprehensive ANN model developed here uses all the major constituents of the proximate and ultimate analyses as inputs while the remaining six sub-models use different combinations of the constituents of the stated analyses. It has been found that the GCV prediction accuracy of all the models is excellent with the comprehensive model being the most accurate GCV predictor. Also, the performance of the ANN models has been found to be consistently better than that of their linear counterparts.

#### *Density measurement of coal samples by different probe gases and their interrelation*

A study which demonstrates that nitrogen, which is cheaper and easily available, can be used gainfully as the probe gas for estimating the true density of coals has been carried out at CFRI. Nitrogen was used instead of the commonly employed helium, for the gas displacement pycnometer based density determination of a number of coals of Indian origin. The results show that the nitrogen-

based densities are always higher than the helium-based ones. Also, empirical relationships between the helium-based and nitrogen-based coal densities have been developed by two modeling methods, namely, multi-variable regression and artificial neural networks. Although the two models have fared well, the neural network model exhibits a relatively better prediction accuracy and generalization performance than the regression model.

#### ***Effect of gasoline composition (olefins, aromatics and benzene) on exhaust mass emissions from two-wheelers***

A study which could be of significance Experimental were conducted study on in-use and new, Indian two-wheelers to study the effect of gasoline composition (olefins, aromatics and benzene) on exhaust mass emissions. Exhaust emissions of benzene were also measured. Six makes of two-wheelers consisting of popular 2-stroke and 4-stroke, mopeds, scooters and motorcycles were tested. Three test fuels, a high olefin gasoline, a high aromatic gasoline and a Euro-III equivalent gasoline were used for the study. Intake system deposit study was also conducted on 4-stroke motorcycles and two-stroke scooters having separate lubrication, using two fuels, i.e. high olefin gasoline and Euro-III gasoline, with and without the use of multi-function additives. The study results that lowering the benzene content in the fuel would greatly help to reduce exhaust benzene emissions. Multi-functional additives were seen to be very effective to control intake system deposits for the oil industry to understand the effect of fuel composition on exhaust emissions from two-wheelers, conducted at IIP shall help the industry to modify the fuel quality as per the future requirements.

#### ***Biodegradable girth gear lubricant***

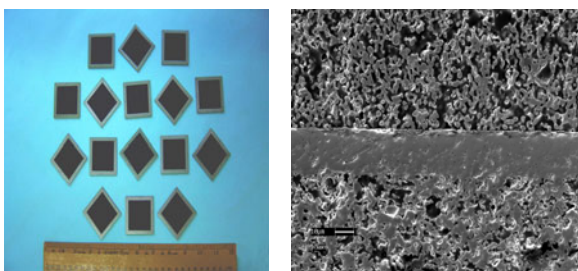
In cement plant, generally girth gears are used for crushing raw materials. Currently, sprayable greases are used for the lubricant of girth gears. The consumption of these greases is about 500-600 metric tons p.a. which is being imported costing around Rs. 20-30 crores. IIP has developed eco-friendly biodegradable sprayable girth gear lubricant for cement plant at lab scale. The performance of this product is better than the existing commercial product, especially in load carrying capacity, and performance properties such as damaged load and wear weight loss. The products developed utilize low value non-edible oil as raw material against imported products, which are based on mineral oil.

#### ***Anode supported SOFC technology***

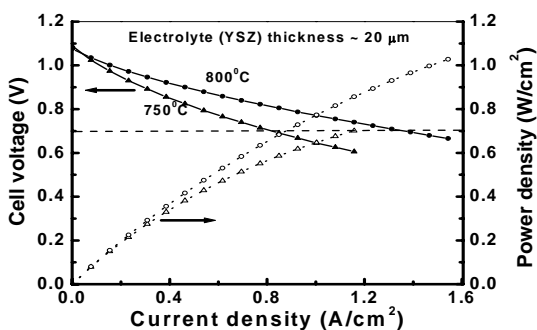
A team of scientist at CGCRI has fabricated large numbers of planar-anode-supported single cells of dimension 5cm × 5cm × 1.5mm by using simple, inexpensive and up-scalable fabrication techniques such as tape casting and screen printing. SEM micrograph revealed that the developed cells had the right kind of microstructure with a 20 μm thin, gas-tight 8 mole% yttria stabilized zirconia (YSZ) electrolyte sandwiched between a porous anode (NiO-YSZ) support (1.5 mm thick) on one side and a 50 μm thick porous Sr-doped LaMnO<sub>3</sub> (LSM) cathode layer on the other side.

The electrochemical performances of these cells were tested at Forschungszentrum Jülich (FZJ), Germany. The performance of the cells has been found to be excellent with current density as high as 1.3 A/cm<sup>2</sup> under a cell voltage of 0.7 V at an operating temperature of 800°C.





(a) Planar anode-supported SOFC single cells (5 cm X 5 cm X 1.5 mm) and  
(b) SEM micrograph of the cross section of a typical SOFC single cell



Electrochemical performance of CGCRI developed 5cm x 5cm SOFC single cells

The performances of cells made by CGCRI are comparable with those made by other leading international SOFC fuel cell stack developers.

## Progress made under Network projects

### I. Coal characterization & resource quality assessment for specific end-users

The project aims at petrographic characterization and coking behaviour of coal, gainful utilization/value addition of North East (NE) coal directly or after suitably blending; developing appropriate technology for carbonization/combustion and/or after sulphur cleaning by suitable process and also the recovery of precious and rare metals from pyritic wastes, if possible; mathematical modelling for prediction of composition of

gas as a function of operating parameters and properties of coal for gasification reactions. During the period of this reports. Identification of few precious metals was carried out and recovery process being tried. Pyritic washes collected for further investigative studies and artificial intelligence based models for classifying Indian non coking coals developed.

### II. Quality enhancement of coal for its efficient utilisation

The project envisages to identify the optimum beneficiation strategy of non coking coals to meet the needs of different end users; to assess the effect of blending of coals, (indigenous & imported) on efficiency of power generation and evolving strategies of blending of dissimilar coals. Use of Computational Fluid Dynamics (CFD) as a modelling tool of the different sub-processes like spiral, cyclone and flotation for improving the design and performance of existing systems has also been amended as an objective.

As this study seeks to assess quality of a wide range of Indian coals samples have been collected from various sites and are being processed. Detailed full scale washability studies were carried out on two high ash coals from ECL and two coals from SECL. Washability studies carried out on two high ash coals from ECL Rajmahal coal (39.0% ash) and Chitra coal (48% ash) reveal that the theoretical yield at 34% ash are 78% and 68% respectively. Washability studies carried out on two coals from SECL Kusmunda (33.1% ash) and Baroud OCP (55.0% ash) reveals that the theoretical yield at 25% ash is 78% while for Baroud the theoretical yield at 34% ash is 29.5%.

Pilot Scale Jigging studies using Kalinga Coal of Mahanadi Coalfields Limited have been

carried out and Ep values were calculated. The tests were conducted on raw coal crushed to 25 mm and it was observed that yield of 40% at about 25% ash content is achievable. Combustion characteristics of five raw coals (Chitra, Kusmunda, Sonapurzazari, Churi and Baroud) have been carried out in Drop Tube Furnace. The burnout efficiency of few samples was estimated from the chemical analysis of the original coal and the char samples collected from the middle port of Drop Tube Furnace using ash constancy approach.

## 2.8 Food & Food Processing

In the area of food and food processing, CSIR is contributing several novel and cost-effective and easy-to-operate techniques and processes for food grains storage, conservation and processing, and has developed various technologies for low cost-nutritious foods, and food preservation, convenience foods, non-conventional foods, spice products, fruit & vegetable preservation, packaging & transportation, besides appropriate and improved designs for a range of machinery for processing, milling etc. Three network programmes are being implemented in this area.

### Scientific & Technological achievements

#### *Consortium for degrading DDT*

Persistent use of organic pesticides such as dichlorodiphenyltrichloroethane (DDT) and related compounds are of environmental concern because of their toxicity, high persistence and resistance to degradation and liability to bioaccumulation. CFTRI has developed a defined microbial consortium, capable of degrading DDT. The microbial consortium consists of ten bacterial isolates, of which seven are of *pseudomonas* species and three are of *flavobacterium*, *vibrio* and

*burkholderia* species. Degradation parameters were optimized using Response Surface Methodology. The optimized conditions were inoculum concentration: 1500µg protein/mL and temperature: 25°C. pH was varied for different concentrations of DDT. The model has been validated.

#### *Specialty fat powders for use in various food formulations*

Fat is an inseparable ingredient of most foods as it imparts desirable textural and organoleptic properties. Fats in natural form have certain disadvantages, mainly in terms of handling and mixing. CFTRI has standardized the formulations and process for preparation of speciality fat powders containing up to 75-80% fat. Casein, whey powder and skim milk powder (SKMP) were found to be the desirable encapsulating agents and spray drying was preferred process. Of these, casein was found to be better in obtaining powders with high fat content. Bulk density of fat powders ranged from 0.30 to 0.47 g/cc. The powder prepared using whey powder was found to have least density and that prepared using casein and SKMP had the highest density.

#### *Enzymatic maceration of jackfruit (Artocarpus heterophyllus) pulp for quality juice production*

It is rather difficult to extract juice from jackfruit pulp due to its highly viscous nature and the presence of 2.1 % pectin (as % calcium pectate) and 1.18 % starch. CFTRI has screened enzyme preparations for jackfruit pulp maceration and optimised enzymatic maceration processing conditions of the jackfruit pulp. The combination of various concentration of pectin degrading enzymes and starch degrading enzymes have been found to be the best enzyme formulation, than the individual enzymes such

as *Pectinase* (CCM), *Biotropicase* and *Trizyme* employed in the jack fruit juice processing. The combination of various enzymes exhibit different degrees of activity when employed to reduce the viscosity of jack fruit pulp. The combination of pectin degrading and starch degrading enzymes rapidly reduces jack fruit pulp viscosity and facilitates smooth juice extraction which could be filtered or centrifuged easily. The effect of enzyme concentration, incubation time and their complex interactions on juice yield, viscosity and juice carotene content in the maceration process have been studied by using optimized process conditions. The process has been scaled up at pilot plant level.

### ***Identification of the gene for pungency in chilli***

Chilli is a spice known world over for its pungency as well as its red colour. The pungency is attributed, mainly to capsaicin which has wide application in food, medicine and as pharmaceutical. There is worldwide interest to identify the gene responsible for the pungency but there has been no clear demonstration of the critical step in the formation of capsaicin. CFTRI has done extensive studies on the formation of capsaicin in chilli fruits, where in the enzymatic condensation of vanilylamine and 8-methyl nanenoic acid leading to capsaicin was carried out leading to the enzyme, capsaicin synthase, which has been purified for the first time and its amino acid composition in the n-terminal determined. Based on this, the gene (*csy-1*) responsible for pungency has been cloned and sequenced. The functionality of the *csy-1* has been demonstrated using expression vector– *E. coli* which produces the recombinant enzyme. This has implications in regulation of capsaicin in *Capsicum* genotypes.

### ***Virgin Coconut Oil***

Virgin coconut oil (VCO) which is colourless and possesses an intense coconut aroma is what every user looks for. CFTRI now has a process ready for CDO, which is rich in lauric fatty acid and contains vitamin E with a peroxidase value of below 1 and less than 0.2% free fatty acid (FFA). It has a long shelf life due to its inherent anti-oxidant properties. It has the longest shelf life compared to other vegetable oils. VCO is abundant in medium chain fatty acids such as C8, C10 and C12, and has a unique role in the diet as an important physiological functional food. It is used as a hair conditioner. It softens the hair and conditions the scalp. Using the coconut oil as a pre-wash conditioner can rid a person of dandruff better than a medicated shampoo. VCO has been recognized for its quality of strengthening the structure of damaged, devitalized hair. It lubricates and softens the hair shaft through the action of minerals such as magnesium, potassium, calcium and iron. As a “functional food” this acts as antibacterial, antiviral and anti-fungal.

