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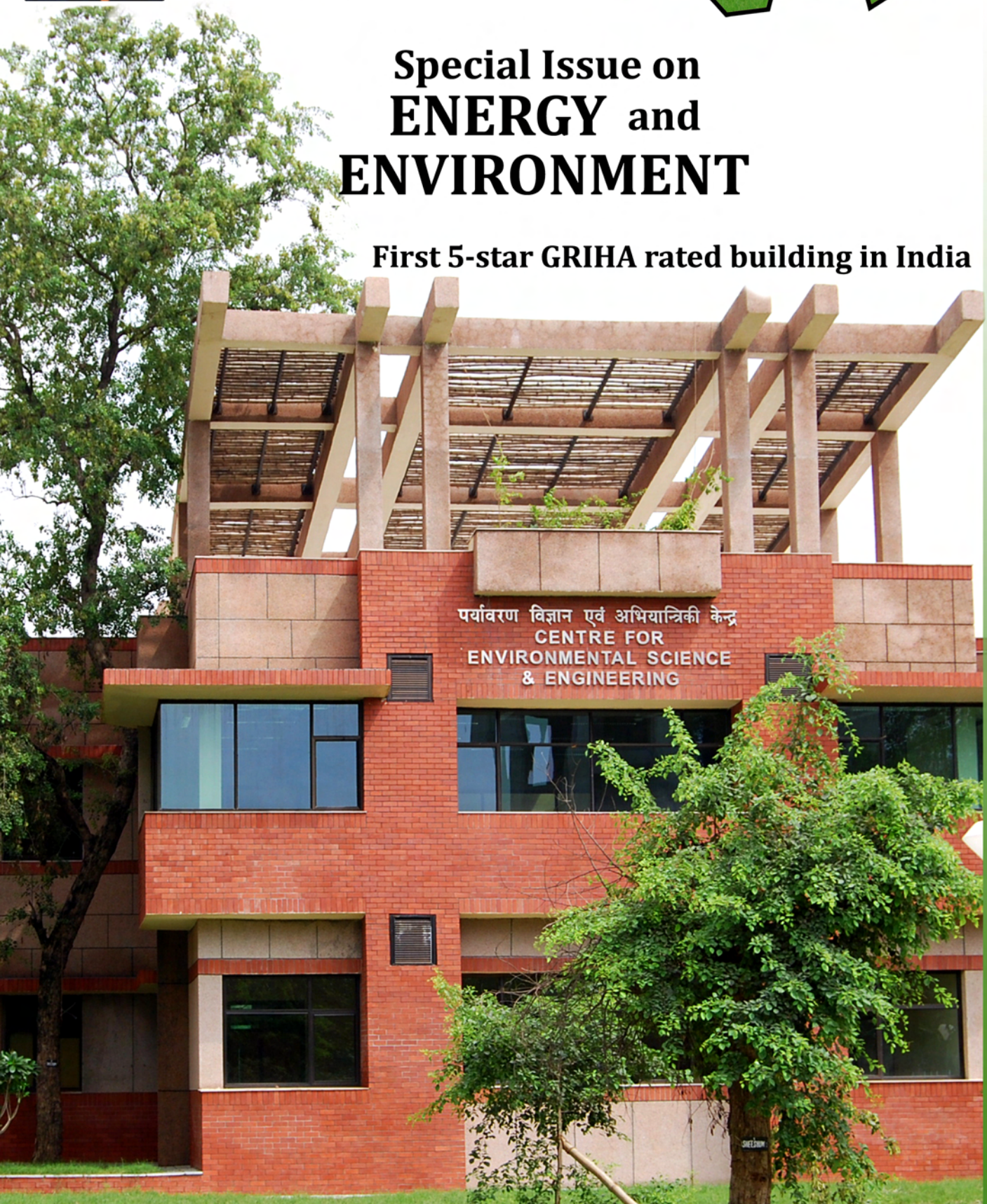
Interview with
Dr. C V R Murthy

NERD

Notes on Engineering Research and Development

Special Issue on ENERGY and ENVIRONMENT

First 5-star GRIHA rated building in India



NERD HERD

Ctrl + Alt + Energy

We sat down to decide the theme of Volume 1 Number 3 of NERD magazine on one electricity-less smoggy evening – scratching our heads for the one subject that would form the spine of the magazine. After several discussions back and forth, watching several smoke guzzlers pass by and cursing the Power Plant nearby hoping against hope for solar powered street lights, it clicked: ***Ctrl+Alt+Energy*** – the new shortcut people are looking for! What better than to address the concerns of the millennium: energy and environment? Throw in a *Techkriti* themed on Energy and then there is no doubt about the theme of this third special issue of NERD magazine.

[Energy] The world is running out of oil. Despite projections by Aramco and others, we will run out of conventional gas at some point of time in the future. Opposed to this, the global demands of energy are nowhere near to settle down. UN forecasts indicate a global population of some eight to nine billion people in 2050 with about 80 percent people living in cities. Increase in population and rising living standards due to economic progress are bound to cause an upward trend in energy needs of the world. Add to this the environmental issues, which go hand in hand with the economic progress and energy statistics. The world needs more energy, clean and lasting, period!

[Alt] Petrodollars lean heavily on governments worldwide due to which the progress in alternative fuels and green legislations has been slow. However with promising new research and increased awareness in the post Al Gore era, the scenario is now changing fast with some of the most powerful venture capitalists in the world (IITians like Vinod Khosla) rushing to aid green ventures across the globe. These include solar power, fuel cells, better batteries, squeezing energy out of algae and other biomass, better engines for conventional fuels, radical shifts in housing and construction design to save energy and what not. These efforts are being complemented by policies like carbon credits and constantly updated emission protocols. However, the feasibility of new technologies and impartiality of green policies are yet to stand the test of time.

[Ctrl] Although conventional fuels will eventually run out, as long as we use them we need to use them as efficiently as possible. We need such energy conversion devices that will ensure that we use the available energy to the best possible extent and that we are still breathing oxygen with every passing day. In addition, we need improved processes for purifying the basic elements of our surroundings to control the damage already done.

CONTENTS:

The question here is - are we, at IIT Kanpur, doing something about this? Thankfully, the answer is yes. In the following pages one can have a glimpse of some of the many projects going on in the institute. Work on organic solar cells is in full swing with the final goal of producing solar films that one would be able to print just like one prints documents on the usual laser printer. A promising industrial application—biodegradable solar cells has been developed at IIT Kanpur and patented. Another revolutionary concept realized within the campus is the Center for Environmental Sciences and Engineering which justifies its name. It has received a five star GRIHA rating from TERI for its superior energy saving construction. The institute is taking long strides in alternative-fuels research at the Engine Research laboratory. Meanwhile, students' research group GE^3 (Group for Environment and Energy Engineering – earlier known as GASE) has taken a lead on auditing the campus for energy consumption. More such initiatives are planned for future.

However, any new technology is useless unless we use it in a just manner. One does not need sophisticated laboratories to start towards a greener planet. Remembering to switch off a light or burning fat on cycles is also a good way to start. The important thing is that the time to act is now!

Teaching Engineering

Interview with C.V.R. Murty (Distinguished Teacher Awardee 2008, IIT Kanpur)

Kirtimaan Mishra and Mohit Kumar Jolly

If your back is hunching while doing engineering drawing in the drawing hall, beware! Dr. C.V.R. Murty may be around. Dr. Murty, a synonym for strict discipline, is the most vivid example of 'Simple living and high thinking'. An inspirational personality, a great orator and a distinguished teacher- he has been idolized by many students at IIT Kanpur. The NERD team interviewed him, when he was on the campus on Teachers' Day (It was his first visit back to the campus after he laid down the office as Head, Department of Civil Engineering, at IIT Kanpur, and went to Hyderabad and assumed the responsibility of Co-Chair of IIT Hyderabad Task Force). Here are some excerpts from the interview:

Dr. C.V.R. Murty

NERD: Sir, you have been a faculty member in this institute for 15 years. What do you feel is the most distinguishing feature of IIT Kanpur?

Dr. Murty: I have been associated with IITs at Madras, Delhi, Kanpur and now at Hyderabad. The respect for the process of teaching and the freedom given to a faculty member to be able to contribute to research, teaching, outreach and consulting, is exceptional at IIT Kanpur. But this freedom comes with responsibility. Many of us don't understand this freedom (especially on the teaching front), and some of us even overstep the line of dignity. Such individuals who exercise 'unlimited freedom' need to curb that instinct/habit; this should happen from within and not through any regulations.

NERD: You have been popular with students as a teacher, and today you received the Distinguished Teacher Award. What pedagogical techniques make you different from other teachers?

Dr. Murty: As a student, I was fortunate to have had brilliant sets of teachers in the bachelors, masters as well as doctoral programmes. We loved especially those few teachers, who focused most of the time of the class on the subject, instead of only cracking jokes and whiling away the time or simply writing text from their notes on the blackboards. Clearly, unless you have a grip on your subject, you can never excite students about it. It was necessary for me to be focused first in learning the basics and then in explaining them to students. While explaining the basics to our students in the classrooms, I had the advantage of teaching structural engineering concepts to large number of practicing engineers and architects. Professor Sudhir K. Jain (of IIT Kanpur) and I conducted these courses across the country since 1992. That professional experience exposed us to a variety of questions. So, the next time we went to teach another group of professionals, we were able to preempt many questions and were that much more prepared to face the class.

Since the early 1990's, the winds in the society and market were taking the attention of the students away from engineering subjects, towards software or finance. It was a double-challenge for the faculty members in Civil Engineering: (1) we had the responsibility to create excitement in the classroom, and (2) address the fact that most students were not be interested in learning the technical subjects that all teachers were carrying to the Lecture Hall Complex. A few years later, we learnt that this was happening with our colleagues in other departments as well. The students had to be 'woken-up'. For this, we (the teachers) had to be 'awake' ourselves, to really create a stimulating classroom environment. I tried a questions-snake in my classes; a question would run around each of the benches in the class throughout the 55 minutes. If the question gets answered, a new question begins, else the snake crawls forward to the next bench. This forced every student to respond. Hence, there have been no back-benches in my class; one can only listen and actively participate in my class, but cannot hide (or even sleep, doodle or chat).

Asking question is an art; the questions must be very precise. And therefore, when a student asked a question, I spent some attention on tutoring the student on the way the question was to be asked.

NERD: Which course did you enjoy the most while teaching at IIT Kanpur?

Dr. Murty: I taught two types of courses – design and analysis courses- design of steel structures, design of concrete structures and analysis of linear and non-linear structures. Each course provided me a breath of fresh air. I departed from the standard content given in the text books, and offered a new line of intuitive thinking. This kept me on the toes, and kept the students thinking.

In other IITs, a faculty member sticks to a certain subject throughout the career as his main subject; he does not teach any other course. But at IIT Kanpur, I (and a few other colleagues in structural engineering) taught a number of structural engineering courses. This way, I enjoyed teaching a spectrum of courses. So, rather than listing the courses that I enjoyed, I thought that the method and process of teaching was the highlight.

NERD: You were instrumental in initiating SURGE (Summer Undergraduate Research Grant for Excellence). What was your motivation behind it?
Dr. Murty: It was Professor Sudhir K. Jain, the then Dean Resource Planning and Generation (DRPG), who initiated the SURGE program. I was just the 'designated hitter' to put in place the system to run it in the years to come.

We have been witnessing the headwind of students graduating with degrees, but not becoming engineers or scientists; they were not getting closer to the subject. Professor Jain wanted to give them an opportunity so that they could push themselves closer to the subject/ specialization they were interested in. It was also felt that the leading institutes of the country, the IITs, should make tomorrow's leaders in both research and teaching. If some of these people are enthused at a younger age, the IITs would make a meaningful contribution to building human resources that will steer the effort to solve India's engineering challenges.

Currently, out of about 500 IIT Kanpur students, who join the UG program each year, the number of students seeking higher studies and eventually taking to research as a career is very small. That does not mean that the students don't have potential to take to research, but the society around the students (especially their parents) does not seem to understand their immense potential and encourage them. They need to be given a chance to discover themselves while they are within the portals of the Institute. So, we came up with this UG research program.

NERD: What, in your view, is the present state of technical education in India, and how will it be affected by the sudden starting of new IITs?
Dr. Murty: We are running a great shortage of engineers on the practicing frontlines. It might sound crazy that even though we have over 1780 engineering colleges in India, I am speaking of shortage of engineers. Yes! We have a large number of degree holders, but no engineers. This shortage has come due to many reasons, including the shortage of teachers, the poor quality of teaching by existing teachers, and the national frenzy that has hijacked the entire youth of the country towards software or finance related fields just for the sake of large starting salaries in the early days after graduation. This frenzy driven from the typical household of the country has hurt the country.

In the IITs, 100% of the teachers hold a PhD degree, but in the other colleges, only about a maximum 20% of the teachers hold a PhD degree (barring exception of a handful of colleges, wherein the number is about 30-35%). This means that one in five teachers has the formal background of research/advanced knowledge and understanding of subject. This is too little to provide good technical education in our country.

Style of education is a major challenge. Today, most teachers are focusing on their 'teaching' and covering the syllabus, and not on the students' 'learning'. In general, a typical class-room today is offering empirical treatment of the subject and not conceptual treatment. Alongside, many of the text books that are being used in the class-rooms in the engineering colleges have only a dry treatment of the subject. It is not uncommon to see a single author publish books on almost all subjects in a branch of engineering; one cannot expect good quality contents in these books.

"The next 15 to 20 years is a difficult time for all the IITs – new as well as old."

On the starting of the new IITs, it is a strange decision to start 8 new IITs in a span of 13 months, when only 7 of them exist currently. To start an IIT, both experience and young hands are needed. And, to start 8 of them and make them successful, a large number of senior faculty members from the existing IITs need to hand-hold the development of the new IITs to create the much acclaimed 'IIT System' in the new institutes. But, it is unlikely that such an efflux is likely to take place from existing IITs to new IITs, thanks to some major reasons namely (a) the Government's policy of lack of pension scheme in the new IITs, and (b) the hardships to be faced by such faculty members if they agree to help start a new IIT, especially when their life is 'cruising smoothly' from personal and professional points of view. This is happening when the existing IITs themselves are facing an acute shortage of quality faculty applicants; about 20%-30% of the sanctioned positions are vacant in the existing IITs. Then, how can the new IITs win this challenge with scanty facilities and basket full of hardships. Clearly, with these 8 more IITs also competing for the same pool of potential faculty members, it is going to be difficult to recruit faculty members. Hence, soon the sustainability of the new IITs will be an issue to grapple with. Very difficult times are ahead for faculty members joining the new IITs to resist dilution of standards. Hence, the next 15 to 20 years is a difficult time for all the IITs – new as well as old.

NERD: You are presently involved in establishment of IIT Hyderabad. What features of IIT Kanpur, especially those related to teaching, would you like to include/ change at IIT Hyderabad?

Dr. Murty: There are a large number of elements of teaching to be ported to IIT Hyderabad, but there are some experiences related to teaching that warrant new initiatives at IIT Hyderabad. Firstly, we have exceptional teachers at IIT Kanpur; most of them are self-made. Interestingly, none of the existing IITs provides formal training to young incoming faculty members to hone teaching skills. They have a PhD degree, but no training in how to teach. So, the young recruits definitely require to be guided towards inspired teaching.

As a Head, Department of Civil Engineering, when I asked two batches of students at the end of their B.Tech program, as to how many courses (out of about 45 of them) they credited were interesting, the answer was a mere 5-6 of them, and not 25-30. This suggests that currently only 20% of the teaching is inspired. While research has been seen as increasingly important today, we are not ensuring at least a minimum standard of teaching. At IIT Hyderabad, we wish to ensure at least a minimum acceptable standard in teaching. Teaching will become an important determinant for faculty members continuing in the institute as well as in their promotions, even though the watch word for faculty members will be research.

"It is the Indian parent who does not want his/her child to be a civil engineer."

Secondly, there is a need for faculty members to apply themselves doing research to improve technological practice. They should be able to contribute to the growth of the country by providing solutions to the grand challenges that the country is faced with. And, unless you have a critical mass of faculty members in each area, the institute cannot contribute to the country. So, we are suggesting that IIT Hyderabad should specialize only in a limited number of areas and have a large number of faculty members in each of these areas. For example, instead of saying that we will do Civil Engineering, we say that we are going to work only on infrastructure engineering which is only a part of civil engineering and that is critically required for the sustenance of civilization and for national core development, like power, water, electricity, roads, and airports.

Thirdly, today in the existing IITs, faculty members are not reminded on a regular basis that they have a responsibility of giving back to the system, and to the country. So, we need to contribute to the system and train young faculty members to think from their younger days that they need to contribute to the system in a local sense and to the country in a global sense. While solving the grand challenges of the country, international state-of-the-art is required. The young faculty members may note that they can still be working at the edge of research in technology and science, even if they are answering the 'Indian' challenges.

NERD: Civil Engineering was once the choice of JEE toppers. Now, it has shifted to Computer Science and Electrical engineering. What trend do you see in the coming 15 or 20 years?

Dr. Murty: In the 1950s, the parents of a daughter looked for a civil engineer son-in-law. With time, this social choice moved to mechanical engineers and electrical engineers in the 1960s, chemical engineers and metallurgists in early 1970s, and electronics engineers in the late 1970s, management degree holders in early 1980s, computer engineers in late 1980s, and computer science graduates in the 1990s. This hijacking by the parents of India is brewing a national crisis, and JEE has become a mad race in the country. Unless the parents wake up in some form at a social level, it is unlikely that JEE choices will change radically. Today, unfortunately, the society determined by thinking of the parents of India, is only teaching its children the materialistic side of the world, and not inspiring them to do something worthwhile for the nation.

Once the roads get fully clogged, airports get fully choked, water stops in the taps and power goes off the lines, the country will 'suddenly' discover that civil engineers are important. Then, the parents of India shall again give priority to civil engineers. There were always careers for civil engineers, and there always will be. It is the Indian parent who does not want his/ her child to be a civil engineer. Further, in not long from today, the country will lay emphasis on product development for boosting the economy of the country. Then, all engineering streams involved in hardcore product development will be back to the fore, be it civil, mechanical, metallurgy, electrical, or chemical.

NERD: What is your opinion about the professional fields being preferred by IIT graduates in recent years?

Dr. Murty: Today's student entering IIT is burnt out; he/she is not excited about working hard again to build a technical base. Parents look at joining their children in IITs as a business venture for trading large dowry or getting large salary. Such decisions to join IITs are faulty. IITs are advanced technical institutes for technology education in the country, so that the

graduates will address the technological needs of the country. Thus, the spirit of an IIT student should be to gather advanced knowledge in technology; any other purpose defeats the very existence of these institutes.

There is no way I can support IIT students' pursuit of MBA degrees immediately after the undergraduate program. Why come to elite institutes of science and technology, and defeat the purpose of these institutes by doing an MBA and becoming an investment banker in a multi-national firm? An analysis of the courses credited during MBA programs suggests that there is a large overlap with courses offered in the B.Com. degree program along with a few operations research and marketing type courses. That is the reason that most of the MBA graduates join as financial analysts and not as technology managers. In any case, it is unlikely that senior technical professionals with over 25 years of work experience will see fresh MBA graduates of 23/24 years of age as their 'managers'.

In every career, the first half (about 20 years) is spent in honing core skills – learning to use technology, spending money with responsibility and getting closer to working with people. And, the next half of the career (another 20 years) is dedicated to helping the younger professionals learn the core skills – managing technology, money and people. Hence, all of us are up for management related activities in the second half of our careers. Then, why should our students embarrass themselves at the tender age of 23/24 by posing that they are 'managers', just because they have a MBA degree when they have no experience of managing anything – technology, money or people. So, if at all, the best time to register for an MBA degree is after putting in 20 years in the engineering career.

In an engineering technology career, one does not get much salary in the early years, because the Bachelors degree training is definitely insufficient to make a graduate a complete technical professional. Master's degree training is needed; and even after that, since engineering is about practicing, the engineering graduates need to go into the engineering stream and practice as an apprentice with senior engineers for about 6 to 8 years. After that, our graduates are going to be worth more than a software engineer with the same number of years of experience.

In the software technology career, there is a threat that another young boy will arrive on the scene, work late nights, and write better-faster computer programs, or there is a threat of a new programming language being discovered, and one can be out of business because he does not know the latest computer language. Such a threat does not exist in classical engineering technology careers, because today's work is the basis for tomorrow's work. Experience is vital in engineering technology career, and youth alone cannot make up for any shortage in experience.

Teachers have to work harder to better apprise the parent and students of India to the realities of the various professions. The first 'Introduction to Profession' courses (100 level courses at IIT Kanpur) have to be given a lot more thrust and energy in terms of bringing different people from industry and academia and showing the scope of the subject to the students. The current poor attendance and disinterest in such events is directly attributable to lack-luster interest shown by the faculty members.

NERD: Describe Dr. C.V.R. Murty in one line.
Dr. Murty: He is ever ready for spending positive energies and positive initiatives!! Life is too short to focus on the negatives. At the end of each day, I ask myself two questions:

"The first 'Introduction to Profession' courses have to be given a lot more thrust and energy."

(1) Have I learnt anything today?
(2) Have I been useful today?

If the answer to both of these questions is 'yes', I sleep in a minute. If either of these questions is answered with a 'no', be sure that I am counting the revolutions of the ceiling fan for the rest of the night. I strive to make my days such that I sleep in a minute; I hope to continue to do that for the rest of my life.

NERD: What message would you like to give to students?
Dr. Murty: Work hard. It is the only thing that can guarantee success eventually. I am not talking of success in terms of money or fame, but of success in terms of seeking internal peace and satisfaction in your heart by contributing to humanity at large. It could be in just a small aspect of science or technology, but you need to make a positive difference to the lives of people.

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Green route to Water Purification

Preparing Carbon Nanofibers (CNF)

Amit Kumar Gupta and Dinesh Deva

Introduction

The discovery of carbon dates back to the pre-historical era. Its abundance and presence in several allotropic forms, together with its utility in a wide range of applications makes carbon the most interesting substance to study. Consequently, it is probably the most cited element in scientific literature. If you hit "carbon" in any scientific search engine, chances that it will reach the engine's page limit are quite high!

Although the commercial application of granular activated carbon (GAC) or powdered activated carbon (PAC) in water purification is well recognized, its ability to remove some of the recalcitrant dissolved solutes in water, such as fluoride and arsenic is limited. The other commercially available adsorbents, for example zeolites, alumina, silica, et cetera have also shown limited success in this context.

Here, we describe our ongoing research activities related to the synthesis of carbon nanofiber (CNF) and its potential applicability in removing those two difficult-to-remove solutes in water, namely fluoride and arsenic.

