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IGC Newsletter

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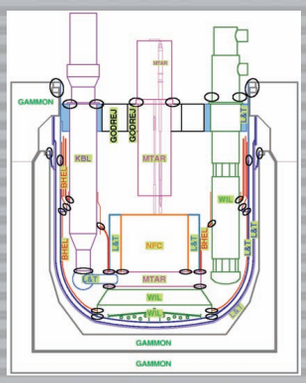
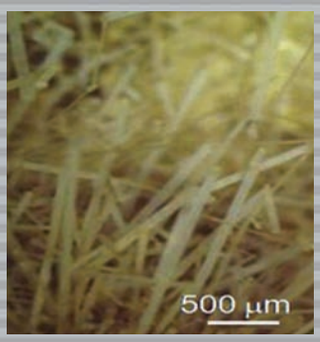
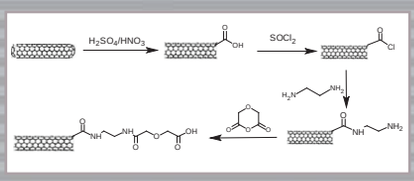
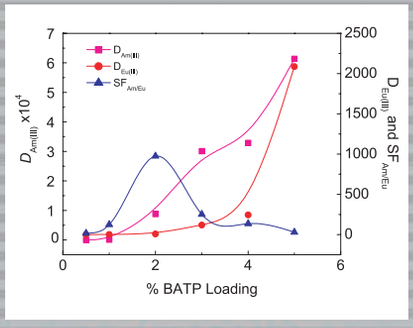








Dear Reader

From the Editor

It is my pleasure to wish you a very happy and prosperous New Year 2012.

It is my privilege to forward a copy of the latest IGC Newsletter (Volume 91, January 2012 issue).

In the Director's Desk, Shri S. C. Chetal, Director, IGCAR has highlighted the Instrumentation and Control activities being pursued in the Centre towards indigenous development of systems and deliverables for Prototype Fast Breeder Reactor and for future Fast Reactors. Apart from this important task, safety critical instrumentation and control systems, sodium instrumentation, wireless sensor networks, development of novel sensors and instrumentation for commercial reactors in the future are some of the activities taken up in the forefront. Director has given a brief description of each of the significant activities.

In the technical article by Dr. P. Chellapandi and his colleagues, an attempt has been made to introspect the challenges faced during the manufacturing and erection of components for PFBR and devise strategies for design of components for future fast reactors based on the experiences gained in the past.

The second technical article by Dr. S. K. Dhara and his colleagues, is on the superhydrophobicity in a single microbelt of gallium nitride which is otherwise hydrophilic in nature. Studies on the properties of the hydrophobic substrate and applications of such surfaces towards fabrication of smart fluid-controllable surfaces have also been discussed in the article.

In the young officer's forum, Shri Ashish Kumar Singha Deb has given an account of studies on functionalized multi-walled carbon nanotubes as a promising agent for the separation of uranium from waste solutions. Ms. P. Deepika shares her excitement in the development of nitrogen donor extractants for the separation of minor actinides from lanthanides in high level waste solution.

This Newsletter carries reports on the SMiRT Post Conference Seminars on Innovative Fast Reactor Design and High Temperature Design, IAEA Technical Meeting on Fast Reactor Physics and Technology, Theme Meeting on the Structure and Thermodynamics of Emerging Materials and the 8th Biennial National Conference on Recent Advances in Information Technology and on the visit of Shri P. Viswanathan, Honorable Member of Parliament from Kancheepuram Constituency, Smt.Vijayadharani, Honourable Member of Legislative Assembly from Vilavancode Constituency and on the visit of delegation from Nuclear Regulatory Commission of the United States led by Dr. Gregory B. Jaczko.

We are happy to share with you the awards, honours and distinctions earned by our colleagues. We look forward to your comments, continued guidance and support.

With my best wishes and personal regards,

Yours sincerely

M. Sai Baba

(M. Sai Baba)
Chairman, Editorial Committee, IGC Newsletter &
Associate Director, Resources Management Group

From the Director's Desk

Instrumentation and Control activities at IGCAR

Instrumentation and Control (I&C) systems ensure safe and efficient operation of a nuclear reactor. They play a major role in all the states of the reactor including operation of the reactor at various power levels to controlled safe shut down. That's why Instrumentation and Control systems are aptly called the eyes and ears of the Nuclear Power Plant (NPP). The Instrumentation and Control systems are designed with safety and availability of the reactor as the guiding requirements through redundant systems and also keeping in mind the simplicity of design and maintainability. A judicious combination of hardwired and computer based Instrumentation and Control systems, state-of-the art design, manufacturing processes and testing were employed in the design of Instrumentation and Control systems. Instrumentation and Control systems for 500 MWe Prototype Fast Breeder Reactor (PFBR) have been indigenously designed and developed and being manufactured at ECIL. In this article, I would like to highlight the activities relating to Instrumentation and Control being carried out at our Centre.

Safety Critical Instrumentation and Control Systems

In PFBR, the heat generated through fission reaction in the fuel sub-assemblies is removed by primary sodium circulating through the reactor core. Intermediate heat exchangers are used for transferring the heat from primary sodium to the secondary sodium system. Secondary sodium circuit is used for transferring the heat from secondary sodium through the steam generator. The large neutron flux range, high power density, high operating temperatures, sodium as coolant and fast response time requirements make the safety critical Instrumentation and Control systems of a fast breeder reactor quite unique as compared to those of thermal reactors. For the design basis events, diverse SCRAM parameters are used to improve the safety.

The neutron flux monitoring systems are provided to monitor neutron flux over ten decades (startup to full power) in the presence of high gamma field (10^6 R/h) to protect reactor against over power and reactivity incidents. High temperature fission chambers with 0.2 cps/nv sensitivity for application in the high temperature (567^{o}C) of fast reactors are developed indigenously and are under testing. For deploying under the safety vessel, fission chambers with 0.75 cps/nv sensitivity has been developed indigenously. 0.1 cps/nv fission chamber is developed for application in start-up of reactor and boron coated counters are also developed for application in PFBR.

The developments in these detectors have been successfully completed by combined team of IGCAR, BARC and ECIL. As the power density in PFBR is very high (500 kW/l), the continuous monitoring of the heat removal from the reactor core shall be ensured. Hardwired systems are used to get fast response time for monitoring the central sub-assembly outlet temperature and reactor inlet temperature as diverse methods to protect reactor against transient over power, primary sodium pump trip and off-site power failure events. The speed and flow of the primary sodium pump are monitored to protect against pump seizure and pump pipe rupture. Triple redundant computer based systems are employed to monitor the outlet temperatures of all the fuel sub-assemblies, to identify against risk of flow blockage and take suitable safety action.

The PFBR is equipped with two independent, hardwired, diverse, fast acting shutdown systems to protect the reactor against neutronic and thermal incidents. The first drive mechanism, called control and safety rod drive mechanism (CSRDM), is connected to safety logic with fine impulse test (SLFIT) system. The second drive mechanism, called diverse safety rod drive mechanisms (DSRDM) is connected to pulse coded safety logic system . Both the safety logics perform two out of three majority voting logic. Since solid-state logic circuits are employed, extensive self-checking is employed to ensure the healthiness of these circuits. The pulse coded safety logic system is a unique and diverse safety logic system, which is inherently fail-safe with built-in self-checking feature.

Safety Related Systems

As part of safety related systems for PFBR, systems like Instrumentation and Control for primary sodium and special supervision systems like reactor & fuel handling startup and discordance supervision for control rods & SCRAM signals were developed. These systems are configured using dual redundant real time computer (RTC) system with switch over logic system . The control systems of control and safety rod drive mechanism, diverse safety rod drive mechanisms, transfer arm, inclined fuel transfer machine form the component handling systems.

Non Nuclear Safety Systems (NNS)

Instrumentation and Control systems for secondary sodium, argon & nitrogen circuits, event sequence recorder, process disturbance analyzer are some of the non nuclear safety systems developed using single Versa Module Europa (VME)

system or micro-controller based remote terminal units (RTU).

Distributed Digital Control System (DDCS)

A state of the art distributed digital control system has been developed for PFBR to interconnect safety critical, safety related and non-safety Instrumentation and Control systems to the plant computers and in turn to operator display stations mounted on control room panels and console, through fiber optic LANs. The distributed digital control system software, for displaying plant information for monitoring and control, running on plant computers & GUI operator stations has been developed to run on Linux platform using open source tools, ensuring complete verification & validation.

Design and Manufacturing Methodology

For the computer based Instrumentation and Control systems, VME bus has been selected as the platform for implementing the various systems and the entire hardware (CPU and I/O boards) was designed and developed indigenously. This standardisation led to huge reduction of spares and standardization of power supplies.

The hardware modules for the hardwired and computer based systems were designed using state-of-the-art industrial grade programmable logic devices. After verification of the designs using simulation, prototype models were built. The printed circuit board design was carried out as per interconnect and packaging center (IPC) standards. The bare printed circuit boards were manufactured and qualified as per IPC-6012 standard. State of the art automatic assembly was adopted for the boards as the inspection was carried out as per IPC-610 standards. The modules were then lacquered for protection against humidity. The software was developed as per Atomic Energy Regulatory Board's safety guide. No operating system was used and only application software developed as per MISRA-C guidelines was used for the embedded system. The software modules for these systems were designed and developed using CASE tools - SCADE for safety critical systems & StP/SE for safety related & non-safety systems. The software developed have been put to independent verification and validation at various stages (requirements, design and implementation).

Testing and Qualification Methodology

The systems were functionally tested using computer based field signal simulator. The systems are qualified as per BIS standard on environmental qualification, EMI/EMC qualification tests as per IEC standard and seismic qualification test as per IEEE standard.

Sodium Instrumentation

The highly reactive nature of sodium used as coolant in PFBR has restricted the use of conventional instruments in fast reactor system. The requirement of enhanced safety and reliability has necessitated development of new techniques of instrumentation for safe and reliable operation of reactors. Permanent magnet flow meter designed based on Faraday's law is used to measure the sodium flow in sodium cooled fast breeder reactor circuits. Permanent magnet flow meter is a non- invasive device. Flow meters of different sizes ranging from 10 to 200 mm pipe diameter are required for the PFBR. Selection of magnetic material, design and development of magnetic circuits, stabilization of the magnet assembly, welding of thin mineral insulated stainless steel sheathed conductor cable to the pipe as signal electrode, positioning of the duct with the pair of electrodes in the air gap of the magnets at exactly perpendicular to the direction of flow and magnetic field, assessment of flow meter sensitivity at different temperatures are the main challenges involved in the manufacturing of flow meter. The technology developed in our Centre was transferred to the Indian industries and flow meters required for PFBR were successfully manufactured.

Mutual inductance based detectors have been developed for the measurement of discrete and continuous measurement of level in sodium capacities. A simple temperature compensation technique has also been implemented in continuous type mutual inductance based level probe. The manufacturing of level sensors and electronics are carried out by industry, based on the technology developed at our Centre. The indigenously manufactured level probes are calibrated in sodium facilities at our Centre. Wire and spark plug type leak detectors are used on pipelines, in bellow sealed valves and leak collection trays for detection of sodium leaks. As a redundant method of leak detection, leak detectors based on mutual inductance method have also been developed at our Centre. This type of leak detector is non-intrusive and easily replaceable and hence it gains importance for usage in the reactor systems. Sodium aerosol detector working on the principle of preferential ionization of sodium aerosol at the detector has been developed for detection of sodium leak in gas. These detectors can detect 1 mg of sodium per m^3 of carrier gas. Under sodium viewing system has been successfully developed as a novel instrumentation tool for visualizing reactor core components before fuel transfer operation.

