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SCRI

ESSENT

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Technical Magazine of Society For Collaborative Research And Innovation

Indian Institute of Technology Mandi

INDIAN INSTITUTE OF TECHNOLOGY MANDI

The name 'Essent' has been taken from the word 'essential' which means absolutely necessary. The name is to signify the essentiality and fundamental importance of research and innovation.

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EDITORIAL

*Amidst new waves of development, Indian Institute of Technology (IIT) Mandi is aiming new heights with its vision, **"To be a leader in science and technology education, knowledge creation and innovation, in an India marching towards a just, inclusive and sustainable society". IIT Mandi** is continuously nurturing new avenues for promotion of research and innovation. It has given a launching pad to **Society for Collaborative Research and Innovation (SCRI)** which aims at providing a collaborative platform for extensive, effective and sustainable research and innovations. SCRI fully realizes the importance of collaborations in research and facilitates the same. **ESSENT** is a part of this quest. It aims to provide a platform for students, researchers, academicians and others to share and exchange knowledge and ideas on research and innovation. **ESSENT** also aims at highlighting the potential areas where research and innovation in technology and social sciences can successfully intervene.*

*We are highly pleased to bring out the second issue of '**ESSENT**' with articles, papers and interviews contributed by students as well as by faculties, academicians and alumni. In the second issue of **ESSENT**, we have tried to include articles from diverse fields so as to make it relevant to a wider section of readers rather than a smaller specialized one.*

Students are frequently appearing in exams like GATE, CAT, UPSC etc., therefore, in this issue, we present exclusive interviews with notable IIT Mandi alumni, who had remarkable performances in these exams. We have also included an exclusive interview with Mr. Aditya Chauhan, Ph.D. scholar at University of Cambridge. We are sure these interviews will act as a key in opening up and igniting a lot of minds.

As we intend to continue this endeavor of opening up to the world via this technical magazine in its subsequent issues, we invite you to be a part of it as a contributor, reader or a well wisher.

We would like to thank all our present contributors and advisors for their support. We are also highly thankful to IIT Mandi administration, especially honorable Director Prof. T. A. Gonsalves for supporting and guiding us.

We look forward for your kind comments and suggestions for improving our future issues.

Prashant Kumar
Editor

Looking Back to the Future

Prof. Timothy A. Gonsalves,
Director,
Indian Institute of Technology Mandi

Prof. Gonsalves did his B. Tech. in Electrical Engineering at IIT-Madras, M.S. at Rice University, Houston and Ph.D. at Stanford University, California. He Joined the Department of Computer Science & Engineering, I.I.T., Madras as an Assistant Professor in 1989 and rose to Professor and Head of the Department.

Prof. Gonsalves is the Cofounder of the TeNeT Group of IIT-Madras and founding Director of NMSWorks Software Ltd, n-Logue Communications Ltd and the IIT-Madras Rural Technology Business Incubator (RTBI).

In January 2010, Prof. Gonsalves was appointed as the first full-time Director of the Indian Institute of Technology, Mandi.

His Research interests include design and performance of computer and telecom networks with emphasis on innovative and low-cost product and technology development for Indian and international industry and fostering software development in small towns and rural areas.

The Nature of Social Change

Societies change from past to present to future. Change in societies is inextricably linked with science and technology. Technology solves problems of society and in its wake brings about changes in society. The change may be slight: a more efficient light bulb reduces the monthly electricity bill which leaves more money for the family to spend on, say, eating out occasionally. Or, the change may be profound: the effect of affordable near universal mobile telephony, the impact of the web on nearly every aspect of our lives.

Conversely, change drives the development of new technologies. During the last Ice Age which lasted from about 1,20,000 BC – 20,000 BC when food was scarce people lived in tiny bands of nomadic hunter-gatherers. As the earth warmed between 20,000 BC to 10,000 BC, people started to settle in villages. In China pottery was developed in 16,000 BC, while in highland Peru buildings with walls were constructed in 11,000 BC.

Change drives science also. Scientists in their quest for knowledge develop new theories or refine old theories to explain change. Even when nature does not change, science changes. Over the past few millennia, astronomy moved from a geocentric flat Earth view, to a recognition of the spherical shape of the Earth, to the realisation that our Earth is a mere speck of cosmic dust on the periphery of the vast universe with over 100 billion galaxies.

Change: Past to Present to Future

Given the centrality of change, it is but natural that we should attempt to understand it, to predict its future course, and to measure the rate of change. Visionaries are often tempted to predict the future of science and technology. Some of these predictions have come true. In 1945 the famous science-fiction writer Arthur C. Clarke foresaw a global communication network using a few geostationary satellites. This became a reality in 1964 with the launch of the satellite Syn-Com3. It is increasingly common for predictions to turn out to be wildly inaccurate. In 1943, T.J. Watson, President of IBM, famously said "I think there is a world market for maybe five computers". Today, billions of people use more than 5 computers each in their mobile phone, laptop, games and appliances.

It appears that the rate of change in our lives is increasing. From the invention of telephony in 1876 to near universal coverage in the US took 60 years. Mobile telephony went from scratch to near universal coverage in India in a mere 20 years. In some other areas, however, change is much slower. For example, the basic design of personal transportation has evolved very little in 108 years since the Ford Model-T was introduced as the world's first mass-produced car. A car still consists of 4 wheels, a chassis, an engine and a body. The driver controls it with a steering wheel, a gear lever and 3 pedals.

Since predicting the future is fraught with risk, can we more reliably quantify the rate of change? If we can measure the rate of change, we would at least be able to predict the magnitude of changes in the future, if not the actual change itself. This is precisely what Ian Morris, who is a Professor of Classics, History and Archaeology at Stanford University, did recently. In his compelling 750-page tour de force *Why the West Rules – For Now*, Morris quantitatively examines social development from the dawn of human existence when ape-men moved out of Africa into Europe and Asia about 1.5 million years ago, up to 2000 AD. He then extrapolates to 2100 AD. In the rest of this article, I shall be largely summarising arguments from Morris' book.

Morris measures social development using four orthogonal traits of a society:

1. Energy capture Only by extracting energy from plants and animals, from wind and water currents, from fossil fuel can a society advance beyond the hunter-gatherer lifestyle. With energy capture, society can solve problems beyond the capacity of human muscle power, and thus its people can have the leisure for intellectually advanced pursuits.

2. Urbanism The size of the largest city in a society is a measure of its ability to organise large, complex teams. A bigger city also gives each individual easy access to a wider range of goods and artifacts, services and intellectual ideas. This results in greater opportunities and generates more ideas.

3. Information processing Writing, language and communications enable knowledge and ideas to bridge vast gaps in time and space. Rulers, sitting in their capital, can issue laws that apply to vast kingdoms and they can get information from remote corners of their empires.

4. Capacity to wage war Development requires resources including food, minerals, land and energy. Sadly, societies that have advanced have almost invariably done so through wars against other societies. The greater the capacity to wage war, the more the victor develops.

Morris has developed a system for quantifying each of these four traits. Drawing on data from history, archaeology, anthropology, economics etc., he estimates values for these traits from prehistoric times to the present.

By Morris's estimation, societies in about 14,000 BC had an index of development of about 7. By 2000 AD, this index had risen to about 910. Extrapolating to the future, the index is likely to increase to about 5,000 by 2100 AD. We see that the change in development over the next fifty years is three times more than the change over the past 16,000 years. Over the next hundred years, change is five times greater. In the lifetimes of today's youth, the world will experience change several times greater than that over the past 16,000 years.

Put into perspective, in 14,000 BC people lived in small tribes and the pinnacle of their achievement was crude paintings of animals and people on the walls of caves. By 2,000 AD, we had advanced to the Age of the Internet with the World-Wide Web, digital photography, supersonic air travel, the miracles of modern medicine, etc. Would any cave-dwelling prophet 16 centuries ago have foreseen any of these miracles? Definitely not! Yet, we are faced with imagining five times greater change within a mere one century.

Speculations

What will life be like with such dramatic change? While any prediction will almost certainly be way off the mark, it is illustrative to speculate on a few possibilities.

1. Today we have always-connected devices that can take a photo and instantly share it on social media with 100s of millions of others. In the future, it is likely that the brains of all 10 billion humans are directly "wired" together. This could be done through devices that detect and generate brainwaves. The implication is that the moment any person has a thought, it is almost instantly known to everyone on Earth. Today, intimate physical union between husband and

wife is the norm of society. Tomorrow we may have to become used to intimate mental union of all of humanity. Social relationships as we know them may be relics of the past.[1]

2. Ego and self-esteem play a big role in our lives. Wars are often fought over trivial insults to the ego. As a species, we are firmly convinced of our mental superiority over all other beings, living and non-living. We worry a lot about the possible existence of extra-terrestrial life that is more intelligent, more advance than us. So far, we as a species have not yet had our intellectual superiority challenged.

This is set to change decisively in the near future. Due to the inexorable, exponential growth in computing power following Moore's Law and advances in software design such as artificial intelligence, machine learning and big data analytics, machines are rapidly catching up with humans. Sometime in the next 15-30 years (depending on whether you believe the optimists or pessimists), machine intelligence will surpass human intelligence.

Many professions are already being taken over by software and Internet servers. Human travel agents, photographers, shop assistants and others are no longer essential. As a consequence of the galloping growth of machine intelligence, more intellectual jobs of today will soon become non-essential. These will include artists, investment advisors, lawyers, physicians, surgeons and even professors at IIT Mandi.[2]

Vast number of humans will be faced with the quandary of how to live their lives with no gainful employment. Even if a benevolent state provides a guaranteed income, will we get satisfaction from a life of leisure? This is the antithesis of the work ethos of most cultures.

The human race will have to come to terms with a breed of machines that are intellectually superior to us. Will they be our slaves, will we be their slaves, or will we cooperate for mutual benefit?

3. The capacity for waging war will increase in manifold ways. Weapons of enormous destructive power will be affordable by and available to small groups of people. Besides more powerful bombs, guns and missiles, we can expect to see the development of novel weapons. With the wired brains about which we speculated earlier, an adversary could instantly control the behaviour of an entire nation by infecting their brains. More conventionally, the adversary could bring a networked society to its knees by a cyber-attack on its key servers.

With such weapons, nations and non-state groups would have the capability to destroy human civilisation as we know it. If we do not figure out how to control such destructive power in the next few decades, the challenges posed by highly intelligent machines and unimaginable change will become irrelevant.

Conclusions

Our experiences over the past few decades clearly indicate that the rate of change of society is increasing. The very convincing study by Ian Morris confirms this and quantifies the likely change in social development over the next hundred years. The clear message is that today's young students will spend their careers in a world of unimaginable change.

Until the present social change has been very slow. Many people seek comfort and stability in their lives, for them it will be frightening and disturbing to face rapid social change. In the past the response of societies to rapid change has often been regression. Individuals and groups seek stability and to maintain their status by rejecting change and clinging to the system they know.[3]

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1. This development and others that we discuss subsequently are technical singularities. Due to compounding of growth year by year, after the occurrence of a singularity, growth is so rapid that society is changed dramatically and irreversibly. https://en.wikipedia.org/wiki/Technological_singularity
2. Jaron Lanier, a computer scientist, explores in his book Who Owns the Future? (Simon & Schuster, 2013) the increasing tendency of jobs to be done by software downloaded from a few global webservers. He looks at the impact on jobs, the economy and human happiness.
3. The Luddites were 19th century textile workers in England who feared that mechanisation of mills would affect their jobs. They attacked mills in order to halt the advance of technology and had to be stopped by a massive deployment of military force. https://en.wikipedia.org/wiki/Luddite

Those who can anticipate and adapt will find the future to be very exciting, extremely challenging, and full of boundless opportunities for engineers and scientists. I hope this includes all IIT Mandi students. However, it will be essential for scientists and engineers to consider the impact of their technological improvements if human society is to progress rather than disintegrate.

Acknowledgement

Most of the ideas and facts in this article are taken from Ian Morris *Why the West Rules – For Now* (Profile Books, 2010). This book is a "must read" for anyone interested in the future.[4] If you are wondering why I turned to a historian to understand the future, philosopher George Santayana wrote: "Those who cannot remember the past are condemned to repeat it"! I am indebted to Priscilla Gonsalves, Devika Sethi, B. Subramanian and Varun Dutt for their insightful comments that helped me refine my understanding and arguments, and for materially improving the presentation of the article and to Debleena Mukherjee for providing some of the facts and figures.

4. Morris has updated his book recently: *The Measure of Civilization, How Social Development Decides the Fate of Nations* (Princeton University Press, 2014).

INTERVIEW with Athar Aamir Khan, UPSC Rank-2, 2015

Mr. Athar Aamir Khan is an IIT Mandi graduate of batch of 2010-14 in Electrical Engineering. He has secured second rank in the prestigious civil services examination, 2015. Mr. Aamir is a resident of Anantnag, Jammu & Kashmir. He has appeared in the list of 'Top 30 under 30' in 2015 edition of Hindustan Times. He was cofounder of 'SCRI (Society for collaborative Research and Innovation)' at IIT Mandi.

By Prashant Kumar

What has been the biggest influence and inspiration for you to join civil services?

The service itself has been the biggest inspiration for me. The kind of work and opportunity this service provides and the impact of your work has on a large number of people is absolutely incredible.

At my home, my grandfather has been a big inspiration. He is an illiterate farmer but this passion and love for education are amazing. His hard work and simplicity influenced me a lot since childhood.

How do you see an engineer working as an IAS?

Civil services are very dynamic and diverse field. It has people from different backgrounds e.g. from engineering, medical, humanities and arts etc. Everyone brings his/her own competence in the system. So as an engineer we also enrich the civil services with our own professionalism, problem solving techniques and analytical abilities.

In these days, technologies are the key aspects in development. We have been talking about e-governance and digitalization etc. so as an engineer, your awareness about technologies will always be helpful.

How important do you think IIT Mandi has been in your success?

IIT Mandi has been the cradle for me, where I could evolve my worldview. This was the place where my dreams got nurtured. I have had guidance of some of the most outstanding teachers there. I would like to mention few of them with honorable director T. A. Gonsalves, Prof. Ramesh Oruganti, Prof. B. Subramanian, Prof. Banerjee and many other faculties. As a new IIT, it gave us the platform to take initiatives, it gave the opportunity to make tradition, not to follow the set tradition. Thanks to IIT Mandi to help me to grow as an individual as well as professional.

What is your best memory at IIT Mandi?

My best memory at IIT Mandi is day one. The first day, when we were in transit campus at IIT Mandi, there was hardly anything, yet the way our director and faculties gave us the confidence was phenomenal. I remember the words of our director sir ***"we are here to make you learn that how to learn***".

What was the motivation behind starting SCRI club at IIT Mandi?

As a new IIT our networking and resource tools were small so the thought behind SCRI was to provide a platform for collaboration among undergraduate students, research scholars and faculties for interdisciplinary research. Generally B.Tech. students don't have much opportunities to do research works, therefore, by being involved in a society like SCRI, they will get an exposure to work with research scholars on different research projects.

When did you start your preparation for civil services? How did you prepare?

I started the preparation when I was in the last semester at IIT Mandi. First of all, I understood the pattern of examination very well. I tried to gain the importance of requirement for the examination. Then, I had created framework for my strategy that how I would go about.

In my strategy, the main strategy was time management. In the last semester, we hardly have time so I used to do very proper time management. I had studied 4-5 hours in a day during the B.Tech. and after completing that I had started to study 9-10 hours regularly. I have made proper study plan and timetable and tried to follow that.

Another key thing was 'constant appraisal'. I used to review my preparation periodically and tried to find out where I stand and what are the areas I need to improve and focus more.

Have you taken any coaching? If yes - How much it helped in preparation?

Yes, I did take some coaching but mostly I relied on test series and mock interviews, which helped me in preparation. There are people who succeed in UPSC without joining coaching, yet I feel that appearing in some mock tests and mock interviews help in preparation.

Which optional subject you had chosen in UPSC MAINS and why?

My optional subject was philosophy. The reason being during IIT Mandi we had also a course ***'Political Philosophy by Prof. B. Subramanian'***. I got some introduction in that course. I had discussed a lot about philosophy with Prof. Subramanian and many others. So I had bit of interest in philosophy. Finally it came to choosing optional for UPSC.