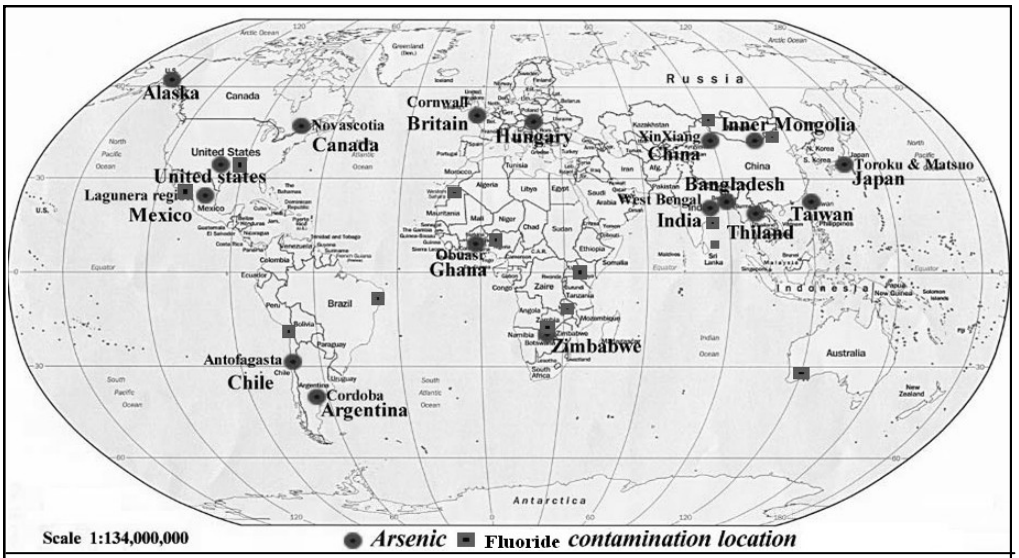


Fig. 1: Countries of large arsenic and fluoride contamination in water

Arsenic and fluoride in drinking water

Fluoride is a highly reactive element that combines with other elements in covalent and ionic bonds. It is mainly found in alkaline rocks, alkaline soils, and industrial effluents such as pharmaceuticals, cosmetics, semiconductors, coal power plants and fertilizer manufacturing. According to WHO (World Health Organization) norms, the upper limit of fluoride concentration in drinking water is 1.5 mg/l. Small quantities of fluoride can protect against dental caries and weakening of bones, but large amounts can impair health by causing dental fluorosis and damage to the bones (skeletal fluorosis). As many as 200 million people worldwide, including in India are affected from fluoride present in the drinking water.

Arsenic contamination of groundwater is also the widespread phenomenon affecting vast regions in Bangladesh, China, Mexico, United States, and Argentina. The maximum arsenic level in the drinking water has been set at 10 µg/l by WHO. The origin of arsenic in water can be natural as well as anthropogenic. Natural sources are mostly geothermal, whereas anthropogenic sources are wastewater effluents from industries, such as metallurgical, pharmaceutical, glassware and semiconductor. Drinking arsenic-rich water over a long period results in various adverse health effects including skin problems, cancers of the bladder, kidney and lung, and disease in the blood vessels of the legs and feet, and possibly also diabetes, high blood pressure and reproductive disorders. A 2007 study found that over 137 million people in more than 70 countries are probably affected by arsenic poisoning of drinking water. Fig. (1) and (2) show the arsenic/fluoride contamination of groundwater in world and its adverse effect on human health, respectively.

Synthesis of CNF

We have synthesized CNF in our laboratory and demonstrated its suitability in the adsorptive/catalytic removal of dissolved fluoride and arsenic in wastewater. The starting material for synthesizing CNF is activated carbon fibers (ACF) in cloth form. We import the viscose rayon precursor based ACF. These are essentially micron-size fibers and are used in our

study as substrate (support) to deposit metals (Ni or Fe or Al) in its vast internal network of micro and mesopores.

CNF are grown on ACF by catalytic chemical vapor deposition (CVD). The technique of using ACF as a substrate to grow CNF obviates the need of post-synthesis step. The current practice is to use metal oxides as support to grow CNF. Consequently, the hierarchal web of micro-/nano-carbon fibers synthesized in our study may be used directly in the end applications without requiring any post-synthesis step. The grown fibers thus prepared may again be re-processed to incorporate appropriate metals and surface functional group as required in the end-applications.

Fig. 2: Adverse effects of fluoride and arsenic on human health

The following properties of ACF make them suitable as a substrate to grow CNF:

1. They are highly microporous and have large internal surface area (~1200-1800 m^2/gm).
2. Unlike GAC, they have a slit type pore structure and the micropores are directly connected to the external surface with minimum mass transfer diffusion resistance because of the narrow diameter of the fiber (usually 10–20 μm), as schematically depicted in Fig. 3.
3. They also exhibit catalytic activities due to the surface functional groups like hydroxyl, carboxylic and quinone that are incorporated during the activation stage.
4. Depending upon the type of adsorbate (basic or acidic, anionic or cationic), the surface of ACF may be accordingly functionalized.

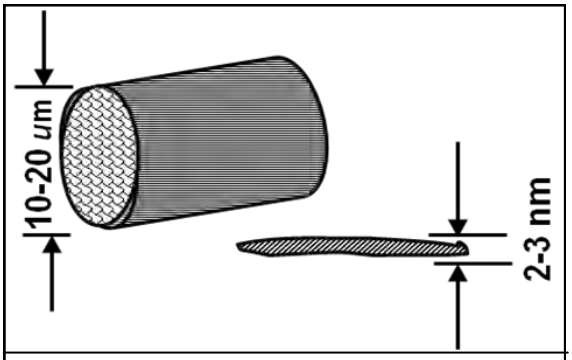


Fig. 3: Schematic of single fiber, slit-type pore of ACF

The method of synthesizing the hierarchal web of carbon micro/nano-fiber impregnated with nano metals briefly comprises of several sequential steps that primarily include impregnation of the fibers with the salts of metal, calcinations (to convert salts of metals into their oxide states) followed by reduction (to convert oxides into the corresponding metallic state in the nano particles form), growing of CNF by CVD, and finally sonication of the product (in dil. HNO_3), which may be re-impregnated with metals to prepare adsorbents applied in specific applications.

Growth mechanism of CNF

CNF are produced as a result of decomposition of hydrocarbons on the surface of transition metal nanoparticles. During the reaction, the hydrocarbon first adsorbs and then decomposes on the surface of the metal particle. The resulting carbon atoms then dissolve in and diffuse through the metal particle. The precipitation of carbon from the saturated metal particle leads to the formation of CNF. The rationale for choosing these metals as catalyst for CVD growth of CNF lies in the phase diagrams for the metals and carbon. At high temperatures, carbon has finite solubility in these metals which leads to the formation of metal-carbon solutions and therefore, the aforementioned growth mechanism. In majority of the cases, the catalyst particle is carried away from the surface of the support and there is sufficient evidence to suggest that the CNF adhere strongly to the support. The general CNF growth mechanism is shown in Fig. 5.

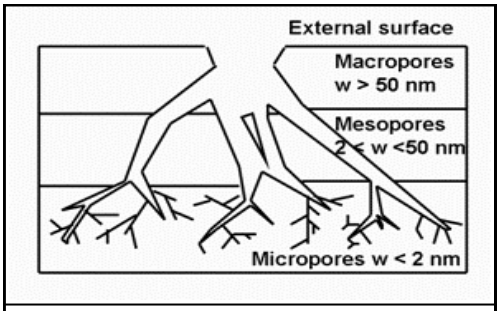


Fig. 4:Typical pore size distribution of ACF

Adsorption data

The prepared adsorbents Al-CNF and Fe-CNF were tested for fluoride and arsenic removal in water, respectively. For equilibrium adsorption, a fixed amount of the sample was put in aqueous solution of fluoride/arsenic until the concentration of the solution remained unchanged and adsorption equilibrium concentration was attained. For dynamic study (under flow conditions), experiments were carried out on a perforated reactor over which adsorbent in a cloth form is wrapped and the fluoride/arsenic water were allowed to flow through it. The procedure was repeated for varying amounts of adsorbent, initial

ions concentration, flow rate and temperature. The solution was collected using METROHM Ion Chromatography.

The prepared adsorbents were shown to have superior performance than the commercially available adsorbents in terms of the equilibrium ions loading, uptake of the solute (mg of fluoride/arsenic per gm of adsorbent) and throughput volume of the solution (l of fluoride/arsenic laden water per gm of adsorbent).

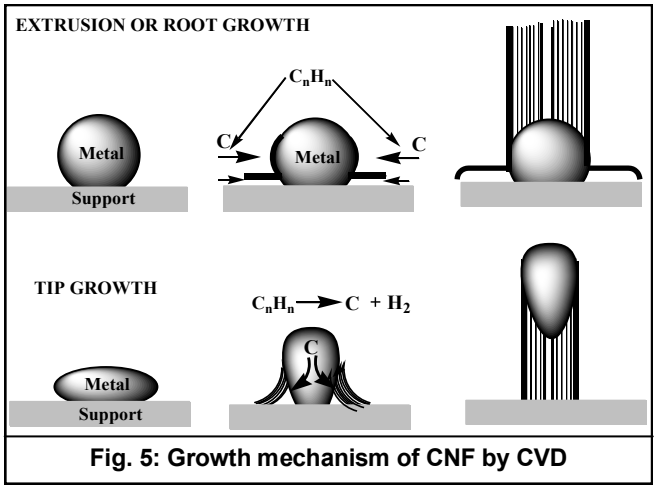


Fig. 5: Growth mechanism of CNF by CVD

Fig. 6 presents the equilibrium concentrations of the ions in the solid phase as a function of the aqueous phase concentration for three types of samples: Al-ACF and Al-CNF with and without sonication (acid treatment). As observed, the equilibrium loading of fluoride is larger on Al-CNF than on Al-ACF. In addition, sonication appears to have enhanced the equilibrium capacity of the prepared nanofibers, possibly due to the dislodging of Ni catalysts from the tips and other surfaces of the grown CNF, thereby creating additional sites for the incorporation of Al in the subsequent impregnation step.

It is also important to compare the loading (mg/g) of fluoride ions on Al-CNF obtained in this work with those reported in literature for fluoride ions on different adsorbents. From Fig. 6, we note that the loading of fluoride ions on Al-CNF is 0.25-17 mg/g corresponding to the aqueous phase fluoride concentrations between 0.06-50 ppm. These values compare to 0.58 mg/g on activated alumina corresponding to 1 ppm of fluoride in water [4], 0.4-5 mg/g on the zirconium impregnated coconut fiber carbon corresponding to 20-100 ppm of fluoride in water, and 2 mg/g on clays and 2.7 mg/g on activated titanium rich bauxite, both corresponding to 10 ppm of fluoride ions in the solution. We have also obtained superior adsorption performance of Fe-CNF synthesized in this study for arsenic, compared to the other types of adsorbents reported in literature.

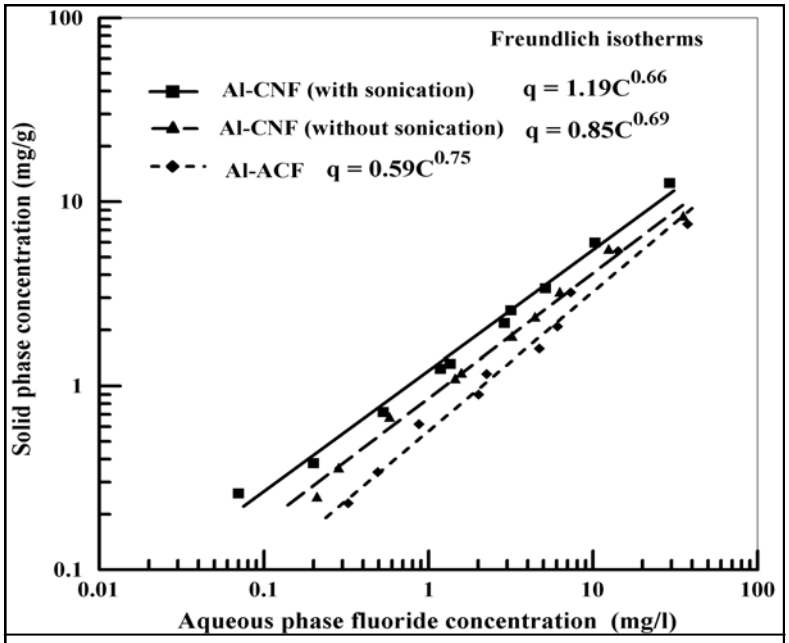
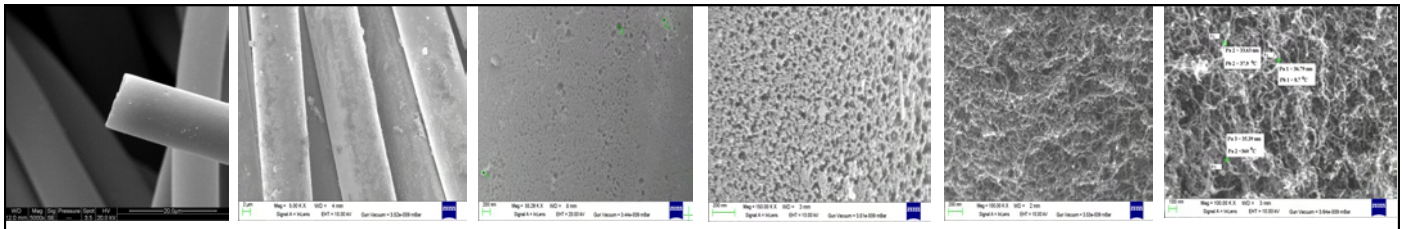


Fig. 6:Comparative performance of Al-CNF and Al-ACF for fluoride removal

SEM/EDX analysis of morphology of CNF

The morphology of Al-CNF and Fe-CNF with and without sonication was examined by scanning electron microscopy (SEM) and Energy dispersive X-ray (EDX) analysis using the Supra 40 VP Field Emission Scanning Electron Microscope procured from Zeiss. A representative SEM image at different stages of the preparation is presented in Fig. 7. As observed from the SEM image of the as-received untreated-ACF shown in Fig. 7(a), the surface of the carbon fibers is smooth, with the diameter in a narrow range of 10–20 µm. The SEM image in Fig. 7(b) shows the homogeneous dispersion of metal nitrate (Ni^{+2}/Fe^{+3}) on the surface of ACF following impregnation and before the calcinations step. Fig. 7(c) describes the SEM images of the ACF surface before the reduction step. Fig. 7(d) describes the SEM images of the ACF surface after the reduction step. Fine particles of nano size may be observed to be uniformly dispersed on the surface of the fiber. No sign of any deformation and loss of integrity or strength were found in the samples. The dispersed particles on the surface of ACF were confirmed as metal particles (Ni/Fe) using EDX spectra.

CNF were grown uniformly and densely on ACF as shown in Fig.7(e). The diameter of most of CNF is observed to be within the range of 30-40 nm and the length up to several micrometers. The bright, spherical metal particles of nano size may be observed at the tip of the CNF, with the size nearly the same as the diameter of CNF. As also observed from the SEM images, the nanofibers are not straight but having crooked morphology with three-dimensional network structure.



(a) (b) (c) (d) (e) (f)

Figure 7: SEM images of (a) ACF as-received, (b) impregnated with metal nitrate, (c) Pre-metal reduction (calcined), (d) post metal reduction (e) CNF grown, (f) after acid treatment/sonication

The morphology of CNF after the acid treatment with sonication (which removes most of the metal catalysts) is presented in the SEM images shown in Fig. 7(f). The density distribution and average diameter of CNF remained almost unchanged after acid treatment. However, small fractions of CNF were found to be removed along with Ni particles during acid treatment. The EDX spectra confirmed the removal of most of the metal particles, with the concentration of the metal particles remaining on the surface of CNF obtained in the small range.

Conclusions

In this study, we have shown that CNF may be synthesized uniformly and densely on metal impregnated ACF by catalytic CVD technique. The experiments conducted under batch as well as dynamic conditions demonstrated significantly larger uptake of the solute (mg of fluoride/arsenic per gm of adsorbent) and throughput volume of the solution (lt of fluoride/arsenic laden water per gm of adsorbent) for CNF in comparison to the commercially available adsorbents. We attribute the superior performance of the developed material in this study due to the combined effects of its large active surface area and the relatively smaller inter and intra-particle diffusion resistance. The prepared adsorbent (Al-CNF/Fe-CNF) in this study has potential for commercialization in the context of the removal of fluoride and arsenic from wastewater.

Acknowledgements

The authors acknowledge the support from the Department of Science and Technology (DST), New Delhi in the form of research grants and through its Unit on Nanosciences. The authors also acknowledge the supply of ACF from Kynol Inc. Japan.

Ponder Yonder

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The Uncommon Sense!

(A) (B)

1. When you lift a heavy load (A) bending your hip joint only as opposed to (B) bending both your hip and knee joint, you have a higher risk of injuring your back or hip joint. Explain why it is better to use posture B than A for lifting a load from the floor.

2. When you eat a sweet dish, the dish tastes sweeter when it is cold; whereas a spicy dish tastes more spicy when eaten hot. What is the reason for this temperature-oriented difference in taste buds of these two tastes?

Send in your answers at nerd@iitk.ac.in latest by March 15, 2009.
Prizes worth Rs. 2000 to be won!

Energy of the future

Ongoing research on Nuclear Fusion

Indranuj Dey

Introduction

The energy requirement for the sustained development of the human civilization has steadily stripped our planet of its natural reserves of coal, oil and gas. We are on the brink of an energy crisis, which deepens with each watt of electric power produced and each mile a car runs. The development for harnessing the alternative sources of energy (solar, wind, geothermal, hydro and nuclear) has been on for a few decades, with varied degree of success.

Nuclear fission based power generation is an efficient alternative, but its byproducts viz. nuclear waste, nuclear weapons and radioactive fallout problems are of grave concern, and unlikely to be solved very soon. This has made the development of sustained nuclear fusion (the phenomenon that occurs in the stars) as the Holy Grail of energy research over this decade. The raw materials for fusion reaction are abundant on earth and the associated nuclear waste and fallout problems are negligible. However, sustained nuclear fusion has not been achieved yet and its use for efficient energy generation remains a dream.

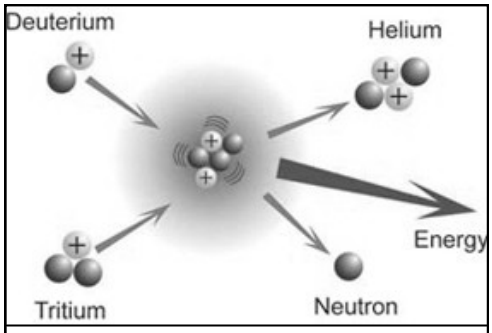

Fig.1: Fusion reaction between D and T nuclei *(published with permission of ITER).*

ITER

Recently, an international research and development covenant has been formed by China, the European Union, India, Japan, Russian Federation, South Korea and the US to conglomerate the economic strength and technical know-how required to make the dream a reality. This project, popularly referred to as ITER (International Thermonuclear Experimental Reactor), has its headquarters in Cadarache, south of France. The prototype reactor is being constructed there, and it is hoped to become operational by 2020. Thereafter the final design would be commercialized for construction of similar reactors around the world, and hopefully provide a solution to the impending energy crisis.

Nuclear Fusion

Nuclear fusion is the process by which multiple like-charged atomic nuclei are forced to join together to form a heavier nucleus. The process is accompanied by either release or absorption of energy. The fusion of two nuclei with lower mass than iron generally releases energy, while the fusion of nuclei heavier than iron absorbs energy.

Fusion of hydrogen isotopes (deuterium and tritium) was first observed by Mark Oliphant in 1932, and the steps of the main cycle of nuclear fusion in stars (proton and carbon cycles) were subsequently worked out by Hans Bethe. Research into fusion for military purposes began in the early 1940s, as part of the Manhattan Project, but was not successful until 1952. Research into controlled fusion for civilian purposes began in the 1950s, and continues till date.

Fig. 1 depicts the process of fusion between a deuterium (D) and a tritium (T), where about 17.6 MeV (~ 3 pJ) is released per reaction. The idea of using such a reaction is that if the products of the reaction can be made to slow down in the fusing medium, they can be used to help maintain the reaction temperature. The neutrons produced can escape the medium to heat up the surrounding materials, which are in contact with a coolant (say water) and can be used to generate electricity using a conventional steam or gas turbine. About a trillion D+T fusion reactions create enough heat for a cup of hot coffee. Therefore, raw materials of the order of few tens of kilograms would be required to generate powers in the megawatt ranges, after considering losses and conversion inefficiencies.

The reactions are difficult to achieve, because the nuclei have a positive electrical charge and therefore strongly repel each other. This can be overcome if their kinetic energy is large enough to bring them close enough, so that the (attractive) strong nuclear force pulls the nuclei together. The measure of the mean kinetic energy of a group of particles is its temperature, and the temperatures required for the above closely approach a few million degrees. At such high temperatures, the electrons become completely separated from the nuclei, forming an ionized gas, or plasma. Therefore the problem of sustained nuclear fusion would be addressed by designing suitable plasma confinement and heating mechanism, so that the condition of D + T ignition can be achieved.

Plasma confinement

Plasma, also called the 4th state of matter, is defined as a quasi – neutral aggregate of electrons, ions and neutral species showing a collective behavior. About 99% of our visible universe is in the plasma state. Stars are the naturally occurring plasma based fusion reactors in which the intense gravitational field provides the confinement scheme. However on earth, we have to rely on the magnetic confinement scheme for plasma trapping, which exploits the cyclotron motion of the charged particles about the magnetic lines of force, coupled with the adiabatic invariance of the magnetic moment to trap the charges particles (refer to 'Introduction to Plasma Physics and Controlled Fusion: Volume 1' by Francis F. Chen for more details). There are various magnetic confinement schemes for plasma confinement, viz., linear magnetic mirrors, magnetic multicusp, pinch device, Stellarator, Tokamak etc. Of these, the Tokamak confinement scheme has been found to be best suited for fusion experiments.

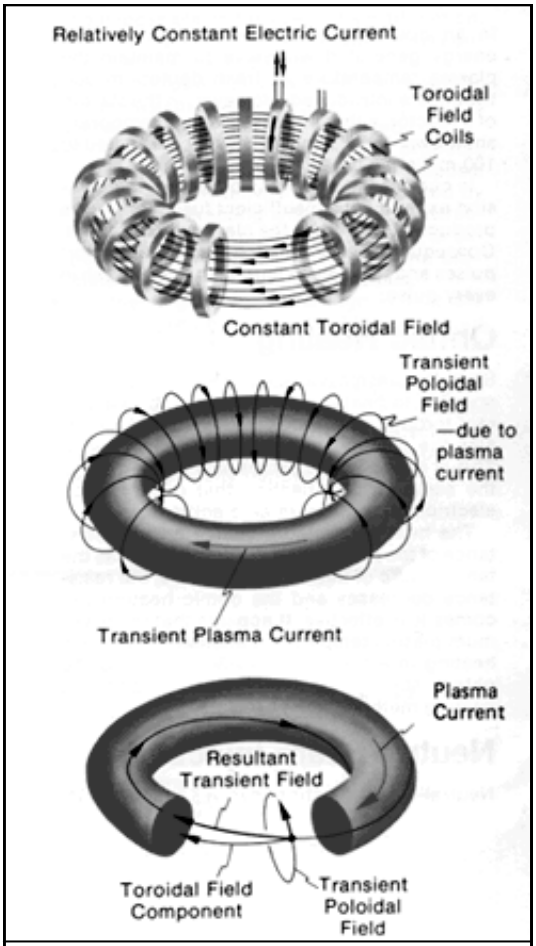

Fig. 2: Tokamak confinement scheme *(source: www.wikipedia.org).*

Fig. 2 shows the schematic of a Tokamak type of confinement. In the Tokamak, a current pulse is passed through the primary winding (the central solenoid), placed in the hole of the torus. This current creates an electric field and hence drives a large current in the plasma ring, which serves as the secondary winding of a transformer. This plasma current provides a component of poloidal field in the plasma which vectorially adds up with the toroidal field provided by coils placed around the torus, resulting in a spiraling field line around the plasma torus, generating a magnetic surface. Particles orbiting the field line are constrained near this surface, unless they collide with other particles, thereby confining them within the toroidal volume. However, a number of instabilities may occur in the plasma, which decreases the efficiency of confinement. Usually, additional fields are applied to enhance confinement and counter such instabilities.