Development of Instrumentation and Control Systems for Future Fast Breeder Reactors

Various development activities are being pursued towards upgradation of Instrumentation and Control systems for future FBRs. These include, development of core thermocouple probe with three thermocouples to simplify the core temperature monitoring system and m ake it in line with the safety criteria (independent and triplicate instrumentation for safety class-1), development of signal processing electronics suitable for placing in the roof slab top to reduce the requirement of large volume of

signal routing from roof slab to the periphery. Development has been initiated to qualify thermocouples made by Indian industries as per the requirements of fast breeder reactors. Indigenous development activities are also initiated to manufacture leak tight penetration assemblies for electrical and Instrumentation and Control cables. Level measurement based on RADAR principle to simplify the level measurement in certain cases by mutual inductance technique, which is available for other fluids are tested for sodium application and found promising. High temperature fission chambers with a sensitivity of 1 cps/nv will be developed in association with BARC for deployment in future reactors in place of the present 0.2 cps/nv detectors being provided in control plug of PFBR. This will eliminate the under vessel fission chambers being provided in PFBR.

Instrumentation and Control for Fast Reactor Fuel Reprocessing

The Instrumentation and Control for fast reactor fuel reprocessing is broadly categorized into process instrumentation, radiological instrumentation and general instrumentation services. Process instrumentation is responsible for the measurement and control of various plant process parameters like liquid level, density, pressure, temperature and ensuring the safety aspects in the process operations. Various operation interlocks ensure equipment protection and operator safety. The high radiation fields and alpha radioactivity make material selection and maintenance very challenging. The ventilation system is monitored and controlled, as it forms the dynamic containment for radioactive materials. Radiological instrumentation deals with the monitoring of various radiations related parameters in the plant areas to ensure safety of operators. Radiometry forms an important part of process analysis. General instrumentation services include plant communications, information systems, in-cell camera, physical protection, fire alarm system and UPS. For the fast reactor fuel reprocessing plants new technological developments like 'smart' field instruments, programmable logic controllers, computer based systems etc are adopted in the Instrumentation and Control. The developmental works include the assay system for fissile materials in waste drums, dual scintillator based radiation monitors and new criticality alarm systems.

Sensor Development for Instrumentation and Control Systems

Pulsating Sensors

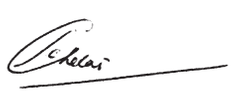
One of the important advancements in sensor development program at our Centre is the evolution of a new class of sensors namely pulsating sensors. Unlike conventional sensors these sensors work purely in digital domain. The primary signal generated from the sensor is a train of rectangular pulses which carry the information of the parameter sensed. One of the important applications of pulsating sensors in the context of PFBR is development of dash pot oil level sensors for control and safety rod drive mechanism system of PFBR to monitor the SCRAM action of control rods. Another important application towards PFBR is development of differential pressure sensors between safety vessel and main vessel. A rapid level monitoring technique using pulsating conductance based level sensor has been deployed to capture online the fluctuations of surface water level in hot pool of SAMRAT - a ¼ scale model of reactor assembly for PFBR. Rapid titration facility using pulsating sensors has been developed for quick assay of uranium, plutonium and hydrazine in reprocessing laboratory. This method enables avoiding handling of large volumes of reagents besides generating minimum radioactive wastes. Another important area of application of pulsating type conductivity meter is to detect the formation of third phase in PUREX campaign in reprocessing plant.

Wireless Sensor Networks

R&D is in progress to use wireless sensor networks in the future reactors as the off-the-shelf wireless sensor nodes are not suitable for reactor applications. Wireless sensor networks has been established for the sodium leak detection in the sodium loops. The radiation monitoring at hot cells and hot mini cells with ^{137}Cs as source is also carried out at Radio Chemistry Laboratory. At present test network is in place at secondary sodium loop area of FBTR, for measuring parameters like temperature and vibration. For securing the wireless data, the enhanced TinySec security protocol has been developed. For improving response and robustness of the routing protocol, the real time routing protocol development is in progress.

Fiber Optic Sensors

Optical fibers are used as sensors for measuring process parameters like temperature, strain, vibration, etc., by correlating changes in intensity, phase, wavelength and polarization of light launched into the fiber, with associated changes in parameters. The suitability of using Raman distributed temperature sensor for high temperature measurement has been demonstrated on sodium loop. The indigenous design, testing and independent verification & validation process through the combined and dedicated efforts of IGCAR, BARC & ECIL has resulted in the development of robust Instrumentation and Control for PFBR and fast reactor fuel reprocessing. R&D road map for Instrumentation and Control systems for future FBRs with emphasis on indigenous supply has been well laid and is progressing well.



S. C. Chetal
Director, IGCAR

Lessons Learnt from Manufacturing and Erection Experiences of Prototype Fast Breeder Reactor

The construction of 500 MWe Prototype Fast Breeder Reactor (PFBR) will be completed this year. Beyond PFBR, DAE is planning to build six 500 MWe Sodium Cooled Fast Reactors adopting twin unit concept. The first twin unit (2x500 MWe) would be constructed at Kalpakkam near PFBR. The capital cost of these twin units as well as construction time should be reduced significantly for the commercial exploitation. To achieve this, many features have been identified and are being studied at IGCAR. One of the essential steps is incorporation of lessons learnt during manufacturing and erection of PFBR components. Robust strategy was adopted for PFBR towards successful manufacture and erection of reactor assembly components. Technology development prior to start of the construction and formation of standing task forces involving IGCAR-BHAVINI for manufacturing and erection of components, which are functioning effectively since September 2006, are the key factors for the success. Regular meetings were held on a day to day basis, to resolve the issues referred by various industries and to deliberate on the manufacturing and erection sequences (about 310 meetings were held and about 900 issues were resolved).

This article provides the lessons learnt from the significant efforts putforth for the successful manufacturing and erection of reactor assembly components.

Salient Features of Sodium Cooled Fast Reactors Components with Reference to Construction

Sodium Cooled Fast Reactors components, in general are characterized by large diameter thin walled shell and slender structures. Stringent manufacturing tolerances are specified to enhance their buckling strength as well as to have possibly minimum vessel dimensions. In the reactor assembly, main vessel, thermal baffles, inner vessel, core support structure and grid plate are to be positioned sequentially maintaining the coaxiality with the safety vessel, so that the core central line will be in-line with the central lines of the vessels: one of the requirements to facilitate smooth operation of control rods as well as for facilitating accurate monitoring of temperatures of sodium emerging from the core sub-assemblies. Further, they have to be erected accurately to maintain the annular gaps for the uniform sodium flows and temperatures. During manufacturing stage, single side welds are unavoidable at some difficult locations particularly in the case of box type structures. In-service inspection is difficult with the presence of sodium and hence, stringent quality control is required in the pre-service level itself. From the dimensional stability point of view, residual stresses should be kept minimum value by adopting robust heat treatment processes and mockup trials. It is preferable to use minimum number of materials from the consideration of economy

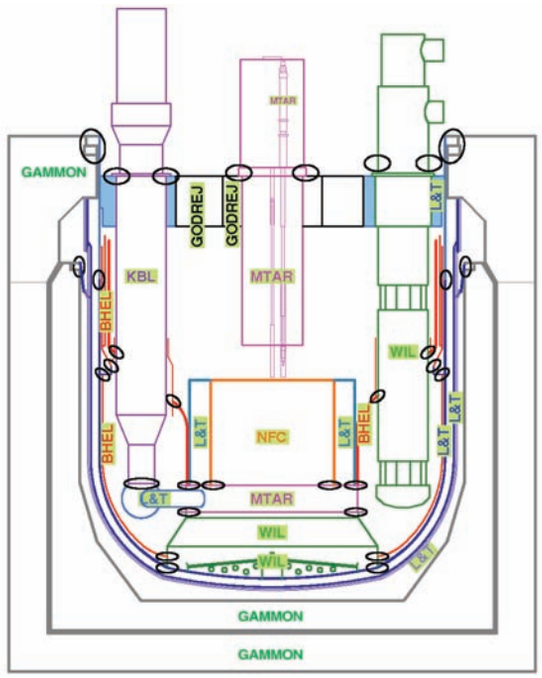


Figure 1: Major industries involved in manufacture of reactor assembly components of PFBR. (Safety Vessels, Main Vessel, Primary Pipe, Roof Slab, Core Sub-assemblies by L & T, CSRDM & DSRDM, Grid Plate, Control Plug by MTAR, Thermal Baffles including cooling pipe, Inner Vessel by BHEL, Core Catcher, Core Support Structure by WIL, and LRP & SRP by Godrej)

and material data generations. This also enhances reliability of performance of materials in the operation. Austenitic stainless steels, the main structural material in particular call for careful considerations for welding without significant weld repairs and distortions. Construction experience of international and PFBR indicates that reactor assembly components decide the project time schedule, even though their cost is relatively small compared to civil, sodium circuits and balance of plant. Only limited experience on manufacturing and erection of components is available. These apart, the design and manufacturing codes are still evolving. These are the major challenges in the manufacturing and erection of reactor assembly components.

Major Decisions taken during Manufacture

While, IGCAR designed the reactor assembly components, six major industries in the country were involved in the manufacture (Figure 1). It has been experienced that industries request the designers to consider accepting the minor deviations in composition of materials for construction based on the availability. Due considerations were given for such requests based on accumulated knowledge / expertise over the years. This has avoided procurement of fresh materials. Thus, as far as possible, fresh raw material procurement including weld electrode and filler wire (thickness of spherical header) was

Figure 2: Manufacturing stages of grid plate

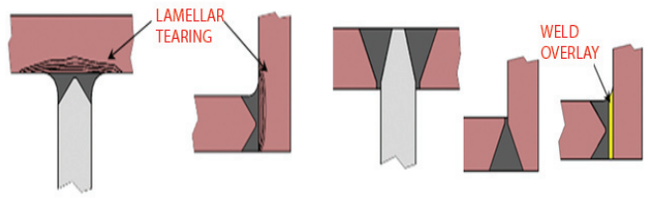


Figure 3: Lamellar tearing at 'T' & 'L' Joints in roof slab and Solutions

avoided by suitable alternatives. This has resulted in significant savings in project schedule. Manufacturing deviations were accepted in the material properties based component duty and environment; for e.g. molybdenum content in weld electrode for low temperature application, ductility requirement for tools. Certain manufacturing and welding procedure qualifications, e.g. relaxation of requirements for the non-load carrying and non-sodium wetted boundaries of safety vessel and core catcher, were accepted. Testing and inspection procedures were simplified based on its importance duty and alternative bend test procedure was suggested for dissimilar weld at roof slab. Assembly procedures of parts were simplified to achieve the tight requirement of erection tolerances. However, for the main vessel, care has been taken so that practically there is no repair of welds or laminations. With thorough and comprehensive analysis respecting interface requirements with other components, the as built dimensions were accepted. For certain non-critical cases (e.g. core catcher and safety vessels), the concept of fitness for purpose approach was adopted judiciously.

