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IGC Newsletter

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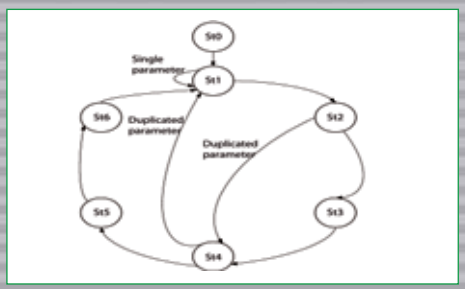
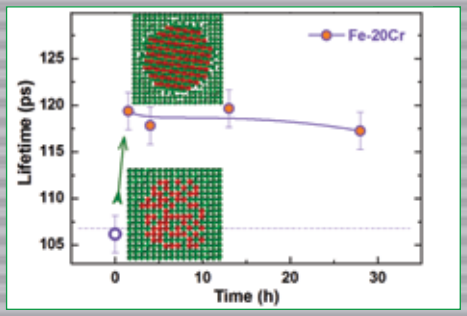




INDIRA GANDHI CENTRE FOR ATOMIC RESEARCH
http://www.igcar.gov.in/lis/nl100/igc100.pdf

From the Editor

Dear Reader

It is my pleasant privilege to forward a copy of the latest issue of IGC Newsletter (Volume 100, April 2014 issue).

In this issue we have had the privilege of Prof. C.N.R. Rao, National Research Professor, Honorary President & Linus Pauling Research Professor, Jawaharlal Nehru Centre for Advanced Scientific Research, Bengaluru, Head of the Scientific Advisory Council to Prime Minister and Director, International Centre for Materials Science, sharing his experiences with a team of young officers and senior colleagues of the Centre.

In the first technical article Shri K.K. Rajan and colleagues have described the development of sodium sensors for Fast Breeder Reactors.

In the second technical article Shri G. Srinivasan and colleagues have given an overview of the utilisation of FBTR as an irradiation facility and enhanced utilisation of KAMINI Reactor.

In the Young Officer's forum Shri Satya Rajesh Medidi has shared his experience in the design and development of fine impulse test system for shutdown by control rod actuation mechanism (SCRAM) logic system of FBTR.

In the Young Researcher's forum Dr. Hari Babu Sata has shared his results on positron annihilation studies of model iron-chromium alloys and ferritic/martensitic steels.

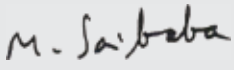
This Newsletter carries reports on the "First International Conference on Structural Integrity (ICONS-2014)", "Second IGCAR-KAERI Workshop on Sodium cooled Fast Reactors", "IAEA Technical Meeting on Development of Advanced Fuels for Fast Reactors" and Seminar on "Chemical Engineering in Nuclear Technology (CHEMENT-2014)" with the theme of "Recent Advances in Fuel Cycle Technologies.

Dr. Avinash Chandra, Scientific Advisor to Defence Minister, Shri P.S. Parihar, Director, AMD, Hyderabad, Dr. R. Chidambaram, Principal Scientific Advisor, Government of India, Shri Amandeep Singh Gill, Joint Secretary (D&ISA), Ministry of External Affairs, Prof. J.B. Joshi, DAE - Homi Bhabha Distinguished Chair Professor and J. C. Bose Fellow and Prof. Valiathan, Founder-Director, Sree Chitra Tirunal Institute of Medical Sciences and Technology & National Research Professor of Government of India, at Manipal University visited the Centre during the last quarter.

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

Interaction with Prof. C. N. R. Rao

Professor Chintamani Nagesa Ramachandra Rao, did his Ph.D. (1958) from Purdue University. He is currently the National Research Professor, Honorary President & Linus Pauling Research Professor, Jawaharlal Nehru Centre for Advanced Scientific Research, Bengaluru, Head of the Scientific Advisory Council to Prime Minister and Director, International Centre for Materials Science. Prof. Rao is the founder of the Jawaharlal Nehru Centre for Advanced Scientific Research and Founder Chairman, Solid State and Structural Chemistry Unit and Materials Research Laboratory, Indian Institute of Science.

Prof. Rao has served as Director, Indian Institute of Science (1984-1994), President, Jawaharlal Nehru Centre for Advanced Scientific Research (1989-99), Member, Planning Commission, Government of India, and Chairman and Director of Reserve Bank of India. Prof. Rao has held important positions in National and International Bodies, some of them include Chairman, Science Advisory Council to the Prime Minister, immediate past President, The Academy of Sciences for the developing world (TWAS), Trieste, Chairman, National Nano Initiative, Government of India and Member, Atomic Energy Commission of India. Some of the important academic positions that he held include; Head of the Department and later Dean of Research of Indian Institute of Technology, Kanpur, Visiting Professor, Purdue University, University of Oxford, Joseph Fourier University, Grenoble, France; Distinguished Visiting Professor, La Trobe University, Melbourne, Australia and University of Cambridge; Honorary Professor, Indian Institute of Science and University of Wales, Cardiff.

Prof. Rao has made significant contributions in the field of solid-state and structural chemistry. He has received Honorary Doctorates from sixty three universities spread across the world such as Colorado, Bourdeaux, Liverpool and Oxford. He has around 1600 research papers to his credit and has authored and edited around 45 books. He is a Fellow of twenty five Science Academies including Indian Academy of Sciences, The Royal Society, London and Foreign Associate, National Academy of Sciences, USA and Founding Fellow of the Third World Academy of Sciences, among others. Prof. Rao has been bestowed with many awards and honours, notable amongst them are Bhatnagar Prize in Chemical Sciences (1968), Padma Shri (1974), Padma Vibhushan (1985), Karnataka Ratna (2001), India Science Award (2004), Dan David Prize (2005), Trieste Prize (2012) and Bharat Ratna - the highest civilian award (2014).

Sir, in your young age have you thought, you will be what you are today?

At the age of around sixteen and seventeen, I made up my mind to do science. I wanted to be a scientist and there was no doubt about that. Fifteen years ago if one had asked me, as to where I would be placed in science by the year 2013, I would not have known. Niels Bohr once said, the amazing thing about prediction is, "one cannot predict the future". Similarly, as far as science is concerned, where it leads you, how far you go, what you discover, what level you reach, whether you will gain fame or not, are things one cannot predict. On the other hand, how you pick problems and proceed, are the factors that decide one's future in science. In India, most of us have to learn how to do this. It is not easy to teach the same as well. Honestly I am not surprised about what I am today, but I am very grateful that things are going on so well. I have no regrets.

How you initially got motivated to do science?

That was during my under graduate days. During this period, India had just got its freedom and was a very poor country. There was no real equipment like for example spectrometers, in most of the universities. As I mentioned earlier, I always wanted to do science, but there was no opportunity for undergraduates to pursue research those days. Then I started looking for an opportunity to carry out research for my Master's degree. Those days Aligarh Muslim University and Banaras Hindu University were two universities of great repute. Banaras was the center where everybody was pursuing research, so I opted to go to Banaras. Those days in Uttar Pradesh only DC electricity was available, and that had to be converted to AC for performing experiments. So we could do experiments only in the night. While returning to my hostel at 1 or 2 AM in the morning, I would see lights, still glowing in most laboratories of Banaras Hindu University. This reinforced my desire of becoming a scientist.

I was exactly 17, when I joined my M.Sc. and that was the time when Linus Pauling had discovered the alpha helix structure of protein, for which he later received the Nobel Prize (for the year 1954). I always wondered how this man determined the alpha helix structure. On hearing from my teacher, that a book on "Nature of the Chemical Bond" had been written by Linus Pauling, I wanted to buy it. Luckily my teacher had a copy and I borrowed the book from him. In 1952, I wrote to Pauling mentioning that I wanted to work with him on the structure of molecules. He then wrote back stating that "I no longer work in that area, I work on proteins. May be if you want to work on molecules you could work with one of my students". Linus Pauling inspired me to move forward towards realizing my dreams.

Can you share with us your experiences at Purdue during your stay for Ph.D?

After completing my post-graduation at Banaras, I spent almost an year in India. Honestly speaking, my initial wish was to pursue my Ph.D. in India, but there was no institute where research was being done in contemporary chemistry. I wanted to learn spectroscopy, quantum mechanics etc. and so I left for Purdue.

Going to Purdue, was like a rebirth to me. I had the opportunity to listen to many good lectures. I used to write notes on some idea arising from some of those lectures. One of my professors told me, why don't you publish these notes, so I started publishing at the age of twenty. As a student, I had published around fifteen papers and those papers had nothing to do with my Ph.D. work. Prof. Lieber, an organic chemist, wanted me to assist him in studying spectroscopy of his compounds, as he was not much familiar with spectroscopy. In fact, I learnt spectroscopy because of him and published papers on Raman, Infrared and Ultraviolet Spectroscopy. Later, I did my Ph.D. on molecular structure by electron diffraction of gases with Prof. Livingston (student of Linus Pauling). He was a wonderful person. Whenever he met me, he used to say "Ram do good work, Ok". He would take me for lunch every Saturday. I would really be waiting for Saturdays, a good lunch was not affordable those days by students like me. I had a wonderful set of people around me, including my teachers who encouraged me to do what I wanted to do.

Sir, you worked with Prof. Lieber, can you share with us your experiences working with him?

Prof. Lieber was the organic chemist who wanted me to work with him. I worked as a research assistant with him for one year. Even after that, I used to go and work with him in the evenings. Though he was not my research supervisor, I published a lot of papers with him. I owe a lot to him as I learnt all the spectroscopy because of him.

One day a teacher was telling us about the isoelectronic principle. Molecules with same number of electrons would have similar structure. They also would have similar properties. If we consider CH_3-F, CH_3-OH, CH_3-NH_2, CH_3-CH_3, as all of them have the same number of electrons. There must be something similar amongst them. Their thermodynamic properties show some simple relationship. Based on

this, we published a paper. I enjoyed doing such things a lot. If I have to redo all over again, I don't mind going back as a Ph.D. student.

What were the difficulties for an Indian staying away from family in a foreign country?

America was a very conservative country those days and living in the Midwest, not too far from the south was difficult. Right at Purdue, we were not served in some restaurants. At Indianapolis, which is in the north, I once went to have a cup of coffee at the bus station, one person said, "fellow aren't you on the wrong side". Only then I realized that black men had to go to the back side for having coffee. Another incident which I recollect is, Dr. J. Ramachandran from Presidency College (he was one of our famous biologists and subsequently became the first president of AstraZeneca, Bengaluru) and me had reserved a room in a hotel in Salt Lake City. On reaching the hotel, the receptionist looked at both of us and told "I don't think we have any room for you". I politely asked how you can deny, when we had reserved our rooms in advance. She replied "you better check at YMCA, you may get a room there". Other than these few experiences, America was a great country. I tell you, I owe a lot to America professionally. It gave me freedom to think, freedom to be independent. I had around thirty publications when I left America, out of which only five were based on the work carried out for my Ph.D.

For my post-doctoral research, I worked with a very great man who had worked with G. N. Lewis (greatest Chemist of 20th Century). I would do something and he would say "Hi Ram, why don' t you publish it". I had four to five papers with him and many others were authored only by me. At that time I decided, not to discourage youngsters. I do not know what young people think of me, but I do my best for the youngsters to come up and stand on their feet.

Sir, how do you go about selecting your students?

I am no longer sitting in selection committees, as I have grown old. I let the young people do this. They select a student and bring him/her to me telling he/she is fantastic. I have had some bad students, but fortunately to compensate for this I had very good students as well. I would say that, on an average, the quality of students in science has come down in the past few years. I am able to see a slight increase in quality in the last two years, may be due to IISERs and similar institutions coming up. Somehow I am not getting as many students of good quality during the last few years.

What is your opinion on the current education system of India?

It is an area where there is high anticipation, but poor funding from the Government. I feel that investment on education, which is at present hardly 2% of the GDP, should be increased to 6%. In the National Policy of Education, which was written long ago, it was proposed to raise the funds for education to 6% of GDP, even though everybody agreed, this has not yet been implemented. Public Universities like Madras University, Calcutta University and at least a few IITs, should have been as good as the best in the world. I always wonder how come we don't have a Harvard or MIT here. I am still a professor at Cambridge University and University of California. I would say that the best of the institutions in India do not have the kind of infrastructure and support facilities that a reasonable institute abroad has.

Take for example South Korea. There nobody can complain that his work was hindered by the lack of infrastructure. In our country, there are enough reasons for people not to work.

We would like to shift the discussion to your research areas. You are a solid state chemist, and then moved to superconductors where you have made significant contributions, from superconductors to fullerenes and graphenes. What we would like to know is how do you focus on a particular area at a given time?

If you are interested in phenomena or areas of a particular kind, your interests become broad. On the contrary, if you are interested in a particular compound or technique, then your interests become narrow and you cannot change easily. Once G.N. Lewis was asked to define "Physical Chemistry or Chemical Physics": He defined chemistry as: "doing anything that is interesting". Science, to me, is doing anything that is exciting and interesting. I did a lot of work on oxides and still continue to work on oxides, not because they are oxides but due to the phenomena associated with them. Today I may be interested in oxides; tomorrow I may be interested in multiferroics. If you are basing your work on structure, phenomena and properties, there is always a link or continuity. If you think you have found a new area, which is exciting to work and where you can contribute, don't hesitate to pursue. As far as graphene is concerned, I thought that I have a lot to contribute as a chemist.

For example, Dr. Sood collaborated with others and did electrochemical doping of graphene, both by electrons and holes, and showed what

happened to the Raman bands. I wondered why should we do that in a complex way, I can just dope graphene with an electron donor/ acceptor molecule and study the G-band shifts. I start relating one with the other. If you start working on things and if you are passionately and intensely involved in them, you create new things. H.C. Brown, quotes a very famous poem to say, “you start with a small idea, it becomes a huge tree and then a forest. This is the beauty of science".

Is it intuition driven, Sir?

It is a combination of intuition, inspiration and of course perspiration.

Sir, in your opinion what should be the main focus of research?

It all depends on an individual’s interest - What excites him/her most, as far as research is concerned. At the institutional level, it all depends on the goals and mission of the institution. Take Sir C.V. Raman, for example. He did his M.A and worked as an Accounts Officer at Nagpur. He used to go to the science college at Nagpur in the evenings and do his experiments on musical instruments. Later he became a Fellow of the Royal Society, based on the experiments he carried out during evenings. To become a Fellow of the Royal Society is very difficult even now, and was more difficult those days. He was awarded the Nobel Prize, for the experiments he carried out during evenings, not full time research as you and I do. We need to ponder as to what made him to do that. I would say knowing stories on science, is more important than knowing science itself. If you know how and why ideas were created, you become more excited. Whatever I am worth today is because, I live with all these scientists and they are my companions. Even in my dream I see, Faraday, C.V. Raman and so on. I tell you nobody can beat Faraday. H.C. Brown, my teacher at Purdue died at the age of 94 and you won't believe he had seven papers the year he passed away.

Who is your role model?

