



IGC Newsletter

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of Dr. P. R. Vasudeva Rao, Director, IGCAR

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Temperature / K vs Time / seconds

RAFM Steel
1273 K / 15 minutes

γ - austenite
α^{*} - martensite

99 K min⁻¹, 50 K min⁻¹, 10 K min⁻¹, 3 K min⁻¹, 1 K min⁻¹

Ac₁, Ac₃, M_s, M_f

Role

Administration, Accounts, Organisation Structure, Purchase, Data, Stores, Employees, Workflow

Chemical Reaction Scheme:

$C_{12}H_{26}$ Dodecane + HNO_3 , HNO_2 , H_2O → $R-C_6H_{13}O$, $C_6H_{13}O$, $C_6H_{13}O$

$(C_4H_9O)_3P=O$ TBP + H^+ → $(C_4H_9O)_2PO(OH)$ HDBP, $C_4H_9OPO(OH)_2$ H₂MBP, $H_3PO_4 + C_4H_9OH$

Primary degradation products of diluents: R_1COR_2 , $R-NO_2$, $R-ONO_2$

Secondary degradation products: $R-C_6H_{13}O$, $C_6H_{13}O$, $C_6H_{13}O$, Lauryl Butylphosphate, $R-COOH$, Lauric acid

Primary degradation products of solvents: $(C_4H_9O)_2PO(OH)$ HDBP, $C_4H_9OPO(OH)_2$ H₂MBP, $H_3PO_4 + C_4H_9OH$

Iron Oxide Nanoparticles: Soluble Cage, Type III, Type I, Type II, Separex

From the Editor

Dear Reader

At the outset, I am extremely happy to wish you a very happy and prosperous New Year - 2015 on behalf of the editorial team. It is my pleasant privilege to forward a copy of the latest issue of IGC Newsletter (Volume 103, January 2015 Issue).

We are happy to include the new year message of Dr. P. R. Vasudeva Rao, Director, IGCAR to the colleagues of our Centre.

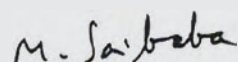
In the first technical article Dr. Raju and colleagues have studied the thermo-kinetic properties, developed modelling and alloy design methodologies with RAFM steel. Shri Narendra Kumar Kushwaha and colleagues share their excitement of development and implementation of payroll package as a part of workflow management system in IGCAR, in the second article. This issue's young officer's forum features an article by Shri Ambuj Kumar Singh on vapour liquid equilibrium studies on tributyl phosphate. Dr. Loushambam Herojit is happy to present his results on stability of iron oxide nanoparticles using Mossbauer spectroscopy.

This Newsletter carries reports on CONCEPT-2014, DAE-CEA meeting and a brief write up about the activities planned at IGCAR to commemorate the Diamond Jubilee of the Department.

We had distinguished visitors to our Centre in the last quarter including, Dr. Anumakonda Jegadeesh, Shri N. Saibaba, Prof. Gautam R. Desiraju, Prof. S. Ranganathan, Dr. H. R. Nagendra and Shri G. Nageswara Rao sharing their thoughts with our colleagues on various occasions.

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,



(M. Sai Baba)

Chairman, Editorial Committee, IGC Newsletter

&

Associate Director, Resources Management Group

New Year Message

My dear colleagues,

It gives me a great pleasure to wish you and your families a happy, healthy and prosperous New Year 2015, full of successes.

As we enter into the New Year, we can look back on last year with a sense of fulfilment and satisfaction, having achieved many milestones and made considerable progress in various facets of fast reactor science and technology.

The Fast Breeder Test Reactor (FBTR) has continued to play an important and critical role as a test bed for various materials including fuels. Today, we can be proud of the fact that the reactor core has three different types of fuels - U,Pu mixed carbide, U,Pu mixed oxide and sodium bonded U-Pu-Zr metal alloy fuels, representing in a way, the past, the present and the future of the fast reactor programme. The irradiation of sphere-pac mixed oxide fuel pins has been completed, and the Post-Irradiation Examination (PIE) of this fuel is in progress. We are also gearing for the PIE of the metal alloy fuel pins. The information that we obtain from these PIE activities would provide us important inputs for developing future fast reactor fuels.

The Prototype Fast Breeder Reactor (PFBR) has made significant progress during the last one year, and is now in the final phase of construction and commissioning. The fabrication of fuel for PFBR has also been continuing in a smooth manner, and we are all keenly looking forward to the attainment of criticality of PFBR in the coming year. IGCAR would continue to play a key role in resolving any technical issues that may be faced during the commissioning and the operation phases of PFBR.

During the year, we have paid significant attention to the conceptual design of FBR-1&2 along with detailed



Dr. P.R. Vasudeva Rao, Director, IGCAR

design of the reactor assembly. Several optimisation studies have been carried out, towards enhancing the safety of the reactor, and improvement in its breeding capability, besides reducing materials consumption and time of construction. This approach has resulted in the conceptual design of the reactor system that would produce 600 MWe, with a breeding ratio in the range of 1.2 and sodium void coefficient < 1 . The design approach is being subjected to peer review, to make it robust and finalise the options. Meanwhile, parallel action is also being taken for manufacture of the model reactor assembly.

CORAL, the pilot plant facility for reprocessing the FBTR fuel, has continued to perform satisfactorily, and the reprocessing of short cooled carbide fuel during the year has enhanced our confidence in the flow sheet as well as equipment. The construction activities at the Fast Reactor Fuel Cycle Facility (FRFCF) have gathered momentum, and in the coming year, we can hope to start construction of the plant buildings.

The Centre has continued to make a mark in various domains of R&D related to fast reactors and associated

fuel cycle. In addition, we have continued to contribute to several national mission programmes such as the space missions, fusion programme, and the programme on setting up an advanced ultrasupercritical thermal power plant as a part of the national mission on clean coal technologies. A number of experimental facilities have been established or commissioned during the current year at our Centre, the notable being the 100 tonne shake table, a unique national facility that would contribute to seismic evaluation of components and systems for various programmes. To ensure that our R&D efforts continue to keep us in the forefront of different disciplines, the exercise of peer review of the Centre's programmes has been continued, and during the year, we had the review of the programmes in the area of sodium technology.

On the human resources front, I am pleased to note that we are continuing to attract bright young students for our training school as well as for doctoral studies under the aegis of Homi Bhabha National Institute (HBNI). I am happy that 55 students have so far obtained their Ph.D degree from HBNI at Kalpakkam. As many as 279 students (employees as well as research fellows) are currently pursuing their research at IGCAR in diverse areas of physical, chemical and engineering sciences. Further, about 170 students belonging to eminent institutions have also come to our Centre in the last one year to carry out their project work. With regular addition of young talent through the BARC training school and the presence of around 125 research scholars, the vibrancy of the research atmosphere is being sustained. As part of our efforts to meet the aspirations of the young officers and motivate them to pursue their challenges with greater enthusiasm, we have formed mentoring committees in each group, and also carried out a mentoring exercise to obtain feedback from the officers on important issues at the Centre level. This mechanism has provided valuable inputs towards improving facilities and the research ambience at the Centre.

This year is an important year in the history of the Department of Atomic Energy - it has completed 60 years and we take pride in its achievements over the years and rededicate ourselves to the task of enhancing the energy security of the country by providing sustainable and economical nuclear energy through fast reactors. The Large Component Test Rig at our Centre has also crossed twenty years of successful and safe operation, and the brief programme that we organised to mark the occasion brought out the important role that it would continue to play in development of fast reactor technology.

The IGC colloquium continues to be an important facet of our human resource development, and professional bodies in the Centre are also contributing by way of organising programmes that highlight important and emerging domains in science and technology and provide fora for information exchange and interactions. In the current year, as part of the celebration of the diamond jubilee year of DAE and the International year of Crystallography, we had several reputed scientists giving lectures on a variety of topics that were inspiring and motivating.

Our Centre continues to attract a large number of visitors every year. This year, a total of around 1000 visitors, comprising students, professors and public had visited our Centre. It is acknowledged by all such visitors as well as the peers and senior colleagues that our Centre has done exceedingly well in the science, engineering and technology programmes. We have to match this with an equivalent level of excellence with respect to several other domains such as administration and accounts, safety and security, water and energy conservation, etc. We need the active participation and co-operation of all our colleagues in achieving a high level of excellence with respect to cleanliness as well as garbage, waste and scrap disposal, especially in the context of the Swatch Bharat Abhiyaan.

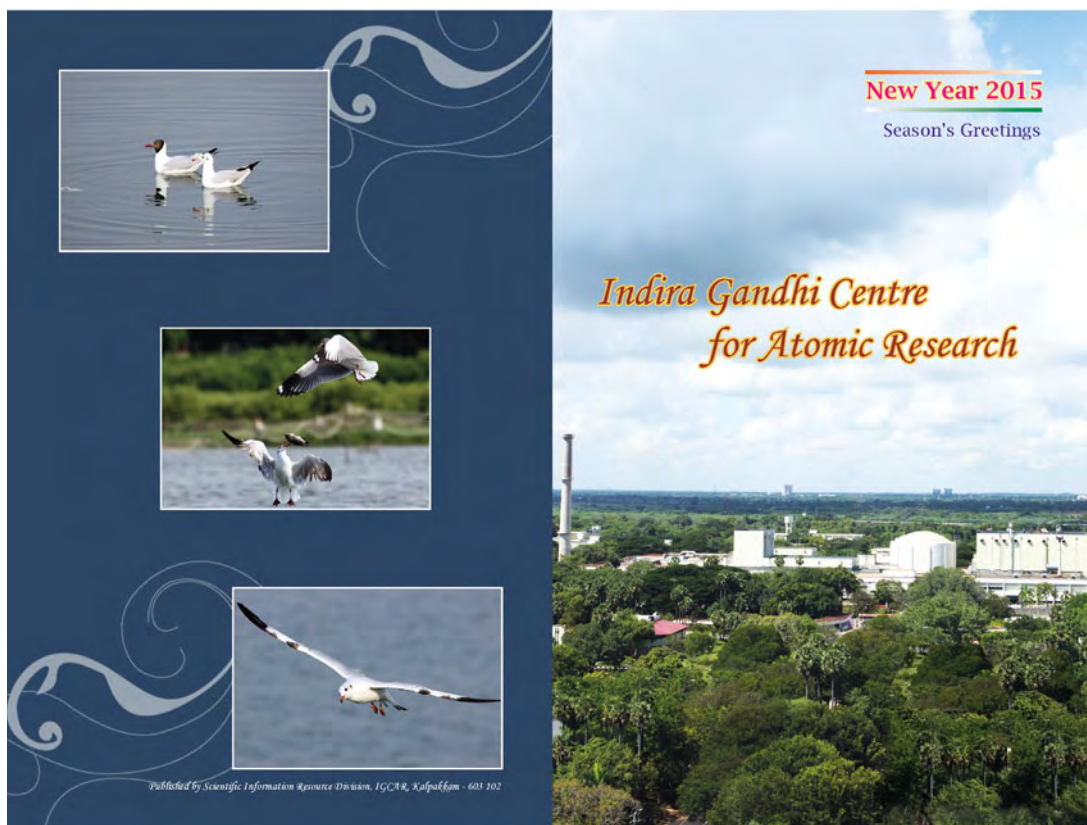
India is one of the few countries engaged in a sustained programme on fast reactors with closed fuel cycle, and one of the very few that have operating fast reactors. We have a huge opportunity to achieve and sustain leadership in this important technology. However, the road map for establishing a large fast reactor programme is indeed full of challenges. The first goal, of course, is to establish that fast reactors and the fuel cycle facilities can be built indigenously as well as operated with high availability and at the name plate capacity, and in a safe and economical manner. Our future goal of realising metal alloy fuelled FBRs as the base of the fast reactor programme needs attention to domains of technologies such as pyrochemical reprocessing and remote refabrication, which have not been achieved on a commercial scale by any country. However, our Centre is a unique organisation, with focussed and mission-oriented approach, and the quality of our work,

the comprehensive range of facilities, and above all, the commitment and enthusiasm of our colleagues and our readiness to take up challenging assignments, have always received good appreciation from visitors and peers. I am therefore, sure that we are capable of achieving great heights in this national mission of fast reactor development with closed fuel cycle. I look forward to your collective, sustained efforts in this important national endeavour.

With my best wishes once again for a prosperous, healthy and successful New Year 2015.