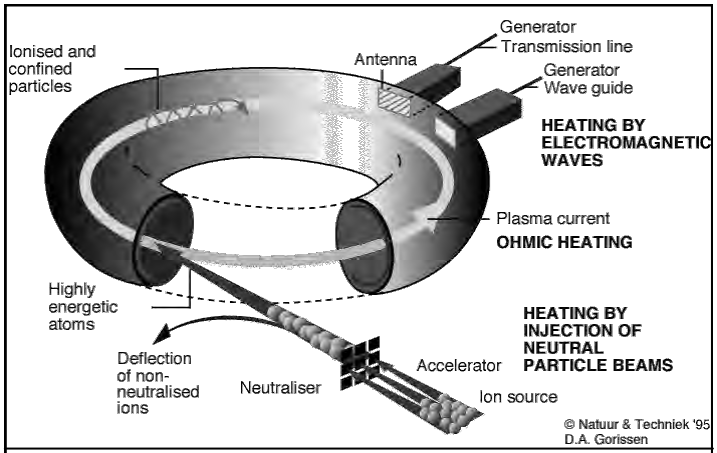

Fig. 3: Various heating schemes for the plasma *(published with permission of ITER).*

Plasma heating

Heating plasma requires putting more energy into the plasma than is lost from it. In magnetic confinement, energy can be lost from the plasma by conduction and radiation, as convection plays a very weak role in heat transfer due to the low gas pressure (~ 5 – 6 orders of magnitude lower than the atmospheric pressure). Radiation inside the plasma comes in two forms - braking radiation due to the deceleration and acceleration of charged particles as they interact with one another, and cyclotron radiation due to the continuous orbiting of charged particles round the field lines. Line radiation also occurs at the plasma edge as the bound electrons in not fully ionized atoms decay into lower energy states. Conduction is due to the particles leaving the system due to collisions with other particles ejecting them or bringing them into a region where the field lines lead out of the system. The larger the ratio of plasma volume to surface, the lower the overall power loss due to conduction. This condition is satisfied very well in the toroidal type of confinement in the Tokamak.

When a current flows in plasma, it gets hot due to its resistance, which is a manifestation of collisions between electrons and ions. Plasma resistance heating, however, gets increasingly weaker with increasing plasma temperature, and at about 10^{6}° C, resistive heating alone cannot overcome even radiation power losses (i.e. the plasma can get no hotter).

Alpha particle heating is produced when the ^{4}He nuclei resulting from the fusion reactions are trapped by the magnetic field and slow down by colliding with plasma electrons, helping to keep the plasma hot. However there are insufficient of these reactions at

10^6 °C, since to heat the plasma up - about 10^8 °C is needed. Bridging the gap requires external heating schemes such as neutral beam injection heating and radio frequency heating, which can be arranged to impart momentum preferentially to the electrons relative to the ions. This allows them to contribute to driving the plasma current. The pressure profiles within the plasma can also be adjusted by the heating schemes. These features allow the Tokamak burn to be stretched well beyond the inductive limit of transformer action and should in theory, allow steady state operation.

Fusion criterion and power amplification

The net result of the heating and loss channels in plasma can be summarized in a single parameter- the energy confinement time of the plasma (t). The energy input to the plasma from fusion reactions scales with the square of the density (n) times the reactivity, which scales with the square of the plasma temperature (T). For this to overcome the losses, it must be greater than the net energy leaving the plasma, which is proportional to the quotient of the pressure (nT) and the confinement time. This reduces to the fact that the fusion triple product ntT must be above a certain threshold value for a successful confinement and ignition of the plasma. This condition is also called the Lawson's criterion, and is the benchmark for achieving successful fusion.

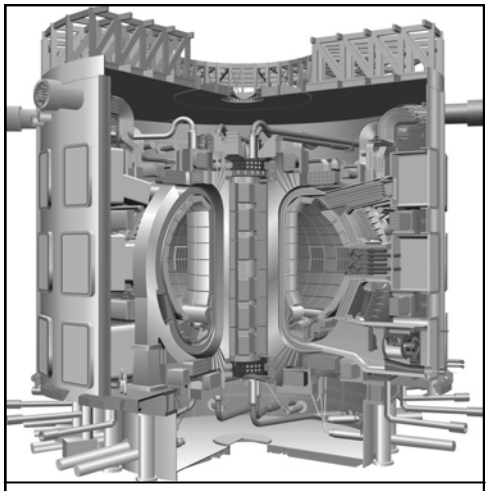

Fig. 5: Schematic of the ITER *(published with permission of ITER).*

To make an attractive source for generating electricity, the net electrical energy input into the power plant must be much less than the electrical energy output. Thus a necessary condition for a fusion power source is that the ratio of integrated thermal power out to integrate thermal power in - the "power amplification" (Q), be sufficiently large. Taking account of the internal system inefficiencies, Q > 10 is considered a reasonable target for a proof of principle in ITER, whereas Q > 30-50 would be desirable for good overall plant efficiency (> 25%) in a reactor producing electricity.

Progress so far

The ITER project is designed to demonstrate the feasibility of nuclear fusion for generating commercially viable electric power. The progress till now has been satisfactory. However recent economic recession has affected the developmental programs, which are being carried out in the partner nations.

US and Russia has promised to supply the initial tritium (~ 12.5 kg) required to start the reactor. The deuterium fuel is abundant in water (30 g/m^3) in the form of heavy water, and can be extracted by electrolysis. After the plant comes into operation, it will produce its own tritium by nuclear transmutation of lithium (contained in the 'blanket' surrounding the reactor core, available abundantly on earth) by the released neutrons. The byproducts of the reactions are very little and will be generally re-utilized in the plant.

Fusion research in India

India is an active member of the ITER covenant. Numerous technical developments are being carried out here for the ITER program. The main contribution will be in form of various cryostatics, vacuum systems, ion and electron resonance heating sources, high voltage supplies and neutral beam diagnostics. These developmental works are mainly being carried out by the Institute of Plasma Research (IPR), Gandhinagar. The IPR has its own Tokamak program, comprising of Aditya and also a new Superconducting Steady State Tokamak (SST), which is under development. Therefore we will be greatly benefitted by our participation in the ITER program in the area of indigenous fusion research.

Other research institutes around India are also contributing to the National Fusion Program initiated by the Department of Science and Technology, India. One such work is being carried out in the Waves and Beams Laboratory – IIT Kanpur, under the guidance of Dr. S. Bhattacharjee in the Department of Physics. A microwave – plasma based negative ion source for neutral beam injection and diagnostics is being developed here, with associated understanding of the physics of wave – plasma interactions.

Remarks

The ITER program is intended to answer all the challenges facing the prospect of sustained fusion today. More and more participation is required from nations across the world to make this endeavor a grand success so that we may achieve the power of the sun.

Ponder Yonder

1. www.iter.org
2. www.wikipedia.org

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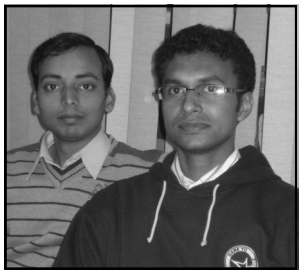
From laboratory to business world

Story of a start-up by two friends at IIT Kanpur

Tapendu Mandal and Prem Prakash

They set out for the journey



A Tuesday, 26 Aug 2008. Not a famous day in the world history. You can search in Wikipedia or any popular search engine to extract some importance of this particular day. Every single day in the calendar holds some importance to someone somewhere in the world.

It was an important day for two young students at IIT Kanpur. Everyday thousands of new companies are registered in different record books around the world. Most of them die and very few sustain in the long run. *Cenogen Materials Pvt. Ltd.* is one of those companies registered on 26 Aug 2008 by two young engineers with the help of few faculty members of IIT Kanpur to create an internationally recognized Indian brand.

The journey started somewhere in 2007. It started with nothing but some technological knowledge, motivations and an entrepreneurial mindset. It was a business plan competition organized by Entrepreneur -cell, IIT Bombay in the year 2007. Two friends together sitting at MT (the exclusive tea spot of IIT Kanpur) decided to participate in that competition and they managed to submit an executive summary based on their research work just in time. They were scared by beautiful and fancy ideas of others which attract the attention of people and hence lesser people care about technology based business ideas. But this myth was broken when they found their name in the top ten selected business ideas. Finally they managed to remain at the top of the ideas presented there at IIT Bombay.

The first milestone

That was the first milestone in their journey. They started submitting their business plan at different B-plan competitions. Most of the cases they found their name among the top three teams of the competitions. Soon they realized the actual commercial potential of their idea. Finally it was 'Indian Innovation Pioneers Challenge 2007-08' jointly organized by Intel and Department of Science and Technology (DST), India where they learned crucial things about technology based entrepreneurship and it's associated business opportunities.

They gradually modified their earlier business plan. One year back their business plan was merely an idea. In this competition they presented a plan which may lead to a real business. And they have found themselves in the list of top three teams among 276 proposals submitted from allover India.

What was that idea?

The Idea was to provide 'nano-solution to bone'.

What is bone?

Bone is a natural nano-composite in which a special type of apatite crystals called hydroxyapatite are distributed in a soft collagen matrix. The overall composition of a human bone is given in the following table.

Materials	Weight %
Inorganic matter insoluble in water	69.66
Inorganic matter soluble in water	1.25
Collagen	18.64
Protein polysaccharide	0.24
Resistant protein material	1.02
Water	8.18

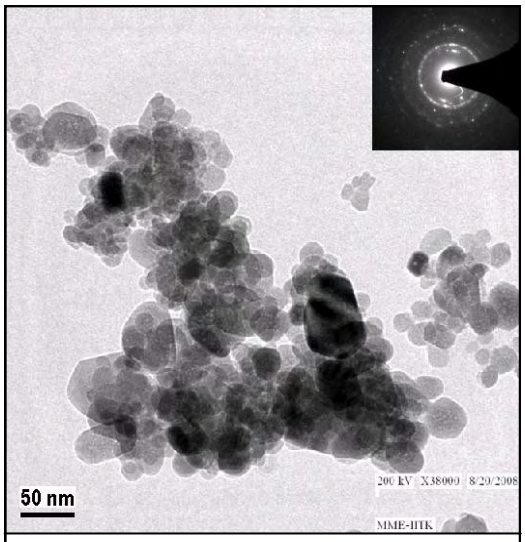
The inorganic constituent (69.66 %) mentioned above is mainly nano-crystalline hydroxyapatite (HAP). HAP is a promising bioactive and biocompatible material not only for its potential to be used as bone substitute material but this particular ceramic material can also be used for bone drug delivery system, separation and purification of proteins, amino acids, saccharides, DNA catalyst etc. Synthetic microcrystalline HAP is readily available in the market but the main drawbacks of microcrystalline HAP are inferior mechanical properties and lower bioactivity than its nanocrystalline counterpart. However synthesis of bulk nanocrystalline powders is always a great technological challenge.

Methods of producing HAP

Presently there are several methods available for producing HAP, most of which employ high temperatures or pressures and are time consuming. High temperature methods can not produce nano-crystalline HAP because of the excessive grain growth at elevated temperature. Few low temperature methods are available to produce HAP but difficulties are encountered in maintaining the stoichiometry and crystallinity of the product.

Reaction milling is a process where mechanically induced chemical reactions may take place in a highly energetic environment. This process can be exploited for ultrafine powder production, mineral and waste processing, metals refining, combustion reactions, production of a fine dispersion of second phase particles, extension of solubility limits, refinement of the matrix microstructure/nano-grain formation, formation of amorphous phases. Planetary mill can induce chemical reactions in a variety of powder mixtures. In fact it has been shown that mechanical activation substantially increases the kinetics of solid-state chemical reactions.

Another important feature of mechanochemical process is the refinement of microstructure (i.e., grain size and particle size) associated with simultaneous particle deformation, fracture and welding processes that accompany ball/powder collision events. The energy transmitted to crystalline powders during milling may result in dislocation cell structure that develops into random nano-structured grains with increasing milling time.



Transmission Electron Micrograph of HAP nanopowders

Related research at IIT Kanpur

At IIT Kanpur, a research group under the mentorship of Prof. B. K. Mishra and Prof. Ashish Garg in the Department of Materials and Metallurgical Engineering (MME) has invented a new and efficient method of producing nano powders of HAP through high-energy reaction milling. Calcium hydroxide and phosphorous pentoxide powders were taken in their stoichiometric ratio and were milled in a specially designed planetary mill, which can generate a force field, 100 times greater than the gravitational force to produce nano-crystalline HAP. It was found that nano-crystalline HAP phase evolved within an hour under ambient temperature and pressure.

Social impact

The method disclosed by this group is a new, cheap and efficient technique for synthesizing nanocrystalline hydroxyapatite (HAP). The cost of available nanocrystalline HAP is extremely high. For example, a five gram packet of nanocrystalline HAP from a renowned company like SigmaAldrich costs Rs.345000.

This new method for producing nanocrystalline HAP has great potential to reduce the cost of orthopedic devices by bringing down the cost of hydroxyapatite and make the orthopedic surgery affordable to the common people.

End note

This is a story of two friends, Tapendu Mandal and Prem Prakash, the authors of this article. This is a story of an initiative taken by them. This may be the end of this article, but not the end of the initiative. This is the beginning of a new story of Cenogen Materials Pvt. Ltd. But a crucial question arises at this juncture. What will happen to Cenogen? Will it survive in this global financial downfall to become a world class Bio-brand? Let's hope for a better tomorrow.

Acknowledgements

We are thankful to Prof. B.K. Mishra, Prof. Sandeep Sangal, Prof. Ashish Garg, Prof. B. V. Phani, Prof. Jayanta Chatterjee and members of SIDBI Innovation and Incubation Centre for their useful advice and motivation.

Laurels

1. First in 'Ideaz-07', a business plan competition organized by E-cell, IIT Bombay.
2. Second in 'IIPC 2007-2008', a business plan competition organized by EDC IIT Roorkee.
3. Third in 'Megabucks-2008', an international business and entrepreneurship festival, IIT Kanpur.
4. Third in 'Indian Innovation Pioneers Challenge 2008', a business plan competition jointly organized by Intel and Department of Science and Technology.

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Prem Prakash (pprakash.iitk@gmail.com) is a Class of 2004 alumnus of IIT Kanpur, and presently a research associate with Prof. Sandeep Sangal (sangals@iitk.ac.in) in the same department.

Cenogen Materials Pvt. Ltd. (www.cenogen.com) aims at providing the best material for the industry at the nano-crystalline scale. Ultra-fine and nano-particle powders of hydroxyapatite, iron carbide, silicon carbides, titanium carbide and bismuth titanate are supplied by the company.

Need of the hour!

Indian patent on organic biodegradable solar cells

Basanta Kumar Rajbongshi and Arun Tej Mallajosyula

Introduction

Electronic devices that convert solar energy into electricity by photovoltaic effect are called solar cells or photovoltaic cells. Such devices based on organic materials are called organic photovoltaic (OPV) cells.

Currently the world consumes an average of 13 terawatts (TW) of power a year. By the year 2050, as the population increases and the standard of living in the developing countries increases, this amount is likely to increase to 30 TW. It is also estimated that about 20.10^{12} kg of carbon dioxide are put into the atmosphere every year mainly by burning fossil fuels and if the 30 TW of power is generated from fossil fuels, the concentration of carbon dioxide gas in atmosphere will get more than double, causing substantial global warming along with many undesirable consequences.

Sun deposits nearly 120,000 TW of energy per year on earth, so clearly there is enough power available if some efficient means of harvesting solar energy of this renewable source can be developed. Solar panels which harvest solar energy directly into electricity, has found application in setting power stations, in building-integrated photovoltaics (Fig. 1),in rural electrification and so on.

Fig. 1 Building-integrated solar panel can act as the principal or an ancillary source of electrical power.

Currently more than 95% solar cells in use are made of crystalline silicon (c-Si). Although the conventional inorganic solar cells can harvest up to as much as 24% of the incoming solar energy, these are too expensive because of high price of crystalline silicone (40% of total cost, Fig. 2), cell processing (25% cost) requires high energy intensive processes (400-1400°C and high vacuum conditions) with numerous lithographic steps. Construction of a solar module (an integrated solar cell consisting of many small solar cells) demands 35% of the total cost. The last and not the least is that inorganic solar cells are not eco-friendly.

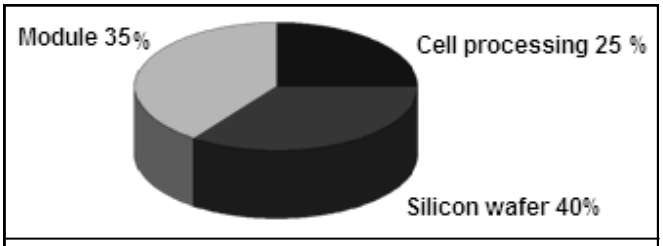

Fig. 2 Silicon photovoltaic cell cost distribution.

Contrary to the inorganic solar cells, organic solar cells are very cheap. The materials for these solar cells can be synthesized from cheap and readily available raw materials. The opto-electronic properties of the organic materials can be tuned by proper design of the chemical structures. Cell processing is easy because of low melting and low evaporation temperatures compared to inorganic counterparts. Organic materials have very high absorption coefficient, as a result a thin film (< 100 nm thickness) of these molecules is sufficient to absorb most of the photons falling on it. Above all, many of the organic materials used in OPVs are biodegradable and so eco-friendly.

Biodegradable materials- a great demand

Most of the inorganic materials used in inorganic and hybrid solar cells like Ga, In, Cd, Te, Cu, Se and even the mostly used Si are toxic and not biodegradable.

Imidazolin-5-one molecules that have been used here are derivatives of the green fluorescent protein (GFP) luminophore (Fig. 3) and are biodegradable. The wide applicability of GFP and its mutants inspired us to synthesize several analogues of GFP chromophore with an intention to evaluate their potential as synthetic extrinsic fluorophores. While doing so, their electrical properties were also checked. Interestingly photovoltaic effect was observed from fabricated devices with few molecules. The photovoltaic properties of the fabricated devices with these molecules led us to carry on designing newer imidazolin-5-one derivatives and fabrication of photovoltaic devices.

Techniques used

The whole work accomplished here can be divided into two parts - synthesis of the molecules and device fabrication.

Synthesis of the molecules

Synthesis (Scheme 1: see at end of article) of the imidazolin-5-ones starts with very cheap chemicals - glycine, N- benzoyl glycine, sodium acetate, acetic anhydride, zinc chloride etc. The third and the fourth steps are solvent free Lewis acid catalyzed melt reactions, so this is an additional advantage over reactions where solvents are used which create environmental pollution. Another advantage is that a wide range of functional groups R_1 and R_2 can be used to generate imidazolin-5-ones and pi-conjugated imidazolin-5-ones with a wide range of optical and electrical properties. Substituents R_1 and R_2 perturb the electronic energy levels of the benzylidene imidazolin-5-one fluorophore and hence the electronic band gap (HOMO-LUMO gap). Thus with a proper design, molecules can be generated that will absorb at longer wavelengths and will be worth for solar cell applications.

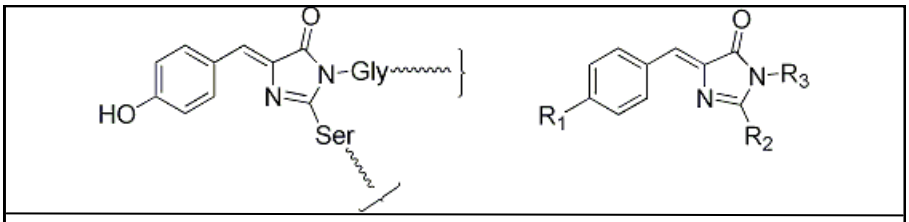

Fig. 3 GFP luminophore (left side) is a hydroxybenzylidene imidazolin-5-one analogue. The synthesized GFP chromophore analogues can be represented by the general structure (right side) where R_1 and R_2 are the side chains which can be varied to change the optical and electrical properties.

Device fabrication

The techniques involved in making the solar cell devices can be interpreted by the flow chart as shown in Fig. 4 .

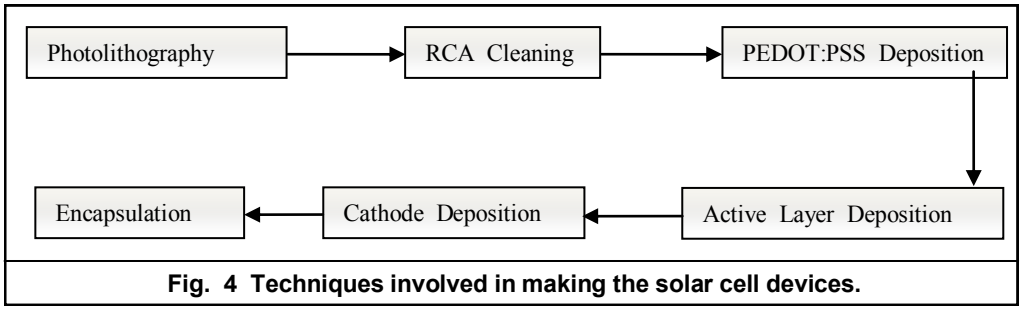

Fig. 4 Techniques involved in making the solar cell devices.

In solar cell devices the indium tin oxide (ITO) coated over a glass substrate works as the anode. The ITO coated glass substrates are generally much larger in size than required device dimensions. Therefore, ITO needs to be patterned into small sizes according to the desired device shape and size. This is done by use of ultra-violet light and the technique is therefore known as photolithography. The patterned ITO coated glass plates are then cleaned in a process which involves the use of a 5:1:1 mixture of deionized water, hydrogen peroxide and ammonia, to remove dust or dirt. This was first used by a company 'Radio Corporation of America' and hence the technique is known as RCA cleaning.

The technique of spin coating involves deposition of a layer of PEDOT:PSS (Poly(3,4-ethylenedioxythiophene) and polystyrene sulphonate) over the patterned ITOs. The PEDOT:PSS layer protects the organic layer from indium which diffuses from ITO. It also smoothens the rough surface of ITO. In the next step, the organic material is deposited over the PEDOT: PSS layer by vapour phase deposition method. This is followed my cathode (Al, Ag etc.) deposition by vapour phase deposition method. The complete device is then encapsulated with epotek epoxy resin or aryldite epoxy resin to protect the device from moisture and air. The structure of the fabricated devices is shown in Fig. 5. The active layer denotes the single layer or the bilayer of imidazolin-5-one molecules.