Michael Faraday is my first role model, second is G.N. Lewis and Linus Pauling. Unfortunately G.N. Lewis never got the credit he deserved, he did not get a Nobel Prize, but many of his students received Nobel Prizes.

Sir, over a period of time basic research itself has changed, now a days people sit in front of computers and control instruments, can the discoveries be made by such approach?

You may sit in front of computers and control instruments, not me. Greatest discoveries still come out of experiments. This year’s Nobel Prize was won by three computer professionals; I would say they must share it with the computers, without which they would not have got the award. In my life, I enjoyed a lot doing experimental work. I collaborate a lot with theoreticians. I owe a lot to theoreticians, and many of my papers I have a theoretician as a co-author.

You have seen the growth of science in India since the 1960's. If science in India has to reach its pinnacle, what are your expectations from the students who are currently pursuing their Ph.D.?

I would like to share with you one of my experience with Sir C.V.Raman with whom I became close towards the end of his life. In 1969, Vikram Sarabhai organized a party to celebrate the 80th birthday of C.V. Raman, you won't believe, every Indian scientist of repute attended the party and I was one of the speakers. In November 1971, just before the death of Sir C.V.Raman, there was the annual academy meeting, where I delivered a lecture on “Hydrogen bonding and structure of water". There were only thirty or so members of the academy and Sir C.V.Raman was seated in the front. After I delivered my lecture, he hugged and told me, ‘what a beautiful lecture!’.At the end he told me" you know C.N.R. Rao, I feel so sad that India has not made to top grade in science. I am going to die one day without seeing India excelling in science". Now that I am 80, I often remember his words. On analyzing why it is so, I feel that it is mainly because of subcritical support to the institutions. We also have not developed a friendly scientific atmosphere where we promote each other. All these have contributed to India not performing well. Even with the existing facilities we can do three times better than what we are doing now.

What is your vision about India in the coming decades?

If we make the right investments, in twenty years, we can easily be among the top three to five in the world. We should support science

financially and morally. Look at nanoscience. We started nano research only ten years back, and we are among the top four countries. With targeted funding and focused effort, we certainly can do well.

You look at the media, nobody talks about the real issues of India like why India did not become top in science. None seems worried about this. In the value system, science does not figure. Only Pandit Nehru and to some extent late Shri Rajiv Gandhi placed science as very important.

In the coming decade, what do you think our prime focus should be towards?

Energy is one. Let us take for example atomic energy. It can provide about 10% of our energy requirement in the coming years. We have done nothing on artificial photosynthesis and lithium batteries. Picking the right problem is the real challenge. Water management is going to be one of the biggest problems of India. If we properly manage rain water and agricultural water, it can be managed but nobody is seriously doing it.

My wife keeps telling me this. "Do you know how man progresses? Because, he has the instinct for self-preservation. If he sees a tiger or snake, he runs away". Similarly, Governments should have the instinct for self-preservation. They must get interested in energy research. I am trying to bring a commission for energy research.

You are heading several policy making bodies in the country, how do you successfully take on such huge responsibilities and continue your active research?

I am not an administrator nor am I running the Government, I am in only one policy making body. For advice and policy making, I spend few days in a month, may be two or three days. I am left with the rest of 28 days. On an average 20-22 days of a month, I am in Bengaluru. I meet my students every day. My main focus is science, and everything else comes later.

With regard to policy making, do you think that we have missed out on semiconductors?

I came from America (with partly physics background) and was shocked to see that there was nothing in silicon research in India. The only thing that was going on those days (in 1950's) was to grow silicon and germanium crystals and work on perfection of crystals and such topics. We certainly missed the semiconductor revolution in India. Microelectronics did not come to India. We never had a proper foundry. This is mainly because of the policy of the Government that decided on the R&D to be carried out in electronics.

One of the weaknesses we see in India, is in the domain of instrumentation, would that become a limitation for us?

Yes, it has always been bad. I am an ardent instrument builder and even now I build instruments. You won't believe. I first did thermogravimetric analysis after building the instrument on my own. Similarly differential thermal analysis, we built many spectrometers. This culture has vanished these days. Everybody wants readymade instruments. It is painful to see money being spent in crores to procure instruments, which in principle can be built indigenously.

Industry and public sector have never had a complete open door policy. We have to privatize semiconductor, electronics, nanotechnology etc., so that they will do something to make profit.

Do you think eminent scientists in India can use their status to bring industry as well as academics together?

I have spent the past fifty five years in India as a Professor and I am yet to get any funding from Indian industry. But I have had a lot of support from outside. Recently, I got a grant of four million dollars from a Sheikh in the Emirates. I have told that I am ready to quit everything, if someone gives four billion dollars to build a university like Stanford or Harvard in India. People like me, are ready to work and accomplish such a mission free of charge, but nobody has come forward as yet. The industrialists have not considered science as an essential ingredient of progress.

How did you conceptualize Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR)?

I did not conceptualize JNCASR. Actually what happened was that there was a committee set up under the chairmanship of former president Shri R.Venkataraman to do something important on the occasion of the centenary of Pandit Nehru in 1989. They received many

ideas, out of which one was to establish a small science institute that would work on a few important areas of research. I got a call from Shri Manishankar Iyer who informed that out of hundred and fifty proposals setting up of a science institute has been approved and requested me to send a plan for the same. Myself and a few of my colleagues prepared a plan and forwarded it. Once the plan was approved, there was real competition. Allahabad and Pune wanted it. I had a discussion with the then Prime Minister, late Shri Rajiv Gandhi on this issue. He asked why don't you set this up at Bengaluru and I accepted it. Initially, it was supposed to be closely linked with the Indian Institute of Science. Somehow IISc was not too welcoming about the proposal. I tried my best. The then Chief Minister of Karnataka allotted 20 acres of land free of cost, and we started building the Centre. It has turned out to be one of the best institutes.

Sir, do you think institutes like JNCASR are very much required in the north east?

Yes, they are required in every part of India. Take the example of IISERs. We instituted one each in the east, west, north, south and centre. We need about 30-40 JNCASRs focusing on five to six areas of research. In India every university has Hindi, Sanskrit, English, Mathematics, Philosophy, Physics, Chemistry, etc., I consider this to be wrong. We must develop universities for specialized subjects like what is done in Japan. There is a University of Computer Science and Electro-technology. India requires two to three thousand universities.

One side we want to have more institutes, but public funding is insufficient for the same, how to overcome this?

Government of India had promised that education and health would be the two priorities for it. But it has not invested in either of them. The investment is very bad in the health sector. They promised to invest 6% on education in 1990, but it is only 2%. Future Government should raise the investment on education to 5 or 6% at least and to 2% on science. When the Government is not making any investment, how can we expect the industries do that?

There was a talk about foreign universities coming down to India; how far has that progressed sir?

Nobody is coming down. If Cambridge or Oxford comes down, I would be happy but they are not coming. When Cambridge or Oxford is reluctant, others would also feel the same. Instead we must have collaborations with these universities which will be very useful.

Sir, we are amazed at your energy and enthusiasm what is the secret behind this?

"sab man me hei, mera shakthi bhi man me hei" (everything is in the mind, my strength is also in my mind). I lead a very disciplined life. God has given me the energy for whatever I want to do.

Sir, we would like to ask you one personal question. You are portrayed to be very frank, has that created trouble?

Yes, of course many people write against me, I am not bothered about it. I have never lied in my life. Even if it is unpleasant, I tell it straight. It is better to be honest. By being honest, by and large I have not suffered. Honesty is something in built in science. You cannot be a scientist being dishonest and telling lies. Even if you have done a mistake, you must admit the same. I am happily married for the past fifty four years. My wife is a very good companion, and she too prefers me to be honest and straight forward.

Why is that we don't have journals of International repute?

We have lost the chance. Look at China. Royal Chemical Society publishes one third of Chinese articles, similarly Institute of Physics, two journals are partly owned by Chinese - they are aggressive. I tried my best to see that the academy in Bengaluru, published one or two journals in collaboration with foreign professional societies, but it was not taken up.

Other than Science what are your hobbies?

Music is my biggest love after my wife. I read a lot, mostly historical novels, poetry and at times fiction too. During the Centenary year of Tagore, I read eight to nine major works on Tagore. Recently I read a book written by Dr. Sudhir Kakar "Tagore in his youth". Tagore had a tough life, as he could never spend more than five minutes with his mother. Servants would take him away, as his parents were of the old Zamindari type. I enjoyed reading about his youth, love, anger and poetry. His entire life is full of pathos and tragedy woven into high idealism, spirituality, imagination and inspiration. This mixture gave him his poetry. At the end, when he gets the Nobel prize he says," I have

reached the pinnacle of success, I find that the pinnacle is just barren and not enjoyable". In one of the poems of Gitanjali, he tells "When the waves of time dash against these rocks of accomplishment, they slowly disappear".

Has winning the Bharat Ratna made any difference to you?

Not really, but it is nice to have received it. It is neither going to change my life nor make me do anything special. I will continue to do what I am doing, continue to do more and continue as a scientist.

What is your advice for the aspiring scientist?

Recently, I was invited to give a lecture at a symposium organized by the Nobel Chemistry Committee in South Korea. There were totally eight speakers; four of them were Nobel Laureates. It was a beautiful symposium organized by the Koreans and was of a new kind. There were 600 people as audience of which 300 were the brightest high school children of Korea and three hundred senior scientists. I asked them, what is this new thing. They replied that the younger generation should listen to such lectures and interact even if they cannot understand the technical content. One of the speakers was a great chef. Her lecture was fantastic and she concluded her lecture saying that "I wanted to be a chef and became a chef". One point I liked the most in her lecture was that, she told the reason young people give up is, they pick up everything other than the thing they like most. Students should not go for engineering, because parents push them into it.

I owe a lot to my parents, I was the only child of my parents. They allowed me to do whatever I wished to I told I am interested to study only at Banaras and they said, 'fine agreed!'. Many wanted me to become an IAS officer, but when I told my parents that I want to be a chemist and do research, they said fine. My father was an educated person who could well understand what I was talking. He could have interfered with my wishes but he never did that I owe him a lot. He said, do what you think best for you.

A child may be interested in art or doing something in theatre. We don't allow that child to pursue his or her passion, but instead force him/her to do engineering. In Bengaluru, people laugh at you, if you go for an undergraduate degree in science; as a result of this many colleges have closed the science departments. I insist that children must be allowed to follow their passion. That is the reason America is what it is today.

Young Officers with Prof. C. N. R. Rao, Dr. P. R. Vasudeva Rao, Director, IGCAR and senior colleagues of the Centre

The team:
Ms. Gurpreet Kaur, Ms. Rimpi Dawar, Shri Anindya Bhattacharya, Shri Suddhasattwa Ghosh, Shri Avik Kumar Saha, Dr. K. Prabakar, Shri Shilpam Sharma and Ms. K.Saipriya

Development of Sodium Sensors for Fast Breeder Reactors

The highly reactive nature of sodium used as coolant in FBRs has restricted the use of conventional instruments and sensors for process monitoring. The requirement of enhanced safety and reliability has necessitated development of new techniques of instrumentation for safe and reliable operation of reactors. Sensors are used in FBRs for measurement of temperature, level, flow and leak. Normally, the sensors are designed to be of non-intrusive type so that the high integrity required for the sodium systems is maintained at all times even during sensor maintenance. The sensor should be made up of materials that are compatible with liquid sodium and capable of withstanding high temperatures as well as radiation. As sodium is a good conductor of electricity, sensors that work on basic electrical principles are being extensively used in liquid sodium systems. This article gives an overview of the specialised sensors developed for sodium at IGCAR.

Sodium Level Sensors

Level sensors are needed for monitoring the sodium level in the various capacities of the reactor systems and to ensure that the coolant level is always at the top of the core. Though discrete level sensing is sufficient, it is advantageous to have continuous level sensors to determine other parameters such as rate of change of level. Different types of sensor developed for level measurement are; spark plug type, resistance type (RTLP), dipstick type and mutual inductance type level probes (Figures 1a to 1d).

Spark plug type level probe works on the principle of grounding the sensor in contact with sodium. It is a simple probe comprising of a spark plug with an extended stainless steel rod welded to the center conductor. The length of the rod depends on the sodium level to be indicated in a vessel. As the sodium level raises and touches the end of the rod, the electronic circuit of the probe will be grounded through sodium. Though simple, this probe is not suitable for high temperature applications as sodium vapour deposition will lead to spurious signals.

Resistance type level probe works on the principle of a step change in its resistance on contact with liquid sodium. It consists of a stainless steel tube inside which copper rod is kept insulated along its length by ceramic beads. The lower end of the copper rod is brazed internally to the stainless steel tube bottom, thus establishing electrical continuity between the tube and the rod at the bottom end. This arrangement is mounted on the vessel in which the sodium level is to be detected. Under healthy condition, a fixed voltage of about 75 mV is dropped across the sensor whose resistance constitutes the resistances of copper rod and stainless steel tube in series. During sodium level appearance, the bottom of the sensor touches the liquid sodium, thereby shorting the stainless steel tube. As the resistance of copper rod is much lower than that of the stainless steel tube, there is a step decrease in the sensor output (i.e., from 75 to about 10mV). The step change is

Figure 1: (a) Spark plug (b) resistance (c) dipstick type level probe and (d) mutual inductance type continuous level probe

detected by the electronics and is used for level monitoring.

Dip stick type level sensor consists of one primary coil and a differentially wound secondary coil. The output will be zero when the probe is fully out / fully immersed in sodium and it will be maximum when the dipstick is half immersed. This enables to determine the exact surface level of sodium easily. This sensor is used as reference probe for calibration of other level probes in sodium facilities.

Mutual inductance (MI) type level probe works on the principle of change in mutual inductance with change in sodium level. These type of probes are used for the measurement of discrete as well as continuous levels in sodium capacities. The MI type continuous level probe consists of one primary coil and one secondary coil as shown in Figure 1d. The primary coil is excited by an AC constant current source which induces e.m.f in the secondary winding by mutual induction. When the sodium level increases in the vicinity of the level probe, eddy currents are induced in sodium that opposes the main flux, which in turn reduces the secondary voltage. Hence as the sodium level increases, secondary voltage reduces. This reduction in voltage is a measure of sodium level. The secondary output is not only a function of sodium level but is also a function of temperature of sodium. Resistivity of sodium increases with temperature resulting in reduction of eddy currents. As a consequence, the temperature raise results in increase in the secondary voltage. For precise level measurement independent of temperature, a technique for eliminating the effect of temperature was developed, where temperature compensation is achieved by connecting an external resistance of suitable value across the secondary winding. Value of this external resistance is determined by calibrating the probe in sodium.

A MI type discrete level probe (Figure 2) consists of atleast three sensing elements for indicating three levels namely, low, middle and high levels. Each sensing element consists of primary winding


Figure 2: Mutual inductance type discrete level probe

and secondary winding. All the primary windings are connected in series, while the secondary windings are independent. As the sodium level approaches a particular sensing element, its secondary output reduces thereby indicating the level status.