### **Progress made under Network Projects**

#### **I. Positioning Indian nutraceuticals and nutrigenomics in a global platform**

The project envisages repositioning India's leadership in the area of nutraceuticals and nutrigenomics through study of molecular basis of bioactives for the preventive, curative and management of several systematic and chronic ailments. The focus is on the health benefits from a variety of plant resources and their ingredients, which may ultimately pave way for this approach called nutrigenomics. During the period under report, work continued apace on several distinct yeast related objectives the pentapeptide was chemically synthesized and the later purified by HPLC. The sequence of the peptide was

evaluated by amino-terminal sequence analysis. About 900 mg of the pure peptide and acetone powder of porcine kidney was prepared for further studies on ACE inhibition using human cell lines. Arachin, the major storage protein of groundnut (*Arachis hypogaeae*), was isolated by ammonium sulfate precipitation. Methodology for the isolation of polyphenol enriched fraction from one source and for one product has been standardized. A green processing technology has been developed for the production of steviosides from *Stevia rebaudiana* dried leaves.

## **II. Nature, nature-identical or similar biomolecules**

India is a country with rich biodiversity and also with established traditions in use of biomolecules for health, nutrition and a host of other useful purposes. In spite of huge demand for such biomolecules throughout the world, their availability is limited and the country even depends on import of a number of biomolecules. The project targets to develop commercially exploitable biomolecules.

The process conditions were optimized for the preparation of radical scavenging conserve from the pruned and coarse tealeaves. The extraction of the waste leaves of *Tectona grandis* has been carried out using polar and non-polar solvents such as hexane and methanol. Solidification of the gummy extract has been tried using different techniques. The maximum yield (14.80%) of the colouring substance was obtained with methanol solvent system.

An eco-friendly process has been developed for the extraction of vanillin from vanilla pods using microwave & ultrasound processes. A convenient HPLC/GC method has been developed for the quantitative determination

of phenolics compounds, present in the vanilla extract

## **III. Establishment of genetically modified food referral facility**

It is imperative for the Government to have testing or referral centers in place with well-developed robust methods to accurately quantitate Genetically Modified Organisms (GMOs) in foods and food ingredients to assure compliance with threshold levels of GM products and evaluate their safety. The project aims to establish a referral center for food and food products, which will boost export of these items based on their declared absence or presence of the GM component.

An exclusive GMO referral centre of excellence with the state-of-the-art facilities has been established and it is fully functional. DNA extraction methods from different food matrices and verifying the purity of the isolated DNA by electrophoretic methods and spectrophotometric method were optimized.

PCR-based screening methods including nested PCR for detecting the regulatory elements (CaMV P35S and TNOS3), specific plant species genes soya/maize (Le 1, Zein and invertase), construct specific genes of herbicide tolerant soya and insecticide tolerant maize (CP4-EPSPS and cry1A (b)) have been developed and validated. These methods are being accredited to NABL 17025 standards. ELISA based methods for detection of CP4-EPSPS in herbicide tolerant soya and Cry1 A (b) in insect tolerant maize are in place. Real time-PCR methods using TaqMan probes for quantitation of CaMV 35S in herbicide tolerant soya and insect tolerant maize have been optimized and are in place. The detection limits for all the above methods are 1% GM at > 99% confidence level.

A number of primer pairs were designed to amplify different regions of the transgene both in maize and soya. In total over 20 different segments of the transgenes of insect tolerant maize (MON 810) and pesticide tolerant soya (RUR soya) have been detected in spiked GM biscuits.

## **2.9 Health Care, Drugs & Pharmaceuticals**

CSIR has developed several cost effective and innovative processes for many a generic drugs. Several herbal drugs were standardized and pharmacopeial standard for Ayurvedic drugs were laid. In addition, CSIR is developing cost-effective and commercially viable technologies for a wide range of essential drugs, such as anti-cancer, anti-virals, anti-bacterials, anti-glaucoma, anti-inflammatory, analgesics, and cardio-vascular among others. This has given much needed fillip to Indian drug industry to emerge as the largest producer of generic drugs in the world. CSIR laboratories are working in network mode within themselves and with some pharmaceutical companies. Some of the significant achievements project-wise are given below:

### **Scientific & Technological Achievements**

#### ***Apoptosis in liver during malaria: Role of oxidative stress and implication of mitochondrial pathway***

A team of researchers from CDRI has shown for the first time that malarial infection induces hepatic apoptosis through augmentation of oxidative stress. Apoptosis in hepatocyte has been confirmed by TUNEL assay and caspase-3 activation. Gene expression analysis indicates significant down-regulation of Bcl-2 and up-regulation of Bax expression in liver of malaria infected mice. Confocal microscopy showed

translocation of Bax from cytosol to mitochondria in apoptotic hepatocyte, resulting in opening of permeability transition pores, which in turn decrease mitochondrial membrane potential and induce cytochrome c release into cytosol. Generation of hydroxyl radical (-OH) in liver during malaria, was significantly inhibited by administration of (-OH) specific antioxidant as well as spin trap, alpha-phenyl-tert-butyl-nitron in malaria-infected mice suggesting implication of oxidative stress induced-mitochondrial pathway of apoptosis in the pathophysiology of hepatic dysfunction in malaria.

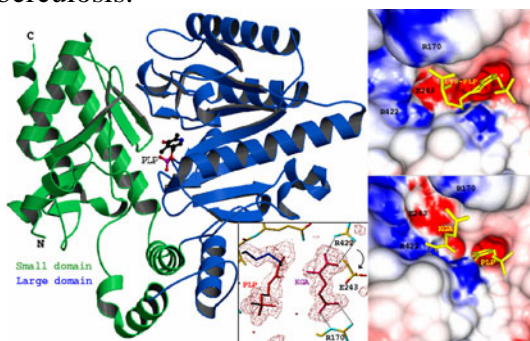
#### ***Novel approach for designing antibacterial peptides***

A novel approach for designing antibacterial peptides with modulation of toxicity against hRBCs by employing the leucine zipper sequence has been reported by CDRI. Leucine residues at  $\alpha$ - and/or  $\delta$ -position substituted with single or double alanine residues exhibited antibacterial activity against the tested Gram positive and Gram negative bacteria. Substitution of alanine progressively lowered the toxicity of Leucine Zipper Peptide (LZP) against human red blood cells (hRBCs) as it impaired the binding and localization of LZP to hRBCs, but had little effect on the peptide-induced damage of *Escherichia coli* cells. Although LZP and its analogs exhibited similar permeability, secondary structures, and localization in negatively charged membranes, significant differences were observed among these peptides in zwitterionic membranes.

#### ***Cloning of Lysine epsilon-aminotransferase***

Yet another significant development from CDRI is the cloning and characterization of Lysine epsilon-aminotransferase (LAT) a Pyridoxal 5'-phosphate (PLP) - dependent enzyme, highly up-regulated in nutrient-

starved tuberculosis models. The crystal structures in the unliganded form, external aldimine with L-lysine, with bound Pyridoxamine 5'-phosphate (PMP) and C5 substrate alpha-ketoglutarate has been reported for the first time. The structures reveal a Glu243 'switch' through which the enzyme changes substrate specificities. The unique substrate L-lysine is recognized specifically when Glu243 maintains a salt-bridge with Arg422 while the binding of the common C5 substrates L-glutamate and alpha-ketoglutarate is enabled when Glu243 switches away and unshields Arg422. This 'glutamate switch' is an elegant solution devised by a subgroup of fold type I aminotransferases for recognition of structurally diverse substrates in the same binding site and provides for reaction specificity. The structures have been used to identify novel inhibitors using virtual screening approaches and these will be evaluated against persistent models of tuberculosis.



*X-ray crystal structures of M. tuberculosis Lysine ε-aminotransferase, a protein upregulated over 40-fold in latent/persistent models of tuberculosis*

### **Progress of Candidate drugs in clinical trials**

Over the years CDRI has developed many drugs, some of them are under clinical trials such as:

**α, β-Arteether** (antimalarial drug): Multi-centric clinical trials for pediatric use have been completed in >230 children suffering

from *P. falciparum* malaria. The response has been quite satisfactory.

**Compound 80/574** (lipid lowering): Phase III clinical trials are in progress at four medical centers in collaboration with M/s Cadilla Pharma Ltd.

**Picroliv** (hepatoprotective herbal preparation): Phase III clinical trials are in progress in patients of tuberculosis receiving MDT and in patients suffering from alcoholic cirrhosis.

**Compound 97/78** (antimalarial): Pre-clinical studies including pharmacology, toxicology, pharmacokinetics and metabolism in rodents and monkeys have been completed in collaboration with IPCA Labs. Dossier submitted to DCG(I) for permission to initiate Phase I clinical trials and an IND application has been filed during the year.

### **Molecular and functional analysis of *whiB* genes of *Mycobacterium tuberculosis* H37Rv**

The *whiB* genes are present in all the genera of actinomycetes including *M. tuberculosis* H37Rv and *M. leprae*. Almost all organisms have multiple *whiB* like genes and their number may vary between the species. These are small proteins between 9KDa to 19KDa and amino acids sequence alignment shows that though both N-terminus and the C-terminus of these protein show strong divergence, the central region is conserved, IMTECH has deciphered the function of two of these genes of *M. tuberculosis* H37Rv. It has been shown for the first time the biochemical properties of these proteins have properties similar to thioredoxin like proteins and may be part of the redox network of *M. tuberculosis*. At least for WhiB1 the *in vivo* target is known.



### ***Altered expression and glycosylation of plasma proteins in rheumatoid arthritis***

During the year IGIB researchers investigated the changes in the Concanavalin-A(Con-A)-bound plasma proteins in rheumatoid arthritis (RA) patients in comparison to that of the healthy controls. The 2-D PAGE analysis of the Con-A-bound plasma samples shows a large number of protein spots, a few of which were differentially expressed in the RA patients. Some unidentified proteins were also detected in the RA patients, which were absent in the controls. The study enunciates the role of carbohydrates as well as that of the acute phase response in the disease pathogenesis.

### ***Evidence of linkage and association on 18p11.2 for psychosis***

The genetic basis of bipolar disorder (BPD) and schizophrenia (SCZ) has been established through numerous clinical and molecular studies. Although often considered separate nosological entities, evidence now suggests that the two syndromes may share some genetic liability. Several chromosomal regions are reported to be shared between these syndromes (18p, 6q, 10p, 13q, 22q). IGIB has reported a positive linkage and association finding at 18p11.2 for psychosis. Two-point linkage analysis performed on a series of 52 multiplex pedigrees with 23 polymorphic markers yielded a LOD score of 2.02 at D18S37. An independent set of 159 parent offspring trios was used to confirm this suggestive finding. The TDT analysis yielded support for association between the marker D18S453 and the disease allele { $\chi^2(2) = 4.829$ ,  $P < 0.028$ }. This region has been implicated by several studies on BPD. The findings provide an independent validation of the above reports, and suggest the presence of susceptibility loci for psychoses in this region.

