# INDIAN NATIONAL ACADEMY OF ENGINEERING

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## INAE Monthly E-News Letter Vol. VII, Issue 8, August 1, 2016

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From the Editor's Desk

Why some minds are more beautiful?

Beautiful minds have existed since the time immemorial. These minds are often ahead of time, unpredictable, misunderstood and limited. Leonardo Da Vinci, apart from painting studied anatomy, biology, mathematics, and engineer Read more...

Purnendu Ghosh

Chief Editor of Publications



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It can't only be the senses that are the differentiators between an ordinary mind and a beautiful mind. It is true that resolve and effort makes one different from the other, but there is something else besides resolve and effort that makes one different from the other. Ernst Schumacher writes, "Beethoven's musical abilities, even in deafness, were incomparably greater than mine, and the difference did not lie in the sense of hearing; it lay in mind." Is it only the mind that makes all the difference?

One view is that "greatness requires enormous time". It suggests that anyone who works hard enough over a long period of time can end up at the top of the field. It simply means that if you have time and you are willing to spend it on something special, there are good chances of achieving it. There is yet another view that says that "achievement is not just hard work: the differences between performance at time 1 and successive performances at times 2, 3, and 4 are vast, not simply the result of additional sweat." According to this view talent and expertise are necessary but not sufficient to make someone original and creative. Perhaps cognitive psychologists will be able to tell us more about the psychology of motivation. We use many tools and data to arrive at a conclusion. We are polymathic. Engineering is polymathic; "further afield your knowledge extends the greater potential you have for innovation."

## ACADEMY ACTIVITIES

**Creation of Data for INAE Expert Pool**

INAE Expert Pool was created with the aim of identifying domain experts in various disciplines of engineering. There has been a good response from the Fellows and Young Associates in uploading their particulars on the INAE Expert Pool website. The INAE Fellows and Young Associates who have not uploaded their particulars are requested to submit their profile details online at the link http://inae.in/expert-search/index.php/inae-members-form

The details of the INAE expert Pool have since been shared with DST, TIFAC, Niti Aayog and Office of PSA. The creation of the website on Expert Pool has been appreciated by all the agencies and the data would be used by them in identifying suitable domain experts and involve the experts in their activities.

**Round Table on "Clean Coal Technologies in India: Current Status, Demands and Aspirations – Pathways to Achievements" held on June 10, 2016 at New Delhi**

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*Dr Baldev Raj, Director, NIAS addressing the audience. Seated (L to R) Brig Rajan Minocha, ED,INAE; Dr BN Suresh, President, INAE; Dr R Chidambaram, PSA to Govt. of India and Prof Ashutosh Sharma, Secretary, DST*

DST requested INAE to provide engineering interventions required in the field of 'Clean Coal Technologies'. Accordingly, a Round Table meeting on "Clean Coal Technologies in India: Current Status, Demands and Aspirations – Pathways to Achievements" under the chairmanship of Dr. Baldev Raj, Immediate Past President, INAE was conducted on June 10, 2016 wherein about 35 domain experts from Industry, Academia and R&D participated. With this, INAE would be able to provide inputs to the DST on the existing state of technologies in the country, technologies available internationally and the short-term and long-term plans for adoption of technologies in the field of Clean Coal Technologies. The e-proceedings are being released shortly.

*Prof Ashutosh Sharma, Secretary, DST Addressing the gathering*

*Dr R Chidambaram, PSA to Govt of India delivering his Address*

**10th National Frontiers of Engineering (NatFoE) Symposium**

## Tenth National Frontiers of Engineering Symposium

(10th NatFoE2016)

23-25 June 2016/IIT/Kanpur

Organized by

Indian National Academy of Engineering & Indian Institute Of Technology Kanpur

1st Row (L-R) DEBDEEP MUKHOPADHYAY, Dr.DEBRUPA LAHIRI, VIKRANTH RACHERLA, Dr. DEEPA VENKITESH, Dr. RAM GUJJULA, YOGESH NIMDEO, Dr. ASHUTOSH KUMAR DUBEY, Dr. NAVANEETHA KRISHNAN S, Dr. SHIVANANDA WAGLE
Dr. RAVI HEGDE, Dr. ANSHU GAUR, Dr.ASHUTOSH TRIPATHI, Dr. VITHYASAAHAR SETHUMADHAVAN

