Shaastra 2013 & The Fifth Estate
present

IIT MADRAS STUDENT
RESEARCH MAGAZINE

In association with GE imagination at work

Edition 1

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iitmadras presents
SHAASTRA 2013
The Spirit of Engineering
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The Fifth Estate

Message from Dean Academic Research

IIT Madras was established more than half a century back by the founders and visionaries like Pandit Jawaharlal Nehru along with other sister IITs. Over the turn of last millennium tremendous and visible metamorphosis has taken place for IIT Madras. It is no longer an Institute recognized only for Under Graduate teaching and learning. Today IIT Madras Campus hosts more than 2500 research students. Research contributions and innovations are also a part of all other Under Graduate and Post Graduate Programmes. Research at IIT Madras is also catered through sponsored programme funded by organizations of national importance and large as well as medium sized industries.

Research is of utmost priority to the institute as was evident with IIT-Madras being recently recognised as the educational institute with the maximum patents. IIT Madras has started the first University based research park in India. In order to recognise, applaud and celebrate the efforts of various research groups in the institute an IIT-Madras Research Expo has been taking place at Shaastra for more than two years. Now moving a step ahead in that direction, the Shaastra team in association with The Fifth Estate has come up with the first ever IIT-Madras Student Research Magazine. I hope this becomes an annual affair with the best of the research at IIT-Madras being showcased to the entire world. I wish both teams all the success in this venture.

Let us share the excitement of research and try to give back what the nation expects from us.

Thank you.

Prof. Sarit Kumar Das

Dean Academic Research, IIT Madras

Message from Research Affairs Secretary

It is believed that as you do research, you gain a philosophical perspective of looking at things. I am not sure if I have yet achieved that perspective, but I have realised the following. Though initially one's 'project' could be just a project, it becomes one's passion, love and life as one delves deeper into one's work. A scholar's world is replete with aspects of his or her beautiful research work. This Magazine is an attempt to take you into their world.

This is the first time an annual magazine showcasing research at IITM is being brought out. Hope you will enjoy it.

Thank you.

Ishita K

Research Affairs Secretary, 2012 - 13

Acknowledgement

The Shaastra team and The Fifth Estate would like to thank Dr Mahesh Panchagnula, the Co-Curricular Affairs Advisor and the Shaastra Steering Committee for giving us the opportunity to bring out the IIT Madras Student Research Magazine, the first ever in the history of this institute. Special thanks to Ishita Kumar, the Research Affairs Secretary and Sohan Jawale, the Co-Curricular Affairs Secretary for guiding us through the initiative, and to Rakesh Varma for helping us reach out to research groups across IITM. We also thank GE, the Research Partner at Shaastra 2013, for their support in releasing the Magazine.

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Contents

The above stories have been chosen from work done by a pool of Research Scholars who came forward to have their projects profiled. While the stories showcase a sample of the research being carried out at IIT Madras, they are not fully representative of the research activities at specific departments or IIT Madras as a whole.

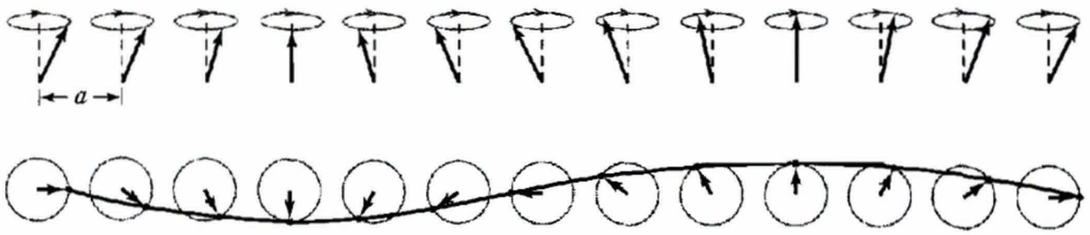


Diagram showing processing moments and spin wave formation [ref : Kittel]

DYNAMAG: A Project on Computational Magnetics

Compiled by Poorna Kumar

From the ancient lodestone to Maxwell's equations, from the first electrical machines to magnetic hard disks, man's knowledge about the fascinating properties of magnetic materials and fields has made great strides over the centuries. Today's emerging fields of research are spintronics and magnonics, which deal with magnetism at the electronic level.

The Electrical Engineering Department of IIT Madras is taking part in a collaborative project on computational magnetics called DYNAMAG. The project is a joint effort by Indian and European universities including IIT Madras, IIT Delhi, IISc Bangalore, SN Bose National Centre for Basic Sciences, University of Exeter and University of Southampton, among others.

Two emerging fields deal with the spins of electrons in magnetic materials - spintronics, and magnonics.

Spintronics is the exploitation of the spin of the electron and its associated magnetic moment for various applications including the encoding of binary information with electron spins. Electrons have two spins ('up' and 'down'), which is well suited to encoding binary data. Recent developments like the Magnetic RAM indicate that conventional data storage could potentially be replaced by spintronic technology which has the advantage of higher speeds.

Magnonics: the theory

Magnonics is the second emerging field, and it deals with 'spin waves' which are, in layman's terms, magnetic waves that propagate in magnetic material. Guru Venkat, a PhD student who is a part of DYNAMAG at the department of EE, IITM, explains, "When one applies an external magnetic field to a magnetic dipole, it begins to precess, i.e., it wobbles about its axis. When the same principle is applied to an ordered array of magnetic moments (which may be found in a ferromagnetic material, for instance), all of them precess, and the moment vector traces a wave, known as a spin wave.

This is the classical picture, and deeper theory lies in quantum mechanics. The frequency of precession determines the frequency of the spin wave."