(P. R. Vasudeva Rao)
Director, IGCAR

"New Year message for Colleagues at IGCAR"



"Wish you and your family bliss, health and successes during the year 2015"

Thermokinetic Measurements, Modelling and Alloy Design: A Case Study on Reduced Activation Ferritic Martensitic (RAFM) Steel

Alloy Design for strategic purposes, such as for applications in fission and fusion reactors is a complex and challenging task. It begins with a comprehensive understanding of typical operating conditions of the reactor such as temperature, pressure, irradiation level, designed loading conditions, anticipated in-pile life time and possible failure modes. As against these design based stipulations, one needs reliable information on various physical, chemical and mechanical property requirements of various probable materials that are likely to fulfill these design based requirements. Besides, the amenability to indigenize the material development, component fabrication and inspection chain are also important in bringing in cost economy of the overall project. In the case of nuclear power generation, the issues encountered at the back-end of fuel cycle or during reprocessing of materials are also of paramount importance in influencing the material selection. Therefore, nuclear material's design depends on the ready availability of highly matured database(s) of various kinds. It is in this perspective, that this article explores the role of thermokinetic experimental measurements and related modelling based research on the development of Reduced Activation Ferritic Martensitic (RAFM) steels, targeted for possible application in the plasma facing first wall components of thermonuclear fusion reactor. It may be added that although thermal stability data are important; it constitutes only a part of integrated materials design database.

Reduced Activation Ferritic-Martensitic (RAFM) Steels

Ferritic-Martensitic (F-M) steels based on 9 wt.% Cr variety, such as P9, P91, P92 grades are generally characterized by good high temperature creep strength, low thermal expansion, high thermal conductivity and good welding characteristics. In addition, the bcc based α -ferrite matrix of standard tempered F-M steels possesses higher neutron swell resistance than austenitic stainless steels. However, in the case of fusion reactor applications, the conventional grades of F-M steels cannot be directly employed owing to the high level of induced radioactivity arising from elements like, Mo, Nb, Mn, Co, Cu, B, N, Al, etc. In order to circumvent this problem, it is therefore necessary to replace some of the major alloying additions of conventional F-M steels with functionally equivalent, yet minimally radioactive substitutes. Thus, W, Ta and V are identified as potential substitutes for Mo and Nb. Elements like Cu, Co, Al, Mn, N, B, S, P are in any case to be avoided or minimized in a nuclear grade F-M steel. Thus, in the case of RAFM steels, by going in for highly pure starting feed and further by adopting vacuum arc secondary remelting process, a tighter control on stray element concentration is also ensured in the final melt. In summary, the composition of RAFM steel is a carefully engineered one, so that the resulting material retains all the desirable attributes of conventional F-M steels, in

addition to possessing a low or reduced radiological hazard.

From the metallurgical point of view, it is possible to engineer the microstructure of conventional F-M or RAFM steels by adopting controlled thermomechanical processing, in order to achieve desirable combination of strength and fracture toughness. However, the microstructure engineering of F-M steels is a non-trivial task, as it calls for the precise understanding of thermodynamic and kinetic issues of various phase transformations that are inherent to any F-M steel. Some of these phase changes are as follows:

- (i) $L \rightarrow L + \delta\text{-ferrite} \rightarrow L + \delta + \gamma \rightarrow \gamma + \delta \rightarrow \gamma \rightarrow \gamma + \text{MX}$;
during ingot solidification
- (ii) $\alpha\text{-ferrite} + \text{M}_{23}\text{C}_6 + \text{MX carbides} \rightarrow \gamma\text{-austenite}$;
during solution treatment
- (iii) $\gamma\text{-austenite} \rightarrow \alpha'\text{-martensite}$ upon normalizing (air cooling)
- (iv) $\alpha'\text{-martensite} \rightarrow \alpha\text{-ferrite} + \text{carbides}$,
during subsequent tempering etc.

For a RAFM steel, the temperature regime at which the above mentioned phase transformations take place as well as their kinetics are decided by both composition and thermal history, namely, heating or cooling rates, holding time and presence or absence of applied stress. The knowledge of these thermokinetic parameters, as a function of steel composition is therefore of utmost importance in arriving at the optimal design of RAFM steels. Such data are readily obtained by high temperature calorimetry measurements, the results of which can be supplemented by phase equilibria modelling. In the following section, a typical illustrative account of high temperature scanning calorimetry measurements done on Fe-9Cr-1W-0.06Ta-0.08C (wt.%) RAFM steel is provided.

High Temperature Calorimetry Measurements

Figure 1(a) presents the on-heating differential scanning calorimetry (DSC) thermogram obtained on a RAFM steel with the following composition: Fe-9.04Cr-1W-0.06Ta-0.22V-0.08C-0.022N-0.0057O-0.02P (all in wt.%). The region around melting is expanded to reveal several high temperature phase transformations taking place prior to melting. It is important to note that the full dissolution of MX type Ta(C,N) precipitate in γ -austenite matrix occurs only around 1600 K, presumably due to kinetic considerations. Further, in W/Ta containing RAFM steel, the complete dissolution of $(\text{Fe}_{1-x-y}\text{Cr}_x\text{W}_y)_{23}\text{C}_6$ type cubic carbides also needs a high solution temperature, of the order of 1473 K. This is in striking contrast to the industrial practice, wherein a solution treatment temperature of about 1253K is recommended, so that some undissolved M_{23}C_6 and full quota of MX precipitates would be retained. This is necessary to stabilize the growth of austenite grains in single phase

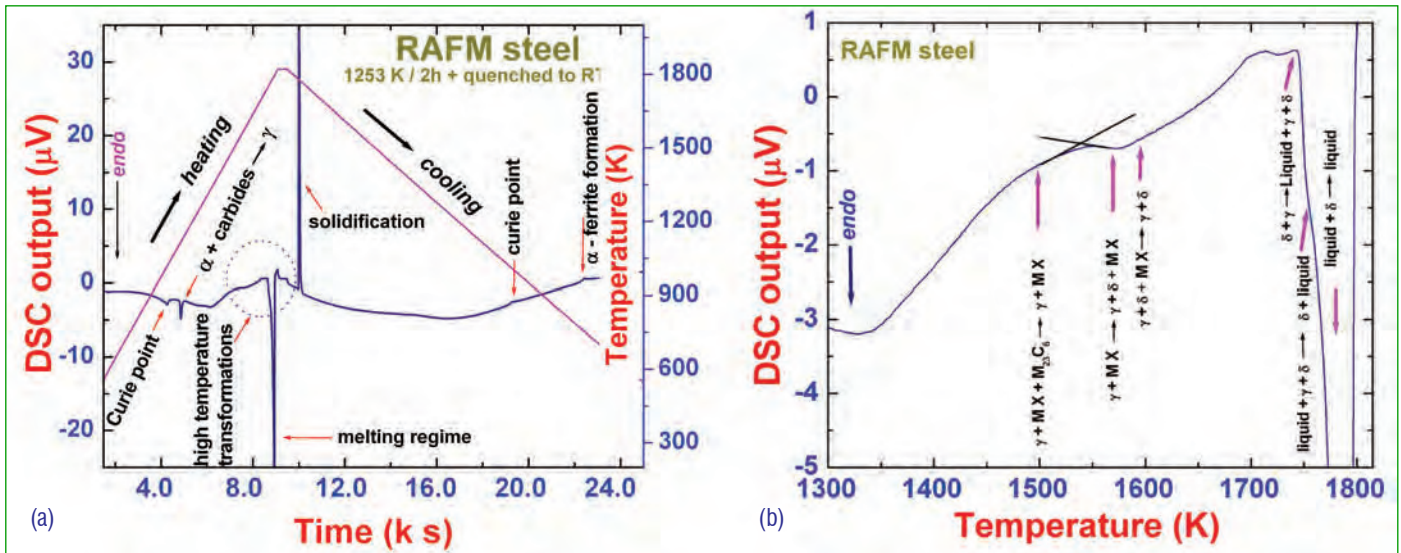


Figure 1: (a) On-heating/cooling DSC thermogram of Fe-9Cr-1W-0.06Ta-0.08C RAFM steel; (b) expanded portion shown around the melting region.

γ -austenite domain. More importantly, the calorimetry experiments indicate that $L+\gamma$ -austenite+ δ -ferrite, three phase equilibrium is actually possible in RAFM steel. This suggests that there is a strong propensity of segregation of W and Ta to δ -ferrite phase even at high temperatures, which would eventually cause retention of some δ -ferrite phase under the conditions of fast cooling, which is encountered in case of welding. Since high temperature calorimetry measurements are quite time consuming to be performed over a large number of RAFM compositions, it is desirable to carry out phase equilibrium simulations and compare the results with actual experimental data. However, in doing so, one has to keep in mind

that thermodynamic calculations are performed assuming full equilibrium, while the same would be difficult to be realized under practical conditions.

Thermodynamic Simulation

In Figure 2, a typical ThermoCalc based equilibrium phase distribution simulation as a function of temperature and carbon content is depicted for Fe-9Cr-1W-0.06Ta RAFM steel. It may be seen that for a carbon composition of around 0.1 wt.%, the observed phase stability sequence in calorimetry is in full qualitative accord with what is expected on thermodynamic grounds. However, phases like Z ($FeCr, Nb$)₂N and Laves $Fe_2(Ta,W)$ are not normally observed during the course of normal cooling from liquid state. In fact their formation requires prolonged aging, besides the presence of stress, as encountered in service. Nevertheless, their dissolution temperatures can be measured by calorimetry, if long term aged or service-seen samples are experimented; or equivalently, a very slow cooling rate like 0.01 K min⁻¹ may be adopted to precipitate these low volume fraction phases. Similar thermodynamic calculations can be performed for a range of W and Ta concentration keeping carbon content fixed at 0.1 wt.% nominal. Such simulations yield valuable data on: A_{c1} (austenite formation start), A_{c3} (austenite completion), $T_{d,MX}$ (dissolution temperature of MX), $T_{d,M_{23}C_6}$ (dissolution temperature of $M_{23}C_6$), liquidus, and solidus temperatures as a function of steel composition. It must also be pointed out that calorimetry offers very useful information on phase transformation enthalpies, which are required in thermal modeling of component's performance made out of RAFM steel.

γ -austenite \rightarrow α' -martensite formation during cooling

As mentioned before, the core of metallurgy and heat treatment of RAFM steels is centred around two principal phase changes. They are: (i) γ -austenite \rightarrow α' -martensite transformation upon normalizing (air cooling) and (ii) α' -martensite \rightarrow α -ferrite + carbides precipitation,

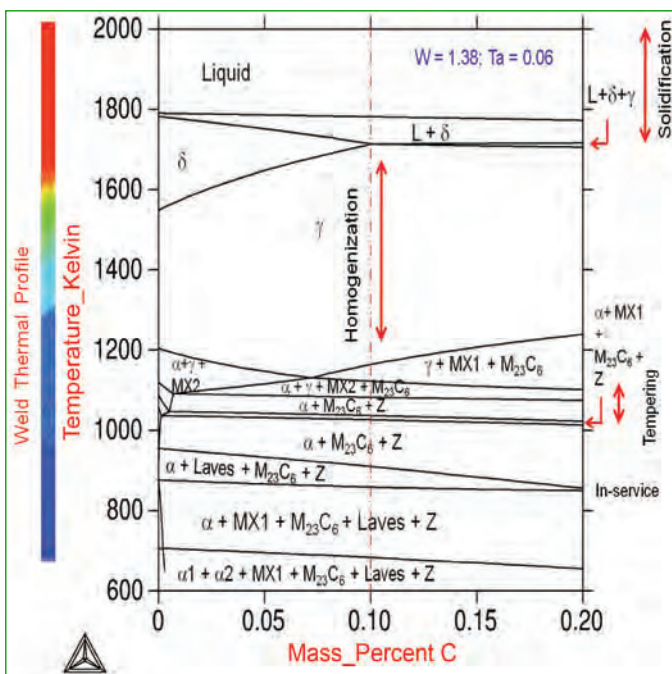


Figure 2: ThermoCalc with TCFE6 database based simulation of phase equilibria in RAFM steel. Various phase fields as well as heat treatment domains are marked for easy identification.