Since I was interested in philosophy so if I don't read it, I might not get opportunity to read it further, therefore I thought that philosophy as an optional will give me the opportunity to read the subject further and know about the western and Indian philosophers.

How was your experience of Interview in UPSC? How did you prepare for the interview?

It was a great experience. When I went to the boardroom, the chairman and panelists were very cordial. They made me comfortable and after that they started asking question from very diverse areas. The questions were from international relations, Indian economy, economy of J&K and my optional subjects. Some questions were about my hobbies, educational background, IITs and IIT Mandi.

Now regarding preparation, while you are preparing for prelims and mains, somewhere you are also preparing for interview. There are two aspects in interviews generally asked, one is current affairs and other thing is your bio data, hobbies, educational background, home state, district, village, work

experience etc. I studied thoroughly and also prepare my bio data for interview.

Please share some preparation strategies for future aspirants of civil services?

Ans: *'There is no shortcut to success, Hard work is must'*. I would suggest to be focused and consistent, have a strategy, have a plan and most important is have balance in your life. Please keep your socialisation alive and at the same time take good care of your health.

An Overview on Eagle 2.0, Formula Car of IIT Mandi

Raptor Racing Team, IIT Mandi

Raptor Racing, the student formula racing team of IIT Mandi, comprises of 20 undergraduate students ranging from second year to final year. We develop high performance formula style race cars, carrying out the designing, manufacturing and testing of the vehicle entirely within IIT Mandi. Based on the Royal Enfield Bullet 500cc engine, Eagle 2.0 was the second race car that rolled out of the stables of Raptor Racing.

The team is organized into Suspension, Steering, Powertrain, Design, Ergonomics & Controls and Business & Marketing subgroups. The vehicle is designed with the objective of competing in Supra SAE India, an annual student formula event organized by SAE India. The event is a comprehensive test of engineering acumen and managerial skills and involves various presentations (design presentation, cost presentation, business plan presentation) as well as tests such as a thorough technical inspection by international experts, brake test, acceleration test, skid-pad test and a final race.

The target is to compete in Supra SAE India 2016 in July this year at the Buddh International Circuit, Noida and establish IIT Mandi's presence among leading automobile engineering institutes.

'Eagle 2.0' is an autocross racer with a tube-frame chassis, naturally aspirated motorcycle derived single cylinder engine and a push rod type suspension. The whole vehicle design process has been centered on the main objective of designing, fabricating, testing and demonstrating a formula style vehicle for the amateur weekend racers market. The criteria kept in mind throughout the design process included very high performance in terms of handling, acceleration and braking, all at an affordable cost and minimal maintenance between events. Apart from reliability and maintainability, safety and aesthetics of the car were given special consideration as we would attempt to 'sell' the design to a 'corporation' that is considering the production of a competition vehicle.

The car has been idealized around a race track which requires high turning ability as compared to acceleration along straights. Majority of the conceptual level specifications are driven by an objective of improving performance during cornering, including a track-width to center of gravity height ratio of 6.39mm and a suspension system that would provide constant wheel attitude control (minus compliance) with respect to vehicle roll angle and moments about the front and rear wheel steer axes. Although transient capabilities of the vehicle haven't been simulated, for quick turning considerations the vehicle has been conceptually designed to have high transient capabilities by incorporating a low yaw polar moment of inertia, low wheel base to track width ratio and low roll angle. Measures are taken while designing the suspension to keep the unsprung mass as low as possible and give better aerodynamics to vehicle.

The power train development was focused towards smooth power delivery over ultimate power as smooth, predictable control of tractive effort was required to balance the slip angle drag of the front wheels during mid cornering and to blend lateral acceleration into linear acceleration during corner exit. Safety related parameters were ensured during the design process by considering various critical cases and simulating those corresponding critical conditions over the designed components and making necessary design changes to accommodate fixes to those issues.

Suspension

Suspension system has been designed keeping in view the three most important car performance parameters viz. camber changes, weight transfer tendency and aerodynamic advantages while rolling, braking and accelerating. A good suspension system eases the car handling and improves driver comfort. For making the vehicle more competitive on the race track, double wishbone push-rod suspension is preferred over other traditional beam axle suspension. The camber change flexibility helps the vehicle to withstand against the traction loss problem and improves cornering performance significantly. An optimized value of ride height and roll center height of 79mm and 5mm respectively have been selected considering the parameters of lateral roll center movement and roll moment. Ride height of rear chassis is kept higher than the front and hence, this increases the aerodynamic down force in the rear. Also, less weight transfer takes place if the roll height is near the ground, hence reducing traction losses. The upper and lower suspension link dimensions along with swing arm length are kept longer which help the vehicle to maintain a good camber curve and less wheel displacement while cornering. Scrub radius has been adjusted to 11mm provides easy handling and kingpin inclination is set to 6o. For smooth ride, generally low ride frequencies had been preferred, which further reduces the roll and roll rate of a vehicle. For racing cars, an optimized value has been selected which is around 70-90 cycles per minute. Hence, decreases the roll rate and weight transfer between the axles for better grip while turning. The ride frequencies can be changed by altering the coil spring stiffness.

Chassis

Our chassis design requirements were high torsional stiffness, compliance with Supra SAE India 2016 rules, ease of manufacturing, protection of the driver and systems packaging. The chassis has been carefully integrated with the suspension system to ensure optimum load paths. AISI 4130 Chromoly steel is used which is appropriate for the frame due to its machinability and ease of fabrication, yield strength of 435 MPa and an ultimate tensile strength of 670 MPa which are very suitable for the kind of forces a formula car has to bear[1]. It is resistant to scaling and oxidation and has a lean, smooth finish. The final chassis has been arrived at by optimizing the weight to torsional strength of the space frame. Keeping the chassis as light as possible, without compromising the driver's safety was a key concern as a lightweight chassis is always an advantage while cornering. The chassis has undergone some major modifications this year from our previous "Eagle 1.0"; firstly we have enlarged the size of the rear portion of the car, adding up more space which helps in the easy access to the engine and neighboring components. The cockpit size has also been increased for comfort of the driver and to decrease the egress time.

Brakes

Eagle 2.0 is designed to use four disc brakes, one at each wheel. Disc brakes are chosen considering their large opened areas and better heat dissipation than other braking systems so temperature of discs do not exceed critical values, hence ensuring minimizing brake pad wear; efficiency of disc brakes is also high. Dual master cylinder is used, giving advantage in case of failure of one of the systems. Biasing has been done in the brake system using proportioning valve in which one can adjust the split point, helping us to get a better braking performance. Maruti 800 sourced brakes with a pedal ratio of 4:1 and bore diameter of 21mm have been used considering their good combination of pedal ratio and bore diameter of master cylinder and easy availability. Pedal travel and pedal ratio are proportional, so these brake pedals have been considered for giving a better feedback to the driver. Pedal ratio is such that for lockup reasonable pedal force (up to 200N) is needed which can easily applied by the average human. Steel brake lines with flexible hoses near the wheels are used to accommodate the movement of the brake calipers due to suspension and steering action. Keeping our speed and car mass in mind, cast iron brake discs (good heat capacity, lighter than steel) and a matching DOT5.1 brake oil with high boiling point (2600C) is used. The brake oil is moisture tolerant as well and thus requires low maintenance and less frequent changes (a key design consideration for all subsystems of the car).

Electronics

The specific electronics design requirements were durability and low mass, much of the complexity goes away with the ECU. A 12V

sealed low-maintenance lead acid battery is selected to provide adequate starting capacity. Simple & easy to maintain analog electronic controls using relays and switches have been implemented to control various electronic systems around the car. These include control of the starter motor, powering spark plugs and lighting systems.

Steering

The steering system incorporates a parallel steer geometry with a low 4:1 steer ratio so that the driver does not have to cross his arms or feed the wheel hand over hand. It was noted that smaller slip angle is required at lighter loads to reach the peak of the cornering force curve and the Ackerman steering geometry forces the inside front tire to a higher slip angle. Moreover dragging the inside tire along at high speed an angle (above the peak lateral force) raises the tire temperature and slows the car down due to slip angle (induced) drag. A parallel or reverse Ackerman geometry was therefore deemed favorable for high speed turns. Also, a controlled amount of toe out at the front of the can improve the vehicle's turn in response when entering a corner however; toe out at the rear of the vehicle should be avoided as it produces unpredictable and potentially dangerous handling characteristics. On the other hand, toe in at either the front or rear promotes better linear stability. Based on this information it was desired to use a manageable amount of static toe out at the front wheels while at the rear either use 0° toe or a slight toe in to promote stability and predictable handling performance. To arrive at some actual numbers it is believed that the best method would be to do some physical testing on the vehicle to work out what setup is the fastest and what feels best to the driver. Keeping all these factors in mind and the fact that reverse Ackerman can prove to be too extreme at low speeds, we have implemented parallel steer geometry with moderate toe adjustments to have the best optimized steering system focused on improving handling on corners. A quick release steering wheel has also been implemented as an added safety feature and also for enhanced compactness of the chassis and cockpit. The steering column utilizes two universal joints and a telescopic spline to accommodate pitch and heave. The rack is placed such that the lower steering column universal joint is close to the roll axis to minimize bump steer.

Engine and Drivetrain

'Eagle 2.0' uses a ROYAL ENFIELD 500cc, carburetor based single cylinder engine which was chosen after considering its ease of maintenance and low cost in the segment. The other engine options included Honda 600cc F4i engine, KTM 450 cc engine, Yamaha 600 cc engine and Royal Enfield 500cc EFI engine. The Honda, Yamaha and KTM engines offered better performance though with the Honda 600cc F4i engine being the frontrunners. But considering feasibility of the vehicle for being used by any commoner in India, the Honda, Yamaha and KTM engines are not such a good options as they are not very common in India. These engines have to be mostly imported, are costly, and are not easily serviceable thus not matching to our goals of a low cost, easy to maintain car. They could not be serviced by any mechanic given their complexities, which need special training and tools, thus reducing their scope in the Indian market. The remaining options were air cooled Royal Enfield 500cc EFI engine and Royal Enfield 500cc Carburetor based engine. These engines offered the advantage that they could be easily serviced as most Indian auto mechanics have dealt with a Royal Enfield Motorcycle. There was a minor difference between Engine performances of these two engines. The Enfield 500cc EFI engine delivers maximum power of 27.2PS at 5250 rpm and maximum torque of 41.3Nm at 4000 rpm, whereas Enfield 500cc Carburetor based engine delivers maximum power of 26.1PS at 5100rpm and maximum torque of 40.9Nm at 3800 rpm. Though the ECU based engine offered a better performance the other aspects of our requirement, which include low cost and easy maintenance, are most fulfilled by the carburetor-based engine. It is easier to handle and tough at the same time. Our engine being a single cylinder type offers very little advantage on using an ECU as they offer their best advantage when used with multi-cylinder engines where altering combusting order and timings help in achieving improved performance. The ECU based EFI engine also had a little disadvantage as ECU is calibrated for particular settings. When any condition arises where these predefined settings are not met the Fuel Injection stops. Also the gear change in ECU engines has to be optimal, and quick, otherwise the engine can stop running abruptly because of fuel injection interruption. This is because the company designs ECU

for maximum performance. ECU based engines are also expensive to repair. The carburetor based engine thus gained an advantage for our design. This engine can easily be serviced across India, is durable, time tested and is comparatively cheap, that will bring the cost of our vehicle down. Using an air-cooled engine is easy and low in cost but they have low performance compared to an oil cooled engine due to heating issues. Our engine being a motorcycle derived is positioned in the motorcycle in the front where it has maximum airflow over it and proper cooling takes place. Being a rear engined car with our engine positioned behind the driver there is restriction to airflow over the engine. To counter this effect two cold air ducts have been designed which take air from the sides of the car and redirect it over the cylinder head of the engine. Apart from this a high nose design has been opted to create a draft of air between the road and the floor of the car. The floor below the cockpit is concealed while the engine bay is left open which helps in sudden expansion of the air under the floor and raising it above for cooling of the engine. The air intake system is a hybrid of short ram and cold air type. The intake filter and nozzle have been positioned strategically over the rear roll hoop where it have unrestricted access to cold air flow and at minimum distance from the engine inlet thus reducing the amount of restriction in its path. The air restrictor has also been optimized with convergent and divergent sections such that it causes minimum loss in pressure while the air flows along it. The drivetrain is designed to have a short distance between engine sprocket and differential rotation axis, high efficiency and low overall rotational inertia for quick throttle response. The distance between the engine sprocket shaft and differential was reduced to have a shorter driving chain and reduce the polar moment of inertia. The differential mounts directly to the rear bulkhead integrating the jacking bar and uses shims to adjust chain tension. The stock 5 speed constant mesh gearbox of the RE 500cc Classic Engine is used with 3.06:1, 2.01:1, 1.52:1, 1.21:1 and 1:1 gear ratios. Since the gearbox is located on one side of the engine, this also causes the left and right drive shafts to be asymmetrical, requiring special consideration of having sufficient torsional stiffness to prevent undesired torque steer effects. Maruti 800 constant velocity joints are chosen because of their light weight, easy availability and good plunge travel and angular limits.

Ergonomics

The goal of ergonomic team wasn't to just ensure driving comfort but assist all departments to make the entire driving experience comfortable that is considering human factor when designing all the subsystems, be it steering, suspension or any other subsystem. The primary ergonomic design goal was to accommodate the 95th percentile male and the 5th percentile female, provide adequate vision and driver comfort whilst ensuring all controls were robust enough to withstand emergency operation. Driver comfort has been addressed by complying with the FSAE rules relating to thermal protection of the driver and providing adequate lateral support for both trunk and thighs. The entire design of roll cage was done keeping driving comfort in mind; the goal was to provide adequate space so the driver does not feel crunched and providing a proper driving posture at the same time. The design of steering was rigorously tested by making prototype to finalize optimum size and shape. Also the steering ratio was kept low at 4:1 so that the driver does not have to cross his arms or feed the wheel hand over hand. Field of view have also been a key design criteria, design of the car ensures maximum visibility during driving and optimal positioning of an instrument panel consisting of tachometer and speedometer. The gear shift mechanism of the RE 500 Classic engine has been retained to have an easily accessible lever with simple forward and backward movements for completing the shifts. Ample space is provided for driver cell, providing space for battery, fuel tank, ensuring driver's comfort and easy egress. Also, the awe-inspiring wing design is a sure shot at attracting potential buyers because of its cutting- edge and stable design.

Micro Sensor Device for Identification of Ionic Contamination in Natural Water

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This work demonstrates interaction between Graphene oxide (GO) and lithography patterned aluminum (Al) micro-interdigitated electrodes (μ–IDEs) on p–Si for aqueous fluoride ion (F^-) sensor. The strong hydrogen bonding and molecular adsorption of aqueous F^- onto the active hydrophilic sites (hydroxyl, carbonyl, carboxyl, epoxy) present in GO integrated with Al–μ–IDEs is examined based on simple electrical (current-voltage) characterization. The adsorption of F^- onto the GO film results increase in charge carriers and finally results the increase in the output current response. Thus, the miniaturized, cost effective, easy processability and selectivity of proposed GO-integrated Al-μ-IDE based real time sensors have a great potential for detection of aqueous F^- present in natural drinking water.

Water is an essential element of the ecosystem, but contamination of sources of natural water from toxic organic/inorganic pollutants is constantly increasing. The increase in contamination in natural water is acquainted from industrial wastes, nuclear plants, cosmetics, drugs, fertilizers. Owing to an inadequate, expensive and time consuming detection of contaminates in water, leading to a major problem related to drinking water in near future. In order to meet the demands, a swift, facile, low cost, fabrication of chemical sensor is desired.

Fluoride (F^-) being the smallest anion is a major constituent in drinking water, but excessive intake leads to adverse health effects (Figure 1). The permissible range of F^- in natural drinking water as per World Health Organization (WHO) standard is 1.5 ppm [1]. However, more than 100 million people drink water with a fluoride concentration greater than the international drinking water standard [1]. Among the anions, F^- with a high charge density is an attractive target for sensor design owing to its association with poisonous gases, liquids. Additionally, among halides, F^- is most electronegative and possesses very high affinity for aluminum (Al).