Spin waves were discovered more than 40 years ago, and differ from conventional EM waves in some important respects. The word 'magnonics' is derived from 'magnon', which is the quantum analog of a spin wave, just as a photon is the quantum analog of the light wave. Spin waves propagating in magnetic waveguides could be potentially used to store and transfer data. Magnonics has made it possible for researchers to contemplate a transistor-less logic circuit in the future, where magnonics and spin-wave phenomena are used to implement logic circuitry.

The frequencies of spin waves can be in the Gigahertz range, while their wavelengths are in the nanometer range. Thus, they travel at a speed significantly lower than that of light. "The gigahertz frequency range of spin waves, coupled with their low wavelength in nanometres, which will keep device size small, is one of the advantages of magnonics. This is in contrast to photonics, where devices are in the millimetre range. The other advantage of magnonics is that it offers a further degree of control. By changing the magnetic field, the characteristics of the spin wave can be changed," adds Guru Venkat.

If the precession is damped, the radius of motion of the magnetic moment of the dipole decreases with time until the moment is aligned with the magnetic field. For sustained spin waves, materials which show low damping are chosen, and currently, one field of active research in magnonics is the identification of materials which exhibit desirable damping characteristics in the nanometer wavelength range.

The second active component of research in magnonics is that of engineering and probing magnonic waves, and examining phenomena like interference, diffraction, modulation and dispersion in these waves.

Project DYNAMAG

Project DYNAMAG aims to develop a theoretical and numerical framework for the analysis of magnonic phenomena. Says Guru Venkat, "We are coming up with tools to analyse spin waves computationally. Precession is governed by a differential equation, and the solution of the equation can be obtained by numerical computer methods. There is a trade-off between complexity and computational power, the resources available, and the size of geometry and duration of the simulation."

He continues, "My part of the project was to simulate dispersion in spin waves. Just as different frequencies of light travel with different velocities in a medium, so do different components of spin waves travel differently in different media. I had to simulate dispersion, and obtained dispersion diagrams for different geometries." Once the dispersion characteristics are known, one can then choose frequency components that travel properly in the desired medium.

Next, Guru Venkat plans to test the results of the simulation with measurements to see how well the predictions correlate to observations. He says, "If there is a significant correlation, it would help researchers. In the future they could run simulations before taking measurements, and the simulations would tell them what to expect in the measurements. This would be useful because measurement is always very difficult, and time consuming."

Guru Venkat is a PhD scholar at the Department of Electrical Engineering, IIT Madras. He is a resident of Sindhu hostel.

"The current work here involves the study of reinforced natural and synthetic fibre gels for clinical applications and to characterise these materials using techniques from rheology..."

Polymer Engineering for Medical Breakthroughs

Compiled by Ranjani Srinivasan

Illness is an indispensable part of life. Humans have forever attempted to relieve one another of the onerousness that accompanies sickness. And predictably enough, history has witnessed huge leaps in the field of medicine which today branches out to innumerable sub-fields. Although technological advancements have occurred, the fundamental purpose of medical research remains unaltered - developing drugs that actively fight against the symptoms or cause of illness.

Administration of a drug, drug delivery, can have various routes – oral intake, or by inhalation among others. But most of these routes pose the challenge of drug-degradation in the path before reaching the desired target. To counter this, many drugs are directly injected into the body at the exact location. These drugs, injectables, form a major component of the changing face of medicine. It is notable that as in the case of many other fields, polymers play a major role in this area too. Polymeric materials are preferred because of the immense control one has over the physical and chemical properties by varying molecular synthesis processes.

Ongoing research at the Polymer Engineering Group at the Department of Chemical Engineering, IIT Madras focusses on the study and development of reinforced natural and synthetic materials (fibre gels) for such use.

The technique of using injectables has been around for quite some time now, with a major success story being that of viscosupplementation, a proposed medication for arthritis. Pain caused due to osteoarthritis can be countered using anti-inflammatory drugs. But these provide only a temporary solution and some patients have adverse reactions to such medication. Direct injection of a preparation hyaluronic acid (the substance whose low concentrations in the knee-joints causes the condition) lubricates the joints and relieves the patient of pain. Though long-term effectiveness of the above procedure is still an active area of research, it seems like the best choice to patients whose bodies do not react positively to non-medical measures or analgesics.

Similar medication/cures have been proposed for many other ailments and the list is only growing longer by the day. Many researchers have tried mimicking the natural fluids present within the human body by synthesizing composites. These composites consist of a homogenous "matrix" component which is reinforced by a fibrous component, generally thicker and stronger. There is a necessity to introduce synthetic polymer-based gels because these provide significant advantages over natural polymers. Firstly, natural polymers are difficult to store or process. And second, mechanical properties of natural polymers cannot be considered even to be of close competition to those of synthetic gels. This is because mechanical properties of the latter can be altered based on requirement and convenience due to reinforcement. Says Jagadeesh Kodavaty, a PhD student and member of the Polymer Engineering Group, "[Hence] the goal is to synthesize a polymer to assist in the drug-delivery system which is both stable and has desirable mechanical properties."

"The current work here involves the study of reinforced natural and synthetic fibre gels for clinical applications and to characterise these materials using techniques from rheology," he adds. Rheology is a branch of physics that deals with the flow and change of shape of matter, especially liquids. It is adopted when the material under study (fibre gels in this case) exhibits elastic, viscous and plastic behaviour.

" More specifically, I am working on mimicking the vitreous fluid (found in the eye) using hyaluronic acid reinforced with collagen type II fibres, with the addition of a synthetic polymer poly-vinyl alcohol and characterizing this complex system using rheology. As there is data available for the natural vitreous fluid obtained from the eye (generally animals) in the literature, I will compare my results with the same," says Jagadeesh.