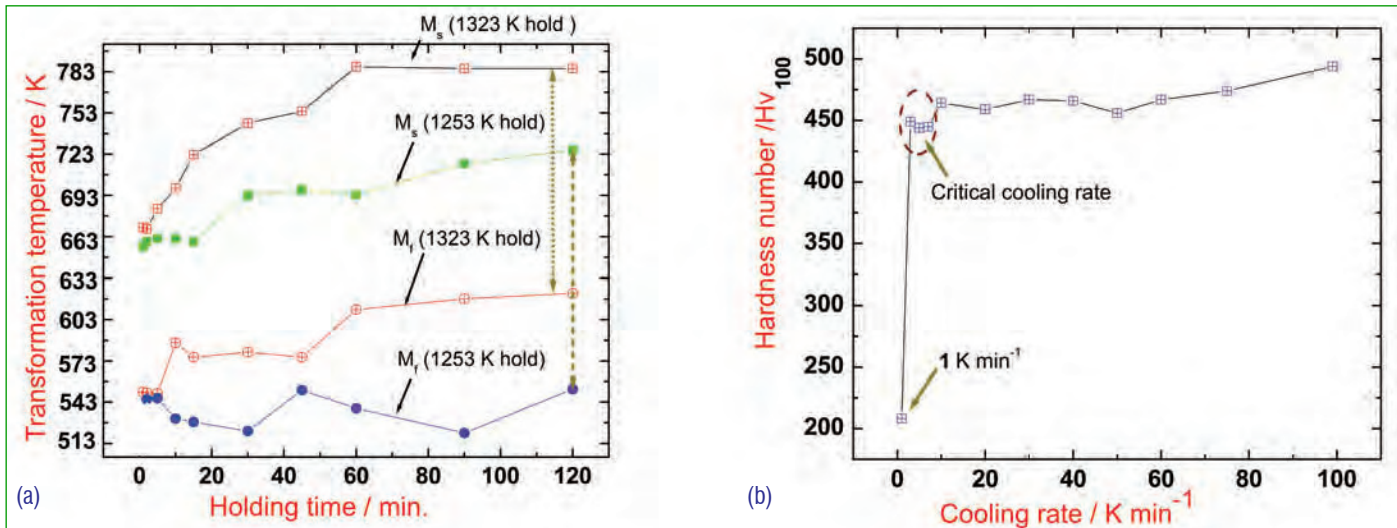


Figure 3: (a) Variation of M_s and M_f temperatures with holding time and at two austenitization temperatures; (b) variation of martensite hardness with cooling rate. Note that the onset of critical cooling rate is accompanied by a sudden increase in hardness

during subsequent tempering. While tempering heat treatment involving precipitation of carbides is amenable for Thermocalc/Dictra based simulations, the formation of α' -martensite from γ -austenite upon cooling cannot be simulated with relative ease. The reason being that martensite forms in a displacive manner under strong nonequilibrium conditions, requiring deep undercooling of austenite. Therefore γ -austenite \rightarrow α' -martensite transformation gets initiated only if a threshold or critical cooling rate is exceeded. This critical cooling rate is a strong function of composition, austenitizing temperature, time and presence of stress, if any. Therefore, the kinetics of martensite formation needs to be determined rather experimentally. Fortunately, dynamic calorimetry is capable of addressing this issue in a comprehensive manner. In Figure 3(a), the dependence of martensite start (M_s) and finish (M_f) temperatures on holding time and temperatures in γ -austenite phase and in Figure 3(b), the variation of microhardness with cooling rate are illustrated.

The kinetics of both tempering, that is $\alpha' \rightarrow \alpha + \text{carbide}$ formation upon heating, and $\gamma \rightarrow \alpha'$ martensite formation can be studied in-situ in dynamic calorimetry. Such data are nicely collated in the form

of continuous heating transformation (CHT) or continuous cooling transformation (CCT) diagrams.

These transformation diagrams represent a graphical summary of high temperature phase stability of RAFM steel under varying heating and cooling conditions, and as such constitute the most important input for designing suitable thermomechanical and post weld heat treatment schedules. In Figure 4(a) and (b), these transformation diagrams are presented for RAFM steel.

Thermophysical Properties

Besides knowing thermal and microstructural stability, it is necessary to have a comprehensive database of thermophysical properties, like heat capacity, thermal conductivity/diffusivity, thermal expansion, elastic modulus etc., Being an in-house developed material, an extensive research program has been initiated to characterize the thermophysical properties of RAFM steel. Towards this cause, the variation of enthalpy increment, $H_T - H_{298}$ as a function of temperature, or alternately, the specific heat has been determined using calorimetry. In Figure 5, the experimentally obtained specific

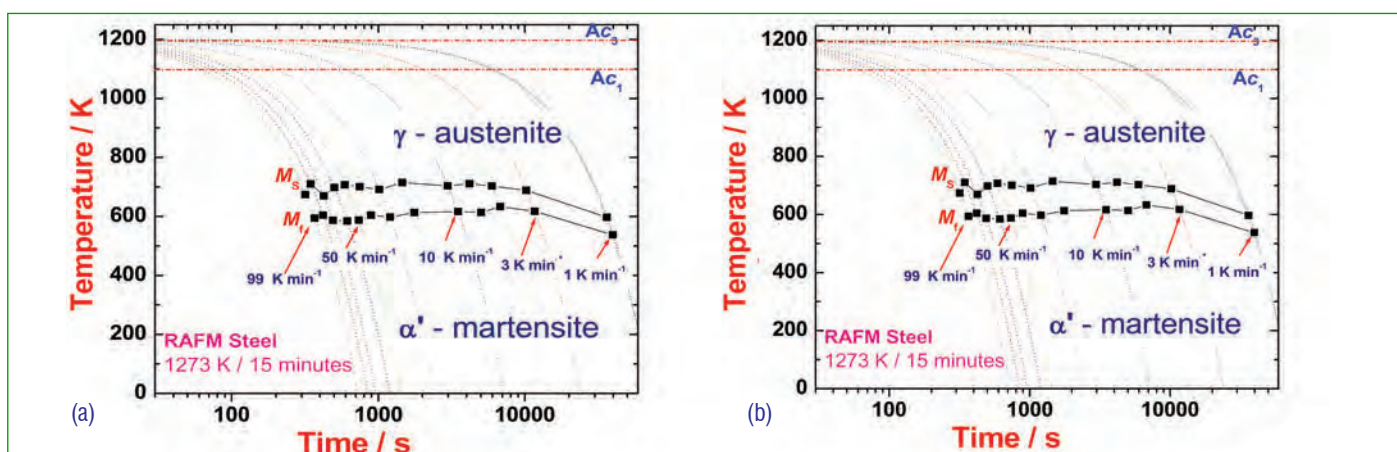


Figure 4: (a) Continuous heating transformation (CHT) and (b) continuous cooling transformation (CCT) diagrams for RAFM steel

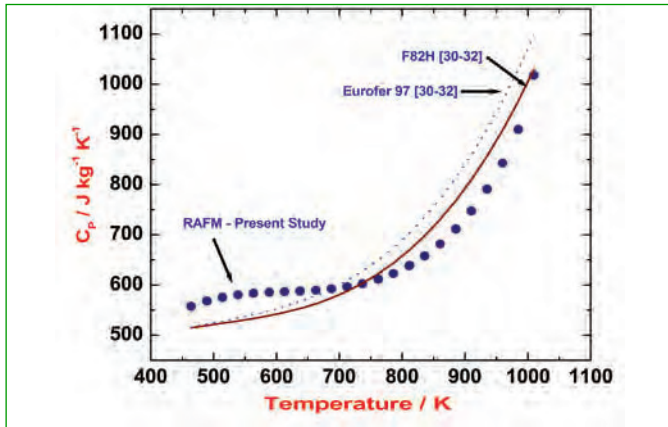


Figure 5: Measured C_p versus temperature data on RAFM steel are compared with literature information on Eurofer 97 and F82 H low activation steels

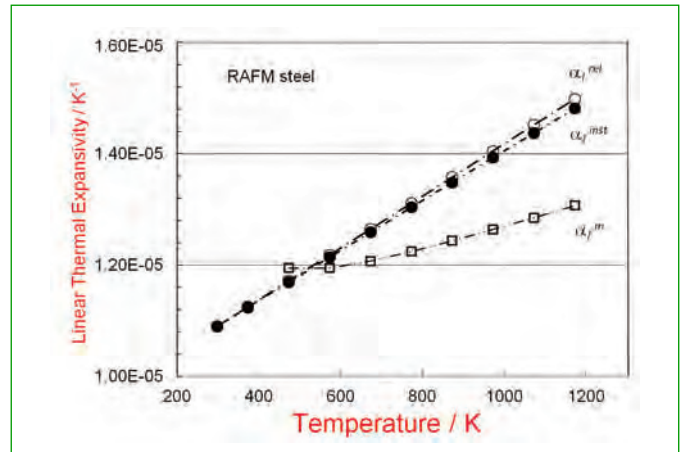


Figure 6: Temperature variation of measured linear thermal expansivity data of RAFM steel

Table 1: Thermophysical property data on RAFM steel

a = Thermal Diffusivity ($m^2 s^{-1}$)	$0.000013 - 1.3324 \times 10^{-8}T + 4.4953 \times 10^{-12} T^2$	($298 \leq T \leq 1073$) K
k = Thermal Conductivity ($W m^{-1} K^{-1}$)	$0.16445T - 0.00028T^2 + 1.3115 \times 10^{-7}T^3 + 6.8248 \times 10^{-12}T^4$	($298 \leq T \leq 1073$) K
C_p = Heat Capacity ($J kg^{-1} K^{-1}$)	$4.63T - 8.49 \times 10^{-3}T^2 + 4.81 \times 10^{-6}T^3 - 122.17 \times 10^3/T + 32.5 \ln [abs \{(T_c - T)/T_c\}]$ $T_c = 1019 \pm 3$ K	($400 \leq T \leq 1073$) K
ρ = Density ($kg m^{-3}$)	$7765 \exp [-\{3 \times 10^{-5}(T-298) + 6 \times 10^{-9}(T^2-298^2)\}]$	($298 \leq T \leq 1073$) K
α = Linear Thermal Expansion Coefficient	$\alpha_l^{rel} = 1/l_{298} (dl/dT) = 4.666 \times 10^{-9} T + 9.5081 \times 10^{-6}$ $\alpha_l^{ins} = 1/l (dl/dT) = 4.0 \times 10^{-9} T + 1 \times 10^{-5}$ $\alpha_l^m = 1/l_{298} [(l_T - l_{298})/(T - 298)] = 4.666 \times 10^{-9} T + 9.5081 \times 10^{-6}$ $\Delta l/l_{298} / \% = 2.33 \times 10^{-7} T^2 + 9.51 \times 10^{-4} T - 2.93 \times 10^{-1}$	($298 \leq T \leq 1173$) K
Elastic Properties: E/GPa , G/GPa , σ , K	$E/GPa = 250.22 - 0.15T + 2.18 \times 10^{-4}T^2 - 1.74 \times 10^{-7} T^3$ $G/GPa = 91.65 - 0.0153T + 2.65 \times 10^{-6}T^2 - 1.9 \times 10^{-8} T^3$ Poisson Ratio $\sigma = (E/2G) - 1$ Bulk Modulus, $K = 1/3\{EG/(3G - E)\}$	($298 \leq T \leq 1053$) K ($298 \leq T \leq 1053$) K

heat data on RAFM steel are compared with similar data on other related steels like, F82H and Eurofer. Notwithstanding small differences in composition between these materials, a good overall agreement between C_p values of different RAFM grades is readily evident. In a similar manner, the thermal expansion of RAFM steel has been characterized by both dilatometry and high temperature X-ray diffraction. The measured linear thermal expansivity data as a function of temperature are shown in Figure 6. Thermal diffusivity is an important design parameter, and together with heat capacity (C_p), density (ρ) data and thermal conductivity k can be estimated. In view of this, the dynamic Laser pulse flash based transient technique has been adopted to measure thermal diffusivity values of RAFM steel. The elastic properties of RAFM steel have also been measured using impulse excitation resonant frequency technique. In Table 1, all the measured thermophysical property data on RAFM steel have been collated. It must be mentioned that the present set of data constitute probably the most comprehensive characterization of phase and microstructural stability as well as thermophysical properties of indigenously developed RAFM steel. Since RAFM steel is a ferromagnetic material, it is also useful to estimate its magnetic

properties, especially since this material is expected to be influenced by the magnetic ambience of ITER first wall. Attempts are already underway to characterize the magnetic properties of RAFM steel. Finally, it must also be mentioned that these out-of-pile data need to be necessarily augmented with information on material's stability and property degradation under the influence of highly intense neutron flux. Only then, it may be truly said that a material is fully qualified for nuclear applications.

A comprehensive knowledge base on diverse aspects of thermokinetic stability and thermophysical property scenario of in-house developed RAFM steel has been built, by a judicious combination of experiments and modeling. This research has thrown open valuable insights towards optimizing the design aspects of a typical high Cr-based reduced activation ferritic martensitic steel. It is demonstrated that as to how carefully planned experimental and modeling input are vital towards building an integrated and highly matured material design database for strategic applications.

Reported by S. Raju & Colleagues
Microscopy & Thermo-Physical Property Division, PMG, MMG

Implementation of Payroll Package under ATOMS in IGCAR

As part of e-governance initiatives of IGCAR, with an objective to automate and integrate the activities in the areas of Administration, Accounts, Stores and Purchase, a software named as “Automated Workflow Management System (ATOMS)” has been implemented in IGCAR and is operational since 2010. ATOMS provide single window self service interface to the employees for transactions pertaining to the Administration, Accounts, Stores and Purchase (Figure 1). It is a workflow and role based system in which the roles of all the employees have been mapped and the data flow takes place as per the defined workflow of each process. It is envisaged to eventually lead to a quick processing, paper-less, person independent work flow of management in the future.

