

Materials Chemistry
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Lecture - 02
Interview with C N R Rao and Interview with E C Subba Rao

Extremely, delighted to talk to you about the materials research in India and with specific reference to projections and possibilities that are before us on material synthesis in India parse. And we have been looking at various modules as specially on the synthesis and all the characterization tools, that are available today to study a range of materials. And as we see that the devices applications of these materials are going nano and we probe into nano word.

The landscape for materials research is not going small, rather it is becoming big and we have larger audience for this research. We have many groups working on a spectrum of issues related to material synthesis, not only it is a field for chemistry to explore for those who involved in chemistry. But, also physicists are equally contributing to materials research and equally from the technology side engineering departments are contributing.

And in today as talk, I want to introduce Professor E C Subba Rao who is with us and it is, rare opportunity to have him visiting I I T Kanpur, he is the one of the person who really pioneered research in materials science. In fact, he was instrumental to start many programs on materials research and also few departments, which are now existing it is, because of his vision and of the untiring efforts that he left behind.

So, he has been with us on and off and today, it is a rare privilege to have him here in the studio and I request Professor E C Subba Rao to come and share few milestones, that I I T Kanpur has travelled through and also, he since he has global understanding of how the material research is going on, both in India as well as in world at large. I request him to give some projection about the importance of materials research, both in India as well as broad, I now give time for professor E C Subba Rao to share his thoughts.

Very kind of Professor Sundar Manoharan to give me a chance to share little bit about materials science, sort of on coming from me. And what I would like to do is as he has indicated, a little bit about the road that material science has taken at I I T Kanpur over a period of time, put it in the framework of the world seen. And then conclude by saying a

little bit about, where is materials science headed in the years to come and its importance.

When the Russians put up sputnik, there ((Refer Time: 03:48)) they were doing a lot of materials this and that, but they did not put science into that very much. And so, they woke up and suddenly, they thought that there is without science we cannot understand materials, just to make something little bit harder and so on, is by processing is not that that is enough.

So, it became kind of a pressing issue and places like M I T and some other the places got into materials science to understand materials from a scientific stand point, not only from engineering and technology stand point. When I I T was set up, there was an agreement between the U S and I I T Kanpur, that we two would work together, there were nine universities in the U S that formed a consort even worked with us and these included some of the best in the U S.

Very interestingly, write from the beginning even for undergraduate students for everybody in the institute. We had a course on material science and this is taught by people from various departments for example, Professor C N R Rao who is one of them and Professor Parasnis and people from other departments also participated, either as teachers or as tutors and so on. And about that time, because that we were having already a course, we wanted to know whether we are doing the right things.

So, in 1966 we held the first conference on Materials Science education in India, very interestingly out of the 100 participates at, so about 50 came from educational institutions, all I I T institute of Science, B H U ensure regional engineering colleges and so on. But, the more interesting part is the other 50 came from industry, they also wanted to know what is going on in Materials Science.

And we were lucky to have three major stalwarts in material science and in the U S, Professor Mari Sako from M I T is sort of a father of material science and john don from U S California, worked in and either are from U S it they together with the local people. We conducted a weeklong conference and in a way that laid the foundation of material science education and research in this country, all these people that came went back and started something in their own institutions.

And our own part, we started the graduate program and the masters and p h d level on material science and manage to set up an advanced centre for material science. And in these courses, as well as in the advanced for materials science, it is a interdisciplinary activity. Which is kind of say a life blood of I I T Kanpur as it grew, interdisciplinary activity is a magic code for Kanpur.

So, we had people from various departments chemistry, physics, electrical engineering, mechanical engineering of course, metallurgy, participating in it. The interdisciplinary program was, so much that my first p h d student in I I T Kanpur got is degree in physics and others too later. Now, starting from there we wanted to educate rest of the education seen in India about this.

So, very religiously for a number of years we ran a 1 month course for engineering college teachers, for on material science and these people went back and started to teach, in their respective universities institutions. The second thing that we did was, it is not enough to read from a book, the relationship between materials their properties, their processing and their behavior unless students read the dirty their hands doing some experiments.