If successful, it's only a matter of time before Jagadeesh's efforts open up new avenues for the medical field to explore. He continues to explain that as in the case of osteoarthritis, a reliable mimicked specimen and further improvisations to it could lead to a variety of medications for glaucoma, retinal repairs and many other ailments of the human eye.

Jagadeeshwar Kodavaty

Jagadeeshwar Kodavaty is a PhD student of the Department of Chemical Engineering and is guided by Dr Abhijit Deshpande. He is a resident of Sindhu hostel and enjoys swimming and cooking.

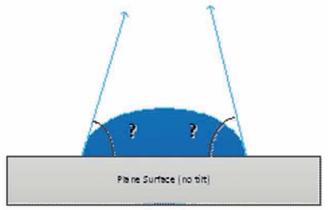


Figure 1: Illustration of a drop on a plane surface (no tilt)

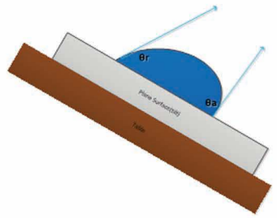


Figure 2: Illustration of a drop on a surface with tilt.
Note the advancing and receding angles.

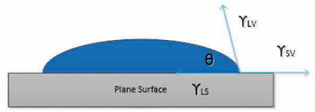


Figure 3: Illustration of the surface tension forces at the interface

All for a Drop!

Compiled by Ananth Yalamarthy

Fluid mechanics is a vast area of science which relies heavily on experimentation to prove its conjectures. The study of droplets is one such subset of fluid mechanics which has attracted thousands of researchers all over the world in recent times. It is an arduous task and people have spent decades trying to build a concrete framework around their shape-shifting capabilities, with lots of questions still unanswered. Being able to control the size of these droplets as they are produced is a prime area of research, for reducing the size of droplets offers a principal advantage: an increased surface to volume ratio, which implies a higher surface energy. This is later exploited in interesting ways that do not seem obvious at first sight. Nachiketa Janardan, a PhD student of the Department of Applied Mechanics at IIT-M investigates droplets from an interesting viewpoint: he looks at the behavior of drops on inclined planes.

Imagine a plane surface parallel to the ground on which a hemispherical drop of fluid is immobile. Now, picture turning the plane surface in small increments and simultaneously imagine the state of the drop on that surface. Intuition suggests that the drop will remain glued to the surface until it reaches a particular critical angle of inclination, after which it starts travelling down the surface. Now try thinking of the geometry of the drop as this transition happens: the drop starts off as a symmetric object with equal contact angles (see figure 1), and when the surface is tilted, this equality is lost. The angle between the advancing side of the interface and the plane surface (the side of the interface which faces down the inline) is referred to as the advancing angle θ_a, while the angle between the recessing side of the interface and the plane surface (the side of the interface which faces up the incline) is called the receding angle, θ_r (see figure 2).

Each of these angles must reach a critical value in order for the drop to move as a whole. The critical angle at an interface is a function of 3 variables: the material of the drop, the material of the solid surface on which the droplet rests and the vapor that surrounds the drop. "When only one of the angles reaches its critical value as the plane on which it rests is tilted, the corresponding portion of the drop begins to move, leading to either a contraction or expansion of the bubble. When the surface is further titled, a situation occurs wherein θ_a and θ_r reach their critical values, and that is when the drop starts to move a whole," Nachiketa says.

When the drop is not moving as whole, one can formulate a relation (1) between the angle of inclination of the plane surface (α), θ_a-θ_r, the perimeter of the drop (L_i) and the surface tension at the liquid-vapor interface (γ_{LV}). The parameter θ_a-θ_r is called the contact hysteresis angle. In parallel with the famous "hysteresis loop" that one encounters in electrical engineering, the hysteresis angle swings between a maximum and a minimum as the angle of inclination is varied. This relation is one of the central ideas behind Nachiketa's research: the interface angles can be changed by varying the size of the drop (perimeter) and the surface tension properties at the liquid-vapor interface.

$$mg \sin\alpha = k\gamma_{LV} L_i (\cos\theta_r - \cos\theta_a) \quad (1)$$

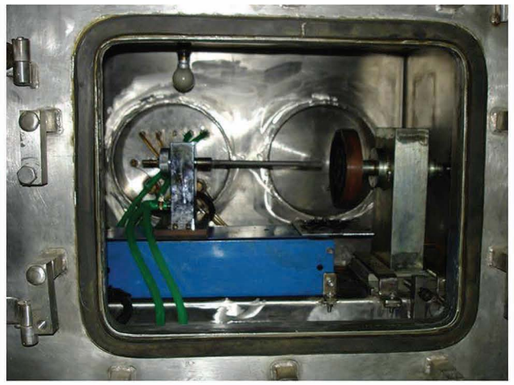
Before we go into the specifics of "characterization", we must make an attempt to understand surface tension. Surface tension is the manifestation of the unbalanced forces that are experienced by a molecule at the interface. A molecule of water at an air-water the interface experiences two forces: "cohesive forces", arising out of interaction between the molecule of water at the surface and those below and "adhesive forces", arising out of interaction between the molecule of water and molecules of air above it. When one does a force balance at the interface where solid, liquid and vapor meet, one discovers three tangential forces: a surface tension force between liquid and the vapor which we denote by γ_{LV}, a surface tension between the solid and the liquid,γ_{LS}, and γ_{SV}, similarly defined (see figure 3) .These can be combined along the interface angle to produce an equation (2):

$$\cos\theta = \frac{\gamma_{SV} - \gamma_{LS}}{\gamma_{LV}} \quad (2)$$

When the drop is in a static state, these surface tension forces balance each other. When the drop moves, this balance is lost. The important thing to note from this lesson is the following: by adding a few nanoparticles to the liquid, the surface tension at the liquid-solid interface and the surface tension at the liquid-vapor interface can be changed. "Very importantly, this means that we can change the inclination angle at which the drop slides down the plane in predictable ways by changing the interfacial surface tension properties; in this case by the addition of a few nano-particles," remarks Nachiketa.