For Administration, processes like Character and Antecedents verification, offer of appointment, introduction note, posting order, employee and pay details, leave request, marriage and joint declaration, nomination, home town change, LTC advance / settlement, air ticket requests, quit order, transport requests, meeting room booking etc. have been introduced under ATOMS. For Stores and Purchase, the modules pertaining to indent, goods receipt note, functional test report, receiving voucher, credit note and item disposal processes have been introduced and are being used effectively towards quick processing of payments to suppliers of items. As part of Budget Monitoring, the monthly projections of expenditure under capital project, work procedures like technical sanction and work orders have been implemented under the

package. New modules are gradually being added to the package to enhance the functionalities and to automate all the processes in order to get an instant update of budget at any given time.

For Accounts, settlement of various bills like temporary advance, entertainment, imprest, local and outstation travelling allowance etc. have already been implemented under ATOMS.

Calculation of pay and allowances has been one of the major activities of Accounts, warranting a lot of calculations as there are a number of employee related subsets in the entitlements and deductions. To automate these activities and for generation of payroll, a module has been developed and integrated with ATOMS and being used successfully.

The payroll package under ATOMS encapsulates the following activities towards generation of payroll.

- Updating employee data like bank account, PF account, PAN and head of account details
- Updating pay data like pay in pay band, grade pay, additional increment etc.
- Load data from other processes like local TA, outstation TA, night duty allowance, overtime allowance etc.
- Add or update data in case of change in eligibility like special pay,



Figure 1: Components of ATOMS

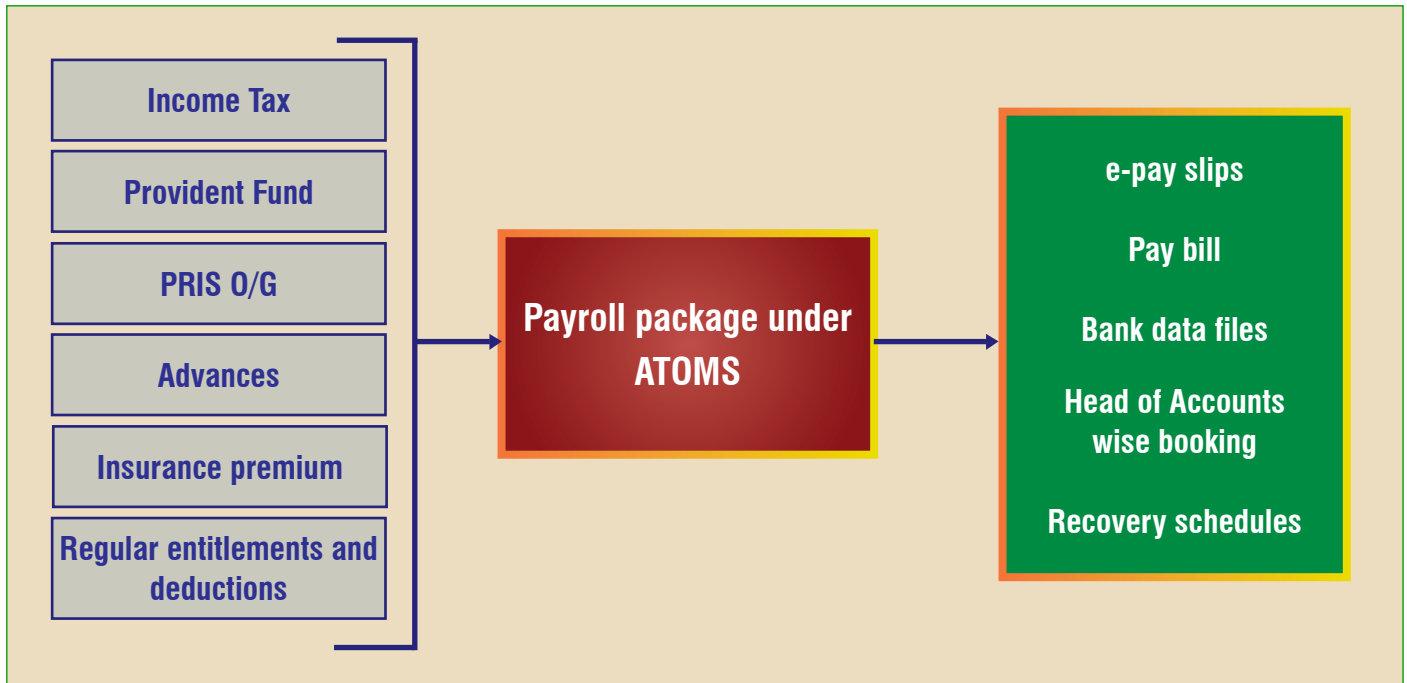


Figure 2: Input modules and output of the payroll package

transport allowance, family planning allowance, qualification incentive allowance etc.

- Advances management for festival advance, two wheeler advance, car advance, PC advance, PF advance, House building advance etc.
- Management of premium payments for insurance policies pertaining to LIC and PLI
- Loading data pertaining to external recoveries like license fee, electricity charges, damage charges and garage fee from GSO and subscription to thrift and co-operative societies
- Processing the PF subscription change, savings details and Form 12 C applications
- Calculation of income tax including the paid as well as projected income for the financial year
- Calculation of arrears, PRIS O and PRIS G components
- Calculation of entitlements and deductions of all the employees based on the inputs received through above mentioned modes and generation of payroll
- Generation of bank data files and pay bill registers, head of accounts wise booking etc.

The functionalities of the payroll package can be broadly divided into two parts. One which has been provided to the employees under

self service option and the other which are available to Accounts for processing the payroll. Prior to this automation, the payroll was generated using legacy system with limitation on the number of components of entitlements and deductions. The present system has been designed to have provision for dynamically adding any number of new entitlements and deductions. Presently the package deals with 164 components, i.e., 68 entitlements and 96 types of deductions. The salient features of the payroll package are:

- Integration with Administration for employee and pay fixation data
- Paper-less application processing of PF subscription change, PF advance and withdrawal
- Email alerts for PF advance and withdrawal processing
- Providing e-pay slips to the employees
- Providing online calculation sheets for income tax, PRIS O and PRIS G
- Business rules are built in the system; hence, the processing becomes person independent.

With the successful completion of the payroll package, pay slips are generated with less effort and errors. We are in the process of implementing newer modules towards achieving a paper-less office in the future.

*Narendra Kumar Kushwaha and colleagues
Strategic Planning & Human Resource Development Division, RMG*

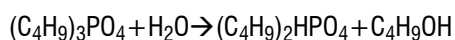
Young Officer's FORUM

Vapor Liquid Equilibrium Data Generation and Analysis for Tributyl Phosphate - Normal Paraffin Hydrocarbon System

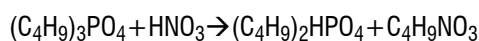
To recover uranium and plutonium from spent nuclear fuel, tri-butyl phosphate (TBP) diluted with n-paraffin hydrocarbon (NPH) is used as an extracting solvent in the PUREX process of nuclear fuel reprocessing plant. During the extraction, the solvent is degraded under the influence of acid and radiation effect, reducing its extraction efficiency; thus, making it necessary to purify the solvent before it is recycled back to process. There are several methods for solvent purification such as steam stripping, adsorption and distillation methods, but distillation has an edge over other methods. To design distillation column, vapor-liquid equilibrium data at different pressures are required. The instability of TBP at elevated temperature requires distillation column to be operated at reduced pressure.

Solvent degradation

The extent of degradation varies with the exposure of the organic extractant phase to radiation and reactive chemicals during the processing of the aqueous feed. The presence of degradation products even at concentrations of 10^{-5} to 10^{-3} M in the solvent can adversely influence its extraction performance. The degradation mechanism for solvent and diluent are quite different to each other. TBP degradation involves hydrolysis or de-alkylation reaction when contacted with HNO_3 . If degradation is by hydrolysis, the primary products will be di-butyl phosphoric acid and butyl alcohol.



If the primary reaction is de-alkylation, initial product will be butyl nitrate and DBP. Butyl nitrate will subsequently slowly hydrolyze to form butyl alcohol.



Butyl alcohol and butyl nitrate are volatile and both would enter the off-gas system and probably be vented safely through the stack. Dibutyl phosphate can hydrolyze to form monobutyl phosphate and phosphoric acid. Extracted metal ions in the extracting solvent accelerate TBP degradation by nitric acid, especially due to the presence of zirconium in the solvent.

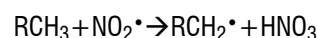
The mechanism for the degradation of diluent by nitric acid involves



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His current area of interest include Vapour Liquid Equilibrium data analysis for different systems, distillation column modeling and solvent purification system.

radical-like NO_2 molecules that react to form a free hydrocarbon radical.



This hydrocarbon radical ($\text{RCH}_2 \cdot$) reacts with a molecule of NO_2 to give nitro or nitrite compound.



When both TBP and diluent are present, the primary degradation products of each will interact to form secondary degradation products. These materials include long-chain organic compounds like acidic organophosphates that are capable of retaining tetravalent ions such as Zr^{4+} and Pu^{4+} . Many other secondary degradation products are surface tension active and their presence in solvent decreases the interfacial tension resulting in increased phase separation time. Additionally, their identities and chemical properties are unknown. The mechanism for formation of primary and secondary degradation products are described in Figure 1.

Different methods of solvent purification

Sodium carbonate scrubbing, adsorption and vacuum distillation

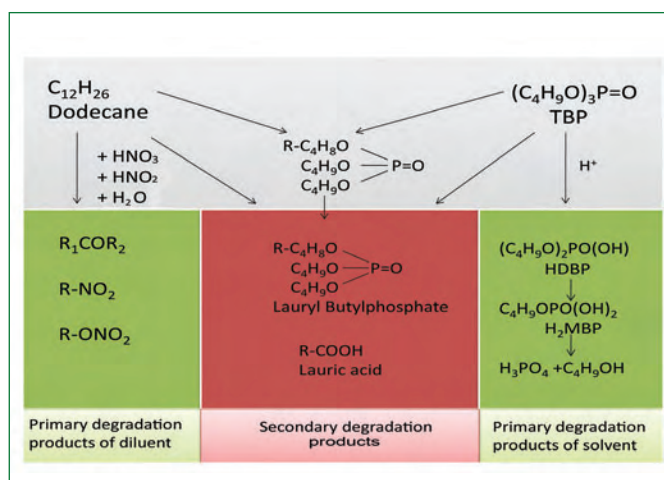


Figure 1: Degradation mechanism of solvent and diluent

are different methods of solvent purification available in literature. They are described briefly below.

Sodium carbonate scrubbing:

Sodium carbonate solution is effective since majority of primary the degradation products are acidic in nature. It is low cost method as compared to other methods used for solvent purification and quite effective in removing primary degradation products, but it is incapable of removing secondary degradation products formed by interaction of primary degradation products.

Adsorption:

The solids proposed for adsorption include macro reticular resins, base-treated silica gel, inorganic ion exchangers, lead dioxide on silica gel and hydrous titanium dioxide. Except for the lead dioxide and inorganic ion exchangers, all the solid sorbents mentioned act as bases to effect removal of the acidic degradation products and are thus, similar in principle to the aqueous scrubbing systems. All these have the potential advantage of the simplicity of packed column operations. The solid sorbents should be strong enough to withstand transfer operations without generating significant amount of dust, must be compatible and should not react to form hazardous materials. Sorbents should have large capacity and should be easily regenerated and regeneration must not result in waste solutions that are difficult to handle. All these requirements limit commercially available materials that can serve the purpose and also make the specially designed ones expensive in comparison to standard solvent cleanup methods.

Vacuum distillation:

In distillation, relative volatility is the driving force for separation of different constituents of a mixture. Further, it does not employ any foreign agent, thus reducing the problem of excess waste generation. NPH and TBP have wide difference in their boiling points (45 & 121°C at 2.4 mm Hg respectively) and the equilibrium curve for TBP-NPH system shows considerable departure from 45° line. This implies higher relative volatility for the system, make distillation as an ideal choice for separation. Another advantage is that it can be easily incorporated into a plant which can do the solvent purification in a continuous manner.

Experimental setup and process description

Before designing distillation column for solvent purification system, it is necessary to have equilibrium data for TBP-NPH system at different pressures. Since equilibrium data for the above mixture are not available in the literature, generation of equilibrium data for TBP-NPH mixture is the first and foremost step. For this purpose, experiments were conducted in ebulliometer at different pressures. Experimental setup is shown in Figure 2.