And, so the first undergraduate lab for material science, was set up in Kanpur and after we refined the experiments. We decided to put it in the form of a book and true to the tradition of I I T Kanpur, though I was in a way the instigator for that effort, I make sure that there were four other coauthors to the book all of them, under 30 and they came with degrees from oxford Sheffield and various places and luckily and everybody in India wanted publish it.

And I did not want to give it to somebody locally, because then he would send you to some local university and they would not even understand what we are talking about and the comments that I get from them are not going to be useful. So, I wanted to give it abroad, so I took two copies with me to the U S and I sent it to two publishers, one publisher returned it in 1 week, saying that we did not look at the technical content, we look at the commercial how many copies, we sell we make our usual amount of money and we thought that we may not make, so much money.

But, second one I did not here for quite a while and that was McGraw hill and after something like 3 months, I get a three paged letter saying that normally, we hire three

reviewer and pay them money and they have to review and give at least a two page report on the book. And the other has to take those things into account and make the revisions of all that, in this case because the book came from India we were skeptical and we wanted to be double sure.

So, we took six reviewers all the reviewers have come and we had the shock of our life, not one had anything negative to say, not a word to be changed. It is such a unbelievable experience for us that we are going break of our publishing tradition and normally when you submit a paper to a journal, the reviewers comments are sent anonymously to you do not know, who the reviewer is and that is more, so in the case of books.

In this case, because they were, so uniformly complimentary we are sending every all the six letters with the letter head and the signature of the man. And the next shock for us is this came from India and the language would be atrocious and therefore, the editorial staff would have to work very hard at it. So, we were sent it to the editorial office and within a week they returning us to saying, we could not touch even a word we could not cross a t or dot an I and this was the second shock for us.

So, with this we sent it to the printer it is under print, here is your contract and it has since been translated into other languages, it is used it M I T Berkeley and everywhere abroad also, translated into Spanish and various other languages. So, that is the spirit of materials science in Kanpur and then there are other things that have been written, but the fact that, it is a maiden effort and that it went, so well and actually when the royalty started coming, they wrote to me you are the senior other how do you distributor the royalties, said everybody is in equal to partner give it 20 percent everybody.

And, then now I would come to a little bit about where materials science is going, understandably in the very early years, it is to try to understand materials that are already in use. Whether it is metals ceramics a bit of polymer and so on, but as time went by it turned out there is feeling, that they are more dimensions to the problem. 1 plus 1 can be 3, so if you are able to make composites of more than one material then the properties may be far better than either of the may have.

So, composites became a pretty fashionable area and it has, added a lot to our understanding and use of materials and the other major change, that has taken place is in processing, they were conventional ways of making materials. If you begin to use some

novels synthesis methods, you may end up with materials with a different set of properties a very good example that is, when you take two materials and mix them together and heat them, you form some new phases and there is a phase diagram for it composition temperature diagrams.

At Caltech Paul way found that some of these materials, when they are cooled rapidly from high temperatures instead of crystallizing with a regular crystal structure, they become what they call metallic glasses with properties, that were unbelievable nobody dream of them, there is a metal inside it is a glass and it opened up a west area in true tradition of I I T Kanpur as soon as Paul way came up with my class here.

We started to work on that for example, I had a b tech student we wanted to study some of his properties and he studied and he came out something, very interesting. It got published in applied physics letters and this fellow wrote to Paul way with a copy of this paper and straight from, his b tech and got into Caltech and got his p h d there.

So, that is another dimension more recently the trend has been, to go to fibers small dimensions and also not only dimensions in diameter, but dimensions in all directions. So, that we end up with materials that are nano particles the properties that these exhibit are very different from what one could predict, from the properties of bulk materials. The other important direction, it is taking is there is a marriage that taking place between materials science and a variety of other fields.

Some of them are unbelievably remote from material science, here I am referring to biological sciences and human body and people are beginning to find out, that our muscles the way they behave, the way, they age and they way give trouble and all that we never understood. Now, by extending our knowledge about, the mechanical properties of other relative species.