Lessons Learnt from Manufacture of Reactor Assembly Components

In the current discussion, three components, viz. grid plate, roof slab and fuel handling systems, are focused, which have been responsible for the considerable delay of the project schedule, in turn motivating us to opt for alternate design concepts. The manufacturing challenges of grid plate mainly originated from large number of sleeves resulting in higher self weight and hard facing of large diameter sleeves. Machining of large diameter plates and shell assembly to the required tight tolerances on dimensions, hard facing with nickel based cobalt free hard facing material on continuous, large diameter (6.7 meter) annular tracks, heat treatment of large austenitic stainless steel parts at 1050°C with controlled rates of cooling and heating together with control on temperature gradient across the parts, complex assembly of a large number of parts (~14900) meeting the important requirements on verticality of sleeve assemblies (Ø0.1 mm), delicate handling and transportation are truly challenging activities in the manufacturing technology (Figure 2).

In case of roof slab, complex manufacturing process, especially welding between the shell and stiffeners caused lamellar tearing problems and extensive testing time (Figure 3). Inclined fuel transfer machine, multiple repairs, heavy weight and testing strategy resulted in long manufacturing and testing time.

It is also worth to note some general lessons learnt. Technology development prior to start of construction is essential for long delivery components. The important outcome of technology development exercise undertaken for PFBR components are brought out comprehensively in Figure 4. Judicious choice of tolerances, number & location of welds and inspections has to be made. Robust criteria need to be applied for the acceptance of manufacturing deviations and material compositions. Indigenous materials should be used after qualifications of manufacturing

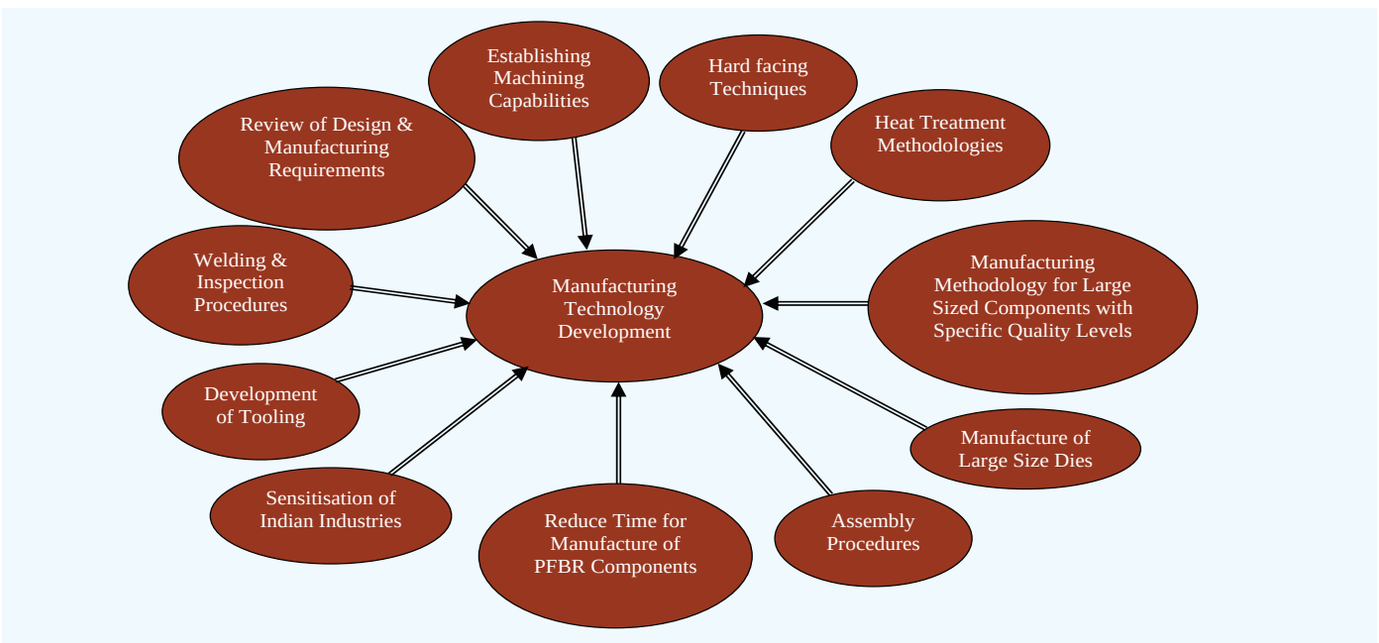


Figure 4: Outcome of technology development exercise

Figure 5: Mockup trials for the successful erection of safety vessel

Figure 6: Full scale top shield layout mockup

process of direct relevance apart from routine standards. Manufacturing drawings should be finalized after a few rounds of discussions with prospective industries giving due considerations to economy. Subsequently, the revision of manufacturing drawings should be minimised in particular materials, tolerances. Single industry for manufacture of permanent components of reactor assembly will certainly help to minimise the integration problems and also avoid delays in the project. In case industry needs technical supports, decisions should be taken quickly based on scientific input giving due considerations to international experience.

Major Decisions Taken during Erection of Components

Computer simulations were extensively used based on 3-D virtual models for establishing erection sequences. The erection sequence established for sequential erection of reactor assembly components were developed. Based on these, a document has been made to give guidelines for industries and erection agencies. Handling scheme structures were designed, developed and tested in novel ways to achieve minimum material, avoid weld attachments and minimum assembly time. Many useful mockup trials ideal for training of crane operations were carried out and confidence has been built-up before going for safety vessel handling. It is worth to bring out here two typical full scale mockups built and employed at IGCAR for the successful erection of safety vessel and welding of roof slab hanging shell and main vessel (Figure 5). Further a full scale mockup has been built for visualizing the complicated layout of top shield components (Figure 6). This mock up will further help to ensure the availability of space and access for adding and removing complementary shield blocks at any time and smooth operation of trailing cables without any entanglement during rotation of plugs. Computer simulations and mockup trials helped to ensure good access for critical welds towards establishing techniques and tools

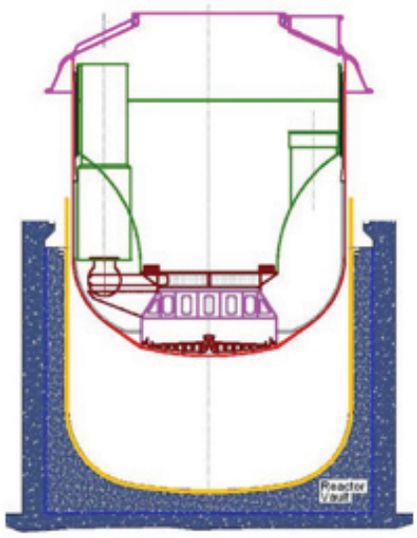


Figure 7: A proposal for manufacture and erection of reactor assembly of future Sodium Cooled Fast Reactors

for the mismatch correction procedure and methodology and appropriate welding sequence to minimize distortion controls.

Lessons Learnt from Erection of Reactor Assembly Components

Erection sequences and handling systems should be finalized after detailed discussions with the use of advanced computer software techniques. Care should be taken so that there is no revision of erection sequences, handling systems and schemes. Judicious choice of construction sequences of civil, mechanical and electrical systems is essential for the success. There is a need of optimum number of site assembly shops. Possibility should be studied to manufacture the entire reactor assembly components as a factory-made single package item. One possible strategy is schematically explained in the sketch (Figure 7). As per this, the reactor assembly components and civil construction of reactor vault along with safety vessel are constructed in parallel in matching time schedule so that that reactor assembly can be erected without any time delay. Subsequently other reactor internals kept ready in site assembly shop can be introduced. It is preferred to manufacture the permanent components of reactor assembly in integrated manner as a single package involving one major nodal industry. Towards achieving this, it is essential to motivate the prospective industries to participate as consortium attracting them with significant business opportunities in the long term.

From the rich experience gained through the manufacture and erection of reactor assembly components of PFBR, important guidelines and approaches were derived. These will be very useful for the success of future SFRs, planned by the department. It is estimated that by adopting these, it is possible to complete the construction of one twin unit within 5 years.

Reported by P. Chellapandi and Colleagues
Nuclear & Safety Engineering Group

Air Trapped Nano-Cavity Induced Superhydrophobicity on Gallium Nitride Microbelt

Nature has learnt to control liquid in a myriad of ways with regard to design of biosurface with special wetting characteristics. The wettability, that is how a liquid behaves on a surface, is an important factor for a wide range of natural systems as well as in several technical applications. It is believed that the excellent water repellence of the lotus leaf can be attributed to an unique combination of micro- and nano-hierarchical surface morphology as one of the major characteristics and the ensuing oriented surface texture can bring about anisotropic wetting on rice leaves and waterfowl feathers. Moreover, surface protrusions create an energetically unfavorable situation for a liquid to be sucked or 'imbibed' into the surface texture of the superhydrophobic (contact angle of water droplet >= 150°) surfaces leading to an increased beading-up tendency. If these protrusions appear as a 'bed of nails', we can imagine the liquid as skating across their tops. When the nails are thin enough, the droplet formed itself into a perfect sphere. Effectiveness of this process for any given textured surface depends on both the roughness amplitude and the wetting property of the liquid. On the other hand, the liquid should penetrate into the bed in case of hydrophilic (contact angle of water droplet < 90°) surfaces, having a tendency to spread the liquid. In this process the additional surface area from the sides of the nails causes a force that sucks the liquid into the texture. Roughness in turn should amplify the hydrophilicity. However, some recent reports demonstrate that roughness can also lead to formation of a superhydrophobic contact angle on a hydrophilic substrate. For example, the leaves of Lady's Mantle show superhydrophobic properties owing to the elasticity of the hydrophilic hairs on the leaves. The self-affine topologies of surface roughness can bring about a superhydrophobic state no matter whether the substrate is hydrophilic or hydrophobic. Some report had shown a transition from hydrophilicity domain to superhydrophobicity region by decorating the substrate with organic polymer surfaces. It is generally recognized that the superhydrophobicity of textured surfaces not only arise from their

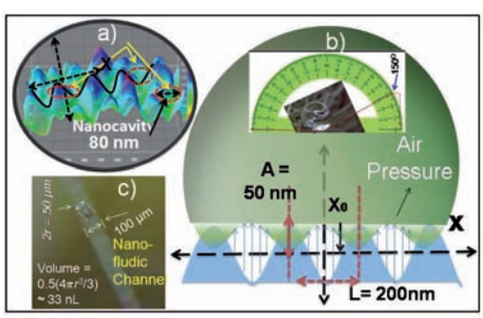


Figure 2: a) Nanocavity created by the nano-protrusions, an image processed data using ImegJ, b) Air trapped nanocavity is schematically shown to dewet the surface and c) Nanoliter delivery in a single microbelt

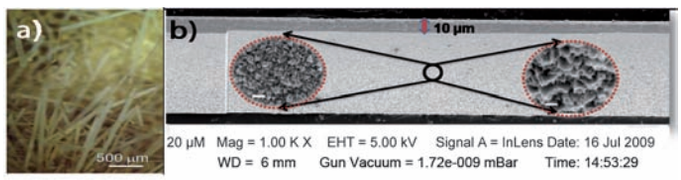


Figure 1: a) Optical image of the micron sized gallium nitride and b) FESEM image of a single gallium nitride belt with high magnification image of the nanoprotrusions in the inset

unique fractal surface structures having micro- and nano-features embedded, but also these surfaces constantly exploit vibration for transition from the Wenzel (wetted) state to a complete Cassie (non-wetted) state to restore superhydrophobicity. In all these cases, the salient feature to promote a favorable non-wetting thermodynamic state is to form a composite state having entrapment of air within the trenches of rough surface. The phenomenon of entrapment of air indicates that the geometrical parameters of a nanostructure have influence on the wetting behavior and contribute to the reversible switching between hydrophilicity to superhydrophobicity.