### ***Small cationic protein from a marine turtle***

Egg white of marine turtle *Caretta caretta* contains a small cationic protein but lacks lysozyme. IICB has sequenced the protein by a combination of sequential Edman degradation, carboxypeptidase digestion, nuclear magnetic resonance (NMR) and electrospray ionization tandem mass spectrometry. The protein contains 36 amino acid residues of which six are half-cysteines. The three-dimensional structure of the protein was deduced from two-dimensional NMR experiments and was observed to be similar to vertebrate beta-defensins. However, disulfide connectivity is C1-C6/C2-C5/C3-C4 different from that of the vertebrate beta-defensins. The protein showed strong antibacterial activity against *Escherichia coli* and *Salmonella typhimurium*. The protein also shows significant antiviral activity against an enveloped rhabdovirus, Chandipura virus, which is an emerging human pathogen. This virus is also closely related to the vesicular stomatitis virus, whose growth was also inhibited. This small cationic protein is a part of the innate immunity of this organism and replaces lysozyme in the egg. It has the potential to be developed as an antibacterial and antiviral agent.

### ***Herbal extract and a molecule from *Murraya koenigii* for the treatment of prostate cancer***

A herbal formulation as well as an extract and composition obtained from *M. koenigii* and *Tribulus terrestris* have been found to be useful for the treatment and remedy of prostate cancer as per a study reported by IICB. It also deals with a process for the preparation of the said formulation that contains extract and synergistic effects of the combined extract obtained from the above plants on androgen-dependent and – independent prostate cancer cells.

### ***Bioactive fraction from plant *Woodfordia fruticosa****

A molecule isolated from the flowers of *woodfordia fruticosa* at IICB has been found to be useful as an anti-peptic ulcer. The molecule exhibits a strong gastric proton pump inhibitory activity as well as acts as a good anti-*H. pylori* activity. Such dual property in one molecule is unique and augurs well for managing gastro-deodenal ulcers, since *H. pylori* and HCl are the two major causes of peptic ulcer diseases. Patent application designating several countries has been filed.

### ***Effect of UV radiation on ciprofloxacin users***

Ciprofloxacin is a widely used fluoroquinolone drug with broad spectrum antibacterial activities. Clinical experience has shown incidences of adverse effects related to skin, hepatic, central nervous system, gastrointestinal and phototoxicity. India is a tropical country and sunlight is abundant throughout the day. In this scenario exposure to ambient level of ultraviolet radiation (UV-R) in sunlight may lead to the harmful effects in ciprofloxacin users. ITRC has made the phototoxicity end point shows a time and concentration-dependent statistically significant ( $p < 0.001$ ) damage. Ciprofloxacin produced reactive oxygen species ROS by Type I and Type II photodynamic reactions, interacted with nucleic acid moiety and inhibited cell viability. Further, UV-induced photo-peroxidation of linoleic acid accorded the involvement of ROS in the manifestation of drug phototoxicity. Appearance of ciprofloxacin induced phototoxicity at the ambient level of sunlight is a real risk for the people of India and other tropical countries. It is suggested that sunlight exposure should be avoided (specially peak hours) during ciprofloxacin treatment.

## **Progress made under Network Project**

### **I. Asthmatic and allergic disorders mitigation mission**

The emphasis is on to explore the mechanism of actions of the preparations / molecules on specific target sites to strengthen the claim with a view to mitigating asthmatic and allergic disorders covering biochemical, immunological, genetical and pharmacological aspects.

*In vivo* anti-asthma activity testing of two lead molecules have been carried out. *In vivo* toxicity studies on above molecules suggest that both the molecules have wide therapeutic window. Preliminary data have already been generated on *in vivo* anti-asthma activity and toxicity on another one lead molecule and appears promising. Pharmacokinetics study on one lead molecule has been completed and the studies with the other molecules have been initiated. One corporate house is agree in principle to file patent and license out the potent anti-asthmatic molecule.

### **II. Newer scientific herbal preparations for global positioning**

The project aims to develop effective standardized herbal formulations for use as health promoters, or for treating various disorders, adaptogens and immunomodulators etc. During the year a Clinical Research Organisation (Nicholas Piramal Research Centre, Mumbai) has been identified for undertaking proof of efficacy studies on a few of Positive Health Promoters (PHP) isolated under this project. MoUs have been signed with two hospitals in Mumbai where the proof of efficacy studies is to be undertaken.

### **III. Predictive medicine using single and repeat polymorphism**

This project being coordinated by IGIB proposes to build an Indian SNP (Single

Nucleotide Polymorphism) database of common diseases and drug response related genes. Such a database is in the larger interest of human health in general and predictive medicine & drug response in particular in the country.

It is known that there are one million genotypings on disease candidate as well as drug responsive genes from 55 distinct populations covering all the major geographical zones representing individuals with different ethnic and linguistic origins (Indo European, Dravidian, Tibeto Burman and AustroAsiatic). This is the first comprehensive analysis of the Indian population with respect to disease predisposition and drug response genes. Analysis of this data has revealed the following:

- contribution of language and ethnicity to genetic heterogeneity in the Indian subpopulations;
- different degree of relatedness of Indian subpopulations to different global populations typed in the International HAPMAP Consortium to the same extent;
- identification of a set of 23 reference populations which cover majority of the genetic spectrum of the Indian population; and
- development of a suite of novel computational programs for large scale variation in data handling and data analysis.

#### **IV. Drug target development using *in-silico* biology**

The project aims to create and develop in-house capability in drug target development using *in-silico* biology; to design programmes for developing new software, which enables identification of therapeutic targets; to design and develop new tools for predicting toxicity

and drug response *in-silico*; and to generate qualified and trained IT professionals for pursuing research in the area of bioinformatics. During the year a novel method for human GPCR protein prediction in human genomes has been developed. Also the non coding DNA motifs have been validated experimentally as potential targets.

#### **V. Animal models and animal substitute technologies**

The project aims to influence the process of new drug development and toxicity/ safety evaluation of drugs/chemicals. It is envisaged to introduce state-of-the-art technologies for new drug development, which will reduce the average time taken for development of new drugs by 2-3 years from the current average of 12-14 years in addition to providing better understanding of the drug action and targets.

Various approaches were worked on during the period, as elucidated below. Dopamine DA-D2 receptor binding assays were carried out in a human neuroblastoma cell line for neurotoxicity assessment using cypermethrin. Neuronal and glial cells of rat were cultured and used as *in vitro* tool to study the mechanism of action of deltamethrin induced neurotoxicity. Estrogenic potential of plant origin was evaluated using a cell line by E-assay. Balb/c 3T3 and C3H10T1/2 cell transformation assay using murine peritoneal macrophages as short term tests for evaluating carcinogenic potential of chromium established and validated.

*In vitro* models for phototoxicity evaluation of the chemicals and industrial effluents were developed and validated. Alternates to animal models (Earthworm, Daphnia, pond snail) were developed and used for ecotoxicity evaluation of heavy metals and pesticides. Growth profiles of different transgenic

mycobacterial strains of *M. aurum* were studied.

Microarray whole-genome expression profiling of central nervous system was carried out at various time-points. Further, 96 well format for GFP assay standardized for single and multicopy promoter GFP fusion assays. Gene expression profiling of STR4Δ strain exposed to *homocysteine*, *cysteine*, *S-adenosyl Methionine* and *S-adenosyl homocysteine* singly or in combination has also been carried out.

## **VI. Advanced Facility for the Safety Evaluation of Genetically Engineered/Modified Drugs**

The project aims to identify the available GM food crops using recent DNA based molecular biology techniques, to develop chip-based diagnostics for the detection of GM foods and to assess their safety evaluation.

Methods have been standardized for biophysical analysis of therapeutic proteins such as recombinant erythropoietin, streptokinase, insulin, interferon, HepB vaccine, etc. Several companies are already making use of the expertise acquired for biophysical analysis of their drugs (batches of drugs already in the market as well as those, which are under development) and testing for the presence of known and unknown impurities.

Data have been generated on few standard materials available in the market, particularly carbohydrate content, glycosilation and biological activity of different batches and different makes of Erythropoietin.

Analytic procedures for micro-analytical techniques such as protein characterization, tryptic peptide fingerprinting, and N-terminal protein sequencing have been standardized.

Laboratory experiments on cell cultures (mouse fibroblast L929) were carried out for cytotoxicity (growth inhibition/cell death), mitogenic stimulation, receptor binding, inhibition of mitochondrial oxidation, etc. using reference standards. The data will be used as base line response of normal/control cell population for comparison of responses on exposure to model GM-drugs in their safety evaluation. OECD-GLP guidelines # 14 for in vitro testing, as made applicable with effect from December 2004 are used towards these studies for their global acceptability.

## **2.10 Housing & Construction**

CSIR has developed techniques and technologies covering the whole gamut of construction activities right from foundations to construction equipments. Newer and innovative building components developed have greatly helped the building industry to standardize optimal structural elements. In the area of structural engineering, CSIR laboratories have specialized in making design and analysis of special and complex structures such as high rise, long span, suspended, offshore, ships etc. and in the integrity assessment of these structures. CSIR is also known for its contribution to the roads sector through designs and constructions techniques of rigid and flexible pavements using local skills and material resources. CSIR is excelling in these areas both through network and non-network modes.

## **Scientific & Technical Achievements**

### **Low cost house in areas affected by natural disaster**

AMPRI has developed low cost houses especially for areas affected by natural disaster. The house can cater to the needs of thousands of families affected by natural

disaster like earthquakes, floods, tsunamis, storms etc. The key features of the house are: weight: 500 kg; fast and easy transportation; easy to assemble and transportation of 20 houses at a time; convenient and durable foundations dismantle; fire retardant; cost effective (twin house costs Rs. 42,000 approximately).

#### ***Wood substitute from red mud***

An R&D application having societal relevance has been the development of a wood substitute using red mud/ fly ash and organic fibre as a reinforcement in polymer matrix by AMPRI. Huge quantity of fly ash generated from thermal power plants can be used as raw material in building components. Composite doors and panels possess properties which are comparable to natural wood and thus could be used as a wood substitute for doors, windows, ceilings, flooring, partition and furniture. The cost of product is lifetime cost, which is inclusive of its maintenance cost.

#### ***Alkali activated cold setting fly ash building brick with ash content more than 80%***

Scientists from IMMT have developed a technology to use 80 to 95% (weight) of fly ash by alkali activation process in the manufacture of cold setting building bricks. The process has been developed to optimize the mix design, preparation of chemical activator and utilization of pond ash and other wastes in the production of building construction bricks and block-like products. The products demonstrate 1350 to 1650 kg/m<sup>3</sup> dry bulk density, 8 to 16% water absorption and 70 to 120 kg/cm<sup>2</sup> in bricks and 150 to 350 kg/cm<sup>2</sup> in block as the crushing strength. The alkali activated fly ash bricks are superior in strength, durability and chemical and heat resistance as compared to other building bricks. The production cost of a brick (230 × 110 × 75 mm<sup>3</sup> size) is estimated to be about Rs.1.45.

#### ***Code of practice/standards/specifications***

Technical know-how in preparation of standards and specifications is a niche domain of CRRI. Such standards are then get approved by Ministry of Shipping, Road Transport and Highways, which then get implemented onto the field. Following codes have been prepared/developed during the year.

- Specification of Paving Bitumen (IS:73-2006) by Bureau of Indian Standards (BIS).
- Specification for Precast Concrete Blocks for Paving (IS 15658:2006) by Bureau of Indian Standards (BIS).
- Code of Practice for Tack Coat and Prime Coat Applications (Approved by Flexible Pavements Committee of IRC).
- Construction of Slurry Sealing and Micro-surfacing (Revised draft submitted to Flexible Pavements Committee of IRC).