Electrical studies

The current density (J) – voltage (V) characteristics of a typical p-n junction solar cell will be as shown in Fig. 7. The device works as a simple diode when kept in dark. In the presence of light, electron-hole pairs are created in the device, which get separated at the p-n junction. This gives rise to free electrons and free holes which flow out through the device resulting in photocurrent. The photocurrent flow is opposite to the direction of current flow due to applied positive voltage. Hence, the J-V characteristics shift down to the 4th quadrant. In this quadrant, the device is acting like a power generator i.e. work is being 'done by the device'. In the 3rd quadrant (i.e. reverse biased device) very little current flows through the device kept in dark. However, when light is incident, large photocurrent flows through it. Thus, in this quadrant, one can use the device as a light sensor. Here, the photocurrent flows in the same direction as the current due to reverse voltage. Thus, the device is not generating any power. The efficiency (η) of a solar cell is defined as the ratio of electric power generated to the optical power incident on it. It is given by the following equation:

$$\eta(\%) = \frac{100 * (J_{sc}.V_{oc}.FF)}{I_0}$$

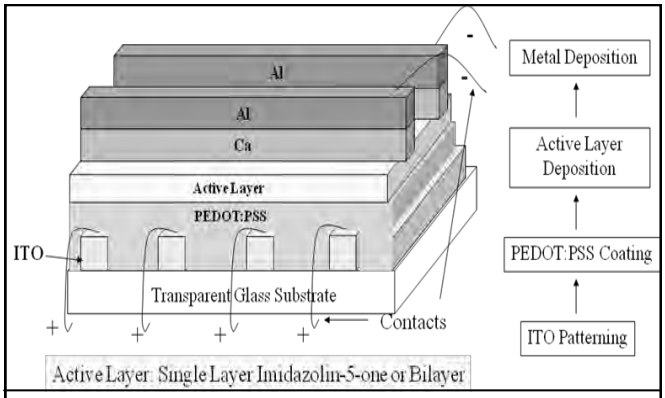

Fig. 5 The photovoltaic device fabricated with imidazolin-5-one

where, I_0 is incident optical power, J_{sc} is called the short circuit current density (defined as the current generated per unit area of the device in the presence of light when no voltage is applied to it), V_{oc} is called the open circuit voltage (defined as the voltage across the device when no current is flowing through it i.e. the light current gets balanced by the dark current at this voltage), and *FF* is called the fill factor (defined as the ratio of area of the largest rectangle that can be drawn in the 4th quadrant to the product of J_{sc} and V_{oc}) . FF determines the maximum power that the device can generate. Needless to say, all these three parameters have to be made as large as possible to increase the solar cell efficiency.

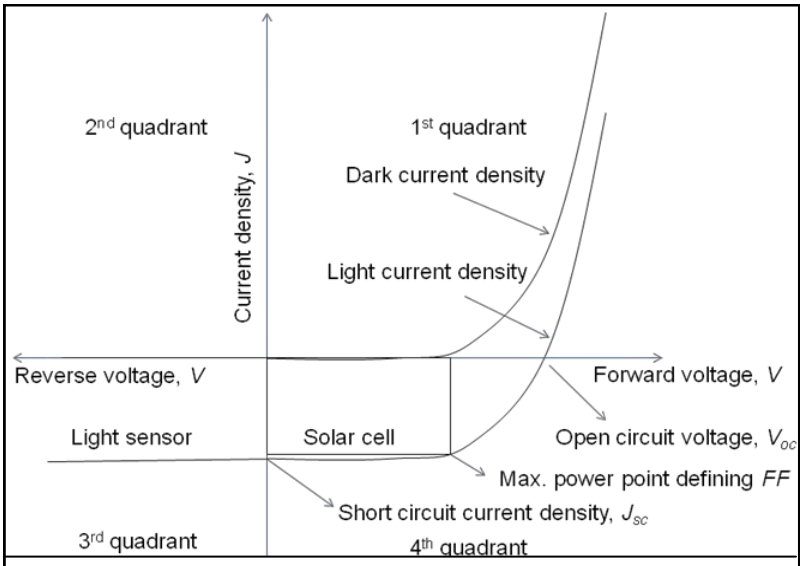

Fig. 7 Current density – Voltage characteristics of a typical solar cell showing the important parameters.

Importance of the devices

The solar cell devices presented here are *small molecule based* and *biodegradable*. Small molecules are easier to synthesis and manipulate than polymers. Most of the polymers used in organic solar cells are not biodegradable and hence 'hunt' the environment. Therefore, our solar cell devices bring a hope of occupying the space in the market for organic biodegradable solar cells.

Conclusions and future work

The solar cell materials used here are cheap and easy to synthesize. Fabrication techniques are also easy and inexpensive as the materials used here are low melting solids. The solar cell devices can also be used as light sensors. There is a lot of scope of increasing the efficiency of the devices by structural manipulation such as attaching some long chain polyene like retinal to the imidazolin-5-one core, optimization of the fabrication techniques, fabricating tandem solar cells and so on.

Acknowledgements

The authors are thankful to Indian Space Research Organization (ISRO), Swiss National Science Foundation (207020–109486/1), Zurich and the Department of Science and Technology (DST), New Delhi for financial support.

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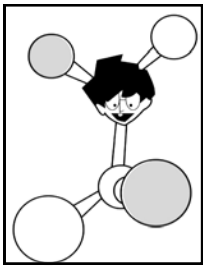

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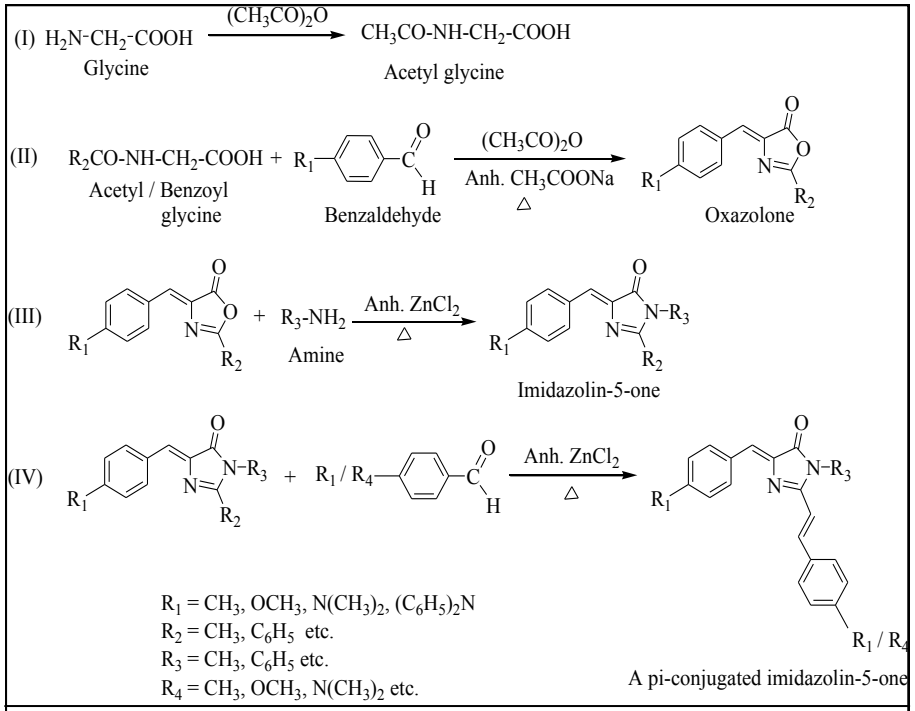


Scheme 1 Various steps of the synthesis of the imidazolin-5-ones. In step IV the pi-conjugated imidazolin-5-one forms if $R_2 = CH_3$.

NMRSMS-08

A National Meet of Research Scholars in Mathematical Sciences (NMRSMS-08) was organized by the Department of Mathematics and Statistics, IIT Kanpur during December 6 -10, 2008 to develop interaction within young researchers to meet the challenges in various fields of Mathematics. NMRSMS-08 was the second meet of its kind, the first being organized last year at IIT Kanpur.

The meet began with the inaugural speech by Prof. S. G. Dhande, Director, IIT Kanpur. The theme of the meet was Dynamical Systems. Each day there were two invited talks by the experts- Professors A. K. Mallik, Malay Banerjee (both IITK), G. Rangarajan (IISc) and Sunita Gakhar (IIT Roorkee). Prof Mallik's motivation to dynamical systems using number theory was magical. Prof. Banerjee touched the crux of nonlinear systems and Prof. Gakhar talked about predator-prey systems. Prof. Rangrajan threw light on stochastic portion.

There were also talks on Research Methodology by Professors D. Bahuguna, D. Kundu, A. K. Sharma (all IIT K), G. Jayaraman (IIT D) and A. Mathai (CMS PALA). Talk on Monte-Carlo Simulation given by Prof Kundu brought acquaintance to many people of simulation tools. Substantial dose of areas like Graph Theory, Logic, Numerical analysis, Bayesian Analysis, Hazard Analysis, PDEs, Mathematical Biology and Finance was there.

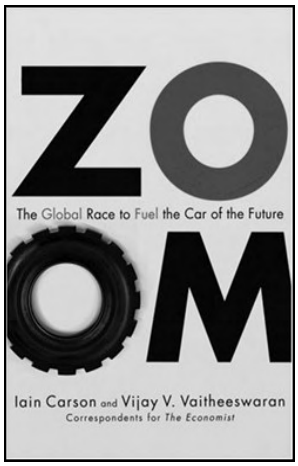
64 talks were given by the young research student participants from the various parts of the country, all of which were being observed by the distinguished judges quite closely. On the final day, competition for the best presentation was held among 12 candidates, selected on the basis of performance in earlier sessions. The presentation given by Aquil Khan (IIT K) on Logic was awarded as the best presentation followed by Dilip Kumar (CMS PALA) and Richa Bansal (DEI Agra).

Eventually the meet brought improvement in the research prospective of many young researchers through various facilities provided to them by the organizers. Prof. D. Bahuguna (dhiren@iitk.ac.in) was the convener of the meet, and it was financially supported by Department of Science and Technology, New Delhi.

DOG-EARED

Book review on 'ZOOM'

Arvind Kothari

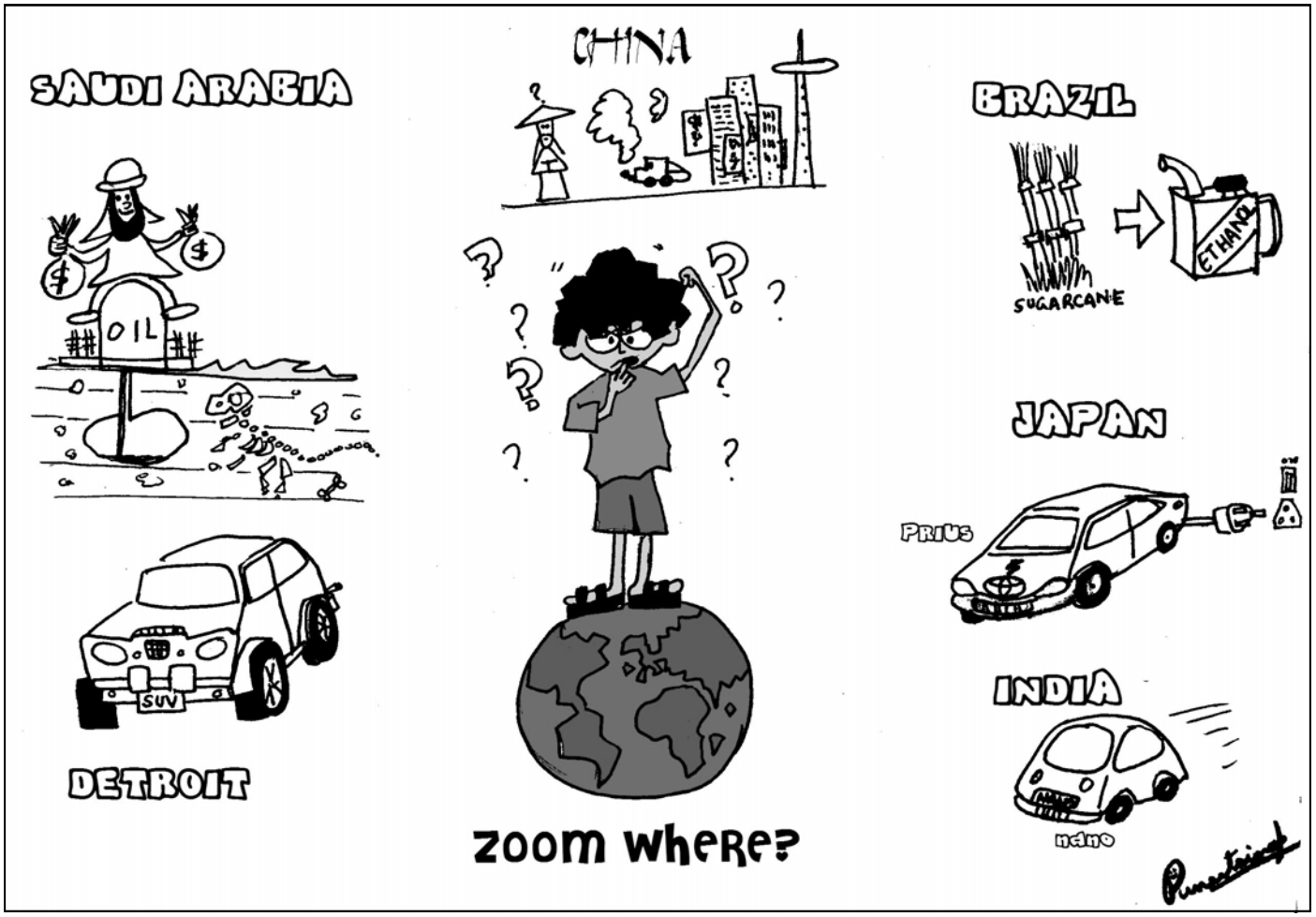


NERD Rating: 2.5/5.0
Published by: Penguin Books
Published: 2007
Price: Rs 395.00
ISBN: 9780141036724
Edition: Paperback
Pages: 356 pp
Genre: Non-Fiction
SAC Book Club Availability: Available (1 Copy)
Awards: None | Shortlisted for the Financial Times/ Goldman Sachs Business Book of the Year award

What do you want out of this book? Take a deep breath and answer this question before you go ahead and buy this book by looking at its cover and back-flap reviews. The warning is - Zoom is a good book only if one knows what they are getting out of it.

If you are expecting a book that would provide an insight into the various technologies and innovations that are being pursued currently to support the human race beyond oil, then you will be disappointed. These developments have been mentioned only in passing, never being the focus of the narrative. This makes the book superficial in terms of scientific value. One can get more, better and current information from the zillion blogs that are updated every other week. If you are interested in a history of the oil crisis and auto industry, the rise and fall of Detroit, the ascent of Asian automakers and the geopolitics and economics of Oil, then this is the book for you. In that sense, it is an entertaining book with catchy titles and interesting anecdotes. It is mostly well written except for its repetitiveness and inherent bias.

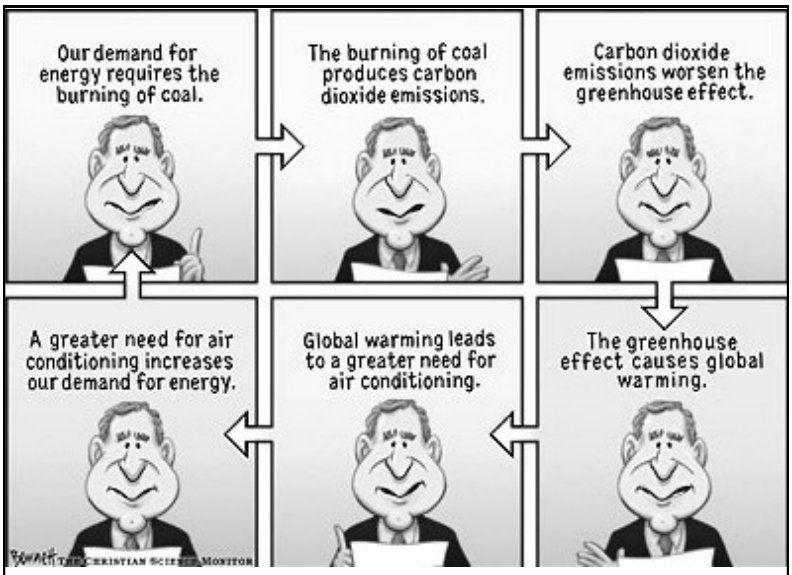
The book starts with a hydrogenized introduction. The introduction soon grows to become a profile on Stan Ovshinsky, the visionary inventor and advocate



of hydrogen economy. Authors trumpet that the hydrogen economy is the key to satisfying the energy demands of future. From then on, the jargon has been thrown in every nook and cranny of the book but the details and pros and cons are never discussed.

The authors set the guillotine for Oil and Auto in the very first chapter. They talk about how Oil companies are taking a beating due to depleting resources, how Detroit is going down in the wake of Asian automakers and their innovations and how the time is ripe for a revolution in the field of fuels and engines. They also talk about the history of auto and green legislations on oil and automobile industries.

In the second and the third chapters, they discuss respectively the state of Oil and Auto industries with a US perspective. Here, one realizes that they are actually reading the same things they read in first chapter. This is not the last time this feeling comes while reading the book.



Source: Clay Bennett (www.claybennett.com)

From here on, the book shifts from an account of the ascent of Asian automakers in Chapter four to the geopolitics of Oil in Chapter five followed by the argument in Chapter seven as to how the economic developments in China and India might actually save the world. It is in the penultimate chapter that authors refer to some technologies in the passing. The emphasis stays on economics, anecdotes and people. Finally, authors end on a motivating note, trying to raise a stirring call to arms while talking about legislations, hurdles and hope.

Zoom could have been a credible scientific and economic document for future strategies for fueling vehicles. However, the book has an inherent bias against the oil barons and the likes and grants green innovators an almost messianic status. In the absence of viable alternate fuel technologies and discussions thereof in the book (there is almost no citation to any evidence for the claims), it ends up being a propaganda device. Moreover, it leaves a lot to be desired. For someone expecting to read about the new technologies, this appears to be a prologue only and not the actual thing. In that sense, the book seems incomplete.

The fact that the book has been written by two economists/journalists haunts every page. The almost manic presence of anecdotes and personal profiles in every chapter is a testimony to this. At times it appears to be a book that does not come to the point. It becomes difficult to determine if it is an oil bashing, automobile crushing bundle of papers or a narrative that, as the flashy subtitle on the cover says, describes the global race to fuel the car of the future. In fact, the book contradicts this dictum. Instead of talking about the future, it spends too much time recalling history. Add to that the fact that there are no illustrations (not even graphs!) makes it text heavy and a dragging read at times.

Zoom could have been a better book. It could have expressed what it does in half its length but for the repetitions. It would have been a credible source of information if only the authors would have cared to include scientific details, statistics and evidence to various proclamations. So, while the authors do well with history and people, they lose out on the technology front something that makes the book weak. Read in accordance with the opening remarks of this review otherwise go search the blogosphere or buy better books on same subject from Amazon.

About the authors: *Iain Carson* has been the Industry Editor of The Economist since 1994, covering the airline, transportation and manufacturing industries. He has also worked as a reporter and anchor for BBC Television and Channel Four. *Vijay V. Vaitheeswaran* is an MIT-trained engineer who spent ten years covering global environmental and energy issues for The Economist. He teaches at NYU's Stern School of Business and is a team member at the Council on Foreign Relations. He is also the author of Power to the People (FSG). Log on to http://www.vijaytothepeople.com/ for more details.

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ATLAS SHRUGGED: Building in the Garden

India's 1st 5-star GRIHA rated building at IIT Kanpur

Parul Singh, Pranav Gupta and Rishabh Chauhan

Introduction

The Center for Environmental Science and Engineering (CESE) building at IIT Kanpur is the first building in India to be awarded the 'five-star' GRIHA (Green Rating for Integrated Habitat Assessment) rating by TERI (The Energy and Resources Institute), with a score of 93 out of 100, on the basis of its 'green features' including insulated walls, ceiling and window glasses, reflective terrace, rain water harvesting, eco-friendly refrigerant for air conditioning and the use of solar energy for heating and lighting. These energy efficient features reduce the impact on the environment by reducing consumption of electricity and water demand and other requirements.

The building has been conceptualized, designed and constructed as a 'building in the garden', that is sustainable, environment friendly and energy efficient. Aesthetically integrated features allow a free flow of air and water in the built environment. This interdisciplinary research facility has been set up at IIT Kanpur integrating the fields of engineering, science and medicine to address various environmental issues.

NERD talks to Prof. Mukesh Sharma

Professor Mukesh Sharma (Coordinator, CESE) told NERD about the execution of this remarkable project at IIT Kanpur, "The building's design was done with the goal of 'preserving and protecting the existing landscape'. Special care was taken in designing the building so as to incorporate most of the trees thus saving them from being cut or relocated. During the period of construction of the building, strict eco-friendly procedure was followed, demonstrated, confirmed and finally certified. To obtain the Green Building certificate, the CESE building project was first registered with TERI."

What is a green building?

The aim of a green building is to minimize the demand on non-renewable resources– water, energy and materials, maximize the efficiency of these resources when in use and maximizing the reuse, recycling and

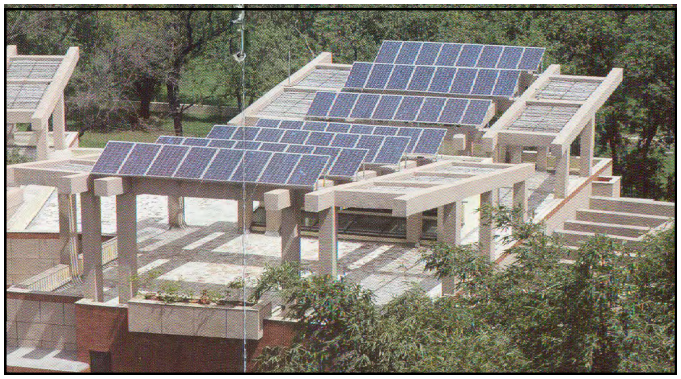
utilization of renewable resources. It maximizes the use of efficient building materials and construction practices, uses minimum energy to power itself, uses efficient equipment to meet its lighting, air-conditioning, and other needs, maximizes the use of renewable sources of energy; uses efficient waste and water management practices; and provides comfortable and hygienic indoor working conditions. The impact of such buildings on environment and human health throughout the lifecycle of the building– design, construction, operation and maintenance– is minimal.

Green Building Features in CESE

The CESE building incorporates many green building features. Let us discuss them one by one:

Preserving and protecting the existing landscape and environment

The building has been located with minimum disturbance to the pre-construction topography and sloe of the land. Special care was taken in designing the



building so as to incorporate most of the trees thus saving them from being cut or relocated. Trees cut during construction were replaced in a ratio of 1:4. By using gunny bags around the trees' bases to prevent dumping and accumulation of debris around the roots, it was ensured that the trees survive the construction period. Barricades surrounding the building were covered with gunny bags/sacks et cetera preventing dust and debris from the construction site to mingle with the outside environment thus checking the air and land pollution and at the same time utilizing waste material.