Sodium Level Probes for PFBR

In FBTR, resistance type level probe and MI type level probe are being used for discrete and continuous level monitoring respectively. Experience of using these probes in FBTR showed that, resistance type level probe was prone to poor sodium wetting problem and performance of MI type level probe was dependent on process temperature. Hence, to overcome these problems in PFBR, sodium level measurement is carried out by means of MI type continuous and discrete level probes. Also, the temperature compensation method was improved by providing external resistance of suitable value across the secondary terminals of the probe. PFBR level probes were manufactured by industry as per IGCAR design and require calibration in sodium before installation in PFBR. There are twenty nine numbers, each of MI type continuous and discontinuous level probes of length varying from 0.66 to 9.6 m. These probes were brought to FRTG and calibrated in sodium at the operating temperature of 180 to 550°C. The calibration of level probes involves testing of the probes at various temperatures and frequencies at different levels. During calibration, the continuous level sensors are characterized to find out the operating frequency and the resistance to be connected across secondary winding for temperature compensation. These level probes were later handed over to PFBR for their installation in its primary and secondary circuits.

Sodium Leak Detectors

Liquid sodium reacts readily with air leading to sodium fire. Hence the piping and components are to be equipped with leak detection system to detect any leak in the incipient stage itself to limit the effects of fire. Various kinds of leak detectors have been developed for this purpose, namely – wire type leak detector, spark plug type leak detector, mutual inductance type leak detector and sodium ionisation detector.

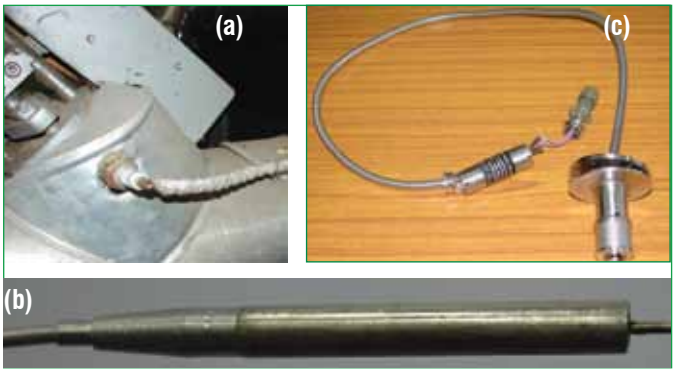


Figure 4: (a) Spark plug type leak detector provided on bellow valves (b) extended spark plug type leak detector and (c) mutual inductance type leak detector

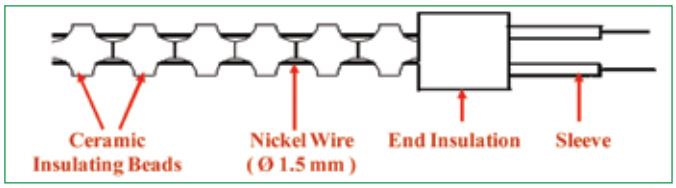


Figure 3: Wire type leak detector

Wire type leak detector (Figure 3) comprise of a wire carrying a small current which is wound over the sodium pipes and capacities with adequate ceramic bead insulation. In case of sodium leak, sodium will short the wire with pipe/ vessel body giving rise to a short circuit and this is sensed.

In case, wire type leak detector fails to detect the leak, sodium would come out of the insulation and drip into leak collection tray. These trays are provided with spark plug type leak detectors (Figure 4a) that work on the same principle as spark plug type level probe. It is used for detecting sodium leak in enclosed space like bellows sealed valves and thermowell. It is also used to detect sodium leak from the double wall pipelines and vessels of fast reactor system. It is usually mounted in a tray / pocket into which the leaked sodium collects and causes electrical short between its insulated central conductor and the body.

A modified version of spark plug type leak detector called as extended spark plug type leak detector (ESPLD) (Figure 4b) was specially developed for use in PFBR to detect any sodium leak from main vessel and safety vessel. In case of sodium leak from the main vessel, sodium will be collected in the safety vessel and if sodium leaks from safety vessel it will be collected in reactor vault. Two numbers of detectors are used for main vessel leak detection and one for safety vessel leak detection.

Miniature mutual inductance type leak detectors (Figure 4c) have been developed for special applications like detection of sodium leak in diverse safety rod driving mechanism (DSRDM) electromagnet. It works on the principle of decrease in mutual inductance between two coils when sodium surrounds it. The secondary e.m.f will reduce when sodium surrounds the guide tube and is the indication of sodium leak.

Sodium ionisation detectors (Figure 5) are used for area monitoring. It works on the principle of preferential ionisation of aerosols of sodium and its compounds (oxides and hydroxides) in carrier gases such as argon, nitrogen and air. It uses a heated platinum filament to ionise the sodium vapour or its aerosols in preference to the constituents of the carrier gas. These positively charged sodium ions are collected by a collector electrode to provide a measure of ion current, which is an indication of sodium leak. Sampled air from the system area is admitted to the sensor and presence of nano gram /m^3 level of sodium ion concentration can be detected by this sensor.

Sodium Flow Meters

Flow measurement in Fast Reactors has either an operational or

Figure 5: Sodium ionisation detector

Figure 6: Permanent magnet flow meter

protective function. The protective function refers to the pump trip/ seizure or leakage in the pipes, while the operational function is the power measurement. The methods that were applied successfully in various Fast Reactors are based on electromagnetic and ultrasonic techniques. Among them, the electromagnetic technique is being widely used and its principle of operation is based on the Faraday's laws of electromagnetic Induction. Electromagnetic flow meters are volumetric type flow meters whose output voltage is proportional to the flow rate. There are many variations of electromagnetic flow meter which can be broadly grouped into two categories based on the type of working magnetic field as- constant field type and alternating field type. Permanent magnet flow meter (Figure 6), the constant field type flow meter and Eddy current flow meter, the alternating kind are being used in IGCAR.

A permanent magnet flow meter comprises of a pipe made of non magnetic material mounted in a transverse magnetic field between the poles of a permanent magnet. Electrodes are mounted on the pipe in diametrically opposite positions at right angles to the field as well as the direction of flow. Here moving sodium acts as the conductor. Hence, when sodium flows through the pipe, an e.m.f is induced across the electrodes. Output voltage is proportional to the velocity of sodium or sodium flow. Permanent magnet flowmeters of size ranging from 15 to 200NB, suitable for single wall and double walled pipes were designed and developed for application in various sodium systems of FBRs.

Eddy current flow meter (ECFM) shown in Figure 7 is used in PFBR for measurement of primary pump flow and also at the outlets of the fuel sub-assemblies to detect flow blockage. It consists of one primary winding which is excited by a constant alternating current source and two identical secondary windings on either side of the primary winding. The primary winding produces a magnetic field which gets changed due to flow of electrically conducting sodium.

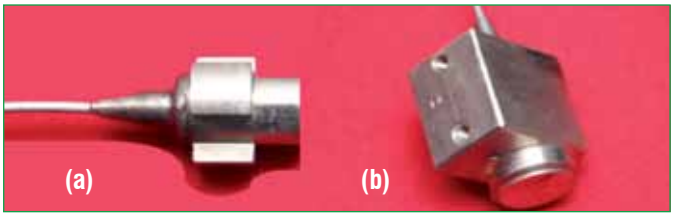


Figure 8: High temperature and sodium immersible ultrasonic transducers

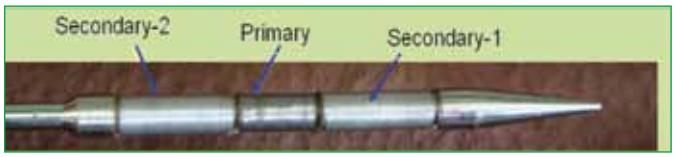


Figure 7: Eddy current flow meter

This change in magnetic field leads to a difference in the induced voltage in the two secondaries. The voltage difference of the two secondaries is proportional to the velocity of sodium and serves as a signal for sodium flow measurement.

Eddy Current Position Sensor

Eddy current position sensor (ECPS) was developed to detect the deposition of diverse safety rod (DSR) at its bottom most position and also to measure its free fall time. It consists of a primary coil placed on the mobile assembly of diverse safety rod drive mechanism (DSRDM) and a pick up coil placed below the primary coil for getting an output signal. Secondary, signal transfer and sensor coils are placed on the DSR sheath side. On exciting the primary coil, e.m.f is induced in the secondary that drives a circulating current in all the three coils on secondary side. Magnitude and phase of this current depends on the total impedance of coils on secondary side. When the DSR is dropped, the sodium in the DSR subassembly is displaced by DSR. The impedance of sensor coil changes with the DSR is in the deposited condition as compared to non-deposited condition. Accordingly, flux linkage with pick-up coil varies, thereby changing the voltage induced in it. This indicates presence of DSR near sensor coil.

Ultrasonic Transducers

High temperature and sodium immersible ultrasonic transducers have been developed in-house for use in under sodium ultrasonic scanner (USUSS) and SONAR. USUSS is a scanning mechanism of PFBR that is used to view its internal components that are dipped in sodium. SONAR device is used to measure the subassembly vibration under sodium in PFBR. The developed transducers are capable of withstanding high temperature, gamma and neutron radiations. Various tests such as - detection capability test, test in flowing water, gamma irradiation test and endurance test in sodium were carried out to qualify the transducers for use in reactor. These transducers were developed (Figure 8) using PZT crystals bonded to the transducer diaphragm using tin-silver alloy having a melting point of 220 °C.

As conventional instruments for measurement of liquid level, flow, pressure and leak cannot be used in sodium because of its high chemical activity with air/moisture, special sensors were developed and qualified for sodium applications which plays a key role in mastering the liquid sodium technology towards the development of fast reactors.

Reported by K.K.Rajan and colleagues
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Utilisation of FBTR as an Irradiation Facility and Enhanced Utilisation of KAMINI Reactor

Utilisation of FBTR as an Irradiation Facility

One of the major objectives of FBTR is to serve as an irradiation facility for the development of fuels and structural materials for fast reactors. The first criticality of FBTR was achieved in October 1985 with a small core of 22 MK-I fuel (70% PuC+30% UC) sub-assemblies, rated for 10.6 MWt. Since 1996, FBTR core has been progressively expanded by loading MK-II sub-assemblies (55 PuC+45% UC) & MOX sub-assemblies (44% PuO_2). Over a period of time several MK-I & MK-II sub-assemblies have reached their respective allowable burn-up levels of 155 & 100 GWd/t. These sub-assemblies have been replaced by MK-I sub-assembly. The current core has 31 MK-I, 10 MK-II, eight MOX and one experimental fissile sub-assembly - taking it to a total of fifty sub-assemblies. The peak operating linear heat rating (LHR) has been raised to 400 W/cm. All these have enabled the reactor power to be raised to 22 MWt, peak flux to $3*10^{15}$ n/cm^2/s and the sodium outlet temperature close to 480°C.

Twenty two irradiation campaigns have been completed so far. Important missions achieved in earlier years are irradiation of Zr-Nb alloys used in Indian PHWR for assessing their irradiation creep behaviour and irradiation of PFBR test fuel. The long term irradiation of structural material (D9) is in progress. In recent years, testing of in-core detector of PFBR and trial production of strontium (^{89}Sr) isotope (for therapeutic use) from yttria have been taken up. The year 2013-14 has seen a significant increase in the irradiation mission of FBTR. Figure 1 shows the typical irradiation capsule.

During 2013-14, FBTR completed 21st and 22nd irradiation campaigns (Table 1). In 21st campaign reactor had operated at a maximum power of 20.3 MWt, generating 3.5 to 4 MWe. In 22nd campaign, reactor operated at a maximum power of 18 MWt for the purpose of irradiating sphere-pac fuel pins. Following experiments have been completed / in progress:

Metallic Fuel Irradiation

Irradiation of three pins of enriched uranium (14.8%^{235}U) - 6% Zr metal fuel in a capsule in SS carrier (ISZ 100) was started in 21st campaign. The design of the pins and the capsule are same as that of the natural uranium-6% zirconium currently under irradiation in the 4th ring, except that the uranium is enriched to 14.8%. The peak LHR is 225 W/cm. The sub-assembly will be discharged for post irradiation examination (PIE) after achieving a burn-up of 25 GWd/t.

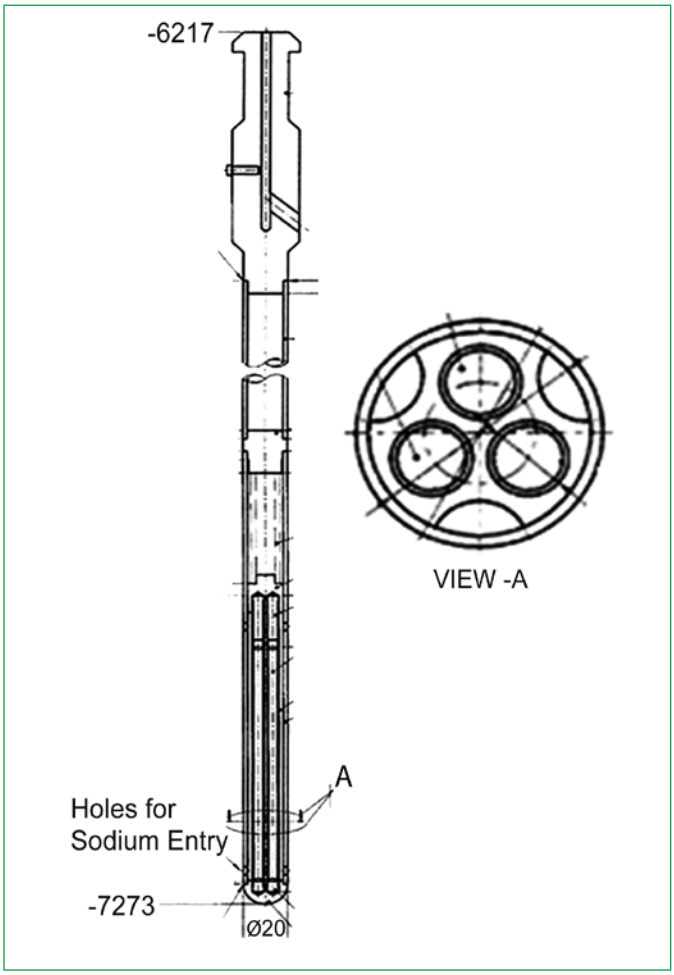

Figure 1: Typical irradiation capsule

Table 1: Irradiation experiments completed during 2013-14

21st campaign	22nd campaign
Irradiation of Natural U-Zr sodium bonded metal fuel pins in 4th ring	Irradiation of Natural U-Zr sodium bonded metal fuel pins in 4th ring
Impact specimens of 304LN & 316LN for low dose irradiation	Impact specimens of 304LN & 316LN for low dose irradiation
Start of irradiation of Enriched U-Zr sodium bonded metal fuel pins in I ring	Irradiation of Enriched U-Zr sodium bonded metal fuel pins in I ring
Irradiation of TRISO coated particles for CHTR	Irradiation of Sphere-pac MOX fuel pins
Irradiation of ferro-boron	Start of Irradiation of U-Pu-Zr in I ring
HTFC testing	
Kalman filter testing	

In the 22nd campaign, irradiation of three sodium bonded fuel pins of 19%Pu-6Zr composition was initiated. The pins operate at 178 W/cm and will be discharged for PIE after achieving a burn-up of 25 GWd/t.