#### ***Studies regarding Landslide and Rockfall on Mumbai-Pune Expressway***

Country's first Expressway, i.e. the Mumbai-Pune which passes through the mountainous and rugged Deccan trap province faces major problems of rockfall/landslide. During 2003 and 2004, a significant number of accidents and casualties have been reported because of rockfalls/landslides. The existing rockfall problem, if not timely and appropriately addressed, may accelerate its intensity as well as magnitude further causing lot of damage to infrastructure and may also lead to loss of life and further hardships to the commuters. CRRI in consultation with Maharashtra State Road development Corporation (MSRDC) has identified thirteen sensitive rockfall/landslides locations which have already been activated and are prone for further failure. The extensive investigations reveal probable

causes and the mechanism of the rockfall/landslide. Appropriate short term and long-term remedial measures like steel fibre reinforced shot crete, soil nailing, wire mesh, provision of drainage system etc have been suggested for specific locations.



*Landslide and Rockfall Site o  
Mumbai-Pune Expressway*

#### ***Utilization of copper slag as fine aggregate in cement concrete***

Copper slag produced as a by-product of metallurgical operations is an inert material with physical properties similar to natural sand. A laboratory study was carried out by CRRI to investigate the potential of using copper slag as a partial replacement of sand in cement concrete. Slag was used in Pavement Quality Concrete (PQC) as well as in Dry Lean Concrete (DLC) mixes and its influence on workability, compressive strength, and flexural strength was determined. It has been reported that use of copper slag in concrete have no adverse effect on its strength blend of copper slag and fine sand with slag up to 40 percent can be used as fine aggregate in pavement quality concrete as well as in dry lean concrete. The study would help in effective handling of disposal of copper slag waste and would save precious land area apart from providing and saving road construction material.

#### ***Bridge distress diagnostics system software***

A software module of Bridge Distress Diagnostics System which is capable of taking input of bridge inventory data and bridge inspection data has been developed by a team at CRRI. After analyzing the bridge inspection data, the severity of damage and guidance on Non destructive testing (NDT)/Partial destructive testing (DT) to be conducted are provided by the software. Further, the software is capable of analyzing the NDT/Partial data/results to confirm the cause of distress.

#### ***Blending of non-biodegradable plastic wastes for use in road construction***

A development which has a great implication in plastic waste disposable and its end-use is using non-biodegradable plastic wastes for the development of modified bituminous mixes in road construction. CRRI has studied the feasibility of using various types of non-biodegradable plastic wastes viz. polyethylene (PE), polypropylene (PP) and polyvinyl chloride (PVC) were tried for disperse in bitumen phase. The study shows that PE and PP are partially dispersible in hot bitumen, however PP needs 20<sup>o</sup>c higher temperature than PE to have better melting and dispersion. It has also been reported that marshall stability retains stability and indirect tensile strength of modified Bituminous Concrete (BC) mixes are significantly higher than that of conventional BC mixes.

#### ***Passive energy dissipation device***

A passive energy dissipation (PED) device using SMA wires as energy dissipation elements has been designed and fabricated at SERC. For this PED, SERC has carried out static and dynamic tests on 0.4mm and 1.2mm diameter shape memory alloy (SMA) based nickel titanium alloy wires for evaluating the



static and dynamic characteristics such as ultimate tensile strength, frequency dependency and number of cycles to failure. The device consists of two concentric pipes that move mutually in opposite directions when subjected to cyclic loading. The test results reveal that SMA based PED devices are effective in providing energy dissipation to reduce the dynamic or seismic deformations. In addition, the re-centering capability combined with large energy dissipation assures good displacement control in the case of strong seismic events thus validating the developed PED device.

### ***Polymer modified fibre concretes***

Polymer modified fiber concretes are found to be ideal for seismic applications with their inherent improved ductile characteristics. Enhancement of ductility and the post-peak behaviour are of special interest for the seismic design of structures. SERC has simulated the monotonic response of the natural rubber latex modified fiber reinforced concrete beam, which exhibits improved ductility. Results are compared with the response of normal strength reinforced concrete beam. The flexural behaviour of polymer modified concrete has been investigated experimentally. Analytical modeling of the beam was carried out in user-friendly finite element software (ANSYS) to predict accurately the monotonic behaviour of beams which is considered to be the envelope of cyclic curve, thus helping the design process. A good agreement has been observed in the strains developed and the force-displacement behaviour, with the theoretical results.

### ***Fatigue crack growth studies on SA 516 Gr. 70 steel in air and sea water environments***

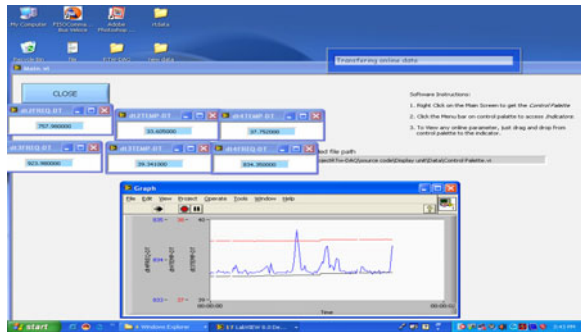
A team of scientists from SERC has carried out fatigue crack growth (FCG) analysis of a

plate subjected to constant amplitude pure membrane and bending stresses to predict the cycles required for an initial semi-elliptical crack to become a through wall crack. Semi-elliptical surface crack represents a more prototypical fatigue crack than the crack represented by standard specimens such as compact tension, C(T), middle tension, M(T) and eccentrically-loaded single edge crack tension, ESE (T) specimens. As yet there is no exact Stress Intensity Factor (SIF) solution for the problem of a semi-elliptical surface crack in a plate of finite dimensions. The empirical expressions developed by Newman and Raju are generally used. These expressions were used in evaluating the SIF range in the present analysis. Paris crack growth model has been adopted for determining the crack growth rates. C and m values for steels reported in the literature have been used for this purpose. An algorithm was developed and implemented in a spreadsheet. The spreadsheet gives the number of cycles to through thickness crack and crack growth curves in thickness and length directions.

### ***Remote health monitoring scheme for civil engineering applications***

Yet another notable development from SERC is remote health monitoring scheme for civil engineering structures. The technology provides simultaneous monitoring of a number of structures, which are geographically located at different places from a single monitoring station. The data can be acquired remotely from different type of sensors which are normally used for structural health monitoring in a single platform. Structural health of one prestressed concrete box girder span of a fly over bridge across dumper lines at Visakhapatnam has been monitored periodically. The bridge has been instrumented with vibrating wire strain gages for measurement of strains. Experiments were conducted to acquire and transmit data from

this bridge to the monitoring station at SERC via GSM network. The performance of the developed remote health monitoring scheme was further tested for long-term health monitoring of structures. Strain, acceleration and wind data was acquired continuously from a remotely located structure using GSM network. The software can be set to acquire data continuously for three days without any supervision. The response of the structure is monitored in real-time in various forms like, graphical display, numerical values etc. A new feature is added to automatically delete old files when storage memory in PXI at site is full.



*Remote Data Acquisition from Field Structures*

### ***Durability and serviceability related provisions in IS 456 for design of reinforced concrete structural elements***

Very few organizations, across the world, have the expertise in the areas of durability-based service life design and remaining life assessment of reinforced concrete structural members. SERC has proposed some recommendations, which improve upon the existing durability and serviceability related provisions for the design of reinforced concrete structural elements in IS 456. These recommendations include a revised classification of exposure conditions based on the major environmental parameters influencing the different deterioration mechanisms related to durability of reinforced concrete, separate values of minimum cover

thickness for reinforced concrete slabs, explicit specification of service life for structures, equations for characteristic crackwidth for reinforced concrete flexural members under static and fatigue loading, and procedure for durability based service life design of reinforced concrete flexural members.

### **Progress made under Network Project**

CSIR is operating three network projects in the area of housing and construction. The achievements during the year are presented below:

#### **I. Developing new building construction materials and technologies**

It is envisaged to develop low cost/ alternative building construction materials such as bricks, blocks, tiles, boards, cement/ concrete products, fibre reinforced composites, wood substitutes, coatings, sealants, paints, pigments etc. to replace/ supplement the conventional building materials which are in short supply in the country.

This network programme has three distinct yet related components; on which during the year, following could be achieved:

**Fly ash utilization:** A process has been developed for the use of fly ash, pond ash and mill reject coal of thermal power plant to prepare sintered lightweight building material aggregate pellet by down draft sintering. Another process using batch type pot grate sinter strand on 50 kg scale has been developed to optimize the mix proportion, solid fuel, pelletization and sintering conditions of fly ash, pond ash and mill reject coal. This type of sintered fly ash pellet is suitable for mixing with cement and sand in the manufacture of special heat insulation and lightweight concrete of M-20 and M-30 grade

for building construction application. Mill reject coal (low caloric value) and solid carbon bearing waste material are suitable to use as fuel in sintering of fly ash material and economical production of sintered aggregate. Other waste fines generating from metallurgical and chemical plants like red mud, sponge iron dust, gas cleaning and flue dust are useable in the process for production of building material aggregate. It is estimated that production of one ton of sintered fly ash pellet will consume about one ton of fly ash or pond ash. The production cost per ton of sintered fly ash (calculated on a 30t aggregate/day plant) is about Rs. 450. The process is ready for demonstration and know-how transfer for commercial use.

**Interlocking bricks:** In yet another significant development, interlocking bricks with provision of semi circular cavity on each of the sides of brick along length or along width were fabricated from alluvial clay mass of Roorkee through hand moulding process. The finished bricks have compressive strength above 75 kgf/cm<sup>2</sup> and water absorption below 17 percent.

**Coating system:** Physico-chemical properties of different coating systems based on epoxy-cardanol and epoxy resins have been determined. 120 days data shows that paints based on epoxy-cardanol are superior to that of unmodified epoxy based paints. The corrosion performance of the developed coating systems namely improved acrylic with conducting polyaniline pigment has been evaluated. This coating system was applied on the reinforcement bars and the corrosion resistant property of these coating systems has been evaluated by using various techniques.

## **II. Design analysis and health assessment of special structures including bridges**

The project envisages to develop capabilities in health monitoring of structures which will

help in integrity assessment, life management and life enhancement of structures, to understand the behaviour of new materials and retrofitting techniques and to prepare guidelines. During the period many significant achievements were made, notably; Software for advanced analysis of steel frames; preparation of design tables for structural steel members and connections as per draft IS 800; instrumentation at nine multi-storeyed buildings located in Delhi to obtain ambient vibration data; Passive energy dissipating devices based on visco-elastic materials and SMA were developed. The devices were tested both in element and structure levels; guidelines for seismic resistant design of framed structures using passive energy dissipating devices and design of prismatic structures under across wind loading have been developed.

## **III. New and improved road technologies**

The project aims to provide the cutting edge technologies for developing the required road infrastructure with reference to construction materials for specific purposes, drainage systems, road management systems, information systems, and models for traffic measurement systems etc.

Since the objectives encompass a broad mandate, the achievements made are:

- A film has been produced incorporating road safety implication of using mobile phones while walking and driving. It is a 20 min film and is being shown at various forums to create road safety awareness.
- The kerb stones presently being used have visibility distance of less than 30 m. New design improves the distance to about 100 m. It would enhance road safety.
- The net-based software has been developed to facilitate the Driver

Licensing Authorities in issuing Driver License more effectively particularly due to effective knowledgebase questionnaire. The questionnaire has been demonstrated and administered over 1000 road users including experts from different organizations.

