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From the Director's Desk

Exploring, Enriching and Enabling Journey

I shall be completing my assignment as Director, Indira Gandhi Centre for Atomic Research, Director, General Services Organisation (GSO) governing body for townships and neighbourhood and Member of Board of Directors of Bharathiya Nabhikiya Vidyut Nigam Limited (BHAVINI) on April 30, 2011.

I joined the Training School of Bhabha Atomic Research Centre in 1969, drawing inspiration from Dr. Homi Bhabha to serve the nation with my intelligence, hard work and total commitment. As I had lost my father when I was eleven years old, my mother was the bedrock of all my decisions. She endorsed my decision and supported me with strength of the moral values. It is an unfulfilled dream that I could never meet Dr. Homi Bhabha, as he left for heavenly abode due to his untimely death in 1966. After a few years in BARC and one year in RISO National Laboratory, Denmark, I joined the then Reactor Research Centre and now Indira Gandhi Centre for Atomic Research in June 1974. The Centre has provided me with challenges and opportunities in abundance in my long association over the last four decades. I visualised and dreamt of leadership for our Centre in the areas of my pursuits, namely, post-irradiation examination, non-destructive evaluation science and technology, advanced materials science and technology, separation sciences, reprocessing technologies, sodium cooled fast reactor design, building of large components with stringent performance demands and safety science and technology. I have thus explored all these areas of research and got enriched with many new results, innovations and joy. In all these areas, it has been possible to realise the dream of being one among the world leaders and in some cases, the world leader, because of team efforts, collaborations, congenial colleagues, leadership and guidance of peers, confidence in our approaches and perseverance. Thus, I feel satisfied that this has been achieved due to our collective dedicated efforts, which have been instrumental in translating the dream into a reality. A large and wide spectrum of sustained collaborations, approximately three hundred in number with academia, research and industries which include some of the excellent national and international individuals and organisations, is the key to achieve science based technologies and making the mission successful and ever growing in content and delivery. The successes in this mission programme are the result of outstanding collaborations, at all levels, between IGCAR and BHAVINI and indeed also with the relevant units of DAE family. Another founding principle of my career has been pursuit of assignments in a holistic manner with high sensitivity to colleagues and peers. To my mind, ethics and transparency in management combined with professional competence and commitment are true strengths of an individual entrusted with the assignment of managing large resources of financial and human capital for a mission as challenging and important as fast reactors with closed fuel cycle technology. It was a rather late realisation (in the last ten years) that motivation I can provide to my colleagues is only through my example of quality of work and commitment to the Centre and not the control through authority or mechanism of confidential reports, etc. I have always believed that only by empowering, enabling and trusting the abilities of younger colleagues, we can achieve the mission-mode objectives of the Centre.

The inspiration from Dr. Homi Bhabha demands making the working environment aesthetically appealing, elegant and functional. The Department has the tradition of caring for all sections of persons encompassing neighbourhood with holistic and innovative approaches for townships, which include hospitals and schools. We have worked with success on beautiful and functional master plan of the Centre, other units of the DAE at Kalpakkam and townships, water and energy conservation approaches and step by step targets till 2030. It has been my endeavor to work in teams with systematic and comprehensive approaches to strengthen the traditions through structured implementation for realisation of the visualised goals. Even though the focus of the Centre is on its mission, it was still possible to contribute to a large number of challenges and relevant programmes, in the Indian context, in domains of defence, space, security, energy, cultural, heritage, health care, education, etc. The Centre has earned respect and appreciation by virtue of these contributions from corresponding organisations and peers. These contributions have also enriched us and sharpened our minds to improve our mission. Basic science is an important pillar of strength for the Centre which has given the capacity and confidence to meet new challenges and discover new concepts, as and when needed, from the reservoir of clear and fresh thinking, even in some practical situations.

The most demanding period of my stay in Kalpakkam was when the Tsunami struck on 26th December 2004. I found myself inadequate to meet and match the challenges and expectations of suffering citizens in Kalpakkam township and our neighbourhood. We would never be able to make up for the losses of the lives of the dear ones in the families. However, I can say that with the best team effort and support of many individuals and organisations, we mitigated the sufferings and recreated a new township, which is more elegant and beautiful. The challenge of evaluation of Tsunami affected foundation of the PFBR and its restoration of foundation to full satisfaction of researchers, utility and regulators, shall remain an important science based technology delivery, in my own assessment of the contributions. The unsolved unique challenge, in international context, was met with multifaceted talented teams and the end result was exemplary and robust. Meeting the challenges of emergency responses, after Tsunami, is a robust answer of the DAE with respect to capacity, synergy and clarity of actions towards achievement of the results.

Many a times managing the Centre, the townships and interfaces within India and abroad required energy and mindset beyond my capacity as a human being. I had to face an inevitable question, many a times, from my wife; *“Baldev, you know that you are a human being, then why you are making efforts to prove yourself to be a super human being by taking up so many diverse and difficult tasks in tandem”*. I did not know the answer, but I had a realisation that I was helped by my thinking of working hard and remaining fun loving just like a good school boy and keeping faith in the teams that I work with. The philosophy of a school boy to me is carrying a bag on the back, run to the work, work with the team, do the work, contribute and learn, have fun, get tired and sleep comfortably. This philosophy has been with me for my life. I am grateful to my divine Guru, ethical parents and teachers, my caring and clear thinking wife, loving and intelligent children and their families, who empowered me to do all the assignments (small and big) by inspiring me and for not placing undue demands on my time and energy. I can take credit for my dreams, but the work and achievements belong to my colleagues who worked with enthusiasm, passion and competence and

were ever ready to be my partners, well wishers and supporters in all the assignments, small and big, which I did during my stay at Kalpakkam. I experienced difficult situations in my career and challenging situations in family, primarily due to the sudden demise of my mother and some other personal severe sadness. The non-linear impact of these difficult periods was encountered with reasonable measures by working even harder, with more intelligence and deeper faith in my loving family members and the dear worthy colleagues and peers. The fact that the challenges did not lessen my faith and confidence in approaches, is primarily due to faith in divine and love of ethical and compassionate human beings.

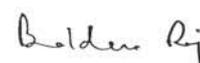
During the seven years, as the Director of the Centre, through my column in the IGC Newsletter, I have narrated the history of the Centre and maturity in science and technology, in different disciplines and mission programmes, with judicious description of challenges and opportunities ahead in coming decade. During this period, I have enjoyed immensely various opportunities to interact with colleagues, students and teachers in our townships, in our country and indeed in many parts of the world.

During the Centre is endowed with capacity and capability to realise, even better successes and achievements. The robust mechanisms of Homi Bhabha National Institute (HBNI), Training School, Nodal Centre of University Grant Commission – DAE Consortium (UGC-DAE CSR) and a large number of excellent students carrying out their research projects in pursuit of higher academic degrees and collaborations would continue to enrich and enhance the capability and capacity of human resources in our Centre. Our two successive peer reviews in physical, chemical and engineering sciences by eminent academicians have provided confidence in our in-house R&D capabilities. I visualise that this capability can be further enhanced with valuable inputs coming from talented and well-trained younger manpower. I am confident that we shall continue to achieve outstanding successes for the Centre, townships and the Department towards realising the objectives of the mission, enhancing the science and traditions founded by Dr. Homi Bhabha and enriched by Dr. Vikram Sarabhai.

I shall deem it, as my privileged duty, to be of value to the Centre, the Department and the Country. Thus, I would strive continuously to look at the opportunities and commit myself to realise substantial contributions of high significance and merit. I resonate with Shri Kumar Mangalam Birla; *“Value what you do, do what you value”*.

I wish to be in contact with you and continue to be inspired and guided by your thoughts and deeds. Finally, I would like to express my heartfelt thanks and sincere appreciation to all my colleagues in Indira Gandhi Centre for Atomic Research, Bharathiya Nabhikiya Vidyut Nigam Limited, General Services Organisation, Department of Atomic Energy and my collaborators outside the Department of Atomic Energy family for their support, cooperation and encouragement throughout this enjoyable journey over four decades.

With my sincere wishes and warm regards,



(Baldev Raj)

Director, Indira Gandhi Centre for Atomic Research
& General Services Organisation

Raman Spectroscopy of Uranium by a Surface Enhanced Raman Scattering Technique

Study of metals by Raman spectroscopy is a challenging scientific problem due to the low penetration of laser into metals and hence low sampling volumes. There are not many reports of Raman spectra of metals in the literature since their spectral intensities are quite weak. Raman spectra of a few elemental metals (with more than one atom per primitive cell) such as beryllium and gallium have been reported at ambient conditions; zirconium and the hexagonally close packed phase of iron have been studied at high pressures in diamond anvil cells. Technologically important actinide metals such as uranium and plutonium have not been investigated using Raman spectroscopy due to poor signal intensities. At Materials Science Group, recently a surface enhanced Raman scattering technique was used to obtain the Raman spectra of uranium by coating a thin layer of gold on it. There is a possibility that this technique can be used to study other metals and materials of weak Raman intensity.

Current interest on structural properties of uranium

At ambient conditions uranium has orthorhombic structure with two atoms per primitive cell. Group theoretical considerations show that three Raman active modes ($A_g + B_{1g} + B_{3g}$) are expected to be present in this α -uranium. Lattice dynamical calculations and inelastic neutron scattering measurements showed the presence of zone center optical modes about 80, 100 and 120 cm^{-1} , but there are no reports of Raman spectra of uranium in the literature. Recently there has been a renewed interest in the phonon density of states of uranium. Inelastic X-ray and neutron scattering studies were carried out at Los Alamos National Laboratory, USA and elsewhere to observe changes above 450 K that could explain the loss of mechanical ductility at this temperature. High pressure X-ray diffraction measurements using a diamond anvil cell have revealed that there are no structural phase transformations in uranium below 1 Mbar, unlike other light actinides such as thorium, neptunium, palladium and plutonium. On the whole however, there is lack of experimental work on actinide metals due to their toxicity, radioactivity and scarcity, and this limits our understanding of these technologically important materials. This study opens up the possibility of bringing into the realm of a versatile laboratory technique i.e. Raman spectroscopy, what has hitherto been studied mainly at large experimental facilities such as nuclear reactors and synchrotrons.

Natural uranium metal discs of about five millimeter diameter and one millimeter thickness (obtained from Chemistry Group) were used in this study. The discs were ground and

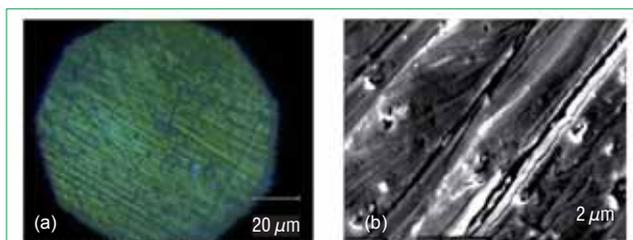


Figure 1: Typical (a) optical micrograph and (b) SEM image of gold coated surfaces of uranium metal

polished with emery papers of gradually finer mesh, finally with one micrometer diamond paste. Even though mirror finish was obtained the sample had a large number of surface scratches as could be seen under optical and scanning electron microscopes (Figure 1). A high throughput Renishaw micro Raman spectrometer was employed to record the spectra using the 514, 785 and 325 nm laser excitations.