Sphere-Pac Fuel Irradiation

To study the irradiation performance of the fuel pins fabricated through sol-gel vibration compaction technology during the beginning of life (BOL) and the column stability, two sphere-pac fuel pins and one reference MOX pins, contained in a capsule in a steel carrier sub-assembly were irradiated in the 22nd campaign.

The sphere-pac pins were required to be operated at a LHR of 205 W/cm for first 200 hours; followed by 260 W/cm for the next 100 hours. For this purpose, reactor was operated at 13.9 MWt for the first 200 hours and at 18 MWt for the next 100 hours to respect the operating limits of the sphere-pac pins. To respect the LHR limits, the special sub-assembly was loaded in 0208 of the core location. The special sub-assembly having sphere-pac pins will be discharged and sent to RML for PIE.

Impact specimens of 304LN & 316LN for low dose irradiation

One of the major life limiting factors for FBRs is the loss of ductility of permanent, out-of-core structures which are subjected to low doses of irradiation (typically 2 to 5 dpa). In order to get base-line data on the out-of-core structural materials in PFBR and other future FBRs, irradiation of tensile, impact and disc specimens of 316LN and 304 LN was initiated in the 4th & 5th rings in the 21st campaign. The specimens are from both wrought and full welds. Hard coated disc specimens of 304 LN & 316 LN were also loaded in these capsules.

IGCAR is developing Reduced Activation Ferritic and Martensitic (RAFM) steel for the test blanket modules of the international thermonuclear experimental reactor (ITER). Disc specimens of RAFM steels were also included in the capsules. One of the capsules was discharged for PIE at the end of the 21st campaign as it has attained a damage of ~5 dpa. The other has attained a damage of 3.7 dpa at the end of the 22nd campaign and irradiation will be continued in the 23rd campaign for getting the target damage of ~5 dpa.

TRISO particles for compact high temperature reactor

Compact high temperature reactor (CHTR) is being designed by BARC with TRISO coated particle type fuel. A joint BARC-IGCAR proposal was received for irradiation of TRISO coated particles with surrogate kernel, disc specimens of CHTR structural materials (Nb-1% Zr 0.1% C) and cold worked SS316 L- disc specimens. These materials viz, TRISO coated materials and structural material for CHTR and cold worked SS316L-disc specimens were in the form of three experimental pins in a capsule inside a steel carrier.

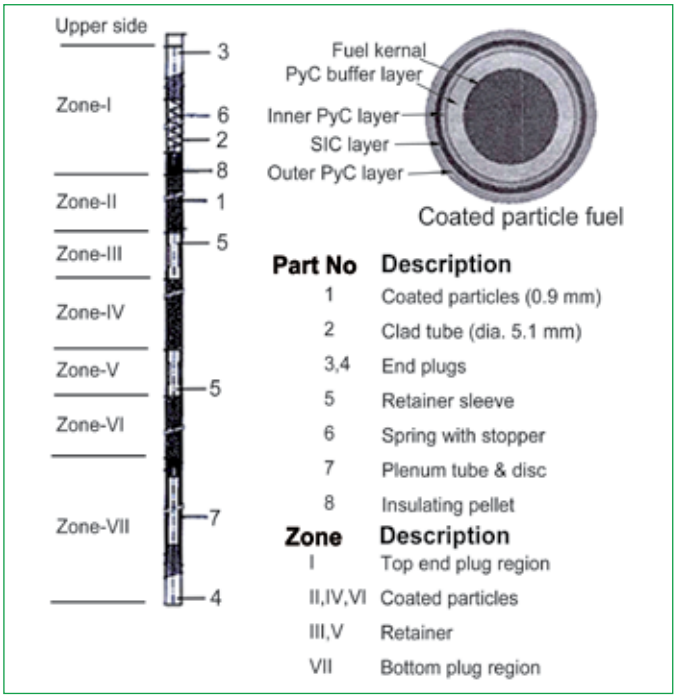

Figure 2: Pin with coated particle fuel

They were loaded in 5th ring for irradiation during 21st campaign.

One of the pins contains the TRISO particles (Figure 2) in double containment to avoid the particles getting into sodium in case of a breach of the capsules holding the spheres. The second pin contains the disc specimens of CHTR structural material. The third pin contains SS316 L- disc specimens. The above special sub-assembly was irradiated for a neutron fluence $>1\times10^{21}$ n/cm^2. The temperature of irradiation is about 420°C. The purpose is to understand the irradiation behavior of the coatings of the TRISO particles and the mechanical properties of the irradiated Nb-1% Zr 0.1% C& 316L specimens. The capsule has since been discharged.

Ferro-boron

Ferro-boron is a prospective candidate shielding material for fast reactors. Capsules containing ferro-boron particles in double containment were successfully irradiated in the 19th and 20th campaigns.

Yttria

^{89}Sr is a medical isotope used as a palliative in bone cancer therapy. This can be produced by irradiating yttria in fast flux. Trial irradiation has been conducted in FBTR thrice, and the results are satisfactory. There is a proposal for regular production of this isotope, after qualifying the product.

Future plans

FBTR will be used for large scale testing and irradiation of metallic fuel pins and sub-assemblies of various designs in future. When completed, FBTR would have truly fulfilled its mission as a fast flux irradiation test-bed.

Enhanced Utilisation of KAMINI Reactor

KAMINI is a 30 kW, ^{233}U fuelled, deminerlized light water moderated and cooled special purpose research reactor. Beryllium oxide (BeO) is used as reflector and cadmium as absorber material in safety control plates (SCP). The reactor functions as a neutron source with a flux level of 8.0×10^{12} n cm^{-2} s^{-1} at the core center and facilitate carrying out neutron radiography of both active and non-active objects. Neutron activation analysis facilities are also available in the reactor for carrying out radiation physics research, irradiation of large samples, calibration and testing of neutron detectors.

Irradiation Facilities

KAMINI reactor houses two irradiation sites Pneumatic Rabbit Fast Transfer System (PFTS), and thimble locations (north and south) for activation analysis experiments and three beam tubes to extract the neutron beams at the core-reflector assembly for neutron radiography of active, non-active and radiation physics experiments. Table 2 shows the flux available in various locations of the reactor.

Pneumatic Rabbit Fast Transfer System

A pneumatically operated fast sample transfer system is provided for irradiation of samples to study short lived isotopes. Samples with a maximum weight of 1.7 g in special polypropylene containers (20 mm diameter and 30 mm length) can be shot into the irradiation site located adjacent to the core reflector boundary during reactor operation and retrieved immediately after irradiation.

Table 2: Flux available in various locations of the reactor

Irradiation site	Flux (n cm^{-2} s^{-1})
Core average	5.3×10^{12}
Peak	8.0×10^{12}
Pneumatic fast transfer system location	2.3×10^{12}
South beam tube	1.70×10^{8}
West beam tube	1.70×10^{8}
North beam tube	6.54×10^{7}
South thimble (peak)	3.21×10^{10}
North thimble (peak)	3.94×10^{10}
Dry Tube-1	$2.3x\ 10^{10}$
Dry Tube-2	2.4×10^{7}
HTFC testing facility	7.0×10^{6}

Several samples can be irradiated sequentially in this location without shutting down the reactor. The retrieval time of the sample is very short so that samples having very short half-lives also can be irradiated. PFTS and thimble locations are shown in Figure 3.

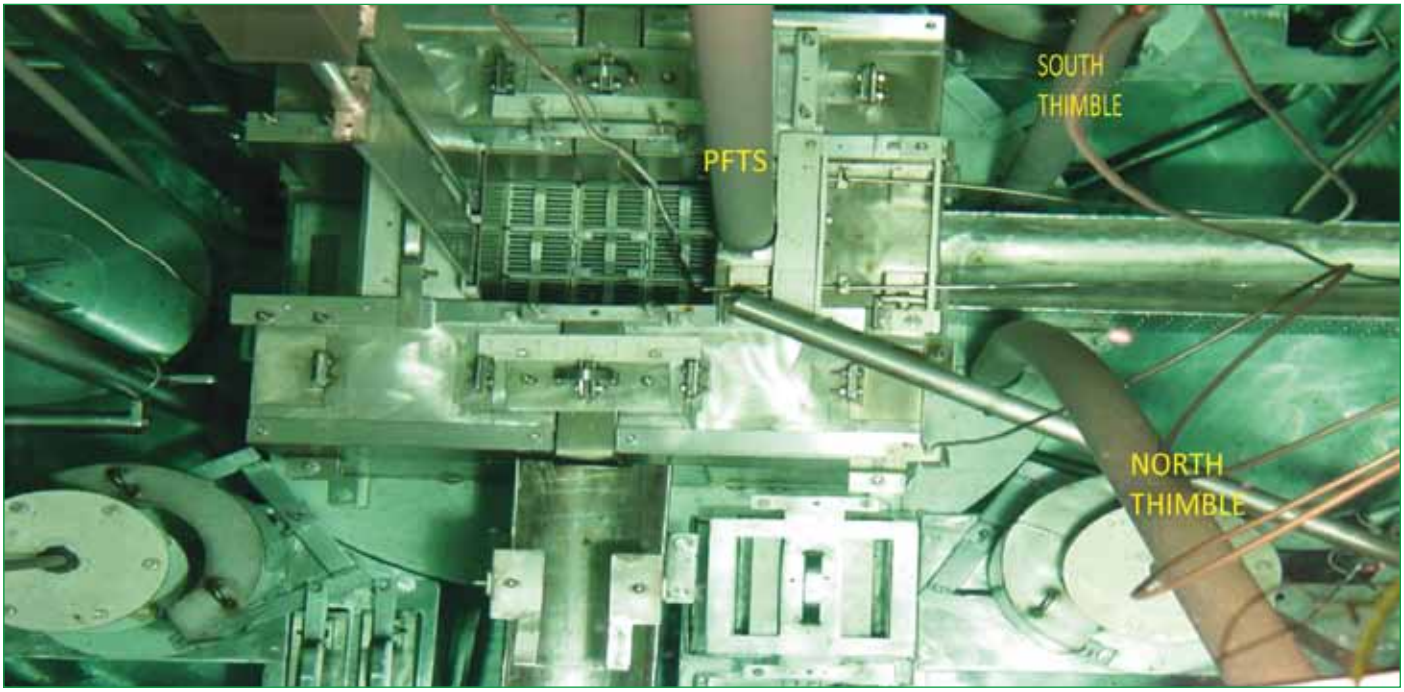

Figure 3: Pneumatic rabbit fast transfer system and thimble locations

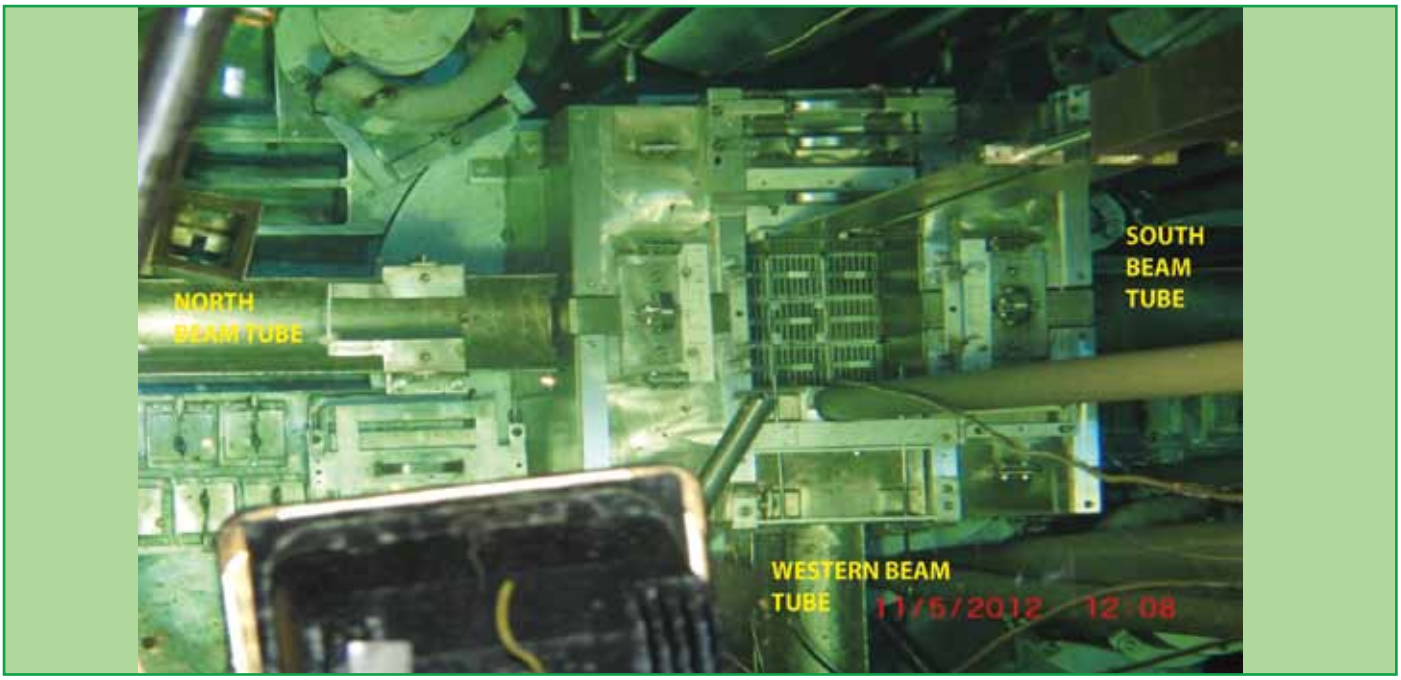

Figure 4: Beam tubes and their locations

Beam Tubes

The south and north beam tubes are for neutron radiography and the west beam tube is for radiation physics research. The neutron flux available at the neutron radiographic site is $\sim 10^6$-10^7 n cm^{-2} s^{-1}. Since the beam tubes are at the boundary of core-reflector assembly, a mixture of thermal and epi-thermal neutrons are available for radiography at these sites. The ratio of length to diameter (L/D) for south and north beam tubes is about 160 and the aperture size is 220 mm × 70 mm. The south beam tube is used for radioactive objects and the north beam tube for non-radioactive objects. Both film and real time neutron radiography are possible. Beam tubes and their locations are shown in Figure 4.

Thimble Irradiation Sites

Two in-tank locations on either side of the west beam tube outside the reflector blocks facilitate irradiation of samples up to 50 ml. These locations provide adequate flux for irradiation due to peaking of thermal neutron flux in the BeO reflector. The samples contained in a 50 milli litres aluminum container (thimble) can be lowered into the irradiation location by means of motorized drive mechanisms from the top of the reactor tank. The neutron flux available at the thimble locations is $\sim 10^{11}$ n cm^{-2} s^{-1} at 30 kW power. Since the loading and unloading is done from the reactor top, the retrieval of samples is delayed. The weight of the sample is limited to 20 grams.