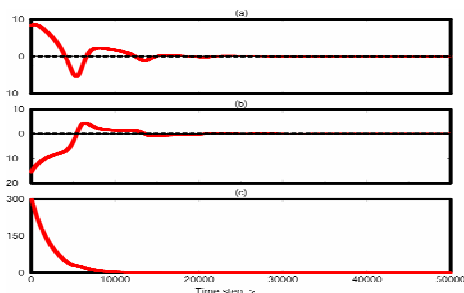
## 2.11 Information Dissemination & Products

Realising the exponential growth in the IT sector and knowledge based societies powering the current century, CSIR laboratories have evolved strategies to derive the benefits from its rich data and information base. Several initiatives towards that have been taken as under:

### Scientific and Technological Achievements

#### *Mutual chaotic synchronization for secure data communication*

Chaotic synchronization is one of most amazing phenomenon in physics. CMMACS has proposed the concept of alternately switching mutual synchronization which possibly can be used for secure communication of information over unprotected channel. This phenomenon can be very well demonstrated on a three variable Lorenz System, where by making only a single state space variable public, two identical chaotic systems can be synchronized.



(a) & (b) Error in the undeclared state space variables between the sender and receiver.  
(c) Monotonic decrease of Lyapunov function with time

This is proved by the existence of a Lyapunov function which monotonically decreases with time as shown in figure (c). Figures (a) and (b) show the convergence of the two secret state space variables between the two chaotic systems with time.

#### *Inflow of papers, rejection rate, subscriber base and impact factor*

Continuous efforts of NISCAIR towards improving the quality and subscriber base of the journals are yielding very good results. During the year, inflow of papers in all the journals increased substantially. At the same time, as a result of critical evaluation, the rejection rate of papers is found to be between 10 and 63%. There has been a steady increase in the subscriber base (~15% per annum) and many of the NISCAIR journals are covered by the Science Citation Index (SCI) and have an impact factor varying from 0.160 to 0.632.

#### *Science popularization*

NISCAIR publishes three well-circulated popular science magazines, *Science Reporter* (English monthly), *Vigyan Pragati* (Hindi monthly) and *Science ki Duniya* (Urdu quarterly) apart from a number of popular science books with a view to generate awareness about scientific developments and creating a scientific temper among the students and the common public. The institute also focuses on the coverage of R&D activities of CSIR labs through the newsletters ‘CSIR News’ and ‘CSIR Samachar’ (Hindi).

#### *S&T for weaker sections and rural areas*

NISTADS continued its thrust to support sustainable growth in rural areas, empower weaker sections through imparting knowledge and supporting poverty eradication; supporting artisans (primarily rural); grass-root innovation; and micro-entrepreneurship through policy advocacy.

### ***Mapping knowledge trends and outcomes in S&T – Indian & Global***

NISTADS has made a mapping of knowledge trends of Indian research output in science and technology in the form of research papers and patents including some leading public health and traditional medicine areas so as to provide policy directions to planners of national S&T.

### ***History and philosophy of science***

NISTADS has investigated social and environmental history with particular reference to nineteenth and early twentieth century to develop insights into foundations of current scientific and environmental endeavours in the country. The logical sciences, particularly ontological engineering, was investigated to draw inferences about its applications in future areas of computational sciences.

### **Progress made under Network projects**

#### **I. Comprehensive traditional knowledge digital library (TKDL)**

The project envisages to collect and collate traditional knowledge that exists in public domain by creating a database on this knowledge in five international languages i.e. English, German, French, Spanish and Japanese and making these available to patent examiners throughout the world to prevent the grant of bad patents. The codified knowledge of the country will be converted into easily accessible and retrievable patent application in digital format.

**Unani:** Approximately 87,000 formulations have been identified, 86,000 formulations have been transcribed and 50,000 formulations scanned from the original texts. Approximately 1 lakh formulations from the

identified texts are transcribed, scanned, verified and validated.

**Ayurveda Phase II:** So far, more than 50,000 formulations have been identified from the Ayurveda texts and checked for the duplicates. Transcription of 36,500 formulations has been completed. Approximately 65,000 formulations are transcribed, scanned, verified, and validated.

**Siddha:** Traditional Knowledge Resource Classification (TKRC) has been developed for Siddha System of Medicine. 10,000 formulations have been identified and 85000 formulations transcribed.

#### **II. Consortium access to electronic journals**

The project aims at providing CSIR S&T staff electronic access to S&T literature worldwide to strengthen the facilities for pooling, sharing and electronically accessing the CSIR information resources; and to nucleate the culture of electronic access with a view to catalysing the evolution of digital libraries.

Agreements were made with four new international publishers as a result of which all CSIR labs are now able to access 4200+ S&T journals vis-à-vis 20 to 200 print journals from 15 publishers. The post-agreement monitoring for all the above 15 publishers is being done regularly. Usage statistics of 15 publishers is being regularly organized and loaded on search interface and monitoring system gateway so that user labs may see it. Users' training and awareness programmes were organized in all CSIR labs during August to October, 2006. In all, 1000+ participants from the various CSIR labs were trained over a period of 45 man days. The average full text download has risen to 276500 from the average download of 200000 of the previous year. A format for walk-in-users, registration and feedback was prepared

and supplied to all nodal officers/Head of libraries to keep record of walk-in-users with request to their respective laboratories.

### **III. Mathematical Modelling and Computer Simulation**

A central forecast engine (a hierarchical model assembly calibrated for different scale) along with specific components to be integrated in the forecast platform has been developed.

India's first dynamical platform for long-range (> 30 days) high-resolution (~ 50 km) forecast of monsoon rainfall has been developed. India's first and the only dynamical fog forecasting platform with an industrial interface, a cyclone forecast platform specially calibrated for the Indian seas with extensive validation are a few of the products from this effort.

#### **2.12 Leather**

Central Leather Research Institute is the largest leather institute in the world. Through inputs of S&T and extension activities it has been transforming the leather industry to a modern, vibrant, environment responsive industry. CSIR's pioneering inputs have been at all stages of the industry's activities starting from techniques for flaying of dead animals to storage of skins, using 'no' or 'less' salt, to appropriate time saving and low pollution tanning and processing techniques, 'low chrome' and 'no chrome' tanning chemicals, to modernization by computerization of net operations in tanning, to new techniques for generating value added specialty leathers, to computer aided designs for footwear, garments, and goods, fashion colour forecasting export certification and not the least of all in creating the human resources needed for the leather industry and the R&D in the sector. It had successfully mounted a pioneering Leather Technology Mission for the sustainable development of the Indian

leather industry with vast grass-roots coverage. R&D programmes undertaken in network mode address the needs and priorities of the country

#### ***Scientific and Technological achievements***

Fundamental microbiological and engineering aspects of chilling system as a method of preservation of hides/skins was taken up as a project by CLRI. The process conditions were standardised. A mobile chiller has been designed and field tested. Trials at commercial scale have also been conducted. The overall cost-benefit that this system offers to salt curing has been analyzed and considered as a viable option.

#### ***Low salt preservation***

CLRI has standardized low salt chemical based system for preserving the skins for a significant span of time, Common salt as low as 5% was used along with MgO and the cured skins could be preserved for a period not less than 40 days. The quality of leathers is at par with that of the made from conventional salt curing. Commercial scale trials have been conducted.

#### ***Sole bonding by microwave heat activation***

The bonding process in shoes generally takes place after the adhesive is activated with IR radiation followed by pressing and curing. Many a times, if temperature and time are not controlled properly, it leads to either weak bonding or material disintegration. To overcome this problem an alternative heat activation technique using domestic microwave oven, CLRI conducted trials at different energy (wattage) levels and time duration of activation. Study was conducted with commonly used upper and soling materials like TPR, PVC, PU and leather sole at 300 watts, 450, watts, 600 watts and 900 watts energy levels and times of activation of 10 seconds and 20 seconds. Microwave heat



activation as a method for sole bonding has been found to be effective at 20 seconds heat activation time.

### ***New materials for therapeutic footwear applications***

Many viscoelastic materials are used in shoes to replace the shock-absorbing and pressure distributing functions of natural fat pad beneath the foot that is lost due to some conditions such as diabetes, arthritis, age or overuse. CLRI has synthesized segmented polyether polyurethanes and converted into sheets by blending with commercially available polyester polyurethane. The cushioning and morphological properties of developed materials were studied for application in therapeutic footwear.

### ***Near zero wastewater discharge in leather processing***

A unique three step tanning methodology towards a near zero wastewater discharge leather processing has been developed by CLRI wherein cow hides are dehaired using enzyme based dehairing method employing standard enzymes. Hides were treated with  $\alpha$ -amylase and water for a few hours in a drum. Alternatively, the hides were treated with 0.9% sodium hydroxide and water in a drum; duration of treatment is one day. A pickle basification free chrome tanning at pH 5.0 has been developed with and without masking. Speciation studies were carried out during the course of tanning in order to understand the mechanistic pathways associated in the novel processing method.

## **Progress made under Network Projects**

### **I. Standardization of technologies for bioresources for and from leather**

Under this project which envisages consolidating lead processes and products and developing technologies with commercial

applications a few enzymes used as derailing agents have been tested and evaluated. Methods for production of animal feed from tannery wastes have been standardized.

## **II. Environment friendly leather processing**

This project which aims to design, develop and disseminate through appropriate measures viable technologies environment friendly leather processing in India at near-zero environmental risk; and seeks to develop technologies for reducing the consumption of water in leather processing; to secure technology options for reducing the TDS level. A pilot scale plant for zero emission has been commissioned at CLRI. Phyto-remediation studies have established the need for cultivation of non-edible plants around tannery sites. A 100 litre/hr RO demonstration plant has been designed & developed and is ready for commercial scale trials. Prototype for treatment of tannery effluent using ceramic membrane has been developed and is ready for testing and evaluation studies. Prototype for nitrification/denitrification has been designed and developed. Eight collagen based products have been developed for application as health care systems. Innovative methodologies for solid waste management has been developed and demonstrated to industry.

## **2.13 Materials, Minerals, Metals & Manufacturing**

CSIR laboratories have played a significant role in the development of special materials for aerospace, defence and sophisticated industrial sectors, viz. electronic materials such as luminescent phosphors for display, piezoelectric materials and devices, high purity alumina, conducting polymers, aerospace materials such as high density carbon-carbon composites, lead-free X-ray

shielding materials, high performance industrial materials such as silicon carbide, silicon nitride bonded silicon carbide, silicon carbide whiskers; special glasses for optical fibres, infrared range finders and sol-gel techniques for glass coatings etc.; and superconducting materials.

Significant contributions have also been made in various aspects of mining operations, especially in coal mines (excluding heavy mining equipments), subsidence prediction and control enabling extraction of coal locked up in pillars and underneath surface structures and water bodies, for designing appropriate mine ventilation systems and for the mine disaster management in the country. CSIR is uniquely positioned in this area both through Network and Non-network projects. The progress achieved is presented in following paras:

### **Scientific & Technological achievements**

#### ***Non-toxic (lead free) X-ray radiation shielding materials***

For the first time in world, AMPRI has developed, under the sponsorship of BARC, Mumbai a novel process for making non toxic, highly effective shielding materials for attenuating X-ray and Gamma radiation, utilizing industrial wastes namely Red mud and Fly ash. The evaluation of shielding characteristics of the developed materials was carried out at Atomic Energy Research Board (AERB), Mumbai. AERB has computed half value thickness (HVT) and compared with conventional concrete and lead materials and suggested that shielding materials being developed can be used for the various shielding applications in diagnostic X-ray and CT installations.



*Actual photographs of non-toxic shielding materials*

#### ***Trace moisture analyser using sol-gel nanoporous thin film technology***

Trace moisture analysers are used for on-line detection of trace moisture present in toxic/non-toxic industrial gases which are used in the nuclear metallurgy, defence, navigation, medicine and food industries. CGCRI has developed a sol-gel based technique which is very cheap compared to the available and conventional technology. It has been estimated that the cost of the CGCRI sensor is five times less than an imported sensor. The sensors are not only cheap; they are also pollution free and can be regenerated by cleaning with organic solvent after prolonged use. The sensor impedance can be matched easily with simple electronic circuit. In view of the low cost of the CGCRI sensors, P.H. Scientific (UK) has purchased six moisture sensors from CGCRI as part of evaluation to market this in UK.