The Micron size (breadth ~ 100 μm, width ~ 10 μm and a length of ~3–7 mm) gallium nitride belts (Figure 1a) having nano-protruded surface (Figure 1b) with average conical tip size ~20 nm and height ~50 nm are designed in a typical chemical vapour deposition technique. The nanosized cavities (diameter ~ 80 nm) on the surface repel water (Figure 2a), making such a surface potentially useful for nanofludic activities and developing biocompatible devices. It can be preferentially integrated to generate nano-electromechanical systems based nanobiosensors and other lab-on-chip purpose where a nanoliter amount of water could be handled with proper care.

We report superhydrophobicity in a single microbelt of gallium nitride, which is otherwise hydrophilic in nature. The result is demonstrated in a gallium nitride microbelt grown by chemical vapour deposition technique at 900°C using Ga as precursor materials and NH_3 (10 standard cubic centi meter) as reacting gas with unique surface morphology. The changeover from hydropilicity to superhydrophobicity on gallium nitride microbelts are examined from the viewpoints of geometry of the surface and surface energy. Presence of air trapped nanocavities of specific height by diameter ratio, made within the nanoprotrutions, on hydrophillic gallium nitride surface are responsible for the transition to superhydrophobicity (Figure 2b). This novel finding may offer an efficient new way of direct production of superhydrophobic material and further to design and fabricate smart fluid-controllable surface. As a matter of fact we could achieve nanoliter delivery in a single microbelt (Figure 2c).

Reported by Sandip Kumar Dhara and colleagues, Materials Science Group

Young Officer's FORUM

Shri Ashish Kumar Singha Deb obtained his post graduation in Chemistry from University of Calcutta, Kolkata in 2007. After successful completion of 51st batch of BARC Training School, Mumbai, he joined in IGCAR as Scientific Officer C in September 2008 and is working in Radiological Safety Division, Radiological Safety & Environmental Group, Reactor Engineering Group. His current research activity includes development of alternative material for treatment of low level effluents.

Functionalised Carbon Nanotubes for Removal of Uranium from Aqueous solution

Since the discovery of carbon nanotubes by Sumio Iijima in 1991, this cylindrical allotrope of carbon has become one of the most researched materials because of their unique physical and chemical properties. Carbon nanotubes include single-walled (SWCNTs) and multi-walled (MWCNTs) depending on the number of layers comprising them. Being porous and hollow with large surface area, low density, high mechanical, thermal and chemical stabilities, carbon nanotubes have been utilized as an adsorbent for removing a wide variety of organic compounds and metal ions from aqueous or organic medium. It has also been used for removal of contaminants in drinking water. Recently carbon nanotubes have also been applied for recovery of radionuclide such as thorium, europium, americium, uranium and plutonium from aqueous solution. Generally, carbon nanotubes are used in pristine form. For optimum sorption selectivity and removal efficiency towards specific metal ions or organic molecules they need to be modified without much alteration of their physical and chemical properties. Modification can be accomplished through covalent functionalization and non-covalent functionalizations. Covalent functionalization involves introduction of organic functional groups or ligands on the surfaces or ends of carbon nanotubes. Ligands or extractants capable of extracting uranium from organic or aqueous solution can be covalently bonded on the carbon nanotubes. Among these extractants diglycolamide derivatives such as N,N,N',N';-tetraoctyldiglycolamide (TODGA) and N,N,N',N'-tetrakis-2-ethylhexyldiglycolamide (TEHDGA) have been reported for the separation of uranium in aqueous solution. Diglycolamides (DGA) is a tridentate ligand due to which it possesses greater tendency to bind with metal ions. In this article, the covalent functionalization of multi-walled carbon nanotubes with diglycolamide group and use of this functionalized multi-walled carbon nanotubes (DGA-MWCNTs) for the removal of uranium from aqueous solution will be discussed.

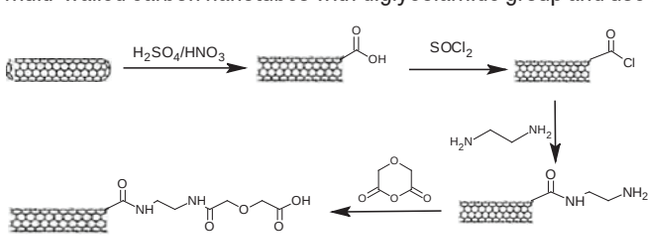


Figure 1: Scheme of functionalization

Functionalization of MWCNTs

Sequential functionalization of multi-walled carbon nanotubes was undertaken. The functionalization involves carboxylation, acylation, amidation and diglycolamide functionalization of the procured multi-walled carbon nanotubes. The scheme for sequential functionalization of multi-walled carbon nanotubes is given in the flow sheet (Figure 1).

Characterization of Functionalized Carbon Nanotubes

Characterization studies were carried out using Fourier transform-infrared spectroscopy (FT-IR), X-ray diffraction (XRD) and scanning electron microscopy (SEM). The chemical modification on MWCNTs in each step was monitored by FT-IR spectroscopy. FT-IR spectrum revealed the introduction of diglycolamide group onto multi-walled carbon nanotubes. XRD pattern of as received and diglycolamide functionalized multi-walled carbon nanotubes indicates that even after the functionalization there is no change in the cylindrical wall structure of multi-walled carbon nanotubes. The retainment of the tubular structure of multi-walled carbon nanotubes has also been confirmed by SEM studies of multi-walled carbon nanotubes before and after functionalization.

Uranium Adsorption Studies

Influence of parameters in adsorption

The variation of distribution coefficient (K_d) of DGA-MWCNTs as a function of nitric acid concentration for uranium adsorption was studied. It is observed that K_d value is increasing with an increase in concentration of nitric acid (Figure 2a). At 4 M nitric acid, the K_d value is 4.75×10^4 milli liter g^{-1} which is about 10^2 times greater than that of various DGA modified substrates such as

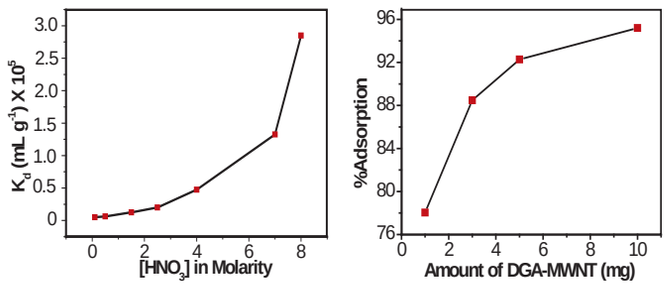


Figure 2: Effect of (a) HNO_3 concentration and (b) DGA-MWCNTs dose on adsorption of uranium in DGA-MWCNTs

chromosorb-W, impregnated magnetic particles and Amberchrom CG-71C. This enhancement in K_d value can be the attributed to the unique nanostructures on the multi-walled carbon nanotubes.

The effect of mass of DGA-MWCNTs (0.001 – 0.010 g, [U] fixed at 20 mg/L) on percentage of adsorption of uranium was also studied. As shown in Figure 2(b), the percentage of adsorption increased sharply with increasing amount of the DGA-MWCNTs adsorbent up to 5 mg beyond which a saturation was observed.

The variation in the concentration of feed was also investigated. It was found that the percentage of adsorption increased with increasing uranium concentration and reached a maximum at uranium concentration of 10 mg/L (5 mg of DGA-MWCNTs were used) and then decreased with increasing uranium concentration.

Adsorption isotherms

The experimental data of adsorption of uranium was analyzed with the Langmuir and Freundlich models. The adsorption isotherm was also plotted against experimental data of uranium adsorption on DGA-MWCNTs. The equation of Langmuir and Freundlich adsorption models are expressed respectively in equation 1 & 2.

$$\frac{C_e}{q_e} = \frac{C_e}{q_o} + \frac{1}{q_o b} \quad \text{.....} \quad (1)$$

$$\ln q_e = \ln K + \frac{1}{n} \ln C_e \quad \text{.....} \quad (2)$$

where C_e (mg L^{-1}) is the concentration of uranium at equilibrium and q_e (mg g^{-1}) is the amount of uranium adsorbed at equilibrium. The value of q_0 & K can be correlated to the adsorption capacity of an adsorbent under particular experimental conditions. b, K and n are isotherm constants. Linear Langmuir (C_e/q_e Vs. C_e) and Linear Freundlich (ln q_e Vs. lnC_e) plots are used to evaluate the Langmuir and Freundlich constants tabulated in Table 1. As can be seen, the q_e are better correlated with the Langmuir model than with the

Table 1: Isotherm model parameters for uranium adsorption onto DGA- MWCNT

Langmuir constants			Freundlich constants		
q_0 (mg g^{-1})	b (L mg^{-1})	R^2	K ($mg^{1-1/n}L^{1/n}g^{-1}$)	1/n	R^2
133.74	12.30	0.99	10.11	0.88	0.98

Table 2: Thermodynamic parameters for uranium adsorption on DGA-MWCNT

ΔH^o (kJ $m^o l^{-1}$) = 6.09	ΔS^o (kJ $m^o l$ $-1K^{-1}$) = 0.106				
T (K)	298	313	323	343	353
ΔG^o (kJ mol^{-1})	-25.51	-27.09	-28.16	-30.28	-31.34

Freundlich model. It shows high values of the constants q_0 and K which are related to uranium adsorption capacity on DGA-MWCNTs.

Adsorption Thermodynamics

The thermodynamic parameters such as ΔH^o and ΔS^o were calculated from the slopes and intercepts of the linear regression of ln K_d Vs 1/T plot using the Van't Hoff equation and the standard free energy (ΔG^o) values were calculated The values of ΔH^o, ΔS^o and ΔG^o are reported in Table 2. The positive value of ΔH^o confirms that this adsorption of uranium on DGA-MWCNT is endothermic. The standard free energy change (ΔG^o) values are negative at all temperatures and decrease with increasing temperature. This indicates the spontaneous nature and feasibility of uranium adsorption on DGA-MWCNTs which becomes more favorable with increasing temperature. The positive values of entropy (ΔS^o) show the increased randomness at the solid/solution interface during the adsorption process which reflects the affinity of the adsorbent for uranium. The positive enthalpy change opposes the uranium adsorption but the larger entropy allows the adsorption.

Conclusion

From the present study, it is concluded that diglycolamide functionalized multi-walled carbon nanotubes are highly promising agents for the separation of uranium from aqueous solution with K_d value as high as 4×10^4 milli liter g^{-1} in 4M HNO_3 and at room temperature. Adsorption is favoured at higher adsorbent concentration and temperature. The adsorption process is endothermic and the percentage of adsorption increases with increasing temperature. Thus, carbon nanotubes can be modified with other pre-designed extractants for actinides and lanthanides and extractant functionalized carbon nanotubes can be employed for the separation of actinides and lanthanides from nuclear waste solution. The adsorbed materials can be incinerated completely resulting in less solid waste.

Reported by Ashish Kumar Singha Deb
Radiological Safety Division, Reactor Engineering Group

Young Researcher's FORUM

Ms. P. Deepika completed her M.Sc. in Chemistry from Indian Institute of Technology, Delhi and joined Fuel Chemistry Division, Chemistry Group, IGCAR as a Research Scholar in February 2006. She worked for her Ph. D. under the guidance of Dr. T. G. Srinivasan, and has submitted her thesis titled "Synthesis and Evaluation of Extractants for Actinide Partitioning". She has six publications in peer-reviewed international journals to her credit. She has thirteen papers in various national and international symposia and has won two best paper prizes (oral presentation).