Dry tubes and High Temperature Fission Counter Test Facility

KAMINI reactor being a neutron source facility, can also be used for testing and calibrating the neutron detectors. In recent years, there has been a pressing demand for testing and calibration of various types of neutron detectors developed and manufactured. To accomplish this, two dry aluminum tubes and another tube made of inconel with heating facility were installed at suitable locations in the core outer location in addition to existing irradiation sites (Figure 5).

Utilisation of KAMINI reactor

KAMINI for Space Applications

Pyro-devices are extensively used in the space industry. These are basically mechanical devices with a small amount of explosive. Different types of these devices are used for ignition, shearing the straps, cables and bolt cutters. Ensuring the reliability of the pyro-device is a very crucial aspect in the space program. Of all the non destructive examination (NDE) techniques, neutron radiography

Figure 5: Dry tubes and high temperature fission counter assembly

is the best for this purpose. KAMINI is being used extensively for the qualification of pyro-devices for all the space missions of the Indian Space Research Organization (ISRO). The neutron radiography of approximately 10,000 pyro-devices from Vikram Sarabhai Space Centre (VSSC) has been completed successfully till date in KAMINI.

Neutron Irradiation of Opto-electronic Sensors

This is another important activity which has been initiated with respect to assessment of performance of various critical sensors used in our satellites. Various opto-electronic devices from laboratory of electro-optics systems was irradiated and their performance monitored for assessing the capabilities to withstand neutron radiation for extended mission in the outer space. The sensors were also required to be qualified in non-ionizing particle radiation up to a certain fluence level for product assurance requirement as well as to assess the degradation of the sensors from non-ionizing radiation for its estimated mission life in orbit.

Neutron Irradiation of MEMS based Sensors and Transducers for LPSC

In another campaign, three macro electric mechanical system (MEMS) sensors and two MEMS transducers were received for neutron irradiation from liquid propulsion system centre (LPSC), Bangalore for testing indigenously developed sensors for their use in GSAT-4 satellite. These MEMS based sensors were required to be tested up to a fluence level 7.0×10^{10} n/cm^2 for studying their performance for the designed life encountered under cosmic radiation.

Neutron Radiography of Fuel

South beam tube has been used extensively for neutron radiography because of the good length to diameter ratio, mobile shielding provision and ease of access to radiography area. Neutron radiography of carbide fuel pins of 25, 50, 100 and 155 GWd/t burn-up was carried out for characterization of fuel and pellet to pellet gap. Neutron radiography of healthy and failed pins of failed MARK-I fuel sub-assembly was also taken to study the cause of failure. Transfer technique was used for imaging of these fuel pins. Resolution of images was found to be satisfactory and pellet to pellet gaps and chipped pellets could be detected. Prior to irradiating the metallic pins in FBTR, pre irradiation data was obtained by taking neutron radiography in KAMINI reactor.

Neutron Activation Analysis

Irradiation of various samples has been carried out at pneumatic fast transfer system and thimble locations for activation analysis. Typical applications of neutron activation analysis using KAMINI include analysis of geological samples like ores, rocks and chemical samples from the forensic laboratories and development of method for neptunium (^{237}Np) estimation at microgram levels for use in reprocessing industry. Assay of iodine in leaf samples as well as rock samples for rare earths were carried out. About 1200 samples have been irradiated in KAMINI till date.

Shielding Experiments in KAMINI

Feasibility of using KAMINI reactor for radiation shielding experiments has been studied. Some experiments of general nature, such as shield material evaluation, neutron and gamma streaming etc are being done here. Shielding experiments using ferro-boron and tungsten-boron have been successfully carried out.

Testing of Neutron Detector

KAMINI being a swimming pool type water reactor with its inherent feature in design, provides easy access to the core without any radiological consequences to personnel, enabling testing of neutron detector. Two vertical dry irradiation tubes having diameter of 74 and 103 mm with removable shield plugs were installed at a distance of 35 and 90 cm from the centre of the core. The fluxes available at these locations are 10^9 and 10^7 n cm^{-2} s^{-1} respectively. These test facilities were installed in 2012 for testing neutron detectors manufactured indeginiously. So far around 138 neutron detectors have been tested in KAMINI reactor.

Electronics Division, BARC has designed and developed high temperature fission chambers of 0.2 cps/nv sensitivity, required for PFBR. Prototypes were fabricated and tested at APSARA reactor, to ensure the functionality of the detectors. To test high temperature fission chambers for the intended range of neutron flux, temperature and gamma field expected in PFBR, it was tested in FBTR up to 450˚C temperature, 1.0 x 10^9 nv. netruon flux and 100 kR/hour gamma field independently. To qualify the high temperature fission counter (HTFC) up to 572˚C and at required flux level simultaneously, a special detector housing assembly with heating arrangement was made and installed in KAMINI reactor for testing HTFC. In this test facility, HTFC meant for PFBR is being tested.

KAMINI is a unique ^{233}U fuelled neutron source facility operating in India. It is providing R&D facilities for neutron radiography, activation analysis and radiation physics experiments. Twenty years of operating experience with this facility has been satisfactory. Neutron radiography of various pyro devices used in our entire space missions including the prestigious chandrayaan mission was carried out in KAMINI reactor. Different types of neutron detectors both prototype and regular were tested and calibrated here. Irradiation of various samples has been carried out for elemental, geological and environmental studies. The utilization of KAMINI has been progressively expanded over the years. KAMINI is also an important aid for India's space mission.

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Young Officer's FORUM

Design of Fine Impulse Test System for SCRAM Logic System of FBTR

Shri Satya Rajesh Medidi received his B.Tech degree (Electronics & Communication Engineering) in 2011 from Gayathri Vidya Parishad College of Engineering, Visakhapatnam and M.Tech Degree in Electronics Engineering in 2014 from Homi Bhabha National Institute. He is from 6th batch of BARC training school at IGCAR campus and currently working in Electronics and Instrumentation Division. His current area of interest is in the field of FPGA based systems design and analog systems design for nuclear reactors.

As part of life extension program of Fast Breeder Test Reactor (FBTR), it is proposed to refurbish the Shutdown by Control Rod Actuation Mechanism (SCRAM) logic and Finite Impulse Test (FIT) systems due to non availability of spare components and maintenance problems.

SCRAM logic system (SLS) is intended to protect the reactor from various incidents such as neutronic, thermal, flow, failed fuel events etc. SCRAM logic receives SCRAM parameter signals, performs 2 out of 3 voting and initiates safety action by de-energizing the electromagnet (EM) coils which hold the control and safety rods.

FIT logic checks the healthiness of SCRAM logic periodically and ensures its availability. FIT logic injects short duration trip pulses on SCRAM parameters in a predefined order and in required combinations. These pulses propagate through various stages of SCRAM logic and appear at electromagnet coils. Based on the presence or absence of pulses at the electromagnet coils, faults are detected and annunciated.

Existing System

The existing SCRAM logic and FIT systems were realized in three panels as shown in the Figure 1. FIT system is located in panel 1. It generates 20 milliseconds test pulses which propagate through relay interface. It also generates address and profile signals.

Interface logic is located in panel 2. It has relay interface at the input side. Interface logic converts 20 millisecond pulses to 2 millisecond pulses and injects them into SCRAM logic.

SCRAM logic system is positioned in panel 3. SCRAM logic was implemented using diode-resistor-transistor technology.

Existing system receives GATE A, GATE B and GATE C from SCRAM logic system through interface logic. Based on the signals recieved from SCRAM logic, fault signals and alarm signals are generated and annunciated by FIT system located in panel 1.

System Specification

SCRAM logic system receives 20 trip inputs which are categorized into two groups viz. Group A and Group B. FIT logic injects short duration trip pulses. These pulses propagate through various stages of SCRAM logic and traverse up to the electromagnet coils. Based on the presence or absence of pulses

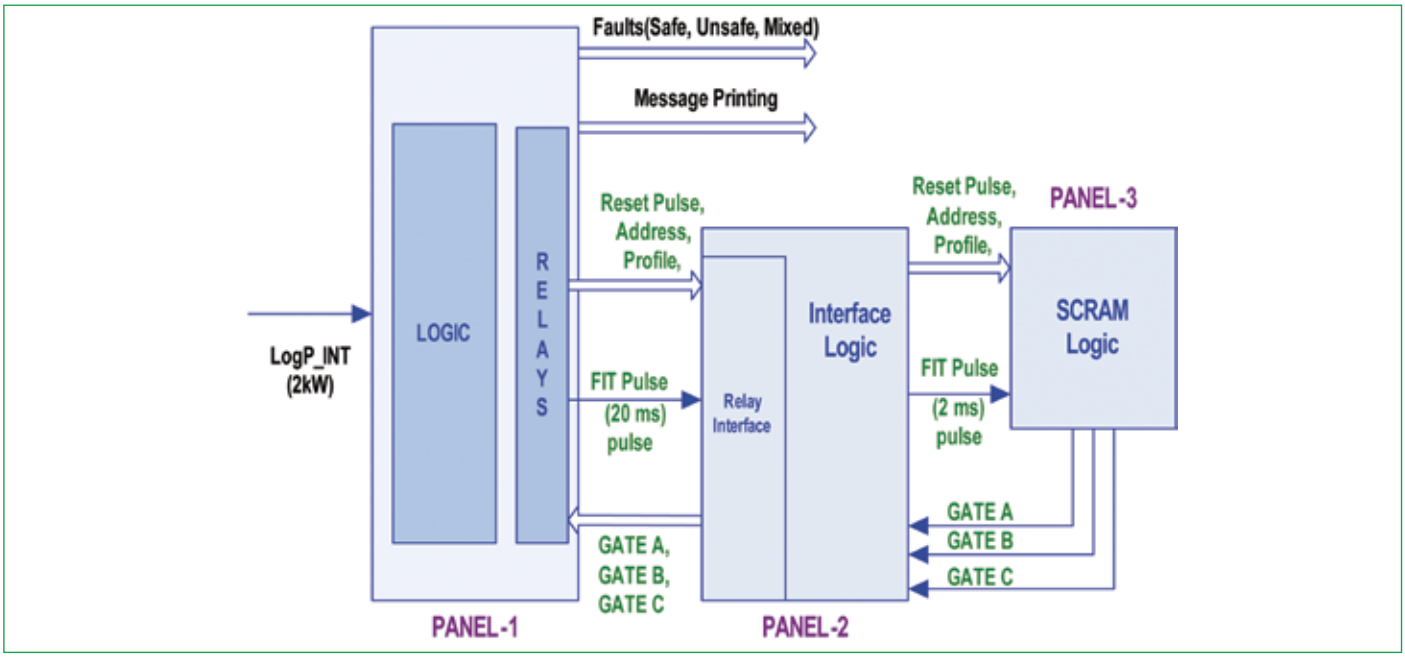

Figure 1: Architecture of existing system with all interfaces

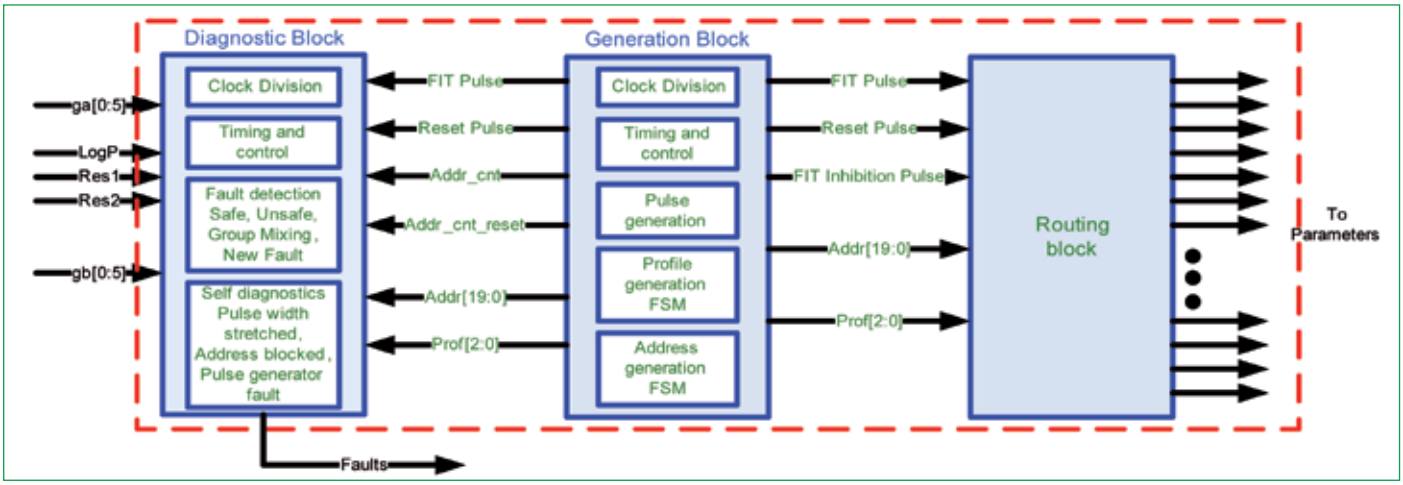

Figure 2: Block diagram of FIT system with all interfaces across the blocks

at electromagnet coils, faults are detected and annunciated. To ensure healthiness of FIT logic, self diagnostic checks are built into the FIT logic. SCRAM parameters are mentioned in Table 1.

FIT system checks the healthiness of SCRAM logic periodically. For each trip parameter, unique address is assigned. For each address, there are six profiles viz., 001, 010, 100, 110, 011, 101 each of 3 second duration for triplicated parameter, 10, 01 each of 3 second for duplicated parameter and only one profile for single parameter. In each profile, FIT logic injects a pulse of 2 milliseconds duration and feeds it to the A, B, C channels of triplicated trip parameter. The propagation of the FIT pulses through the SCRAM logic is checked by monitoring pulses at both the terminals of electromagnet coils.

FIT system detects the faults of selected trip parameter under test, based on response of GATE pulses from SCRAM logic and annunciates fault alarms. All faults are listed in Table 2.

SLS-FIT logic fault is a group alarm that indicates the overall healthiness of SCRAM Logic and FIT Logic system which appears if any one or more of the above conditions/faults are detected in SCRAM logic.

Table 1: SCRAM parameters

S No	Parameter	Type	Group
1	LogP 10%	Triplicated	A
2	Tp	Triplicated	A
3	Lin P	Triplicated	A
4	+Reactivity	Triplicated	B
5	-Reactivity	Triplicated	B
6	Qmini	Triplicated	B
7	DND East	Triplicated	B
8	DND West	Triplicated	A
9	LogP125%	Triplicated	B
10	Manual SCRAM	Single	A
11	LOR Ineffective	Single	B
12	Delta Theta	Single	B
13	Theta m	Single	A
14	Theta i	Single	A
15	Reserve 1	Triplicated	A
16	Reserve 2	Triplicated	B
17	Log C	Duplicated	A
18	Tn	Triplicated	B
19	Log N	Triplicated	A
20	Log No	Triplicated	B

Design and Testing

The salient features of the proposed system are:

- Simplification of interface logic
- Saves significant amount of space in the panel
- Self diagnostic features like pulse generator fault and address blocked fault are provided.