*CGCRI developed moisture sensors supplied to P.H. Scientific, UK*

### **Corrugated steel strap (W-STRAP)**

A development of considerable importance for mining industry has been the design and development of a corrugated steel strap (W-STRAP) which is commonly used in underground coal mines and tunnels. The new design would help fabricated roof bolts to enhance safer working. It also increases production in mines and will reduce the injuries and fatalities. Further, it can promote safe and more economic excavation at more depths. It is flexible and takes up the configuration of mine roof, which is not possible with steel channels. It is easy in transportation as it can be packed in bundles of 20 or 25 at a time. Pre-made holes in the W-strap suits the desired pattern of bolting. In case of emergency, extra bolt can be fixed in the roof after making hole into the roof through the pre-made holes of the strap. Its breaking strength is more than 20 tones and is cost effective compared to steel channel.

### ***Emulsion based explosive and cord system for use in Blasting Gallery (BG) in underground coal mines***

CMERI has developed for the first time an emulsion based explosive which has met the statutory requirements and considered suitable for use in BG panels. In order to achieve the required safety against inflammable atmosphere during trials for incendivity studies, flame retardant Polyethylene (FRP) tubes were used for the first time in designing permitted explosives in India. This system has a channel in the FRP tube for insertion of detonating cord for proper contact between the explosive and cord ensuring un failing, safe and efficient blasting throughout the borehole.

### ***Black box housing for automobiles***

CMERI has developed a black box to house the entire circuitry including embedded

software and hardware for automobiles. The housing is shockproof, fireproof, waterproof so that the assembly can absorb and withstand shock, impulses and possible escalation in temperature when a vehicle suffers from an accident. Centre for Development of Advanced Computing (CDAC) is developing, parallelly, the entire system including sensors softwares and related hardware for data acquisition for an Automobile Black Box. After design and first prototype testing, 13 units were handed over to the CDAC for field applications.

### ***Efficient filter press for vegetable oil of 40 & 90 l/hour***

Using a filter press constitutes the quickest way of filtering expelled oil. Conventional filter presses available in the market are generally not optimized for efficient performance. CMERI has developed cast aluminium plates for filter presses to render the filtered oil more amenable to food standards. Use of aluminium alloy of 2014 grade reduces the total weight of the filter press from 14 kg to a mere 6 kg, while retaining, and improving upon the other operational parameters. Further to that the aluminium press was replaced by a polypropylene filter press which, while retaining all the major design features and advantages of the previous model, improves upon quality of the pressed oil.

### ***National testing facility for general purpose rolling element bearings***

Antifriction bearings are very important components of all machines and equipment as their malfunctioning affects very adversely the performance of the system. Therefore, understanding and evaluation of the life of rolling element bearings is of great concern. In response to this need, CMERI has established a National Test Facility for

General Purpose Rolling Element Bearings at its premises in Durgapur in collaboration with Tata Bearings, a division of Tata Steel Limited. This facility, a unique one in the country, accommodates ten test rigs designed and developed at CMERI and can carry out accelerated life testing of bearings under controlled conditions. The load and lubricants are chosen in a manner to retain a minimum lubricant film thickness to avoid the metal-to-metal contact during the test run.

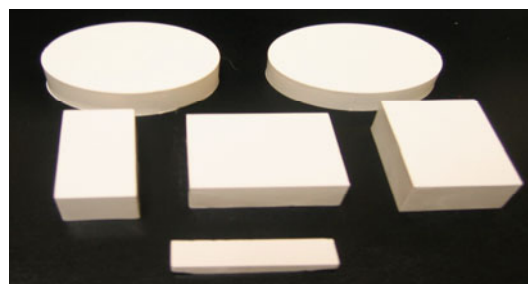
### ***Graphite from calcined petroleum coke***

IMMT has carried out, on 200gm scale, a series of experiments for the production of artificial graphite from calcined petroleum coke (cpc) powder employing catalysts such as B, Ti, Ni, Fe, Cu, Al, Mg, TiO<sub>2</sub>, B<sub>2</sub>O<sub>3</sub> etc. Results indicate 82 to 92% degree of graphitization and product yield of 90 to 94%. On the other hand, large-scale experiments on 1.5 kg basis, have shown physico-electrical properties very close to the commercially available pure graphite samples. The electrical power consumption per kilogram of graphite powder produced is around 5.0 Kwh. The typical properties of graphite produced using B, Ti and Ni catalysts by static bed plasma heat treatment are: density as 2.0 to 2.2 g/cc, electrical resistivity as 0.019 to 0.02 A Ωcm and d<sub>002</sub> as 3.369 to 3.37 Å. Experiments were also conducted to produce graphite powders from cpc using above mentioned catalysts by inflight heating at different electrical power input levels and powder feed rates. The heat-treated end product showed density of 2.06 g/cc, electrical resistivity of 0.02 Ωcm and d<sub>002</sub>=3.39Å. The electrical power consumption is also much lower (2.5 to 3.5 kwh/kg) than static plasma heating method.

### ***Low toxicity environment friendly gel-casting system for industrial application***

Conventionally, gel casting uses toxic acrylamide monomer for gelcasting process.

IMMT has evaluated several eco-friendly monomers such as albumin, carrageenan, chitosan etc, for their possible utilization for gelation. The monomers were evaluated for gelling characteristics and kinetics of gelation using rheology measurement at increasing temperature ramps. After establishment of the gelation temperatures of each monomer, their yield points have been determined to assess the strength of the gels. Subsequently, actual gelcasting of ceramic systems such as alumina have been carried out using these monomers. Dense/porous bodies have been developed using Albumin. Dense bodies developed with chitosan showed 95-96% of theoretical density.



*Dense products developed using environment friendly gel casting system*

### ***Electrolytic reduction of iron (III) present in phosphoric acid to iron (II)***

Using electrochemical route, scientists at IMMT have converted Iron (III) present in Merchant Grade Phosphoric Acid (MGPA) to iron (II). The electrochemical process provides better accuracy in control of electrochemical parameters and obviates any possible inclusion of impurities. An engineering package has been prepared for electrochemical reduction circuit for processing 5 l/h of MGPA along with details on equipment size and specifications, critical equipment design, safety aspects, equipment fabricator/manufacturer list etc. The unit, fabricated and tested at IMMT, has been installed at Heavy Water Plant (HWP), Talcher and is running successfully.



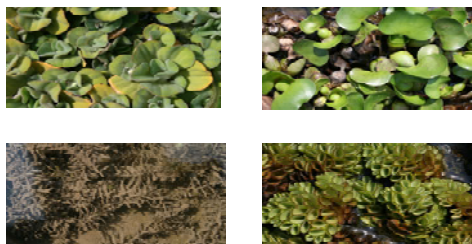
*Demonstration unit*

***Phytoremediation studies of fly-ash using aromatic and aquatic plants***

Studies on metal uptake and microbial population changes using aromatic grass of *palmarosa*, *jamarosa*, *lemongrass*, *citronella*, and *vertives* fly ash of Pradeep and NTPC origin were taken up at IMMT. For the remediation of ash pond water, four aquatic plants species were used. Studies reveal that the concentration of metal ions per gram of dry matter produced increased with increase in days of harvest. In case of aquatic plants, the highest total metal uptake was observed with *Eichhornia sp.* due to higher biomass yield. In aromatic grasses, the highest available metals like Co, Cu, Zn, Cd, Cr were taken up by *Citronella sp.* and Ni and Fe by lemongrass. The bacterial load from the rhizospheric region of lemongrass was maximum whereas the fungal load was maximum in case of palmarosa and jamarosa sp. In addition to this, phytoremediation and phytomining studies were also carried on nickel bearing chromite overburden of Sukinda (Orissa) and copper ore of Malanjkhanda (MP) using the same aromatic grasses.



*Experimental setup for phytoremediation of fly ash.*



*Aquatic plants used for phytoremediation of fly ash*

***Entrained flow biomass gasifier for thermal applications using powdery biomass***

A team of scientists at IMMT has developed a 30kW<sub>e</sub> capacity entrained flow biomass gasifier for thermal application for efficient gasification of powdery biomass such as rice husks, saw dusts, coir dusts etc. L/D ratio (length to diameter of gasifier) of 10 has been adopted to improvise the mixed flow and plug flow reactor characteristics to ensure full suspension of powdery biomass in a vigorous radial mixing condition in the reactor and to achieve high intensity reaction and gasification. The gasifier-reactor attains a temperature of 900-1200<sup>o</sup>C to take the advantages of the kinetics of the process and produce low tar and char formation. By maintaining a pre-estimated equivalent ratio of 0.27, temperature of the partial oxidation can be varied as per requirement. The endothermic steam induced reactions with a steam injection at a rate of 10-15 kg/hr coupled with the gasification reactions conserves the sensible process heat in the form of more hydrogen and carbon monoxide.



*Prototype of entrained flow biomass gasifier system*



### ***New phosphor materials***

New phosphor materials based on alkaline earth rare earth phosphates, which are likely to find practical applications in white light generation, Cathode Ray Tube (CRT) screens and other display devices have been developed at NIIST. Novel red and green emitting phosphors were synthesized by solid-state method. X-ray powder diffraction analysis confirmed the formation of xenotime type structure. Photoluminescence results showed that the phosphors can be efficiently excited by near-UV irradiation (396 nm/378 nm) and they give bright red and green emission with good chromaticity coordinates.

### ***Production of synthetic rutile, metallic iron and high purity iron oxide***

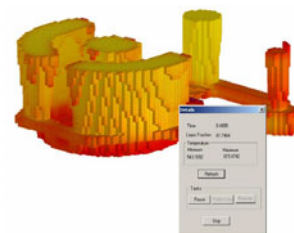
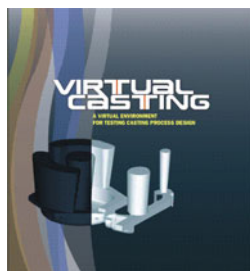
A newly designed and fabricated innovative cold plasma technique for the continuous melting of pre-reduced ilmenite has been found to result in separation of ilmenite into titania slag and metallic iron. This NIIST developed technique has been found to be better than a batch reactor in terms of high throughput and energy efficiently separation into titania slag and metallic iron to enable for continuous operation with very high throughput and energy efficiency than a batch reactor.

The process is simple and eco-friendly and results in separation of more than 90% of the iron in pre-reduced ilmenite. A valuable and salable by-product in the form of pig iron is also separated from the pre-reduced ilmenite. In addition to the metallic iron, the process also ensures a complete recovery of iron values from the leach liquor in the form of high purity iron oxide. The process flow-sheet is completely free from iron containing acidic effluents. The main product obtained, *synthetic rutile* is a suitable titanium feedstock for the chloride process of  $TiO_2$

pigment production. The plasma reactor showed the power consumption of 1.2 KWh/kg and productivity (30 kg/hr). Synthetic rutile with more than 93%  $TiO_2$  which ideally suited for chlorination was obtained in the pilot plant. Based on this technology, National Mineral Development Corporation is planning to establish a fully integrated pilot plant facility with a capacity of 1.5-2.0 tonnes /hr.

### ***Making Computer simulation affordable to the Indian foundry***

Virtual Casting, a software for simulation of casting solidification for the Indian market, seeks to help foundry men to create virtual environments to test out new designs and process innovations before actually implementing them on the shop floor. The software developed by NIIST makes it possible to shift the trials from the shop floor to the computer, saving time, effort, energy and material. As the casting industry in the country gears up to face the challenges of global competition, Virtual Casting attempts to make casting simulation useful and affordable to the small and medium scale foundry. It can be used, not only for industrial process design, but also in teaching and learning. Students of foundry technology can use the software as a virtual laboratory.