Keeping in view the above discussion, an inexpensive, miniaturized, simple, ultra sensitive, low power, F^- sensor system is fabricated. The sensor consists of integration of oxygenated graphene (GO) with Al micro interdigitated elec-

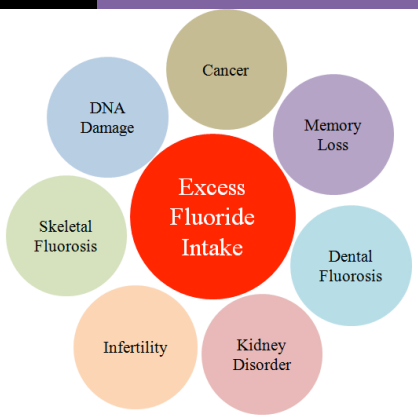

Figure 1 *The possible adverse health Effects related to excessive intake of Fluoride.*

trodes (μ-IDE) over p-Si as a sensing medium [2]. The working principle of GO/Al-μ-IDE/p-Si senor system is based on change in sensing signal-voltage (I-V) response due to strong molecular interaction, hydrogen bonding and ionic conduction between the oxygen containing functional groups onto GO and F^-.

Figure 2 shows the schematic, mechanism of adsorption and photograph of the fabricated Al-μ-IDE over p-Si. The response of the sensor system shows a significant increase in sensing signal with

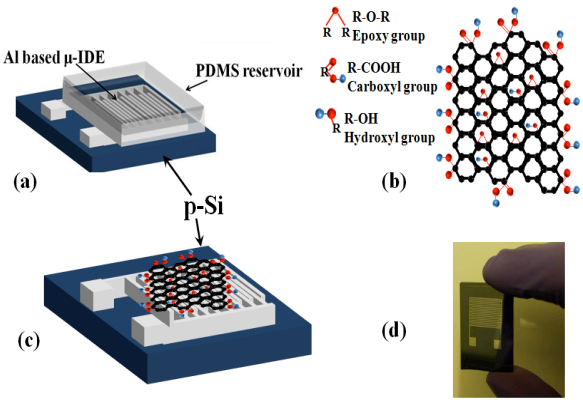

Figure 2: *Shows the (a) Schematic used for measurement of sensing signal-voltage characteristics (b) monolayer GO sheet with the functional groups attached (epoxy, hydroxyl, carboxyl). (c) GO/Al-μ-IDE/p-Si senor system. (d) The top view photograph of the fabricated Al-μ-IDE over p-Si.*

an increase in F- concentration ranging from 0.1-1000 ppm.

Figure 3 shows the I-V characteristics of the fabricated sensor system. The GO/Al /p-Si sensor system shows ~ 82 % increase in the sensing signal for 0.1 ppm GO+F^- solution with respect to GO. The response of the sensor for 1, 10, 100 and 1000 ppm of GO+F^- solution shows almost 220, 415, 500 and 305 times increase in sensing signal with respect to GO. The significant enhancement in sensor response at lower concentration (0.1-100 ppm) of F^- is observed. However, at high concentration, (1000 ppm) of F^- the interlayer swelling and expansion of GO dominates and results in the reduction in sensing response of GO/Al /p-Si sensor.

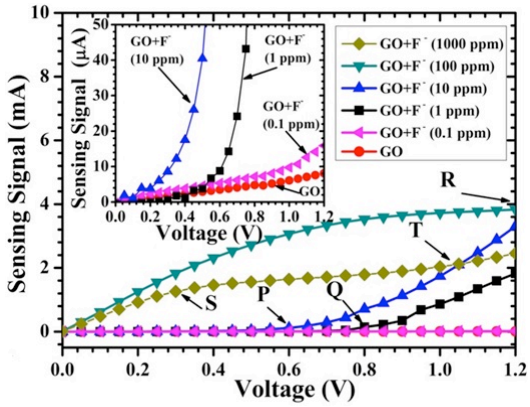

Figure 3: *Sensing signal-Voltage (I-V) characteristics for Al-μ-IDE as a function of GO and GO+F^- in the range of 0.1-1000 ppm up to 1.2 V. Inset shows the zoom in I-V curves for GO and GO+F^-.*

In the conclusion, the aqueous F^- are adsorbed on the hydrophilic functional sites (–OH, C–O–C and CLO) available in GO. Thus, the proposed GO/Al–μ–IDEs/p-Si sensing device shows a significant increase in I-V for the F^- concentration in the range of 0.1-100 ppm. The GO/Al–μ–IDEs/p-Si based sensor, with low cost, low power and easy fabrication, as well as scalable properties, showed great potential for ultrasensitive detection of fluoride ions present in the aqueous solution.

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Field Programmable Gate Array Based Signal Processing: Erudite and Illusive

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Abstract

The article focuses on the use of field programmable gate arrays (FPGA) for signal processing applications. Allowing designers to create circuit architectures developed for the specific applications, yields high levels of performance using FPGA for many digital signal processing (DSP) applications providing considerable improvements over conventional microprocessor and dedicated DSP processor solutions. A key reason is that an FPGA can side step the classic Von Neumann architecture's instruction—fetch, decode, execute, load/store bottleneck—found in most DSP. The paper highlights the flexibility offered by FPGA in realizing signal processing architectures and algorithms. The possibility of realizing low power signal processors on FPGA by functional transformation approach has also been discussed. The bottlenecks faced in the state of the art technologies have also been explained.

Introduction

Signal processing algorithms have been used to transform or manipulate analog or digital signals for a long time. One of the most frequent applications is obviously filtering the signal. Digital signal processing has found many applications, ranging from data communications, speech, audio or biomedical signal processing, to instrumentation and robotics.

Digital signal processing (DSP) has developed over the past decade and has almost replaced analog signal processing (ASP) systems in many applications. DSP systems enjoy several advantages over ASP systems such as insensitivity to change in temperature, aging or component tolerance [1]. Originally analog chips yielded smaller die sizes, but with the advent of VLSI design in the deep submicron regime, digital chips can be realized on a smaller area with denser integration. This yields compact low power and low cost designs.

Signal processing applications are typically computationally intensive and heavily rely on the efficient implementation of such digital signal-processing (DSP) algorithms as filtering, transforms and modulation. In past systems, conventional digital signal processors were used to perform many of these algorithms. Programmable DSP introduced in the late 70's incorpo-

rated a multiply accumulate operation in only one clock cycle which was a dramatic improvement over the Von-Neumann microprocessor based systems [2].

The advent of field programmable gate arrays (FPGA) has revolutionized the field of digital signal processing over the past decade. By allowing designers to create circuit architectures developed for the specific applications, high levels of performance can be achieved for many DSP applications providing considerable improvements over conventional microprocessor and dedicated DSP processor solutions. However, field-programmable gate arrays (FPGA) deliver an order of magnitude higher performance than traditional DSP. A key reason is that an FPGA can side step the classic Von Neumann architecture's instruction—fetch, load/store bottleneck— found in most DSP. Modern FPGA families provide DSP arithmetic supports with fast carry chains, which are used to implement, multiply accumulates at high speed, with low overhead and low costs [3]. Another reason is the FPGA has lower power consumption [4, 5].

Overview of FPGA

FPGA is a member of a class of devices called field programmable logic (FPL). FPLs are defined as programmable devices containing repeated fields of small logic blocks, called configurable logic blocks (CLB). A typical FPGA consists of three major types of elements viz. configurable logic block (CLB), programmable interconnects and I/O blocks. Fig. (1) shows the basic architecture of FPGA that incorporates these three elements.

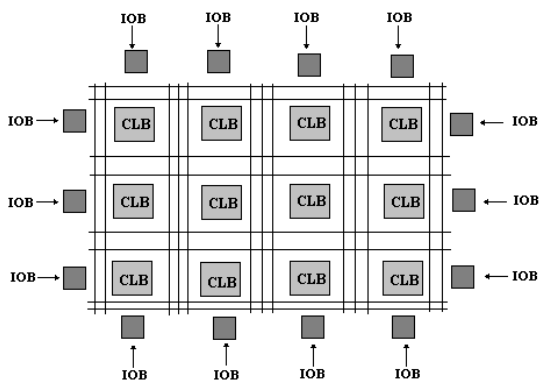

Figure 1: *Basic Architecture of FPGA*

The CLB can usually form the function of typical logic gates but it is still small compared to the typical combinational logic block found in a large design. The programmable interconnects are made between the logic elements. These interconnects may be logically organized into channels or other units. FPGA typically offer several types of interconnect depending on the distance between the combinational logic blocks that are to be connected; clock signals are also provided with their own interconnection networks. I/O pins may be referred to as I/O blocks (IOB).

They are generally programmable to be inputs or outputs and often provide other features such as low power or high-speed connections. Multiple I/O pads may fit into the height of one row or the width of one column. An application circuit must be mapped into an FPGA with adequate resources. A typical FPGA configurable logic block consists of a 4- input lookup table (LUT), and a flip-flop, as shown in Fig. (2) below:

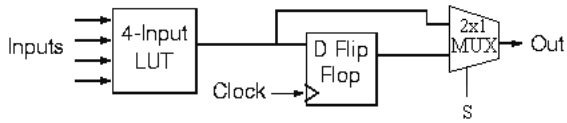

Figure 2: *Structure of a Configurable Logic block with multiplexed registered and unregistered output*

The look up table stores the truth table of the Boolean function to be implemented. Since the LUT is a 4 input LUT, hence, up to 4 variable Boolean functions can be implemented using LUT. By storing the truth tables of Boolean function on the LUT, the CLBs are configured for specific logic functions. There is only one output, which can be either the registered or the unregistered LUT output. The registered and unregistered LUT output is connected to the final output through a 2X1 multiplexer. The logic block has four inputs for the LUT and a clock input. Since clock signals (and often other high-fanout signals) are normally routed via special-purpose dedicated routing networks in commercial FPGAs, they are accounted for separately from other signals.

Flexibility offered by FPGA in signal processing applications

Fitting multiple DSP functions into a single FPGA has many integration challenges, but also

offers significant advantages to the designer in performance and flexibility. The primary reasons for integrating DSP functions into a single FPGA are system-level reductions in size, weight and power. For example, eliminating the transfer pathways between separate FPGA and DSP significantly reduces power consumption and, therefore, heat. This, in turn, reduces the system- cooling burden of the design. Recent releases of design and place-and-route software have advanced power-awareness features that significantly reduce dynamic power use of the FPGA. These options can be important to the designer; the benchmark of device logic density among competitive FPGA providers is beginning to give way to functionality-per-watt metrics, due to the sensitivity of power and cooling requirements in emerging systems.

Performance is also a key driver as FPGA based signal processing has become more reliable and faster than traditional processing technologies [6]. We have reported in literature how FPGA based pipelined and pipelined parallel hybrid architectures lead to computation with an increased throughput [7, 8]. In applications where performance is the driving parameter, efficiency can be sacrificed for application speed, where a memory-intensive, massively parallel floating-point mathematical operation is desired. Alternatively, highly iterative DSP calculations can be implemented for applications where moderate performance is allowable, but where logic-element usage is limited [9]. This logically leads to the advantage of flexibility. The designer has the flexibility to decide between high-speed performance and the number of logic elements in every DSP operation, whereas calculation bandwidths and iterations would be more difficult and costly to modify in a dedicated DSP device. In addition, consolidating DSP functions within an FPGA allows for post-design system changes in the signal-processing architecture, whereas using separate DSP locks the designer into a fixed set of chip interfaces once the board is designed. FPGA designers can alternately switch between 9-bit, 18-bit or 36-bit or 18-bit complex math functions without changing the system hardware. Additional flexibility can be designed into the system when the designer uses fast-embedded processors for the execution or routing of complex floating-point operations.

Prospects in algorithmic mathematical functions

Typical algorithmic mathematical functions in signal processing systems include recursive least-square and square-root operations [10]. Many designers have implemented these functions in C-based processors (in fixed decimal and floating-point operations), or with proprietary FPGA VHDL operations. The current FPGA devices include embedded processor and logic-cell resources to efficiently implement these processes; future generations will also have these capabilities [11]. Additionally, IP cores and reference designs are becoming available to transition anywhere from dozens to hundreds of these operations into a single FPGA. Tools are available to translate processor-based algorithms from C code to hardware languages, such as very high-level descriptive language (VHDL). These tools can be used to optimize certain logic functions from a standard main processor into an FPGA co-processor operating in parallel with the main processor, or to move entire operations from the main processor to the FPGA hardware.

Matrix inversion is an important component of adaptive array designs and standard spatial-transceiver-array processing (STAP) [12]. These operations are commonly performed in fixed hardware elements, though efficiently implemented embedded processing has been demonstrated in some radar/sonar development programs. The logic-element size and potential parallelism of a matrix inversion engine depends on the size of the array used in the radar system. As the size of the array is increased, so does the number of floating-point multiplications required by the system. Therefore, in larger arrays, there are more trade-off options between the speed of the system and the number of logic elements required by the system (both of which increase as the parallelization of the architecture increases). Implementing this function using a combination of a DSP and a group of internal memory blocks is the most likely design path for radar-system designers. As these operations are often tailored to the adaptive-array algorithms of the radar system, they are likely to be custom designed in VHDL. However, reference designs that are optimized for the place-and-route capabilities of an FPGA device can be offered or designed-to-order from the FPGA manufacturer, if required for the radar or sonar system.

Implementing Fast Fourier Transforms

Using FPGA

Signal processing typically entails to time to frequency domain conversion and vice versa for the ease of analysis. Fast Fourier Transforms (FFT) and their inverse are effectively used for time to frequency domain conversion and vice versa. A review of literature reveals implementation of FFT with DSP and ASIC [13-18]. FFT has also been implemented with FPGA for 1D [19-21] and 2D [22, 23] transforms. Fig. (3) shows the performance comparison of different programmable devices in the perspective of signal processing.

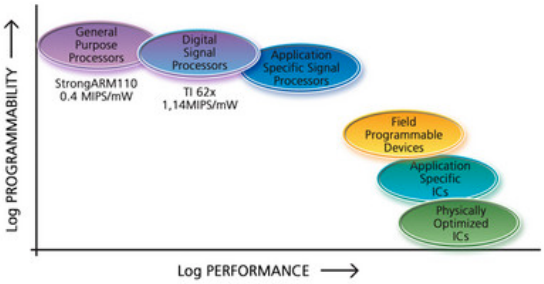

Figure 3. *Performance comparison of different programmable*

Implementing fast-Fourier transforms (FFT) and their inverses in FPGA logic has advantages in prototyping and scalability, and offers design flexibility between a system's speed and the number of required logic elements. For example, massively parallel implementations can be designed and distributed among the logic elements of a single or multiple FPGAs. However, while these implementations can significantly reduce latency, they impose the penalty of a greater number of logic elements. However, the limitations on the number of logic elements in an FPGA can be done away using reconfigurable architectures. Recently, a reconfigurable signal-processing chip with an embedded flash memory has been patented [24].

In fact, the primary flexibility advantage of an FPGA for FFT is the ability to select the optimal balance between these two parameters in the initial design. This is fortunate, because the implementation of large or complex FFT should be the primary factor in any design, and the advantages of an FFT implementation in an FPGA are apparent. Fig. (4) shows the FFT implementation using an FPGA. However, creating code or modifying existing code from previous designs can be cumbersome when testing and verifying code units. Therefore, what is needed is a comprehensive suite of FFT design tools that allows a nearly infinitely scalable FFT design. These tools are available and they allow scripted logic distribution among multiple FPGA where necessary. They can also automatically generate numerical coefficients having floating- point accuracy.