FIT logic generates and injects 2 millisecond pulses directly into SCRAM logic which eliminates relay interface. FIT logic system consists of three blocks namely generation block, diagnostics block and FIT interface block as shown in Figure 2.

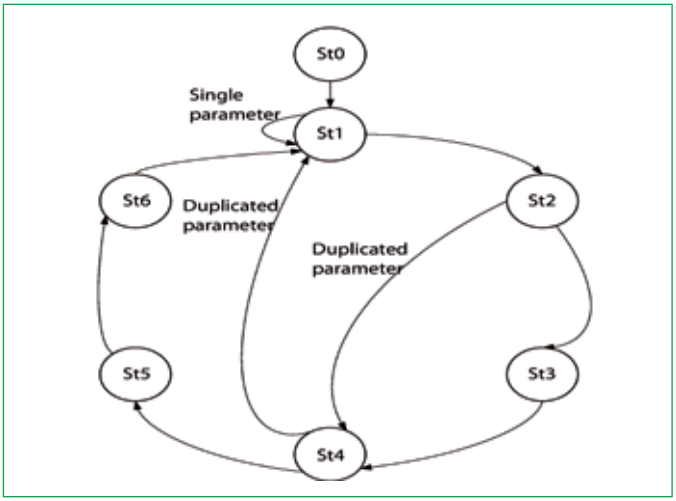

Figure 3: State machine for profile generation

Table 2: Faults and their description	
Name of the fault	Fault description
Safe fault	Whenever a triplicated parameter is tested by FIT in 1/3 mode (A or B or C profile), no pulse shall be present at the EM coils. If a FIT pulse appears, then it is detected as 'Safe fault'
Un-safe fault	Whenever a triplicated parameter is tested by FIT in 2/3 mode (AB, BC, CA) or duplicated parameter is tested in 1/2 mode or single parameter is tested in 1/1 mode, a pulse shall appear at the EM coils. If a FIT pulse doesn't appear, then it shall be detected as 'Unsafe fault'
Group mixing fault	Trip parameters of the SCRAM logic are divided into two groups as Group A and Group B. When the FIT pulse is injected in a group on a single parameter, the pulse shall appear at the same group only. If the pulse appears at both the groups, then it shall be detected as 'Group mixing fault'
New fault	If already a safe/unsafe/group mixing fault for a parameter is detected and a fault of the same type appears on a different parameter, then it shall be detected as new safe/unsafe/group mixing fault depending on the type of fault
Pulse stretched fault	If FIT pulse width exceeds 3 ms, fault signal (faulty FIT) shall be generated and if it exceeds 5 ms, FIT shall be disabled
Pulse generator fault	If the pulses are not generated periodically, the fault signal shall be generated
Address blocked fault	All the trip parameters (address) shall undergo FIT in a pre-determined sequence. If any one or more addresses are missed in the sequence, the fault shall be detected (address blocked)

Generation Block

The function of generation block is to generate trip parameter addresses, profiles, FIT pulse (trip / inhibition type) and reset pulse. In addition to the above, this logic block also generates other timing signals which are useful for address sequence blocked detection.

Profile generation and address generation is done using 'safe' state machine approach. The state machines for profile and address generates profile and address signals respectively with periodicity defined by the type of parameter. State machine for profile generation is shown in Figure 3.

Diagnostic Block

Diagnostic logic is provided for online detection of various types of faults in the SCRAM Logic system. Further, it also monitors the healthiness of the FIT Logic by providing built-in self tests.

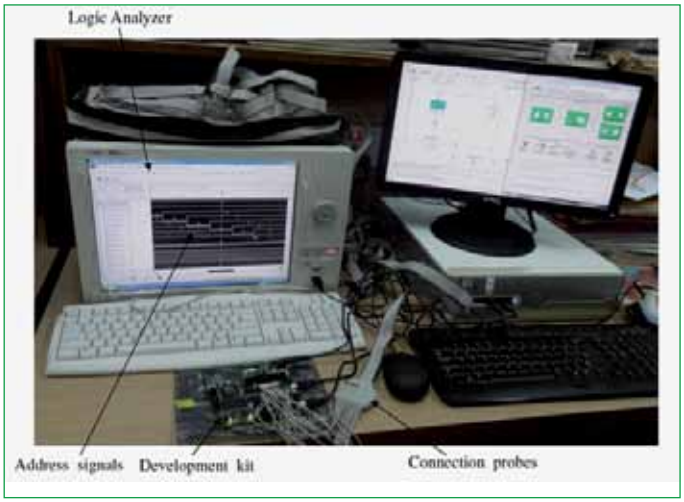

Figure 4: The room temperature diffraction patterns obtained in powdered single crystals along with Rietveld refinement for representative Ru fractions

Routing Block

This logic module is used to inject FIT pulses into the respective trip parameter, auto / manual inhibition channels. There are two FIT pulse routing logic modules. One is for Group-A trip parameters whereas the second logic module is for Group-B trip parameters.

Register transfer level (RTL) code for each module shown in the above block diagram is written in very high speed integrated circuit hardware description language (VHDL) and thoroughly simulated at various stages of design viz. pre-synthesis, post-synthesis and post place and route using VHDL test-benches.

Hardware testing was done using Cortex M1 enabled ProASIC3 development kit. Programming of field programmable gate array (FPGA) was done using Flash Pro software through onboard USB port. Important signals are captured and viewed in logic analyser. Conceptual timing diagrams and real time waveforms were compared and no deviations in functional and timing specifications were observed. Testing of generation block is shown in the Figure 4. Similarly, testing was carried out for all the blocks of the FIT system and it was found to perform satisfactorily as per its functional and timing specifications.

In future, it is planned to develop an engineering hardware for FIT system using Actel one time programmable (OTP) devices with all interfaces. Necessary qualification tests and compliance tests will be conducted on developed hardware and deployed in FBTR.

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Young Researcher's FORUM

Positron Annihilation Studies of Model Iron-Chromium Alloys and Ferritic/Martensitic Steels

Ferritic/martensitic steels are the prospective candidate materials for structural components of nuclear systems where intense neutron irradiation conditions are envisaged. They include (i) first wall and breeding blanket in fusion reactors (ii) clad, ducts and fuel sub-assembly in future fast reactors, which also envisage high operating temperatures and (iii) structural materials for spallation targets of accelerator driven systems (ADS), which envisage intensive neutron fluxes produced by proton beams operating at GeV energy with MW range power. They are potential candidates due to their high swelling resistance, impressive thermal conductivity and flexibility to attain reduced activation by appropriate choice of alloying elements and their compositions.

Two issues that pose problems with regard to usage of ferritic steel are (i) creep strength, which degrade both with high temperature as well as irradiation and (ii) aging (~ 748 K) or irradiation induced embrittlement.

Ferritic Steels

Microstructure of Ferritic Steels and Role of Precipitates

The typical microstructure of ferritic steel for its operating condition is tempered martensite with ferritic matrix containing lath structure. The metal carbide/nitride precipitates distribute along the lath and grain boundaries as well as within the laths. A typical schematic of microstructure is shown in Figure 1. In the case of ferritic steel, the microstructural factors that affect hardness and strength are (a) solid solution (b) dislocation density (c) lath width and (d) inter-particle spacing. Compared to free dislocations and precipitates, lath structural contribution is significantly higher in typical ferritic/martensitic steels, while solid solution strengthening is the base strength. Microstructural modifications, that affect mechanical properties, occur mainly by migration of lath boundaries leading to lath coarsening. The grain and sub-grain boundaries in pure metals and solid solution alloys are highly mobile under stress. The movement of these boundaries

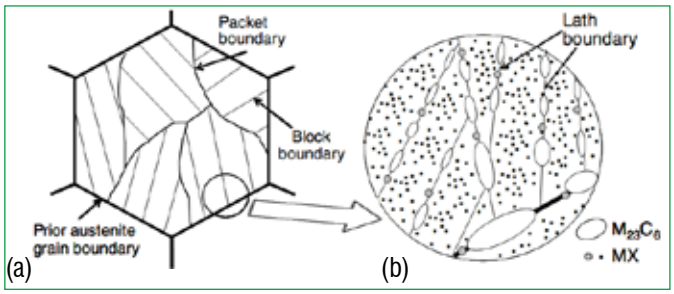

Figure 1: A typical microstructure of ferritic/martensitic steel

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can absorb excess dislocations from inside the sub-grains causing dynamic recovery process, resulting in softening. The distributed precipitates, apart from contributing to strength, can reduce lath coarsening by pinning dislocations. One of the current practices to improve creep strength is to design the distribution of MX (X refers to C or/and N) precipitates along boundaries and within boundaries comparable in number to $M_{23}C_6$ precipitates, by increasing carbide/nitride forming elements such as V, Nb, Ta, Ti etc. One such modification found reducing creep rate and increasing time to rupture significantly (nearly an order) at elevated temperature of 923 K and a stress of 140 MPa.

The R&D of these precipitate design demands an extensive characterization. Transmission electron microscopy (TEM) is the main characterization tool and atom probe tomography (ATP) is also emerging as a powerful technique to investigate nano-precipitates in materials. However, both TEM and APT require laborious sample preparation and time consuming experiments and analysis. During extensive study of varying microstructural changes, time and labour impose constraints on the number of samples that can be investigated. Indicative changes from relatively faster techniques could provide valuable information before performing detailed microstructural studies using TEM or ATP.

This study aims at understanding the effect of thermally induced carbide precipitate evolution on positron annihilation lifetime (PAL) in ferritic/martensitic steel. It allows finding the applicability of positron annihilation spectroscopy (i) as a 'fast' technique to obtain finger prints of microstructure and (ii) as a non-destructive tool to study microstructural changes of materials in use.

Positron Annihilation Spectroscopy

Positron annihilation spectroscopy (PAS) is sensitive in probing open volume defects. Positron being positive charged particle traps in open volume defects as the nuclei will be missing. The electron concentration and their momentum distribution influence the annihilation characteristics in terms of PAL and Doppler broadening of 511 keV annihilated photons, respectively. In this study, the open volume defects associated with microstructural changes are probed to estimate the microstructure.

Correlation between Positron Lifetime and Phase Evolution

Two representative ferritic/martensitic steels, EUROFER 97 and

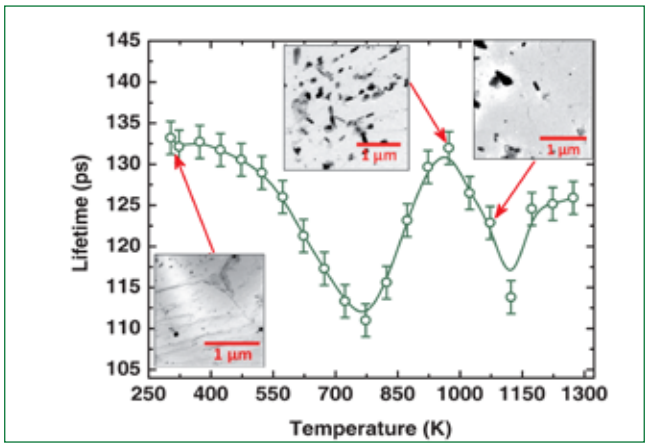

Figure 2: Positron lifetime in EUROFER 97 steel sample subjected to corresponding tempering treatment, after normalization

modified 9Cr-1Mo, are studied using positron lifetime technique and corroborated with typical characterization techniques. The PAL in EUROFER 97 steel normalized and subsequently treated at different tempering temperatures is shown in Figure 2. The PAL in defect free Fe and Fe-(2-20)Cr alloys is 108 ± 2 ps. Higher PAL in as-normalized sample corresponds to dislocations and the subsequent decrease is due to annealing of dislocations. Observations from TEM showed that below 773 K the microstructure remains same as, as-normalized sample indicating that lath boundaries are not responsible for higher PAL in initial state. The increase in PAL above 773 K is due to nucleation and growth of carbide precipitates. Above 973 K, the precipitates coarsen with decrease in number density leading to decrease in lifetime. During this process smaller precipitates dissolve and larger precipitates grow by diffusion of solute away from small precipitates to larger precipitates, due to relative concentration gradient of solute in the matrix. One more important observation is that the volume fraction of precipitates in sample treated at 1073 K decrease as compared to sample treated at 973 K, indicating high solubility of alloying elements, hence, dissolution of some of the precipitates. The increase in PAL above 1123 K corresponds to formation of martensitic phase similar to as-prepared sample, for structure being FCC at treatment temperature (Figure 2).

PAL study of modified 9Cr-1Mo steel showed similar stages of lifetime and the SEM observation of precipitation corresponding to stages of nucleation, growth and coarsening are shown in Figure 3.

The precipitate volume fraction and interfacial area are quantified from TEM study of EUROFER97 steel and compared with

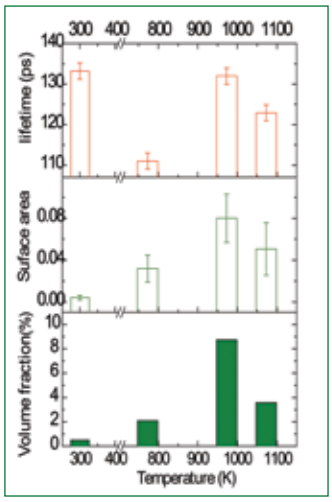

Figure 4: Comparison of lifetime with precipitate-matrix interfacial area and precipitate volume fraction, as a function of tempering temperature

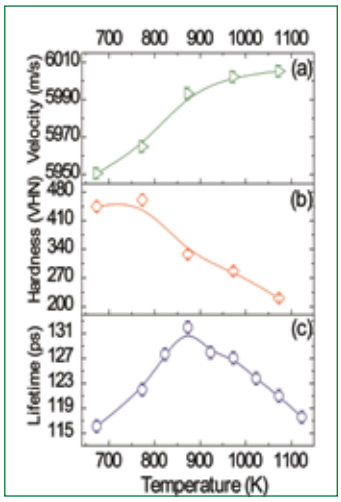

Figure 5: Positron lifetime, hardness and ultrasonic velocity variations during precipitate evolution stage in modified 9Cr-1Mo steel

corresponding PAL values. A direct correlation can be found between the parameters as shown in Figure 4. The higher lifetime at 300 K is dictated by contribution from dislocations. By hypothesizing that the precipitates are defect free, as growth process occur by diffusion of atoms, the trapping sites are considered to be interfacial defects and hence increase in PAL with increase in interfacial surface. The observations show that if there are changes in precipitate number density and/or volume fraction there will be a change in interface surface area and the positron lifetime changes.