What might be the potential applications of this work? "My research is more curiosity driven than application driven," says Nachiketa with a grin on his face. He does, however, divulge a few ideas where his work could be put to use. You've all seen streaks of paint flowing down a wall after it has been painted. By using ideas from Nachiketa's thesis, one can alter the surface tension of the paint in such a way that smaller drops are produced, and this in effect implies that the paint is less likely to coagulate and agglomerate into long streaks. Another potential application could be in oil-spills. One typically combats an oil spill by spraying a coagulant on the oil; this does the job of bringing the oil droplets together by enhancing their size. Who would have thought that studying so subtle and small a phenomenon could turn out to be so far-reaching!

Nachiketa Janardan is a PhD student of the Department of Applied Mechanics and is guided by Dr Mahesh Panchagnula. A resident of Mahanadi hostel, he loves trekking, rock climbing and is an avid Metalhead



ARC DISCHARGE

Carbon Nanotubes: Re-forging the Damascus Blade

Compiled by Ananth Yalamarthy

Deep down in the clandestine hearths of the Muslim Crusaders of almost a thousand years ago, bladesmiths excelled at fashioning 'Damascus blades'. With distinctive vortex-like patterns etched on their surface, they were completely resistant to shattering even under protracted periods of use, much to the agony of the Christian Crusaders. The mystery of the swords would have been lost unto the world if not for a group of German researchers who unlocked the enigma back in 2006. The swords' surfaces, when analyzed by a transmission electron microscope, were found to contain cylindrical arrangements of carbon atoms first discovered in 1991 and now made in laboratories all over the world: Carbon Nanotubes.

Known for their preternatural thermal conductivity, resilience as a mechanical material and electrical conductivity, carbon nanotubes is a thriving area of research today, the prime emphasis being to reduce the cost of the material and transform it into a commercially viable technology.

IIT Madras is no stranger to this development. Joseph Berkmans, a final year PhD student at the Carbon Nanotube (CNT) lab at the Department of Metallurgical and Materials Engineering, has been making inroads into developing such a technology. The focus of his research is developing a rotating arc method for the simultaneous manufacture and alignment of carbon nanotubes.

CNTs are typically forged by an arc-discharge method. A current of 100 Amperes flows between a pair of graphite electrodes (immersed in an inert atmosphere) spaced by a distance of 1 millimetre. When the temperature of the anode exceeds about 4000 degrees Celsius, the graphite evaporates as carbon ions which get attracted to the cathode and settle on it as soot. This deposit, when analyzed under a scanning electron microscope (SEM), reveals a haphazard arrangement of carbon-nanotubes, along with spherical balls called fullerenes. Seems like a simple enough process, doesn't it?

The real challenge however lies in making long nanotubes (~1.8 cm vertically aligned and 18.5 cm horizontally aligned is the record) and aligning them by having their axes parallel to one another, something that doesn't happen using the standard arc discharge method. "A single walled carbon nanotube possesses a current density that is 3 orders higher than that of copper, due to the greater mean free path of electrons in the former," says Joseph. Long nanotubes are currently produced using chemical vapor deposition(CVD), but this is an expensive and time-consuming process. The orderly arrangement is what results in the magical properties of these tubes, just as the way in which an electric potential leads to an orderly arrangement of electrons in a wire.

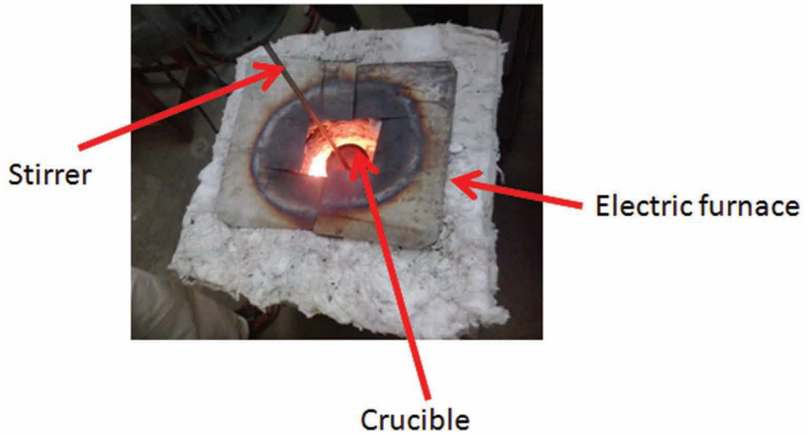
The next question that naturally comes to mind is: how does one align nanotubes? Joseph is quick to answer, "Scraping is the crudest way of aligning CNTs. Ingenious methods however exist: one adds a infinitesimal amount of magnetic nickel and iron to the CNT concoction and uses a magnetic field to align the tubes, after which hydrochloric acid is added to wash away the nickel and iron as chloride salts".

Joseph however, has come up with a clever scheme wherein he both produces and aligns in one go: by using a rotating cathode instead of a stationary cathode. In this method, the cathode is an oversized cylindrical plate with a scraper held against its surface by means of an external support. When the anode is brought near it, a spark is generated as before and soot is collected on the rotating cathode. This time however, the soot rains down as flakes on a petri-dish because of the scraper, whose action also aligns the soot. Unlike the previous method, a large yield of aligned CNTs are produced in almost no time, with the added advantage that one does not require an inert atmosphere."One can produce as much as 10-grams in 10 minutes using impure graphite rods," remarks Joseph unlike the chemical vapour deposition (CVD) route or the standard arc route.