Unpolished discs exhibited Raman bands characteristic of UO_2 and oxidised UO_2 at 450 and 580 cm^{-1} respectively (Figure 2) that disappeared upon polishing the metal to a silvery mirror finish (Figure 2a). In the frequency region below 150 cm^{-1} down to 50 cm^{-1} , however, a number of sharp Raman bands characteristic of the rotational modes of N_2 and O_2 are obtained (Figure 2a and b). They are due the molecules from the ambient air adhering to the metal surface. This is in the same wave number region in which uranium Raman bands are expected. Thus it becomes a non-trivial problem to detect the Raman spectra of uranium metal. Techniques such as polishing and encapsulating the metal in an argon atmosphere in a glove box or even vacuum annealing the sample in a quartz tube at 573 K for two hours followed by vacuum sealing did not dispense with the adsorbed air molecules, as determined from the recorded Raman spectra. A layer of gold was coated on the sample to see if surface enhanced Raman scattering effect could be invoked

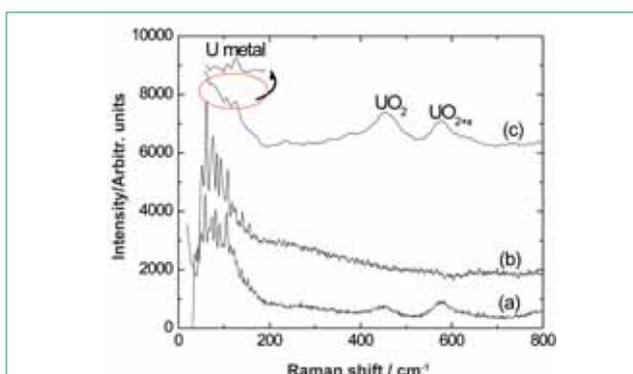


Figure 2: Raman spectra of uranium discs (a) unpolished (b) freshly polished and (c) 15 nm gold coated

from the proximity of gold of a few nanometers thickness.

Gold layers of 5 and 15 nano meter thickness were deposited by pulsed laser deposition and thermal evaporation respectively on two different, polished discs of uranium. The skin depth of the laser excitation wavelength of 514 nm in gold is about 20 nm, and hence the photons could penetrate into the uranium disc through thin layers of gold. Laser excitation of dark scratch lines and pits on the samples gave rise to Raman spectra expected of uranium metal (Figure 3). Spectra were recorded at many such points on from both samples. Well resolved Raman bands about 82 (B_{1g}), 108 (A_g) and 126 cm^{-1} (B_{3g}) were obtained. All sharp bands of N_2 and O_2 disappeared, indicating that the adhesion of N_2 and O_2 to gold surface is quite low. Several bands of different uranium oxides such as UO_2 and UO_{2+x} were observed in the extended range of wave numbers up to 800 cm^{-1} (Figure 2c). Laser excitation of smooth golden yellow surface however did not result in uranium spectra.

Surface enhanced Raman spectroscopy

The phenomenon of surface enhanced Raman spectroscopy to enhance the Raman signal intensity of weakly scattering molecules adsorbed on roughened gold or silver surfaces a million fold was discovered in the 1970's. But there are no reports of surface enhanced Raman spectroscopy studies of underlying metals as observed in the present study. The current understanding of surface enhanced Raman spectroscopy is that it arises mainly due to the excitation of localised surface plasmons of the sensitive metal (such as gold or silver); when the surface plasmon frequency is in close resonance with the exciting laser frequency, there is a large increase in the local electromagnetic field that polarizes the adsorbed molecules. Though it is well known that the optical dielectric constant of the ambient medium plays a critical role in determining the enhancement factor, currently there is no clear understanding of the role of the dielectric substrate.

Electrical conductivity of uranium is an order of magnitude less than that of gold, but being a good conductor it cannot support surface plasmons of gold. It is envisaged that the thin uranium oxide layer that forms rapidly and naturally on the polished surface before gold coating serves to localise the surface plasmons. This oxide layer is akin to the ~ 2 nm SiO_2 or Al_2O_3 shell on 55 nm gold particles in the SHINERS (Shell-isolated Nanoparticle-Enhanced Raman Spectroscopy) technique that was reported recently. Sharp edges of gold in the scratch lines act like nanorods with a range of aspect ratios. When these edges are excited by the 514 or 785 nm laser we have a surface enhanced Raman spectroscopy effect that enhances the Raman signal from uranium oxides and the metal itself. This is thus a 'sub-SERS effect' since we are looking at the surface

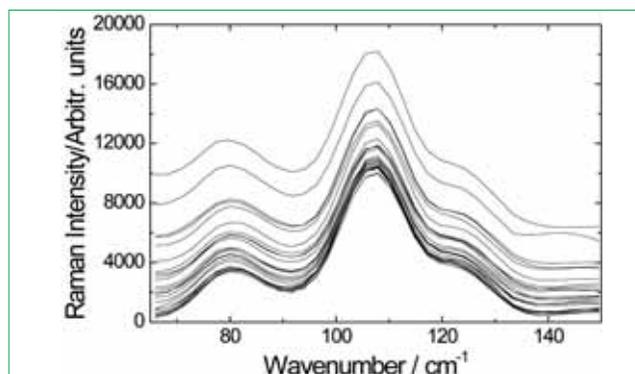


Figure 3: Raman spectra (background subtracted) of uranium disc coated with 5 nm gold film using 785 nm laser excitation

enhanced Raman effect on uranium metal that is under the gold layer. The optical absorption spectrum of gold nanorods has two maxima, one about 520 and the other around 700–1050 nm for nanorods of different aspect ratios; aspect ratio of about four is expected to exhibit a maximum about 785 nm. Hence laser excitation at 514 and 785 nm can be expected to give rise to surface enhanced Raman spectroscopy spectra. 325 nm laser excitation did not result in Raman bands of uranium, consistent with the fact that the absorption spectrum of gold nanorods has no peak around this wavelength.

SHINERS is a technique that involves chemical synthesis of gold nanoparticles of uniform diameter of ~ 55 nm and coating them with an ultra thin (~ 2 nm) layer of either silica by chemical methods or alumina by atomic layer deposition to obtain 'smart dust' that is sprinkled on surfaces of interest to obtain surface enhanced Raman spectra. Each insulated gold nanoparticle acts like a tip enhanced Raman spectroscopy tip, and because a large number of nanoparticles can be spread on samples, the surface enhanced Raman spectroscopy intensity is much higher in SHINERS technique compared to tip enhanced Raman spectroscopy. Another extremely successful and reproducible surface enhanced Raman spectroscopy substrate is AgFON that is obtained by nanofabrication techniques, by coating a thin silver film over a self assembled array of polymer nanospheres. The current technique is much simpler to implement compared to the above methods, involving only deposition of a thin film of gold on the surface oxidised metal. It is surmised that the current sub-surface enhanced Raman spectroscopy effect would be useful to study other metals and materials with low Raman scattering cross section.

This is a report of recording of the Raman spectra of uranium metal by a sub-surface enhanced Raman spectroscopy technique by coating 5 and 15 nm gold layers on the surface of the metal. Naturally formed thin oxide layer on the metal before gold coating provides the dielectric base to localise the surface plasmons of gold that enhance the Raman signal.

*(Reported by T. R. Ravindran and colleagues,
Condensed Matter Physics Division, MSG)*

Development of Local Area Network based On-line Gamma Dose Logger

Continuous environmental gamma dose monitoring around a nuclear reactor and associated fuel cycle facility is mandatory to ensure that the radiation levels in the site boundary are within the acceptable limits. Such monitoring also provides for early detection of excess release in case of an untoward incident and also to estimate the source term, which is essential for emergency response. The data also provides a means for validation of the computer codes used for atmospheric dispersion modelling.

Commercial systems called as gamma tracers are available and operational at Kalpakkam for more than a decade. These are stand-alone systems with local data archival feature and the data needs to be collected at the actual location. Alternatively the gamma tracer has to be brought to the laboratory for downloading the archived data. The present generation of gamma tracers have advanced features such as RS485 network, radio frequency link for short range of up to five kilo meter and long range of 9 – 100 kilometer. Such radio frequency link based systems are prohibitively expensive. Taking into account the factors such as requirement of communication towers, data security, cost effectiveness and expandability, Radiological Safety Division embarked on the design and development of a integrated indigenous gamma dose logger with capabilities of existing state-of-art gamma tracer with advanced features such as transmitting online data through local area network while being eco friendly.



Figure 1: Schematic of the indigenous on-line gamma dose logger

The system (Figure 1) essentially consists of an energy compensated Geiger-Muller tube (detector), a microcontroller with dedicated software code embedded to organise the data, RS232 to ethernet data gateway interface module for data communication and work on the novel concept of maintenance-free battery charged through a solar panel. The data gateway ADAM 4571L is used to get the real time data. The sampling rate is ten seconds and the averaging data of one minute and ten minutes is displayed graphically. Ten minutes average data; statistical parameter like standard deviation is also computed and stored in a repository. All these features are specially incorporated to serve as inputs for detailed dispersion model studies. The measuring range of the instrument is 20-100 mGy/h