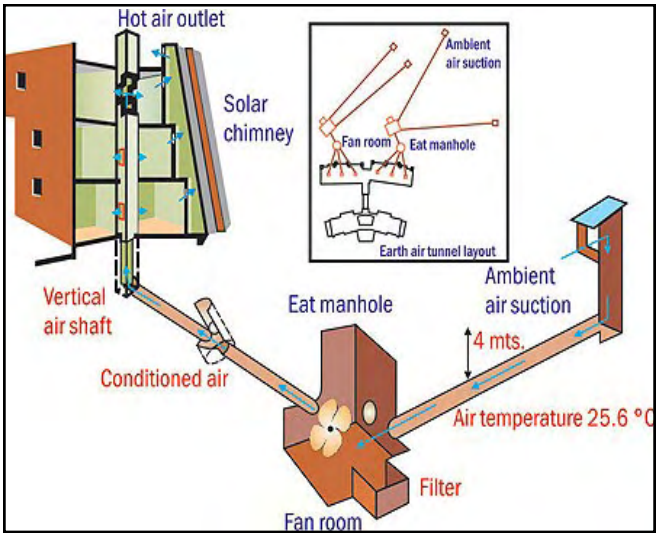
Efficient lighting system

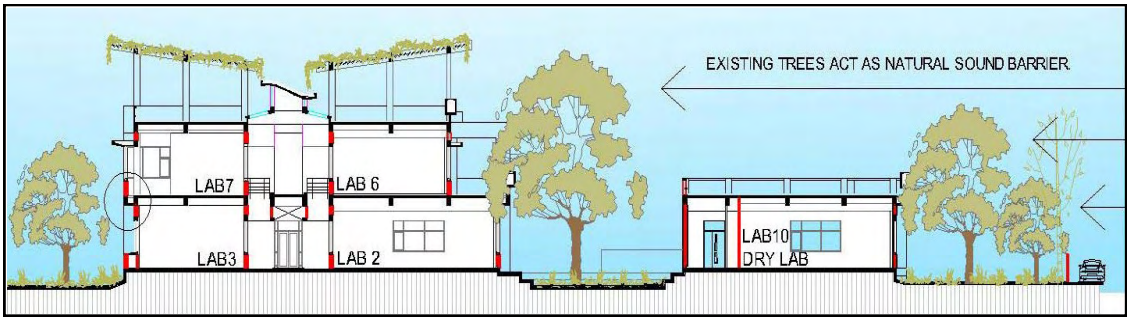
CESE building has the most advanced and efficient lighting system in whole IIT Kanpur campus. The lighting system is designed with controls and integrated daylight. There is almost no need of artificial lighting in day time, 85% building area is day lit (TERI proposes a minimum requirement of 75% day lit area). To meet TERI-GRIHA lighting requirements, CFLs (Compaq Fluorescent Lamp) and CDMT (Ceramic Discharge Metal Halide) lamps have been used. They consume less power and have longer life.

Motion sensors are used in places to control usage of light. These sensors detect movement and automatically control the lighting. One footstep and light turns on/off automatically. Isn't that wonderful? Tube lights have been provided with reflectors which increase luminosity and increase efficiency. Low powered CFLs have been used in staircases to save energy. 30% of internal lighting demand is met from solar energy using photovoltaic panels whereas outdoor lighting demand is met almost solely by solar energy.

Air-conditioning requirements and ventilation

To decrease the building's air-conditioning requirements, passive space conditioning is used. It maintains an almost constant room temperature throughout the year. In this technique, a tunnel is dug four meters below the surface (as temperature four meters below the ground remains almost constant irrespective of the outside seasonal fluctuations) and all air coming inside the building passes through this tunnel.





When hot air (in summers) passes through this tunnel exchange of heat takes place and the air cools down, and vice-versa in winters. Hence, the temperature inside the building is maintained throughout the year at between 26°C and 30°C. This does away with the need to air-condition the corridors and other common areas. The labs which are maintained at a temperature of 22°C also require the temperature to be brought down by only 6°C and hence the load on the air conditioning system is reduced. As a result of all these measures, they have been able to bring down the air conditioning load from 200 tonnes to 142 tonnes - a considerable saving of 29 percent.

Solar chimneys are used to improve ventilation of the building by convection of air heated by passive solar energy. As the air inside the rooms gets heated, it rises and gets dissipated outside through the chimneys.

Optimization of building envelope

The walls of CESE have been insulated by using less U-value (overall heat transfer coefficient– a measure of rate of heat loss through a material) material. The lower the U-value, the better is the building insulation. The double glazed glass windows also prevent heat conduction. They block infrared part of the light and allow only visible radiation to come in, thus lowering the inside temperature.

The building's roof has been fitted with broken china mosaic to reflect heat. The roof has also been covered with *Brise Soleil* (permanent sun-shading techniques) which acts as sun breaker, i.e. it does not allow direct sunlight to fall on roof top. Further a louvered trellis with green cover shades the roof again resulting in better temperature/heat control. Deciduous trees have also been planted on the south side so that they provide shade in the summer and as they shed their leaves in the winter, they do not block heat and light in the cold season.

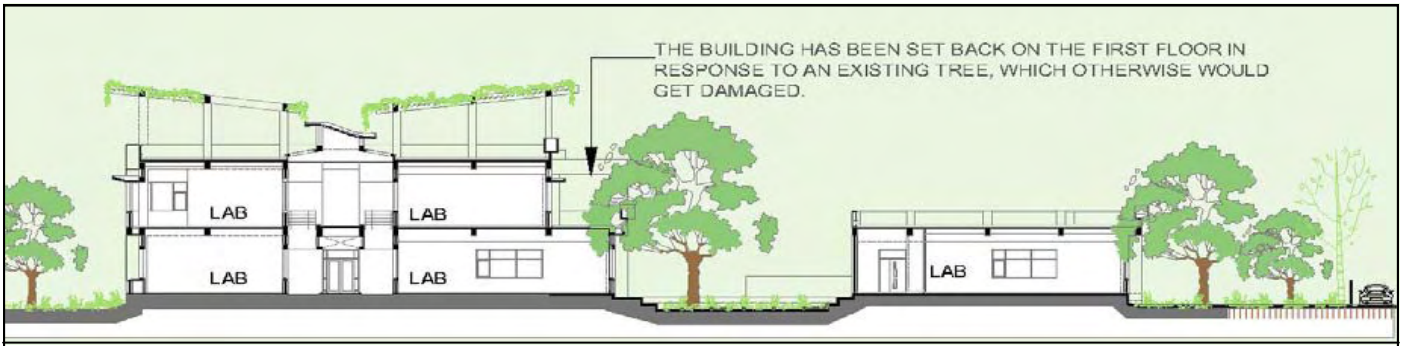
The paints applied onto buildings also play a role in determining the 'Green Quotient' of the building. Paints, finishes and varnishes release low level toxic emissions into the air for years after application. The source of these toxins is a variety of VOCs (Volatile Organic Compounds) present in them which, until recently, were essential to the performance of the paint. To control this toxic emission, the CESE building uses paints and adhesives with a low VOC content thereby reducing damage to both human and environmental health. Also, the building minimizes the use of ozone depleting substances by using CFC free refrigerants/sealants.

Noise reduction

Being a hub for research and academics requires a noise free environment. CESE building fulfils this requirement as well. The trees are planted on the periphery with the purpose of reducing incoming noise disturbance. The floor has been cushioned to reduce noise transmission to the lower floor. The walls of seminar and class rooms are all covered with sound absorptive panes hence reducing the transmission of sound.

Water conservation

The water body has been located in accordance with the site contour, thus acting as a reservoir for the storm water runoff from the building. Rain water from the building and surrounding area collected and routed through a sedimentation tank to water body for AC cooling. Overflow is led to a groundwater recharge pit. The building boasts of an artificially in-



The first floor of the building has been pushed inside to protect a tree outside.

corporated lake which creates a micro-environment and helps optimizing the microclimate. Also during construction, the water requirements were kept to a minimum by storing and reusing water in make-shift water holes.

The building is well equipped with solar water heaters -there are 20 solar collector panels to meet the hot water requirements. The building also has a water treatment unit to maintain water quality. This continuously supplies clean water in building. Treated water is mainly used to meet landscape water demands. Dedicated sewage treatment plant has been provided and the grey water is used for horticulture. All this has led to 59.6% water saving in the building.

Other salient features

Recycled and indigenous materials with low embodied energy have been used in the construction of the building. Provision of an internal court shaded by louvers allows free air movement. The facility is fully ECBC (Energy Conservation Building Code) compliant. With the use of such modern and energy efficient technologies, energy savings are order of 50%. Though initial cost of the building is increased by 10 to 15 % of the original, but the payback is expected to be obtained in nearly 5 to 7 years. An estimated net savings of 15% of total cost in 15 years is expected.

Message

Prof. Sharma says, "To be associated with this project has been very important learning process. The whole (CESE) building operation- from its construction to future use is strict and environmental friendly. You can't forget it later. You have to change your attitude, change your work ethics to keep the building GREEN during its entire life time. Maintain the GREEN status."

Inauguration of the building

This initiative, which has approximately 41% reduction in energy consumption from the TERI-GRIHA baseline, has been funded by Mr. Arun Shourie (Member, Rajya Sabha, Indian Parliament) under MPLADS (Member of Parliament Local Area Development Scheme). The foundation stone for the building was kept on April 23, 2006. A technical workshop on 'Development of Technologies for improvement of environment: Advancements and challenges' was conducted on January 8, 2008 on the occasion of inauguration of the building by N R Narayan Murthy (Mentor, Infosys) and Arun Shourie.

The building, spread over 1.75 hectares, has been designed by New Delhi-based architect Kanvinde Rai & Chowdhury. It has been ensured that the building remains 'nestled' in the natural environment, dotted with full grown trees and greenery.

Organization

The activities of the centre will be overseen by a NAC (National Advisory Committee) and institute level CCC (Centre Consultative Committee). It will actively support research carried out by students, and try to provide special fellowships to students working on the projects operational at the centre.

GRIHA Rating System

GRIHA rating system includes 34 criteria, with no. of points attached to each one of them. This system was introduced on August 6, 2008 to facilitate the design, construction, operation and evaluation of environment friendly buildings. The evaluation panel consists of eminent professionals.

The rating evaluates the environmental performance of a building holistically over its entire life cycle, thereby providing a definitive standard for what constitutes a 'green building'. This voluntary scheme measures the 'greenness' of a building. It seeks to strike a balance between the established practices and emerging concepts, both national and international and is based on accepted energy and environmental principles.

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3.www.falcon-crest.com/energy-efficiency/index.html
4. http://en.wikipedia.org/wiki/Brise_soleil

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Fundamentals of Microfabrication

Interview with Dr. Marc Madou

Pranjal Nayak and Chandra Shekhar Sharma

Dr. Marc Madou is the Chancellor's Professor in the Department of Mechanical and Aerospace Engineering and in the Biomedical Engineering Department at the University of California, Irvine. He is also a Distinguished Honorary Professor at IIT Kanpur. He has more than 100 peer-reviewed international journal papers and has several international patents to his credit. He has served in many scientific societies as an advisor, chairman, editor etc. He is also the author of several books including 'Fundamentals of Micro-fabrication', which is used as a textbook in many classrooms around the world and is considered the bible for microscale research. His current research interests include Carbon-MEMS, CD Microfluidics and polymer actuators.

Dr. Marc Madou

NERD: Please tell us something about your association with IIT Kanpur.

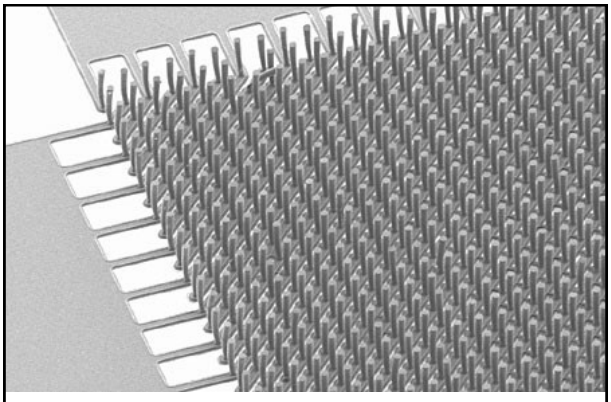
Dr. Madou: A conference on advanced manufacturing was organized in IIT Kanpur in 2004. It was sponsored by the National Science Foundation (NSF) of the US. I was nominated as an Honorary Distinguished Professor of IIT Kanpur on that occasion, and we engaged in discussions with faculty members here on campus about possible scientific collaborations. We subsequently received funding from the DST (Department of Science and Technology) of India and the NSF for a three year project, in which we had extensive exchange of students. Some of my students went to IIT Kanpur and IIT Kharagpur for a period of three months, and some Indian students have been at the University of California, Irvine.

NERD: You specialize in research on MEMS. Please give a brief overview of the chemical, biological and other domains of applications of this technology.

Dr. Madou: At IIT Kanpur, we are working on Carbon-MEMS (micro fabrication with carbon as the basic building material). Silicon is often used to micro fabricate things but we have chosen to look at carbon as a material to micro machine. Specifically we are looking at carbon electrodes and we try to make what are called fractal electrodes. A fractal electrode is a tree-like electrode that maximizes the surface area of the electrode while minimizing the amount of work it takes to reach all of the points on its surface. If we can make that, it'll lead to better batteries and better fuel-cells. We are making good progress towards that goal.

With IIT Kanpur we are also working on another application of fractal electrodes i.e., the construction of more sensitive bio-sensors such as better glucose sensors. In this project, which is bio-medical in nature, we are trying to make a smaller glucose sensor that produces more analytical current. In this fractal electrode design we decorate the "electrode-tree" with the enzyme glucose oxidase.

At IIT Kharagpur, we are working with CDs (compact discs) to propel fluids in little chambers and channels carved into the CD. The ultimate goal is to carry out molecular diagnostics on a CD, in which case you perform an analysis based on specific DNA or proteins in the test sample. For example in the case of food poisoning, you might have lysteria in your blood. A drop of infected blood is put onto the CD and if lysteria is indeed present a fluorescent signal is observed on a DNA array also embedded on the disc.



Design of unique fractal electrode made out of carbon at University of California, Irvine. *(Image: Dr. Marc Madou, http://www.spectrum.ieee.org/print/4029)*

We are also doing extensive work on speeding up DNA hybridization on DNA arrays in confined fluidic conduits. If one miniaturizes a DNA array and assorted fluidics then the sample solution cannot mix very effectively over the DNA array because the Reynolds's number is so low. That means that the DNA species in the sample can only reach the DNA array by slow diffusion rather than by the more effective convection. So we are looking at all types of tricks to try to speed up the hybridization reaction in such low Reynolds's number reaction chambers. Now that's a nice interdisciplinary topic because it brings in mechanical engineering for the fluidics, biology for a good understanding of the DNA reaction and even medical doctors for the final application. The outcome might

be that eventually instead of waiting for 2 or 3 hours for a DNA analysis it may take only 10-15 minutes.

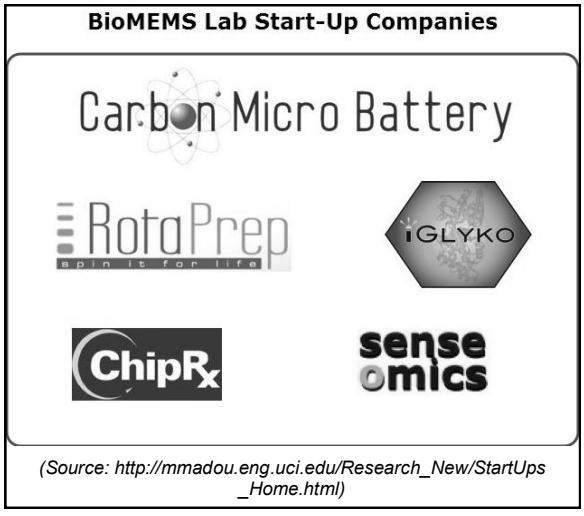
We are also active in the field of responsive drug delivery. We are developing what we call a 'smart pill'. The idea is to put such a smart pill under the skin of a patient. In the case of a diabetic the smart pill would at any given moment deliver the amount of insulin needed by the patient. There is a sensor incorporated into the smart pill that determines how much the patient needs of a particular drug (e.g., insulin in the case of a diabetic), and the sensor provides active feedback so that overshooting or undershooting the amount of drug is minimized.

"Batteries using the C-MEMS and fractal approach shall last at least 2 or 3 times longer."

All the examples of my work I have given are MEMS applications. They involve mostly micro fabrication applied to chemical and biological problems and some nanotechnology. The role of nanotechnology in my work is still limited to the use of genetically engineered proteins and DNA arrays or some nanoparticles we use while working on the fractal electrode design.

NERD: You said you have been working on batteries with IIT Kanpur. Do you think your technology will revolutionize the battery market and make an impact on the energy-crisis across the globe?

Dr. Madou: We must remain very modest as to what our technology can accomplish. But it indeed could revolutionize the amount of capacity one can get out of small batteries like the ones that are used in hearing-aids, pacemakers and Bluetooth devices. If we succeed we might be able to make these types of batteries last at least 2 or 3 times longer. We cannot project that same advantage yet for bigger batteries used for cars. Within two years, we will have battery prototypes using the C-MEMS and fractal approach we discussed earlier.



(Source: http://mmadou.eng.uci.edu/Research_New/StartUps_Home.html)

NERD: How long do you think it will take before these things might be coming into the market?

Dr. Madou: (Laughs) If you look at fuel-cells, after all these years and many promises these are still not widely available on the market and just like batteries they evolve very slowly. We know that the semiconductor/IC industry has grown exponentially, its capacity improving following Moore's law (doubling in capacity every 18 months). With batteries, progress is much, much slower. If people can make battery capacity improvements of 1 or 2% a year, they are pretty happy. You can't imagine an improvement of 200-300% in a year, and if we achieve that, it will be quite an accomplishment.

For the smaller batteries, the prototypes may be ready within 2-3 years, and to make big batteries, it may take 5-10 years because for them, we need many smaller elements and then we need to solve how we connect/stack these smaller elements.

NERD: You founded Teknekron Sensor Development Corporation (TSDC), one of the first MEMS companies in the Silicon Valley. Presently, you are associated with the newly founded Carbon Micro Battery. Please tell us something about the patents and products of the companies.

Dr. Madou: I'll start with the latest. The Carbon Micro Battery is a company founded by two of my students. I'm only a consultant to them. They were fortunate that they raised venture money for the company just before the financial collapse in the US, and we hope that they can stretch the money till the economy picks back up steam. They have a good patent portfolio, and I'm hopeful for them.

TSDC, which does not exist anymore, was a company ahead of its time. It had many patents and we did a lot of MEMS foundry work for the Japanese. That was the time when America was perceived to be way ahead especially in MEMS and so we did a lot of contract work for Japanese companies trying to get into MEMS. It was kind of job shop or foundry for MEMS. In that type of company you work on a project 12 months or 18 months and then transfer the technology to the paying company and start another project, so your learning curve does not go far enough. That is something that I would really not do again. Foundry work is a kind of slavery (Laughs). It is fine in terms of your salary and salary of a few others, but in terms of your patents and long-term financial health, it is perhaps not the best way to proceed. You should produce your own product and sell that instead of selling a service.

NERD: You have been associated with industry and universities for a long time. What differences have you observed in the area of industry-academia

collaborations in top universities in US and that in India?

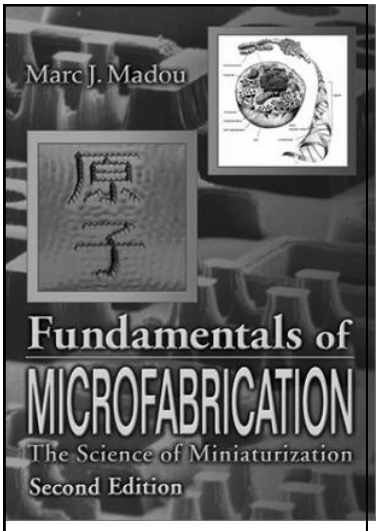
Dr. Madou: Private institutes like MIT and Stanford in the US encourage collaboration of their faculty members with industry. In case of state universities, which are 'paid with state money', professors have to be much more careful as private and state money might get mixed up. Industry collaboration is much easier in private universities. I think we must collaborate but due to the collapse of the US economy there is not much talk currently of more collaboration.

"IITs are well known for their excellence in education but they are not competitive worldwide in terms of research yet.

In India, I have heard that such collaboration is quite minimal, and there's not much outreach at all. This is quite shameful because if India wants to go beyond an information technology driven economy, it will have to start putting more emphasis on its own intellectual property (IP) in a variety of areas and start manufacturing their own innovative hardware. Investment in this field is very necessary for India and if it is not done now, India will be back where it was before the information technology revolution.

NERD: You have been actively involved in Indo-US Program initiated by IUSSTF (Indo-US Science and Technology Forum). How is this program helpful to enhance the quality of research being carried out in India?

Dr. Madou: When I came first to visit the IITs in India, I was shocked because I did not find the quality of research I had expected. IITs are well known for their excellence in education but they are not competitive worldwide in terms of research yet. One finds that, upon more exposure to the various IITs, that there are more and more IIT professors that are starting to produce experimental research results that are world class.



(Source: http://otho.douban.com/lpic/s2736069.jpg)

Exposing all the IITs to experimental research all over the world is starting to make the whole system more competitive with institutes like Berkeley and Stanford. By only comparing IITs internally within India one is kind of fooling the country, one must open up the whole system to compete worldwide not only in education but also in research. I think IUSSTF is helping to make this possible.

NERD: One of your books 'Fundamentals of Micro fabrication' is very well accepted as the 'bible' for MEMS. We are soon going to see its third edition. What changes in this fascinating world of micro and nano- fabrication have you observed in the last decade?

Dr. Madou: There are three top level observations I can make:

1. MEMS as applied to mechanical sensors has arrived/matured in a major way and is now being absorbed by the "traditional" IC industry-e.g., accelerometers are being used in computers and in iPods. Chemical and biological MEMS still are much less mature and not yet market ready. That's why much of the research interest has shifted to biomedical applications.

2. There has been a huge shift from micro fabrication to nanofabrication, and that has shifted the emphasis from mechanical and electrical engineering to all types of engineering, physics, chemistry and biology. As a consequence of this tremendous opening up of the field, my book has grown from 10 chapters to 27 chapters. (Smiles)

3. Whereas silicon is still king in the electronics world (IC) and mechanical MEMS world, other materials such as polymers and carbon have become much more dominant building materials in biomedical MEMS applications.

NERD: What final message would you like to give to students?

Dr. Madou: Broaden your horizon as much as possible. Never trust that a particular field or application will be the only one determining your future. Do many things in parallel especially in a difficult economy. Try to have some exposure to as many things as possible rather than becoming an expert in one narrow field.

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Chandra Shekhar Sharma (cssharma@iitk.ac.in) is a research scholar in the Department of Chemical Engineering at IIT Kanpur. His research interests are synthesis of carbon nano-structures and their application in MEMS. He is working on a collaborative project on C-MEMS with Prof. Madou at UCI.

Old is Gold

Looking into the past for materials of the future

Rishabh Chauhan

The Delhi Iron Pillar

You all must have seen iron getting corroded in presence of air and moisture. Can you think of a pillar made of iron which has withstood corrosion for over 1500 years? The Delhi Iron Pillar, established during the Gupta period (i.e. 280 AD – 550 AD) speaks of the high level of skill achieved by the ancient Indian iron smiths in the extraction and processing of iron, and has attracted the attention of corrosion technologists all over the world.