"The requirement for a cost-effective in-situ alignment method holds center-stage in the electronics industry," says Joseph. In the quest to pack ever-smaller electronic devices more densely with integrated circuits, researchers keep running up against some bitter truths: higher current density leads to phenomena which produce excessive heat and cause premature damage of ICs. Carbon nanotubes are not constrained by this (they don't follow Joule's law of heating in the first place!) and if Moore's law is to keep its truth, you now know how that's going to happen.

The uses of carbon nanotubes are slowly opening up to the modern world. "One may soon see touch screens which are see-through and flexible using carbon nanotubes," says Joseph. The material seems to have become the black gold of the aerospace industry: the new Boeing 787 Dreamliner uses it to enhance its wing strength. Even better, new aeroplanes are coated with a thin film of CNTs so that the plane acts as a conductor to discharge current during a lightning strike. The sports industry has realized its potential too; the latest badminton and tennis racquets now have strands of CNTs in their frame. The applications of CNTs are on a roll as researchers set out to discover newer secrets about them and ways to use them. So much for carbon and its allotropes, for they seem to pervade almost every aspect of our lives (Don't forget the greenhouse effect!) and will continue to do so in the future.

Joseph Berkmans is a PhD student of the Department of Metallurgical and Materials Engineering, and is guided by Dr Pratap Haridoss. He is a resident of Krishna hostel.



Experimental setup of stir casting for fabrication of Carbon Nanotubes reinforced Metal Matrix Composites

Strengthening the Future

Compiled by Rajaram Suresh

Over the years, material science has opened doors to vistas of innovation. Designs like bullet-proof vests, heat resistant and water repelling suits and rust-deferring metals stand testimony to this fact. The conventional methods of improving material properties have been tried and tested for many years now. With the current generation riding high on the technological wave, the emphasis on novel avenues of research can't be emphasised stronger. Carbon Nanotubes (CNTs) burst into the scene in the late twentieth century, creating a buzz in research circles. Of its numerous applications, its relevance to Strength of Materials is something that can hardly be overlooked. This aspect of CNTs was identified by M. Jagannatham, a PhD scholar of the Department of Metallurgical and Materials Engineering, whose project is to design Carbon Nanotube reinforced composites.

Materials are best described by and used for the characteristic properties they exhibit. It has been observed that CNTs play a key role in amplifying select properties of metals and polymers. Jagan's work deals with the reinforcement of purified CNTs in metal and polymer matrices, aiming to improve mechanical and electrical properties of the same.

Metal Matrix Composites

Metal Matrix Composites (MMCs), typically a mixture of powdered CNTs in a metal matrix, are manufactured either by Powder Metallurgy or Liquid Metallurgy. In Powder Metallurgy, the mixture of CNTs and the metal is blended by ball milling (grinding into an extremely fine powder) following which they are compacted with the help of a pressing machine to consolidate the powder and achieve uniform density. The resulting article is then subjected to elevated temperatures (sintered) to produce the final composite with enhanced metal bonding.

Powder Metallurgy is generally preferred over Liquid Metallurgy (also called Casting) wherein a molten metal is poured into a mould containing CNTs with subsequent solidification needed to produce the final composite.

CNTs suppress the electrical conductivity of metals and enhance their strength, making them ideal electronic packaging materials.

Jagan is quick to point out that every endeavour has its own share of hurdles and that his project is no different. Special care has to be taken to match the density of CNTs with that of the liquid metal, failing which the CNTs come out of the matrix. This can be achieved by depositing the CNTs with a coating of metals like Nickel or Copper. While compacting, the pressing machine should be handled properly lest gaps arise in the compacted mixture. Different metals require different levels of precaution. For instance, in case of Aluminium, the formation of Aluminium Carbide renders the composite brittle and hence should be kept in check. Improper density and insufficient wettability of the CNT powder can lead to non-uniform composition of the liquid mould.

Thus the required uniformity and strength of the composite warrants a careful examination of the manufacturing process.

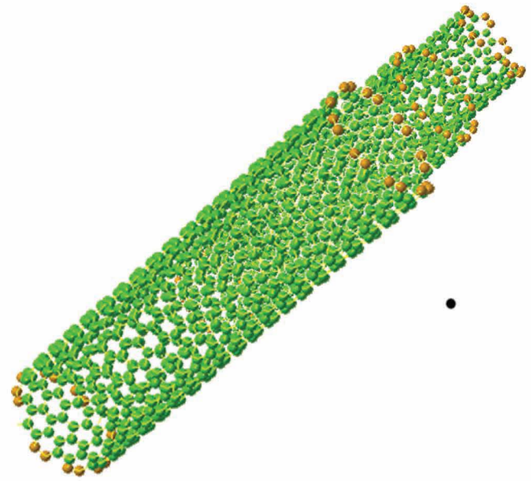
Polymer Matrix Composites

Jagan also designs Polymer Matrix Composites which are produced in sealed vessels called autoclaves, where the pressure vessel supplies both heat and pressure to the workload placed inside it. "The fact that CNT reinforced polymer composites can boast of enhanced electrical conductivity and mechanical properties is a boon to the aircraft and automobile industries," he remarks.

CNTs seem to offer a convincing solution to strengthen metals and polymers. Their presence has penetrated almost every branch of life today from packaging to automobiles, sports equipment to aircraft; the potential of CNTs to improve their durability follows suit.

"CNTs suppress the electrical conductivity of metals and enhance their strength, making them ideal electronic packaging materials."

M Jagannatham is pursuing his PhD at the Department of Metallurgical and Materials Engineering. He is a resident of Mahanadhi hostel.