While positron results show these stages of precipitation having sensitivity to associated open volume defects, hardness and ultrasonic techniques looks at the ductility and modulii of the material. The results of these three techniques in the precipitation range are compared (Figure 5) and found that positron technique could distinguish the transition stage where coarsening process takes over growth stage. Other two techniques showed monotonic changes with increase in ductility and modulus which is ineffective to identify the transition. However, the advantage of positron does not hold everywhere. For example, if microstructure of the material put in use is to be identified where the treatment conditions vary, there will be an ambiguous assessment of two or more possible microstructures for a given lifetime (a straight line corresponding to measured lifetime intersect twice in Figure 5c). However, by

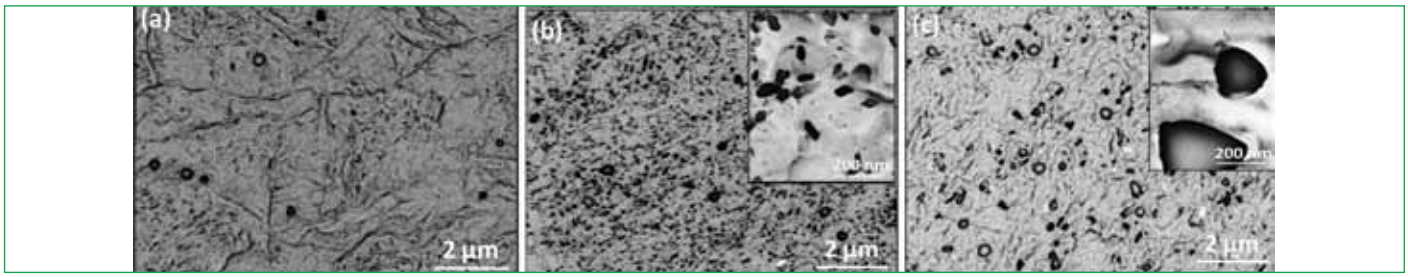

Figure 3: Precipitate evolution in modified 9Cr-1Mo steel as a function of tempering temperature (a) 773 K, (b) 873 K and (c) 1073 K, indicating nucleation, growth as well as increase in number density and coarsening of precipitates

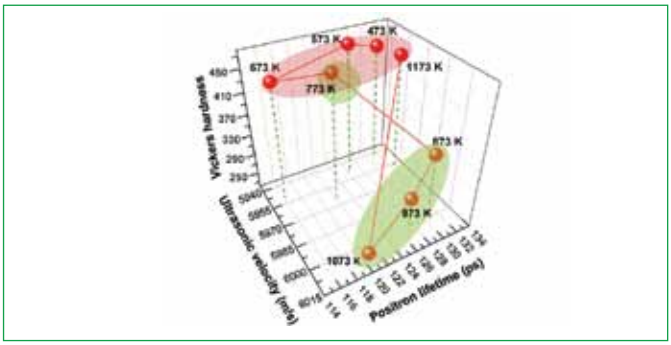

Figure 6: Correlation between observed lifetime, ultrasonic velocity and hardness

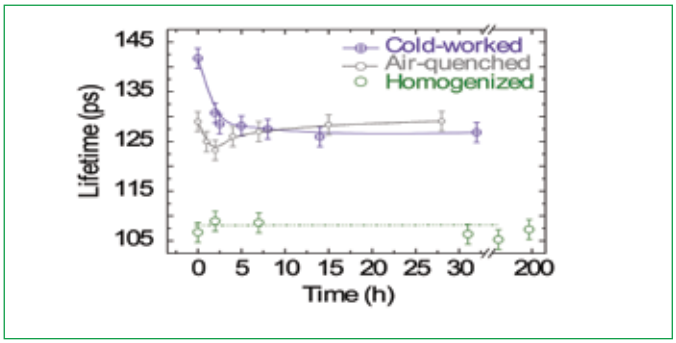

Figure 8: Lifetime as a function of heat treatment time in Fe-9Cr alloy, on the defect containing cold-worked and quenched samples

measuring positron along with hardness and ultrasonic velocity one can get comprehensive information which would be different for different microstructures, because the set of three values will be unique for a given microstructure. A correlation plot depicting different microstructural changes as a function of tempering temperature is shown in Figure 6. The red region represents martensitic phase and the green region represents precipitation stages. The green region at temperature 773 K also shows its tendency towards precipitation. It should be noted that nucleation of precipitates is observed in SEM micrographs of 773 K tempered sample.

Scope of Utilization of this Methodology

This methodology can be used for microstructural characterization in R&D of ferritic steels. In particular (i) to probe the precipitate evolution (ii) to compare the isothermal kinetics of precipitate evolution with varying chemical composition (example: effect of Mo replacement with W on kinetics) (iii) having known that precipitates such as M_2X, $M_{23}C_6$ and MX evolve at different temperatures, the isothermal studies could access the relative contribution to positron lifetime. This information may be useful to study individual precipitate evolution in newly designed ferritic steels (iv) to identify Ac1 temperature with less sample preparation (unlike techniques such as ultrasonic velocity, hardness, calorimetry, dilatometry and thermo emf).

Having generated data, this methodology can be used for NDE study of steels in use for more pointed identification of microstructure. This data generation on modified 9Cr-1Mo steel would be more appropriate, as it is chosen as steam generator structural material for PFBR.

This methodology may also find an application in some of the specified steel processing stages for microstructural assessment, where conventional techniques find the ambiguity.

Fe-Cr Binary Alloy

Problem of Irradiation Embrittlement and 475 °C Embrittlement

Thermal aging around 748 K or/and irradiation is known to cause embrittlement (known as 475 °C embrittlement) in ferritic steels with chromium concentration greater than 12%. It is quite often attributed to chromium rich α' (BCC) phase formation in α (BCC) phase by segregation. However, iron and chromium lattice parameter being close (i.e., 2.87 Å and 2.91 Å, respectively) theory does not support that the magnitude of increase in hardness is due to this BCC(α') in BCC(α) coherent phase formation. A rigorous study is carried out to identify and substantiate the nature of the phase and the factors that effect its formation.

Identification of Chromium Segregation

Two sets of samples each, with Fe-(9, 12 wt%)Cr composition, are treated (i) inside high temperature FCC loop and (ii) at 1073 K, just below FCC loop. They are quenched to room temperature. Isochronal study of quenched samples showed chromium precipitation stage following dislocation annealing, below 873 K. The precipitates dissolve into matrix for temperature above 873 K. The sequence of evolution and dissolution has been identified by TEM observations (Figure 7). These precipitates are found to be rich in chromium. Sample treated in BCC state, at 1073 K, are dislocation free and the subsequent heat treatment did not result in chromium precipitation.

Role of Dislocations on Chromium Segregation

To ascertain the role of dislocations, further confirmation studies

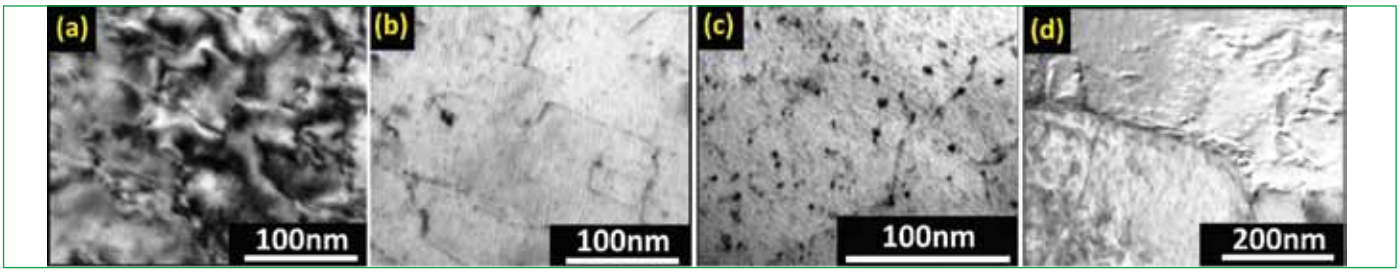

Figure 7: TEM micrographs of Fe-9Cr alloy in (a) as-quenched state, containing dislocations, and subsequently heated at (b) 773 K, majority of dislocations annealed and a few dislocation loops formed (c) 900 K, formation of precipitates of size 4-6 nm and (d) 973 K, dissolution of majority of precipitates and grain growth observed

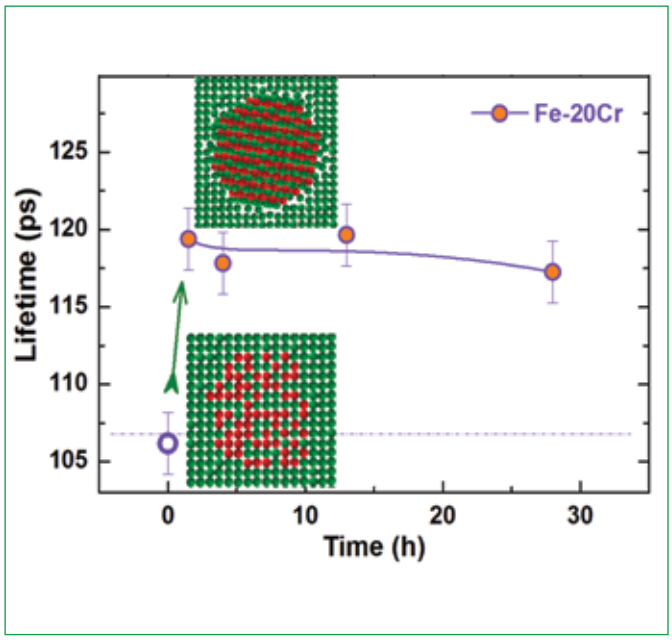

Figure 9: Change in positron lifetime corresponding to phase transition of Cr-rich BCC α' into intermetallic σ-phase. The transition causes production of interfacial defects and hence the increase in lifetime

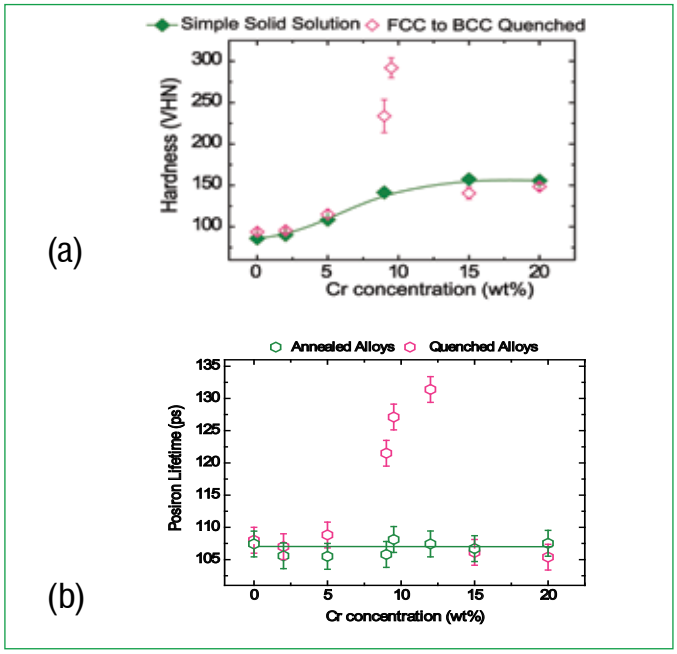

Figure 10: Comparison of (a) hardness and (b) lifetime between regular equiaxed grain structure and the structure resulted of quenching as a function of chromium concentration

were carried using positron lifetime as a function of isothermal heat treatment of homogenized, quenched and deformed samples (Figure 8). Treatment was carried out at 748 K. While latter two samples, having dislocations, showed higher PAL corresponding to precipitate formation, homogenized sample showed no increase from defect free PAL value even after 198 hours of aging. These observations clearly indicated the role of dislocations in chromium segregation.

Identification of Segregation as σ-phase

According to Fe-Cr phase diagram, in high chromium alloys, chromium rich α'-phase and intermetallic σ-phase are known at equilibrium for temperatures below and above 785 K, respectively. The nature of precipitates is confirmed by studying Fe-(15, 20)Cr alloys with no initial dislocation. In Fe-(15, 20)Cr samples, PAL studies as a function of aging time at 748 K showed no change from defect free initial lifetime i.e., 108 $\pm$ 2 ps, up to 210 hours. With this prior aging of 210 hours as initial condition, the samples were treated at 873 K. This resulted in lifetime increase (Figure 9) indicating the formation of open volume defects. However, separate samples with no prior treatment at 748 K retained the defect free bulk lifetime of 108$\pm$2 ps, after similar treatment at 873 K. This observation shows that chromium segregation occurred in the 748 K treatment and in the subsequence 873 K treatment, the local chromium rich phase converted into intermetallic phase. However, in the case of Fe(9, 12)Cr samples, the extra internal energy associated with initial dislocations or/and sub-grain structure causes accelerated segregation and σ-phase formation at 748 K. These observations strongly support that the magnitude of hardness observed in embrittlement of high chromium steels is due to intermetallic σ-phase due to similar defect structure associated with Fe-Cr alloys.

The high temperature FCC phase containing pure Fe-Cr alloys, with chromium concentration above 7 wt%, form martensitic like structure during quenching due to chromium solute effects. The resultant structure is harder, compared to regular equiaxed grain structure, due to sub-grain boundaries. It is surprising that the literature never attempted to clarify this effect and found reporting that there is no effect of quenching. This is the first time that the hardness difference is reported explicitly (Figure 10a) and corroborated with positron lifetime (Figure 10b) and Doppler broadening spectroscopy studies. As these defects and sub-grain structure is influencing the aging effects, it should be of interest to computational modelling community and experimental studies to bring a meaningful correlation between the results existing.

Implications on Future High Chromium Ferritic Steels

Ferritic steels with high chromium concentration (12%) are prone to have intermetallic σ-phase as a resultant of aging around 748 K or/and irradiation leading to embrittlement. These steels cannot be free of dislocations in its making and processing, hence the composition selection is crucial. However, the periodic transient conditions of reactors which envisage higher temperatures (>873 K) are beneficial for the intermetallics to dissolve back into matrix. For the components which do not have this advantage, there should be a periodical treatment at higher temperature for de embrittlement.

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Materials Physics Division,
Materials Science Group

Conference and Meeting Highlights

First International Conference on Structural Integrity (ICONS-2014)

February 4-7, 2014

Dr. T. Jayakumar, Director, MMG, Dr. P. R. Vasudeva Rao, Director, IGCAR, Shri S.S. Bajaj, Chairman, AERB, Dr. K. Tamilmani, Chief Executive, Center for Military Airworthiness & Certification and Dr. B.P.C. Rao seated on the dais during the inaugural function

The First International Conference on Structural Integrity (ICONS-2014) was successfully organised at Convention Center, Anupuram, during February 4-7, 2014. The main objective of ICONS-2014 was to provide a forum for engineers, scientists, academicians, industry experts, plant managers and regulatory personnel to discuss the recent advances and future directions in structural integrity, encompassing design, material selection, stress analysis, manufacturing, materials evaluation, welding, quality assurance, microstructure characterization, corrosion, non-destructive evaluation (NDE), damage mechanics, failure analysis, life extension and related aspects that ensure safe and reliable operation of components in nuclear, defense, aircraft and other industries.