Nitrogen Donor Extractants for the Separation of Minor Actinides from Lanthanides in High Level Waste

The separation chemistry of actinides is crucial to nuclear waste management since the long-lived minor actinides such as ^{241}Am, ^{243}Am, $^{(242, 244, 245)}$Cm are the major contributors to the radiotoxicity of the high-level waste (HLW) obtained from spent fuel reprocessing. Presently, the high-level waste is vitrified into glass matrices and deposited in deep geological repositories. The long half-lives and radio-toxicity coupled with high aqueous mobility of these minor actinides necessitates the need for continuous long-term surveillance of these repositories. Removal of the minor actinides from the high-level waste (i.e., the partitioning of minor actinides) followed by their transmutation into short-lived isotopes by neutron bombardment in accelerators or fast breeder reactors, will greatly reduce the radio-toxicity of the waste. The partitioning of minor actinides from the high-level waste is a challenge to separation chemists due to the presence of a high concentration of trivalent lanthanides in the high-level waste, which have chemical properties similar to those of the actinides. Separation of the lanthanides is essential for the subsequent transmutation of these actinides, as the lanthanides have high neutron absorption cross sections and will interfere with the transmutation efficiency of the actinides.

In this context, the seminal work of Musikas in the mid-1980s, in which he reported that an extractant consisting of tripyridyltriazine and dinonylnapthalene sulfonic acid (HDNNS) or bromocapric acid in a suitable diluent preferentially extracted Am(III) from dilute nitric acid solution containing Am(III) and trivalent lanthanides, triggered a cascade of studies on the ability of nitrogen containing extractants to achieve separation of trivalent actinides from trivalent lanthanides. Many of the nitrogen containing extractants that have been studied have heterocyclic molecules containing nitrogen since these have "soft" donor electron capacity which show selectivity for actinides(III) over lanthanides(III). It is proposed that there is a modest enhancement of co-valency in the actinide-ligand bonding compared to the lanthanides in case of ligands containing soft-donor atoms such as nitrogen, sulfur and chlorine resulting in the formation of stronger bonds with actinides relative to that of lanthanides and thus achieving the trivalent lanthanide-actinide separation. This article briefly discusses the chronological development of the nitrogen donor extractant family, and the work done with the nitrogen based triazine group of extractants to achieve the difficult seperation of lanthanides from actinides at our Centre.

Figure 1 shows the different nitrogen donor extractants that have been investigated for trivalent lanthanide-actinide separations. One of the earliest nitrogen-donor extractant studied for the separation of actinides and lanthanides was 2,2´:6´,2´´-terpyridine (Terpy), a heterocyclic, aromatic, tridentate nitrogen-donor ligand that would become the basis of many extracting molecules such as BTPs and BTBPs developed recently. The Terpy ligand forms complexes with metals in which one or two Terpy molecules coordinate with each metal ion following an ion-pair extraction mechanism that also requires a lipophilic anion (such as α-bromodecanoic acid) to neutralize the charge of the metal ion. This need for a hydrophobic, anionic synergist to enable extraction is one of the drawbacks related to Terpy; another drawback being the narrow range of pH over which the Terpy ligand operates effectively. This is so since at pH above 3.5, an emulsion is formed owing to the deprotonation of the carboxylic acid and the carboxylate anion acting as a surfactant, whereas at pH lower than 1.3, the pyridine nitrogens within the Terpy molecules protonate, resulting in extractant transfer to the aqueous phase.

Attempts were made to improve the extraction properties of the metal binding Terpy by lowering its affinity for protons, thus reducing the transfer of the extractant to the aqueous phase when the pH is low. Since it is known that as the number of nitrogen atoms present within polyazabenzene increases, the π orbital system of the aromatic ring becomes more electron poor and the pK_a of the protonated form of the polyazabenzene decreases, this was used as a strategy to design new and improved molecules over Terpy. Consequently, the inner ring of Terpy was replaced with a symmetric triazine (1,3,5-triazabenzene), to get the ligand tripyridyltriazine (TPTZ), which behaves similar to Terpy in that it acts like a solvating reagent forming 1:1 and 1:2 complexes with trivalent metal ions, and requires a lipophilic

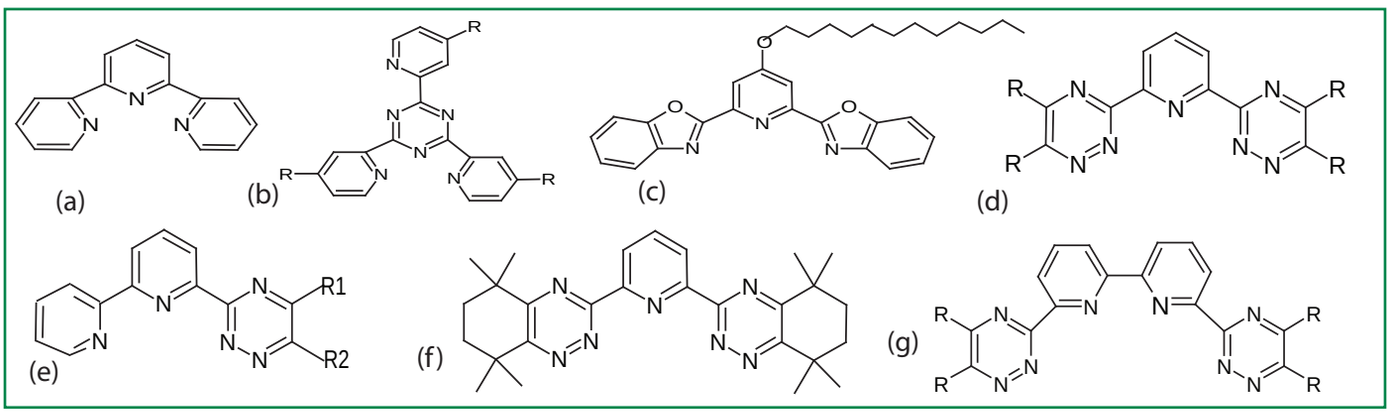


Figure 1: Nitrogen donor extractants for trivalent lanthanide-actinide separation: (a) terpy(2,2':6,2"-terpyridine), (b) TPTZ(2,4,6-tripyridyl-1,3,5-triazine), (c) BODO(2,6-bis-(benzoxazolyl)-4-dodecyl-oxylpyridine), (d) 2,6-bis(5,6-dialky-1,2,4-triazine-3-yl)pyridine (BTP), (e) Hemi-BTP(1,2,4-triazin-3-yl)bipyridine, (f) 2,6-bis(5,5,8,8-tetramethyl-5,6,7,8-tetrahydro-benz)-1,2,4-triazine-3-yl)pyridine,cyMe$_4$-BTP and (g) 6,6'-bis-(5,6-dialkyl-[1,2,3]-triazin-3-yl-2,2'-bipyridine)

anion like α-bromodecanoic acid in order to extract actinides. As expected, it has a lower pK_a than Terpy, thus mitigating the problem associated with the protonation of Terpy at low pH. TPTZ was the first nitrogen donor extractant reported to extract Am(III) from nitric acid with a separation factor (Am(III)/Eu(III)) of 10 or greater, slightly higher than that of the Terpy system (~7). Alternatively, the outer pyridine rings of Terpy were replaced with heterocyclic benzooxazol-2-yl groups, resulting in the formation of 2,6-bis-benzooxazolyl-4-dodecyloxylpyridine (BODO) molecule, in which both the aromatic rings withdraw electron density through resonance effects from both the oxygen and nitrogen atoms and the oxygen atom withdraws electron density through inductive effects from the nitrogen atom, thereby enabling the molecule to resist protonation. Like Terpy and TPTZ, two BODO molecules coordinate in each actinide complex and the extraction mechanism is similar to that of Terpy, requiring a synergist such as a carboxylic acid. BODO showed higher distribution ratios and separation factors (An/Ln) than Terpy.

In common with BODO, the outer pyridine rings of Terpy were also replaced with 1,2,4-triazin-3-yl groups resulting in a new group of molecules called the 2,6-bis(5,6-dialkyl-1,2,4-triazin-3-yl)pyridines (BTPs), with a poor ability to bind protons. These compounds were first prepared by Case in the 1970s, but were introduced by Kolarik as possible extracting reagents for nuclear reprocessing later only in 1999. The BTP molecules are one of the most thoroughly studied groups of extractant molecules developed for separation of trivalent actinides from lanthanides. Extraction experiments with Am(III) and Eu(III) nitrates into a TPH based diluent showed both distribution ratios and separation factors much higher than those previously reported for nitrogen donor extractants. As opposed to Terpy, TPTZ and BODO, the BTPs can form americium complexes that are extractable as nitrate salts thus avoiding the need for addition of a synergist. Since high concentrations of nitrate ions are present in the process solution coming from the PUREX process, this is very advantageous. Another property that distinguished the BTPs from the earlier N-donor extractants was that three and not two ligand molecules can coordinate to each atom of the trivalent actinides. The BTP molecule is tridentate, forming 1:3 complexes with the trivalent metal ion, where the three BTP ligands are bound to the M(III) ion through three nitrogen atoms. Consequently, the metal center is nine-coordinate, each BTP ligand being attached via the nitrogen atom of the pyridine fragment and the nitrogen atoms at the 2-position of the triazine rings. In fact, the greater selectivity of BTPs have been attributed to the fact that the BTPs are able to form single hydrophobic species $[Ln(BTP)_3]^{3+}$ in which three BTP ligands completely fill the primary coordination sphere of the M(III). In such a species, it is difficult for water and nitrate ligands to be located within the coordination sphere of the metal cation so that a single hydrophobic entity may be involved in the separation process.

A serious drawback of the BTP based systems is the lack of stability of the BTPs bearing normal alkyl side groups towards both radiolysis and chemical degradation due to the presence of nitrogen oxo acids. Attempts were made to increase the resistance towards radiolysis and hydrolysis by adding annulated rings to BTP molecules, resulting in the so called BATPs (A=annulated). BATPs were found to be resistant to hydrolysis, but the sensitivity towards radiolysis was still a problem. Also it required longer time to reach equilibrium during the Am(III) extraction experiments, and hence required the addition of a phase transfer catalyst such as dimethyl dioctyl hexylethoxy malonamide (DMDOHEMA) to expedite the rate of the reaction. While BATPs gave very high selectivity (~ 5000), the distribution ratios for the lanthanides and actinides were too high that it was not possible to recover the metals from the organic phase by stripping. It is suspected

that strong complexes are formed between the BATP and actinides which are not labile and thus back-extraction is impossible.

The hemi-BTPs were designed as molecules which are part way between the BTPs and Terpy because they contain one outer pyridine ring and one outer triazine ring. It was concluded that the chemical properties of hemi-BTP are closer to those of Terpy than BTP, since the hemi-BTPs do not form 1:3 complexes, as observed in the case of BTP, and similar to Terpy, the hemi-BTPs need a synergist, e.g. bromodecanoic acid to extract americium. In addition, the hemi-BTPs were also found to be prone to hydrolysis.

The problems with the strong complexation of the BATPs and the associated difficulties in stripping lead to the development of a molecule with good separation but less strong complexation. The BTBPs (6,6´-bis(5,6-dialkyl-[1,2,4]-triazin-3-yl)-2,2´-bipyridines), which have an additional aromatic nitrogen heterocyclic ring and a lower crystal-field stabilization energy than the BTPs are intended to be more resistant towards hydrolysis and radiolysis and allow stripping. The BTBP molecules are tetradentate, planar and do not require a synergist to enhance the extraction and extract more Am(III) as the nitric acid concentration increases. The kinetic behaviour varies with the diluents and in some cases DMDOHEMA has been added as phase transfer reagent to decrease the contact time required for reaching equilibrium. Complexes between actinides and BTBPs exist either as 1:1 or 1:2 complexes. Stripping and recycling the organic phase proved to be possible for BTBPs using glycolic acid.