A Nano-solution for Cancer Cure

Compiled by Rajaram Suresh

From Lance Armstrong to Yuvraj Singh, the medical fraternity boasts of stories of cancer survivors – heroes who provide inspiration to those diagnosed with the disease to fight all odds. The road to recovery, as we may be aware, is not a rosy one. Chemotherapy, currently the most popular way for combating cancer brings with it a number of side-effects that have a lasting impact on the body. There are complications that survivors may have to deal with, post cancer cure. Carbon Nanotubes (CNTs) are today emerging as a viable alternative to existing methods of cancer cure.

CNTs – A welcome entrant

Conventional chemotherapy is based on the principle of arresting the uncontrolled and unrestricted growth of the malignant cells. Apart from being the cause of the disease, malignant cells are identical to normal body cells in most aspects.

Hence, the efficiency of a chemotherapeutic drug not only depends on its power to 'kill', but also on the ability to differentiate between the malignant cells and the surrounding normal cells. The delocalised attack by the drug often kills other fast growing normal tissues leading to side effects such as hair loss. This is where the CNTs prove to be important because they enhance targeted drug delivery thereby localizing the effect of the drug. CNTs have proved to be advantageous in more ways than one. Thanks to their small size and a large surface area, CNTs have an increased penetration power and carrying capacity. They transport the drug to the malignant site and release the drugs, thereby facilitating action without causing obvious damage to the surrounding cells. In the early stages of cancer, the action of a drug requires targeting molecule which detects the receptor in the malignant cell - this is again carried by the CNT. This targeted action minimizes damage to non-malignant cells and enhances the efficiency of the drug. The optical properties of CNT also render it traceable and facilitate in locating the drug inside the system.

Just like any other cure, CNTs have their own disadvantages. Chemists have made observations about the resemblance of CNTs with Asbestos thereby raising concerns about its toxicity. The toxicity of CNTs depends on multiple factors which require to be taken care of, appropriately. This is the challenge that Hindumathi, a PhD scholar of the Department of Biotechnology at IIT Madras, has taken up in her research project focussing on the 'Application of CNTs in Biomedical Treatments'.

The Project

Hindumathi's work tackles the challenge of minimizing toxicity and maximizing efficiency of the Carbon nanotubes. "CNTs, if improperly selected, can turn toxic and defeat the very purpose for which they were initially synthesised," she remarks. Recognizing the utmost need to address this issue, Hindumathi aims to achieve minimal toxicity by comparing their action on malignant glioma cells (brain cancer cells). CNTs are rolled graphene sheets forming a cylindrical contour with a hexagonal network of carbon atoms. They are generally synthesised using Chemical Vapour Decomposition or Arc-Discharge methods. The toxicity of CNT is determined by factors such as size, purity, structure and the catalyst used for preparing the CNT. The project aims to arrive at a desirable combination of the above factors to minimize toxicity. Quiz Hindumathi on the challenges faced while experimenting and she is quick to remark that not much importance has been given towards the toxicity of the CNTs. Not all the factors responsible for toxicity were analysed before the clinical trials in previous studies. Thus, reliable data on these factors is virtually non-existent, and Hindumathi is looking to provide breakthroughs on that front.

The Road Ahead

Though costly for small scale synthesis, large scale synthesis of highly pure CNTs is comparatively cheaper than other nanoparticles, which fall second in terms of cost effectiveness. CNTs have the potential to usher a wave of innovation and impact in cancer cure and through her work, Hindumathi hopes to make a small contribution towards bringing that change.

"Thanks to their small size and a large surface area, CNTs have an increased penetration power and carrying capacity. They transport the drug to the malignant site and release the drugs, thereby facilitating action without causing obvious damage to the surrounding cells."

Hindumathi R is pursuing her PhD at the Department of Biotechnology as part of the interdisciplinary Biomedical Devices and Technology Programme – a 3 institute initiative involving IITM, Christian Medical College (CMC) Vellore and Sree Chitra Tirunal Institute of Medical Science (SCTIMST), Trivandrum. She is guided by Dr Pratap Haridoss (IITM) and Dr Chandra Sharma (SCTIMST). Reading novels and dabbling in poetry are her pastimes, but it's her one and a half year old daughter she enjoys spending time with the most.

"The major application of the research is that these compounds can be used to make supercapacitors which are expected to replace batteries in the future... With their huge power density, supercapacitors could also revolutionize electric vehicles, where huge lithium-ion batteries struggle to strike a balance between mileage, acceleration, and longevity."

A Wonder Material waiting to Happen

Compiled by Reshmi Suresh

Graphene is an allotropic form of carbon with atoms arranged in a regular hexagonal pattern similar to graphite, but in a one-atom thick sheet. Several potential applications for graphene are under development, including lightweight, thin, flexible, yet durable display screens, electric circuits, and solar cells, as well as various medical, chemical, and industrial processes enhanced or enabled by the use of new graphene materials. The most ground-breaking of them all is the production of graphene supercapacitors or electrochemical capacitors.

Researchers claim to have found a way to increase the energy density and turn supercapacitors into a viable alternative for batteries by using electrodes built from graphene, which has shown superior mechanical and electrical properties in the past and apparently revealed excellent electrochemical attributes under high mechanical stress.

Current research suggests that the graphene supercapacitors hold just about as much charge as a normal battery, but they come with a feature that could transform the way gadgets and other battery-driven products such as electric cars and smart phones are used. These supercapacitors can be charged and discharged a hundred to a thousand times faster than regular batteries.

Metal Oxide Graphene Composites and Electrochemical Studies is a project led by Umesh Ediga, a PhD scholar in the Department of Chemistry, IIT Madras to tap into the huge potential of the graphene composites. If successful, this project will provide improved methods to modify the electrochemical properties of these compounds, and hence offer insights into their largely unexplored applications.