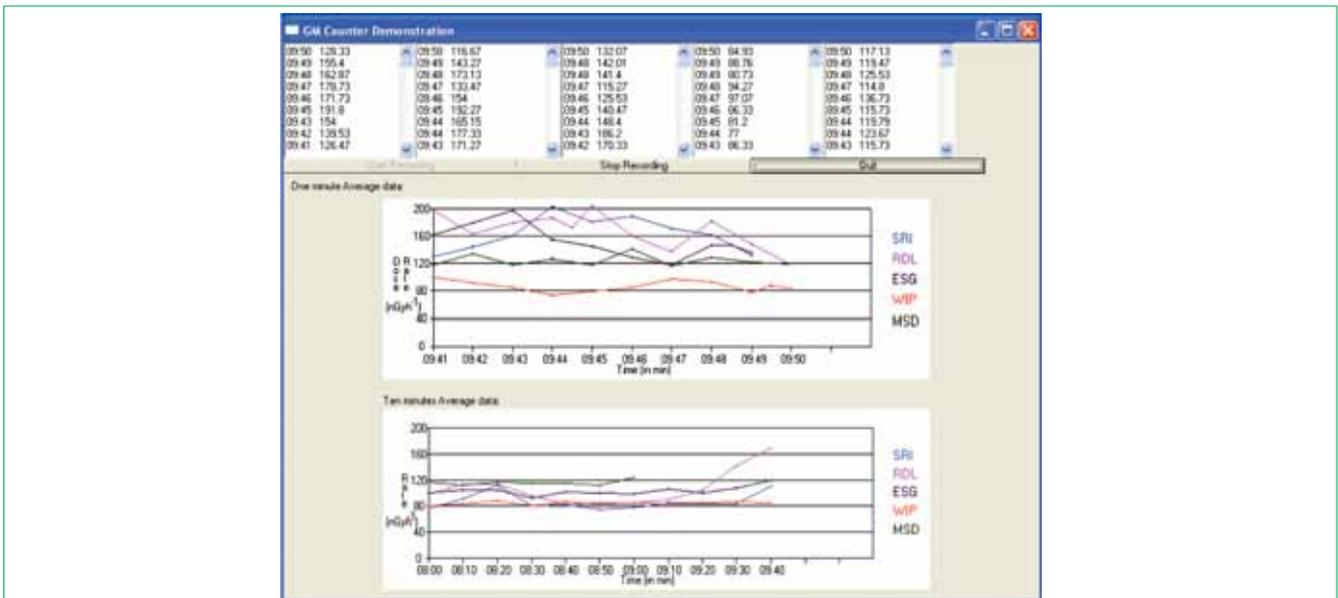


Figure 2: Snapshot of on-line gamma dose logger data at different locations and the corresponding graphs

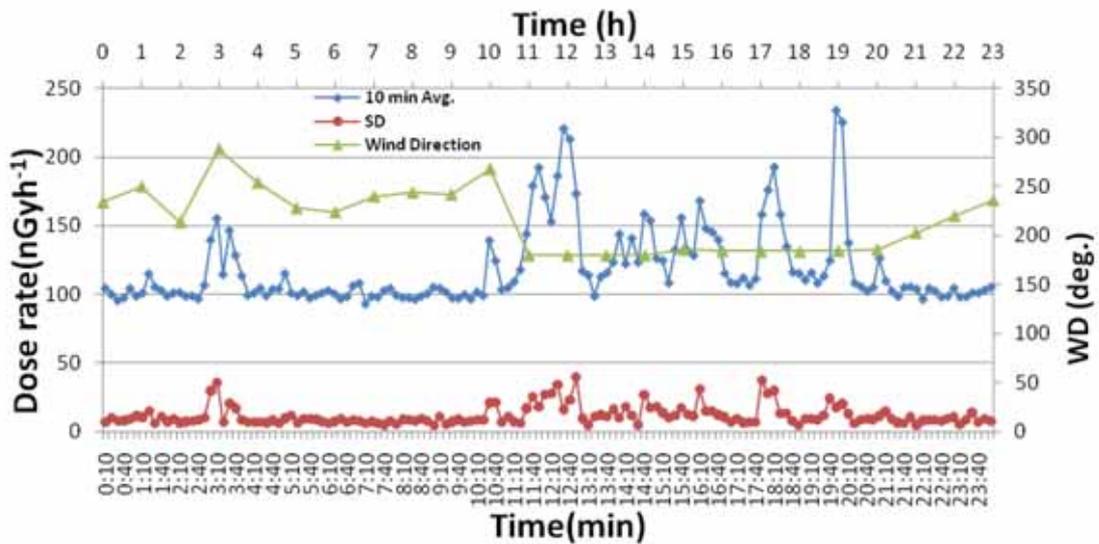


Figure 3: Comparison of radiological surveillance data with wind direction

For simultaneous collection of online data from several stations, the system installed at remote location is assigned an IP address and connected to the local area network to transfer the online data to a server. The server is configured to receive the data from stations through serial ports by creating virtual COM ports and mapping them individually to the allotted IP address of the monitoring systems. This way, the data and the location from where the data is sent are identified. A communication software tool has been developed in Visual Basic 6.0 and installed on the server to collect the online data. The byte array received is transformed to its floating point equivalent and simple statistical estimates on the average and standard deviation are computed to provide real-time comparison to gamma dose rate in all stations. Figure 2 shows a snapshot of actual data as received from different locations; one minute and ten-minute average data are displayed in the form of graphs.

Figure 3 provides a comparison of dose rate with wind direction, at a monitoring station located in North. The display helps to monitor the gamma dose rate on a real time basis and observing the peaks, which are due to Argon release, easily indicates any increase.

By correlating the collected data with the wind direction, the argon release from the reactor stack is confirmed with the perturbations when the direction is between South-South East & South-South West.

Apart from the maintenance free battery charged through solar panel, the other novel features of these indigenously developed systems are

- ✦ Real time data access to data through local area network
- ✦ Automatic display at regular intervals
- ✦ On-line average dose rate including graphical display for one minute and ten minutes value along with standard deviation. Distinct display with time stamp of data from different locations.
- ✦ Resetting of graphical display to provide clear presentation at any time

Figure 4 shows online gamma dose logger monitoring locations in and around IGCAR. The system has been successfully installed at four locations (SRI, MSL, ESG & RDL) and the system has been working smoothly and satisfactorily for the last six months. One more monitoring location at WIP has been added recently.

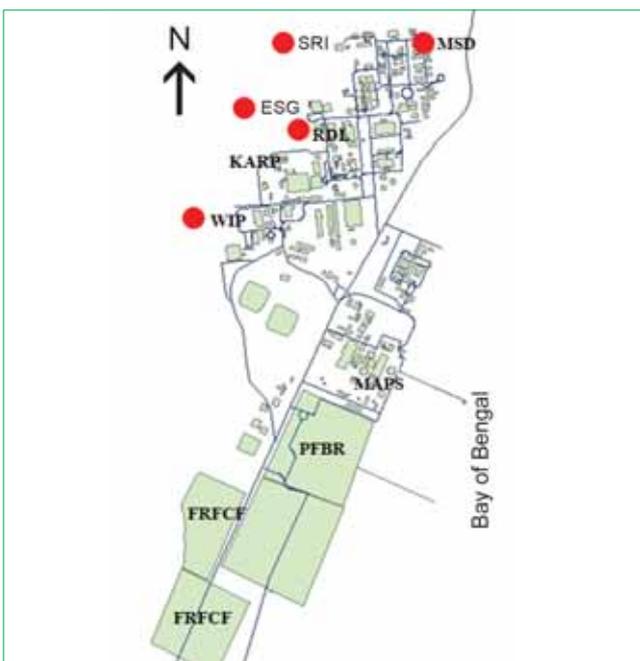


Figure 4: On-line gamma dose logger monitoring around IGCAR

(Reported by G. Surya Prakash and colleagues, Radiological Safety Division, REG)

Young Officer's FORUM

Characterisation of Biofilms on Titanium Surfaces by Raman Imaging

The extensive usage of titanium and its alloys as condenser materials in nuclear power plants is broadly affected due to biofouling by macro and microorganisms. The biofouling leads to the physical obstruction to the water flow through the condensers and reduces the heat transfer properties of titanium. In order to overcome the drawbacks, studies have been carried out on the modification of titanium surfaces so as to control the microbial attachment on the titanium surface. The surface modification of titanium mainly concerns the anodic oxidation or anodisation at the metal surface, which leads to the formation of anatase, TiO_2 at the surface. The oxidised titanium surfaces were reported to show photocatalytic, antimicrobial and disinfecting properties. Generally, antimicrobial properties were assessed by determining the reduction in the number of cells of microorganisms on the surface of titanium on illumination. However, fast and effective method for monitoring the biofouling was needed. In this respect, the single analysis through Raman spectroscopy with a simplified sample preparation method was considered for analysing the molecular composition in biofilm components on un-anodised and anodised titanium surfaces. The normal Raman experiments on the biofilms of un-anodised and anodised titanium surfaces gave unclear spectra. Hence, the surface enhanced Raman scattering using Ag/Cu bimetallic colloid was used to enhance the signal intensity and resolution.

Pure Titanium grade-2 (commercial) samples were used in this study. The titanium metal was bought in the form of sheets and the coupons of size 30 x 20 x 1 mm were cut from it. These specimens were pickled in an acid bath (HNO_3 , 400g/L + HF, 40g/L + water) to remove any surface scales present. The pickled specimens were then cleaned ultrasonically in a detergent solution, washed in running tap water and finally rinsed in distilled water and air-dried. Anodisation was carried out at 298K in orthophosphoric acid (30 g/L) for 10 minutes at 30 V. Normal Raman experiments (data is not shown here) were done on anodised surfaces to confirm the presence of anatase. The acid pickled specimens were used as a control to compare the photocatalytic activity of the anodised specimens. These specimens were then suspended in the outfall water from



Dr. S. Ramya completed her Ph. D. in Chemistry and joined as a K.S. Krishnan fellow in IGCAR in 2007. Currently, she is a Scientific Officer (SO/D) in Corrosion Science Technology Division and is working on the characterisation of various materials in the specific areas of passive films, surface oxides, nanomaterials and biofilms using Raman spectroscopy. She has published around seventeen journal papers and thirteen conference proceedings. Her main interests are spectroscopy and surface chemistry of materials.

Madras Atomic Power Station, Kalpakkam. The specimens were withdrawn after one week and it was clearly seen that there was a considerable biofilm growth on the titanium surfaces. The titanium coupons with the biofilms were immersed in the Ag / Cu colloidal suspensions and their analysis in Raman microscopic scanning mode were carried out with Raman spectrometer equipped with 1800 grooves/mm holographic grating. He-Ne laser of 633 nm was used as an excitation source. The reason for selecting He-Ne laser was to avoid sample degradation. Raman spectra were collected at various points of each sample, and were observed to be reproducible.

Figure 1a and 1b showed the light microscopic image and average Raman spectra of the algal and bacterial biofilms formed on un-anodised titanium surface. A tentative assignment of bands was performed by referring to Raman and surface enhanced Raman scattering assignments for biological samples from the literature. Dominant polysaccharide vibrations were seen in algal Raman spectra whereas protein frequencies were observed in bacterial spectra. The Raman spectral maps (Figure 1a and 1b) were obtained over 200 x 200 μm^2 area of algal and bacterial patches on the un-anodised titanium surface. The mapping experiments showed the distribution of biofilm components on the un-anodised titanium surface. The Raman map of algal film was taken from 990-1100 cm^{-1} (C-C and C=O stretching of polysaccharides) and the Raman map of bacterial film was taken from 800-900 cm^{-1} (Ring I deformation and different C-N stretching of proteins).