All the above mentioned extractants until now have been investigated by solvent extraction method for the extraction and separation of trivalent lanthanides and actinides. Though solvent extraction based methods have been found promising, two major limitations of solvent extraction to be overcome are the third phase formation and phase disengagement. Also, minimizing the solvent inventory is becoming an increasingly important factor in technology development due to reasons such as cost and environmental burden of hazardous volatile organic carbons (VOCs). In this context, solid phase extraction has emerged as an excellent separation technique in recent years in view of the immiscibility of resins with the aqueous phase, low rate of physical degradation, minimum release of toxic organic solvents and recycling options. For solid phase extraction, the extractant can be either sorbed (as in extraction chromatography) or anchored to an inert polymeric support and it has the advantages of both solvent extraction and ion exchange. Separation methods based on extraction chromatography have become increasingly popular in radiochemical analysis due to their simplicity, rapidity, savings in the reagent and waste disposal costs compared to the traditional liquid-liquid extraction methods. An attempt was made by us to investigate two nitrogen-based extractants: 2,6-bis(5,6-dipropyl-1,2,4-triazin-3-yl) pyridine, or n-Pr-BTP; and 2,6-bis-(5,5,8,8-tetramethyl-5,6,7,8-tetrahydro-benzo-1,2,4-triazine-3-yl)pyridine, or CyMe4-BTP (also referred to as BATP) via extraction chromatography for the separation of minor actinides from lanthanides. Extraction chromatographic method was chosen over solvent extraction in order to overcome the problems associated with the use of these extractants in solvent extraction, e.g., the need to use a phase-modifier such as octanol to enhance solubility of BTP in aliphatic diluents, or the need to use a phase transfer reagent such as DMDOHEMA in case of BATP to improve the process kinetics.

The two extractants, n-Pr-BTP and BATP, were synthesized by the reaction between 2,6-pyridine dicarboxamide dihydrazone and the diketones, octane-4,5-dione, and 3,3,6,6-tetramethylcyclohexane-1,2-dione, respectively and these were then impregnated on to XAD-7 resin. XAD-7 is a macroporous cross linked ester acrylic polymer ($[-CH_2-CH(COOR)-]_n$) with a hydrophobic surface of moderate polarity. The BTP/XAD-7 and BATP/XAD-7 resins were evaluated for the uptake of Am(III) and some lanthanides, and other fission and activation products found in the HLW in batch studies from nitric acid medium. Figure 2 shows the variation of distribution ratios, $D_{Am(III)}$ and $D_{Eu(III)}$, and the separation factor ($= D_{Am(III)}/D_{Eu(III)}$) against the weight % loading of BATP on the XAD-7 resin at 0.1 M HNO_3 up to 5% loading of the extractant. It was observed that the Am(III)-Eu(III) separation factor was maximum at 2% loading of BATP/XAD-7 (approx. 1000), and it decreased for higher loading of BATP, owing to enhanced uptake of Eu(III). In fact, the performance of BATP/XAD-7 resin was observed to be superior to that of BTP/XAD-7 resin in batch studies. BATP/XAD-7 displayed higher $D_{Am(III)}$ values in nitric acid

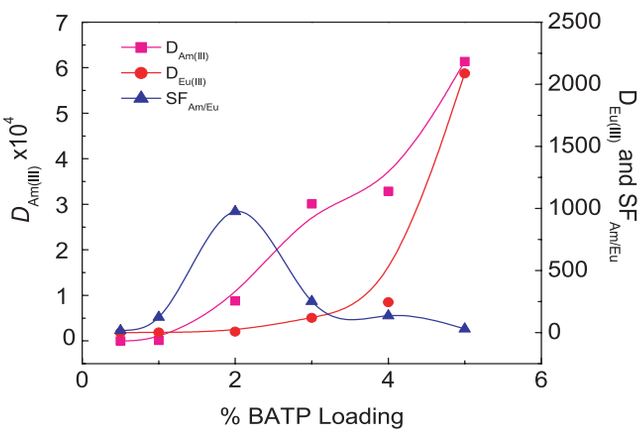


Figure 2: Variation of $D_{Am(III)}$, $D_{Eu(III)}$ and Separation Factor with weight % loading of BATP on to the XAD-7 resin. (0.25 g resin, 3 mL 0.1 M HNO_3, 1 hr equilibration, 303 K)

Table 1: Variation of D value of Am(III), lanthanides and fission products as a function of HNO_3 concentration for BATP/XAD-7 (1.5% BATP/XAD-7, 0.25 g resin, 3 mL HNO_3, 1 hr equilibration, 303 K)

[HNO_3] M	Ba(II)	Fe(III)	Mo(VI)	Ru(III)	Sr(II)	Zr(IV)	Cs(I)	Ce(III)	Gd(III)	La(III)	Nd(III)	Eu(III)	Am(III)
0.01	0.5	4	1	3	2	0	0	0	0	0.7	0.5	3	40
0.05	0.5	3	2	4	2	0	2	0.5	2	0	0.5	4	1256
0.1	0	3	2	4	1	0.2	2	0.3	1	0.2	0.3	6	2459
0.5	0	2	0.9	6	0.5	0	0.4	0	1	0.5	0.3	6	2841
1	0	1	0.2	7	0.5	0	0.6	0.5	1	0.2	0	2	1452
2	0	0.9	0.5	1	0.5	0	0.2	0	1	0	0	2	270
3	0	0.4	0.7	9	0.2	0.5	0.2	0	0	0	0	2	112

aqueous phase than BTP/XAD-7 which required the addition of excess NO_3^- salts to the aqueous nitric acid phase. The weight % loading of BATP on to XAD-7 required for high $D_{Am(III)}$ was less when compared to n-Pr-BTP. While a maximum $D_{Am(III)}$ value of 4000 was obtained for 10% loading of n-Pr-BTP/XAD-7 resin from a solution of 0.1 M HNO_3 - 2 M NH_4NO_3, only 5% loading of BATP on to XAD-7 was sufficient to obtain a maximum $D_{Am(III)}$ of 65000 from 0.1 M HNO_3. For BATP/XAD-7, turbidity observed in the aqueous phase post equilibration above 5% loading of extractant restricted the higher loading of the BATP extractant on to the XAD-7 resin for the uptake studies and 1.5% loaded BATP/XAD-7 was found optimum for extraction chromatography studies. Such a turbid behaviour was not observed for n-Pr-BTP/XAD-7 up to 40% loading, and to ensure a high throughput during the column studies, a high weight % loading of 40% was used for extraction chromatographic studies using n-Pr-BTP/XAD-7. The Am(III)-Eu(III) separation factor obtained for 2% loaded BATP/XAD-7 was observed to be 17 times higher than 40% loaded n-Pr-BTP/XAD-7. The kinetics of Am(III) uptake was observed to be faster in case of BATP as compared to n-Pr-BTP. BATP/XAD-7 also displayed high selectivity for Am(III) compared to trivalent lanthanides and other elements found in the high-level waste. Table 1 shows the D values for the uptake of lanthanides and other elements by BATP/XAD-7 resin, and these are observed to be very low compared to the corresponding $D_{Am(III)}$ values at all acidities.

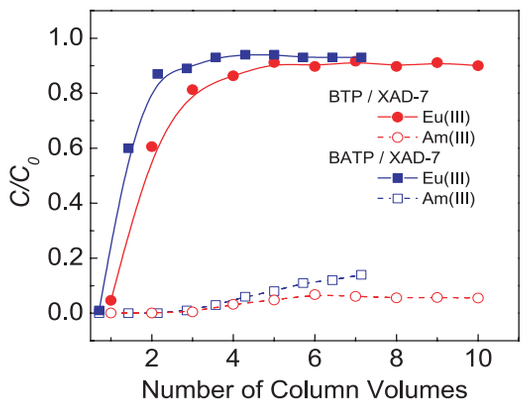


Figure 3: Loading profile for Eu(III) and Am(III) loaded together on to the extraction chromatography column (Flow Rate = 0.3 mL/min, 298 K) for BATP/XAD-7: Loading Solution = 0.1 M HNO_3; Bed Volume = 7 mL; For BTP/XAD-7: Loading Solution = 2 M NH_4NO_3 - 0.1 M HNO_3; Bed Volume = 5 mL

Based on the results of the batch studies, column experiments were performed for the separation of Am(III) from Eu(III) using both the resins. A 50 ml solution containing both ^{241}Am and $^{(152+154)}Eu$ (1:40 ppm) was passed through 2 g of the resins packed in a glass column of 10 mm inner diameter. A complete separation of Eu(III) was achieved from Am(III), as Eu(III) was not retained by the column for both the resins, and was recovered quantitatively in the loading and column wash stages. Figure 3 shows the separation profile for the separation of Eu(III) from Am(III) for both the resins. In case of BTP/XAD-7, the loaded Am(III) was eluted with 0.3 M DTPA (pH = 4). However, in case of BATP/XAD-7 resin, it was observed that the loaded Am(III) was held very strongly in the column and could not be eluted even with strong eluting agents such as ammonium carbonate and DTPA. It can be concluded that the use of bistriazinyl pyridine group of extractants via extraction chromatography by impregnation on XAD-7 resin shows promise for the partitioning of minor actinides from the HLW and further studies are required to optimize the experimental conditions for the same.

Reported by P. Deepika,
Fuel Chemistry Division, Chemistry Group

Conference/Meeting Highlights

SMiRT Post Conference Seminars on Innovative Fast Reactor Design and High Temperature Design
November 14-15, 2011

Delegates of the SMiRT Post Conference on Innovative Fast Reactor Design

Structural Mechanics in Reactor Technology (SMiRT) is an international conference being organised once in every two years. Two of the Post Conference Seminars (PCS) on "Innovative Fast Reactor Design" and "High Temperature Design" were held concurrently at IGCAR, Kalpakkam during November 14-15, 2011. The objective of both the seminars was to provide a global platform for in-depth discussions and deliberations on the roadmap, R&D being carried out, results obtained so far within the various fast reactor development programmes and high temperature design issues.

The seminar on Innovative Fast Reactor Design focused on the themes such as technological concepts covering fuel, operating experience, numerical and experimental studies on PFBR systems and sodium technology. The themes were chosen to avoid any overlap with the physics and advanced reactor concepts themes of the IAEA technical meeting which were held concurrently. There were 42 participants including 6 from Japan, Netherlands, Ukraine and Belgium. Experts from academic institutes also presented their research results. There were a total of 35 technical presentations in seven technical sessions in the topics of Reactor Physics and Fuel, Advanced Reactor Concepts, Advanced Materials, Experience in Manufacture and Reactor Operation, Reactor Systems Optimization, Sodium Technology and Testing. The major feedback from the seminar are (i) co-operation among fast reactor countries should be on a larger framework (ii) academic institutes should get involved on a much larger scale (iii) more experimental programmes need to be undertaken.

The seminar on high temperature design was to cover all the technical and professional practice issues in the concerned area of nuclear power plant components, to discuss about the high temperature failure modes like creep, fatigue and their interactions, the codes and standards, materials and piping analytical methodology at high temperature. There were twenty nine IAEA participants including seven from France, Japan and Russia. There were a total of twenty technical presentations in five technical sessions in the topics like high temperature codes and standards, materials, piping, etc. The major feedback emerged from the seminar is that there should be many such international seminars arranged in future on this topic which is crucial for the fast reactor technology. There were also participants from BARC, NFC and IPR, Gandhi Nagar. An important highlight was that an 'Young Engineer Session' in each Post Conference Seminar was conducted in which many young engineers presented their technical study results, which was well appreciated. Young engineers presented their work on advanced high temperature design and innovative design concepts for the advanced fast reactor systems. This event would help in establishing collaborations with participating countries apart from strengthening the existing technical collaborations towards developing science & technology of Sodium Cooled Fast Reactors.