We are beginning to understand, how the muscles behave under various conditions this has become a pretty big area, another very big area is things connected with heart for example, whether it is a heart valves or whether it is a stent, people were putting in whatever is available in India. We never made valves, so we need to input and it is out of the reach of the most people.

So, we luckily we were there is a man from Hopkins that came to India and he wanted to set up a cardiology center, but that would have a lab and a manufacturing facility, It is called [FL] in Trivandrum. And he set it up they joined hands with d m r in Hyderabad and they started to make, titanium based valves and they are available for fraction of a cost, that and imported one would do.

So, like this there are, it has become even more interdisciplinary then it started out with the applications have, become rather wide spread and the dimensions were changed completely, that synthetics methods of making these materials, in the shape size and composition that we need them complete drastically changed. And this has opened up a vast new area and I would say that high strength materials and biomedical applications are two areas, where materials science is going to grow, in a very big way anything to know thank you very much.

Sir, I came for viva versa I I S C, I am, so happy that you have been to spare your precious time to this video interview, on the theme of materials chemistry recorded to viewed by NPTEL subscribers. In India you have had the longest journey with the area of solid state chemistry and materials chemistry, we would like to long strong foundation for this field and have put India in the map of materials world. I have as we know you have a thought wonderful physical chemistry courses at IIT Kanpur in nearly 70's and solid state chemistry.

So, I want to know when exactly you started, for me solid state chemistry is part of my life, In fact its slowly emerged to become materials chemistry, when I started working at it nearly 53, 54 years ago this subject was not known. In fact, if ever wherever I mentioned this subject name called solid state chemistry people, would laugh and will make jokes about it, they all knew solid state physics. But, very few know solid state chemistry.

In fact, in that entire world at large they are not even 20,30 known chemist at that time and I thought to know someone very closely like j s Anderson in oxford some other in Germany slowly, at the then I decided around 1957, that this will be one of my major areas to research and I started working in it as soon as I joined Indian institute of science as the faculty member in 1959.

And slowly I developed the subject in various ways particularly in the area of oxides, because on that time I decided oxides constitute, the best and the most important family of materials, to the widest range of properties any property electrical property any property you take oxides offer, the maximum range and that maximum varieties and structures at all.

So, I have worked on synthesis, structures, phenomena properties and number of things slowly, I expanded my area to various other things carbon materials, hybrid materials and I do more synthesis and much more chemistry today, than in the early days it was all dry chemistry, now much more wet chemistry I do. And I have always used lots of spectroscopy diffraction and the number of technique, that is the beauty of the subject it is highly interdisciplinary.

In fact, you have to know enough physics to do good chemistry and if you are knowing physics aspects, In fact they have to know good chemistry materials itself, has become a area where, we I can introduce very needful knowledge of sister disciplines. It has been a pleasure to work here and train the large number of students, ((Refer Time: 21:37)) I do not know how many, now at least 100 people who has got P h d is with me and more and a large number of others.

And it has been a wonderful thing to grow with the subject., In fact, I still remember John Good enough and hark parlharmudemude though they are much older, than me they are almost my contemporaries inside. Because, their first papers are also in 50 is, then I was very young I was also starting doing at the same time. So, it is a wonderful thing to see a lot of work coming not only that lot number of wonderful young people not only in India, but abroad who have worked with me or have collaborated with me, some other have become famous now in this subject.

So, they ate then a pleasure I think the area is becoming much more interesting in the last few more years, because of the tremendous interface it has developed with biology physics, chemistry, materials like that various branches of chemistry. So, I think it is a good area and I, In fact believe in the entire area of chemical science materials from one direction biological direction is the other one.

So, I think in India they are not people less working in it, but fortunately I think seem to be improving and I hope that, the more people working this area and contribute to((Refer

Time: 22:56)). Whatever I have going do today is, because much of the work has area and have large number of books, I brought out papers people have read some other they site lot of my papers, so even from India we are been able to do good work and which is noticed all over the world that is been a pleasure.

Sir, actually you mentioned about oxides in particular along the various inorganic solid you worked can you, please give some one or two examples of.