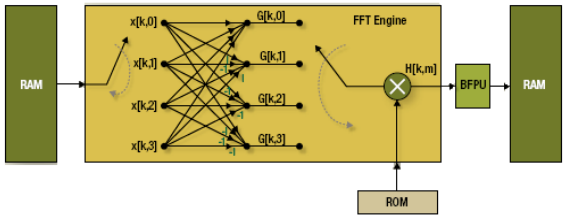

Figure 4. *FPGA based implementation of FFT*

System transformation for low power dissipation using

The average dynamic power dissipation of a CMOS logic circuit is given by:

$$P_{avg} = E_{switching} \times f_{clk} \times C_{load} \times V_{dd}^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where is the average power dissipation, is the load capacitance, f_{clk} is the clock frequency, is the supply voltage and is the expected value of output switching per clock cycle. For a CLB in an FPGA, is a function of the number of fan-outs of the CLB. f_{clk} refers to the clock frequency of the FPGA. $E_{switching}$ can be computed as:

$$E_{switching} = 2p(1-p) \ldots\ldots\ldots(2)$$

Where refers to the probability that the output of the CLB is 1, so that $p(1-p)$ is the probability of having a 1 to 0 transition and $p(1-p)$ is the probability of having a 0 to 1 transition and the two transitions being mutually exclusive. The probability p can be computed from the truth table realized in the CLB. Specifically, p is equal to the sum of the probabilities of the input combinations which produce a 1 in the output of the truth table of the Boolean function. Extensive studies have been carried out in technology mapping algorithms to reduce the power dissipation by minimizing the number of CLB [25] and minimizing the length of critical path [26,

27]. One transformational approach aims at minimizing the number of CLB as a starting objective and then applying functional transformation to the mapping solution to reduce the power consumption without increasing the number of CLB [4]. Formally, let the output of a CLB F_0 is a Boolean function:

$$\emptyset(x_1, x_2, x_3, \dots \dots x_n)$$
$$F(G(x_1, x_2, x_3, \dots \dots x_m), x_{m+1}, x_{m+2}, x_{m+3}, \dots \dots x_n)$$
.....(3)

Where $G(x_1, x_2, x_3, \dots x_m)$ is the output of CLB G_0.
$F(G(x_1, x_2, x_3, \dots \dots x_m), x_{m-1}, x_{m+2}, x_{m+3}, \dots \dots x_n)$ is a Roth Karp decomposition [28, 29] of $\emptyset(x_1, x_2, x_3, \dots \dots x_n)$. The transformational approach attempts to find an alternative Roth Karp decomposition such that:

$$\emptyset(x_1, x_2, x_3, \dots \dots x_n) =$$
$$F(G(x'_1, x'_2, x'_3, \dots \dots x'_m), x'_{m-1}, x'_{m+2}, x'_{m+3}, \dots \dots x'_n)$$
……..(4)

Where $x'_1, x'_2, x'_3, \dots \dots x'_m$ is some permutation of $x_1, x_2, x_3, \dots \dots x_m$. Here, F' and G' are functions, possibly different from F and G. However, F' and G' map into the same CLBs F_0 and G_0 respectively, since the total number of inputs of F and G remains unchanged after transformation. If the switching density of $G'(x'_1, x'_2, x'_3, \dots \dots x'_m)$ is less than that of $G(x_1, x_2, x_3, \dots \dots x_m)$ then we achieve a reduction in power dissipation.

Challenges in signal processing using FPGA

Despite such huge potential of FPGA in signal processing applications, it suffers from lots of limitations. Signal processing algorithms often require elementary functions like logarithm, exponential, trigonometric, etc. There are no such operators defined in the library for FPGA based system design. Many libraries of floating point operators for FPGA now exist typically offering the basic operators like +, -, X, / and √ [30-34]. As FPGA floating point is clocked 10 times slower than the equivalent in contemporary processors, hence massive parallelism can allow these applications to be competitive to software equivalent [35-37]. We have reported in our work [38], how by using multi-core superscalar architectures on an FPGA, computational speed up have been achieved. Moreover even if it is possible to implement floating point algorithms on FPGA, the current state of the art algorithms do not scale well beyond single precision. It is therefore necessary to explore algorithms, which work up to double precision which is standard in processors.

Conclusion:

FPGA have been found to a highly robust architecture that can be tuned for lots of signal processing applications. By allowing designers to create circuit architectures developed for the specific applications, high levels of performance can be achieved using FPGA for many DSP applications providing considerable improvements over conventional microprocessor and dedicated DSP processor solutions. The paper highlights the flexibility offered by FPGA in realizing signal processing architectures and algorithms. The possibility of realizing low power signal processors on FPGA by functional transformation approach has also been discussed. However, there are lots of limitations in regard to floating point computation and implementing logarithmic, exponential and trigonometric functions using FPGA. The current state of the art algorithms for FPGA do not support multi-precision floating-point operations. It is therefore necessary to explore algorithms, which work up to double precision, which is standard in processors.

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INTERVIEW with GATE-2015 (EE) Topper Pradeep Seervi

Pradeep seervi is an IIT Mandi graduate of batch of 2011-15 in Electrical Engineering. He secured AIR-1 in Electrical Engineering in Graduate Aptitude Test in Engineering (GATE) 2015. He is resident of Jodhpur, Rajasthan. Currently, he is working as an Engineer in PowerGrid Corporation of India Limited (PGCIL).

By Prashant Kumar

What motivated you for appear for GATE?

I have always wanted to work in some core electrical company and PSUs are the best options for that. So I decided to appear for GATE 2015.

When did you start your preparation? How was your strategy of preparation?

I started my preparations after the third year of my engineering i.e. August 2014. I made a rough study schedule for the entire August-November period. I allocated around a couple of weeks for each subject and tried to strictly follow the schedule. I read handwritten notes of Made Easy, my personal class notes and some book material during the two-week's allocated time. Then I made schedule for December-January period. I allocated around 4 days for each subject during which I used to read K-notes and attempt all Kuestions (K-notes and Kuestions are a part of the Crash course of the coaching institute, Kreatyrx) and then give subject-wise test and full syllabus mock tests. Finally during the week before the exam, I quickly went through all the K-notes and some previous year papers.

Have you taken any coaching? If yes, how did it help?

No, I didn't take proper coaching as such.
Instead, I joined an online program Krash 2015 by Kreatryx. The K-notes and the Kuestions provided by Kreatryx were really very good and helped me during the final stages of my preparation. This was a crash course to fine tune my initial preparation.
I also joined the online test series of MADE EASY. The test series helped me a lot in planning the correct strategy for attempting the GATE exam. It also helped me identify sections where I was weak and improved my problem solving ability.

How much the courses at IIT Mandi were helpful to prepare for GATE exam?

The courses at IIT Mandi were quite helpful especially the core subjects; control system, power system, power electronics, network theory and electrical machines. The course content taught in the class was almost similar to the GATE syllabus.

Did the college curriculum interfere with the GATE preparation? If yes then how did you balance it?

Yes, the college curriculum did interfere in my preparation, but I found a way of handling both side by side.

I prepared a rough study plan giving sufficient time for each subject and tried to strictly follow it. I could not set any fixed time for preparation. As I was in college, so I had to find time amidst all the assignments, projects and quizzes. But I tried to strictly follow my study plan. I studied with full concentration whenever I got time to get the most out of it. But I completely devoted entire December and January months for GATE Preparation. I solved a lot of online test to improve my problem solving ability and speed.

What do you think is the reason for your success in GATE 2015?

As it is truly said, "Hard work is the key to success". Dedication and willingness to work hard is the only way to crack GATE. Constant support and motivation from my family and friends inspired me a lot. I tried to build my concepts right from the 1st semester in the college, which proved beneficial.

Name some important topics that are very important for attempting GATE exam?

All topics are important but I feel the following ones carry more weightage and one should compulsorily cover them.

- Control System
- Network Theory
- Power system
- Electrical Machines
- Analog and Digital electronics

How should one schedule answering the GATE exam – which section to attempt first and which next?

I feel, this depends upon the student himself. One can attempt the paper in any way one likes. But it is important to finalize a good strategy before the exam like how much time must be devoted to each section. This strategy can only be built by giving several mock tests. When you do so many tests, you realize the strategy that works for you best.

Can you share some preparation strategies for future aspirants?

I would like to give some suggestions for the future GATE aspirants:

- Try to build concepts right from your UG Courses.
- Make a study schedule/plan and try to follow it.
- Please join some Online Test Series during last 2 months and attempt them honestly. It will help you to make your strategy for attempting the main exam.
- Solve as many questions as possible but keep in mind that variety of questions matters, not number of questions. Solving a number of questions, which are of same type, will not help in any manner.
- Try to make some short notes of your own if you need. (By the way K-Notes were sufficient for me)
- Don't try to remember all the formulae. GATE doesn't ask direct formula based question, even if it does, then they are based on very trivial formulae.
- Never lose hope during your preparation. Have faith in God and work hard.

A Finite Element Study of Acoustic Wave Propagation through Sonic Crystal

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and

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Abstract

A sonic crystal is a periodic array of scatterers in which scatterers are embedded on a material having low acoustic impedance. Successful applications of sonic and phononic crystal have led to a growing interest in the periodic structures embedded in a homogeneous material. These periodic arrangements of different materials have the ability to stop the sound waves within certain frequency bands. Such arrangements exhibit acoustic band gaps, which are very useful in many commercial applications. Frequency filtering, mirroring and guiding of acoustic waves are few applications in which sonic crystals can be used. In this article, we have studied such a 2-D sonic crystal in which circular scatterers are placed in square grid. A finite array of scatterers is analyzed here and its transmission loss is calculated. Bloch Floquet theorem is used to analyze this periodic structure. Eigenvalue study is also done on a single unit cell by applying periodic boundary conditions. The commercial software, COMSOL Multiphysics is adopted to implement the procedure. It is shown that significant sound is attenuated (~ 20 dB) due to the presence of the band gap in the sonic crystal. The obtained results of band gaps and transmission losses are compared with previous literature.

Keywords: *Sonic crystal, Sound attenuation, Periodic scatterers.*

Introduction

Sound is present everywhere in the world during our life. Sometime it gives a stress free environment in term of music but sometime when the amplitude of sound is quite high then it is very irritating and displeasing to human ear. This undesired sound is called noise. The rising interest of social media in eco-friendly environment has led to the requirement of noise free devices and equipments. From past few decades, sonic and photonic crystal has been successfully used for sound reduction. The paper written by Martinez et al. [1] in 1995 gives initial theory about sound reduction by sculpture. This theory was based on modern art classified as 'minimalism'. Minimalism are periodic structures in which the scatterers are embedded with a period vary from few centimeters to one meter. The set-up used at outdoor conditions. It has cylindrical hollow tubes of diameter 2.9 cm made of stainless steel arranged periodically with a cubic

unit cell with edge length 10 cm embedded on circular surface of diameter 4 m shown in Fig 3. This sculpture gave a very large sound reduction by reflection from the nearby buildings. A infinite array of scatterers is analyzed in this article and its band gap and transmission loss is calculated here. Taking the advantage of periodicity, only one unit cell is analyzed. Further band structure of an infinite array of scatterers is calculated by eigen value analysis on a unit cell. The wave propagating in the periodic scatterers is given by the Bloch Floquet theorem is represented as [6]

$$p(r) = u(r)e^{ikr} \quad \text{.....(1)}$$

Where, p(r) is the Bloch function, which represents the wave function, and u(r) is a periodic function with periodicity of the lattice. The Bloch Floquet theorem is used to compute the behavior of periodic structure. This procedure is implemented using the software COMSOL multiphysics. The Bloch Floquet theory is widely used to compute the dispersion analysis and to estimate the wave mode and velocity. Present work shows a 2-D model of sonic crystal having 20 circular scatterers in matrix form of order (10 x 2) arranged periodically. Eigen frequency study is also done here on a unit cell using Bloch Floquet theorem. The study shows a considerable amount of sound reduction through the structure.

2-D Sonic Crystal

The 2- D designed sonic crystal is shown in Fig 1. There are total twenty scatterers arranged periodically. Scatterers are circular in shape and diameter is 2.9 cm. Centre to centre distance is 10 cm arranged in the middle of rectangular lattice of 140 cm length and 20 cm breath. In Material properties for this system, density of air is taken 1.25 Kg/m^3 and speed of sound in air is 343 m/s. Total 18644 number of triangular elements are created after meshing using Nyquist criteria and size of mesh is defined by $\frac{c_c}{10 \cdot f}$.

Where, c_c is speed of sound in air and f is the frequency. Here we have taken ten points per unit wavelength. Pressure field is applied on left side with pressure amplitude of 1 Pa. Plane wave radiation boundary condition is applied both side left as well as right side. The whole finite element procedure is solved in COMSOL Multiphysics.

In present work, it is assumed that circular scatterers are embedded in air. For Eigenfrequency study, only single unit cell is considered for computation of infinite array of scatterers. Single unit cell is square in shape having edge length 10 cm and circular scatterer having diameter 2.9
cm is embedded on it. Results of this 2-D sonic crystal are compared with the result of a sculpture designed by Martinez in 1995.

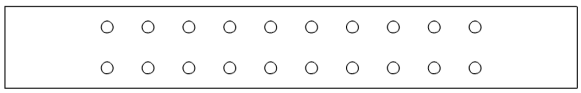

Figure 1: *Model used for analysis*

Sound Transmission Analysis

The following equation is used to solve this acoustic problem.

$$\frac{\partial^2 p}{\partial x^2} - \frac{1}{c_c^2}\frac{\partial^2 p}{\partial t^2} = 0 \qquad [2]$$

Where, p is the acoustic pressure and c_c is speed of sound.

Power of incoming wave is defined as w_in = (incident pressure)^2/(2 x ρ_c x c_c)

Power of outgoing wave is defined as w_out= (absolute pressure)^2/(2 x ρ_c x c_c)

Transmission loss is given by = 10 x log10(w_in/w_out).

Where, ρ_c is the density of air.

Sound hard boundary conditions are applied on the circular scatterers. Radiation boundary conditions are applied on both side at inlet and outlet. Sound attenuation is measured in terms of dB. Main application of sonic crystal is attenuation of propagating sound in the structure. Here when pressure of magnitude 1 Pa (94 dB) is applied at the inlet, nearly 18 dB transmission loss occurs at outlet as shown in Fig 2 between 1450 Hz to 1900 Hz.

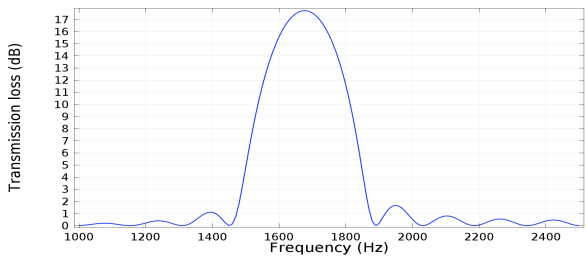

Figure 2: *Sound attenuation through the structure*

Previous literature [1] shows a sculpture design shown in Fig 3 consisting steel cylinder of diameter 2.9 on a unit cell of length 10 cm fixed on a circular space of diameter 4 m in 3-D. Result shown in Fig 4 represents the transmission loss in sculpture versus 2-D design sonic crystal. Maximum transmission loss obtained in sculp-

ture is 20 dB that is very closer to the transmission loss in 2-D design of sonic crystal.

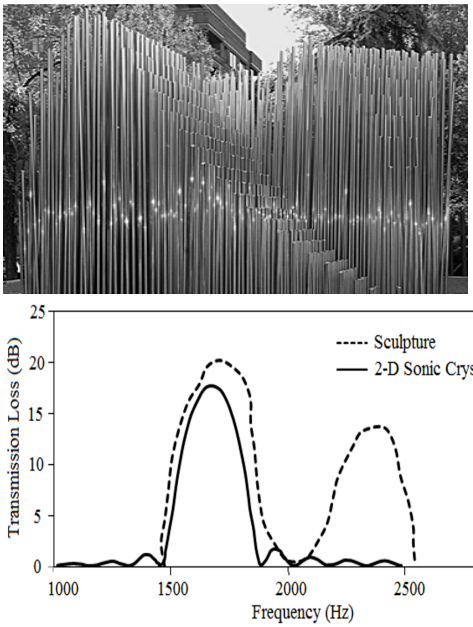

Figure 3: *Kinematic sculpture by Eusebio Sempere*
Figure 4: *Sound attenuation in sculpture vs. 2-D model*

Pressure Variations in 2-D sonic crystal at frequency 1650 Hz is shown in Fig 5. Pressure plot in the 2-D sonic crystal and variation in absolute pressure along the length of sonic crystal are also shown. At 1650 Hz, pressure variation along x-axis shows the standing wave at the inlet.