Ebulliometer is made up of boro-silicate glass of capacity one

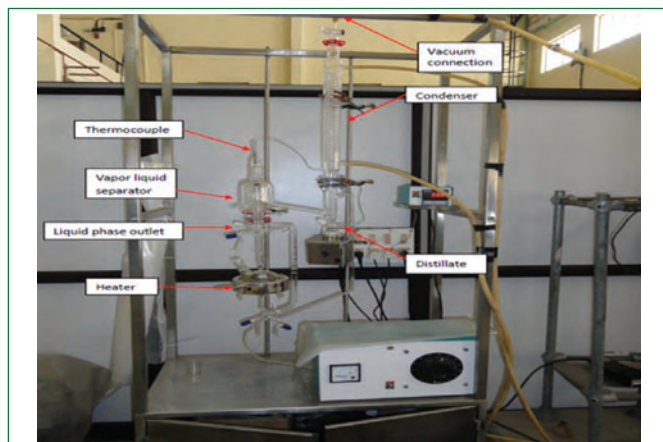


Figure 2: Ebulliometer setup employed in the studies

litre to withstand high temperature and pressure conditions and to provide sufficient transparency to observe the level of liquid inside the still. It has three essential parts, vaporizer or heater, flash/equilibrium section and condenser. A thermocouple is inserted in to equilibrium section to record the temperature throughout the process and to give an indication when equilibrium is achieved. The vaporiser section has a heater surrounding it. The top end of the condenser is connected to a vacuum pump. Equilibrium section consists of a double glass vessel with perforation on the wall of inner vessel allowing vapor formed in the chamber to escape to the condenser section, while liquid falls to liquid collection chamber under action of gravity. Escaped vapor in condenser section is cooled by water at 12°C and it settles down as liquid in distillate pot. Distillate pot is provided with magnetic stirrer to reduce differential settling of heavier component below lighter component. Ebulliometer used is recirculation type to achieve more accuracy in equilibrium data generation.

To start with the experiment, a mixture of TBP and NPH was prepared fed to vaporizer and heater was switched on. Vacuum pump was started and pressure inside the ebulliometer was reduced slowly to prevent sudden suction of the feed mixture into the pump line. Pressure was maintained at less than 10 mm Hg. Circulation of cooling water to condenser section was started. As the mixture gets heated up, the vapour produced moved to equilibrium section with liquid entrained in it. The vapor moves out of equilibrium section to condenser section leaving liquid phase to percolate in liquid collection pot. The vapor condensed in distillate pot of condenser section was recirculated to vaporiser. This process was allowed to continue for about 3-4 h till constant temperature was recorded in the thermocouple mounted in equilibrium section, indicating that equilibrium was reached. After attainment of equilibrium, the process was left for another one hour to allow complete recirculation of vapor condensed in the distillate pot. After that, samples were taken from distillate pot and liquid collection pot and analysed for the composition of TBP in the

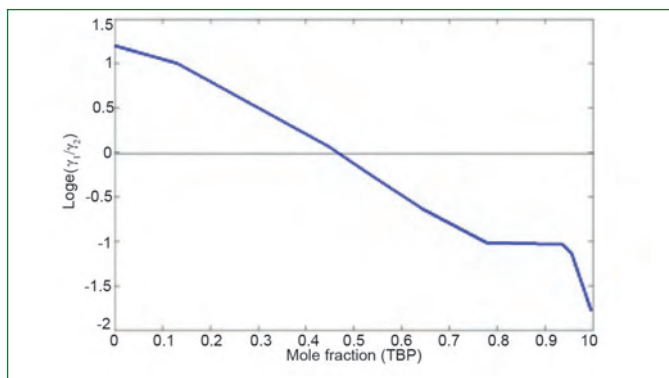


Figure 3: Plot showing thermodynamic consistency

sample with the help of gas chromatography. The above process was repeated by replacing some amount (say 10 ml) of feed with pure component (TBP or NPH) till equilibrium temperature for the entire range of composition was achieved.

Data analysis and thermodynamic modelling

Since TBP-NPH system forms a nonideal solution, we started with modified Raoult's law which is given below.

$$\Phi_i y_i P_{\text{Total}} = P_i^{\text{sat}} x_i \gamma_i \quad (1)$$

where Φ_i = fugacity coefficient, γ_i = activity coefficient, x_i = liquid phase mole fraction, y_i = vapor phase mole fraction, P_i^{sat} = saturated vapor pressure for component (i) and P_{Total} represents total pressure of the system. x_i and y_i are obtained from the analysis of sample collected from liquid collection pot and distillate pot respectively. P_i^{sat} is obtained by Antoine relationship. Antoine coefficients for TBP were obtained from literature. Since NPH contains some percentage of C-10, C-11 and C-13 alkane group in addition to C-12 (NPH contains about 90% dodecane), it is required to generate Antoine coefficient for NPH. For this, experiments were conducted and vapor pressure of NPH at different temperatures was generated and subsequently curve fitting was done to generate Antoine equation which is given below:

$$\log_e p(\text{kPa}) = 12.87 - 3441.41/[T(\text{K}) - 71.18] \quad (2)$$

Since the experiments were conducted below 10 mmHg (near vacuum condition), the vapour phase behaves like an ideal gas; so fugacity coefficient of vapor phase which tells the departure of vapor phase from ideality is assumed to be one ($\phi = 1$) for further calculation.

Before proceeding to calculate activity coefficients, it is necessary to verify the consistency of data. Using Gibbs Duhem rule to check consistency, $\log_e(\gamma_1/\gamma_2)$ is plotted against x_{TBP} (Figure 3) to carry out Gibbs Duhem integration. Total area under the curve was approximated to be near zero (neglecting higher concentration points i.e. beyond $x_i > 0.95$ where some abnormality was observed).

Different models were used for calculation of activity coefficients which describe the departure of a solution from ideality.

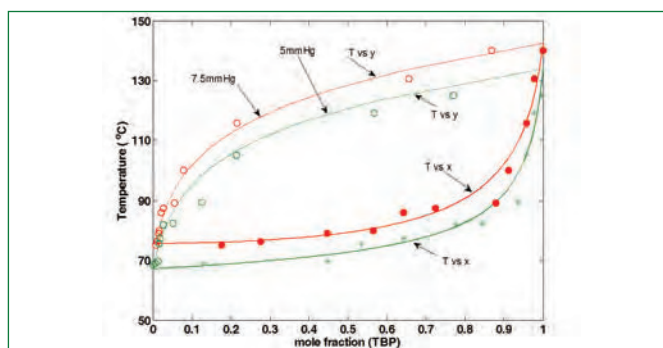


Figure 4: Comparison of experimental and predicted Vapour Liquid Equilibrium data with Wilson model.

All models use excess Gibbs energy equation as their basis.

$$\frac{G^E}{RT} = x_1 \ln \gamma_1 + x_2 \ln \gamma_2 \quad (3)$$

Activity coefficient for component (i) was calculated by differentiating equation (3) partially w.r.t. x_i :

$$\ln \gamma_i = \left[\frac{\partial (nG^E/RT)}{\partial n_i} \right]_{P,T,n_{j \neq i}} \quad (4)$$

We considered four models viz., Margules, Van Laar, Wilson and NRTL model. All four models have empirical basis for their derivation. These models except NRTL model (which employs 3 parameters) employ 2 parameters based on intermolecular interaction between different molecules. Margules is the oldest one and is simple to use but it is least accurate followed by Van Laar model. Wilson comes out as the best model ahead of NRTL for the given system at all pressure, below 10 mmHg (experiments were conducted at 2.4, 5, 7.5 and 10 mmHg). The different models are shown as:

Margules model:
$$\frac{G^E}{RT} = x_1 x_2 (A_{12} x_1 + A_{21} x_2)$$

Van Laar Model:
$$\frac{RT}{G^E} = \frac{1}{A_{12} x_1} + \frac{1}{A_{21} x_2}$$

Wilson Model:
$$\frac{G^E}{RT} = -x_1 \ln(x_1 + x_2 \Lambda_{12}) - x_2 \ln(x_2 + x_1 \Lambda_{21})$$

NRTL Model:
$$\frac{G^E}{x_1 x_2 RT} = \frac{G_{21} \tau_{21}}{x_1 + x_2 G_{21}} + \frac{G_{12} \tau_{12}}{x_2 + x_1 G_{12}}$$

The experimental and predicted Vapour Liquid Equilibrium data with Wilson model at 5 and 7.5 mm Hg are compared in Figure 4. As the model predicted values are in good agreement with experimental data, it is concluded that Wilson model can be used to estimate Vapour Liquid Equilibrium data for TBP-NPH system for pressures below 10 mmHg.

Reported by Ambuj Kumar Singh
Reprocessing Research & Development Division, RpG

Young Researcher's FORUM

Aspects of the Stability of Iron Oxide Nanoparticles as Addressed using Mossbauer Spectroscopy

Spinel iron oxide nanoparticles continue to play an important role in technological applications including magnetically guided drug delivery, high density magnetic memory, spintronics, and hyperthermia. A complete understanding of several issues related to structure, magnetic and electronic properties are yet to be obtained. Several of the applications of the cubic iron oxide nanoparticles impose stringent constraints on the nano size of the particles and the aggregation of the particles is strictly forbidden. Cubic iron oxide nanoparticles should be of size less than or close to 10 nm (single magnetic domain) and exhibit super paramagnetic nature and high saturation magnetization so that the particles show a large response to applied magnetic field.

A proper encapsulation of nanoparticles with suitable surfactant depending upon the application is needed to prevent aggregation of nanoparticles. Another possible way of providing thermal and chemical stability is to get the nanoparticles strongly bound in a suitable template. As the systems concerned exhibit size dependent magnetic and structural properties, it is required to address these issues using a technique characterized by a measurement time



Dr. Loushambam Herojit did his Masters in Physics from Manipur University, Canchipur, Manipur. He joined IGCAR as a DAE research fellow in Physical Sciences in August 2008 and carried out his doctoral work in the Materials Physics Division, MSG, under the guidance of Dr. R. Govindaraj. His doctoral thesis titled "Aspects of local structure and magnetic properties of the Fe based nano and bulk ferrites using Mössbauer Spectroscopy" has been submitted to Homi Bhabha National Institute and has received his degree recently.

of the order of or smaller than the Neel spin relaxation time. ^{57}Fe based Mossbauer spectroscopy turns out to be one of the most powerful techniques to study these systems satisfying all these criteria, in addition to the fact that these systems are Fe based. In this article some of the Mossbauer results obtained by us on the stability aspects of cubic iron oxide nanoparticles encapsulated with oleic acid and bound by zeolite template (Cf. Figure 1) would be presented in comparison with that of bare cubic iron oxide nanoparticles neither encapsulated nor template bound.

Bare cubic iron oxide magnetite nanoparticles were prepared from Fe^{3+} and Fe^{2+} based salt solutions viz. FeCl_3 and $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ in the molar ratio of 2:1 by co-precipitation following the literature procedure. In order to prepare Oleic Acid (OA) capped cubic iron oxide nano particles, NaOH was added to the above salt solution and subsequently OA was added with rigorous stirring. Procedure for obtaining the bare nanoparticles of cubic iron oxides has been followed but for stirring at high speed in order to disperse these nanoparticles in a zeolite template.

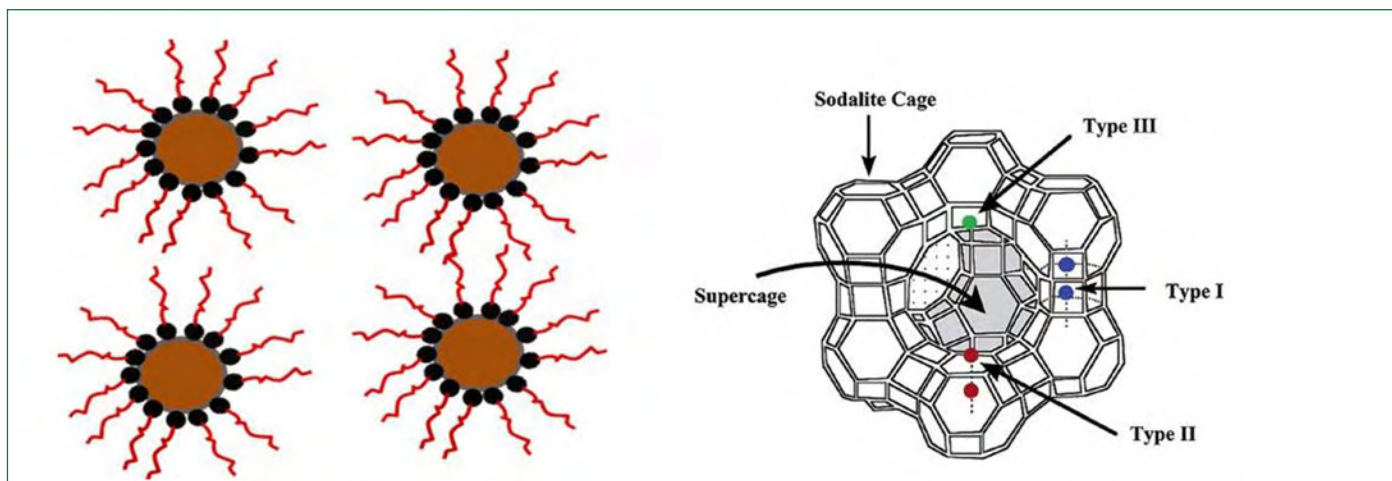


Figure 1: Schematic of the iron oxide nanoparticles capped with oleic acid surfactant. Framework structure of zeolite 13X is also shown displaying the sodalite and supercages

Mossbauer spectrometer was operated in constant acceleration mode and in transmission geometry. ^{57}Co source dispersed in Rh matrix has been used as a source for Mossbauer measurements. Each Mossbauer spectrum has been acquired in 1024 channels. The spectra were calibrated with a $10\ \mu\text{m}$ $\alpha\text{-Fe}$ foil and the values of isomer shifts are presented with respect to that of $\alpha\text{-Fe}$ obtained at 300 K. The spectra were fitted with Lorentzian line shape of line width Γ using nonlinear least squares program to obtain hyperfine parameters such as isomer shift δ_i , quadrupole splitting Δ_i and magnetic hyperfine field (Bhf) experienced by relative fraction f_i of distinct ^{57}Fe absorber atoms.