Similar micro-surface enhanced Raman spectra experiments were conducted on the biofilms formed on anodised titanium surfaces. The light microscopic image, average Raman spectra and the Raman map of bacterial biofilms formed on anodised titanium surface are shown in Figure 2. The light microscopic image of the biofilm on anodised surface was totally different than that of un-anodised titanium surface. This was due to the modification of the titanium surface during anodisation. Anodisation changed the titanium metal to TiO_2 and was confirmed by the Raman study. When we analysed

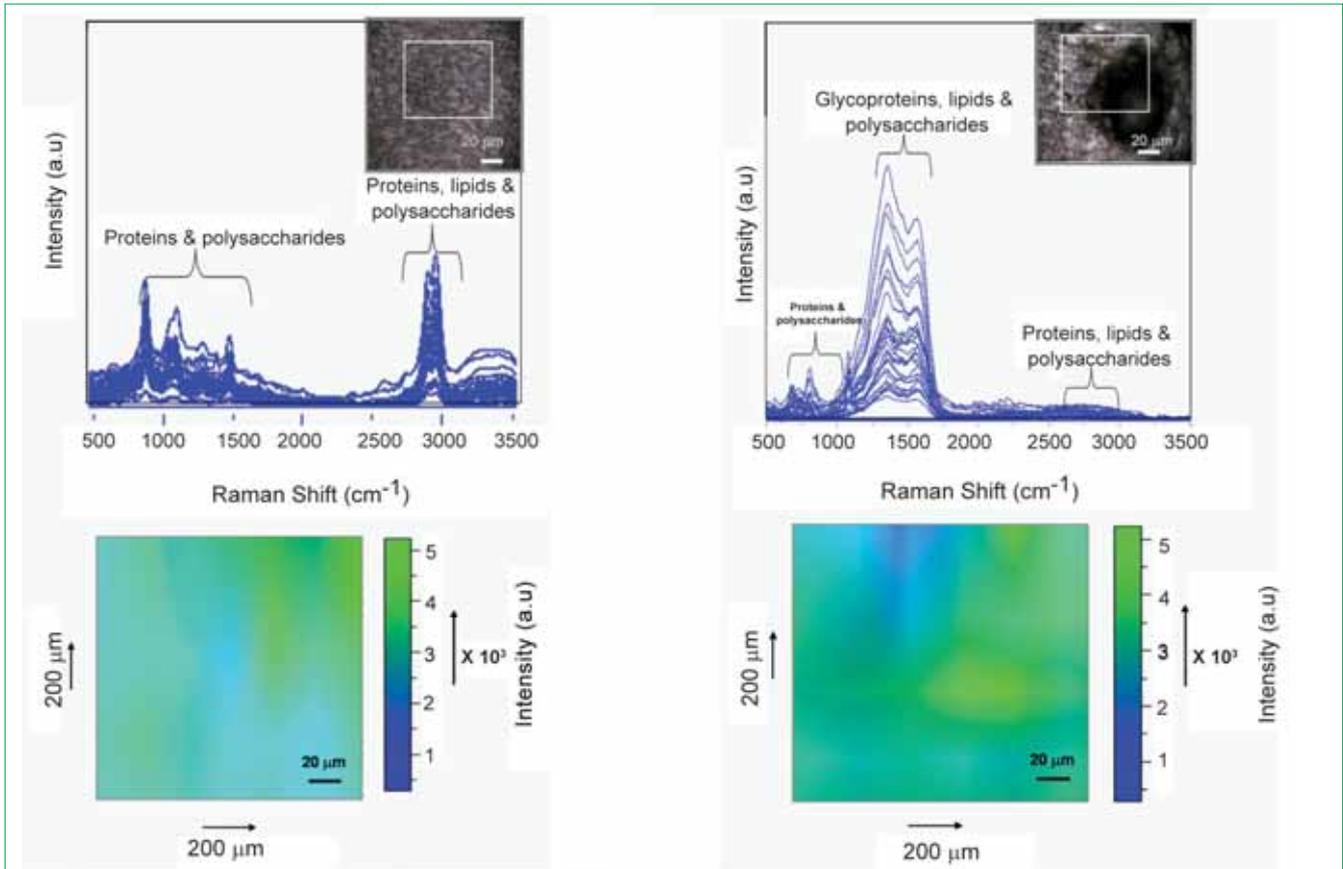


Figure 1: Average Raman spectra, light microscopic image and Raman map of a) Algae and b) Bacterial biofilms on un-anodised titanium surface. The square box inside the light microscopic images indicates the region where Raman maps were recorded. Algal Raman maps were recorded from 990-1100 cm^{-1} (corresponds to polysaccharides). Bacterial Raman maps were recorded from 800-900 cm^{-1}

the anodised samples simply by visual inspection, it looked very clean just like a bare titanium metal as if there was no biofilm formation. This indicated that the growth of the algal film was reduced markedly. Though the algal growth was visibly reduced, we wanted to verify the bacterial distribution in both the surfaces. Hence, we compared the Raman maps of bacterial patches on the un-anodised and anodised titanium surfaces and found that the bacterial growth was drastically reduced. The Raman maps of bacterial biofilms (Figure 1b and 2)

on un-anodised and anodised titanium surfaces inferred that the biofilm distributions on the anodised titanium surfaces were almost 10^2 times lesser than that of un-anodised surface. The study has demonstrated the efficacy of employing micro-Raman coupled with surface enhanced Raman scattering for assessing the level of bacterial attachment to the surface. The appearance of the algal spectra was different than that of the bacterial spectra wherein the Raman signal due to proteins and amino acids were not prominent. Rather, strong signals

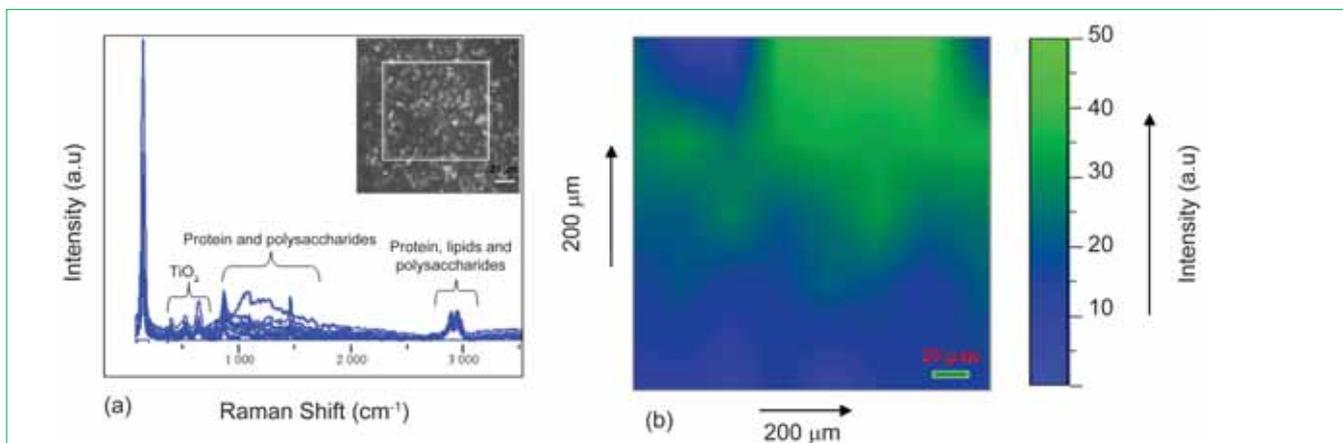


Figure 2: a) Average Raman spectra and light microscopic image b) Raman map of bacterial biofilm on anodised titanium surface. The square box inside the light microscopic image indicates the region where Raman maps were recorded. Raman maps corresponding to proteins were recorded from 800-900 cm^{-1}

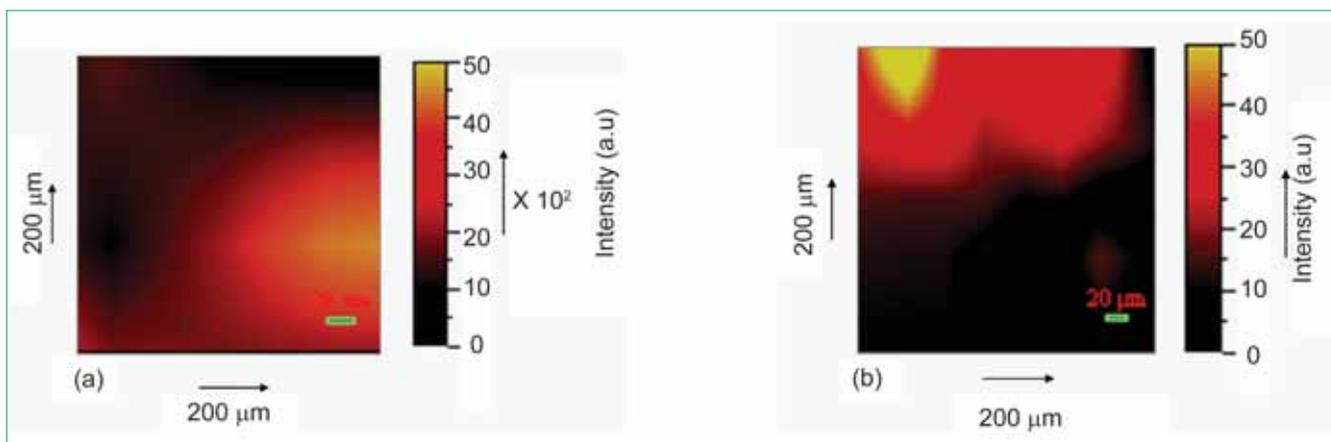


Figure 3: Distribution of biofilm based on C-H stretching frequency in different regions of biofilm formed on a) un-anodised and b) anodised titanium matrices. Mapping was carried out from 2850-3030 cm^{-1} corresponding to C-H stretching from protein, lipid and polysaccharides

with comparatively higher background were obtained around 1350-1400 cm^{-1} and 1580-1600 cm^{-1} . An interesting feature was observed with regard to C-H and CH_3 stretching frequencies around 2900 cm^{-1} , which created a subtle distinction among algal and bacterial biofilms. In the algal Raman spectra, single peak was observed around 2900 cm^{-1} whereas a strong doublet was detected for Gram-negative species, due to C-H and CH_3 stretching vibrations from proteins and lipids. Since Gram-negative bacteria has a characteristic lipoproteinaceous cell wall, these vibrations probably aroused from the proteins and the lipids of the cell wall. For gram-positive stain, a peak with a small shoulder was appeared around 2900 cm^{-1} due to C-H and CH_3 stretching vibrations from their peptidoglycan units. For an easier and better comparison of microbial reduction, one may not have to look for algal and bacterial regions. The shape and intensity variations of the C-H stretching around 2900 cm^{-1} will alone enable us to know the dominance of bacterial or algal biofilm. Hence, the Raman mapping of C-H stretching around 2900 cm^{-1} of un-anodised and anodised titanium surfaces can be compared to quantify the microbial attachments at the surface. In the present case also, mapping experiments were

carried out with regard to C-H stretching (Figure 3).