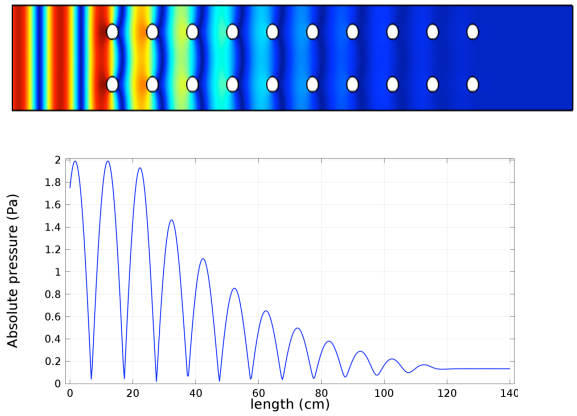

Figure 5 *(a) Pressure plot in the 2-D sonic crystal at frequency 1650 Hz (b) Pressure variation through the structure along x-axis at 1650 Hz*

When incoming acoustic wave of 1 Pa collide with scatterers, then these are reflected with each other and interference will occur. This combination of interference and reflection results standing wave. The maxima and minima of standing wave as can be seen from fig. 5 (b) is approximately 2 Pa and 0 Pa respectively. This is due to constructive and destructive interference at pressure antinodes and nodes respectively. At 1650 Hz, transmission loss is 17 dB. As shown in Fig 5, Sound is attenuated by high amount at this frequency and amplitude of outgoing waves is very less than the incoming acoustic waves.

Band Gap and Eigenfrequency Analysis

Eigenfrequency study is done here for infinite structure of 2-D sonic crystal. To analyze the infinite structure, a single unit cell is used for calculation. If structure is periodic along length with a period 'a' and along breath with a period 'b', it can be described by two basis vector (a,0) and (0,b). According to Bloch-Floquet theory, pressure distribution at boundary will be [11]:

$$p(\vec{x}+\vec{a}+\vec{b}) = p(\vec{x})\exp[i(k_x a + k_y b)]$$

[3], where x is position vector and (k_x,k_y) are the wave vectors.

Finite element method is used to obtain band gap implemented through COMSOL multiphysics. As the length of unit cell will increase, range of band gap will be thinner [12].

Here two periodic boundary conditions are applied in x (top and bottom) and y (left and right) direction. The wave vector (k_x,k_y) is swept over brillouin zone. K_x is taken as (0, *pi/a*) and *ky* is 0. Parameters of unit cell shown in Fig. 6 (a) have 10 cm length (square in shape) and a circular scatterer of 10 cm diameter is embedded on it. Solution of first six eigen values and their eigen vectors are computed here. Fig. 6 (b) shows the graph of these six eigen modes plotted as a function of k_x from k_x =0 to k_x=65. The range of frequency in which no eigen modes are present– is called band gap. In the band gap, there is no propagation of acoustic wave.

First band gap is shown here ranging approximately from 1450 Hz to 1890 Hz. First six Eigen values computed at k_x=30 are 1509.50 Hz, 1833.36 Hz, 3476.45 Hz, 3736.22 Hz, 3773.36 Hz, and 4130.87 Hz. These are six natural frequencies of the system at kx = 30.

So here, we get some useful band gaps for this two-dimensional design of sonic crystal in which sound cannot be transmitted through the structure.

b

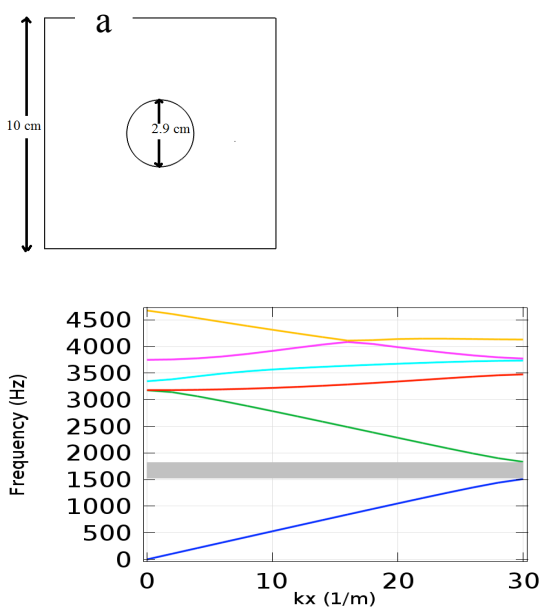

Figure 6: *(a) A unit cell of infinite structure for eigenfrequency study (b) Dispersion relation for sonic crystal and grey part shows the first acoustic band gap.*

As we compare our result with the sculpture, first band gap in sculpture ranges from 1450 Hz to 2000 Hz giving sound attenuation of 20 dB and first band gap in 2-D sonic crystal ranges from 1450 Hz to 1900 Hz giving sound attenuation of 18 dB. So the results of 2-D sonic crystal are quite comparable with the results of sculpture.

Conclusion

In this work, we conducted a finite element study of acoustic wave propagation through two dimension sonic crystal having circular scatterers. This 2-D design analysis involves finite element study, transmission loss, pressure variation along the sonic crystal and dispersion relations. Sound propagation through a single unit cell is analyzed by using Bloch-Floquet theory. A finite array of scatterers is analyzed over a frequency range 1000 Hz to 2500 Hz. Finite model assumes plane wave radiation for incoming and outgoing acoustic waves and computed result reveals a high amount of sound attenuation over a large band gap. Acoustic band gaps are studied theoretically by plotting the eigen modes as a function of wave vector in *x*-direction. A comparison between this 2-D design and a sculpture is also done here and found that results of sculpture and 2-D design sonic crystal are quite similar. This finite element study predicts high transmission loss and this design can be suited for the noise reduction applications. We can extend this work in future by considering wave vector at an oblique angle.

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Detection of electro magnetic radiation in ferroelectric ceramics for non-contact sensing applications

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and

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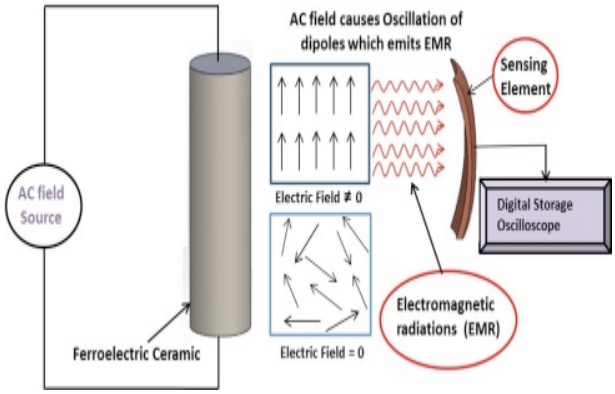
Graphical Abstract



Keywords: *Electromagnetic radiation (EMR); lead-free piezoelectric ceramics; non-contact sensor; Morphotropic phase boundary (MPB).*

1. Introduction:

Structural health monitoring is a non-destructive evaluation technique, which continuously monitors the state of the structures and provides valuable information so that remedial action can be taken in time. Smart structures give alarming signals in its initial stage in response to external stimuli i.e. deformation, temperature, pressure etc. so that any catastrophic failure can be avoided. In this context emissions from materials due to deformation can be utilized to develop non-contact sensors. This will help in reducing the array of sensors, which are installed onto the structures and in turn can reduce the overall cost as well. Electromagnetic radiation (EMR) detection is a novel technique to monitor the state of structures with the help of non-contact sensors. Piezoelectric materials [1, 2] being smart materials have a wide range of applications such as energy harvesting, vibration and noise control, ultrasonic cleaners, biomedical applications and thus can be a potential candidate for electromagnetic radiation emission. Moreover embedding the piezoelectric materials in the structures will lead a way towards the development of smart structures which will allow continuous and efficient monitoring [3].

This article involves the case study of six compositions of lead-free ceramics viz. (1-x)($Bi_{0.5}Na_{0.5}TiO_3$)– x ($BaTiO_3$) [(1- x)BNT- x

BT] ($0.04 \leq x \leq 0.08$) where $x = 0.06$ is a MPB (Morphotropic Phase Boundary) composition. In case of BNT-BT, MPB is a transformation line where rhombohedral and tetragonal phases coexists giving rise to enhance piezoelectric properties [4]. So, in this article MPB composition i.e. BNT-6BT and compositions in its vicinity are studied for their EMR response under the application of electric field.

2. Experimental Procedure:

The five different compositions of lead-free ceramics viz. $0.96(Bi_{0.5}Na_{0.5}TiO_3)$–$0.04(BaTiO_3)$, $0.95(Bi_{0.5}Na_{0.5}TiO_3)$–$0.05(BaTiO_3)$, $0.94(Bi_{0.5}Na_{0.5}TiO_3)$–$0.06(BaTiO_3)$, $0.93(Bi_{0.5}Na_{0.5}TiO_3)$–$0.07(BaTiO_3)$ and $0.92(Bi_{0.5}Na_{0.5}TiO_3)$–$0.08(BaTiO_3)$ designated as BNT-4BT, BNT-5BT, BNT-6BT, BNT-7BT and BNT-8BT respectively were prepared by using conventional solid route mixture method. Samples under study were formed into cylindrical shape having diameter of 12 mm and height of 8mm with hydraulic press. Electroding was done on both the opposite faces and alternating electric field was applied with the help of Sawyer-Tower loop tracer, which is having a capacity of 5 kV. Sawyer-Tower loop tracer also had a facility to plot Polarization- Electric field (P-E) loops. Loop antenna made of copper and a Digital Storage Oscilloscope was used to capture EMR signals. Schematic diagram of Experimental set up is shown in Fig. 1.

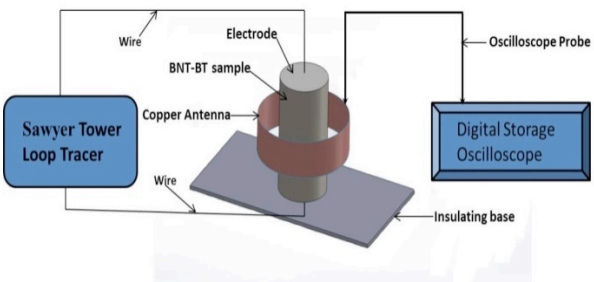


Fig. 1. Schematic diagram of Experimental set up.

3. Results and discussions:

Fig. 2 shows the sample plot of EMR signals obtained for the different compositions of BNT-BT at alternating electric field of 2.9 kV/cm and frequency of 50 Hz.

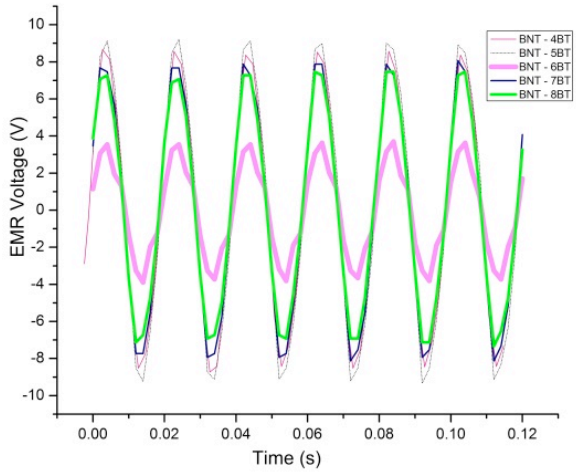


Figure. 2. *EMR signal sample plot for all the compositions at electric field of 2.9 kV/cm at 50 Hz.*

The occurrence of these EMR signals observed as depicted in Fig. 2 can be explained as follows. As an external electric field is applied to a ferroelectric material the domains within it, which are randomly oriented, get aligned with the direction of applied electric field and an internal electric field is set up within the material. The internal electric field is in the form of electric dipoles aligned in one direction compatible with the applied electric field. The applied alternating electric field keeps changing its direction after every half cycle and thus these dipoles too will have to change their orientation after each half cycle of the applied electric field. This leads to the oscillations of the dipoles with a frequency equal to the frequency of the applied electric field. The oscillating dipoles will then give rise to the electromagnetic radiation. Thus when a piezoelectric material is subjected to applied alternating electric field it is likely to produce the EMR with a frequency same as that of applied electric field. This is confirmed from the results depicted in Fig. 2. However ferroelectric materials exhibit polarization also when they are strained. This suggests that the ferroelectric materials will generate electromagnetic radiation when they are subjected to varying load or a sudden load.

Figure 3 shows the variation in EMR voltage obtained with different increase in strength of applied electric field for the five compositions of the ferroelectric ceramics under study. It is observed that the EMR voltage increases with the increase in applied electric field. The higher applied electric field causes a stronger polarization of the material.

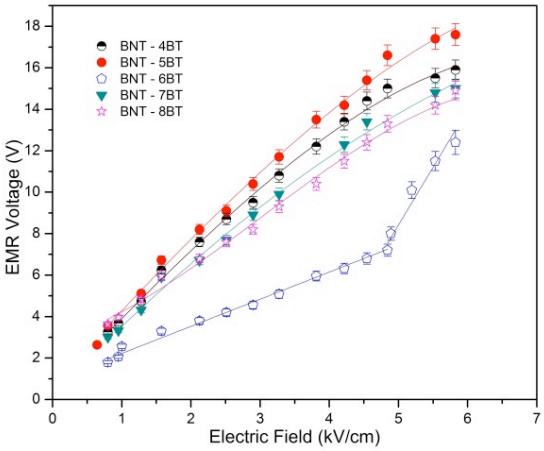


Figure 3.*EMR voltage variation with increase in the strength of applied electric field at 50 Hz.*

In Fig. 3 BNT-6BT shows a different behavior, in case of BNT-6BT firstly the EMR signal increases linearly having less slope and then abrupt increase in the slope occurs indicating spontaneous increase in EMR voltage. This sharp increase in the EMR voltage nearby 5.1 kV/cm indicates that net polarization is increasing spontaneously. Further if we consider any particular value of applied electric field the compositions having one of the structural symmetry (rhombohedral or tetragonal) dominating are showing higher values of EMR signal and the MPB composition which is having coexisting rhombohedral-tetragonal structural symmetry is showing least EMR signal. The MPB compositions usually give better polarization because the co-existence of two different phases allows higher number of directions favorable for poling. The rhombohedral structure has eight possible polarization directions and the tetragonal structure has six possible polarization directions. Therefore an MPB consisting of both phases has 14 possible polarization directions which may contribute to a large coupling factors (ks). If electric fields beyond 5.8 kV/cm could be applied to these materials then the EMR voltage emitted by the BNT-6BT composition would have been highest at higher applied electric fields. This suggests that at low applied electric fields there is higher resistance offered to the polarization by the ceramics with MPB compositions. This must be caused by coexistence of two phases the interphase interactions offer resistance to domain switching, this cause the net polarization of the material to get reduced and consequently the EMR signal is less. However as the applied electric field is increased then the effect of the large number of favorable poling directions exceed the effect of interphase interactions and thus better polarization is observed with MPB compositions at higher electric fields. Thus for ferroelectric materials with MPB composition, there exists a threshold value at which transition from dominance of interphase interactions to dominance of effect of large no. of favorable poling directions occurs.

It can be observed from fig. 4 that the EMR voltage versus polarization curves are straight lines suggesting that the EMR voltage is directly proportional to the extent of polarization in the ceramics being studied. Thus measurement of EMR can lead to a new technique for the measurement of the extent of polarization in the ferroelectric materials.