Mossbauer measurements have been carried out at 300 K in the as prepared bare, oleic acid coated and zeolite templated iron oxide nanoparticles, followed by annealing treatments at different temperatures to study the stability of the nanoparticles in terms of the variation of hyperfine parameters as experienced by ^{57}Fe atoms corresponding to these matrices.

Decomposition of bound oleic acid is dictated by the binding energy of the nanoparticles as capped by the oleic acid. This is expected

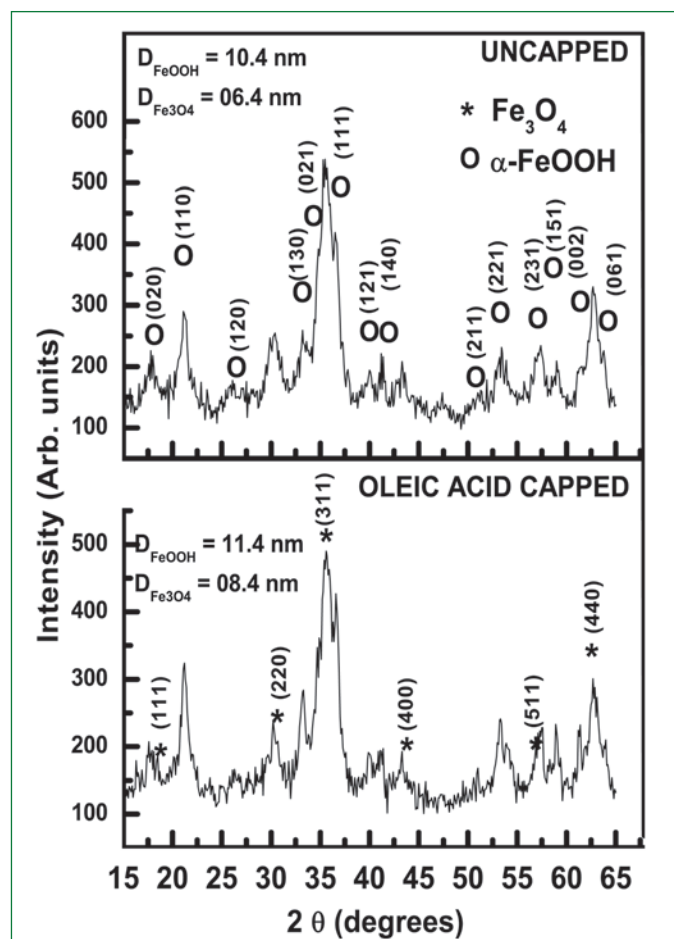


Figure 2: XRD spectra corresponding to bare and oleic acid capped iron oxide nanoparticles

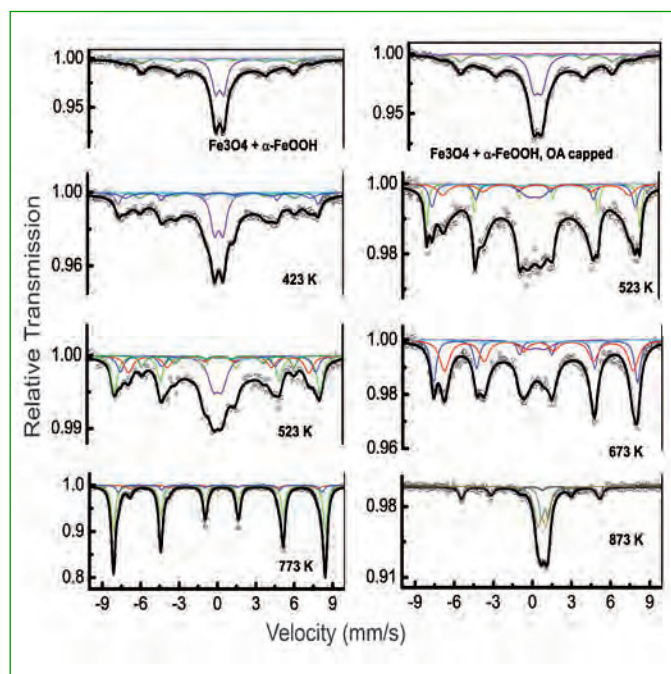


Figure 3: Mossbauer spectra obtained in bare and OA coated nanoparticles followed by annealing treatment at temperatures as mentioned in the figures

to result in reduction of the nanoparticles in addition to coarsening. In the case of zeolite dispersed iron oxide nanoparticles, the coarsening temperature of the particles is dictated by the binding energy of the nanoparticles in the traps present in the template structures.

The obtained nanoparticles are composed of $\alpha\text{-FeOOH}$ and Fe_3O_4 as deduced based on XRD spectrum shown in Figure 2. On the basis of the Scherrer analysis, the mean size of uncapped or bare nanoparticles of $\alpha\text{-FeOOH}$ and Fe_3O_4 were deduced to be around 12 and 8 nm respectively.

Mossbauer spectra obtained for the bare and oleic acid coated iron oxide nanoparticles are shown in Figure 3. In the case of bare iron oxide nanoparticles, an increase in the magnetically ordered fractions at the cost of Fe atoms associated with the super paramagnetic fractions is observed with increasing annealing temperature. Mossbauer spectrum subsequent to annealing at 773 K resulted in 75% of area associated with a hyperfine component having a mean field of 51 Tesla, quadrupole splitting $-0.2\ \text{mm/s}$ and an isomer shift of $0.3\ \text{mm/s}$, which is interpreted to be due to absorber atoms associated with $\alpha\text{-Fe}_2\text{O}_3$. The remaining fractions of ^{57}Fe atoms are understood to be associated with off-stoichiometric magnetite based on the hyperfine parameters.

Mossbauer spectra obtained subsequent to annealing treatment at 673 K in OA coated nano particles are distinctly different as

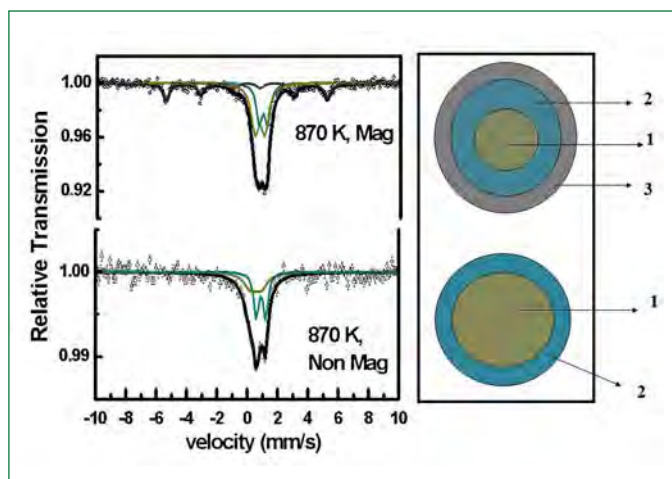


Figure 4: Mossbauer spectra of the sample containing the OA coated iron oxide nanoparticles subsequent to annealing treatment at 870 K.

compared to that of the bare nanoparticles, resulting in a reduction of α -FeOOH to stoichiometric magnetite based on the hyperfine parameters. Only a slight coarsening of the particles to a size close to 15 nm has been observed based on XRD studies. Based on the hyperfine parameters obtained in the analysis of the spectrum subsequent to annealing at 870 K, the occurrence of the phases corresponding to FeO and Fe could be identified. Subsequent to annealing treatment at 870 K, the magnetically attractive portion of the sample was separated from the non attracting portions and the Mossbauer spectra obtained in these samples are shown in Figure 4. These results are understood in terms of the occurrence of FeO-Fe core-shell configurations. (f_1 , f_2 and f_3 are fractions of Fe atoms associated with off stoichiometric wustite, stable wustite and α -Fe respectively). This is shown schematically in Figure 4.

Mossbauer spectrum corresponding to bare iron oxide nanoparticles prepared based on a high stirring speed of NaOH added precursor solution displayed a single doublet implying the super paramagnetic fluctuations of spins. The mean size of iron oxide particles in both the bare and zeolite dispersed is deduced to be around 4 nm based on XRD results, which is in accordance with the Mossbauer spectra resulting in superparamagnetic doublet as shown in Figure 5. When bare nanoparticles were subjected to annealing at 520 K, a broadening of the spectrum occurred which could be fitted with a predominant doublet and a broad six line spectrum implying that about 20% of Fe atoms are exposed to magnetic interaction. The onset of magnetic interaction is understood to have been caused either due to coarsening of the nanoparticles or a considerable decrease in the mean distance of separation between particles. This further implies that the onset of migration of bare nanoparticles might be occurring around 450-500 K.

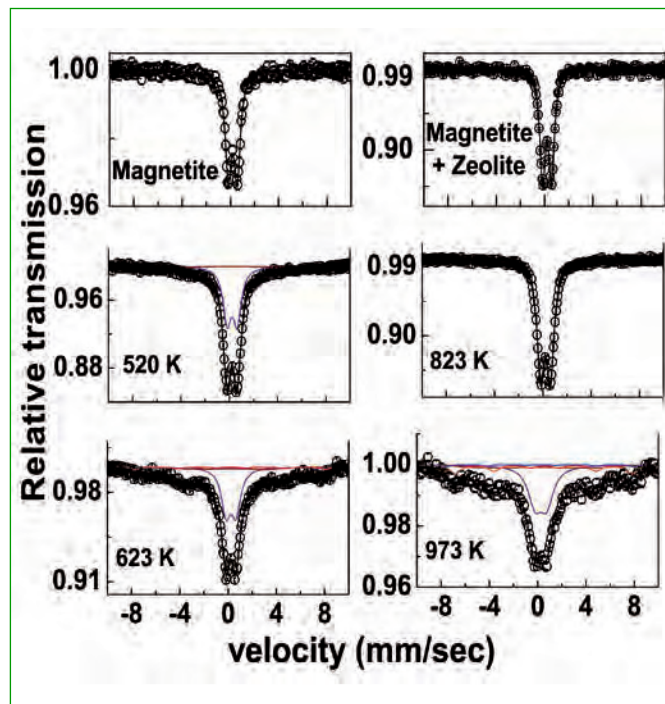


Figure 5: Evolution of Mossbauer spectra corresponding to bare and zeolite dispersed superparamagnetic iron oxide nanoparticles due to annealing treatments carried out at different temperatures at a partial pressure close to 10^{-6} mbar.

The Mossbauer spectrum evolves as a clear sextet along with doublet subsequent to annealing treatment at 623 K in the case of bare nanoparticles of cubic iron oxide. Whereas in the zeolite dispersed case, it is interesting to note that the Mossbauer spectrum remains as a doublet even after annealing treatment at 823 K.

This evolves in to a clear six line spectrum along with doublet following the annealing treatment of the sample at 973 K. This implies that the cubic iron oxide nanoparticles are strongly bound in zeolite matrix, the source of binding centers could be pores or the cationic vacancies in zeolite which could also act as strong trapping centers of the nanoparticles of cubic iron oxides.

The results of the Mossbauer studies reported here indicate a strong reduction of nanoparticles due to dissociation of oleic acid as bound to these particles in the annealing interval 600-700 K. This study has provided the possibility of obtaining nanoparticles of stoichiometric magnetite and also to obtain oxides of different phases in core-shell configurations. Also a strong binding of cubic iron oxide nanoparticles in zeolite templates with a binding energy close to 3 eV has been elucidated in this study for the first time.