2nd Row (L-R) GAURAV CHOPRA, AKSHOY RANJAN PAUL, SHIKHA AWASTHI, ADITI PANDEY, Dr. GURURAJ TELASANG, Dr. NIMISH DIXIT, ALOK DIXIT, AMIT KUMAR, Dr. RONITA BARDHAN, Dr. SOURABH GHOSH,
DR. RIDDHI SINGH, SHIJO THOMAS, Dr. MANISH KULKARNI, Dr. RAJESH KRISHNAN, ANUJ JAIN, NAVROSE

3rd Row (L-R) Dr. ARVIND PATEL, Dr. A. K. DUTTA, Dr. ANIL PRABHAKAR, Dr. YOGESH JOSHI, Dr. SANJAY MITTAL, Dr. KANTESH BALANI, Dr. BIKRAMJIT BASU, Dr. SANDIP PATIL, Dr. ARUN K. SRIDHARAN, DHANANJAY UMRAO

The *Tenth National Frontiers of Engineering 2016* Symposium was organized, at Indian Institute of Technology (IIT) Kanpur, in four thematic sessions: (i) Multifuntional Biomaterials Technology, (ii) Laser Engineering and Technology, (iii) Flexible Electronics, and (iv) Smart Cities. Prof Sanjay Mittal, FNAE was the Coordinator of the event along with Prof Yogesh Joshi and Prof Kantesh Balani of IIT Kanpur. The event started on the afternoon of June 23 and ended at noon on June 25, 2016. It was attended by 45 participants from various institutes. The event began with welcome remarks by Prof. I Manna, Director IIT Kanpur and Vice President INAE and Prof S.C. Srivastava, President INAE, Kanpur Chapter. The inaugural-talk was delivered by Dr. A. Mathur, DG, TERI, on "*Energy for tomorrow: The Changing Nature of Energy Demand in India*". Two pre-Dinner talks were delivered by (i) Prof. Vinod Tare on "*Playing with Water and Water Bodies: For Life and for Business*", and (ii) Prof. Milind Sohoni on "*Knowledge, Culture and the Development Question*". A panel discussion was held on the last day: "*International collaboration*".

Welcome address during NatFoE 2016 by Prof. Indranil Manna, on Jun. 23, 2016 at IIT Kanpur

Pre-dinner talk being delivered by Prof. Vinod Tare during NatFoE 2016 on Jun. 23, 2016, at IIT Kanpur.

Each of the four thematic sessions consisted of an introductory presentation by the session organizers followed by four talks and discussion/interaction session. The session organizers (one each from academia and industry) ensured balance of talks on academic and applied aspects. The format of the symposia encouraged informal collective as well as one-on-one discussions among participants. Speakers focused their talks on current cutting-edge research in their disciplines to colleagues outside their field and to address questions such as: What are the major research problems and distinctive tools of their field? What are the current limitations in advancing their field? How might insight derived from other fields contribute to overcoming these limitations?

**National Workshop on "Towards Self-Reliance in Advanced Ceramics for Strategic Sectors"**

The National Workshop on "Towards Self-Reliance in Advanced Ceramics for Strategic Sectors" was organized by INAE in association with Vikram Sarabhai Space Centre on July 14-15, 2016 at Thiruvanthapuram. Shri AS Kiran Kumar, Chairman, ISRO and Secretary, DoS; Dr S Christopher, Secretary, DoD (R&D) & Director, General, DRDO and Dr BN Suresh, President, INAE were the Patrons of the Workshop. Ceramic experts and end users across the nation mainly in the strategic sector participated in the workshop. The event featured invited talks by eminent experts on topics related to processing, characterization and application of advanced ceramics. A Panel discussion was convened among professionals to work out future directions and formulate a comprehensive approach towards meeting goals of self-reliance in advanced ceramics.