Figure 3 showed the effective reduction in microbial attachment on the anodised titanium surface. The photocatalytic activity of the TiO_2 was well known and was expected to produce hydroxyl radicals. The generated hydroxyl radical (OH^{\bullet}) at the TiO_2 / biofilm interface was primarily accountable for the production of short lived H_2O_2 , which played a significant role in the microbial destruction of the biofilm. The Raman spectrum of biofilm (Figure 4a) on un-anodised titanium surface indicated the presence of prominent carboxyl group stretching (around 1375-1390 cm^{-1}) and amino group stretching (around 1230 cm^{-1} and 1560 cm^{-1} due to N-H and C-N of amide III of proteins). Those frequencies were found to be absent in the biofilm on the anodised surface. The possible reason was that the carboxyl and amide III groups were involved in the photocatalytic reaction of TiO_2 and completely disintegrated. Generally, compounds having ester and amide groups in their molecular structure degrade via hydrolysis in the presence of water, where hydroxyl group was expected to initiate the reaction. In photocatalysis, the OH^{\bullet} radical reacts like a strong base and nucleophilic attack at the acyl carbon in the ester will increase by water, leading to the breakage of carbon oxygen bond. In the case of proteins, the amide bond reacts with the hydroxyl radical and disintegrates to give acid and amide radical. The acid may further decompose to carbon dioxide and water. On account of all these effects, the biofilm matrix will loose essential extracellular polymeric substances necessary for its integrity. The studies have demonstrated the potential of micro Raman spectroscopy along with surface enhanced Raman scattering features in materials characterisation.

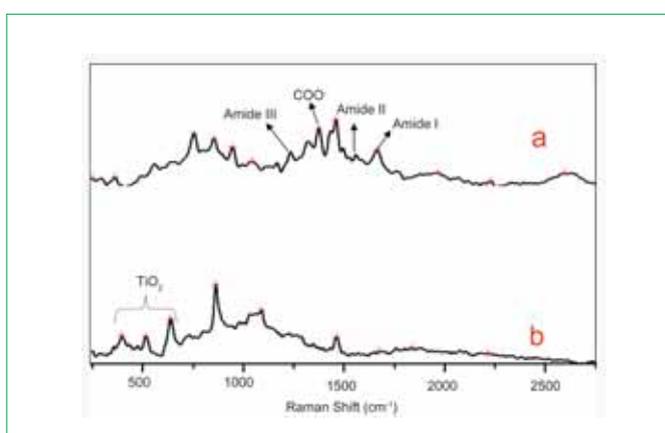


Figure 4: Micro-surface enhanced Raman spectra of bacterial regions of the biofilm on the a) un-anodised and b) anodised titanium surfaces

(Reported by S. Ramya,
Corrosion Science and Technology Group, MMG)

Young Researcher's FORUM

Studies on Significance of Aluminium on Physical and Mechanical Properties of $Ti_{1-x}Al_xN$ Thin Films

The demand for thin films as protective coatings is increasing day after day. Thin films are deposited on a material to enhance or modify the properties of the material. Some of the property modifications by thin films are high or low friction, corrosion resistance, high hardness, wear resistance, desired electrical and thermal conductivity, magnetic and optical properties.

Several transition metal nitride films exist, especially TiN which is an important material for protective coatings and other functional applications. Following the long time development of TiN coatings and improvements of coating processes, the stage was set to go beyond the binary nitrides and introduced more complicated metal nitride systems. For wear protection, nowadays, the metastable solid solution of TiAlN formed by the addition of aluminium into TiN was found to give a considerable or in some cases a drastic improvement in performance compared to TiN coated tools. $Ti_{1-x}Al_xN$ is a metastable solid solution with cubic (like TiN) or hexagonal (like AlN) or combination of structures. The fundamental advantage of $Ti_{1-x}Al_xN$ is its high temperature oxidation resistance (up to 1073 K) and higher hardness. The higher hardness is due to the compressive stress introduced into the film by the partial replacement of titanium atoms by aluminium atoms of smaller radius. High temperature oxidation resistance of these films increases with aluminium concentration, because of the formation of dense Al_2O_3 layer on the surface which prevents further inward diffusion of oxygen into the system. $Ti_{1-x}Al_xN$ films can also be used in

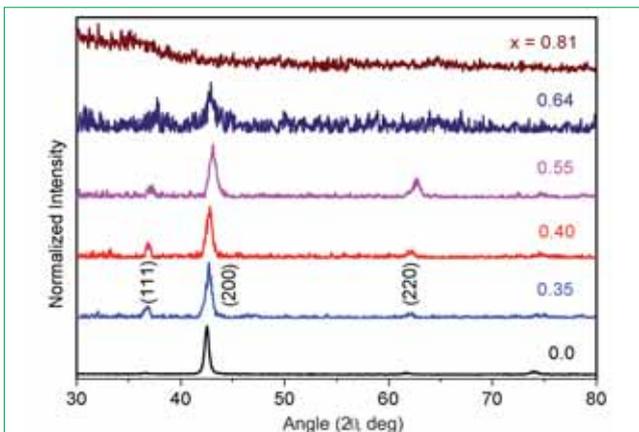


Figure 1: GIXRD profile of $Ti_{1-x}Al_xN$ films on SS304LN



Shri Feby Jose did his Masters in Physics from Mahatma Gandhi University, Kottayam, Kerala. He joined as a Research Fellow in June 2005 and has submitted thesis on November 2010 at University of Madras, under the guidance of Dr. Sitaram Dash, Head, Thin Films & Coatings Section, Surface and Nanoscience Division. The title of his thesis work is "Synthesis and Characterisation of Monolithic and Multilayer (Ti,Al)N Coatings".

semiconductor industry as insulating layers in semiconductor devices due to its wide range of band gap. The range of optical properties of the $Ti_{1-x}Al_xN$ films can be controlled by suitably altering the aluminium concentration, because TiN has metallic character whereas aluminum nitride is a wide band gap semiconductor. Generally, non-equilibrium physical vapor deposition techniques are used to achieve the solubility of TiN and AlN phases. With the increase in aluminium concentration, the stability of $Ti_{1-x}Al_xN$ cubic structure decreases and finally it is transformed to hexagonal AlN. Among the physical vapor deposition methods, magnetron co-sputtering has several advantages such as easy control of chemical composition, deposition rate and low temperature to realise metastable phase formation with good surface finish.

An experimental attempt was undertaken to deposit both cubic and hexagonal phases of $Ti_{1-x}Al_xN$ thin films on Si (100) wafer and AISI SS 304 LN substrate with various aluminium concentrations by reactive magnetron co-sputtering technique and study their properties. The GIXRD profiles of as-deposited $Ti_{1-x}Al_xN$ films on AISI SS304LN substrates, at different aluminium concentrations are shown in Figure 1. The elemental compositions of these films were determined with the help of electron probe micro analysis and secondary ion mass spectroscopy and found to be $x=0.0, 0.35, 0.40, 0.55, 0.64$ and 0.81 . The films with aluminium concentration up to 64% exhibited signature corresponding to NaCl structured TiN whereas the other one with higher than this concentration was amorphous. With increase in aluminium concentration, the width of the peaks increases and shifts towards higher Bragg angle (2θ). This is because of the partial replacement of titanium atoms with a smaller atomic radius with a resulting in lattice contraction. The grain size decreases with the increase in aluminium concentration until it finally becomes amorphous at 81% aluminium. This can be explained by the following reasons: (i) the addition of aluminium to TiN hinders the surface diffusion behavior of titanium and nitrogen atoms and (ii) the grains of disordered or amorphous AlN prevents the growth of TiN phase.

The GIXRD profiles of the $Ti_{1-x}Al_xN$ films ($x=0.64$ and 0.81) annealed in nitrogen atmosphere for four hours at 1073 K are

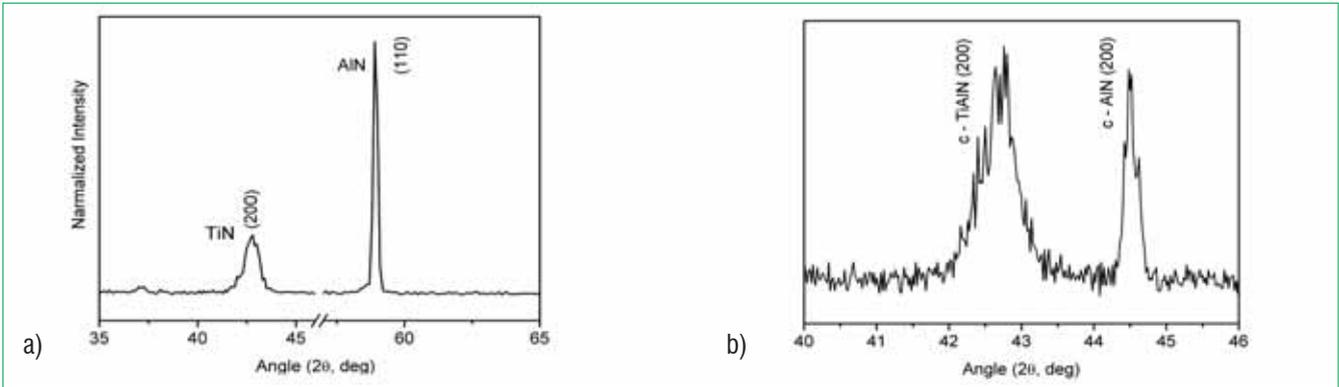


Figure 2: GIXRD profiles of $Ti_{1-x}Al_xN$ films annealed at 1073 K for four hours with aluminium concentrations of (a) 64% and (b) 81%

shown in Figure 2. $Ti_{1-x}Al_xN$ films of aluminium concentrations up to 55% annealed under the above mentioned condition did not exhibit any phase separation. The film with 64% aluminium decomposed into c-TiAlN and c-AlN whereas the amorphous one with 81% aluminium become crystalline with hexagonal AlN and c-TiN phases after annealing. The redistribution of aluminium atoms by titanium atoms is the cause of decomposition of the TiAlN phase at high temperature.

For understanding the structural properties in detail, films with 64 and 81% aluminium were deposited on carbon coated copper grids. Figure 3 shows the bright and dark field transmission electron micrographs of $Ti_{1-x}Al_xN$ films with 64 and 81% aluminium, respectively.