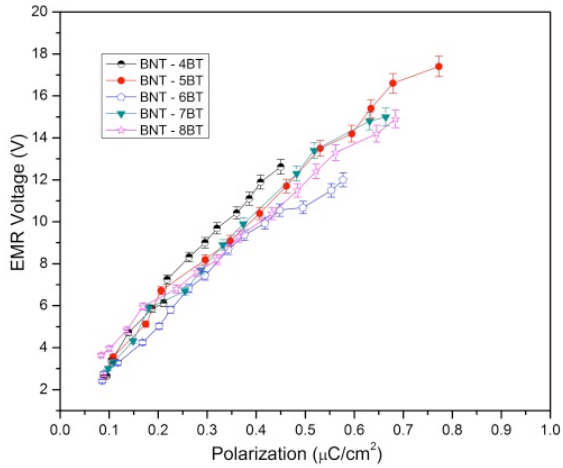


Figure 4. *EMR voltage vs. Polarization curves for all the the (1-x)BNT-xBT compositions under study.*

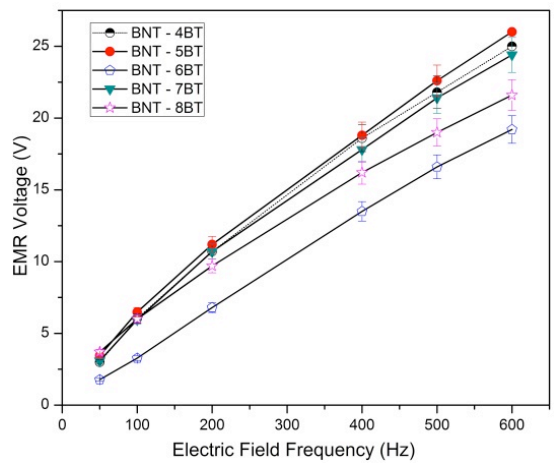


Figure 5. *EMR voltage variation with increase in frequency at 0.8 kV/cm of applied electric field.*

In fig.5 the EMR voltage linearly increases with the increase in the frequency of applied electric

field which suggests that the higher frequencies lead to higher accelerations / oscillations of the dipoles formed under the application of electric field thereby giving rise to the EMR of higher amplitudes. This is in agreement with the fact that the radiation from electric dipole is proportional to the frequency of the oscillations of dipole [5].

4. Conclusion:

Based on the present study following conclusions can be drawn.

1. Since EMR can be measured using a non-contact antenna it may lead to the development of a non-contact sensor for excessive deformation in structures.
2. In case of MPB composition it is found that there is a threshold value up to which resistance to polarization due to interphase interactions dominates the higher number of favorable polarization directions in case of the MPB compositions. It is beyond the threshold value that the availability of larger number of favorable polarization directions starts dominating which causes the MPB compositions to show better polarization at higher electric fields.
3. The variation of the EMR voltage with applied electric field is observed to be proportional to the extent of polarization. This suggests a new technique to measure the extent of polarization with the help of measurement of EMR voltage.

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INTERVIEW with Aditya Chauhan, Ph.D. Scholar at University of Cambridge

Mr. Chauhan is pursuing his Ph.D. at Department of Materials Science and Metallurgy, University of Cambridge. He had completed his M.S. in Materials Science at IIT Mandi under the guidance of Dr. Rahul Vaish, Assistant Professor at IIT Mandi. He was researching materials for energy applications while at IIT Mandi. For his research and publications he was awarded the Indian Science Congress Association's Young Scientist award in 2015 (materials science category). His PhD is focused on development of novel nano materials for efficient solar energy harvesting and conversion. He is interested to continue his research towards discovering new materials for energy applications.

By Prashant Kumar

Please tell about yourself.

Honestly, this is the one question I have dreaded in all my HR interviews, as there is no obvious answer. The best I can summarize is by saying that I was born and brought up in Meerut and discovered my love for physics early on when I used to craftily dismantle the speakers in our home to get hold of the magnets to build huge floating structures (and received a nice scolding for my endeavors). However, as is the unfortunate scenario in India, I was sucked into the world of engineering (mechanical) due to lack of options. However, I rediscovered my passion for materials when I met Dr. Vaish and since then it has stuck with me and I have stuck with it. You could say that I am (almost and figuratively) married to my work and we are very much in love. Apart from that I could say that I come across as a bit introvert. After coming to Mandi I discovered my love for adventure and exploring. I love trekking, swimming, kick boxing, adventure sports and computer games. I hardly give up on trying anything new; but I know my priorities straight.

What inspired you to pursue PhD?

Well, there are plenty of reasons including my thirst for knowledge, my innate desire to understand the world the around me and the opportunity to join the intellectual elite and (hopefully) leave a positive impression on this world. But most importantly this feeling which keeps me content and gratified. I will elaborate with an example, since the question demands.

"The myth of Sisyphus" as described by great philosopher Albert Camus in his essay; where as per the Greek myth, Sisyphus the king of Corinth was condemned to roll a giant stone uphill to have it slip down before it reaches the top. Ultimately, Camus saw a parallel to life: we are born, we live, and we die but to what end?

You see the analogy; we never have an-

swers to all the questions. We try to answer a few but some difficult ones pop up. Just like the head of Hydra/Ravana. That's how researchers are never out of work. And that keeps me inspired and motivated.

Why did you choose to attend Cambridge University, UK?

An easy way out of this one would have been to simply copy-paste the essay I wrote in my application. However, to be completely honest with you, Cambridge is a brand in itself, one that has been unshaken and respected for perfection since the last eight centuries. Not unlike the IITs in India, it helps to lend credibility to one's efforts and provides an excellent platform from where to launch oneself into the professional world. Apart from this, what I have realized after coming to Cambridge is the unique culture of the place. Cambridge will allow you and support you to be anything and anyone you want to be in life and that in itself is mind-blowing and unique. This is what I love this place for.

Tell about the selection process you have gone through to get PhD at Cambridge University.

Securing an admission into Cambridge involved mainly three steps for me:

- Identify a potential supervisor.
- Make an application
- Secure a scholarship.

Once all three are done you are pretty much good to go.

What do you plan to do after completing PhD?

I plan to continue working in the field of research, preferably for energy-based materials, in either a good R&D facility or as a faculty at one of the leading Universities

Tell us about your research project on which you are currently working in your PhD.

I am trying to make new materials, which will allow trapping of solar energy directly, to be used for splitting water to produce hydrogen as a clean fuel.

Tell us about your journey at IIT Mandi.

I don't think it would be just of me to describe in a few words what I experienced at Mandi, nor would it be possible. I took three years to complete my MS, got awarded the young scientist award, made some of the best friends I have ever had in my life and got a place at Cambridge. However, it would be lying if I told you it was all rosy and sunshine. I have had my fair share of stress, anxiety and helplessness, more to do with securing a good PhD position and sorting out my personal life and less to do with my research. However, if I had the chance to go back and change anything, the only thing I would've changed is to stop myself from worrying so much. "What has to be will be and there is nothing you can do to change it", or as my father best describes it "Take pride in how far you've come and have faith in how far you can go".

What was the research project on which you were working at IIT Mandi during your MS?

We mainly worked on ferroelectric materials for energy harvesting, storage, generation, conversion and refrigeration applications. However, we were not rigid in our approach and did try to solve and publish whatever we could get our hands on including design, optimization, ranking and a host of other problems.

What was the biggest challenge you had faced in that?

Initially, it was the lack of research facilities, Mandi being a new institute and still in the process of being set-up. Later, it was the limitation oh having just two hands and only

24 hours in a day to complete the work. But hard work was the way to tackle all these problems.

How important do you think IIT Mandi has been in your success?

In one word “too much". Though I would lay the credit of the success to two people mainly, my supervisor and my beloved colleague.

What is your best memory at IIT Mandi?

I would say that getting the acceptance mail from Cambridge would have made it to the top spot. However, what happened afterwards would indeed be the icing on the cake (wink wink). I enjoyed myself a lot with my friends and the period that followed was the best I have ever had in my life.

Please give some advice to the students, those are interested in research and higher studies.

Well, censoring it for the readers, I will quote (and manipulate) the words of Richard Feynmann “*Science is like love: sure, it may give some practical results, but that's not why we do it.”*Wink*

Don’t be afraid to take risk, make mistakes, fail or mess up. Don’t mess up on purpose, but don’t let fear of making mistakes/messing up intimidate you.

Resilience is a key personality trait one must try to develop. Try, fail and then try again. You *will* mess up for sure but just don’t let it get to you.

And a mild motivator for those who might be hindered due to monetary prospects, as a researcher abroad you will save more than you can ever hope to make in India while still continuing that awesome ‘student phase’ of your life for a few more glorious years.

What if n=1/3, 1/2 or 2/3 or any fraction in $\frac{d^n y}{dx^n}$?

Dr. Syed Abbas, *Assistant Professor, School of Basic Sciences, IIT Mandi*

Dr. Abbas did his PhD in Mathematics from Indian Institute of Technology Kanpur in 2009. He has worked as a postdoctoral fellow at University of Bologna, Italy and visiting scientists at TU Dresden, Germany. His area of interest is almost Periodic Solutions, Functional Differential Equations, Ecological Modeling and Fractional Differential Equations.

Abstract

Most of us are familiar with ordinary derivatives of a given function. In this note, we discuss and explore the concept of fractional derivatives from an amateur point of view. But as Albert Einstein said "Everything should be made as simple as possible, but not simpler", this is very much true with this concept too. This field is quite emerging and finds applications in various disciplines.

Key words: *Reimann Liouville/Caputo fractional derivative; Mittag Leffler function*

Most of the people who have decent level of higher mathematics knowledge know the meaning of derivative of order one and more. Now a natural question one may ask is that what if we replace integer by any real number. Is there any such kind of mathematical quantity? Does it make sense? The answer is yes; it makes sense and has numerous applications. It is well known that when $n=1$ in $\frac{d^n y}{dx^n}$ it represents velocity and the case $n=2$ represents acceleration when x represents time and y represents displacement. But what happens if n is a fraction between one and two. The very first person to ask this question is Marquis de L'Hopital. He asked in the year 1695 in a letter to Gottfried Wilhelm Leibniz, which sought the meaning of Leibniz's notation for the derivative of order n when $n=\frac{1}{2}$. In his reply, dated 30 September 1695, Leibniz wrote to L'Hopital as follows: “This is an apparent paradox from which, one day, useful consequences will be drawn". The subject fractional calculus that is, calculus of integrals and derivatives of any arbitrary real or complex order has gained considerable popularity and importance during the past three decades or so, due mainly to its demonstrated applications in numerous seemingly diverse and widespread fields of science and engineering.

The integral of function f is defined by $(If)(x)=\int_0^x f(t)dt$. Taking integral of integral, we obtain

$$(I^2 f)(x) = \int_0^x (If)(t)dt = \int_0^x \int_0^t f(s)dsdt = \int_0^x (x-t)f(t)dt$$

Similarly one can define $(I^3 f)(x)$ and so on. For any natural number n it is defined by $(I^n f)(x) = \frac{1}{(n-1)!}\int_0^x (x-t)^{n-1} f(t)dt$. By replacing factorial by gamma function, this formula can be extended for any fractional α , which we mention below (R-L fractional integration).

There are many different ways to define a fractional derivative and all ways leads to different definitions. One thing, which is common and should be common in all fractional derivatives that these coincide with usual derivative when fractional parameter approaches to integer.

Let us now discuss the mathematical formulation of fractional derivatives. From the first principle of derivative, $f^n(x) = \lim_{h\to 0} \frac{1}{h^n}\sum_{k=0}^{n}(-1)^k \binom{n}{k} f(x-kh)$.

We can generalize it for any integer p . After generalization, we get

$$f_h^{(p)}(x) = \frac{1}{h^n}\sum_{k=0}^{n}(-1)^k \binom{p}{k} f(x-kh).$$

Then we have for

$$p \le n, \ \lim_{h\to 0} f_h^{(p)}(x) = D^p f(x)$$

Also,

$$\lim_{h\to 0} f_h^{(-p)}(x) = D^{-p} f(t) = I^p f(x) = \int_0^x \frac{(x-s)^{p-1}}{\Gamma(p)} f(s)ds$$

Using the above representation, we can generalize the integral and derivative of arbitrary order. The major integration and derivatives occurs in the fractional world are:

(I) R-L fractional integration: ${}_0I_x^{\alpha} f(x) = \int_0^x \frac{(x-s)^{\alpha-1}}{\Gamma(\alpha)} f(s)ds$

(II) R-L fractional derivative: ${}_0D_x^{\alpha} f(x) = D^n\, {}_0D_x^{\alpha-n} f(x) = D^n\, {}_0D_x^{n-\alpha} f(x)$.

(III) Caputo fractional derivative: ${}_0{}^CD_x^{\alpha} f(x) = {}_0D_x^{\alpha-n} D^n f(x) = {}_0I_x^{n-\alpha} D^n f(x)$.

For $0 < \alpha < 1$, R-L derivative is given by $\frac{1}{\Gamma(1-\alpha)}\frac{d}{dx}\int_0^x (x-s)^{-\alpha} f(s)ds$ and the Caputo derivative is given by $\frac{1}{\Gamma(1-\alpha)}\int_0^x (x-s)^{-\alpha} f'(s)ds$. Further, the R-L derivative of any constant function c is $\frac{cx^{\alpha-1}}{\Gamma(1-\alpha)}$ and the Caputo derivative is 0. The $\frac{1}{2}$ R-L and Caputo derivatives of $f(x) = x$ is given by $\frac{2\sqrt{x}}{\sqrt{\pi}}$.

Figure-1 and 2 depict the graph of the fractional derivatives of two functions.

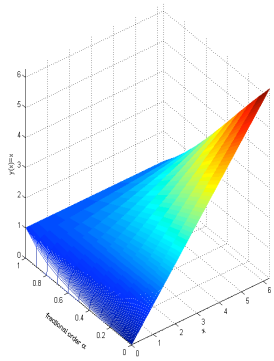

Figure 1: *Graphs of fractional derivative of* $f(x) = x$ *with fractional order* $0 \le \alpha \le 1$

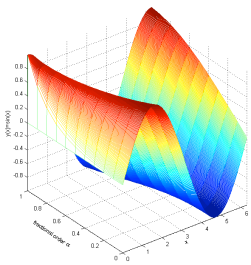

Figure 2: *Graphs of fractional derivative of* $f(x) = \sin(x)$ *with fractional order* $0 \le \alpha \le 1$

Geometrical interpretation of R-L fractional integration is that it represents a shadow on the wall, which is depicted in the figure-3 (more details can be found in [3]).

The integral ${}_0I_x^{\alpha} f(x) = \int_0^x \frac{(x-s)^{\alpha-1}}{\Gamma(\alpha)} f(s)ds$ can be written as ${}_0I_x^{\alpha} f(x) = \int_0^x f(s)dg_x(s)$,

Where $g_x(s) = \frac{\{x^{\alpha} - (x-s)^{\alpha-1}\}}{\Gamma(\alpha+1)}$ Also, ${}_0I_x^{1} f(t) = \int_0^x f(s)ds$

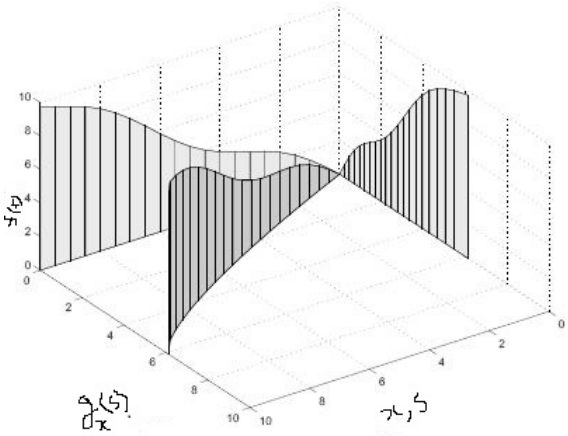

Figure 3: The fence and its shadows: ${}_0I_x^{1} f(x), {}_0I_x^{\alpha} f(x)$ ***for*** $\alpha = 0.75, f(x) = x + 0.5\sin(x)$

We can understand the physical interpretation of fractional integral by the following example. Consider a moving car equipped with speedometer recording individual velocity $v(s)$ and the clock show the individual time s. Let A be the driver in the car and O be observer at the fixed frame of reference and knows the clock of mobile observer is slow. So correct time is given by $T = g(s)$. Driver A compute the passed distance as $S_A(t) = \int_0^t v(s)ds$ and the observer compute the really passed distance $S_O(t) = \int_0^t v(s)dg(s)$.

Now the question is, Why fractional order systems? The reason is since we observe failure of ordinary derivatives in the following cases.