Fig. 1 Delhi Iron Pillar at Qutub Minar Complex in New Delhi

The fact that an iron structure could remain resistant to corrosion over such a long time is indeed incredible. Several theories have been proposed to explain the same. The proponents of the environment theory state that the mild climate of Delhi is responsible for the corrosion resistance of the Delhi Iron Pillar as the relative humidity at Delhi does not exceed 70% for significant periods of time in the year, which therefore results in very mild corrosion of the pillar. However the cause of this unique feature of this pillar is the presence of relatively high phosphorus (0.25 wt-%) in the forge welded Delhi Iron Pillar. The presence of phosphorus leads to the formation of a protective passive film on the surface and provides the pillar its exceptional corrosion resistance properties. However, in modern steel making process, the phosphorus content is controlled to 0.05 wt-% because phosphorus segregation to grain boundaries reduces ductility of steel.

Now let me explain what a grain boundary is. Different crystals grow in different crystallographic directions. When the growing grains meet each other their growth is obstructed and a grain-boundary (GB) forms there. Grain boundary is an interface between two grains in a polycrystalline material.

Understanding the mystery

To study the useful aspects of this ancient technological achievement in modern day applications and to understand possible industrial applications of phosphoric irons, a detailed study was undertaken by a PhD student, Gadadhar Sahoo, under the guidance of Professor R. Balasubramaniam of the Materials and Metallurgical Engineering Department, IIT Kanpur. The first aim was to render the phosphoric irons ductile. The second aim was to locate a modern application wherein the corrosion resistance of phosphoric irons could be put to good use.

Ductility is a very important property from the point of practical application of any engineering material. Also it is known that phosphorus segregation to the grain boundaries makes these locations weak and results in poor ductility. Therefore, the first aim of the work was to find out methods to keep phosphorus away from the grain boundary. It was first realized that phosphorus will not be present in regions where carbon is located in the iron matrix because phosphorus is a substitutional solute element whereas carbon is an interstitial solute element i.e. carbon gets preference in the placement in a matrix of iron. Therefore, a small amount of carbon needs to be maintained in phosphoric irons. The next challenge is to locate these carbon atoms along the grain boundaries, thereby keeping the phosphorus atoms away from these locations. In order to achieve this, an intelligent use of the phase transformations in the iron-phosphorus system was applied.

The phase diagram of iron-phosphorus shows a (alpha + gamma) dual phase region at high temperature (see Fig. 2). If a phosphoric iron in the composition range 0.25 and 0.50 wt %P, is soaked in the two phase region (temperature between 1000°C and 1100°C), the austenite phase (g) will precipitate on the grain boundaries of ferrite phase (a). This is well known in physical metallurgy. Austenite has a higher solubility for carbon than phosphorus and therefore all the carbon is pushed to the grain boundary region while the phosphorus is removed from the grain boundary region. After a suitable soaking time at high temperature, the phosphoric irons can be air cooled to room tem-

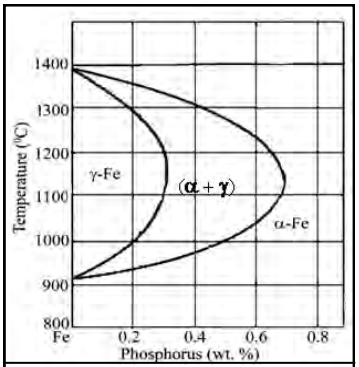

Fig. 2: The high temperature gamma loop region of the Fe –P phase diagram.

perature. The beneficial aspect of this treatment is that phosphorus, which was removed from the grain boundary regions, does not go back to these regions during air cooling because phosphorus requires time to diffuse to the grain boundary regions. In this manner, a high temperature soaking in the two phase region and subsequent air cooling should result in good ductility for phosphoric irons.

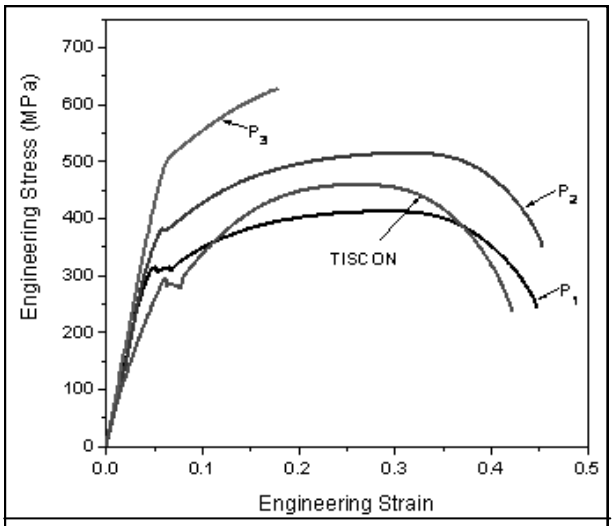

Fig. 3: Typical engineering stress-strain curve of the specimens P1, P2, P3 and TISCON

Testing ductility for phosphoric irons

In order to test this hypothesis, three phosphoric irons P1 (0.11 wt. % P), P2 (0.32 wt. % P) and P3 (0.49 wt. % P) were ingot cast and later forged to rods. In all these phosphoric irons, a small amount (0.02 wt. %) of carbon was maintained. Appropriate heat treatments were devised for these irons, as per the philosophy outlined above. Tensile testing of triplicate samples indicated good ducitlities for phosphoric irons, especially P1 and P2 (see Fig. 3). In the same figure, the tensile test result of a commercial reinforcement bar (TISCON of Tata Steel) used for concrete reinforcement applications is also shown.

Good ductilities were obtained for phosphoric irons because phosphorus was kept away from the grain boundaries. This was confirmed by microscopy (see Fig. 4). In this figure, the optical micrograph of P2, that was soaked in the (alpha + gamma) dual phase region is shown, after etching with Nital (2% nitric acid + 98% ethyl alcohol). The light contrast at the grain boundaries indicates locations of low phosphorus content. Interestingly, this structure is known as a 'ghost' structure because although the entire structure is ferrite at room temperature, the location of prior austenite and prior ferrite is revealed by the contrast that obtains due to differences in phosphorus contents. Now you know that the idea of 'ghosts' does also apply in metallurgy! Funny, isn't it?

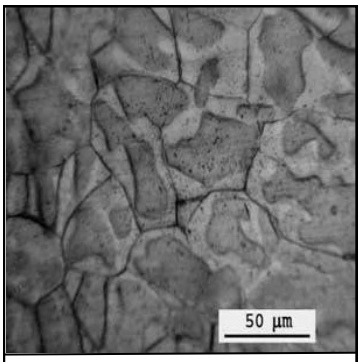

Fig. 4: Optical micrograph of heat-treated specimen P2 after etching with Nital

The good room temperature ductility obtained in phosphoric irons will remain as long as the materials are not exposed to the temperature range of 200°C to 600°C for long times. When phosphorus containing steels are exposed in this temperature range, phosphorus diffuses and segregates to the grain boundaries, leading to their embrittlement. This is known as temper embrittlement.

In case phosphoric irons have to be applied commercially in ambient temperature conditions, there would be absolutely no problems regarding their ductility. We need to keep this in mind while looking for suitable applications where phosphoric irons can be applied.

In this context, it is important to consider the production of reinforcing bars in concrete because a large tonnage of steel produced in a developing country like India is used for reinforcement of concrete in structural applications. The reinforcement bars have to possess the necessary strength, ductility and corrosion resistance. Modern-day reinforcement bars are strengthened by three methods, namely, (1) microalloying with costly elements like Nb, Ti, etc., (2) cold twisting (which used to be popular earlier), and (3) by controlled cooling in the bar mill plus cooling process. The last process is increasingly becoming popular in India and you must have noticed the advertisements for bars indicating that they are 'TMT bars' which stands for 'thermo-mechanically treated bars'. Phosphoric irons can be processed by a similar method utilizing the existing arrangements, with the major difference being the ingot soaking, bar quenching and further cooling arrangements have to be fine tuned to produce phosphoric iron with a tough surface and a strong interior. This can be achieved by suitable design criteria.

Several methods are used for improved corrosion performance of reinforced bars in concrete structures. One of the popular methods has been to use protective coatings on the surface. These include the use of galvanized and epoxy-coated reinforced bars. In case of any damage to the surface epoxy coating, severe corrosion occurs at these breaks and this may lead to intensive localized attack. Hence special care is required in selecting coated reinforced bars in applications. In such cases, phosphoric irons may prove to be the best solution to the problem.

Testing the corrosion performance

The corrosion behavior of phosphoric irons has been evaluated in a wide variety of environments. It was concluded that phosphoric irons possess necessary corrosion resistance in near neutral and alkaline conditions. A typical industrial application for which

phosphoric irons may be applied is for reinforcing concrete. Therefore, the corrosion resistance of phosphoric irons was evaluated extensively in simulated concrete environments and compared with commercially available material from Tata Steel. The results of the detailed study indicate the superior corrosion resistance of phosphoric irons in concrete conditions.

For example, the corrosion rate of TISCON (superior rebar, manufactured by Tata Steel through the TMT (Thermo-mechanical treatment) process) was much higher compared to phosphoric irons. Interestingly, phosphoric irons exhibited good passivity in concrete environments. A wide variety of techniques was used to study corrosion in concrete conditions. These included polarization methods (linear and Tafel polarization), potentiodynamic polarization and potentiostatic polarization, electrochemical impedance spectroscopy, salt fog immersion, complete immersion and atmospheric immersion experiments. Apart from samples exposed to aqueous solutions, cement-grouted samples were also tested to simulate actual application conditions.

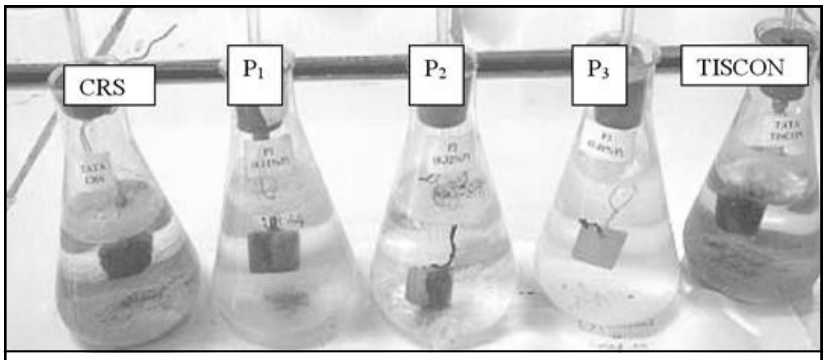

Fig. 5: Immersion testing samples after 125 days of immersion in saturated $Ca(OH)_2$ solution containing 5 % NaCl

It is known that chloride ions are damaging to surfaces because they generally tend to destabilize the protective passive films on the surface. Surprisingly, phosphoric irons showed excellent corrosion resistance even in their presence. This significant result indicates that phosphoric irons will provide good service in environments where chloride ions are present, like in case of structures near seacoast.

As India possesses a large coast line, there is wide scope for using phosphoric irons in reinforced concrete structures near coastal areas, which generally calls for higher material quality. This is the reason that the major steel makers in India , SAIL (Steel Authority of India Ltd. - the largest integrated iron and steel producer in India) and TATA STEEL, market another quality of reinforcement bars, which they call CRS indicating 'corrosion resistant steel.' Generally, these steels contain a little amount of Cu (Copper) and Cr (Chromium) as alloying additions and they are costly compared to normal reinforcement bars. Phosphoric irons can perform as good as, if not better, than these commercial CRS materials. An added advantage is that they will not be costly compared normal TMT bars.

In order to visually show the good corrosion behavior of phosphoric irons, the result of immersion testing in saturated $Ca(OH)_2$ solution containing 5 % NaCl is shown in Fig. 5. The nature of surface after 125 days of immersion can be noted for five different surfaces-three phosphoric irons and two commercial grades of reinforcement steels from Tata Steel (TISCON and CRS). The severe nature of corrosion in case of P1, TISCON and CRS is quite clear.Phosphoric iron P3 is the most resistant, followed by P2 and then P1. These visual images clearly prove the beneficial effect of phosphorus in conferring corrosion resistance, especially in simulated concrete pore solution containing a relatively high concentration of aggressive chloride ions.

As you now realize that ideas for developing phosphoric irons originated from the study of the metallurgical wonder of India – the Delhi Iron Pillar. We hope that now you believe in the old adage that 'the best of the new is often the long forgotten past.'

Special Thanks

We are thankful to Professor R. Balasubramaniam of the Department of Materials and Metallurgical Engineering at IIT Kanpur to help us with his story of week, and some research papers he gave to NERDs to compile this interesting article.

Ponder Yonder

1. R. Balasubramaniam, "On the Corrosion Resistance of the Delhi Iron Pillar," Corrosion Science , *42* (2000) 2103-2129.

2. R. Balasubramaniam and A.V. Ramesh Kumar , "Characterization of Delhi Iron Pillar Rust by X-ray Diffraction, Fourier Infrared Spectroscopy and Mössbauer Spectroscopy," Corrosion Science , *42* (2000) 2085-2101.

3. R. Balasubramaniam, "Phosphoric Irons for Concrete Reinforcement Applications," Current Science , *85* (2003) 9.

4. Gadadhar Sahoo, "Corrosion of Novel Phosphoric Irons for Concrete Reinforcement Applications," PhD. Thesis, IIT Kanpur, 2007.

5. R. Balasubramaniam and Gadadhar Sahoo, Corrosion Resistant Phosphoric Iron for Concrete Embedment and Reinforcements Application, Indian Patent Application Number 1823/Del/2005.

Zonked!

1. MowTow wants change!
Back in Roadland, they are proud to have a network of roads which do not cross each other except at cities. (This corresponds, if you want your problem stated more formally, essentially to a planar graph with the cities as vertices and direct roads between two cities as edges). MowTow is a Roadlandian who has lived in four different Roadlandian cities. However, all these cities had at most five direct roads to other cities. Now, as a high-ranked Roadlandian official, MowTow wants to make sure nobody ever has to undergo such misfortune, and so he declares that he wishes to design a new network where there would not be any four cities each having direct connections to not more than five other cities. However, he also wants to preserve the Roadlandian tradition of letting roads cross only at the cities.

Can MowTow succeed? If yes, give such a network assuming the number of cities is $n \geq 4$, and if not give a proof.

2. In Las Vegas, or is it Monte Carlo?
So you go visiting Kathmandu (I believe that's the only place in the Indian subcontinent where casinos are legal) and enter ChowRow's casino. ChowRow is slightly down on business, and he offers to pay the following game with you: He will place 20 red and 20 blue balls, which are otherwise identical, in a big bag, and mixes them to your heart's content. You will then place a bid, say Rs.n>1. Now the game proceeds in the following manner: you will draw balls one by one from the bag, until you draw a blue one. You will be given Re. 1 for each red ball you draw.

Is ChowRow playing fair? In other words, do you expect to break even for any permissible bid?

Question by Piyush Srivastava (piyushs@iitk.ac.in)
Send in your answers at nerd@iitk.ac.in latest by March 15, 2009. Awards worth Rs. 1000 to be won!!
For solutions of Zonked! In issue 2, please log on to http://www.nerdmag.org/.

Gene thief: Plant or animal?

Plants have been considered as 'solar-powered machines' with their tiny cell organelles (called chloroplasts) trapping the sunlight and converting it into energy by the process of photosynthesis. Animals, as we know, cannot harness sunlight directly but depend on plants for their energy requirements. But biologists have recently found an entirely different species which lies somewhere between the plant and animal kingdom and is an excellent example of solar powered 'plant-animal hybrid'.

Elysia chlorotica, a lurid green sea slug, exhibits a plant-like behaviour of running on solar power. It has a gelatinous leaf-shaped body, is about 3 cm long and lives along the Atlantic seaboard of the US.

Elysia chlorotica- the 'solar-powered' sea slug *(Image: PNAS)*

Mary Rumpho from University of Maine, an expert on *E. chlorotica*, found that young *E. chlorotica* could survive for the rest of their year-long lives without eating once it is fed with algae for two weeks. She also discovered how the sea slug gets its ability: it photosynthesises with genes 'stolen' from the algae it eats. This phenomenon of stealing is known as *kleptoplasty*, generally referred to as the 'Gene theft'. The sea slug also steals the chloroplasts from the algae and stores them in the cells lining its gut.

Greg Hurst of Liverpool University in the UK says that DNA jumping from one species to another is not unheard of but that normally the DNA does not appear to function in the new species. "What is really unique here is the fact that the gene is transferred and appears to be working", he says.

Ponder Yonder
1.www.sciencedaily.com/releases/2008/11/081125112958.htm
2.www.newscientist.com/articlevideo/dn16124/3188438001-solarpowered-sea-slug-harnesses-stolen-plant-genes-.html
3. www.seaslugforum.net/factsheet.cfm?base=solarpow

Zero or not Zero?

Polynomial Zero testing

Chandan Saha

Introduction

Polynomial Zero Testing is one of the intriguing open problems in the field of theoretical computer science. For over a decade this problem has drawn intense research efforts from many leading researchers across the world. There are many promising approaches and some fascinating success stories to tell. Stories about how this problem helped solve another open problem [AKS] that was open for centuries, about how researchers are unraveling deep connections between this problem and the famous *P vs. NP* problem.

So what is this Polynomial Zero Testing? As the name suggests the problem has got to do with checking, using a computer algorithm, if a given polynomial is zero. For example, suppose we feed in the polynomial $p = x_1(3x_2-x_3) + x_2(x_3 - 3x_1) + x_3(x_1 - x_2)$ to a computer. How can the computer tell that p is zero? In comes the first answer. The computer can simply expand out the summands (like, $x_1(3x_2 - x_3) = 3x_1x_2 - x_1x_3$) and then add them. That's right! But imagine a bigger expression like,

$$p = \prod_{i=1}^{d}(a_{i1}x_{i1} + \ldots + a_{in}x_{in}) + \prod_{i=1}^{d}(b_{i1}x_{i1} + \ldots + b_{in}x_{in}) + \prod_{i=1}^{d}(c_{i1}x_{i1} + \ldots + c_{in}x_{in})$$

where a_{ij}, b_{ij}, c_{ij} 's are integers and x_{ij} 's are variables. How long is the expression? The expression has 3 summands, each of them is a product of *d* linear functions. Each linear function is of length *n*, which makes the total length *3nd*. Suppose our computer had employed the strategy of 'completely multiplying out' as before. That would have involved 3nd multiplications, which means even with $n = 10$ and $d = 30$, the computer would have taken more than the expected age of the universe to decide if *p* is zero! Hmm ... We need a smarter way for checking zeroness. This makes the problem challenging.

Why is Zero Testing important?

We will give two main reasons behind increasing popularity of this problem among researchers. But before that we need to formalize the notion of *efficient algorithms*.

Polynomial time algorithm - An algorithm is efficient if for an input of size *s* it computes the output using at most s^c operations, where *c* is an arbitrary constant fixed for a particular algorithm.

1. Finding efficient algorithms for other problems

One of the most important examples of Zero Testing playing an important role in finding efficient algorithms is *primality testing* i.e. checking if a given integer *n* is prime or composite. In 2002, Agrawal, Kayal and Saxena came up with a polynomial time algorithm for primality based on the following polynomial zero testing:

Let $p = (x + 1)^n - x^n - 1$. Is $p = 0 \bmod n$?

It can be shown that, $p = 0 \bmod n$ if and only if *n* is prime. They gave an efficient algorithm to test if $p = 0 \bmod n$. This ingenious idea of using Polynomial Zero Testing to decide primality eventually settled the century old open problem.

2. Proving lower bounds

Roughly speaking, proving lower bounds means proving statements of the form – 'Any algorithm can not compute "something" using less than "this much" operations.' Surprisingly, an apparently innocuous problem like Zero Testing is deeply connected to proving lower bounds. It plays a promising role in separating classes of polynomials that are efficiently computable from those that are not. To formalize this a bit, we need the notion of *arithmetic circuits*.

Arithmetic circuits - An arithmetic circuit is like a boolean circuit where instead of AND, OR, NOT gates we have addition (+) and multiplication gates (X). Such a circuit naturally computes a polynomial. For example, the following circuit computes the polynomial $3x_1x_2+4x_3^2x_4$.

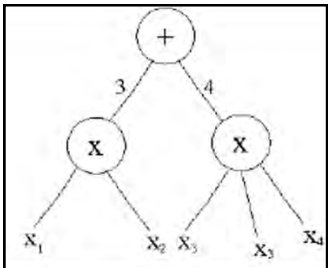

Fig.1: An arithmetic circuit

An arithmetic circuit has two important parameters associated to it - its size that is the total number of gates and wires; and its depth, which is the length of the longest path from the inputs to the output gate. For example, the size of the circuit in Fig. 1 is 10 and depth is 2.

Complexity classes VP and VNP - Valiant (1979) defined the complexity classes *VP* and *VNP*, which are arithmetic analogs of the classes *P* and *NP*. Roughly speaking, *VP* includes all families of polynomials that

are computable by small arithmetic circuits. On the other hand, class *VNP* not only includes *VP* but also several other families of polynomials that are unlikely to be computed by small circuits.

To give a more concrete example, let *Det* be the family of polynomials $\{det_n\}_{n\geq 1}$, where det_n is the determinant of the matrix $X_n = (x_{ij})_{1\leq i,j\leq n}$. Also, let *Perm* be the family $\{perm_n\}_{n\geq 1}$ such that $perm_n$ is the permanent of X_n. Treat both det_n and $perm_n$ as polynomials in the variables x_{ij} 's. It is known from Valiant's work that $Det \in VP$ and $Perm \in VNP$. But it is widely believed that *Perm* is not an element of *VP*. Proving this would imply that $VP \neq VNP$, which is an arithmetic analog of the statement $P \neq NP$.

The reason Zero Testing comes into the scene is because of a remarkable connection shown by Impagliazzo, Kabanets (2002) and Agrawal (2005). They showed that a polynomial 2 time Zero Testing algorithm will 'almost' imply that the class of polynomials Perm can not be computed by small sized arithmetic circuits and hence will also imply that $VP \neq VNP$.

Algorithms for Polynomial Zero Testing

Now that we have seen a couple of compelling reasons for studying Polynomial Zero Testing algorithms, let us briefly touch upon some of the known important algorithms for Zero Testing. These algorithms fall in two categories - randomized and deterministic.

Randomized vs. Deterministic algorithms - Randomized algorithms differ from deterministic algorithms in their power of generating random numbers within a certain range. Intuitively, the reason why random choices are helpful is that no input instances can be 'too bad' for the algorithm. For instance, in the case of Zero Testing, irrespective of what polynomial we feed in, an efficient randomized algorithm gives the right answer in a short time with reasonable probability. Unlike deterministic algorithms, a randomized algorithm may not be able to give a 100% guarantee on the correctness of the answer it outputs. But for all practical purposes, even a 90% assurance is good enough.

In a short while, we will see a randomized polynomial time algorithm for Zero Testing. Before that, I would like to raise one question here and then quickly sweep it under the carpet. It is natural to ask, "How do we generate 'random numbers' in practice?". This question takes us to a new area, called Pseudo Random Generators. It is about study of functions that are fairly random in nature. In case of randomized algorithms, we do not bother about generation of random numbers. We simply assume that whenever such an algorithm needs to generate a random number it just gets it instantly for free.