The corresponding selected area diffraction patterns (SADP) and the histograms of the particle size distributions as obtained by analysis of DF images are shown as insets. It is seen from Figure 3a that the TiN crystallites of size around 5 to 10 nm are embedded in an amorphous matrix, a typical characteristics of nano-crystalline thin films. On the other hand, it can be seen from Figure 3b, that the crystallite sizes of 81% aluminium film are smaller (~ 5 nm). The selected area diffraction patterns shows that the film is composed of polycrystalline AlN. Therefore, the 81% aluminium thin film can be visualised as a system in which 5 nm size AlN polycrystals are embedded in amorphous Ti-Al-N matrix. However, no AlN peaks could be

observed in the GIXRD pattern corresponding to this specimen owing to its low crystalline volume fraction.

Micro-Raman spectra of $Ti_{1-x}Al_xN$ thin films in the wave number range $150 - 1500\text{ cm}^{-1}$ are shown in Figure 4. The Raman peaks of TiN, observed at $206, 306$ and 558 cm^{-1} , arises from the first order transverse acoustic (TA), longitudinal acoustic (LA) and transverse optical (TO) modes. The changes in the Raman spectra are almost linear in the range of aluminium concentration from 0-55% whereas varied drastic from 64% of aluminium onwards. A hump is observed at 730 cm^{-1} starting from 40% of aluminium. With the increase in aluminium concentration the intensity of this hump increases and the hump shifts towards higher frequency. For 64% aluminium, Raman spectra consist of peaks corresponding to both TiN and hex-AlN. The observed peaks of TiN match with the profile of un-doped TiN. AlN exhibited two peaks, one at 514 cm^{-1} (TO) and another prominent one at 791 cm^{-1} (LO). This can be understood from the TEM result, which shows that the 64% aluminium thin film consists of amorphous matrix of AlN and TiN. Amorphous AlN signature can be clearly obtained by Raman spectra over GIXRD for the films with concentrations of aluminium above 40%. Further increase of aluminium to 81%, the peak corresponding to E1(LO) mode is shifted to 830 cm^{-1} , matching with E1(LO) peak of AlN. TEM analysis of this specimen substantiates this finding which shows a dispersion of AlN crystallites in 3-7 nm size range in the amorphous matrix.

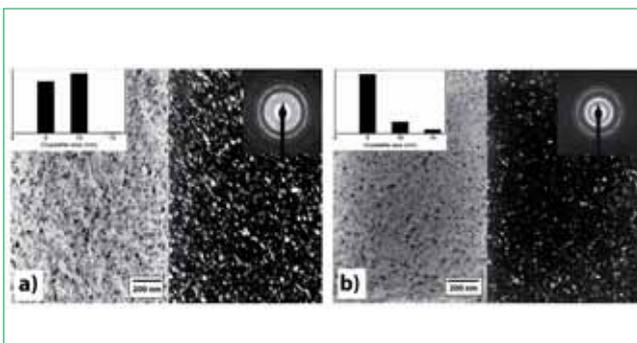


Figure 3: TEM micrographs (BF and DF) with crystallite size distribution histograms and SADPs of $Ti_{1-x}Al_xN$ films (a) 64% Al and (b) 81% Al

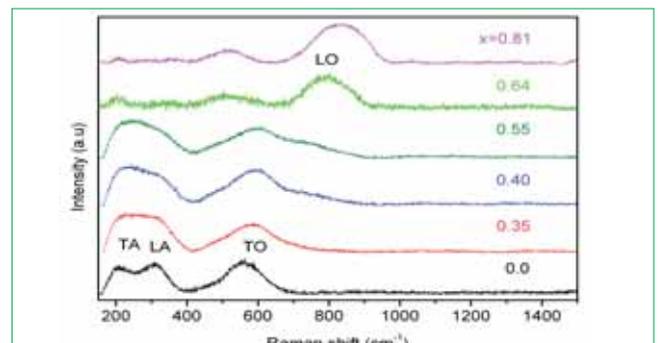


Figure 4: Raman Spectra of $Ti_{1-x}Al_xN$ films with increasing aluminium concentrations

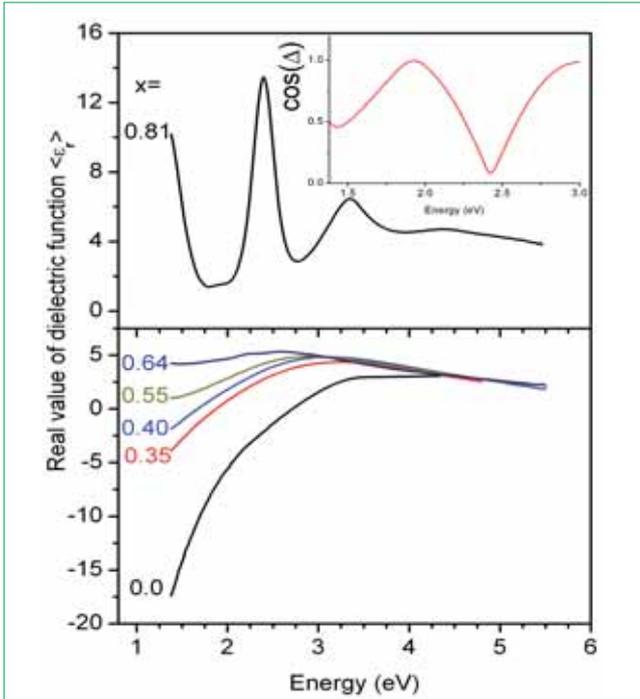


Figure 5: Variation of dielectric function with % of aluminium, (Inset) shows the variation $\cos(\Delta)$ with energy of the spectrum which clearly reveals the reduction in intensity with increase in energy

The real and imaginary parts of the dielectric functions for $Ti_{1-x}Al_xN$ were computed from the ellipsometric parameters and the real part of the dielectric function is shown in Figure 5. The $\langle \epsilon_r \rangle$ increases with increase in concentration of aluminium. The $\langle \epsilon_r \rangle$ for TiN is typical of metals and has a large negative value, typically -15 at 1.5 eV. The imaginary parts of the dielectric function are also typical of the Drude behavior. In this case, we see that the plasma frequencies for the 0, 35 and 40% of aluminium are 2.7, 1.87 and 1.67 eV, respectively. It is seen that the $\langle \epsilon_r \rangle$ increases with increase in aluminium concentration signifying a systematic reduction in the metallic character of these films. This is due to the addition of aluminium into the matrix and consequent formation of insulating AlN phase. In $Ti_{1-x}Al_xN$ films of aluminium concentration $> 50\%$ the material is predominantly insulating and hence the magnitude of $\langle \epsilon_r \rangle$ does not show any negative contribution. For films with $x=81\%$ of aluminium, the observed signature of interference fringes is mainly due to the insulating AlN phase. It is to be pointed out that the dielectric functions of all these films except that of $Ti_{0.19}Al_{0.81}N$ does not show any interference effects.

The surface morphology and roughness of $Ti_{1-x}Al_xN$ films were investigated using a atomic force microscopy (shown in Figure 6). In general, the grain size reduction is observed in atomic force microscopy images which substantiate the broadening of GIXRD peak with aluminium addition. The surface morphology of the pure TiN film is uniform with variation in the grain size and clustering of grains. Addition of aluminium to TiN has changed the topography and shape of these grains significantly. Roughness of these films decreased drastically from 4 to 2.5 nm with the addition of aluminium (35%) to TiN. Further increase in the aluminium concentration (55 and 64%) made the grain size uniform and the surface with homogenous features. The shape of the grains tends to become spherical in nature. The surface roughness of these samples did not change up to 64% aluminium, whereas with 81% aluminium, it decreased further to the lowest of all. The fine grain size and amorphous nature of these films are well supported by the GIXRD.

The hardness of the as-deposited and annealed $Ti_{1-x}Al_xN$ were measured by nanoindentation and variation of hardness of as-deposited and annealed specimens, with increasing aluminium concentration is depicted in Figure 7. The as-deposited and annealed specimens followed same trend. The maximum hardness values of 35 and 38 GPa was observed for the as deposited and annealed specimens, respectively. The increase in hardness is due to compressive residual stress developed in the film due to lattice contraction on partial replacement of titanium atoms by aluminium atoms of lower atomic radius. The cubic structure, compressive residual stress and the subsequent reduction in the grain size contributed to the increase in the hardness. At very high concentration of aluminium (81%), the crystal structure becomes hexagonal AlN, so the hardness decreases. In the annealed specimens, no phase change was observed and hardness was less when compared with the as-deposited ones up to 55% aluminium. This may be attributed to the defect annihilation in the films during high temperature annealing. At 64% aluminium, there is a co-existence of c-TiAlN and c-AlN phases. The cohesive stress produced by lattice parameter mismatch of these phases is responsible for the higher hardness than the as-deposited film. At 81% aluminium, the amorphous phase, decomposed into hexagonal-AlN and c-TiN while the hardness decreases and becomes nearly similar to hexagonal-AlN.

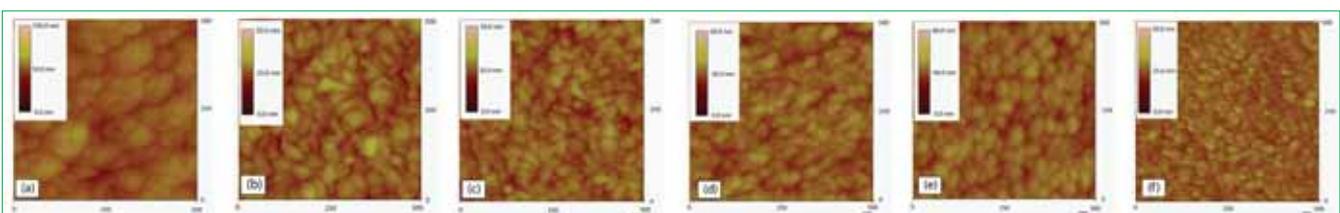


Figure 6: Surface topography $Ti_{1-x}Al_xN$ films at $x =$ a) 0.0, b) 0.35, c) 0.40, d) 0.55, e) 0.64, f) 0.81

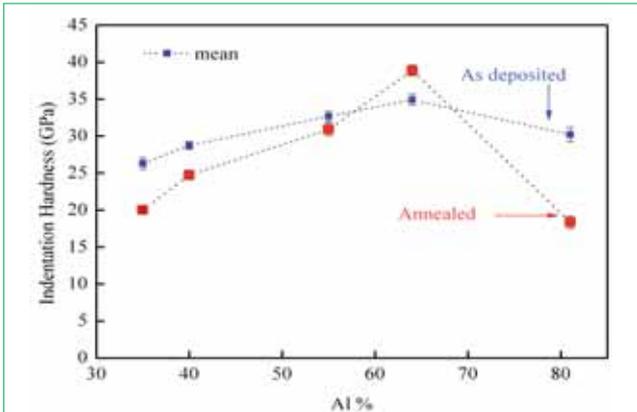


Figure 7: Hardness Versus concentrations aluminium of as-deposited and annealed $Ti_{1-x}Al_x$ films

The continuous multi-cycle (CMC) indentation studies were carried out on all these specimens up to film-substrate interface, to understand the crack formation and the interfacial strength existing between film and the substrate. In mode, the specimen is loaded to a specific value, then unloaded and immediately reloaded at the same place; a cyclic nanoindentation curve is generated.