**Engineers Conclave 2016**

Engineers Conclave 2016 is being held at Indian Institute of Technology Madras during Sep 1-3, 2016. Prof. Bhaskar Ramamurthi, FNAE, Director, IIT Madras and Dr BN Suresh, President, INAE are the Co-Chairs of the Engineers Conclave 2016. The themes of the Conclave are "Engineering Education 2020" being coordinated by IIT Madras and "Smart Cities" being coordinated by INAE. Prof. MS Ananth, FNAE is the Coordinator from IIT Madras for Theme I on "Engineering Education 2020". Theme I on Engineering Education 2020 shall have the following sub-themes: Industry Expectations; Curriculum and Flexibility; Pedagogy; Start ups; Research Excellence; Quality Control; Skill Development and International Comparisons. Prof Prem Krishna, FNAE is the Coordinator of Theme –II on "Smart Cities" which shall have the following sub-themes- e-Governance/ICT Enabling; Urban Water Management; Healthcare/Sanitation; Transportation & Infrastructure and Energy & Ecology. During the deliberations in the theme "Smart Cities" executives of the Ministry of Urban Development shall participate. The Conclave shall provide an opportunity for a close interaction between technologists and the Chief Executives of chosen cities under the "Smart Cities Project" of Government of India. An invitation for participation in the Engineers Conclave 2016 has been sent to all INAE Fellows.

**INAE Annual Convention**

This year, the INAE Annual Convention is being held at Space Applications Centre (SAC), Ahmedabad on Dec 8-10, 2016 which will be preceded by Governing Council meeting on 7th Dec 2016. Mr. Tapan Misra, Director, SAC has kindly consented to host the event. The details of the event will be forwarded shortly.

**Annals of INAE**

The soft copy of the Annals of the INAE Volume XIII, April 2016 containing the text of the lectures delivered by Life Time Contribution Awardees; Professor Jai Krishna and Prof. SN Mitra Memorial Awardees, newly elected Fellows of the Academy and INAE Young Engineer Awardees during the year has been uploaded on INAE website under the Publications sub-head. The same can be downloaded from the link https://www.dropbox.com/s/b3vyi5d029krakf/Annals%202016.pdf?dl=0

**Research Journal -INAE Letters**

The Agreement for publishing the Research Journal "INAE Letters" has been concluded with M/s Springer as approved by the Governing Council. The website for the Research Journal "INAE Letters" to include facility for submission of papers online has been launched. The first issue of the Research Journal "INAE Letters" will be released on Sep 1, 2016 at IIT Madras, Chennai during the sidelines of the Engineers Conclave 2016. The soft copy of the INAE Letters can be viewed at the link http://www.springer.com/engineering/journal/41403

**Opening of Facebook and Twitter Accounts by INAE**

The Department of Science and Technology (DST) has recommended enhancing Social Media Optimization through creation of Facebook and Twitter accounts. Accordingly a Facebook page and Twitter Handle for INAE have been created. All INAE Fellows are requested to visit the page and post their comments, if any. The Facebook page of INAE can be viewed at https://www.facebook.com/pages/Indian-National-Academy-of-Engineering/714509531987607?ref=hl and Twitter handle at https://twitter.com/inaehq1

**Important Meetings held during July 2016**

- INAE Corpus Fund Committee meeting was held on July 18, 2016
- Meeting of INAE Forum on Technology Foresight and Management was held on July 19, 2016
- Selection Committee for shortlisting of Nominations for Innovative Student Projects Award was held on July 20, 2016
- INAE Apex Committee Meeting was held on July 20, 2016

**International Conferences/Seminars being organized by IITs/other Institutions**

To view a list of International Conferences/Seminars being held in the month of August 2016 click here.

**Honours and Awards**

The following INAE Fellows were selected for conferment of awards by the Selection Committee on Life Time Contribution Award in Engineering, Prof Jai Krishna/ Prof SN Mitra Memorial Awards and Outstanding Teachers Award during its meeting on June 16, 2016.

**Lifetime Contribution Award in Engineering 2016**

1) Dr PS Goel, Prof MGK Menon DRDO Chair, Honorary Distinguished Professor, ISRO, Raja Ramanna Chair Visiting Professor, NIAS, Bangalore and Formerly Secretary, Ministry of Earth Sciences and Director, ISRO Satellite Centre, Bangalore.