The Project

The primary objective is to study the capacitance of transition metal oxide graphene composites and improve their conductance and capacitance values, using cyclic voltometry, chrono-potentiometry, impedence spectroscopy and other methods. Umesh intends to calculate the specific capacitance and the 'poison' of the catalyst using electro-catalysis studies.

The inspiration for the project was his guide, Mr. G Rangarao, says Umesh, who suggests the type of metal oxides to be prepared and the methods suitable for each type. Once the data is obtained, Umesh synthesizes the composites and uses X-ray diffraction to determine the particle size of the material. Brunauer-Emmett-Teller (BET) Surface Area Analysis and Thermo Gravimetric Analysis (TGA) and other tests are done on the compounds to get an idea of their chemical and physical properties and their variation with time and temperature, and also their stability. The electrochemical studies are done by Mr. Rajesh Khanna, his partner in the project, who also handles the making of working electrodes and simple calculations.

With an estimated budget of Rs. 5 lakhs, the equipment and other resources required for the project is provided by the labs in IIT Madras and also by MNRI. Having a total duration of three and a half years, Umesh undertook this as his PhD project a year and a half ago. So far, Nb_2O_5 graphene composite has been prepared and tests are being conducted on the same. Plans for the future include preparation of $NiCo_2O_4$, Co_3O_4 and V_2O_5 graphene composites and data collection and analysis of all the compounds. "What I want to achieve at the successful completion of this project is to come up with new methods to improve the material properties of these composites. This will in turn help increase the cycle life of capacitors and batteries," Umesh says. On a national scale, similar research is done in IISc Bangalore and various other institutes in the country.

The Impact

The major application of the research is that these compounds can be used to make supercapacitors which are expected to replace batteries in the future. These graphene supercapacitors could transform the technology landscape. While computing power roughly doubles every 18 months, battery technology is almost at a standstill. Supercapacitors, which suffer virtually zero degradation over 10,000 cycles or more, have been cited as a possible replacement for low-energy devices, such as smartphones. With their huge power density, supercapacitors could also revolutionize electric vehicles, where huge lithium-ion batteries struggle to strike a balance between mileage, acceleration, and longevity. It is an interesting fact that lithium-ion batteries have their capacity increased ten-fold just by the addition of graphene. Could graphene be that 'wonder material' the world has been waiting for? Umesh and his team are at the cusp of finding out.

Umesh Ediga is a PhD student at the Department of Chemistry and is guided by Prof G. Rangarao. A day scholar, he enjoys playing cricket and chess.

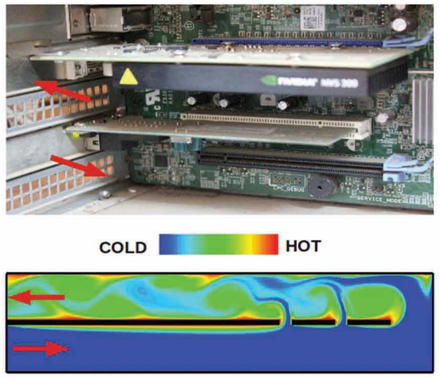


Image showing flow around an electronic circuit board inside a CPU (*top figure*) modeled as a two-dimensional finite element model (*bottom figure*). Using CFD it was found that provision of small slots of specific size can cool the board since the fluid particles oscillates at certain flow velocity and creates strong heat-carrying vortices

Computational 'Fuel Cell' Dynamics

Compiled by Aravindabharathi R

The story of Fluid Mechanics dates back to ancient Greece, to the time of King Hiero II who asked the mathematician, physicist, and engineer Archimedes of Syracuse to determine the purity of a golden crown he'd had made. As the famous story goes, the absent-minded genius took to the streets, naked, screaming "eureka! eureka!" once he realised that he could use the volume of water displaced to measure the crown's density, and hence purity. He later published a book titled, "On Floating Bodies", the first known work on hydrostatics, the part of fluid mechanics which deals with fluids at rest.

Later, with the development of calculus, giants like Euler, d'Alembert, Lagrange and Laplace - names familiar to anyone who has taken an advanced calculus course - unraveled the curtains of mystery to reveal that fluid flow was governed by partial differential equations. With the derivation of the Navier-Stokes equations, fluid mechanics reached a stage familiar to modern physicists today. It is revered as holy equation in classical mechanics that could answer many questions in the world of fluids.

However, none have been able to arrive at a closed form theoretical solution due to its inherent non-linear character.

With the coming of the age of computers, fluid dynamics simulations could become more realistic - the immense number crunching abilities of modern computers gave scientists the ability to model increasingly complex phenomena. As you read this line, thousands of processors around the world are inverting matrices and computing determinants, all with the aim of understanding the flows of fluids in various situations. It is a field which promises a lot: more aerodynamic cars, more efficient engines, and better methods of refrigeration are just a few that one can recall. Because of the complexity of the calculations involved, CFD researchers are among the largest users of the High Performance Computing Centre (HPCE) facility at IIT Madras. One of the main driving forces behind the evolution of Computational Fluid Dynamics is the speed at which simulations can be made - it is cost-effective to teach a computer physics and have it simulate air flow instead of building a large test chamber to figure out how air flows through the engine of an aeroplane.

Also, it ensures repeatability and can be performed at any location. It is interesting to note that the mathematical methods developed by these researchers can be applied in a number of fields which at first sight bear no relation to CFD whatsoever.

"Fuel cell" is one of the most bandied-about terms in the field of sustainable energy today. The promises of energy from water and of hydrogen-powered vehicles all rest upon the development of better, more efficient fuel cells. Structurally, fuel cells consist of arrays of square compartments in which the electricity-generating reactions occur. Each compartment has a size of about 1 cm by 1 cm, and as the fuel flows through them at speeds of around 10 cm/s, it may not stay long enough in the reaction chamber to be completely utilised. One way to get around this problem is to drill in small grooves in the reaction chambers, forcing the fuel to take a longer path, ensuring that it stays inside long enough to be completely consumed. But what is the best possible curve?