The continuous multi-cycle profile and atomic force microscopy scan on the indented area of $Ti_{1-x}Al_x$ film with 64% aluminium alone discussed and it is shown in Figure 8. The hardness of $Ti_{1-x}Al_x$ films decrease slowly with depth of penetration as expected. The decrease in hardness with depth is due to substrate effect, formation of microcracks within the film and the indentation size effect associated with plastic deformation around the indenter. The existence of large compressive stress

in the film and the continuous plastic deformation are the main reason behind the formation of hysteresis loop observed in the repeated loading nanoindentation test. The slope of the reloading curve increases up to the previous load for all these films and are an indication of strain hardening.

In order to analyse the deformation process of the films during continuous multi-cycle loading, atomic force microscopy was used to scan the indentation contact zone. AFM topography of the indented zone of $Ti_{0.36}Al_{0.64}N$ film is shown in Figure 8. All these films, except film with 64% aluminium exhibited edge cracks for an applied load of 100 mN. The film with 64% aluminium did not exhibit any crack or delamination from the substrate for a maximum load of 100 mN. To understand the failure modes of the film, continuous multi-cycle tests were carried up to 200 and 300 mN. Their corresponding AFM topographies are shown in Figure 8c and d, respectively. It is clear that the formations of circumferential cracks are out side the indentation zone along with sink-in on the film. These circumferential cracks were initiated at the surface but associated with cracks running parallel to the substrate - film interface. Even though the indenter penetrated up to the substrate surface, there is no sign of radial crack formation and no abrupt spallation of the film. These circumferential cracks are attributed to nanoscale character of the layered structure and good adhesion of the films with the substrate. In spite of large difference between the hardness of substrate and the film, the indentation cracking of the film is basically circumferential which is different from the case of hard coatings which invariably depict radial cracking.

Summary

Metastable solid solution $Ti_{1-x}Al_xN$ thin films with varying aluminium concentration ($x=0.35, 0.40, 0.55, 0.64$ and 0.81) were synthesised using reactive DC/RF magnetron sputtering method. The as-deposited films were crystalline for concentrations of aluminium (35, 40, 55 and 64%) and amorphous at 81% aluminium. Grain size decreases with increased percentage of aluminium. The films annealed at 1073 K and found that the films with 64% aluminium decomposed into c-TiAlN and c-AlN, whereas films with Al 81% high density of crystallites with dimensions between 3-11 nm was dispersed in amorphous matrix for 64% aluminium films. These films show a change from metallic to insulating behavior with increase in aluminium concentration. The films become insulating for aluminium concentration for 81% aluminium. Hardness of $Ti_{1-x}Al_xN$ increases with the increase of aluminium content up to 64% (35 GPa) beyond which the hardness decreases (for 81%). Hardness of $Ti_{1-x}Al_xN$ with 64% aluminium increased to 38 GPa after annealing.

(Reported by Feby Jose,
Surface & Nanoscience Division, MSG)

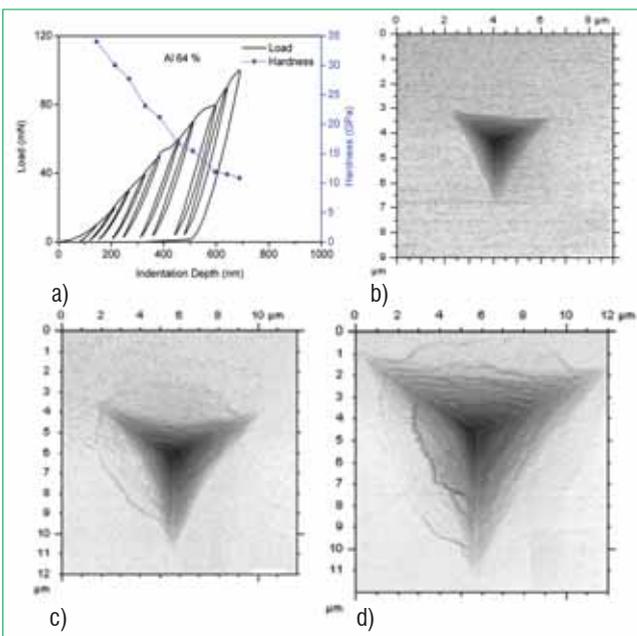


Figure 8: (a) Typical continuous multicycle load-displacement profiles of the $Ti_{0.36}Al_{0.64}N$ film for a load range of 10-100 mN. Atomic force microscopic topographies of the continuous multicycle indented area of $Ti_{1-x}Al_x$ ($x=0.64$) films loaded up to, (b) 100 mN (c) 200 mN and (d) 300 mN

Conference/Meeting Highlights

Theme Meeting on “Alloy Design”

March 11, 2011



Dr. Baldev Raj, Director, IGCAR while delivering his address, also seen are Prof. Markus O. Speidel, Swiss Materials Science Academy, Prof. Jacques Foct, Universit e Lille and Dr. U. Kamachi Mudali, Chairman, IIM-Kalpakkam Chapter & Head, CSTD seated on the dais

IGCAR and the Indian Institute of Metals, Kalpakkam Chapter organised a theme Meeting on “Alloy Design” on March 11, 2011 at IGCAR, Kalpakkam coinciding with the visit of two eminent professors to IGCAR, viz. Prof. Markus O. Speidel of Swiss Materials Science Academy, Switzerland and Prof. Jacques Foct of Universit e Lille, France. The theme meeting started with a welcome address by Dr. U. Kamachi Mudali, Chairman IIM- Kalpakkam Chapter & Head, CSTD who mentioned the necessity for organising such theme meetings. In his opening remarks, Dr. Baldev Raj, Distinguished Scientist and Director, IGCAR highlighted the need for designing suitable alloys which can withstand severe environments like high radiation field as in the case of FBRs or fusion reactors, and the elevated temperatures and pressures as anticipated in ultra supercritical power plants. He also emphasised the need to address global problems like climate change and green house effect when choosing materials for meeting the requirements.

The theme meeting consisted of three talks with the first talk delivered by Prof. M.O. Speidel who covered at length various aspects of alloy design at length in terms of his experiences with nitrogen added steels. Prof. J. Foct introduced the audience about the basic mechanisms behind designing interstitial alloys, functionally gradient alloys, thermodynamically forbidden alloys etc. and highlighted a few in terms of their unique properties and low cost, refractoriness etc. The third lecture was delivered by Dr. M. Vijayalakshmi, Head, Physical Metallurgy Division, MMG who discussed about the alloy design for avoiding sensitisation of stainless steel, preparing dissimilar weld joints without soft zones through suitable filler materials etc. Dr. P. Parameswaran, Convener of the meeting proposed the vote of thanks. The meeting was well attended by the scientific community at Kalpakkam with good interaction and wide ranging discussions.

(Reported by U. Kamachi Mudali, CSTG,MMG)

16th International Workshop on Electromagnetic Non-destructive Evaluation (ENDE-2011)

March 10-12, 2011



Dr. Baldev Raj, Director, IGCAR releasing the souvenir of ENDE-2011 workshop during the inaugural function held on March 10, 2011 Prof. M.S. Ananth (second left), Prof. Fumio Kojima, Prof. Krishnan Balasubramaniam and Dr. B. P. C. Rao at the inauguration

Indira Gandhi Centre for Atomic Research, Kalpakkam and Indian Institute of Technology Madras, Chennai jointly organised the 16th International Workshop on Electromagnetic Non-destructive Evaluation (ENDE-2011) during March 10-12, 2011 at IC&SR Auditorium, IIT Madras, Chennai. One hundred and fifty delegates from fifteen countries took part in the workshop, organised for the first time in India. The objective of ENDE-2011 is to bring together the scientists and engineers to discuss the recent advances in electromagnetic NDE techniques including eddy currents, magnetic flux leakage, micro-magnetics, Barkhausen emission, potential drop and microwave, by giving

Conference/Meeting Highlights

special emphasis to innovative applications, modeling, novel sensors, signal & image processing techniques, material characterisation, quality assurance, in-service inspection and automation. The workshop was inaugurated by Dr. Baldev Raj, Director, IGCAR. During the inaugural address, Dr. Baldev Raj recalled how a variety of electromagnetic nondestructive evaluation techniques were developed for the Indian nuclear power programme and highlighted the future role to be played by these techniques for enhanced quality and safety of engineering components through early detection of defects and microstructure degradations. Prof. Fumio Kojima, Chairman, ENDE Standing Committee, Kobe University, Japan gave a brief account of the ENDE workshop series. Dr. B.P.C. Rao, Convener, ENDE-2011 and Head, Electromagnetic Modelling Sensors & Imaging Section, NDED, MMG, IGCAR gave the details of the structure of the technical sessions of ENDE-2011.

(Reported by B. P. C. Rao, Convener, ENDE-2011)

Theme Meeting on “Advances in Electronics, Instrumentation and Information Technology”

March 24, 2011



Dr. P. Swaminathan, Director, EIG delivering the address during the theme meeting. Shri S.C. Chetal, Director, REG, Shri S.A.V. Satya Murty, AD, EIG and Dr. M. Sai Baba, Head SIRD are seated on the dais

A Theme Meeting on “Advances in Electronics, Instrumentation and Information Technology” was organised by Electronics and Instrumentation Group, IGCAR on March 24, 2011 at Sarabhai Auditorium. Shri S.A.V. Satya Murty, Associate Director, EIG welcomed the participants and gave the genesis of the theme meeting. Shri S. C. Chetal, Director, REG, delivered the inaugural address with an appreciation for progresses made in Instrumentation and Control Systems for PFBR compared to FBTR. He highlighted the use of advanced electronics towards enhanced reliability and safety of the reactor and simulator for operator training. He also stressed the importance of conducting a thorough and independent verification and validation of I&C systems before implementation in the plant. He emphasised the need for R&D efforts towards the improved control room configuration and layout for better information management and avoid operator overload. Dr. P. Swaminathan, Director, EIG presented the reminiscences of his experiences in the Centre. Dr. M. Sai Baba, Head, SIRD, proposed the vote of thanks. Invited lectures were delivered by the system experts in each field covering, various topics - Security concerns in Wireless Sensor Networking, R&D activities of Real Time Systems Division and open platform for leveraging collective wisdom, Good Practices for Grounding of instrumentation and control systems, Design experiences of instrumentation and control for PFBR, Digital Library at IGCAR, Vital signs of Identity –Radio Frequency Identification and Biometrics, Challenges in neutronics instrumentation, Evolution of real time computers for reactor control and Development of Time domain electromagnetic system for exploration of Conductive deposits. About 200 officers of IGCAR working in the field of Electronics, Instrumentation & Control systems and Information Technology attended the theme meeting. The technical talks were very informative and were well received. The theme meeting was followed by a felicitation function to Dr. P. Swaminathan, Director, EIG.