By experimenting with different process variables and seeing the impact on the final outcome, they can acquire great insight into the design process. It has been licensed for use by academic and industrial users.



### ***Small capacity rubber sheet driers for marginal farmers***

Technologists and engineer of NIIST have developed reverse flow natural convection driers, popularly known as RRLT-NC driers to help marginal farmers and cottage scale processors for rubber sheet drying. The drier has a capacity to handle 25-30 natural rubber latex sheets per batch, total hold up 60 rubber sheets and the drying time is 2 days. Fire wood /agricultural waste materials are used as fuel for the generation of hot air and smoke needed for curing the drier. The approximate cost of the drier is Rs. 13,000.



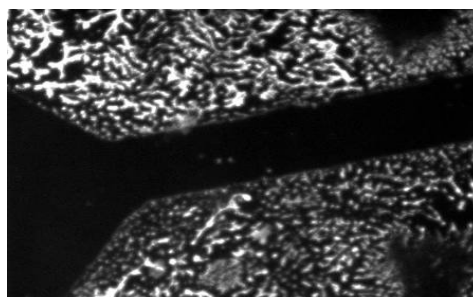
*Glimpse of rubber sheet drier*

### ***Micropatterning of biological molecules***

Patterning of biomolecules with micron and submicron resolution on to different solid surfaces is the key to the development of advanced biosensors, fundamental studies of cell biology and tissue engineering. NPL has used a simple technique based on microcontact printing of hexadecane thiol (HDT) and polyethylene glycol-thiol (PEG-thiol) to create pattern structure on gold-coated substrate exhibiting high hydrophobicity and high hydrophilicity, respectively. The hydrophobic regions strongly support the adsorption of proteins while the hydrophilic regions strongly resist the adsorption of proteins.

The pattern hydrophobic and hydrophilic regions have been further utilized to selectively deposit bovine serum albumin

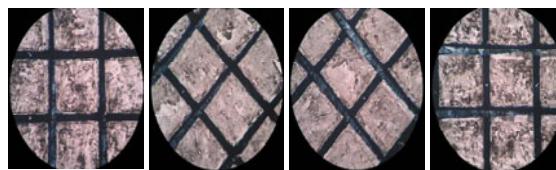
(BSA) tagged with Fluorescein isothiocyanate dyes. The figure shows the selective deposition of BSA-FITC conjugated molecules as seen under a fluorescence microscope. These experiments would form the basis to fabricate fluorescence based array biosensors for various biological applications.



80  $\mu$ m

### ***Micropatterning of alignment layers to produce pattern liquid crystal displays***

The planar alignment of liquid crystals takes place only on the area having bilayer of amino propyl tri ethoxy silane & cinnamoyl moieties. Area patterned with Octyl-Triethoxy-silane (OTS) shows homeotropic alignment of liquid crystals. Alignment direction is governed by the polarization direction of the UV-light and can be varied locally. These two independent techniques have been combined to produce samples showing both homeotropic as well as planer alignment of liquid crystals in a single cell. This has given rise to the possibility of creating new storage liquid crystal displays. The technique may also be used to produce patterned liquid crystal displays. Both the alignments have been found to be stable with time and temperature.



*Fluorescence micrographs of selectively deposited BSA\_FITC conjugated molecules on HDT coated regions*

### ***Self-cleaning coatings on glass substrates***

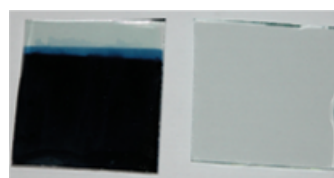
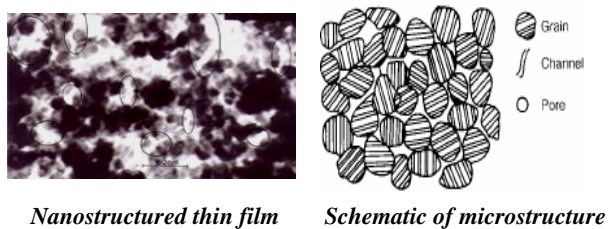
An equipment which enable a user to obtain thin films of metal oxides by sol-gel dip coating technique developed by NPL is not only cheap as compared to the conventional coating equipment, but is simple to operate as adjustment of coating parameters can be done by simple knob operation. This equipment gives thin film coating on both sides of the substrate simultaneously. Uniform film thickness can be obtained on large area substrates up to 1 meter x 1 meter with this equipment. The coating solution is partially hydrolyzed metal alkoxide solution with catalyst. The composition of different constituents is adjusted in such a manner that the solution can be reused for coating up to six months if stored under sealed conditions. The solid films obtained from this solution are scratch proof and are stable under various environmental conditions.

Simple glass windowpanes coated with films using the said technique blocks up to 30% of IR radiations and allows up to 80% of the visible part of the spectrum. These films absorb ultra-violet radiations to excite electrons from the valence band to the conduction band. Valence band electrons helps in dissociating the organic matter which make the windowpane dirty while valence band holes helps adsorb  $O^{+1}$  groups on the surface thereby making the surface superhydrophilic. Both these properties are very important from architectural point of view. Such glass, used as windowpane reduces the heating and cooling cost of the building and its cleaning require little labour and less detergents which saves the cleaning costs.

### ***Tungsten oxide films with a novel microstructure for fast switching smart windows***

A group of researchers at NPL has used a potential driven self-assembly of sodium

dodecyl sulfate/ tungsten oxide aggregates at the electrolyte-electrode interface followed by template extraction and annealing which results in mesoporous thin films of electrochromic tungsten oxide ( $WO_3$ ). This is a first report on hybrid structures comprising nanoparticles and nanorods with a tetragonal crystalline phase of  $WO_3$  with the measured lattice parameters. In addition to pentagonal voids characteristic of the tetragonal  $WO_3$  phase at the lattice scale, open channels and pores of 5-10 nm in diameter lie between the nanoparticles, which cumulatively promote rapid charge transport through the film. This results in a large coloration efficiency and switching kinetics higher and faster than previously reported values for mesoporous  $WO_3$  films. Repetitive cycling between the clear and blue states has no deleterious effect on the electrochromic performance of the film, which is suggestive of its potential as cathode in practical electrochromic windows.



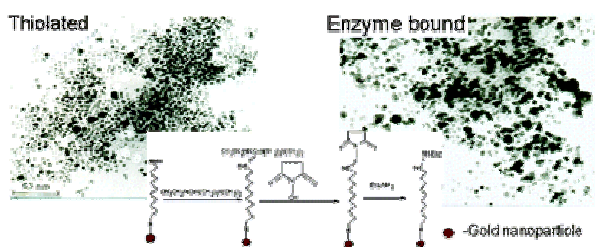
*Coloured and bleached level*

### ***Thiolated gold nano particles for the enhancement of glucose oxidase activity***

Biosensors have attracted much attention in recent times because of its potential applications in clinical diagnostics, environmental monitoring, pharmaceuticals, and food processing industries due to their

fast response and ease of operation. The stability of enzymes is crucial for the fabrication of biosensors. A number of techniques have been used for the immobilization of enzymes on different substrates to improve the enzymatic activity and stability. Nanostructure materials exhibit interesting properties such as a large surface-to-volume ratio, high surface reaction activity, high catalytic efficiency, and strong adsorption ability that make them potential candidate materials to play a catalytic role in the fabrication of a biosensor. Glucose oxidase ( $GO_x$ ) has been covalently immobilized onto chemically synthesized thiolated gold nanoparticles (5-8 nm) via N-ethyl-N'-(3-dimethylaminopropyl) carbodiimide (EDC) and N-hydroxysuccinimide (NHS) by a group of researchers at NPL.

The covalently immobilized  $GO_x$  thiolated nanoparticles exhibit a response time of 30 s, a shelf life of more than 6 months, and improved tolerance to both pH and temperature.



*Nanostructured thiolated and enzyme bound gold nano particles*

### **Modelling of crack tip blunting using Finite Element method**

A study which could help understand the blunting process in ductile material was carried out at NML, through finite element simulation (FEM) of standard fracture mechanics test specimen. From the load-displacement data generated by FEM, the crack tip opening displacement (CTOD) as

well as  $J$ , an energy parameter of elastic plastic fracture mechanics, and  $\Delta a$ , the crack extension, accompanying the blunting process have been calculated. The effect of variation of material properties like Young's modulus,  $E$ , yield stress,  $\sigma_y$  and strain hardening parameter,  $n$ , on the shape and slope of the blunting line has been established. The numerically obtained blunting line has been validated using experimental results. The blunting line is mildly sensitive to the level of flow stress, with the inflection occurring at a lower flow stress and with reduced sharpness as the flow stress is increased. The blunting line slope is higher in low strength materials. The nature of the blunting line is greatly dependent with the work hardening capacity of the material, with the overall slope of the blunting line increases with increased hardening behaviour.

### **Beneficiation of iron ore from Joda (East) using Floatex Density Separator**

In another study NML investigated the applicability of Floatex Density Separator (FDS) in removing alumina from iron ore fines (1.0 mm). Screw classifier feed containing 3.91% alumina has been used as feed to the FDS. Experiments according to a three-factor factorial design revealed that in single stage processing in FDS, a maximum of 72 % of the feed alumina could be removed. However, a loss in iron value is always associated with the removal of alumina. The recovery of iron under optimum condition was 61% in FDS. A final concentrate containing 1.66 % alumina could be achieved at a yield of about 57%.

### **Processing of waste printed circuit boards**

Recovery of metal values from waste printed circuit boards (PCB) using physical beneficiation techniques using a combination of dry and wet processes involving desliming, tabling, flotation, multigravity separation,

electrodynamic and electrostatic separation was developed at NML. The process produces a rich concentrate with significantly high recoveries of metals from ground -0.5 mm PCB powder. A concentrate grade of over 93% total metal at a recovery of over 54% or a grade of 66% total metal at 95% recovery could be achieved. It gives a feasible alternative to purely dry processes that have inherent inefficiencies and which may not provide a cost-effective technology for processing electronic scrap. The flowsheet does not warrant any use of sophisticated machinery and relies on time-tested equipment with reasonably good efficiency. Precious metal content was found to be significant in the PCB powder and it calls for development of proper hydrometallurgy based technology to recover them.

#### ***Microwave assisted combustion synthesis of magnetic alloys: nanoparticles and nanowires***

Electromagnetic radiation (microwave) do to play a role in the decomposition of organometallic complex, leading to a mechanistic pathway for bulk nano nickel wire bundle and sponge formation under ambient conditions. During the year NML has studied, what this role could be. Formation of wire is critically dependent on two factors: the mechanistic decomposition of complex under continuous exposure to microwave and extensive H- bonding in the molecule plays an important role in the decomposition mechanism. The formation of Ni wire is both thermodynamically and kinetically controlled in that, termination of exposure of microwaves on complex during decomposition results in an intermediate state (as Ni veins) prior to the formation of Ni wire. The shape and mass of Ni wire formation resembles heavily to the solid-state packing of organo metallic complex (bundle shape). On the other hand pulsed exposure to

microwave results in finely divided, highly porous Ni sponge, a disrupted form of Ni wire. Ni wire exhibits a blocking temperature,  $T_B > 300K$  with the saturation magnetic moment ( $M_s$ ) of 55emu/g, could be suitable for high temperature applications in the field of memory storage. It would open a new approach in the nano materials synthesis, in bulk form.