During the inaugural function held on 4th February, Dr. P.R. Vasudeva Rao, Director, IGCAR extended a warm welcome to all the speakers and delegates from abroad and India. He highlighted the need to have a conference series like this to bring researchers together to discuss the advances in structural integrity of engineering components and structures. Dr. T. Jayakumar, Chairman, ICONS-2014 gave details about the conference. He stated that more than two hundred seventy research papers were being presented in fifty four technical sessions and there were sixty two plenary (invited) talks by eminent international experts from thirteen countries including Austria, Australia, Czech Republic, Germany, Hungary, Italy, Japan, Portugal, South Korea, UK and USA. He pointed out that ICONS-2014 had attracted delegates from R&D, academic institute and industry.

Shri S.S. Bajaj, Chairman, Atomic Energy Regulatory Board (AERB) inaugurated the conference. During the inaugural address, he highlighted the important role of structural integrity in ensuring safe and reliable operation of Pressurized Heavy Water Reactors (PHWRs) as well as Kudankulam nuclear power plant and the significant role played by the regulatory systems. He released the Souvenir of ICONS-2014 and gave the first copy to Dr. K. Tamilmani, Chief Executive, Center for Military Airworthiness & Certification (CEMILAC), Defence R&D Organisation (DRDO). Dr. Tamilmani delivered the presidential address and emphasized the importance of materials selection and imparting stringent quality assurance during manufacturing and assembly stages, on the structural integrity, especially in airborne military platforms. He released the CD proceedings of ICONS-2014 consisting of 185 full text of papers presented at the conference. Dr. B.P.C. Rao, Convener, ICONS 2014 proposed a hearty vote of thanks.

Three hundred fifty delegates attended ICONS-2014 and four sessions were conducted in parallel. ICONS-2014 closing session was chaired by Dr. T. Jayakumar on February 7, 2014. Dr. David Smith, UK, Dr. Ward Rummel, USA, Dr. Raman Singh, Australia, Dr. G. Raghava, SERC, Chennai, India and Cmdr Mohamed Salih, Indian Navy, New Delhi spoke and gave feedback. They appreciated the arrangements and congratulated the organisers for successfully conducting the conference and expressed their desire to take part in future conferences. It was decided that the 2nd International Conference on Structural Integrity would be conducted during February 2017.

Reported by
T. Jayakumar, Chairman &
B.P.C. Rao, Convener, ICONS-2014

Second IGCAR-KAERI Workshop on Sodium Cooled Fast Reactors

February 18-19, 2014

Dr. P. R. Vasudeva Rao with delegates of IGCAR-KAERI Workshop

The second IGCAR-KAERI Workshop on sodium cooled fast reactors was held during February 18-19, 2014 at IGCAR, Kalpakkam. KAERI delegation comprising of nine engineers, led by Dr. J. H. Baek, Technical Manager in SFRA/KAERI, visited IGCAR to participate in this workshop. From IGCAR & BHAVINI twenty four delegates attended the workshop. Dr. P.R. Vasudeva Rao, Director, IGCAR, welcomed the KAERI delegation. Dr. P. Chellapandi, Director, Reactor Design Group, summarised the workshop.

IGCAR and KAERI participants presented the progress in research activities in the areas of SFR technology and the future plan of SFR in each country for the items agreed on the workshop agenda. It was especially worthy to note that six parallel sessions were arranged for the detailed face-to-face discussions among the responsible engineers from each country. And after the technical discussions, KAERI delegation was taken for technical visits to the test facilities of IGCAR and PFBR simulator at BHAVINI.

The present workshop and interaction was beneficial towards the design of Generation IV Fast Reactors. At the end of the second workshop, future collaborative studies have been proposed in the areas of

- sharing facilities like SADHANA and STELLA-1
- dedicated theme meetings for the presentation of the position papers
- common benchmark studies
- joint development of computer codes for reactor safety
- evolve the criteria associated with clad rupture
- the behaviour of molten debris in the hot pool
- expert support and visit of the engineers/scientists between KAERI and IGCAR.

Reported by
K. Madhusoodanan, RDG

Delegates of IGCAR-KAERI workshop with Dr. P. R. Vasudeva Rao, Director, IGCAR and senior colleagues of the Centre

IAEA Technical Meeting on Development of Advanced Fuels for Fast Reactors

March 03-06, 2014

Dr. P. R. Vasudeva Rao, Director, IGCAR addressing, Shri U. Basak, IAEA, Scientific Secretary and Dr. K.Nagarajan, Director, CG seated on the dais during the inaugural function

An IAEA Technical Meeting on Development of Advanced Fuels for Fast Reactors was held at IGCAR during March 03-06, 2014. Thirty seven delegates from abroad and other DAE units participated in the meeting. Presentations made during the meeting by eminent scientists included various aspects of advanced fuels, such as fabrication, property measurements, fuels for reactors for transmutation of minor actinides, reactor physics aspects of these reactors and fuel cycle. The presentations were followed by detailed discussions with active participation of all the delegates. After the meeting, there was panel discussion on the possible collaborations between various institutions and IAEA Co-ordinated Research Projects (CRP). Visits to FBTR and PFBR for the outstation delegates were arranged during the meeting.

Reported by
K.Nagarajan, CG

Participants of the meeting along with senior colleagues of the Centre

Seminar on Chemical Engineering in Nuclear Technology (CHEMENT-2014) with theme of "Recent Advances in Fuel Cycle Technologies"

March 06-07, 2014

A seminar on Chemical Engineering in Nuclear Technology (CHEMENT-2014) with the theme of "Recent Advances in Fuel Cycle Technologies" was jointly organized by Indian Institute of Chemical Engineers (Kalpakkam Regional Center) and IGCAR during March 06-07, 2014. The Seminar was partially sponsored by Board of Research in Nuclear Sciences (BRNS) of the Department of Atomic Energy. This seminar was the second in the series of seminars on Chemical Engineering in Nuclear Technology (CHEMENT). The primary aim of the seminar was to discuss the advances in fuel cycle technologies with a focus on equipment design, modeling and simulation, plant experience sharing and performance evaluation.

CHEMENT-2014 was attended by leading experts from DAE as well as from reputed academic institutions, several research students and representatives from industry. In the inaugural session, Dr. R. Natarajan, Director Reprocessing Group and Honorary Chairman, IIChE-KRC welcomed the delegates. The inaugural session was presided over by Shri N. Saibaba, Chief Executive, Nuclear Fuel Complex. Keynote address was delivered by

Release of book of abstracts by Chief Guest Shri N. Saibaba, Chief Executive, NFC

Dr. P.R. Vasudeva Rao, Director, IGCAR. While exploring the challenges and targets for fuel cycle technologies, he stressed the need for new vistas in the reprocessing activities especially for metal fuels and for actinide recycling. He stressed for the creation of new benchmarks and novel challenges and directions. Vote of thanks was proposed by Shri Shekhar Kumar, Honorary Secretary, IIChE-KRC and organizing Secretary, CHEMENT-2014.

There were five technical sessions spanning over two days with intense interactions. A total of fourteen invited talks covering various topics of interest to nuclear fuel cycle, were delivered by eminent speakers. These included Shri N. Saibaba, Chief Executive, Nuclear Fuel Complex, Shri P.K. Wattal, Director, NRG, BARC, Shri P.R. Mohanti, Director (Technical), Heavy Water Board, Mumbai, Shri Y. Kulkarni, General Manager, INRP(WM), Nuclear Recycle Board, BARC, Dr. S.B. Roy, Head, UED, BARC, Prof. V.G. Gaikar and Prof. Ashwin Patwardhan, ICT Mumbai, Shri Amitava Roy, Facility Director, BARCF, Kalpakkam, Dr. Neerav Bhat, IITM Chennai, Prof. C. Anand Babu, PSG College of Technology, Dr. M. Sridhar of IICT, Hyderabad, Dr. K. Ekambara of M/S Technoforce, Mumbai, Shri K.,T. Shenoy, Head ChED, ChEG, BARC and Shri Surya Kumar, Alwaye, IREL. The technical sessions were chaired by Dr. R. Natarajan, Prof. P.S.T Sai, Head, Department of Chemical Engineering, IIT Chennai, Shri Amitav Roy, and Prof. C. Anand Babu. The talks were well received and there were many interactive responses.

In addition to oral technical sessions, forty two contributed papers were presented in poster session on both the days. A special interactive session with the students and faculty of chemical engineering departments of various engineering colleges in Tamil Nadu was organized on the second day. Fifteen faculty members and thirty one students from fifteen engineering colleges attended the session. This session consisted of three exclusive talks tailored for students. Shri P.K.N. Panicker, President, Chemical Industries Association, Chennai and past national president, IIChE, spoke on “Nuclear Science from an industrial perspective”. Dr. R. Natarajan spoke on the subject “Chemical Engineer-A Key player in Nuclear Technology”. Prof. K. Krishnaiah, Emeritus Professor and Ex-Dean, IITM, Chennai spoke on the topic “What is your scale in chemical engineering?”.

At the concluding session, Dr. P.M. Satya Sai, Convener summarized the technical and poster sessions. After presentation of poster awards and feedback from outstation delegates, vote of thanks was proposed by Shri Shekhar Kumar, organizing Secretary, CHEMENT-2014.

The deliberations in CHEMENT-2014 focused on identifying the challenges in areas related to advanced fuel cycle technologies and to evolve an action plan. It provided an opportunity to persons in R&D and in operation to meet and interact with the academia and industries dealing with solvent extraction.

As a concluding event for CHEMENT-2014 on March 12, 2014, IGCAR, IIChE-KRC and BHAVINI felicitated Prof. J.B. Joshi, Homi Bhabha Professor, HBNI on being awarded the Padmabhushan.

Reported by

Shekhar Kumar,

Organising Secretary, CHEMENT-2014

Visit of Dignitaries

Dr. Avinash Chandra, Scientific Advisor to Defence Minister, with
Dr. P. R. Vasudeva Rao, Director, IGCAR and senior colleagues of the Centre

Dr. Avinash Chandra, Scientific Advisor to Defence Minister, visited IGCAR on January 02, 2014. After a meeting with Dr. P. R. Vasudeva Rao, Director, IGCAR and senior colleagues of the Centre, Dr. Avinash Chandra visited the Fast Breeder Test Reactor & KAMINI Reactor, Hot Cells and Non-Destructive Evaluation Division and construction site of Prototype Fast Breeder Reactor.

Shri P. S. Parihar, Outstanding Scientist & Director, AMD, Hyderabad, delivered the IGC colloquium on "Status of Uranium Resources in the Country" during his visit to the Centre on January 17, 2014.

Shri P. S. Parihar, Outstanding Scientist & Director, AMD, Hyderabad, delivering the IGC colloquium

Dr. R. Chidambaram , Principal Scientific Advisor, Government of India, delivering the lecture, organized as a part of series of lectures to commemorate the International Year of Crystallography

Dr. R. Chidambaram, Principal Scientific Advisor, Government of India, during his visit to our Centre on January 28, 2014, delivered the lecture on "Crystallography, Materials Science and Biology", organized as a part of series of lectures to commemorate the International Year of Crystallography.

Shri Amandeep Singh Gill, Joint Secretary, Disarmament and International Security Affairs (D&ISA), Ministry of External Affairs visited the Centre during February 28- March 2, 2014. After a meeting with Dr. P.R. Vasudeva Rao, Director, IGCAR and senior colleagues of the Centre, Shri Amandeep Singh Gill visited the Fast Breeder Test Reactor & KAMINI Reactor, Hot Cell Facility and Construction Site of PFBR.

Shri Amandeep Singh Gill, Joint Secretary (D&ISA), Ministry of External Affairs with Dr. P. R. Vasudeva Rao, Director, IGCAR

Prof J. B. Joshi, DAE-Homi Bhabha Distinguished Chair Professor and J. C. Bose Fellow, delivered the IGC colloquium on "Wealth Generation Through University – Industry Partnership" during his visit to our Centre on March 11, 2014.

Prof J. B. Joshi, DAE-Homi Bhabha Distinguished Chair Professor and J. C. Bose Fellow, delivering the IGC colloquium

Prof. Valiathan, Founder-Director, Sree Chitra Tirunal Institute of Medical Sciences and Technology & National Research Professor of Government of India, at Manipal University, delivering the IGC colloquium

IGC colloquium on "Biomaterials, Bio-Devices and the Story of the TTK-Chitra Heart Valve" was delivered by Prof. Valiathan, Founder-Director, Sree Chitra Tirunal Institute of Medical Sciences and Technology & National Research Professor of Government of India, at Manipal University, during his visit to the Centre on March 21, 2014.

Forthcoming Events / Awards

DAE-BRNS Theme Meeting on Recent Trends in Spectroscopy (RTS-2014)

Society for Advancement for Chemical Sciences and Education (SACSE), Indira Gandhi Centre for Atomic Research and Indian Institute of Technology Madras, Chennai are jointly organizing a Theme Meeting on Recent Trends in Spectroscopy (RTS-2014) during June 20-21, 2014 at IIT, Madras, Chennai, Tamil Nadu. The technical programme of RTS-2014 will include plenary lectures and invited talks by eminent speakers from leading institutions. The talks are aimed at providing an insight into the latest developments in various spectroscopic techniques to the research students and practicing scientists. In addtion there would be oral and poster presentations by young researchers.

Topics covered include:

- Infrared and Raman Spectroscopy
- Time resolved spectroscopy
- Mass spectrometry
- Nuclear magnetic resonance spectroscopy
- Electron spin resonance spectroscopy
- Rotational & vibrational spectroscopy
- Fluorescence spectroscopy
- Cavity ring down spectroscopy
- Laser based spectroscopic techniques
- Electrochemical spectroscopy

Address for Correspondence
Secretary, RTS-2014
Materials Chemistry Division, Indira Gandhi Centre for Atomic Research, Kalpakkam
Website: http://chem.iitm.ac.in/RTS2014

Awards & Honours

Dr. K. Nagarajan, CG has been awarded the MRSI Medal for his significant contributions to Materials Science and Engineering by Materials Research Society of India during the annual general body meeting held at Bengaluru during February 12-14, 2014

Shri A. Ravishankar, RpG has been elected, Fellow of the Indian National Academy of Engineering

Dr. U. Kamachi Mudali, MMG has been elected as Academician (Fellow) of The Asia-Pacific Academy of Materials (APAM)

Best Paper/Poster Award

Development of Prototype Fibre Optics Dosimeter for Remote Radiation Measurements
Ms. Asha Jayaprakash, Shri D.N. Krishnakumar, Shri A. Dhanasekaran, Dr. M.T. Jose, Dr. B. Venkatraman and Shri S.A.V. Satya Murty from EIRSG
31st National Conference on Advances in Radiation Measurement Systems and Techniques March 19-21, 2014, Indian Association for Radiation Protection, Mumbai
Best Poster Award

Camel Foot Tree

Dr. M. Sai Baba,
Chairman, Editorial Committee, IGC Newsletter

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