2) Dr VK Aatre, Formerly Scientific Adviser to Raksha Mantri, Ministry of Defence, New Delhi; Formerly Director, NPOL, Cochin and Former CC (R&D), DRDO, New Delhi

**Prof Jai Krishna Memorial Award 2016**

- Dr V Adimurthy, Honorary Distinguished Professor, ISRO and formerly Outstanding Scientist and Associate Director, VSSC, Trivandrum

**Prof SN Mitra Memorial Award 2016**

- Prof VS Borkar, Professor, Department of Electrical Engineering, IIT Bombay

**INAE Outstanding Teachers Award 2016**

1) Prof SK Sarangi, Director, NIT Rourkela

2) Prof SN Singh, Professor, Department of Electrical Engineering, IIT Kanpur

**News of Fellows**

| | |
|---|---|
| 1 | Prof. Amlan J. Pal, FNAE and Senior Professor, Indian Association for the Cultivation of Science, Kolkata was awarded with J C Bose Fellowship of DST, Government of India. |
| 2 | Dr DR Prasada Raju, FNAE Professor of Mechanical Engineering and Dean, MVGR College of Engineering, Vizianagaram and R&D Adviser, IIT-Madras has been assigned the role of Member Secretary of Programme Review and Monitoring Committee of Dept of Heavy Industry (DHI), Govt of India. This Committee will oversee implementation of a few major projects, partly supported by Industry, in the area of Advanced Manufacturing Technology. |

International Conference on Innovative Research in Material Sciences, Energy Technologies and Environmental Engineering for Climate Change Mitigation (GREENTECH-2016) on Aug 6, 2016 at New Delhi
http://www.conferencealerts.com/show-event?id=173054

International Conference on Distributed Computing, VLSI, Electrical Circuits and Robotics 2016 on Aug 13-14, 2016 at Mangalore
http://www.conferencealerts.com/show-event?id=166825

1st International Conference on Advanced and Intelligent Computing Technologies on Aug 25-26, 2016 at Bangalore
http://www.conferencealerts.com/show-event?id=172013

# Environmentally-Sustained Coal-Based Power Generation: what it takes?

Mukesh Sharma, PhD
Professor, Department of Civil Engineering
Indian Institute of Technology Kanpur, Kanpur 208016

India's economic growth has become the envy of the world. The economic growth has been fueled by relatively inexpensive electric power i.e. from coal. As per the estimates of Geological Survey of India, the coal reserves stand at 290 billion tonnes. In last two decades, coal consumption and demand have grown dramatically. The power sector accounts for over 80% of the total coal consumption in the country (over 400 million tonnes in 2012-13; CEA, 2013) producing over 760676 million unit (MU) of electricity in 2012-13(CEA, 2013).The erstwhile Planning Commission had planned an addition of over 88,000 MW of power generation capacity in the 12th Plan period (2012-17). It appears coal will continue to be at the pinnacle of our energy supply for many years to come.

Coal mining and combustion severely degrade the environment and results in an intangible cost, which is often ignored. However, the solace is that environmental regulations have moved from laxity to stringency, particularly in the last decade. Public at large, now more aware of ill effects of coal-based power generation, argue not in my backyard. There are social issues as well. Resource depletion and pollution generation at some pristine area to feed guzzling air conditioners in Delhi or any other metro is neither justice nor equality. For sustenance of dominance of coal-based power generation, there are several issues those need to be addressed. For engineers, bureaucrats and policy makers, time is not to ostracize environmental and social issues but to act.. Major environmental issues comprise air emissions and ash disposal. Emissions of air pollutants pose serious environmental concerns, and if not resolved, will cause degradation and can severely impact public and ecological health. Although environmental regulations may force pollution control actions, at times, laws are inadequate.

The important emissions from coal combustion include carbon dioxide ($CO_2$), nitrogen oxides ($NO_x$), sulfur dioxide ($SO_2$), air-borne inorganic particles such as flyash, and other trace elements, especially mercury. Through atmospheric chemistry, oxides of nitrogen and sulfur play an important role informing very fine particles along with ammonia and calcium, adding to already existing high levels of particulate pollution in our air. These ammonia-based particles may constitute up to 35 percent of total fine particles in air that we breathe.