Reported by P. Chellapandi, NSEG

IAEA Technical Meeting (TM-41429) on Fast Reactor Physics and Technology
November 14-18, 2011

Shri S. C. Chetal, Director, IGCAR addressing the gathering during the inaugural session. Seated in the dais are Dr. Andrej Zeman, Scientific Secretary of the meeting, Dr. P. Chellapandi, Director, NSEG, IGCAR and Dr. Stefano Monti, Head, TWGFR, IAEA

A five day Technical Meeting on "Fast Reactor Physics and Technology" was held at IGCAR under the auspices of IAEA during November 14-18, 2011. The objective of the meeting was to bring together the experts to discuss the state of the art reactor designs and in particular, recent innovative reactor concepts, novel core structural materials and to evolve designs with improved reliability & cost effectiveness for future FBRs. Seventy delegates including twenty-nine international participants from fifteen countries and forty one national participants from BARC, BHAVINI, SRI, NPCIL and IGCAR attended the meeting. Dr. P. Chellapandi welcomed the delegates and highlighted the significance of organizing the meeting in the current Indian context. Shri S. C. Chetal, Director, IGCAR gave an inspiring inaugural address and brought out the multi-disciplinary capability of IGCAR towards scientific research, advanced engineering of fast reactors and its associated fuel cycle. He gave a comprehensive view of various activities of IGCAR and the current status of fast reactors worldwide. Dr. Andrej Zeman presented an overview of the activities of IAEA including the various co-ordinated research projects and training programmes. This was followed by an overview of fast reactor activities being carried out under TWGFR by Dr. Stefano Monti. Forty six presentations were made in seven technical sessions including seventeen by international delegates. The main focus of the meeting deliberations was on the current status of fast reactor activities in fifteen countries, innovative fast reactor designs to improve safety, economy, strategy & key results of R&D carried out in various countries including India. The meeting brought out the current international re-look on various load combinations including design extension conditions and the comprehensive approach to address the safety issues post Fukushima accident. Alternative coolant technologies like Lead and Lead-Bismuth were also discussed. Concepts of development of core structural materials to improve burn-up, advanced fast reactor thermal hydraulics and safety were discussed in-depth. The presentation on PFBR construction experience, design approach for CFBR, various R&D and Technological activities at IGCAR were well appreciated. Though many countries do not have an active fast reactor programme, they showed a keen interest to work with India and collaborate on various R&D activities. The technical sessions were very lively with active participation from the delegates. They evoked great interest and motivation among the younger colleagues currently involved in the design and development activities of future FBRs. Overall, the technical meeting evoked a positive response from various countries to interact more effectively and to provide a basic platform for more active joint co-operative efforts to sustain and improve the economy and safety of fast breeder reactors. It also gave a valuable opportunity to the Indian delegates to interact with renowned experts and to present their current work to the international community.

Reported by P. Chellapandi, NSEG

Theme Meeting on Structure and Thermodynamics of Emerging Materials (STEM-2011)

November 24-26, 2011

Prof. Ajay Gupta, Director, UGC - DAE consortium for Scientific Research, Indore Centre delivering the plenary lecture during STEM 2011

The BRNS sponsored theme meeting, 'STEM-2011' focusing on "Diffusion, Mass Transfer and its Consequences in Materials" was organized jointly by Indira Gandhi Centre for Atomic Research and The Indian Institute of Metals – Kalpakkam Chapter during November 24-26, 2011 at Convention Centre, Anupuram. Dr. M. Vijayalakshmi, Associate Director, PMG welcomed the participants and highlighted the wide spread application of diffusion in various fields. She emphasized the necessity to explore the possibility of extending the diffusion based concepts to new and advanced materials and processes. Dr. S. Saroja, Convener, STEM 2011 briefed upon the genesis of the STEM annual meetings on a focused theme to foster professional knowledge. Professor Ajay Gupta, Director, UGC-DAE Consortium for Scientific Research, Indore Centre delivered the plenary lecture on "Nanoscale Atomic Diffusion in Thin Films and Multilayers Studies using X-ray Techniques" and provided an excellent insight into the basic difference between diffusion in bulk, thin films and various experimental techniques used to measure the diffusion parameters in multilayer thin films. The vote of thanks was proposed by Smt. C. Sudha, Secretary, STEM 2011.

On the first day, lectures were delivered by eminent scientists from leading national R&D institutions and academia covering aspects related to mass transport in materials of importance to the power generation industry, diffusion bonding of dissimilar materials, diffusion studies with respect to materials used in the back end of the fuel cycle and the Kirkendall effect in solid state interdiffusion. On the second day tutorial lectures and practical demonstrations were held on the application of Monte Carlo and molecular dynamic simulation techniques to study the diffusion of atoms. On the third day the participants were taken for field visit to MAPS and to the Laboratories in the Physical Metallurgy Group. About 120 specialists, delegates and students from various acadamic institutes such as IISc, IITs, NIT, IPR, Anna University, Bengal Engineering College, Sandvik and DAE units of BARC, NFC and IGCAR, participated in the deliberations. The technical programme was appreciated by the participants and valuable inputs for future theme meetings were provided during the feedback session at the end of the theme meeting.

Reported by C. Sudha, Secretary, STEM 2011

Participants of STEM - 2011

8th Biennial National Conference on Recent Advances in Information Technology (READIT)

December 28-29, 2011

Dr. M. Sai Baba, Convener, READIT addressing during the panel discussion chaired by Dr. Sandhya Shekhar, CEO, IITM research park, Chennai and other eminent panelist

The 8th Biennial National Conference on Recent Advances in Information Technology (READIT) was organized by Scientific Information Resource Division of IGCAR in association with the Kalpakkam Chapter of Madras Library Association (MALA) during December 28-29, 2011. The theme of the Conference was "Knowledge Sharing with Semantic Grids". More than 200 delegates including information technology professionals, librarians, students and academicians attended the conference. The sub themes of the conference were Advanced Digital Library Infrastructure, Grid Computing and Semantic Web Technologies, Content Organizing and Knowledge Management, Collaboration and Connecting Libraries. The format of conference included invited talks by eminent experts, oral/poster presentations by research scholars/participants. The conference was preceded by a one day Tutorial Session on the theme "Preservation Technique for Archives and Access Management" on December 27, 2011. The conference was inaugurated on December 28, 2011 by Prof. R. Balasubramanian, Director, Institute of Mathematical Sciences, Chennai. The function was presided over by Shri S.A.V. Satya Murty, Director, EIG, IGCAR & Chairman Library and Information Services Committee. Dr. M. Sai Baba, Convener, READIT, AD, RMG & Head, SIRD welcomed the gathering. Prof.R. Balasubramanian released the Souvenir and Shri S.A.V. Satya Murty inaugurated the exhibition. Shri E. Soundararajan, SIRD delivered the vote of thanks. Intensive technical discussions on various aspects of Semantic Grids, Digital Library Infrastructure, Knowledge Management and implications for the Libraries were presented during the conference. The conference concluded in the evening of December 29, 2011 with a panel discussion on the topic "Emerging Trends in Digital Technologies and Implications for Information Access". This panel discussion was chaired by Dr. Sandhya Shekhar, Chief Executive Officer, IITM Research Park, Chennai and was moderated by Dr. M. Sai Baba . The panelist were Shri Umesh Chandra, Senior Executive Director, Safety and Knowledge Management, NPCIL, Mumbai, Prof. C. K. Ramaiah, Head, DLIS, Pondicherry University, Dr. S. Venkadesan, Director, Learning Resource Centre, ISB, Hyderabad, Dr. J. K. Suresh, Vice President, Knowledge Management, Infosys Technologies Ltd, Bengaluru, Shri Vikram Pothnis, Product Manager, Wipro Infotech Ltd, Bengaluru and Shri Prashant Gangwal, Key Account Manager, Elsevier. Interesting and inspiring discussions were made by the delegates and students during the panel discussion. At the end, the summary of technical sessions was presented by Dr. M. Sai Baba.

Reported by M. Sai Baba, Convener, READIT

Dr. Balasubramanian, Director, IMSc, Shri S. A. V. Satya Murty, Director, EIG, Dr. M. Sai Baba, Convener, READIT & AD, RMG and Shri E. Soundararajan, SIRD during the release of souvenir at the inaugural function of READIT

Visit of Dignitaries

Delegations from United States Nuclear Regulatory Commission led by Dr. Gregory B. Jaczko, with Shri S. C. Chetal, Director, IGCAR and senior colleagues of the Centre

Delegation from the United States Nuclear Regulatory Commission led by its Chairman Dr. Gregory B. Jaczko, visited the Centre during November 16-18, 2011. After meeting the Director and senior colleagues of the Centre, the delegation visited the Fast Breeder Test Reactor, Hot Cells and Non-Destructive Evaluation Division, Facilities in Fast Reactor Technology Group, Sodium Fire Facility in Nuclear and Safety Engineering Group, Structural Mechanics Laboratory, construction site of Prototype Fast Breeder Reactor and Madras Atomic Power Station.

Shri P. Viswanathan, Honourable Member of Parliament, representing the Kancheepuram Constituency with Shri S. C. Chetal, Director, IGCAR, Dr. Prabhat Kumar, Project Director, BHAVINI, Shri C. D. Rajput, Chief Superintendent, Madras Atomic Power Station and senior colleagues of the Department

Shri P. Viswanathan, Honourable Member of Parliament, representing the Kancheepuram Constituency visited the Centre on December 10, 2011. After a meeting with Shri S. C. Chetal, Director, IGCAR, Dr. Prabhat Kumar, Project Director, BHAVINI and Shri C. D. Rajput, Chief Superintendent, Madras Atomic Power Station Shri P. Viswanathan visited the Fast Breeder Test Reactor, Madras Atomic Power Station and the construction site of Prototype Fast Breeder Reactor.

Smt. Vijayadharani, Honourable Member of Legislative Assembly, representing the Vilavancode Constituency visited the Centre on December 14, 2011. She visited the Madras Atomic Power Station and the Fast Breeder Test Reactor. She addressed the women employees of IGCAR and discussed the issues pertaining to violence against women and girls, during the commemoration of International Day against Elimination of Violence against Women and Human Rights Day.

Smt. Vijayadharani, Honourable Member of Legislative Assembly of the Vilavancode Constituency addressing the women employees of IGCAR

DAE AWARDS

Department of Atomic Energy has instituted annual awards for excellence in Science, Engineering and Technology in order to identify best performers in the area of Research, Technology Development and Engineering in the constituent units (other than Public Sector Undertakings and Aided Institutions). The Young Scientist, Young Engineer, Young Technologist, Homi Bhabha Science and Technology Award and Scientific and Technical Excellence Award fall under this category. Group Achievement awards for recognition of major achievements by groups have also been instituted. Life time Achievement Award is awarded to one who has made significant impact on the DAE's programme. They are the i-cons for young scientists and engineers to emulate. The awards consist of a memento, citation and cash prize.