Well oxides for example, it has been I start working as simple binary oxide for luckily I ((Refer Time: 23:32)) or three like that, but later the complexity of oxides at the at the same time excitement of a oxide it, because wonderful structures they can made. Another reason is the metal oxygen bar is not metal sulphur bar 2 power, it is not a metal ion bond two ionic, it is s just right things with metal oxide d electrons.

So, give interesting magnetic properties and metal oxide and the right amount ionicity as covalence, give also metal city, metal city is possible in metal oxides at the same time you can have properties, localized electronic all kinds of variety of properties entire of properties that is one. And particularly some other structures like porous oxide, most materials that took whether it is ferroelectric super conductors, many of them almost of them mark having a ferroelectric like that.

So, ferroelectric one of my favorites, but I worked on other things too, but increase the time charge on materials are not ferrous necessarily or similarly multi ferrites, a multi ferrites is very exciting very interesting problem, that I worked on last few years. So, I think oxide gives a very nice way of even, today surprise I will give one example for example, aluminum oxide most used in any where aluminum oxide in a coriander structure, something related iron oxide Fe_2O_3 these also ((Refer Time: 25:03)).

You mix it with a $AlFeO_3$ is most stable not in coriander structure, but in the non center symmetry structure non symmetry specimen. So, this surprises like always I have a surprises and then many, new phenomena properties keep coming because of in this in think tremendous year for this.

Sir, since you mentioned about alumina a $AlFeO_3$ case, just I want to know whether there is anything that we need to know bear in mind to master making this components.

I think semi to be two things you have to train your mind try to think in material, that is way in India I do not see enough people do not know, how to think in this subject. Every subject if you are very dedicated to that subject, after 10 to 20, 30 years depending on once ability and once luck, you develop feeling when a subject it is intuited, that intuition in middle it is very complex.

It is a bear knowledge about periodic table plus other than that how to use a periodic table that is not easy to learn, it is you teach something to 1 k age, but use it very clever use as a ((Refer Time: 26:12)) other then, that the structures how to deal with a structure manipulating structures. Once you get that the intuited feeling you know, then you can to you can design two things, how to design a new material for example, that is why designing new structures new compounds.

But, even hybrid materials inorganic, organic hybrids and did fantastic area to work in unfortunately, I have done enough someway, but I would have done much more ((Refer Time: 26:41)) very good area to work on. So, like that for example, inorganic nano tubes people all made carbon, why only the carbon where carbon is also inorganic, but inorganic oxide nano tubes, sulphide nano tubes lot of work is to be done, then the grapy inorganic grapy every ever you know, that is what I did a nationalize graphics can start working on grapy in dust structures are baronets time, modicum sulphides same in the nano tubes.

So, right away induced to newer area is getting to just, because the verity that chemistry offers and verity not only a compositions, but also other structures.

Sir, you also mentioned about interfaces that has emerged, because of working on solid state chemistry when the advance of nano science.

Sure.

And nano technology coming is there any reason why we need to stay focus on material chemistry and how much we can study solid state chemistry.

Non chemistry is part of solid state chemistry, I do not like solid state chemistry at any more, unfortunately you can see what was happened to that old wonderful general for under the solid state chemistry as under ((Refer Time: 27:47)) journal started in 1968.

But, unfortunately that all become dry materials in one of the really materials, today make it by different method design that much more complex, much more chemical then some of the structures, that you see in the old soil state chemistry.

So, by better do say material chemistry or chemistry materials rather, than solid state chemistry, so that very few people call that solid state chemistry any more they call that pleasures materials chemist or something. But, even solid state chemistry, orbital chemistry whatever you call it has taken over entire nano not 9, 90 percent of nano is not a chemistry materials, solid state chemistry making studied properties, phenomena property making composites, that is all solid sate material chemistry. Actually ((Refer Time: 28:43)) separate subject part of materials. Sure sir, that is pleasure there is also slide shift from working on bulk materials going to thin films and nanostructures.