Anomalous dynamics: A medium can distort the dynamics of a phenomenon to such a extent that it leads to anomalous behaviour and ordinary derivative is inadequate to simulate the dynamics. For example diffusive-type phenomenon across a cell with fractal surface, adsorption of medicine or cosmetic gel through skin (a highly heterogeneous porous medium with strongly delineated changes in scale).

Viscoelasticity: Experimentally it has been observed that viscoelastic behavior of materials (like biological tissues, tissues mimicking phantoms etc) is more accurately described by fractional viscoelastic model (Scott Blair stress-strain law) rather than integer derivative model.

These anomalous changes are better modelled by fractional derivatives with great flexibility. The fractional derivative is not only model a physical system but also control the dynamic of the system as well. An order lesser than one allows to slow down the dynamics, while greater than one leads to faster dynamics. From several perspectives the fractional derivative allows to consider new situations and behavior in the systems dynamics.

Apart from the above mentioned fields, fractional calculus finds applications in various other fields too, for example in Fluid Flow, Rheology, Dynamical Processes in Self-Similar and Porous Structures, Diffusive Transport Akin to Diffusion, Electrical Networks, Probability and Statistics, Control Theory of Dynamical Systems, Electrochemistry of Corrosion, Chemical Physics, Optics and Signal Processing, and so on. Research in fractional differentiation is therefore inherently multi-disciplinary and its application across diverse disciplines. Few engineering problems where fractional calculus is useful are listed below, the readers may explore these [4].

- Tuning of PID controllers using fractional calculus
- Fractional dynamics in the trajectory control of redundant manipulators
- Circuit synthesis using evolutionary algorithms
- Fractional PD^{α} control of a hexapod robot

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Importance to Mathematics

Mathematics is very important for human evolution. It is a basic language of science. In our regular language, we express our feelings and record social events, but in mathematics we develop and transfer our scientific knowledge to next generation. A very important feature of this language is that it is same for all countries, continents. There are many advantages of doing mathematics, some are visible and some are invisible. Visible advantages are problems from various branches of engineering, biology and physics modeled in terms of mathematics. Invisible advantage is that it sharpen your abstract thinking, makes your brain more alert. Solving puzzles is one of such example. The more general form of puzzle is proving theorems. Creating theorems in mathematics is like building a house. We use our basic assumptions like bricks and follow some rules to build various structures. Some are just beautiful, some are just complicated and some are beautifully complicated. Mathematics actually simplifies things, but since it simplifies difficult things, hence the difficulty is in its gene. Let us talk about an example, suppose we have a given set in which there are 100 tigers, 50 sheep and 150 horses and our job is to study the properties of this set. A smart person will choose a set consists of one tiger, one sheep and one horse and studies it. In mathematical language, we can say that we formed a basis of the original set. So the actual problem is now simplified. Here, I assume that most of you are familiar with the concept of basis.

Mathematics offers you everything, if you are not interested in divine enjoyment of doing mathematics, you can also do mathematics to make money. So it can also make you rich. For example there are several unsolved problems in mathematics; you can find them on the website of “Clay Mathematics Institute” under the title “The Millennium Prize Problems”. Each problems offers one million dollar as prize money. A word of caution: since several well trained people are working on these problems, so before proceeding, one needs rigorous training. Also even after rigorous training, it may take one’s lifetime to solve a problem. There is also a danger of not succeeding even after devoting whole life, but following the path, you will certainly discover several beautifully complicated results or patterns.

INTERVIEW with Hemant Chawla, IIM-Ahmedabad, CAT Percentile 99.95%

Hemant Chawla is an IIT Mandi graduate of batch of 2011-15 in Electrical Engineering. He got 99.95% percentile in Common Admission Test (CAT) in 2015. He is resident of Aligarh, Uttar Pradesh. He will be joining IIM-Ahmedabad this June.

By Prashant Kumar

Why do you want to do MBA after doing B.Tech from an IIT?

I like taking up managerial roles, while working in industry I want to work on such roles, an MBA will prepare me for that. It will help me improve interpersonal skills and surely broaden my perspective. Also, going for an MBA right now will give more freedom in terms of deciding which industry or department to work in post MBA.

When did you start your preparation? How was your strategy of preparation?

This was the second time I attempted CAT. I had covered most of the topics while preparing for CAT 2014 and needed to revise a few of them. I relied mainly on the mock tests, mocks are the best way to prepare for CAT.

CAT is basically a speed test now, so while taking mocks my strategy used to be to not get stuck on a particular question and try to attempt maximum number of questions with good accuracy. Accuracy along with speed is what an aspirant should focus on while preparing for CAT.

Did you take any coaching classes? Is it necessary to take coaching classes?

I initially joined Career Launcher in the 3rd Year of B.Tech but then realised that self study will be more beneficial for me, basically it's an individuals' choice whether to take coaching or not. Yes, coaching classes do prove helpful as one can get valuable guidance through them, but taking classes is not necessary as guidance can be easily sought from seniors as well.

What was your overall percentile? Did you expect this much?

My overall percentile was 99.95%. To be honest, I was expecting something around 99.8 assuming around 80% accuracy in the

test. Thankfully, my answers were more accurate than my prediction.

Which IIM is your choice and why?

I would prefer any of IIM-A,B or C. But yeah IIM-A a bit more because it is more renowned for its case based pedagogy and highly intellectual faculty.

What was your strategy in testing room to attempt the questions from different sections: Quantitative Ability, Verbal Ability, LR & DI?

Kept calm throughout the test and followed the same strategy which I used to follow for mocks. Avoided sticking on a particular question and tried to attempt maximum number of questions. Specifically for LR & DI section, I tried to pick sets, which seemed doable and required less calculation.

Please tell few questions that were asked to you during personal interview (PI) round?

In each interview first question asked was: "Tell us something about yourself". This is an icebreaker and also the trickiest question, you can tell anything about you and guide the interview along that direction, it's like ball is in your court now. Few other questions were : Have you seen Aligarh (maybe because I am from Aligarh), what is it about, problems with China's economy, how falling oil prices are affecting world economy and a few related to academics and work-ex.

What is your advice to CAT aspirants?

I would say try to take as many mocks as possible, analyse them and find out topics you need to work on. Work on your weaknesses and while writing exam focus on your strengths, most important be accurate. Also, getting a good percentile is only first step, once you are done with that a big hurdle awaits (PI Round). Start reading newspapers, especially business news and editorials. Editorials will also help in your preparation for RCs, if you get good at comprehending editorials your RC solving skills will definitely improve.

Artificial Photosynthesis: If Plants Can Do, Why Can't We!

Dr. Venkata Krishnan, *Assistant Professor, School of Basic Sciences, IIT Mandi.*

Dr. Krishnan did Ph.D. in physical chemistry in 2006 from the University of Stuttgart in Germany. Subsequently, he worked as a postdoctoral researcher from 2006 to 2010 at the University of Pennsylvania in U.S.A. and then as a research associate from 2010 to 2012 at the National Institute for Materials Science, Tsukuba, Japan. During his academic career, he has received several fellowships and awards. Recently, he has received the DST INSPIRE faculty award in chemical sciences in 2011. His broad research interests are in the fields of materials chemistry and x-ray science. He has published many research articles in reputed international journals.

and

Suneel Kumar, *Ph.D. Scholar, IIT Mandi*

Mr. Suneel Kumar is Ph.D. student at IIT Mandi working with Dr. Venkata Krishnan. Previously, he received his B.Sc. and M.Sc. degrees in chemistry from Himachal Pradesh University, Shimla in 2011 and 2013, respectively. His main research interest is in the field of semiconductor based photocatalysis and artificial photosynthesis, involving the design and development of efficient photocatalysts for water splitting applications based on biomimetic approaches.

and

Vipul Sharma, *Ph.D. Scholar, IIT Mandi*

Mr. Vipul Sharma is a Ph.D. student at IIT Mandi working with Dr. Venkata Krishnan. Previously, he received his M.Tech. degree in nanoscience and nanotechnology from Amity University, Noida in 2012. His main research interest is in the field of fabrication and characterization of biomimetic functional surfaces for technological applications, including fog harvesting, surface enhanced Raman scattering (SERS), photo-catalysis, etc.

Abstract

In the pursuit towards efficient and environmentally sustainable energy conversion, artificial photosynthesis, involving hydrogen production from solar water splitting, has recently gained significant importance. Research in this field is aimed at solving the global energy crisis in an environmentally friendly way by using two of the most abundant natural resources, namely sunlight and water for the generation of clean, renewable and viable energy in the form of hydrogen through light driven water splitting.

Natural Photosynthesis

In nature, plants convert sunlight and carbon dioxide (CO_2) into oxygen and carbohydrate food source. Chlorophyll plays vital role in this process by capturing the energy of sunlight and allows it to be used to power the complex chemical reactions inside the plant. Plants then use this energy to make a compound called NADPH, repeatedly cycle between its two forms in order to bind oxygen to the carbon of carbon dioxide to create various forms of carbo-

hydrates. These carbohydrates are a very efficient source of chemical energy.

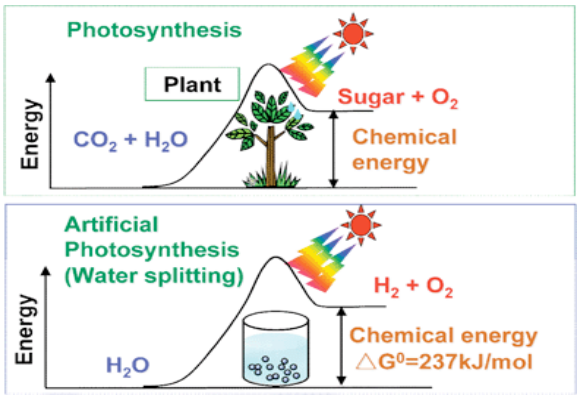

Figure 1. *Photosynthesis by green plants and photocatalytic water splitting as artificial photosynthesis (adapted from ref. 1).*

Artificial photosynthesis (Water splitting)

Artificial photosynthesis is a chemical process that replicate natural process of photosynthesis, means it convert sunlight, water and carbon dioxide into carbohydrates and oxygen.

Natural Photosynthesis $CO_2 + H_2O \rightarrow$ Carbohydrates + O_2 + Energy

Artificial Photosynthesis $H_2O \rightarrow H_2 + O_2$ + Energy

Thus artificial photosynthesis includes production of hydrogen by water splitting using sunlight. In its pure diatomic form (H_2) it can be used in fuel cells and hydrogen combustion engines to release its stored energy cleanly. Water contains mainly hydrogen and oxygen so no additional by-product is released during its decomposition and this makes this process cyclic and ecofriendly.

Water splitting process for H_2 generation has two major advantages:

1. Raw material is abundant and cheap
2. Combustion of hydrogen in air produces water

Overall water splitting reaction is given as

$H_2O \rightarrow H_2 + 1/2\ O_2 \qquad \Delta G^0$=238 kJ/ mole

Thus this is non-spontaneous reaction with large positive change in Gibbs free energy (ΔG^0)

History and ongoing research

In 1972, Fujishima and Honda achieved water splitting by photo electrochemical process using TiO_2 semiconductor as anode and Pt as cathode under UV irradiation.[2] After that semiconductor based material with suitable band gap has attracted much attention in this field. In order to make the utilization of solar energy efficiently many photoelectrochemical cells have been developed for hydrogen production and it was illustrated that band gap and stability play an important role in harvesting solar energy. Overall water splitting reaction takes place in three steps on the surface of semiconductor photocatalyst material as,[3]

1. The photo catalyst absorb photon energy greater than the band gap of semiconductor and electron-hole pairs are generated in the bulk
2. The photo-excited electron hole pairs separates and migrates to the semiconductor surface
3. The reduction and oxidation of the adsorbed species take place on the surface of semiconductor by the photo generated electron and hole pairs

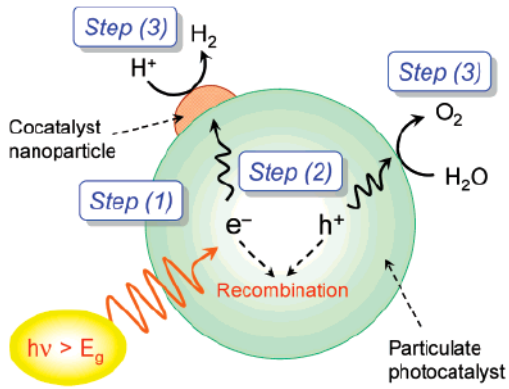

Figure 2. *Hydrogen generation on the surface of semiconductor photocatalyst (adapted from ref. 4).*

The most important point in achieving water splitting is the position of VB and CB in semiconductor materials. The bottom level of CB must be more negative than redox potential of $H^+ \rightarrow H_2$ (0 V vs NHE, where NHE refers to normal hydrogen electrode), while the top level of VB must be more positive than oxidation potential of $H_2O \rightarrow O_2$ (1.23 V vs NHE). Therefore 1.23 eV is the minimum band gap for water

splitting and this band gap correspond to the light of 1008 nm wavelength (near IR region).[5]

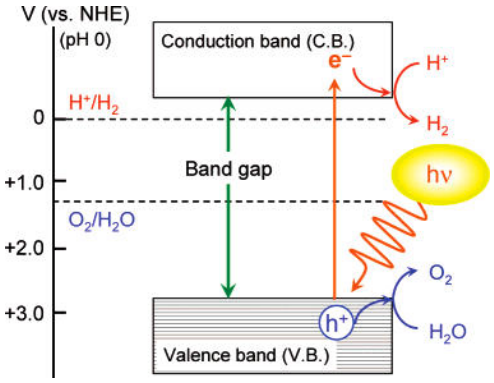

Figure 3. *Suitable band gap positions of semiconductor for hydrogen generation through water splitting (adapted from ref. 4).*

Conclusion

Thus artificial photosynthesis can be described as creating tomorrow's solar fuel today. Although a huge number of photocatalysts have been explored for hydrogen generation by solar water splitting, but the significant breakthrough in harvesting solar energy still needs to achieved, because of some limitations, such as reaction feasibility to generate hydrogen and hydrogen storage to make its utilization as clean, renewable energy source, need to be overcome. Hope in the near future, we will have sustainable energy in the form of hydrogen.

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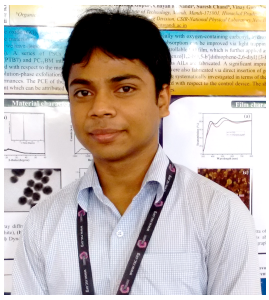
Recent Advances in Organic Photovoltaics

Abdus Salam Sarkar, *Ph.D., IIT Mandi*



Mr. Abdus Salam Sarkar did his B.Sc in Physics from University of Calcutta and M.Sc. in Physics from Department of Physics and Astrophysics, University of Delhi. Currently, he is pursuing Ph.D. under the supervision of Associate Professor Dr. Suman Kalyan Pal in School of Basic Sciences, Indian Institute of Technology Mandi. He has keen interests in organic photovoltaics. Currently, his research interests are focused on physics of novel organic semiconductors and organic solar cells.

Finding clean and renewable energy sources has become one of the greatest challenges of our modern society, due to the rapidly increasing energy demand and the limited reserve of traditional fossil fuel sources (coal, oil and natural gas). Technologies that harvest the clean, renewable and abundant solar power are among the most attractive methods to solve this energy challenge. Among those technologies, photovoltaic (PV) cells, or solar cells, which directly convert solar energy to electricity, have emerged as a promising candidate. Currently, inorganic solar cells are dominated photovoltaic (PV) technologies commercially available due to the high efficiency and long term stability. However, the high cost of inorganic solar cells and related environmental issues partially impede their pace to widespread deployment, which spurs research effort to explore alternative approaches given the growing demand for power worldwide. Organic solar cells, in particular thin film polymer solar cells (PSCs) hold promise for fabricating lightweight and flexible devices via the low-cost and high-throughput roll-to-roll production process. Due to these advantages, extensive research efforts around the world have been devoted to understanding and improving the performance of PSCs in the last two decades. In the thin film PSCs the active layer (organic materials) is sandwiched/stacked between two electrodes. The first successful bilayer organic photovoltaic device was reported by Tang in 1986 with a power conversion efficiency (PCE) of about 1% [1]. After six years in 1992 Heeger and Wudl suggested the use of composite materials containing both conjugated polymers as electron donors and fullerene derivatives as electron acceptors (D/A), so-called bulk heterojunction (BHJ) in PSCs [2].