The recipients of the Group Achievement Awards from IGCAR for the year 2011 are:

Group Achievement Award:

Design and Development of roof slab for Protoype Fast Breeder Reactor

Dr. P. Chellapandi, NSEG, Group Leader

Shri Sriramachandra Aithal, Shri S. Raghupathy, Shri P. Puthiya Vinayagam, Shri V. Balasubramaniyan, Shri V. Rajan Babu, Shri P. Selvaraj, Dr. K. Velusamy, Shri S. Jalaldeen, Shri R. Gajapathy, Shri A. Biswas, Shri T. Selvaraj, Shri K. Natesan, Shri C. Raghavendran, Shri R. Suresh Kumar, Shri S.D. Sajish, Shri Bhuvan Chandra Sati, Shri Abhishek Mitra, Shri Gagan Gupta, Shri Arul Bhaskar, Shri Ramkumar Maity, Shri S. Saravanan, Shri G. Venkataiah, Shri S. K. Rajesh, Shri M. Babu Rao, Shri R. Manu, Ms. P. Swetha, and Shri V. Devaraj from NSEG, Dr. Arun Kumar Bhaduri, Shri V. Ramasubbu, Shri M. Arul, and Dr. Shaju K. Albert from MMG, Dr. R. S. Keshavamurthy, Dr. B. Venkatraman, Shri R. J. Paul Surendranath, Shri Abdul Gani H I, Shri V. Venkatachalapathy, C. Sivathanu Pillai and Shri C. Hari Kumar from CEG, Shri P. Ramesh, Shri D. Sunil Kumar, Shri G. Radhakrishnan and Shri R. Mathiarasu from REG .

Design and Development of Dual Phosphor Hand Monitor

Shri P. Vijayasekaran, RpG, Group Leader

Shri A. Dhanasekaran from REG, Shri K. P Desheeb, Shri S. Manickam , Shri P. C. Sandeep and Shri P. Anbazhagan from REG.

In-Sodium Materials Testing Faciility

Dr. M. D. Mathew, MMG, Group Leader

Dr. S. Venugopal, Dr. K. Laha, Dr. R. Sandhya, Shri S. Ravi, Shri R. Kannan, Shri K. Mariappan, Shri G. Sukumaran, Shri V. Ganesan, Shri P. C. Gopi and Shri S. Sakthy from MMG, Shri M. Shanmugavel, Shri M. Shanmugasundaram, Shri S. Vijayaraghavan, Shri P. Rajasundaram, Smt. Sundari Madasamy, Shri T. Chandran, Shri J. Vincent, Shri M. Mani, Shri K. K. Rajan, Shri T. Ramalingam, Shri R. Kamaraj, Shri V. Tharmaraj, Shri R. Sabari Kumar, Shri S. Rangasamy, Shri K. Narasimha and Shri V. Suresh from FRTG.

Steam Generator Test Facility Group

Shri I. B. Noushad, FRTG, Group Leader

Shri V. A. Suresh Kumar, Shri B. K. Sreedhar, Smt. J. I. Sylvia, Shri G. Madhusoodhanan, Shri V. S. P. Babu, Shri V. Vinod,

Shri N. Nagarajan, Shri K. Thanigairaj, Shri A. Ashokkumar, Shri S. Kishore, Shri L. S. Sivakumar, Shri Rakesh Kumar Mourya, Shri M. Ravishankar, Shri K. Jayagopi, Shri S. P. Pathak, Shri Vishal D Paunikar, Shri M. Anandraj, Shri T. V. Maran, Shri Shiv Prakash Ruhela, Shri D. Laxman, Shri V. S. Krishnaraj, Shri Gautam Anand, Shri Y. Suresh, Shri R. Kannan, Shri P. Sivasubramaniapillai, Shri Ramesh Kumar Sharma, Shri Chaitlal Thakur, Shri P. Anupkumar, Shri P. Mohanraj, Shri V. Elumalai, Shri P. Narayana Rao, Shri K. Selvaraj, Shri K. V. S. S. N. Murthy, Shri V. Saravanan, Shri Sukanta Kumar Roy, Shri K. G. Radhakrishnan Unni, Shri G. Anandan, Shri T. Solaiappan, Shri M. Sankaran, Shri K. Radhakannan, Shri S. Shanmugham, Shri Vijay Tirkey, Shri A. Kolanjiappan, Shri R. Kuppuswamy, Shri A. Kumaraswamy, Shri M. Muralidharan, Shri M. P. Sunny, Shri N. Premanand, Shri K. Sekar, Shri E. G. Prabhakaran, Shri K. Sadiq Batcha, Shri C. Pavaderadjane, Shri A. Saravanan, Shri G. Rathnachalam, Shri P. Hrishikesh, Shri J. Jaikanth, Shri S. Kannan, Shri J. Prem, Shri H. Rafiq Batcha, Shri M. Munikumar, Shri S. Saravanan, Shri K. Arulselvam, Shri S. Ponthilagar, Shri L. Muthu, Smt. Indra G Ramdoss and Shri A. Elumalai from FRTG.

Design, Manufacture and Testing Challenges of Prototype Fast Breeder Reactor Secondary Sodium Pump

Shri K. V. Sreedharan, REG, Group Leader

Shri A. S. L. K. Rao from ESG, Shri V. Balasubramaniyan, Shri S. Athmalingam, Shri Bhagwana Ram, Shri S. Chandrasekar, Shri S. Satheesh Kumar, Shri K. Madhusoodhanan, Shri S. L. N. Swamy and Shri M. Sakthivel from REG, Shri K.Velusamy, Shri S. Jalaldeen, Shri K. Natesan, Shri Bhuwan Chandra Sati and Shri P. Jayaraj from NSEG, Shri B. K. Sreedhar from FRTG

Setting up, Commissioning and Operating the SAMRAT Model Test Facility for Conducting Experiments in Water to Validate the Thermal Hydraulic Design of Prototype Fast Breeder Reactor

Shri G. Padmakumar, FRTG, Group Leader

Shri N. Murali, Shri P. Parimalam and Shri A. Shanmugam from EIG, Shri V. Prakash and Shri G. Madhusoodanan, Shri Indranil Banerjee, Shri D. Ramadasu, Shri N. S. Shivakumar, Shri Gautam Kumar Pandey, Shri S. Ajesh Kumar, Shri Viajunath Mente, Shri Piyush Kumar Aggarwal, Shri M. Thirumalai, Shri M. Anandaraj, Shri P. Anup Kumar and Shri J. Saravanan, Shri R. Rajendra Prasad, Shri Gautam Anand, Shri D. Laxman, Shri K. Jayagopi, Shri P. Adhithan, Shri R. Raghuraman, Shri K. H. Anub, Shri K. Srinivasa Rao, Shri N. Mariappan, Shri S. Rajkamal Singh, Shri J. Jaikanth, Shri A. Kanakaraj, Shri K. Tamil Selvan, Shri R. Iyyapan, Shri T. Soliappan, Shri V. Veeraraghavan, Shri R. Kuppuswamy, Shri V. Gunasekaran, Shri M. Kathiravan, Shri R. Rajendran, Shri C.N. Sridhar and Shri Hadibandu Singh from FRTG.

Setting up and Engineering Scale Facility for Pyroprocess studies and Demonstration of Electrofining of Uranium

Dr. K. Nagarajan, CG, Group Leader

Shri G. Ravisankar, Dr. B. Prabhakara Reddy, Shri V. Sureshkumar, Shri P. Venkatesh, Shri T. Subramanian, Shri G. Seenivasan, Shri Suddhasattwa Ghosh, Smt. S. Vandarkuzhali, Dr. Manish Chandra, Smt. Nibedita Gogoi, Shri R. Sridhar, Shri A. Ananthakumar, Shri G. Rajendra Prasad, Ms. B. Suhasini, Shri N. Ravi, Shri E. Mohanraj, Shri K. Satya Govinda Raju, Shri M. Ganapathy, Shri S. Vannia Perumal, Shri S. Nedumaran, Ms. S. Suganthi, Shri M. Kakkum Perumal, Smt. K. Suriyakumari, Shri S. Mariyappan, Shri A. S. Ganapathi, Ms. S. Raja Rajeswari, Shri V. Arunkumar, Shri V. Yuvaraj, Shri N. Vinodkumar, Shri M. Saravanan, Shri P. Marimuthu, Shri P. Jagannathan, Shri K. Logannathan, Shri R. Rajaram, Shri N. Eswaran, Shri E. Nagappan,Shri K. Dayalan, Shri N. Radhakrishnan, Shri N. Nagarajan, Shri G. Raman, Shri K. Ganesan, Shri V. Balagopalan, Shri S. Rajendran and Shri D. Kothandan from CG, Shri S. P. Ruhela from FRTG, Dr. U. Kamachi Mudali, Shri G. Senthil Kumaran, Shri S. Sakthivel, Shri R. Ravikumar, Shri K. V. Kasi Viswanathan and Shri D. Jagadisan from MMG, Shri Vijayan Varier , Shri P. Jagannathan, and Shri K. Logannathan from REG.

DAE Awards Continued.....

Homi Bhabha Science & Technology Award	:	Shri A. Ravisankar, RpG
Young Applied Scientist & Technologist Award	:	Shri V. Rakesh, MMG and Shri Abhishek Mitra, NSEG
Scientific & Technical Excellence Award	:	Shri U. Partha Sarathy, REG and Shri S. Raghupathy, NSEG
Meritorius Award	:	Shri A. Govindarajan and Shri T. Logaiyan, FRTG , Shri B. Syed Ali and Shri K. Ganesan, ROMG, Shri T. G. Swaminathan, ESG and Shri K. Dasarathan, MSG
Young Engineer Award	:	Shri G. V. Prasad Reddy, MMG and Shri E. Hemanth Rao, NSEG

Awards & Honours

Dr. A. K. Tyagi, MSG has been awarded "Award of Excellence" by Sathyabama University, Chennai in the area of Nanoscience and Nanotechnology.

Shri Sumantra Mandal, MMG has been selected for the "IEI Young Engineers Award 2011-2012" in Metallurgical and Materials Engineering discipline.

Dr. Vaidehi Ganesan, MMG has been awarded with Marie Curie Mahila Vijnana Puraskara during the fourth National Women's Science Congress held at Bengaluru during November 7-9, 2011.

Best Paper / Poster Awards

Dr. B.P. C. Rao, Shri S. Thirunavukkarasu, Dr. T. Jayakumar, Dr. Baldev Raj, Shri Aravinda Pal, Shri T. K. Mitra and Shri Pandurang Jadhav of MMG have been adjudged the winner of "Weldman Award-2011" for the best Technical paper on "A new Methodology for Qualification of Welding Procedure for Circumferential Shell Welds of Steam Generators of PFBR" presented during National Welding Seminar -2010.

Shri Girish Kumar Padhy, Research Scholar, MTD, MMG has been adjudged the winner of "ESAB India Award-2011" for his paper on "Diffusible Hydrogen Measurement in Steel Welds using an Electrochemical Hydrogen Sensor" for the best Technical paper across all categories.

Shri Ashish Jain, Shri S. Kandasamy and Dr. K. K. Satpathy recieved 2nd prize for poster presentation on "Construction site monitoring through a systematic Safety observation methodology in IGCAR" during 28th DAE Safety & Occupational Health Professionals Meet-2011.

Shri M. Santhanam, Shri V. Venkatachalapathy, Shri C. Sivathanupillai and Shri R. Gettu got "Corps of Engineers Prize" from The Institution of Engineers (India) for their paper on "Mechanical properties of High Density Concrete used in Fast Reactors for Structural and Shielding Purposes" published in the Journal of the Institution during 2010-2011.

Mangroves in the backwaters of Kalpakkam

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