(Reported by S.A.V. Satya Murty, EIG)

News & Events

IGCAR Transfers Flux based TIG Process to Industry



Dr. Baldev Raj, Director, IGCAR, Shri Raman Kumar, Managing Director and Shri R. Ravi, M/s. ADOR Welding Ltd. and Dr. U. Kamachi Mudali, Head, Technology Transfer Cell during the signing of MOU with M/s. ADOR Welding Ltd.

Indira Gandhi Centre for Atomic Research, Kalpakkam has entered into a memorandum of agreement with M/s. ADOR Welding Limited, Mumbai for the transfer of an international patented process “Penetration Enhancing Activated Flux for TIG Welding of Austenitic Stainless Steels”.

Activated Tungsten Inert Gas process involves the development of formulation and technology for using a specially designed flux that can enhance the penetration, depth and quality of austenitic stainless steel welds. The flux thus developed can be used for deep penetration welding of Stainless Steel plates of 10 mm thickness for one meter length with one gram of the flux. The process was demonstrated to the industry for transferring to the same for a period of three years on a non-exclusive basis.

In an exclusive function at IGCAR, the memorandum of agreement between IGCAR and M/s. ADOR Welding Ltd., Mumbai was signed by Dr. Baldev Raj, Director, IGCAR and Shri Raman Kumar, Managing Director, M/s. ADOR Welding Ltd. for the transfer of Activated Flux based TIG Process. During the occasion Dr. Baldev Raj, Director IGCAR addressed the importance of technology transfer and explained how this would enhance the strength of Indian industry with indigenous technologies. He also explained the importance of pooling the technological resources in the country and effectively utilising the same for demanding applications. Shri Raman Kumar thanked IGCAR for providing valuable technologies for the benefit of Indian industry and assured the utilisation of the technology transferred.

(Reported by U. Kamachi Mudali, Technology Transfer Cell)

Visit of Dignitaries



Dr. Yukiya Amano, Director-General, IAEA with Mr. Rafael Crossi, Chief De Cabinet, IAEA with Dr. Baldev Raj, Director, IGCAR and other senior colleagues of the Centre and the Department

Dr. Yukiya Amano, Director-General, Mr. Rafael Crossi, Chief De Cabinet and Mr. S. Akbaruddin, Director, Office of the external relations and policy creation, IAEA visited the Centre on January 18, 2011. After meeting the Director and the members of DAC, they visited Fast Breeder Test Reactor, Hot Cells and Non-Destructive Evaluation Division, Sodium Fire Facility in Nuclear and Safety Engineering Group, Atmospheric Aerosol Dispersion Facility in Reactor Engineering Group, Magnetoencephalography studies laboratory at Materials Science Group, Safety Research Institute of Atomic Energy Regulatory Board and construction site of PFBR.

Visit of Dignitaries



Dr. C.V. Krishnaswami delivering the Vikram Sarabhai Memorial Lecture

Dr. C.V. Krishnaswami, Honorary Consultant and Head of the Diabetes Department, Voluntary Health Services, Chennai, (Formerly) Honorary Clinical Professor & Honorary Physician, Government Stanley Hospital, Chennai, Chairman, Healthtrack Info Solutions Private Limited, Chennai visited the Centre during February 11-12, 2011 along with his wife, Dr. (Mrs.) Prema Krishnaswami, renowned Obstetrician and Gynaecologist, Chennai to deliver the 7th Vikram Sarabhai Memorial Lecture on the topic, "Medical Education and Research in Independent India". Dr. Krishnaswami visited the Fast Breeder Test Reactor, Magnetoencephalography studies laboratory at Materials Science Group and construction site of PFBR. The dignitaries also interacted with the medical fraternity and the students from the schools at Kalpakkam.



Delegation from Idaho National Laboratory led by Mr. John Grossenbacher with Dr. Baldev Raj, Director, IGCAR and other senior colleagues of the Centre

A delegation from Idaho National Laboratory, USA led by its Director, Mr. John Grossenbacher, along with Dr. Harold McFarlane, Deputy Associate Laboratory, Director and Technical Director of Generation-IV International Forum, Dr. Satish Kulkarni, INL Consultant and Dr. Hamilton Maxwell Janek, Political/Economic Officer, American Consulate, Chennai visited the Centre on February 16, 2011. After a meeting with Dr. Baldev Raj, Director, IGCAR and a meeting with the DAC members. The team visited Fast Breeder Test Reactor, Large Component test facility and Steam Generator Test facility facilities at Fast Reactor Technology Group, Magnetoencephalography studies laboratory at Materials Science Group, Sodium fire test facility at Nuclear and Safety Engineering and the construction site of PFBR at BHAVINI.

Visit of Dignitaries



Team from Institute of Defence Studies and Analyses and Indian Pugwash Society, led by its convenor, Dr. Arvind Gupta with Shri S.C. Chetal, Director, REG and senior colleagues of the Centre

A team from Institute of Defence Studies and Analyses and Indian Pugwash Society, led by its convenor, Dr. Arvind Gupta, Additional Secretary, Ministry of External Affairs & Lal Bahadur Shastri Chair, Institute of Defence Studies and Analyses along with Mrs. Purnima Gupta, Economic Advisor, Tariffs Commission, Government of India, Prof. K.D. Kapur, Consultant, Indian Pugwash Society, Dr. Ch.V. Sastry, Research Fellow, Institute of Defence Studies and Analyses, Shri P.K. Sundaram, Senior Research Fellow, Indian Pugwash Society and Shri Kapil Patil, Intern, Indian Pugwash Society visited the Centre during February 25-26, 2011. The team had discussions with Dr. Baldev Raj, Director, IGCAR and DAC members and visited Fast Breeder Test Reactor, Hot Cells and Non-destructive Evaluation Division, Development of sodium testing of components and magnetic bearings with ferrofluid seals in the Fast Reactor Technology Group, Sodium Fire Facility in Nuclear and Safety Engineering Group, Aerosol and Atmospheric Dispersion studies at Reactor Engineering Group and the construction site of PFBR at BHAVINI.



Delegation from Engineering and Physical Sciences Research Council, UK with Shri S.C. Chetal, Director, REG and other senior colleagues of the Centre

A delegation from the Engineering and Physical Sciences Research Council, UK under the leadership of Dr. Jason Green, visited the Centre on March 8, 2011. The delegation held discussions with senior colleagues of the Centre on possible avenues of collaboration. The team later visited Fast Breeder Test Reactor, Accelerator studies facility at Materials Science Group, Facilities for newer welding methodologies at the Metallurgy and Materials Group and the construction site of PFBR at BHAVINI.

Forthcoming Meeting / Conference



6th International Conference on Creep, Fatigue and Creep-Fatigue Interaction (CF-6)

January 22-25, 2012



IGCAR is organising the 6th International Conference on Creep, Fatigue and Creep-Fatigue Interaction (CF-6) during January 22-25, 2012. The conference provides a forum for interaction among scientists and engineers from national and international research institutions, industry and academic institutions working in the areas of creep, fatigue, creep fatigue interaction, materials development, high temperature design and modeling. Delegates consisting of experts, research scientists, academicians, design engineers and research students from India and abroad are expected to participate in this conference. CF-6 is being organised jointly with the Metal Sciences Division and Kalpakkam Chapter of The Indian Institute of Metals. The conference is being sponsored by the Board of Research in Nuclear Sciences, Department of Atomic Energy, India and co-sponsored by The Japan Society of Mechanical Engineers.

Following are the broad areas included in the scope of the conference:

- Creep deformation and damage
- Low cycle fatigue and creep-fatigue interaction
- Creep and fatigue behaviour of welds
- Thermo-mechanical fatigue
- High cycle fatigue
- Fretting fatigue
- Component testing and multi-axial fatigue
- Innovations in mechanical testing
- Structural integrity and remaining life assessment
- Damage assessment using NDE techniques
- Environmental effects
- Irradiation effects on mechanical properties
- Design codes and standards
- Damage mechanics
- Multi-scale modeling
- Creep and fatigue of nanostructured materials
- Creep and fatigue crack growth behaviour of metals
- Fast reactor and advanced nuclear reactor materials
- Oxide dispersion strengthened materials
- Materials for fusion reactors
- Advanced materials for ultra super critical power plants

Deadline for submission of abstracts: July 31, 2011

Address for Correspondence

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Awards & Honours

Dr. Baldev Raj, Director, IGCAR shall deliver Prof. N.P. Gandhi Memorial Lecture, organised by Indian Institute of Metals (2011).

He is the receipt of Indian National Science Academy Prize for Materials Science, from Indian National Science Academy (2010), for his contributions to nuclear materials, technologies, cultural heritage and mentoring of generations of students and colleagues.

He shall deliver the Portevin Lecture of International Institute of Welding (2011) for his contributions valued for sustained excellence in welding science and technology.

He has been awarded 16th M.N. Saha Memorial Lecture Award, from Indian Science New Association, Kolkata (2011).

He has been honoured with 6th Raja Ramanna Memorial Lecture award by VECC, Kolkata during June 2011.

He shall deliver the First Annual Materials Lecture of International Centre for Materials Science in June 2011.

He has been elected:

- Member of the Tamil Nadu State Council for Science & Technology (2010-2013)
- Honorary Member of the Association of Scientists, Developers and Facilities (2011)
- Honorary Professor of Sichuan University, Chengdu, China
- Member, Editorial Board, Nano Trends

Dr. P. R. Vasudeva Rao, Director, Chemistry Group, was selected for award of silver medal by the Chemical Research Society of India in 2011.

Dr. P. R. Vasudeva Rao, Director, Chemistry Group, was awarded the MRSI-ICSC Superconductivity and Materials Science Senior Award-2011 by Materials Research Society of India.

Dr. B.V.R. Tata, CMPD, MSG has been recognised as "ERUDITE Visiting Professor" at the School of Chemical Sciences, Mahatma Gandhi University, Kottayam, Kerala.

Shri J. Daniel Chellappa, TC&PAS, ROMG has been elected the Honorary President of the 'Federation of Science Clubs of Tamil Nadu (FSCT)' and Honorary Secretary of the 'Public Sector PR Forum, Tamil Nadu (PSPR Forum-TN)' for a period of three years (2011-13).

Shri M. R. Rajesh Kannan, Research Scholar, MSG has been awarded a gold medal for securing 1st rank in M. Tech, in Laser Electro Optical Engineering from Anna University, Chennai.