#### ***In-situ generation of stabilized metal nanoparticles in interlamellar spacing and on mesoporous surface of Montmorillonite clay***

Metal nanoparticles supported on microporous/mesoporous acidic oxide matrix are expected to behave very differently from bulk metals and are likely to act as bifunctional catalysts i.e. both as metal as well as acid function. Intercalation of metal acetate like  $M(CH_3COO)_2$  ( $M = Ag, Ni, Co, Zn, Cu, \text{ etc.}$ ) into Na-montmorillonite produces intersalated product  $M(CH_3COO)_2$ -M11-Montmorillonite(I) which on reduction by polyols (ethylene glycol) method generates *in situ* the corresponding metal clusters in the form Mo-Montmorillonite(II) composite. NEIST has used incipient impregnation technique for deposition of  $M(CH_3COO)_2$  on the micro/mesoporous clay support and subsequently dialyzed it to obtain composites with the salt loaded clay. The composites are characterized by X-ray diffraction. The supported metal salts were subjected to polyol reduction at  $\sim 195^\circ C$ . It has been observed that in some composites an ordered or channeled supported metal nanoparticles are formed. Similarly, mesoporous clay supported Au-nanoparticle (8-16 nm size) are also synthesized and characterized by TEM.

#### ***Propensity for the air/water interface and ion pairing in magnesium acetate vs magnesium nitrate solutions***

NEIST researchers during the period under report carried out molecular dynamics

simulations in slab geometry and surface tension measurements for aqueous solutions of magnesium acetate and magnesium nitrate in various concentrations. The simulations reveal a strong affinity of acetate anions for the surface, while nitrate exhibits only a very weak surface propensity, and magnesium is per se strongly repelled from the air/water interface.  $\text{CH}_2\text{COO}^-$  also exhibits a much stronger tendency than  $\text{NO}_3^-$  for ion pairing with  $\text{Mg}^{2+}$  in the bulk and particularly in the interfacial layer. The different interfacial behaviour of the two anions is reflected by the opposite concentration dependence (beyond 0.5 M) of surface tension of the corresponding magnesium salts. Measurements, supported by simulations, show that the surface tension of  $\text{Mg}(\text{NO}_3)_2(\text{aq})$  increases with concentration as for other inorganic salts. However, in the case of  $\text{Mg}(\text{OAc})_2(\text{aq})$  the surface tension isotherm exhibits a turnover around 0.5 M, after which it starts to decrease, indicating a positive net solute excess in the interfacial layer at higher concentrations.

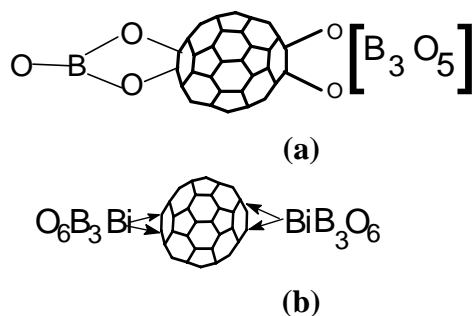
## Progress made under Network Projects

### I. Custom tailored Special Materials

Advanced information and communication technology and ultra-fast processing devices are based on custom tailored special materials. It is envisaged to generate strong knowledgebase and up-to-date expertise by developing new generation materials like novel non-linear optical materials, bio-molecular electronic materials and functional nano-materials. The knowledgebase would be needed by both the Indian industries and also the strategic sectors to remain globally competitive in terms of technological and financial advantages.

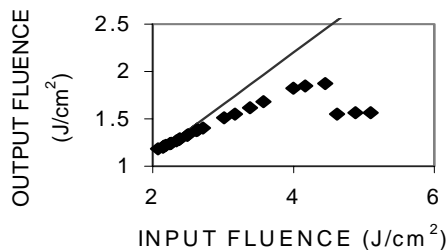
Under this project Fullerene  $\text{C}_{60}$  and  $\text{C}_{70}$  doped monolithic bulk glasses for nonlinear

applications were studied: Two novel high temperature chemical reactions of  $\text{C}_{60}$ -fullerene respectively with Boron and Bismuth have been discovered in the course of development of high concentration of fullerene glass. The mechanism of chemical reactions has also been proposed. The structures of Boron and Bismuth complexes were also detected in the mass spectrum.



Detected structures (a) Boron complex ( $\text{C}_{60}\text{B}_4\text{O}_{10}$ , Mass = 925) and (b) Bismuth complex ( $\text{C}_{60}(\text{BiB}_3\text{O}_6)_2$ ; Mass = 1397)

Nonlinear optical properties of the fullerene-glass composites reveal that the composites can limit the transmission of high intensity light. An optical-limiter transmits light when the latter is at low intensity but limits the transmission at its higher intensity, i.e. the efficiency of limiting of light transmission of such material, increases with the increase of intensity of the incident light and hence can function as a protector of laser sensor.



Variation of transmitted intensity with input intensity of 5 ns laser pulses at 532 nm through the glass. The straight line represents the extrapolated linear transmission.

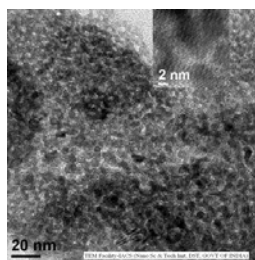
Apart from showing the unique optical properties, these nano-composites are found



to have good electrical conductivity which may find applications in fabrication of conducting coatings. The processes of preparation and the products have been patented in India and abroad. The nanocomposites have been included in the CSA Materials Research data base with Metadex database, USA.

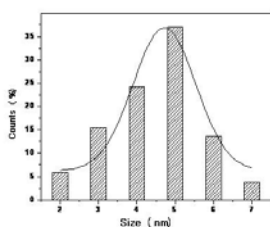
Developing nanoclusters of semiconductors like metal oxides, chalcogenides doped glassy films: is also an objective of this project, where in quantum confinement behaviour of indium tin oxide (ITO) nanoparticles was observed in the nanostructured sol-gel ITO films on glass. The excitonic transition due to confinement of electron-hole pair exhibited fluorescence behaviour which decays in the nano-second to pico-second range. The particle size distribution of the ITO nanoparticles was evaluated by transmission electron microscopy. Detailed analysis of the photoluminescence (PL) bands of nanostructured Mn (II) doped ITO revealed the exciton-phonon interaction.

The fluorescence life time measurement showed fast decay in the nanosecond to picosecond range which suggested that the exciton-phonon interaction did not change the PL life time.



(a)

(a) TEM image of ITO nano-particles and (b) particle size distribution

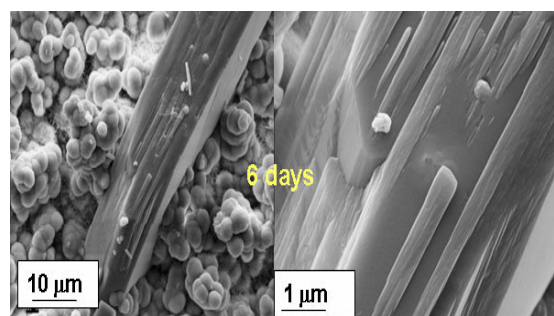


(b)

### ***Ceramic cellular products based on biomorphic route***

Silicon carbide (SiC) based materials have been developed through biomorphic route by replicating the cellular morphologies available in woods. Anisotropic structural feature of the Cellular or biomorphic Si/SiC ceramic composites may be employed to advantage in various micro-electronic applications such as design of a network of Si/SiC micro/nano-electrical heaters or power generators for micro-electronic circuitry which can be used in space technology, local communications, small batteries, refrigeration etc.

Novel synthetic route for Biomaterials and their applications was taken up being one of the objectives. The success of the use of metallic bio-implants depends on their bio-compatibility with the surrounding tissues inside the human body. One of the ways to achieve this is to give a Ca-hydroxiapatite coating of suitable morphology. A method for giving a coating of Ca-hydroxiapatite has been developed by using a biomimetic method in presence of protein. The coating has been characterized to find as to how the morphology and orientation of the coating are affected by the substrate. Detailed microstructural study has shown that the self assembly of protein molecules changed the morphology and orientation of the coatings.



Porous and solid HAp rods (~561 μm) developed on α-Al<sub>2</sub>O<sub>3</sub> by adapting bio-mimetic route.



## **II. Capacity building for coastal placer mineral mining**

In spite of having maximum enriched placer deposits, India continues to play a minor role in the marine mineral export compared to other dominating countries that have lesser potential than India. There is a high scope to improve the status of Indian placer export market through the development of indigenous mining and processing technology especially for buried placers and offshore resources. It is aimed to enhance the capability of country's technologies in the field of placer mining. The output of this work would put India as a global leader in this field, besides appreciable economic returns from the export potential. During the period, deposits of placer mineral available at Poompukar-Karaikal were characterised and pre-monsoon studies on profiling and sediment assessment including mineralogical studies and sediment budgeting through beach profiling for various season carried out. Likewise, about 75 samples were collected along West Bengal Coast of which profiles of 5 have been completed. 65 samples were processed mineralogically and 15 samples were analyzed through SEM. Micro-morphological features were studied. New set of exploration data upto 3 to 4 m depth at selected locations was created.

## **III. Developing capabilities in advanced manufacturing**

The project aims to explore the applications of advanced manufacturing methods and to upgrade the indigenous expertise both in manufacturing automation and near net shape manufacturing to become self-reliant.

The network project has many ambitious goals, one of which, the facility for Virtual Prototyping and Immersive Visualization has been established. First indigenous AMR Prototype is ready for testing. In technology

for tailored Stainless Steel Implants developed through the Investment Casting route has been transferred to M/s Manish Metals, Jamshedpur for manufacture of ADI crank shafts for automobiles.

## **IV. Biomineral processing for extraction of metal values from ores and concentrates and wastes**

The project aims at bioleaching of low grade copper ores of Malanjkhanda (0.3%Cu); Bioleaching of uranium (UCIL, 0.026% U); Strain improvement; Continuous down-stream processing for recovery of metal values (10 litres/hr capacity). During the year, after standardizing parameters for shake flask and column leaching of copper from lean ores of Malanjkhanda, facilities for heap leaching have been established at IMMT, Bhubaneswar to study and demonstrate bioleaching process. Two bioheap leaching plants of 15 ton and 30 ton capacity have been installed for uninterrupted running. The leach liquor is being processed for continuous solvent extraction and electro winning to get high pure copper (99.98%).

## **V. Technology for engineering critical analysis**

The project aims at development of technology for engineering critical analysis of the following components: pressure vessels and pipelines of the thermal and nuclear power plants, petrochemical and process industries; airframes and aeroengine components; infrastructural assets of the transportation industry: e.g. concrete and steel bridges, railway wheels and railway tracks; offshore structural components. During the period under review damage resistance of engineering materials was quantified. Experimental quantification of FCGR and fracture behaviour of 304LN SS was used for primary heat transport piping of nuclear power plants.

**VI. Upgradation of SI Base units, National standards of measurement & creation of a network of Calibration and testing laboratories and preparation & dissemination of CRMs**

The project has the mandate to upgrade Base Units and National Standards of measurements for: Mass, Luminous Intensity, Time; Chemical Metrology: Upgradation of apex level calibration facilities in the following parameters - Mass, AC Power & Energy, AC Voltage & Current, Length,

Force, Temperature, Ultrasonics, Acoustics, Networking of calibration and test facilities existing in 12 CSIR laboratories for providing high quality testing and calibration facilities to users in all parts of the country at a reasonable cost and in a reasonable time; Preparation, certification and dissemination of certified reference material. The work carried out during the year has led to enhancement of capability in Luminous intensity, Temperature, Time, Current and Length. 21 CRMs were released and CRMs in pesticides, gas metals are being prepared.