Thin films, I want to go there I am not interested in that, but nano materials also partly like thin films, but thing is that is only the form, I mean it is not a new materials concept thin film are used in the properties in films ((Refer Time: 29:10)). But, solid state chemist, study forms a study material in various forms, so thins films is not some of it is bulk, some of it is purely poly crystal, some of may be film form, some may be some other form., so some of the nano form nano materials.

So, I do not think everything is includes the solid state chemistry is deals with materials of compressing of organic inorganic and all possible ways of making them, it includes all forms amorphous crystalline nano films, every kind of form it also includes all properties surface properties, ((Refer Time: 29:52))properties, electrical property, magnetic properties, every type of property that is why this subject is exciting on permeable, because it could all phenomena all possible properties, all formal forms and all formal component it need that crystalline ((Refer Time: 30:08)).

So, if you like glass you do not say solid state chemistry, you do not mind you can study that, so I think that is why that is how why new subject.

Sir, one of the problem you have sitting website is which paper to read, because so, many papers have come. No. But I just want to know in the three decades whatever you publish, some 3 or 4 classic papers that you still search.

I would I can reach the 20 papers, actually recently in Indian society science press along with the work scientific broad collection of my 60 papers, I do not you would have seen that is ((Refer Time: 30:41)) material chemistry. And earlier brought down, when I am 17, a volume called advance in chemistry subject I am thought where 17 papers, but any way that show you summary.

But, actually ((Refer Time: 30:57)) as in the last 3 years, I published best papers in my life, after my 70th year as my best research in my subject, the last 6 to 7 years after became 70, so and psytrance increasing like mad is the last 5 years is more 3 and half, 3000, 3 and half 1000 per year. So, I just now cross 40,000 psytrance ((Refer Time: 31:24)).

So, there is no you know that the thing about this subject is old age and all does not matter, you can work for a very long time you would improve even you become old. So, I do not want pin point one for example, atoms are very interesting is a grapy in this ground, some other things are oxides not a interest.

So, we can look at this trends in. yes Chemistry that I can I will give you a copy of that.

Student: Sure sir, pleasure and also we can give this as a radian material for.

Sure.

And last question also touched up on thing, that we need to bear in mind specially when we work it on solids, you are advice to those who are is going to future generation.

I hope young people will take of this subject, because of the inevasible nature and also possible applications, technology that may come out also is there, more than anything the subject number of phenomena, number of properties requires. If you experiments is a number of techniques in other word you are not technique man, In fact some people in they do some spectroscopy, then they go on doing spectroscopy all kinds of materials you using that technique.

I will we are not non spectroscopy infrared, tomorrow you mass the day after tomorrow you neutron diffraction electric property you magnetic. So, that is why I like this subject you try to solve problems rather than be a in a s r servant of technique. So, I material chemistry offers tremendous opportunity, In fact fresh tools are taken they are just come

here is I do not know for example, I trained them within 1 year to make all kinds of ((Refer Time: 33:09)) kinds of spectroscopy diffraction, so it is a very wonderful to see good issue.

Sir, actually there is a rate amount ((Refer Time: 33:21)) said any example of specially in abroad, laboratories are also working equally in this field, any advice that we need to have on ethics issues.

I do not have any all science they should be need for ethics people, will cheat in all fields people also honest in all the fields very good honest people, so I cannot say much about ethics and I try to as ethic as I can be a never be a cheated anybody and I never lie or copy, I noted I hope others I have nothing to say. But, this much I can say that the subject requires very hard work, that is why people do not like people want easy life this is the wrong subject to take.

If you want to make good contribution to this field, even as seniors you should keep on learning there is no even last few weeks, I have done the something I did not know before I have to learn something theory to understand subject all that. So, people who do not want to keep changing and learning new things, a proper define this area is too difficult to demanding.

But, however it will helpful for live challenges it is a batter subject to work on that standard inorganic chemistry coordination, chemistry organic synthesis after all reactions any synthesis, you make use all those reactions. What is brilliant about that I do not see anything here you have much more possibilities of using intelligent design and novel approaches to this subject.

Thank you sir.