Estimated emissions of major pollutants from coal-based power plants in the country are: 1.6 million tonnes of particulate matter, 1.5 million tonnes of $NO_x$ and 3.0 million tonnes of $SO_2$ every year and whopping over 160 million tonnes of flyash generation. These are large quantities. If we do not recognize this enormous environmental issue and not invest in technology, we pay through increased human morbidity and mortality. As seen, the coal-based power generation produces massive amounts of sulfur and nitrogen oxides, the convenient alibi not to control these gaseous emissions is sulfur and nitrogen dioxide levels in air are low. Science tells that sulfur and nitrogen oxides convert into fine particles of sulfates and nitrates posing greater health problem than the precursor gases sulfur and nitrogen oxides.

Mercury is the single important toxic metal emitted from coal combustion. Although air concentration of mercury may be low and be in safe limits, the airborne mercury deposits in rivers, lakes, oceans, and move up in the food chain and pose major health risk. Although present in trace levels in coal, approximately 148tonnes of mercury is estimated to be released in India by the year 2021(UNEP, 2014). The issue of environmental pollution, especially that of mercury, is compounded in the areas those concentrate power plants. The Singrauli area has an installed capacity of over 20000 MW of power and expected to be infested with high mercury pollution. Engineers and regulators need to understand that cleanup after-the-fact is hugely expensive and only option that we are left with is to clean it up at the source.

Technology can deal with the environmental issues and can sustain long-term coal-based power generation without compromising environmental quality and public health. The high efficiency technologies (particulate control efficiency exceeding 99.9%) are ESPs and fabric filters. An ESP electrically charges the ash particles (mostly negative) in the fluegas stream and particle migrates towards grounded plates where it is collected. The ESP consists of a series of parallel vertical plates through which the flue gas passes. The charging electrode is between the collecting plates and charges the ash particles. The local specificities such as ash content in coal, resistivity of the ash, size of ash particles, moisture etc. are important considerations in designing the ESP. Indian coal has high ash content and resistivity and these concerns should be inclusive while designing the Indian-version of ESPs.

$SO_2$ removal technologies include wet flue gas desulfurization (FGD), dry FGD utilizing a spray dryer absorber and dry adsorbent (lime and lime stone) injection. Most $SO_2$ removal processes are engineered oxidation systems which convert $SO_2$into calcium sulfate (CaSO4: gypsum) which is removed in ESPs. In a De-NOx-ing (removal of NOx) system, NOx is reduced by ammonia ($NH_3$) or urea to nitrogen and water. Based on economic considerations, a suitable reducing agent can be selected out of ammonia like materials. This process is called Selective Catalytic Reduction (SCR). SCR De-NOx-ing system consists of reactor, injection system and the catalyst.

Mercury removal remains a challenge and technology is in its infancy, largely because of economic consideration. During high temperature combustion in the furnace the major part of mercury is volatized in the form of gaseous elemental mercury ($Hg^0$) and is not readily removed by existing air pollution control devices. Activated carbon is most effective adsorbent for removal of $Hg^0$ but at the same time not affordable; to remove one kilogram of mercury could cost USD 30,000–$85,000 (year 1995 $;Romero et. al, 2006). There is a need that we develop non carbon adsorbents such as zeolite, calcium-based sorbents, fly ash, chitosan and other organic/inorganic adsorbents to remove mercury.

The other issue often ignored is the utilization and management of ash. While the regulation for ash utilization has proved effective and currently we utilize about 60 percent of the generated ash, mostly in cement industry and highway construction. Flyash contains high levels of toxic heavy metals such as arsenic, lead, selenium, and other trace metals. The discharge of fly into surface waters can disturb the ecology of the region. The flyash escaping into the atmosphere from chimney or from ash ponds settles down in the vicinity of the power plant and over a long period can bring about considerable changes in soil characteristics in addition to posing health hazards and nuisance.

The cost of pollution control including ash management needs to be internalized in the installation cost of power plant and pollution control be integrated with other parts of the power plant. A broad cost break (can vary significantly) is for every MW, the installation cost is about Rs 7.0 crore (including particulate control). For $SO_2$ and $NO_x$ control, an additional cost could be about 0.7 crore per MW, which is about 10 percent of the total cost. The cost of pollution control device may appear high but this possibly overshadows the cost of environmental degradation and cost of public health in terms of increased morbidity and mortality.