Randomized Zero Testing

In the following discussion we will assume that the input polynomial is given in the form of an arithmetic circuit. Suppose the input polynomial is:

$$f(x_1, \ldots, x_n)$$

The coefficients are all integers and total degree is *d*.

Schwartz-Zippel Test - For a fixed $a_1, \ldots, a_n$, where all a_i's are integers, the value

$$f(a_1, \ldots, a_n)$$

can be efficiently computed from the circuit. Schwartz and Zippel (1979) showed that if each a_i is chosen randomly from a set of size *m*, then probability that

$$f(a_1, \ldots, a_n) = 0$$

is at most d/m if the input polynomial is non-zero. This immediately yields a randomized algorithm. Choose each a_i randomly from a set of integers of size $16d$. If

$$f(a_1, \ldots, a_n) = 0$$

then the algorithm declares that "input polynomial=0" or else it outputs "input polynomial ≠ 0". Thus, the algorithm runs in polynomial time and outputs the right answer with more that 90% guarantee.

Agrawal-Biswas Test - Another approach, proposed by Agrawal and Biswas (1999), is to transform *f* to a univariate polynomial by the following substitution:

$$x_i \rightarrow x^{d^i - 1}$$

The input polynomial is zero if and only if

$$f\left(x, x^d \ldots, x^{d^{n-1}}\right) = 0$$

Compute the output of every gate of the circuit modulo $x^{16} - a$, where *a* is a randomly chosen integer in the range 0 to d^n. The final output would be precisely

$$f\left(x, x^d \ldots, x^{d^{n-1}}\right) modulo (x^{16} - a)$$

Declare that "input polynomial = 0" if and only if the output is zero. It can be shown that this algorithm runs in polynomial time and gives high correctness guarantee. In fact, a careful 'derandomization' of a modified version of this algorithm led to the efficient *primality testing* algorithm.

Randomized algorithms are nice in practice but in order to get a theoretical result like $VP \neq VNP$ we need a deterministic polynomial time algorithm. Researchers believe that any polynomial time randomized algorithm can be sort of 'derandomized' to a deterministic polynomial time algorithm. Although, nobody has proved such a result yet, one way to show it would be

to give an explicit construction of efficient Pseudo Random Generators. Okay, let it be there under the carpet! Let's see what deterministic algorithms are known.

Deterministic Zero Testing

A depth-*k* circuit is an arithmetic circuit with *k* layers of alternating addition and multiplication gates. The final layer consists of a single output gate.

Kayal-Saxena test - In 2006, Kayal and Saxena gave a deterministic polynomial time Zero Testing algorithm for depth-3 circuits where the output addition gate has only constantly many wires coming into it. The result uses Chinese Remaindering Theorem over certain algebraic structures called *local rings*.

As such no other general deterministic algorithm is known. Why is Zero Testing for small depth circuits difficult? An answer to this is provided by Agrawal and Vinay (2008).

A chasm at depth-4 - Agrawal and Vinay showed that a deterministic polynomial time algorithm for depth-4 circuits will 'almost' solve the general Zero Testing problem in polynomial time.

Concluding remarks

In this article we have seen why Polynomial Zero Testing is an interesting problem in computational complexity theory. A deterministic polynomial time algorithm is yet to come by. Whereas, depth-4 circuits are 'almost' the general case, it remains to see if one can first get a hand on general depth-3 circuits.

In a recent development it has been shown that an efficient algorithm for testing if the polynomial

$$p = \prod_{i=1}^{d} (a_{i1}x_{i1} + \ \ldots + \ a_{in}x_{in}) = 0$$

Here a_{ij} 's are 2 x 2 matrices with entries in a field, would imply an efficient algorithm for depth-3 circuits. Here testing $p = 0$ means checking if p is the zero polynomial in the ring $M_2[x_1, \ldots, x_n]$, where M_2 is the ring of 2 x 2 matrices. Further, using a structure theorem involving local rings, it has been shown that an efficient algorithm exist if a_{ij} 's mutually commute. Can the richness of abstract algebra be exploited further to handle the case when a_{ij} 's do not commute? Only time can tell!

Ponder Yonder

1. http://www.cse.iitk.ac.in/users/manindra/ (*Determinant versus Permanent* by Manindra Agrawal and *PRIMES is in P* by Manindra Agrawal, Neeraj Kayal, and Nitin Saxena.)
2. http://www.claymath.org/millennium/

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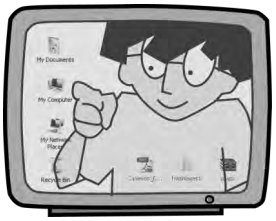


Empowering UG Research: ICARUS

Background

A lot of undergraduate students engage in research related activities every year. Not all the output is authentic but even when some exemplary work is done, many times students do not find any appropriate forum to showcase it. An undergraduate research conference is an ideal forum to showcase the achievements of undergraduate students involved with student/faculty research projects. It will also serve to excite and motivate additional students and faculty to get involved in the UG research experience.

For IIT Kanpur, initiative of an undergraduate conference comes as a natural next step to initiatives like SURGE and REACH. The time is ripe for IIT Kanpur to take a lead on the Undergraduate Research. As the golden jubilee approaches, the institute seeks to redefine its goals and establish itself as a premier research institute and so the present initiative seems highly relevant. IIT Kanpur being the leading technical institute in India is an ideal place for the genesis of something that might revolutionize and mark a significant paradigm shift in the undergraduate education in India. The mission is to permanently enhance the culture of discovery.

Vision

Our vision is to start an annual nation-wide conference in order to provide a forum to communicate and celebrate undergraduate student achievement. The aim of the conference would be to:

1. Showcase and reward exceptional original research by undergraduate students, as well as the ability to communicate it.

2. Increase awareness of current research and career options in science and technology among UG students.
3. Continue a self-propagating system of Indian Undergraduate conferences, to occur annually.

This conference will provide undergraduate students with a unique opportunity to present their own ongoing research in a public format to their peers. Because of the nature of Undergraduate Research, *the conference should welcome the presentation of research at any stage of completion.* It is hoped that through such an event, students' attitude towards research will improve based on their own research experience and/or those of their peers. This will make them more inclined to support research missions in their future careers in academia or industry.

Long term objectives

The long term objectives of the conference have been listed thus:

1. Expand and publicize undergraduate research opportunities.
2. Identify research work presented in the conference for further research and technology transfer.
3. Identify a group of faculty committed to UG research and form a national level **C**ouncil for **U**ndergraduate **Re**search (**CURE**) which will work to promote UG research at a national level.
4. Publicize and secure funding for UG research.
5. Increase industry-academia partnership by using the conference as a forum for networking with industries and showcasing industry defined research carried out by UG students during internships or semester projects.
6. Make the forum international by inviting students from outside India.
7. Develop and maintain various outreach tools for UG research (website, presentations, posters, information brochures, guidelines for research proposals, reports on completed projects etc.).

Features

Initially the emphasis should be on establishing ICARUS as a place where Undergraduate students can talk about science and technology. *This means that the quality of research showcased in the initial years may not be very high.* However, once a platform is established, it can serve as a motivation for students to undertake research. These aims would be realized through:

1. Student Presentations: The conference will include oral and poster presentations. Participants will present talks on their current research projects. These presentations will give participants insight into current research of students as well as give them new ideas in order to improve their own work. Appropriate panels may adjudge the future scope of the work done, suggest improvements in the work and may either incorporate the work in ongoing research or initiate research in those directions.

2. Lectures: It is proposed that a perspective lecture segment, delivered by renowned researchers, be included in the conference. These lectures will instill scientific fervor in the students. They will be exposed to the current trends in research. Speakers can be invited from reputed institutes like IISc, BARC, TIFR, Industries etc.

Modus Operandi

The usual implementation procedures for conferences can be applied here. A *Steering Committee* of faculty from a wide variety of academic disciplines to generate ideas and create broad support for the conference may be desirable. The steering committee will decide the timeframe for preparation and issues related to execution of the conference every year. These issues include advance planning, budget, publicity, abstract submissions, finalizing articles to be accepted, the conference event itself and afteractions. Before that, the committee will have to answer questions pertaining to the philosophy of the conference: *What would classify as UG research in current Indian scenario? Will the conference include working models as technology demonstrators or will it accept only theoretical papers which, given the fact that this will be an undergraduate conference, will be hard to find? Will the conference be departmentalized or will it be themed?*

The first Indian Conference for Academic Research by Undergraduate Students can be organized as a part of the Golden Jubilee Celebrations at IIT Kanpur. For that, various student groups and the Dean of Research and Development Office will have to coordinate and start working immediately after this release. Timeline for subsequent actions can be accordingly set by the Steering Committee. It is hoped that following this release, relevant parties will be willing to take action and organize this event marking a real paradigm shift in the research scene in India. The country still lacks a properly organized undergraduate conference with wide outreach and ICARUS can fill that void in the process adding another 'first' to IIT Kanpur.

ICARUS was conceived by Arvind Kothari (arvikot@iitk.ac.in) This idea was presented in the Institute Research and Development Committee (IRDC) on October 17, 2008. The idea has been approved in principle.

Winter course on energy efficiency

Group for Environment and Energy Engineering (GE^3) conducted a lecture series on energy efficiency from December 10-13, 2008 in the Centre for Environmental and Science and Engineering (CESE) building at IIT Kanpur. Mr. Veerendra Kothari (BT/ME/IITK/1977) delivered the lectures covering related areas such as the basics of an energy audit, renewable energy options, combustion, electrical systems, economic and financial analysis, fired equipment etc.

Mr. Kothari has been involved in many prestigious projects in the field of energy in his industrial experience of over 25 years. Students from different streams of science and engineering attended the course. They enjoyed this kind of exposure and participated well through discussions.

The discussion on the electricity distribution, economics of energy pricing in India was perhaps the most illuminating part of the lecture series. Mr. Kothari talked about energy efficient equipments used in the industry and explained their energy consumption behaviour in general.

Fixed Skylight. *(Source: http://www.peakwindow.com/Velux.htm)*

The lecture series also included evening sessions at which speakers were GE^3 members who gave presentations on efficient lighting, energy efficient buildings and IIT Kanpur Energy Efficiency project (currently in progress). The audience seemed quite awestruck when they were made aware about the technologies that are in use in these buildings to make them more energy efficient. The presentations had multiple aims attached to them– to instil the spirit of scientific enquiry among students, to initiate brainstorming sessions for a better understanding of the subject, to help improve the communication skills of participants and to spread knowledge and awareness in minimum possible time to maximum number of people by exposing them to the new concepts

Rahul Singh, a second year undergraduate in the Department of Mathematics and Scientific Computing at IIT Kanpur, gave a presentation on energy efficient buildings (buildings which use resources as energy, water and materials with a higher efficiency and reduce the impact of building on environment during their lifecycle). Emphasizing on the need and importance of energy efficient building in present scenario, he discussed the Energy Conservation Building Code (ECBC) compliant design strategy for a building, and acquainted the audience with the rating system followed to rate such buildings in India such as LEED (Leadership in Energy and Environmental Design) and TERI- GRIHA (The Energy and Resources Institute - Green Rating for Integrated Habitat Assessment) system. Case studies of CESE building, TERI retreat centre and BSBE (Biological Sciences and Bioengineering) building at IIT Kanpur were discussed in detail. Energy savings in these buildings are of the order of 50%. Though the initial cost increases by 10-15% but the payback is obtained within 5 to 7 years.

Akshit S, a second year undergraduate in the Department of Electrical Engineering at IIT Kanpur, gave a presentation outlining the various aspects of the IITK Energy Efficiency project- the flagship project put forth by GE^3. This multidisciplinary project aims at making the campus energy efficient through the systematic study of the energy system of the campus. It also involves the integration of non-conventional sources of energy into the existing system. It has potential brainwork for fields varying from data analysis, management to the study of energy systems and non conventional sources of energy.

Harsh Gupta, a second year undergraduate in the Department of Civil Engineering at IIT Kanpur, gave a presentation on efficient lighting system. Starting with analysing present devices used for producing light like incandescent lamps (which are basically space heaters that give off light as a by-product and are very inefficient), tungsten lamps which work at an efficiency of about 1%, and halogen and sodium lamps which run at 2.2% and 22% efficiency respectively, he explained various technologies like compact fluorescent lamp (CFL), Organic Light Emitting Diode (OLED) and Quantum Dot which can be substituted to improve efficiency. Sunlight can also be trapped and use for illumination purpose. Sky light is one of such methods in which 60000 lux of light produced by direct sunlight is used by putting layers of composite transparent material on top of a building.

The overall feedback for the lecture series was very encouraging. Videos of lectures are available freely.

The article is compiled by GE^3 team members- Pranav Gupta (pranavk@iitk.ac.in) and Anand Vardhan Mishra (avmishra@iitk.ac.in). For any more details regarding the workshop/group, please contact them.

We shall print solar films one day

Work on Organic solar cells

Debjit Datta

Introduction

Recently there has been an increasing concern over the use of excess energy based on non-renewable energy sources and their harmful side effects such as global warming and pollution. Solar cells seem to be the most viable solution- they utilize solar energy and convert it into electricity without any harmful side effects. At present, the most popular solar cells use crystalline and multi-crystalline silicon based technology that are highly expensive and requires tedious manufacturing processes. In fact, the technology required for the complete manufacturing of a Si based solar cell is absent in most developing countries.

These problems make solar cells not used by majority of the world population residing in developing countries. However, solar cells using polymers and small molecule organic compounds (Organic Solar Cells, OSCs) can be made potentially cheap and, in principle, can be printed on various substrates. The benefits of mature organic solar cell technology are far reaching. Similarly, there are parallel and very close technological developments in the field of Organic light emitting diodes (OLEDs) and Organic thin film transistors (OTFTs). Future applications might be based on clean energy and something as fascinating as color changing car displays, self-powered electronic newspapers and hoardings which may generate all their electricity from sunlight.

The basic requirement from any solar cell is the generation of electricity when light is incident on it. The fundamental processes of conventional solar cells can be understood by studying a Si based p-n junction diode under illumination. Fig.1 (a) and (b) shows the p-n junction solar cell (Inorganic Solar Cell). Under incident light, absorption of photons in the semiconductor leads to the formation of 'free' electrons (in conduction band) and 'free' holes (in valence band). They can be formed in n-type, p-type or the depletion region depending on the penetration of light to that region.

Inorganic and Organic Solar cells

The holes in the n-type region and the electrons in the p-type region diffuse without getting recombined and reach the depletion region. In depletion region, along with the charges generated in the depletion region itself, they get required columbic force, due to the in-built electric field, to reach the other side. Altogether, the holes from the n-type material ultimately reach

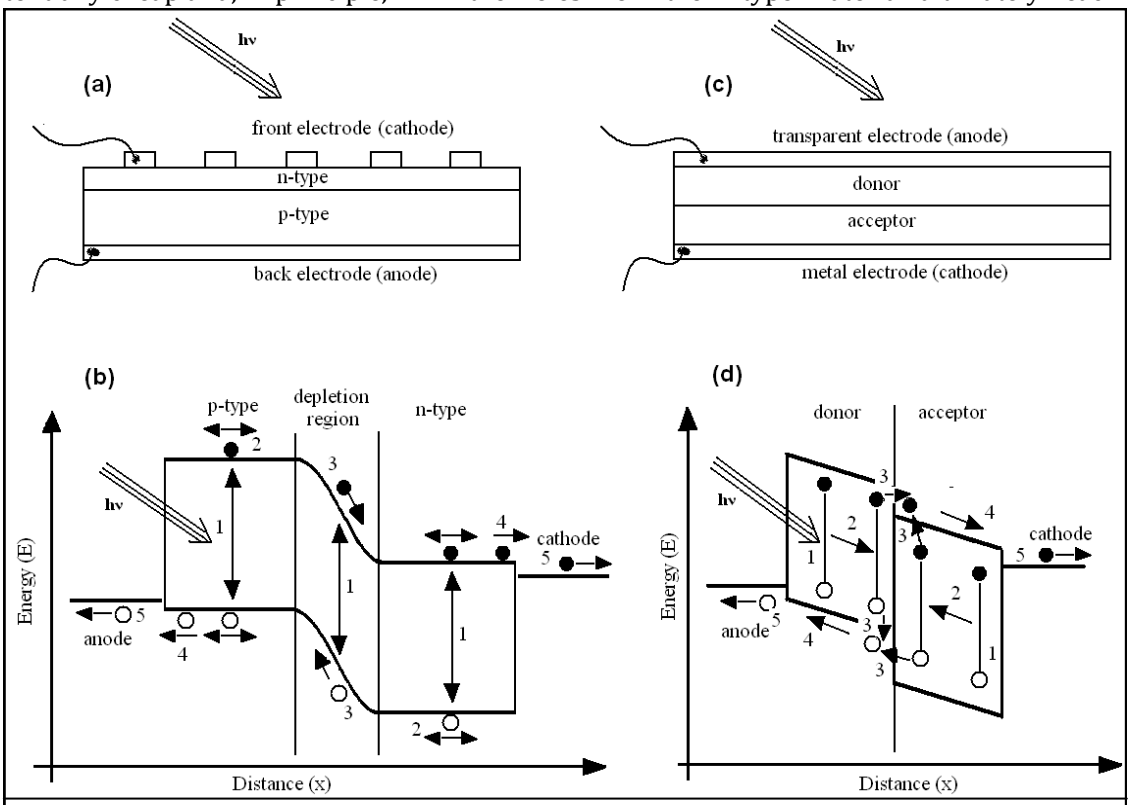


Fig.1.Comparison of Si based conventional p-n junction solar cell and an organic solar cell. The thicknesses are not scaled. (a) p-n junction cell is illuminated from the cathode side that has metallic stripes. The back electrode is deposited completely on the device. (b) Steps in p-n junction solar cell: 1. 'Free' carrier generation, 2. Carrier diffusion, 3. through depletion region, 4. Transport through opposite layer without recombination, 5. Collection at electrodes. (c) Organic solar cell is illuminated from the anode side which is a transparent electrode. (d) Steps in organic solar cell: 1. Exciton generation, 2. Exciton diffusion, 3. Charge transfer, 4. Charge transport, 5. Carrier collection at electrodes.

the p-type material and electrons from the p-type material reach the n-type material. Thereafter, they get transported to the nearby electrodes. Finally, the holes are collected at the anode and the electrons are collected at the cathode. Hence, under a small positive voltage across the terminal (p-type to the positive terminal and n-type to the negative terminal), a negative current is generated. This means the I-V curve moves to the 4^h quadrant and hence power consumed by the device (+V×-I) is negative. In other words, under the incident illumination, electric power is generated.

In organic solar cells, though the requirement of power generation under incident illumination is fulfilled, the basic process of its working is slightly different. In addition, the p-n material in inorganic semiconductor has analogous donor/acceptor (D/A) material in organic semiconductor as shown in Fig.1 (c) and (d). They are based on ionization potential and electron affinity of the organic materials.

Organic materials have an additional property that optically generated electron and hole are not 'free' but are bound to each other by columbic attraction just like a negative electron in a hydrogen atom is bound to its positive nucleus. Hence, the optically generated electron and hole cannot move around separately as they do in inorganic semiconductors. They have to move around together till they ultimately get recombined or separated. If they recombine, they will loose energy and under certain conditions, will emit light. On the other hand, if they can be separated, they can contribute electric current to the external circuit.

Concept of 'exciton'

It must be noted that the pair together is electrically neutral and does not get separated by small electric fields inside the device. Hence, they keep 'diffusing' in random directions having particular diffusion length. This bound pair behaves like a particle (quasiparticle) and is called an *exciton*. The clever way of separating the charges out of the bound pair is to make them diffuse to the 'interface' of the donor and acceptor. Here, as the difference between the ionization potential of the donor and electron affinity of the acceptor is lesser than the exciton energy, it is energetically favorable for the exciton to get separated to electron in the acceptor material and hole in the donor material. Thereafter, by the same logic as in inorganic devices, the electron transports through the acceptor and hole transports through the donor, avoiding recombination, to the respective electrodes.

As the breaking of the exciton into electron and hole is extremely crucial in the performance of the device, there had been efforts to break them close to the point of generation of the exciton rather than making it diffuse to the junction. This can be implemented by smart device structuring incorporating a 'blend' layer of donor and acceptor so that excitons generated in the donor (acceptor) molecules will break up very close, finding the acceptor (donor) molecules, and subsequently result in charge carriers to be transported. However, there exist further challenges in the transport of charges in the blend where their mobility is lower, due to its high 'resistance' to charge flow compared to the pure materials. In addition, the optical properties of the blend have to be extracted from the pure donor and acceptor thin film optical properties.

Among the common organic materials, copper phthalocyanine (CuPc) and fullerene (C60) are among the most promising candidates for donor and acceptor layers, respectively, due to many of their inherent properties. In addition, they can be cheaply made, in fact; CuPc is used in common dye technology like car paints and C60 can be made using graphite. However, purity of the materials made from these cheaper technologies is to be enhanced in future.

Understanding device performance

In this article, we mention some of the work carried out for understanding material aspect as well as device performance. Firstly, we present the optical studies of CuPc, C60 and their blend using spectroscopic ellipsometry (optical technique for the investigation of the dielectric properties of thin films) with suitable optical dispersion and effective medium models. Then we present device performance of a CuPc/C60 based solar cell and the role of exciton blocking layer at the acceptor/cathode interface.

Spectroscopic Ellipsometry has proven to be a crucial tool in modeling the optical dispersion of the materials in thin film form. Various reports have shown successful modeling of optical properties of organic thin films using well known dispersion relations. Most of the dispersion relations used for inorganic materials is fundamentally derived from the interaction of optical fields with the electrons in the material and the consideration of its band structure (density of states) near the band edges. In case of organic thin films, the absorption is due to the molecular orbitals and close interaction between the molecules can lead to only slight alteration of the dispersive properties.

Here we apply Tauc–Lorentz dispersive model on CuPc and C60 thin films. Bruggeman and Maxwell–Garnett effective medium theories were applied to model the ellipsometric data on CuPc: C60 blend. Both the models fail to fit the experimental data. This indicates that during the formation of blend there is no

formation of clusters of the pure material and hence the standard EMA are not applicable. The optical properties of the film are found to be strongly dominated by the molecular properties of pure materials.

Making solar cells with CuPc and C60

Further, we made solar cells with CuPc and C60 as the 'active' layers. Fig.2(a) compares the I-V of device with CuPc/C60 planar structure and CuPc/CuPc:C60-blend/C60 sandwiched heterostructure. Blend device has higher current due to enhanced exciton dissociation and higher voltage due to better matching between the quasi Fermi levels and approaches the built in potential. However, the fill factor is reduced due to non-abrupt interface between CuPc and C60. Overall, blend sandwiched device showed much better performance than the planar device.