Reported by Loushambam Herojit
Materials Physics Division, MSG

Conference and Meeting Highlights

12th Joint Coordination Committee Meeting of DAE-CEA at IGCAR

November 24-25, 2014



Chairman AEC and Chairman CEA along with delegates during the meeting

The 12th Joint Coordination Committee Meeting of DAE-CEA took place on 24-25th November 2014 at IGCAR, Kalpakkam to review ongoing collaboration between DAE and CEA France. Dr. R. K. Sinha, Chairman, AEC led the Indian delegates whereas French delegates were led by Dr. B. Bigot, Chairman, CEA. In their opening remarks both the Chairmen expressed their happiness on the progress of collaboration between the two countries in the field of Nuclear Energy. Dr. P. R. Vasudeva Rao, Director, IGCAR made a presentation on highlights of the cooperation in the field of basic research and fast reactor safety. He also made a presentation on strategy for enhancing cooperation in the field of fast reactor safety. Mr. P. K. Wattal, BARC

made a presentation on summary and highlights of cooperation in the field of waste management. Mr. R. C. Sharma, BARC presented the summary and highlights of JHR cooperation. Dr. P. Chellapandi, IGCAR, made a presentation on codes, licences and on possibility of Indian cooperation on PLINIUS -2. Presentation on review of the developments in the field of basic research was made by Dr. B. K. Panigrahi, IGCAR. Dr. A.K. Nayak, BARC made a presentation on possibility of cooperation in the field of In-Vessel retention. During the meeting three implementing agreements were signed between DAE and CEA. All the delegates visited PFBR site, FBTR and RML. Both the Chairmen wished to strengthen the cooperation between the two countries in nuclear field for mutual benefit.



Chairman AEC and Chairman CEA along with delegates during meeting

Reported by Shri B.K. Nashine, RDG

Conference and Meeting Highlights

Course on Nuclear Chemical Engineering and Present-day Technologies CONCEPT-2014

December 01-12, 2014



Prof. K. Krishnaiah addressing the participants during inauguration of CONCEPT-2014

To commemorate the diamond jubilee of Department of Atomic Energy, IChE, Kalpakkam, in collaboration with IGCAR, had organised a winter course, Course on Nuclear Chemical Engineering and Present-day Technologies (CONCEPT) for third year students of BE (Chemical Engineering) during December 01-12, 2014. It was a two-week course in which, in addition to all the aspects of the nuclear fuel cycle, essentiality and environmental impact of nuclear energy were taught. The course was structured in such a way to promote the nuclear technology to the budding chemical engineering graduates, who would not only be inspired to take nuclear technology as their career but also would spread the challenges in the nuclear technology to the general public. CONCEPT-2014 was inaugurated by Prof. K. Krishnaiah on December 01, 2014 and thereafter technical lectures were delivered by senior scientists of IGCAR, BARC and BARCF for the benefit of students. Students were also provided with the preprints of the lecture-contents for further study and perusal. Course content included advanced lectures on solvent extraction, membrane technology and extraction equipment. Visits to Madras Atomic Power Station (MAPS), Fast Breeder Test Reactor (FBTR), Centralised Waste Management Facility (CWMF) and Environmental Survey Laboratory (ESL) were also part of the course. About 44 students from various engineering colleges of Tamil Nadu, including IIT Madras had participated in CONCEPT-2014 and

successfully completed the course. A chemical engineering quiz was also organised as a part of the course. In the fond memory of Late Shri N. Srinivasan, former Director, RRC (now IGCAR) and founding member of IChE-KRC, IChE-Kalpakkam Regional Centre has instituted an award for the quiz winners. This award will be given annually.

After completion of the course, valedictory function was held at Sarabhai Auditorium, HBB Building, IGCAR on December 12, 2014. The function was inaugurated by Dr. P. R. Vasudeva Rao, Distinguished Scientist and Director, IGCAR. It was presided by Prof. P.S.T. Sai, Head, Chemical Engineering Department of IIT Madras, Chennai. Dr. R. Natarajan welcomed the participants and colleagues. Dr. P.M. Satya Sai briefed the gathering about the course and its contents. For the year 2014, Shri N. Srinivasan memorial Award was awarded to the winners of the chemical engineering quiz by Shri G. R. Balasubramanian, former Advisor to Chairman AEC and erstwhile colleague of late Shri N. Srinivasan at FRD, BARC and IGCAR. Award consisted of a silver medallion and a certificate. All the successful participants were also given certificate of merit. A feedback session was also organised. Honourable Secretary of IChE-KRC, Shri Shekhar Kumar proposed the vote of thanks.

Reported by Shri Shekhar Kumar, RpG

Conference and Meeting Highlights

Diamond Jubilee Celebrations of the Department of Atomic Energy at Kalpakkam

The Department of Atomic Energy was established in the year 1954 under the direct charge of the Prime Minister through a Presidential Order. In order to commemorate the sixty years of commendable achievement of the Department, a series of programmes are proposed to be conducted during the year long celebrations (from August 2014-July 2015) across various Units of DAE. At IGCAR, we have planned several programmes during the year targeting students, teachers, professionals and public to disseminate the achievements of DAE, taking the help of various professional bodies functioning at Kalpakkam.

“Know your DAE” Lecture series:

In order to bring out an awareness about the activities being pursued in various Units of the Department, a lecture series titled “Know your DAE” with talks by Heads of Units/ Senior colleagues of DAE is being organized along with the Kalpakkam Chapter of the Indian Nuclear Society (INS). The series of talks started with Dr. M. R. Srinivasan, Member, AEC and former Chairman, AEC, recalling the earlier days of the Department and how it grew over the years. Shri N. Saibaba, Chief Executive, NFC, Dr. Prabhat Kumar, the then Chairman & Managing Director, BHAVINI and Shri G.Nageswara Rao, Director (Technical), NPCIL have delivered lectures as a part of this series. Lectures by other Unit Heads are on the anvil. These lectures are quite informative and have aroused good response from the colleagues, especially the young colleagues.

Exhibitions to bring awareness about the Departmental activities:

IGCAR is making preparation for taking active part in putting up posters and exhibits at the DAE Pavilion during the Science Congress, Mumbai University premises in the month of January 2015.

A public exhibition in the Kalpakkam Township, “AnuVigyan” is being organized during January 24-25, 2015, with the participation of Public Awareness Division, DAE and various units of DAE at Kalpakkam. The exhibition will have stalls highlighting the activities of IGCAR and other DAE Units at Kalpakkam. This exhibition is targeted to attract residents of the township, students, local press and people from the neighbourhood.

During the Annual Chennai Science Festival organized by Science City of Government of Tamil Nadu, it is proposed to put up special posters, exhibits and working models for attracting and educating public visiting the stalls from



Dr. P. R. Vasudeva Rao, Director, IGCAR, Shri G. Nageswara Rao, Director (Technical), NPCIL during the “Know your DAE” Lecture series

various cities in Tamil Nadu. More exhibitions with the theme of “AnuVigyan” are planned in various locations of Tamil Nadu during the year.

State-level Quiz and Painting Competitions:

It is proposed to conduct a state-level Science Quiz and painting competition, at various locations in Tamil Nadu,

Brochures:

Special brochures on the activities of IGCAR, FBTR and DAE Units at Kalpakkam have been brought out. Some of the brochures have been translated to Hindi and Tamil for distribution during various exhibitions. Similarly brochures on radiation safety and awareness are being brought out. Calendars depicting the achievements of various activities of IGCAR and radiation awareness have been brought out. Programmes to demonstrate handling of radioactivity in various schools and colleges are on the anvil.

Lecture-cum-Demonstration on handling Radioactivity:

Students from secondary and senior secondary (Classes IX and XI) from the KV and AECS schools in the township were given a lecture-cum-demonstration on the activities of DAE and on handling radioactivity and were shown around the facilities at IGCAR in December 2014 by a team of members from IANCAS. Kalpakkam chapter of IANCAS is also organizing a number of programmes on this theme at various colleges and schools across the state.

About 100 teachers participating in the in-service programme at AECS were shown various facilities in IGCAR. Visits to facilities at IGCAR for students from various colleges and educational institutions are being organized every week.

Reported by Dr. M. Sai Baba, RMG

Visit of Dignitaries



Dr. Anumakonda Jagadeesh, Director, Nayudamma Centre for Development Alternatives delivering the lecture

Dr. Anumakonda Jagadeesh, Director, Nayudamma Centre for Development Alternatives, delivered a talk on " Innovative Renewable Energy Technologies" during his visit to the Centre on October 7, 2014



Shri N. Saibaba, Distinguished Scientist and Chief Executive, Nuclear Fuel Complex, delivering the lecture

Shri N. Saibaba, Distinguished Scientist and Chief Executive, Nuclear Fuel Complex, delivered a talk on "Nuclear Fuel Fabrication – Its Challenges & Technological Spin Offs" on October 10, 2014 as a part of "Know your DAE" series being organised to commemorate the Diamond Jubilee of our Department



Prof. Gautam R. Desiraju, from Indian Institute of Science, delivering the lecture

Prof. Gautam R. Desiraju, Immediate Past President, IUCr, Solid State and Structural Chemistry Unit, Indian Institute of Science, delivered a lecture on " 100 Years of Diffraction Celebrating the International Year of Crystallography " organized as a part of series of lectures to commemorate the International Year of Crystallography on October 13, 2014



Dr. Prabhat Kumar, Chairman & Managing Director, Bharatiya Nabhikiya Vidyut Nigam Ltd (BHAVINI) delivering the lecture

Dr. Prabhat Kumar, Distinguished Scientist, Chairman & Managing Director, Bharatiya Nabhikiya Vidyut Nigam Ltd (BHAVINI), delivered the lecture on "Technological and Management Challenges, in Technology Launch Mega Project-PFBR", on October 31, 2014, as part of "Know your DAE" series



Prof. S. Ranganathan, from Indian Institute of Science, Bengaluru delivering the lecture

Prof. S. Ranganathan, NASI Senior Scientist Platinum Jubilee Fellow, Indian Institute of Science and Homi Bhabha Visiting Professor, IAS, Bengaluru delivered a lecture on "Quasicrystals: The golden Road to Stockholm" organized as a part of series of lectures to commemorate the International Year of Crystallography, during his visit to the Centre



Dr.H. R. Nagendra , Chancellor, S-VYASA Yoga University, Bengaluru, delivering the IGC Colloquium

Dr. H. R. Nagendra, Chancellor, S-VYASA Yoga University, Bengaluru, delivered the IGC Colloquium on " Four Decades of Research Highlights on Yoga for Stress and Diabetes Mellitus Control", during his visit to the Centre on December 17, 2014



Ms. Nisha Singh, Joint Secretary, DAE, with Dr. P.R. Vasudeva Rao, Director, IGCAR and senior colleagues of the Centre

Ms. Nisha Singh, Joint Secretary, DAE, visited IGCAR on December 23, 2014. Ms. Nisha Singh met Dr. P.R. Vasudeva Rao, Director, IGCAR, senior colleagues of the Centre and discussed about various programmes in progress. She then visited the Fast Breeder Test Reactor & KAMINI Reactor, Hot Cells and Non-Destructive Evaluation Division, Virtual Reality and Simulator at Electronics Instrumentation and Radiological Safety Group and Facilities at Fast Reactor Technology, Reactor Design and Materials Science Groups.



Shri G. Nageswara Rao, Director (Operations), Nuclear Power Corporation of India Limited, delivering the lecture

Shri G. Nageswara Rao, Director (Operations), Nuclear Power Corporation of India Limited, delivered a talk on " Indian Nuclear Power Program – Stage 1 Experiences" as part of Diamond Jubilee Celebration, during his visit to the Centre on December 26, 2014.

Awards & Honours

Dr. U. Kamachi Mudali has been awarded the **G.D. BIRLA GOLD MEDAL** for the year 2014 for his outstanding Research work in the field of Materials Science and Technologies from Indian Institute of Metals, Kolkata

Dr. S. Venugopal has been elected as a Fellow of the Academy of Sciences, Chennai

Ms. Dipti Samantaray has received the "Young Metallurgist Award for the year 2014" from Ministry of steels, Government of India on National Metallurgist Day, for her outstanding contribution in the field of flow behavior and microstructural evolution of nuclear grade steels"

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 Applied 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 programmes. They are the icons for young scientists and engineers to emulate. The awards consist of a memento, citation and cash prize.

The recipients of the Awards from IGCAR for the year 2013 are:

Homi Bhabha Science and Technology Award	: Dr. B. Purna Chandra Rao, MMG
Scientific and Technical Excellence Award	: Shri R. Suresh Kumar, RDG Dr. N. Subramanian, MSG
Young Applied Scientist/Technologist Award	: Shri Sanatana Maharana, RpG Shri P. Varadharajan, RpG Shri S.C.S.P. Kumar Krovvidi, FRTG
Young Engineer Award	: Ms. Saritha P. Menon, EIRSG Shri Nimala Sundaram, RDG Shri Y. V. Nagaraja Bhat, FRTG Shri Gagan Gupta, RDG
Meritorious Technical Support Award	: Shri A. Ananthakumar, CG Shri K. Arumugam, FRTG Shri S. Sundaramurthy, RpG Shri C. Ambujakshan Nair, FRTG Shri K. Subramanian, ROMG
Meritorious Service Award	: Shri R. Ranganathan, Administration Shri R. Sriram, Accounts

Group Achievement Awards:

Collaborative Research Coordination Under BRNS and Outreach Activities for Human Resource Development

Dr. D.M. Gaitonde, **Group Leader**

Dr. M. Sai Baba and Dr. Vidhya Sundararajan from **RMG** and Shri G. Padmakumar from **FRTG**.