In view of the discussion above, all concerned, engineers, bureaucrats, and politicians have to come on board. Technologies for particulate and $SO_2$ removal are established, though not fully adopted in the country. Challenges remain for controlling NOx and mercury, especially from economic consideration. The focus of new generation of research should be on low cost non carbon mercury adsorbent which can effectively remove mercury. No alibi is acceptable for not controlling the emissions from power plants. Current and future technologies can provide effective solutions to arrest large air emissions. Adequate environmental protection can only sustain coal-based power generation in future.

It is apparent that fossil fuels will be with us until the alternatives can prove themselves. The intelligent strategy will be to invest in cleaning the coal combustion emissions for immediate benefits and at the same time let us *invest* in alternatives for future. Across the country, bright young entrepreneurs have ideas for alternatives to fossil fuels and to improve the efficiency of energy use. Let us move forth boldly to invest in the ideas that will carry the world to where we want to be.

References

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Romero, C.E. et al. 2006. Modification of boiler operating conditions for mercury emissions reductions in coal-fired utility boilers. Fuel, 85(2), pp.204–212.

UNEP. 2014. Assessment of the Mercury Content in Coal fed to Power Plants and study of Mercury Emissions from the Sector in India,

**Materials Sustainability and the Need for a National Life Cycle Assessment Initiative**

**S. Srikanth**

**Director CSIR-National Metallurgical Laboratory**

Never in the history of mankind has "Sustainability" become such a critical issue as it has today. Sustainability of life in the universe demands sustainability of natural resources including food, water, clean air and other material resources, sustainability of energy resources and sustainability of environment. However, the term sustainability is interpreted differently by different stake holders. A material scientist looks at sustainability from the prism of raw materials availability, an environmentalist from the perspective of environment, an economist from the point of view of cost, an agriculturist from the viewpoint of food, a biologist from the considerations of sustaining life and so on. Nevertheless today, there are universally accepted definitions for "Sustainability", the most common being that of the *World Commission on Environment & Development which defines sustainability as;*

"forms of progress that meet the needs of the present without compromising the ability of future generations to meet their needs"

Although this definition is broad, simple and elegant, it lacks details. I found a more lucid definition of sustainability in a review paper published by Patzek and Pimentel [1] in a review article in "Critical Reviews in Plant Science" in 2005 which is *given below:*

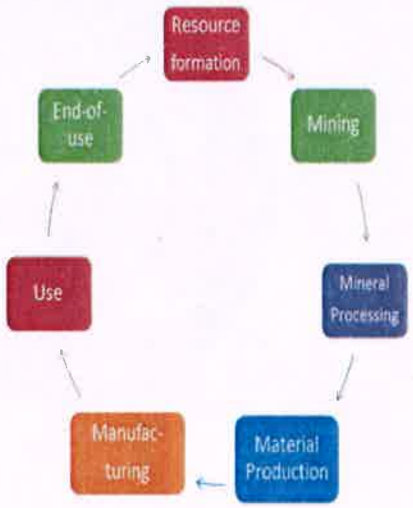
"A ***cyclic process*** is sustainable if and only if it is capable of being sustained, I.e., maintained without interruption, weakening or loss of quality **"forever"** and the **environment** the process feeds and to which it expels its waste is also sustained forever"

The essence of this definition lies in the three phrases *cyclic, forever and environment*. Although materials sustainability can be evaluated for the full life cycle of the process, practical considerations would warrant that the analysis is carried out *for the part of the cycle which is relevant within a finite & defined time period & only changes to the immediate environment is considered.*

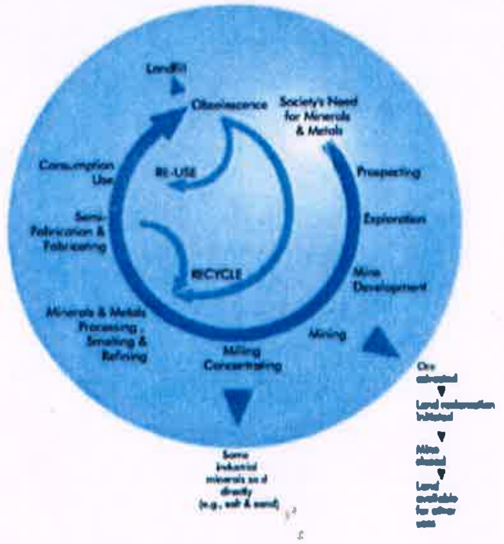
Sustainability can be applied to any resource such as food, water, land, natural resources, energy and environment as also processes or practices or services. However, in this article, I would restrict to only sustainability of materials especially in the context of mining, mineral processing and metallurgy.