A challenge in exciton diffusion in acceptor layer is that it tends to get recombined at the acceptor/cathode interface. Hence, an exciton blocking layer (EBL) is commonly used that blocks the excitons at acceptor and simultaneously allows electron from the device to pass through to the cathode. We investigated various EBL materials towards obtaining optimized device efficiency. Devices with ITO / CuPc / CuPc: C60 (optional) / C60 / EBL / Al structure were made. For EBL, bathocuproine (BCP), bathophenanthroline (BPhen) and 1,3,5-tris(N-phenylbenzimidazol-2-yl)benzene (TPBi) were used. The results are shown in Fig.2 (b). We find that TPBi works as efficient exciton blocking layer.

Fig.3. A researcher at Samtel Centre for Display Technology (SCDT) holding an 'in house' made organic solar cell generating power under the sun to operate a calculator.

The higher current is due to the excitons in acceptor material that do not quench at the interface and electrons from CuPc/C60 interface find more defect states in TPBi to pass through to the cathode.

Research group and facilities at IIT Kanpur

At IIT Kanpur, we have a dynamic group consisting of several faculty members and students actively pursuing work in these fields. We have already demonstrated 2inch×2inch solar panel and powered small equipments such as calculator as shown in Fig.3. IIT Kanpur already has bulk of equipments to fabricate and test such solar cells. For example, we possess high vacuum multi-source evaporation chamber, sophisticated patterning and photolithography equipments, encapsulation techniques under inert gas etc. For device testing, we have state of the art solar simulator, spectrophotometers and diode characterization facilities.

Future plans

Though we have demonstrated active solar cells, we still need to address some crucial issues such as enhancement of device efficiencies by smart device structuring, scaling-up the device sizes and increasing the stability, so that it could become a prototype for future market products. We believe that through team work and perseverance we will be able to take this environmentally favorable technology to the people for widespread use in daily life.

Debjit Datta (debjitdt@iitk.ac.in) is an experimental condensed matter physicist. He is a research scholar at IIT Kanpur. His thesis advisors are Prof. Satyendra Kumar (Department of Physics) and Prof. S.S.K. Iyer (Department of Electrical Engineering). He has been passionate on clean energy solutions and environmental issues and is a firm believer of alternate energies for the future. He works in organic solar cells and focuses on the optoelectronic properties of organic thin films.

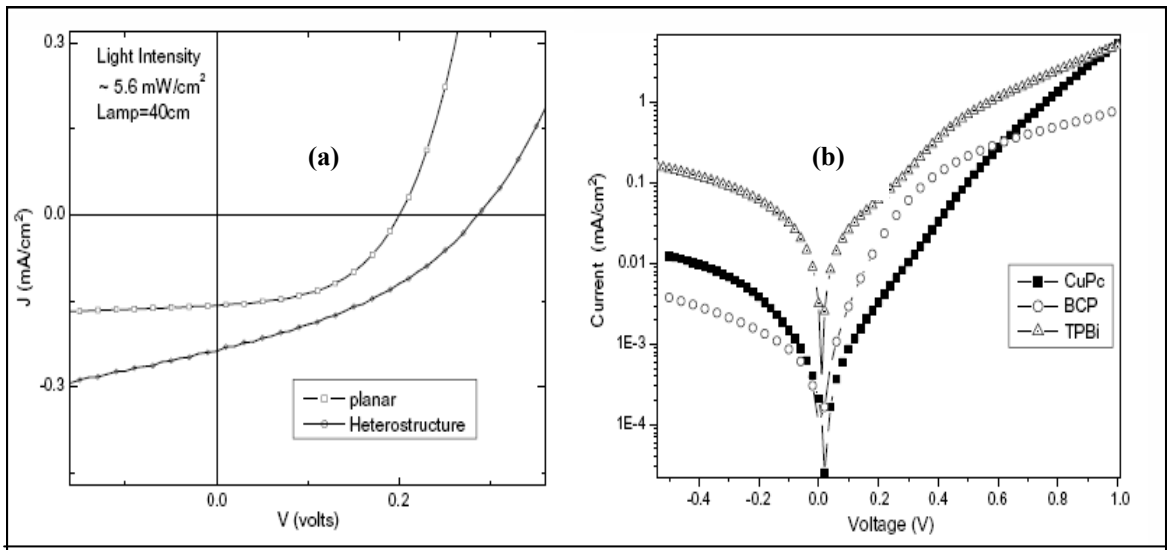


Fig.2.Current-Voltage characteristics of CuPc/C60 based solar cell. (a) Blend heterosructure device is found to be more efficient than the planar device. (b) Comparison of the solar cell performance with various exciton blocking layers. TPBi is found to be the best exciton blocking layer. Also note that (a) and (b) are two different ways of representing the I-V results of a solar cell.

Home Green Home

Sustainability: A homely look

V, Gopikrishna

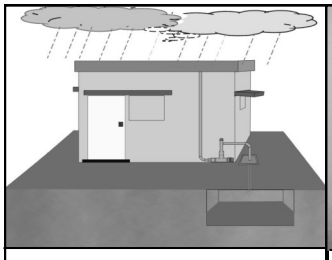
Much is being talked about the development of sustainable and eco-friendly units as a step forward, particularly with regard to managing energy and water consumption. Since a lot of this remains at a level of big talk, one man, along with his family, has set out to put those principles into action and demonstrate its feasibility in the best starting point: his home.

"Saurabha", Vijayanagar, Bangalore.

Mr. A R Shivakumar is a Senior Scientist and Principal Investigator (Rain Water Harvesting) at the Karnataka State Council of Science and Technology (IISc Bangalore) where he works to bring the research generated in universities to practical use across the state. His house, "Saurabha", on a 40X60 sq. ft. site located in the southwestern urban area of Bangalore, has not used a single drop of the Corporation water for the past 14 years, deriving all its water requirements via rainwater harvesting. In addition to that, there is a saving of 30-40 % in power consumption, and the family has no need for Air Conditioners or fans in order to keep the temperature cool throughout the year! And when you consider the fact that even cooking for a family of four is done without the need for electricity and the ground beneath the house is the only spot which retains ground water in the whole block, you would really have to pause and pay attention. Which is precisely what was done, and the responses to questions are given in this article.

Rain Water Harvesting

Primarily, rain water harvesting was chosen for this house because of the availability of nearly 1000 mm rainfall annually in Bangalore. Using almost all the roof area for collecting water, and placing the storage tanks at a height such that there would be no need for pumping up the water again, the house manages to collect nearly 2.5 lakh liters of water annually – more than sufficient for all the family's uses. Water filtration is done via sand-bed method (which is the traditional method) and also via an innovative self designed 'PopUp filter', which actually functions like a valve as well. The water collects in an underground sump and the excess water percolates right down to the ground, replenishing the ground water.



Rain Water Harvesting with Underground Sump

PopUp Filter for filtering the rainwater

House Dynamics

A lot of attention has gone into building the house with regard to the direction of the winds, and sunlight, throughout the year. By placing water bodies such that the wind blows moisture rich air in through the windows, and by painting only the wall that is exposed constantly to the sun (even the roof is painted white!), the house needs no artificial cooling systems. Not caring for the traditional brick and cement system, a Rat-Trap design of bricks has been used, which essentially means that every alternate brick area is an air pocket. The insulation this provides works well for all seasons. Since the sun is predominantly in the southern side of the sky, as we are in the northern hemisphere, the solar cooker and the kitchen windows face south. By arranging the plants and gardens around the house suitably, a look out of every window presents a pleasant green window.

In addition, the bathrooms and the kitchen, which require water supply, have been built in such a way that the pipes installed on one side of the house suffice to connect to all the outlets.

The plants grown, meanwhile, are not arbitrarily selected. Most of them are medicinal plants, and the neem leaves are used to prepare their own pesticides for the mini-garden. All the compost and organic waste, other than plastic and metal (which are recycled) are deposited into an earthworm pit which also forms the basis for the manure required for the plants.

Energy Dynamics

Lighting is done very efficiently by the placements of windows, and skylights which also serve as exhaust for hot air while simultaneously lighting up the interior. No part of the house needs lighting at all during the day. Use of solar panels for water heating has another surprise in store: the panel is *part* of the roof, instead of being an addition – saving the cost of that part of the roof! The insulation for the hot-water tank is via rice-husk, another original design. The solar cooker containing black cylindrical containers saves on the gas. The end result of these measures is that the family uses only 80kWh of energy per month, with no more than six lights used in the entire house.

Solar Cooker with mirror as reflector

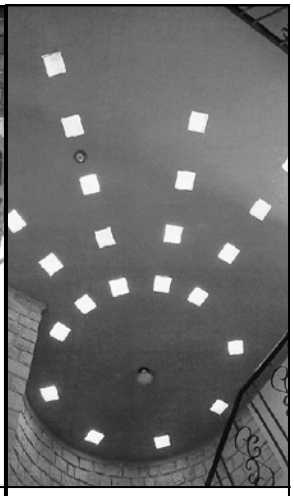
The Interview

Both Mr. Shivakumar and his wife patiently answered all the questions thrown at them, and provided additional information which showed that such a setup was more of a mentality than a bag of tricks.

NERD: What motivated you to design your house like this?

Mr. Shivakumar: I noticed that just small changes and an attention to certain details are enough to design a house working with nature, and efficient at that. It is important to show these things by action, instead of through talk, as it can then be duplicated. We used rainwater alone even for construction. Now that this has been shown, many places have started adopting it at different scales, from Vidhana Soudha to rural areas.

A R Shivakumar indicating the solar panels in-built in the roof



Sky lights on the roof, designed like the sun-rays

NERD: Can you give an example of some of these "small changes"?

Mr. Shivakumar: For example, the roof of any house is responsible for roughly 60% of the heat generated inside. If we desire to keep the place cool, why don't we paint the roof instead of decoratively plastering and painting the entire house? We did that, and that has created an enormous difference: the rooms are at least 3-4 degrees cooler.

Placing of water bodies near windows helped in cooling, but placing a few guppy fish in the water prevented the proliferation of mosquitoes!

NERD: You have integrated even the plants and gardens to serve sustainability…

Mrs. Shivakumar: Yes, the plants actually revitalize the whole place, if we provide appropriate places. There is a bird bath, fish, and earthworms, leading to the formation of a little ecosystem. The plants which we have planted on the first floor have been chosen carefully, so that they do not disturb the integrity of the wall, and at the same time are not stunted. Thanks to the constant use of medicinal plants, even the kids remain healthy!

NERD: How do you make sure that the water obtained by rain water harvesting is potable? Is it really safe?

Mr. Shivakumar: There is a simple way to accomplish that. We use plastic bottles which have a small strip or foil of silver dipped in them. Storing the water in such a container for a few hours would totally disinfect the water, as silver ions are powerful anti-bacterial agents. The water has been tested in the laboratory and subscribes to the standards required very well. Hence there is no need for AquaGuard or any such instruments in the house!

NERD: You have obtained so many patents for your innovative designs. How did you get those ideas?

Mr.Shivakumar: Understanding two concepts are essential: One, that nature would provide all that is required if we approach things with that mentality. And secondly, to *think* and apply them to all situations before embarking on any construction or building. For example, think how much energy is wasted by using refrigerators which are built for left hand users (you use the right hand only to open the door). All that left-handed balancing, and the swinging around of the door… just reversing the construction would save a lot of energy. Toilet flushes are another source of unnecessary wastage, they can be regulated.

Mrs. Shivakumar: Once people start thinking along those lines, solutions are apparent, and application would increase. Happily, this is increasing nowadays. We get visitors almost every day!

NERD: How much work has been done in this regard as of today?

Mr. Shivakumar: The KSCST (Karnataka State Council for Science and Technology) has been working with various governmental institutions, private colleges, villages and schools to implement these ideas, and has been moderately successful. The primary impediment is the hesitation to change. We were ridiculed a lot by our relatives, one of whom was in the architecture field, for our insanity in building a house like this! So, it is important to keep an open mind, as the work is simple. One only needs to do it.

NERD: Thanks Sir, and Madam, for spending so much time for this purpose.

Mr and Mrs Shivakumar: You are welcome. We hope it was worth it, and that the students understand it.

Ponder Yonder

1. http://kscst.iisc.ernet.in/rwh.html
2. "Amruthavarshini - A guide for Rainwater Harvesting" by A R Shivakumar, KSTSC.

V. Gopikrishna (gopiv@iitk.ac.in) is a final year undergraduate in the Department of Physics at IIT Kanpur. He is interested in what one might call as the fringe areas of science. He gave two talks in the TaLeS series (Talks and Lectures by students) in August 2008 at IIT Kanpur.

Need a tea break?

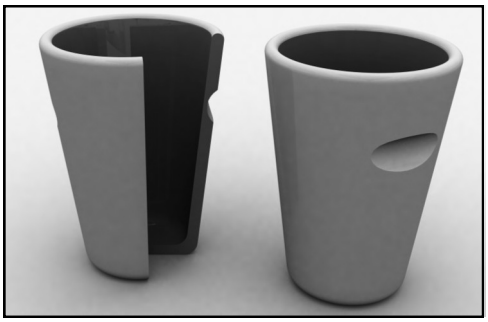
Award wining Product in Design Conclave 08 Organized by FICCI

Arun M

Introduction

For the past few minutes, words like technology, atoms, ions, particle and even lengthy equations have been bombarding in our mind, which makes us to take a tea break. TEA- the word itself has a very powerful emotional feel in it. Everyone takes a tea break; it can be with friends, with relatives or even with professors. It can be with everyone who is passionate of having a tea.

When you ask me about the most memorable moment in my life, the answer would be the moments which I shared with my friends, classmates and even professors in having a small cup of Tea. This made me to think of a Futuristic Tea / coffee mug.



Every one knows to prepare tea but it's my duty to tell about it. The ingredients include milk, tea powder and sugar.
Step 1: Boil the milk in a container.
Step 2: Pour the tea powder
Step 3: Boil it again.
Step 4: After few minutes add some sugar as per your requisite.

It is very simple to make but no one will spend time in making this simple thing every day for his/her own need. Here is the idea to make tea in a minute which will save most of your valuable time in waiting to get one cup of tea in our canteens.

Project Brief

The aim of this project is to design futuristic tea / coffee mugs considering the usage of plastic and its impact on environment.

Innovation

The designed plastic cup is new in its form and usage. The interior wall of the cup is coated with a film (mixture of milk powder, sugar and tea in appropriate content). The coating inside the cup is protected by another layer made up of gelatin which normally melts at 35 degree centigrade. So when the hot water is poured inside the cup, the gelatin layer melts and the content oozes out mixing with the hot water to form a sweet tea. This content can also be varied depending on our requirement. Some people like to have more sugar and even some with more tea/coffee powder but soon their requisite would be fulfilled by varying the mixture content of the coating.

Once the cup is used, instead of throwing it back to dustbin, it goes back to the manufacturer and gets recycled and comes back to the market with new coating. For the recycling process, the thickness of the cup is increased by using Styrofoam (hard plastic) material.

As we all know the usage of plastics are increasing day by day. Even though it affects the environment, one cannot live without it, but its usage can be reduced

innovatively. This product can target the passengers in railway station, bus stations, airports where the waste disposal in itself pose a threat in the Indian context.

In fast moving world, this product also fits well with busy corporate executives and their house holds. This product will meet the demand of new environmental threat before mankind providing a less waste generating design.

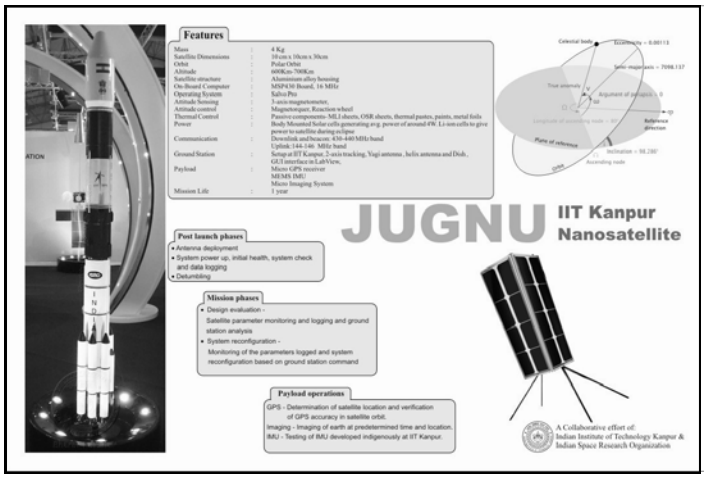
Accolades

This concept won second prize for the category "Design for Recycle market" organized by FICCI during the DESIGN CONCLAVE '08

Arun M (arunn@iitk.ac.in) is a final year Master of Design student in the Design Programme at IIT Kanpur. He is working with Dr. B. Bhattacharya (bishakh@iitk.ac.in). His research includes design of Advance Automobiles taking into the consideration of style and materials used for building an Automobile.

Space Expo

There has been a recent trend to attach the word 'nano' with every existing or upcoming technology. In case of satellite, it is used for satellites having mass in between 1 to 5 kilograms. You may be wondering of what practical use shall be such small satellites, but these satellites are becoming increasingly popular among universities and educational institutions.



27 such satellites have been made till date in different countries like USA, Netherland, Germany, Japan, Denmark et cetera but none from India. IIT Kanpur has started building one such satellite and has named it *Jugnu* which is a hindi word for name of an insect known as firefly .It signifies an effort to illuminate the surroundings with its own little light when there is infinite darkness all around. Also this satellite is aimed to be a HAM (informal term for amateur radio operator)satellite—it will transmit beeping morse code signal all over the world just like a firefly flickers.

This project has 27 students and around 10 professors associated with it from different department. Some members of this team recently went to Bengaluru to present the idea of this satellite at Space Expo 2008 organized by CII (Confederation of Indian Industry) in association with ISRO (Indian Space Research Organization) and ANTRIX corp. This space expo had stalls from many companies as Asia broadcast satellite and Hindustan Aeronautics Limited (which was involved in development of aircrafts like *Sukhoi* and Helicopters like *Dhruv* and *Cheetah*).

A display of cutting edge technology which ISRO has developed over last 50 years as a result of extensive research, was also displayed. The area which caught every eye was the one that displayed facts about Chandrayaan1– its model, 3D images of moons surface taken by it and description of the technology used in it. Description and models of ISRO's upcoming missions like CARTOSAT-2 were also there, and people from ISRO were all around to brief about their displays and clear your doubts. It was a great learning experience.

IIT Kanpur had also set up a stall at the Expo. Posters were put up displaying technical specifications of *Jugnu*, and animations were run to show the concept behind and the mission phases. Senior officials from ISRO visited the stall as well, and students received their feedbacks. They were happy about this initiative taken by IIT Kanpur and gave their best wishes for the success of this mission.

Read more about Jugnu : IITK Nano-Satellite in the next issue of NERD.

WIRED

This is the feedback column of NERD. Various comments, general or article specific, that we receive at *nerd@iitk.ac.in* will be published here with occasional replies from the **NERD**. Feel free to express your views. Here are the comments that NERD received for its second issue:

"This issue shows an exponential improvement over the previous one. The wonder of it started with the cover page itself, which was visually riveting and worked very well with the cover story. The range of articles in this one was fabulous -literally, something for everyone, even completely non-technical people like me. And better yet, the technical articles themselves had a wonderful range of writing that made them a delight to read. I would like to see one kind of basic content addition to NERD- something on the history/philosophy/sociology of science and technology." **Professor Suchitra Mathur, Department of Humanities and Social Sciences, IIT Kanpur.**

"I enjoyed reading this volume having a mix of articles of different flavors covering various subject areas. The magazine should motivate more students to opt for research oriented careers. Congratulations for starting a novel activity and hope it is sustained which is definitely not easy." **Professor A.K. Mallik, Department of Mechanical Engineering, IIT Kanpur.**

"Congratulations! This is shaping into a useful resource for IITK community. The curve is going exponentially up. Nice work. Keep it up." **Professor Tarun Gupta, Department of Civil Engineering, IIT Kanpur.**

"I was so excited to go through the latest issue of NERD. I was blown away by the incredible organization and content I found in the issue." **Professor S. Dhamodaran, Department of Physics, IIT Kanpur.**

"I read the interviews with Dr. Mallik and with Dr. Raychaudhari. I found both articles to be very carefully done. I hope that we will continue to see NERD for many many years to come." **Professor R. Potluri, Department of Electrical Engineering, IIT Kanpur.**

"I went through the issue, the quality and presentations have improved, and the magazine looks great now. I feel the online version of this can be in html format, with possibilities for feedbacks, discussion and many such add on features - something similar to the online version of the science/nature journal." **Professor S. Ganesh, Department of Biological Sciences and Bioengineering, IIT Kanpur.**

"The team has done a wonderful job- highlighting research achievements across the institute in a compact albeit attractive manner. Congratulations!" **Professor R. N. Mukherjee, Department of Chemistry, IIT Kanpur.**

"Articles should be written in humorous language so that they are more appealing to the readers. Include more pictures to make the magazine attractive. Don't limit it just to IITK campus but it should reach broader masses. You can look up to magazines like Technology Review (MIT Publication) as a role model." **Professor Amitabh Mukherjee, Department of Computer Science and Engineering, IIT Kanpur.**

"The issues are coming out very good. It may be a good idea to publish one column about the recent science news. You may also like to publish a column about research positions available here." **Professor A. Ghatak, Department of Chemical Engineering, IIT Kanpur.**

"NERD has provided the platform to be in touch with the campus and know what else is happening here and recognize the good work of the professors as well as the students. More variety can be added. Cover page was very nice. NERD is maturing. It has reached one level higher." **Professor Gouthama, Department of Materials and Metallurgical Engineering, IIT Kanpur.**

"NERD is something that was long overdue. It is good on technical content. All issues of NERD should be focused towards a theme. 50% of an issue should be theme wise and rest general items." **Professor Avinash K. Agarwal, Department of Mechanical Engineering, IIT Kanpur.**

"It's a very good effort, but it should be made still more attractive. Cover page design can be made more attractive something like Scientific American. Colored photos should be used in NERD." **Professor Joydeep Dutta, Department of Mathematics & Statistics, IIT Kanpur.**

"I think NERD is a very good attempt. Such activities should be nurtured by faculty members so that interest for research can be created in students." **Professor D.P. Mishra, Department of Aerospace Engineering, IIT Kanpur.**

"I have gone through NERD and think it's a great and wonderful initiative. Best Wishes!" **Professor B.V. Phani, Department of Industrial and Management Engineering, IIT Kanpur.**

"Initiatives like NERD make me believe again that we are distinct. Great work! Let this NERD instill spirit of research in IITK junta." **Shubham Gupta (BT/EE/ IITK/2008), Festival Coordinator, Techkriti'08, IIT Kanpur.**

"I'm HIGHLY impressed and truly wish something like this had happened during my time. You guys are simply amazing."**Vinod Khare (BT/CE/IITK/ 2007).**

and the list continues...so will NERD!!

We see the THREAT...

We know the SCIENCE...

And we know the
TIME for ACTION is NOW...
...then WHY WAIT to ACT?

Be the change you wish to see in the world.

- Mahatma Gandhi

OUTREACH

The gestation period of NERD - the science and technology magazine of IITK is over. IIT Kanpur community has responded very enthusiastically to this student initiative. NERD invites articles from students of educational and research institutes all over India. It does not matter if you are a research scholar or a first year undergraduate, just express your original work for all of us and get published in NERD

For more details, please visit www.nerdmag.org

CREATE,
COMMUNICATE,
CONTRIBUTE!!

Contact :

nerd@iitk.ac.in

Nest, SAC 210