The award was shared by colleagues from **BARC, IGCAR, NFC, VECC** and **DAE**

Design, Confirmation of Primary Sodium Pump by Analysis Testing and Evaluation

Shri V. Balasubramaniyan, **Group Leader**

Shri K.V. Sreedharan, Shri S. Athmalingam, Shri Bhagwana Ram Manda, Shri P. Chandrasekaran, Shri S. Chandrasekar, Shri S. Satheesh Kumar, Shri K. Madhusoodhanan, Shri S. L. N. Swamy, Shri M. Sakthivel, Shri Govind Kumar Mishra, Ms. R. Varuna, Dr. K. Velusamy, Shri S. Jalaldeen, Shri K. Natesan, Shri R. Suresh Kumar, Shri Bhuwan Chandra Sati, Shri P. Jayaraj, Shri R. Arulbaskar, Shri Ram Kumar Maity, Shri Juby Abraham, Shri Kulbir Singh and Ms. E. Bagyalakshmi from **RDG**, Shri V. Prakash, Shri B. K. Sreedhar, Shri Ranga Ramakrishna, Shri P. Anup Kumar, Shri P. Ravi, Shri J. Jaikanth, Shri K. Tamil Selvan, Shri P. Adithan, Shri N. S. Shivakumar, Shri S. Sureshkumar, Shri S. Balakrishnan, Shri A. Gururajan, Shri S. Rajkamal Singh and Shri K. H. Anub from **FRTG**

Development of In-sodium Sensors for PFBR

Shri B. Babu, **Group Leader**

Shri B. K. Nashine, Shri C. Asokane, Shri S. Chandramouli, Shri S.K.Dash, Shri G. Vijayakumar, Shri R. Rajendraprasad, Ms. P. Anitha, Ms. M. Mohana, Shri Chandra sekhar Singh, Shri M. R. Jeyan, Shri M. Kathiravan, Shri V. Gunasekaran, Shri A. Selvakumaran, Shri K.A. Bijoy, Shri A. Ashokkumar, Shri D.K. Saxena, Shri P. Bhavanirajan, Shri Prashant Sharma, Shri Vijay Sharma, Shri Krishnakumar, Shri Gautam Anand, Shri R. Punniyamoorthy, Shri D. Muralidhar, Shri S. Ravishankar, Shri S. Alexander Xavier, Shri Parmanand Kumar, Shri N. Venkatesan, Shri A. Thirunavukkarasu, Shri C. Rajappan, Shri P.C.V. Murugan, Shri R. Shanmugam, Shri C. Adikesavan, Shri M. T. Janakiraman, Shri N. Sreenivas, Shri L. Eagambaram, Shri P. R. Ashokkumar, Shri K. Arumugam, Shri R. Iyappan, Shri N. Mohan, Shri R. Parandaman, Shri S. Kannan, Shri M. Karthikeyan, Shri K. Ramesh, Shri Shaik Rafee, Shri J. Prabhakaran, Shri V. Kumaraswamy, Shri K. Ganesh, Shri Ashish Tiwari, Shri L. Mohanasundaram, Shri L. Muthu, Shri Pothi, Shri P. Lakshmayya, Ms. M. Chandra, Shri B. Veeraraghavan, Shri M. Arjunan, Shri Sudheer Patri, Shri S. Sureshkumar, Shri Tribhuvan Ram, Shri Muhammad Sabih, Ms. S. Narmadha, Shri N. Ravichandran, Shri A. Gururajan, Shri Hadibandhu Singh, Shri C.N. Sridhar, Shri K. Balaji, Shri S. Balakrishnan, Ms. J.I. Sylvia, Shri P. Vijaya Mohana Rao, Shri V.S. Krishnaraj, Shri M. Anbuchelian, Ms. S. Divya, Ms. S. Nagajothi, Shri G. Anandan, Shri P. Bakthavatchalam, Shri C. Ambujakshan Nair, Shri A. Kulanthai, Shri R. Gunasekaran, Shri V. Krishnamoorthy, Shri S. C. S. P. Kumar Krovvidi, Shri J. Jaikanth, Shri T. V. Maran, Shri K. Mohanraj, Shri P. Madankumar, Shri Rakesh Kumar Mourya, Shri Shiv Prakash Ruhela, Shri C. Meikandamurthy, Shri Vijay Tirkey, Shri R. Ramalingam, and Shri A. Kolanjiappan from **FRTG**, Dr. C. Babu Rao, Ms. S. Sosamma, Shri K. A. Gopal, Ms. Romali Biswal and Shri Rajesh Saxena from **MMG**, Shri M. Krishnamoorthy, Shri K.M. Natarajan, Shri. A. Padmanabhan, Shri B. Thiruvengadam, Shri C. Arumugam, Shri G. Ramadoss, Shri J. Abilash and Shri B. Palani from **ESG**, Shri S. L. N. Swamy, Shri M. Sakthivel, Shri Govind Kumar Mishra, Ms. R. Varuna, Shri B. Madhavan, Ms. R. Vijayashree from **RDG**, Shri Saju T. Abraham, Shri C. Muniyandi, Shri K. Krishna Chaitanya, Shri P. Narayana Rao, Shri D. Henson Raj, Shri M. V. Kuppasamy from **EIRSG**

Development, Production and Supply of Enriched Boron Carbide (B₄C) Pellets for PFBR Project as control and Diverse Safety Rods (CSR and DSR)

Dr. S. Anthonysamy, CG and Dr. R.C. Hubli, MG, BARC, Group Leaders

Shri A. Veerapandian, Shri I. Kaliappan, Shri R. Ranganathan, Ms. B. Suhasini, Dr. K. Ananthasivan, Shri G. Rajendra Prasad, Shri R. Krishna Prabhu, Dr. Ashish Jain, Shri M. Stanislas, Shri J. K. Sekar, Shri T. Ramamoorthy, Shri V. Paramasivam, Shri E. Gajendran, Ms. K. Usha Lakshmi, Ms. Umamaheswari Rajendraprasad, Shri V. Suresh Kumar, Shri Y. Ravi, Shri D. Seenivasan, Shri V. Venkatachalam and Ms. Preeti Saroop from CG. Shri G. Mohankrishnan, Dr. C. Anand Babu, Shri D. Sujish, Shri S. Vikraman, Shri S. Suresh, Shri R. Nagaraj, Shri Joby Joseph, Shri V. Nandakumar, Shri R. Kannan, Shri R. R. Sridharan, Shri M. R. Marikumaran, Shri E. Radha, Shri S. Anbarasan, Shri D. Alagar from FRTG, Dr. B. K. Sharma from ROMG, Ms. T. Sridevi and Shri M. Vincent from EIRSG.

The award was also shared by colleagues from BARC, HWB and NFC

Fabrication of Sphere-PAC and Preference Test Fuel Pins and Irradiation in FBTR

Dr. K. Nagarajan, CG, Group Leader

Shri G. Ravisankar, Dr. K. Ananthasivan, Dr. R. Venkata Krishan, Shri Dasarath Maji, Dr. R. Babu, Shri Abhiram Senapati, Shri Gude Jogeswararao, Shri B. Kothandaraman, Shri N. Vinod Kumar, Shri Y. Yuvaraj, Shri D. Kothandan, Shri T.V. Prabhu, Shri R. Padmanabhan, Shri A. Anantha Kumar, Shri R. Lavakumar, Shri Abhishek Kumar Yadav, Shri G. Nantha Kumar, Shri M. Masanam, Shri G. Parthiban, Shri R. Rajaram, Shri K.A. Samuel Kutty, Shri N. Eswaran, Shri P. Arunagiri, Shri V. Dilli babu, Shri A. Praveen, Shri G. Lakshmanan, Shri R. Kumaran, Shri T. Ramamurthy, Shri E. Nagappan, Shri E. Mohanraj, Shri B. Vijayavelu, Shri Kathiravan, Shri B. Radhakrishnan, Shri M. Saravanan, Shri R. Parthasarathy, Ms. Sai Subbulakshmi, Shri G. Rajendra Prasad, Shri Y. Ravi, Ms. B. Suhasini, Shri J. Prabhakar Rao, Shri Ajay Kumar Keshari, Shri G. Gunasekaran, Shri K. Vijayakumar, Shri D. Vijayakumar, Shri Mohammad Sithick, Shri T. Ravi, Ms. R. Akila, Ms. N. Chitra, Shri Brahmaji Rao and Shri N. Ravi from CG, Shri P. Narayana Rao, Shri Krishna Chaitanya, Shri C. Muniyandi, Shri D. Henson Raj and Shri G. Vijayaraghavan from EIRSG, Shri S.A. Natarajan, Shri P. Karuppasamy, Shri P. Balakrishnan, Shri E. Venkatesh, Shri S. Manimaran, Shri P. Loganathan, Shri K. Narayanan, Shri C. Muthusamy, Shri M. Damodaran from ESG, Shri S. Clement Ravi Chandar, Shri M. Asok Kumar and Shri T. Rajkumar from RDG, Dr. S. Murugan, Shri K.A. Gopal, Shri M. Muthu Ganesh, Shri Rajesh Saxena, Shri R. Ramesh, Shri K. Purushothaman, Dr. Divakar Ramachandran, Shri C.N. Venkiteswaran, Shri A. Vijayaraghavan, Shri V. Anandaraj, Ms. M. Padalakshmi, Shri S. Vinod Kumar and Ms. S. Gomathi from MMG, Shri S. Varatharajan, Shri S. Kanagaraju, Shri K. Kamaludeen, Shri G.N. Chandrasekaran, Shri V. Gunasekaran and Ms. Gowri Lakshmanan from ROMG, Shri N. P. Seshadreesan from FRFCF

The award was also shared by colleagues from BARC

Salvaging a Worn Out Cast Iron Flywheel Casing of Ward Leonard Assembly of Sodium Pump

Shri M. Babu, ROMG, Group Leader

Shri G. Srinivasan, Shri A. Babu, Shri V. Alagudurai, Shri K.G. Subramanian, Shri U.Chandrangdan, Shri D.Vignesh Babu, Shri N. Kathiresan, Shri R. Desingu, Shri M. Arumugam, Shri Syed Saleen, Shri K. Subramanian, Shri S. Sundaramurthy, Shri R. Gopal, Shri Augustine Chacko, Shri A. Nagalingam, Shri M. Chitrarasu, Shri M. Maharajan, Shri C. Kannan, Shri M. Soundar, Shri N. Basaviah, Shri E. Ramesh and Shri A. M. Kannan from ROMG, Shri C. Palani, Shri S. Sateesh Kumar, Shri T. Saravanan, Shri S. George, Shri P. Loganathan, Shri A. Ramanathan and Shri S. Ramesh from ESG

Best Paper/Poster

Corrosion behavior of 304LN Activated TIG and Flux Cored Arc Weld Metals

Ms. Anita Toppo, Dr. M.G. Pujar, Dr. B. Arivazhagan, Dr. M. Vasudevan, Dr. C. Mallika and Dr. U. Kamachi Mudali from MMG

International Welding Symposium (IWS2K14), held at Bombay Convention and Exhibition Centre, Mumbai, during October 28-30, 2014

Best Paper Presentation Award (Royal Arc Award)

Temperature Dependent Phonon Frequencies in Monolayer MoS₂

Shri P. Anees, Shri M. C. Valsakumar and Dr. B.K.Panigrahi from MSG

DAE BRNS Multiscale Modeling of Materials and Devices (MMMD-2014), held at Bhabha Atomic Research Centre, Mumbai during October 30 - November 2, 2014

Best Poster Presentation Award

Synthesis of Fe₃O₄-SiO₂ Core-shell Nanoparticles and High Temperature Thermal Stability Studies

Shri Gopinath Shit and Dr. John Philip

5th DAE-BRNS Interdisciplinary Symposium on Materials Chemistry, held at Bhabha Atomic Research Centre, Mumbai during December 9-12, 2014

First Best Poster Presentation Award



Hummingbird hawk-moth

Dr. M. Sai Baba,

Chairman, Editorial Committee, IGC Newsletter

Editorial Committee Members: Dr. K. Ananthasivan, Shri M.S. Chandrasekar, Dr. N.V. Chandra Shekar, Dr. C. Mallika, Shri K. S. Narayanan, Shri V. Rajendran, Dr. Saroja Saibaba and Dr. Vidya Sundararajan