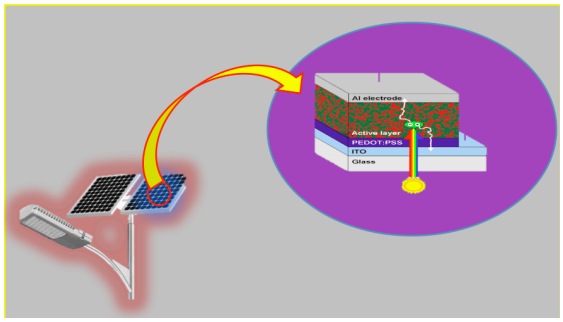


Figure 1. *Schematic device structure of polymer solar cell*

Figure 1 shows the schematic device architecture of a conventional thin film PSCs. Where indium tin oxide (ITO) coated glass substrate as a transparent conductive electrode, PEDOT:PSS as an electrode interface layer, blended materials as an active layer and a metal electrode.

The photovoltaic effect involves generation of electrons and holes in a semiconductor device under illumination of sunlight, and subsequent charge carrier collection at opposite electrodes. The general mechanistic picture summarized up as following essential steps:

- Photon absorption
- Exciton (electron-hole pair) generation
- Exciton diffusion and dissociation into free charges (charge separation)
- Charge carrier transport to the electrodes
- Charge carrier extraction and collection at the respective electrodes

Photon absorption of organic optoelectronic materials often creates bound electron–hole pairs (i.e. excitons), which diffuse and dissociate into free charges at D/A interface. These transported free charge carriers are then collected at the respective electrodes.
The electric current that a photovoltaic solar cell delivers corresponds to the number of created charges that are collected at the electrodes. This number depends on the fraction of photons absorbed the fraction of electron-hole pairs that are dissociated, and finally the fraction of (separated) charges that reach the electrodes determining the overall photocurrent efficiency. The fraction of absorbed photons is a function of the absorption spectrum, the active layer thickness, and of internal multiple reflections at metallic electrodes. The fraction of dissociated electron-hole pairs on the other hand is determined by whether they diffuse into a region where charge separation occurs and or the charge separation probability there. The absorption of the organic semiconductor can be tuned by using novel organic semiconducting polymers. However the photogenerated charge carriers are efficiently extracted and collected at the electrodes, thus opening gates to develop efficient electrode materials. Supramolecular chemistry might be a powerful approach to address these issue.

Tremendous progress has been made recently in almost every aspect of PSCs. Continued development of novel polymeric/organic materials, optimization of device structures and improvement of fabrication techniques have steadily increased the power conversion efficiency (PCE) of PSCs. The current challenge is to achieve a high photo current generation, efficient charge transport and collection while maintaining a higher PCEs and device stability in PSC devices. To date, the PCEs reported in the scientific literature for single, double or triple junction based solar cells are around 9%, 10% and 11% [3-5] respectively. In order for PSCs being competitive with conventional photovoltaic technologies based on silicon or other inorganic materials, the efficiency and lifetime of PSCs still need to be improved significantly.

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Nanotechnology and its Future

Ashish Tiwari, *Ph.D. Scholar, IIT Mandi*

Mr. Tiwari is pursuing his Ph.D. under the supervision of Dr. Jaspreet Kaur Randhawa in School of Engineering, Indian Institute of Technology Mandi. He had completed his M.Tech. at CIPET, Bhubaneswar in polymer nanotechnology. In his Ph.D. he is working on nanomaterial for biomedical applications. His research interest areas are nanotechnology and nanomedicine.

Nanotechnology, a scientific concept first proposed by Richard Feynman that "there is Plenty of Room at the Bottom" was later promoted by Erik Drexler in his book "The Engines of Creation." The book outlined widely about the possibility of nanomachines capable of doing pretty much like anything. Today nanotechnology is still in an influential phase and maturing rapidly. Between 1997 and 2005, investment in nanotechnology research and development around the world soared upto 4 billion dollars. Till 2016, market products integrating nanotechnology will contribute approximately 1 trillion dollars to worldwide global economy and about two million people will be employed in nanotechnology industries and that of many will have supporting jobs as well. Accounts of nanotechnology typically illustrate it in terms as tiny size of the physical features with which it is concerned likewise assemblies among the size of an atom about nanometer in size. This portrayal makes it sound as nanotechnology is simply looking to use infinitely smaller parts than conventional technology. But at this scale, modulating atoms and molecules specifically leads to new properties, which enable a transition between the fixed and adaptable behavior of individual atoms in materials. To state further, nanotechnology might be regarded as the application of nanospecific phenomena to deeply control the behavior and properties of matter respectively. Over time, nanotechnology should be beneficial for every industrial sector and importantly in health care field. From the environmental point of view, with respect to human being, nanotechnology will bring a revolution towards more efficient uses of existing energy resources and enable better alternates for their utilization more or less in a proper way. The nanotechnology will expand to include nanosystems in which molecular structures serve as distinct devices. Electronic devices, computers and robots could be reduced to extremely small sizes. Biomedical applications and disease therapies might be as ambitious as new types of surgical treatments. Nanotechnology does, however, stance new challenges to risk researcher community as well. Technically, ample work is required to update the scientific information needed to resolve the obscurities and to review proper regulatory oversight. Eventually, serving people to perceive nanotechnology gravely in a big depiction that retains human ethics and quality of life will also be important for this influential technology to live up to its astonishing potential. Of course, there is a long way to go and we are not even close, progress has been continuing in some surprising ways for its useful executions in nanotechnology.

OLEDs for Display Application and Solid State Lighting

Dr. Subrata Ghosh, *Associate Professor, School of Basic Sciences, IIT Mandi.*

Dr. Subrata Ghosh received his Ph.D. from IIT Guwahati and various Post-Doc from Bar-Ilan University, Israel, Case Western Reserve University, USA and AvH Fellow, University of Leipzig, Germany during the period 2006-2010. The material development for OLED application is one of his many explored research areas.

and

Sunil Kumar, *Ph.D. Scholar, School of Basic Sciences, IIT Mandi.*

Mr. Kumar is doing Ph.D. under Dr. Ghosh. His work focuses on development of organic material designs for OLED application.

Abstract: Organic light emitting diode (OLED) is a flat light emitting technology, made by placing a series of organic materials between two conductors and when electrical current is applied, a bright light is emitted. OLEDs have attracted considerable interest owing to their promising display applications. Despite the remarkable improvements in OLED performances, the quest for small molecule with stable and efficient colour emission continues to hold the attention of a number of research institutions. In this context, the present article gives an outline of the OLED materials developed at IIT Mandi. The noble material design concepts have been successfully utilized for the development of green and white light emitting OLEDs.

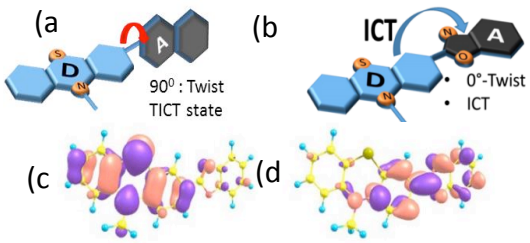
One of the promising and emerging fields is the OLEDs in the field of organic electronics. The highly luminous OLEDs are becoming more and more energy efficient lighting and display devices. The major reason for their popularity among scientific and industrial world is their energy efficiency along with efficient luminous flux produced from stacked organic materials within small OLED devices.

Since the introduction of electroluminescence property of organic compounds in 1987 by Tang and VanSlyke [1], the library of organic emissive materials has expanded vastly. Today, a lot of interesting applications have emerged and became available on the market which comprises these tiny OLED devices. Common examples that we see around us include smartphones, tablets, flat TV sets and many more electronic equipment having display screens along with the recent OLED solid state lighting devices. The awe-inspiring proportion of organic materials used is metal complexes, oligomers, polymers and small molecules. Thus, it is not wrong if we say that the current state of art is the development more efficient materials for the OLED fields.

As said, OLEDs are electronic devices, and hence the comprising compounds should be conducting in nature. Therefore, the organic materials used within a device are generally π-conjugated aromatic units which facilitate charge transport on these molecular structures, and the recombination of charge carriers on the emissive organic layer generates the light. Organic emissive materials are either efficient solid state emitters or solution sate emitters. But the archive of materials having emission property in both states is still limited and needs to be reinforced. To make OLEDs more energy efficient, material design strategies have to be developed to maximum extent. The organic OLED emitters generally comprise of electron donor (D) and acceptor (A) units connected covalently and, in this arrangement charge flows from donor to acceptor which is called intramolecular charge transfer (ICT). The ICT process is responsible for light emission from the molecules. But the covalently linked aromatic systems through single or double bonds tend to have twist between donor and acceptor units and form non-emissive TICT (twist intramolecular charge transfer, Scheme 1) state. It is a very rare instance that the D-A units share the same plane

and has molecular orbitals (MOs) on donor and acceptor units, respectively. It is considered that such planar emitting core can have efficient ICT (Scheme 1) and solution emission property. But planar molecules form π-π stacks [2] in solid and loose the emission property. Thus, if protected from π-π stacking, such molecular design can have dual state emission property.

In this regard, we successfully designed and synthesized a zero twist (planar) luminophore, **DA1** (Scheme 1 and Fig. 1) having segregated molecular orbitals (MOs) on donor and acceptor units, respectively [3]. The MO segregation imparted active ICT property for efficient solution state emission. The fluorescence emission of **DA1** was at 501 nm (quantum yield: Φ = 0.7). But the solid state emission of **DA1** was quenched (Φ = 0.02) which is due to the formation of aromatic stacks and intermolecular interaction. In the next step, the new compound, **DA2** (Fig. 1) was synthesized which had an



Scheme 1: Schematic showing the dark TICT state (a) emissive planar ICT state (b) and segregated HOMO and LUMO of **DA1** (c, d)

aromatic unit at a perpendicular plane to the plane of molecular plane to prevent π-π stacking. It was observed that **DA2** (Φ = 0.90) also had emission like **DA1**in the solution state, but the solid state emission of **DA2** (Φ = 0.33) was much enhanced as compared to **DA1**.

Finally, OLED devices [4] were fabricated having structure: ITO/F4TCNQ/α-NPD/**DA1** and DA2 / TPBi /Alq3 /LiF/ Al. The device comprising **DA1** had maximum current (CE_{max}) and power efficiency (PE_{max}) of 0.12 cd/A and 0.04 lm/W with $CIE_{x,y}$ = 0.28, 0.51. As expected, the device comprising of **DA2** as emitter had CE_{max} = 0.85 cd/A and PE_{max} = 0.24 lm/W with $CIE_{x,y}$ = 0.32, 0.55. Both devices showed low turn on voltage of 4V. The working OLED pixel is shown in Fig. 2. Thus, the compound **DA2** exhibits a bright future as green OLED emitter.

White light generation is also important for fancy home interiors but single molecules capable of emitting white light are very rare. In

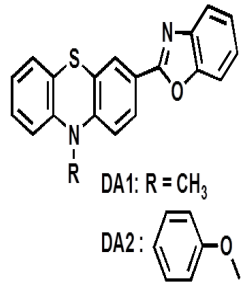


Figure1: *Molecular structure of compounds* ***DA1*** *and* ***DA2***

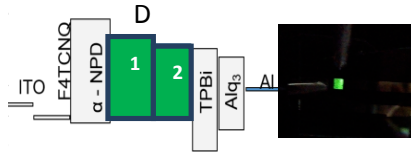


Figure 2: *Schematic of the devices used and glowing OLED pixel.*

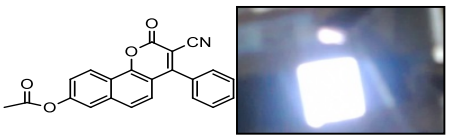


Figure 3: Synthesized coumarin derivative with the working white light emitting OLED pixel.

another work toward white OLEDs, a noble coumarin comp- ound (Fig. 3) was synthesized from a non-emissive coumarin dye. In the device structure ITO/ αNPD/s- CBP: 1% **Coumarin**/ PBD /LiF/Al, the generation of pure white light from a single molecule (coumarin) was observed [5].

Altogether, the ongoing research demonstrates a novel design strategy to prevent planar solution emitter from concentration quenching in aggregate state through integration of suitable stacking controller into molecular backbone for the potential OLED device application.

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INTERVIEW with Shubham Ajmera, Software Engineer at Google

Shubham Ajmera is an IIT Mandi graduate of batch of 2011-15 in Computer Science and Engineering. Software giant Google has offered him a "Software Engineer" role at the Google headquarters located at Mountain View in California. He is currently working in the Android Runtime team. He is resident of Jaipur, Rajasthan.

By Prashant Kumar

What inspired you to choose Computer Science and Engineering?

Computer Science demands logic, reasoning and questioning. It stimulates our thought processes and allows us to be creative and convert crazy ideas into reality. Since the very beginning, I wanted to be in a field wherein I could use my logical and mathematical abilities and hence I chose Computer Science.

Please tell about your Journey at IIT Mandi

I've had an amazing journey at IIT Mandi. I learnt from the awesome teachers at IIT Mandi and also made great friends along the way.
There were both ups and downs both but when I look back, the journey's been all worth it.

What is your next goal?

Well, there's a long way to go. I've just started now. Though I am not very sure what I'll do next. I'm considering several options like academia, startups and also other ladders at Google. Let's see how things turn out!

Please tell about the Google recruitment and selection process you have gone through.

I had participated in Google APAC University Aptitude Test held on August 2014 and got the interview call. I was called for the onsite interviews at Google Bangalore office on 5th December 2014. There were 4 technical rounds and I got my result on 19th December 2014.

How much the courses at IIT Mandi were helpful to be hired at Google?

Courses in the last 2 years at IIT Mandi were very helpful. Courses like Operating Systems, Networks, Systems Practicum, Big Data, Distributed Systems etc. were

helping in giving me a strong base in Computer Science, which in turn helped me in my technical interviews.

How is your experience of working at Google?

Its great working at Google. Apart from the free food and the great offices spaces (I got a chance to visit 7 Google offices across the world since I joined, the work I do is very interesting and impactful. I am currently working in the Android Runtime team, which manages Android compiler and Java. The people working at Google are smart and helpful, and the icing on the cake is to be able to see, listen to and meet with people in Computing who I grew up admiring.

Please share some preparation strategies for future aspirants for hiring at Google?

Google not only tests the programming skills, but it also focuses design, and core CS topics like OS, Networks, Databases. For improving programming skills I would recommend to participate regularly in contests like CodeChef CookOffs. For more information, you can also refer my interview - https://goo.gl/A0zq8c

ISTP - A Unique Course Curriculum at IIT Mandi (Interactive Socio-Technical Practicum)

IIT Mandi has a unique course curriculum wherein the interdisciplinary academic culture is encouraged and the curriculum is substantially oriented towards design and innovation. ISTP course is run in collaboration with the Worcester Polytechnic Institute (WPI), U.S.A. since 2013, with faculties and students from WPI visiting India to work jointly with IIT Mandi mentors and students on a variety of socio-technical projects for a period of two months every year.

ISTP exposes students to the complex interactions of technology and society. It equips the students with the tools and skills to systematically understand and evaluate these interactions. On a higher plane, ISTP is intended to,

- Sensitize students with the problems around them in their society,
- Develop a sense of responsibility by being the solution provider,
- Nurture the qualities required to become an excellent engineer or technocrat who contributes to society in a variety of ways.

For more details about ISTP, please visit: http://www.iitmandi.ac.in/istp/index.html

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Nestled in the Sivalik Range of the Himalayas, away from the bustle of the metropolis, a new abode of learning has germinated. A few hours before the Himalayan resort Kullu in Himachal Pradesh, IIT Mandi has been established with the vision to be a leader in science and technology education, knowledge creation and innovation, in an India marching towards a just, A inclusive and sustainable society.

SCALING THE HEIGHTS