For a long time, people thought that it was the serpentine. The word serpentine, meaning 'snake-like' was first used to describe a curve by Sir Isaac Newton. This shape, which resembles the letter S, was thought to provide the longest possible path between the opposite vertices of a square. However, scientists and engineers are not as sure of this as they once were, and are beginning to investigate other geometries which may be more efficient. At IIT Madras, S. Ravishankar's work involves trying to find these geometries using computer simulations. "We propose new computational techniques to solve fuel cell problems," he says.

The key to simulating fuel flow in a computer lies in making the computer understand the various geometries involved. "There are commercial simulation packages available, but many researchers prefer to write their own code so that they have complete knowledge and control over the simulation," explains Ravishankar.

However, once we surmount the initial hurdles of coding the partial differential equations involved and making the computer understand the physical laws that come into play, the same code can be reused to study a wide range of problems from oil extraction in deep wells to formation of galaxies in space. Biotechnologists, for example, use CFD engineers to study the diffusion of newly synthesized drugs in blocked arteries. So, once a model has been developed, it can be easily applied to various flows of matter and energy, with different geometries corresponding to each application.

Previously, Ravishankar had used similar programs to model heat transfer inside CPUs. The codes were tested well with a broad range of design parameters to obtain deeper physical insights of how the temperature on the electronic chips could be reduced. The model was enriched further with complex three-dimensional equations governing the deposition of hydrogen fuel and oxygen in a fuel cell catalyst. Currently, he is working on the principles of protonic and electronic charge creation and consumption in a fuel cell module. The models will be tested in a novel 'flow field geometry' which is aimed at improving the functioning in terms of even distribution of heat and fuel over long periods of operation without compromising on the electricity generated.

Ravishankar ends with a word of caution - although computational fluid dynamics simulations have revolutionised the design processes of modern machinery, a researcher is always skeptical about the validity of the simulated results. It always requires confirmation with experiments to a sufficient and satisfactory extent. Digital approximations are, however, extremely useful in design and optimisation, and that is something the march of technology will certainly require.

S Ravishankar is pursuing his MS at the Department of Applied Mechanics.
He is a resident of Sindhu hostel.

"[Secret Sharing] is a concept widely used to store confidential information among network servers. In the event of multiple server crashes, the information could still be retrieved with a minimum number of working servers."

Sharing Secrets Rationally

Compiled by Anand Rao

The demand for network engineers today is ubiquitous – not only do they design and build networks connecting millions of nodes across the globe but also solve problems to improve existing ones. The parameters available to them to construct a network, say the number of nodes, capacity and so forth are almost always insufficient. Thus the underlying algorithm, called a distributed algorithm, used to make the various elements of the network come together and achieve an acceptable level of performance while solving a given problem, gains paramount importance. "That's what I hope to be developing during the course of my PhD," says William K. Moses Jr., a research scholar at the Department of Computer Science and Engineering. "A simple instance of a distributed algorithm is how file sharing is done on DC++ [IITM's internal LAN]."

But what really motivated him to undertake a PhD in the field was the research topic for his MS degree earned from the same department at IITM, on Rational Secret Sharing.

"The challenge of actually designing an algorithm on my own and pushing existing limits led me to appreciate what research meant and more specifically what research in distributed algorithms was about," he says. "While my MS gave me a taste of what it means to work in the broad area of distributed algorithms, I wish to use the time during my PhD to really probe the field deeper."

Rational Secret Sharing

Secret Sharing is a cryptographic concept which William explains with an example. "Suppose I am a manager in the bank looking after five subordinates. Only I have access to the main safe. On the days when I am not available, my subordinates need access to it. I devise a method by which I give each a unique key, and only if three or more of them come together, will they be able to crack the code. This way, I ensure that nobody independently has access to the safe but it can still be opened." This can be achieved by constructing a second degree polynomial, and giving each subordinate a data point – requiring at least three of them to reconstruct the original function.

This is a concept widely used to store confidential information among network servers. In the event of multiple server crashes, the information could still be retrieved with a minimum number of working servers.

However, secret sharing makes one critical assumption – the existence of 'honest' and 'malicious' players. 'Honest' players follow a certain protocol without deviation, and 'malicious' ones are those who look to crack the secret following everything but the protocol. However, this does not always model the players (or the users of a network) correctly. In fact, players are usually 'rational', where they work on the principle of 'doing what is best for me'. Modelling the middle ground is the challenge, and this is where William has used Game Theory to redefine the behaviour of the players involved and effectively simulate a setting of rational secret sharing (RSS).

But what sets William's work apart is the fact that he has applied RSS to an 'asynchronous' broadcast channel, which is what is usually in play in the real world. The network has no control over the time of sending and arrival of messages, making it difficult to provide a secure and reliable link for nodes to communicate. Previous work focused on solving the problem of RSS over simultaneous and 'synchronous' networks, and the those who have attempted to go down these lines have each come up with their own set of limitations. William hopes his work leads to further breakthroughs in the field.

Future Work

Currently William is pursuing his PhD and focusing his efforts on distributed algorithms. As the state of networks and how they are being used continues to evolve, challenges continue to present themselves. William hopes to be there on the bleeding edge of research and take the study of the area to new levels

William "Billy" Moses Jr. completed his MS at the Department of Computer Science and Engineering, guided by Prof C. Pandu Rangan. He is currently pursuing his PhD under Prof John Augustine. A resident of Cauvery hostel, he is an avid reader and enjoys playing chess and table tennis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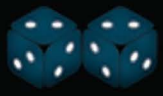


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