The full life cycle of a material, more specifically a metal (after the formation of the universe through cosmological evolution) would comprise of ore formation through geological processes, mining, mineral processing, metal extraction, manufacturing, use and end-of-use which could be renovation/rejuvenation& re-use, recycling or burial back to earth and its subsequent geological transformation. Extrapolating the definition of Patzek and Pimentel to this context of materials would imply that:

"The cycle of ore formation, mining, mineral processing, metal extraction, manufacturing, use and end of life stages are maintained without interruption, weakening or loss of quality **"forever"** and no net **environmental** change is brought about by this cycle over a period of time".




**The Ideal Material Cycle**




**The Actual Material Cycle**

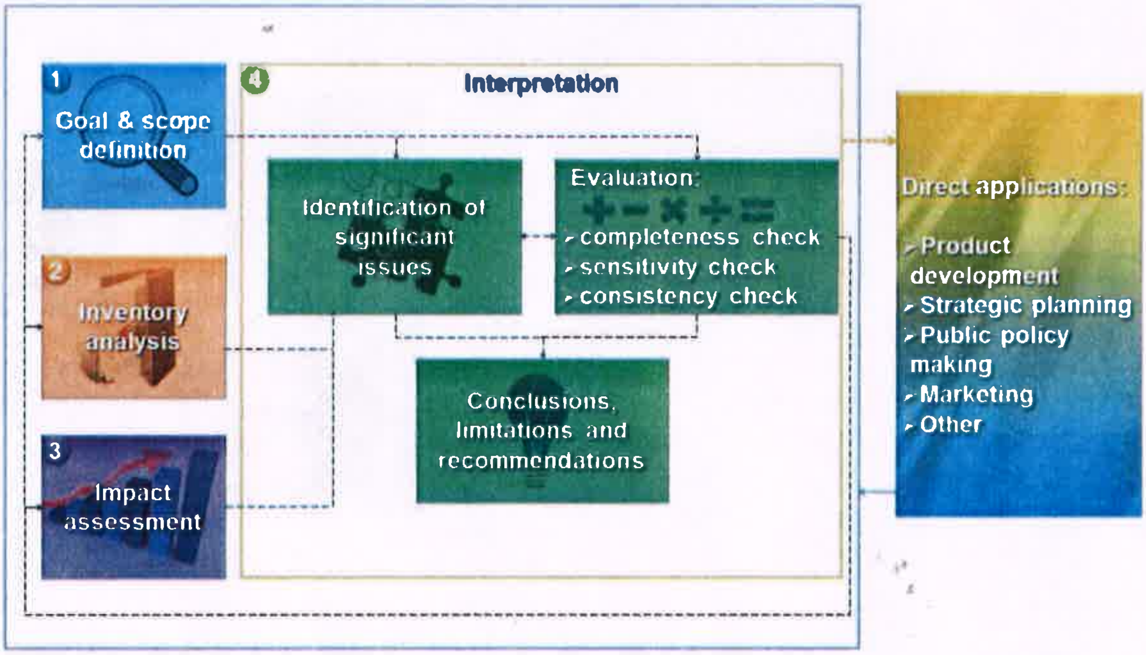
**(Fig Reproduced from Sustainable Development & Minerals & Metals. An Issue Paper by Natural Resources, Canada)**

I have in the past tried to address the thermodynamic, kinetic and environmental aspects of materials sustainability in terms of laws of thermodynamics, applying rate equations and Le-Chatelier's principle to the materials cycle [2]. However, in this article, my main emphasis will be on how to quantify and measure materials sustainability as well as to how to carry out an objective "Sustainability Analysis". The best method to assess and evaluate sustainability of a product or process cycle is through a "Life Cycle Assessment".

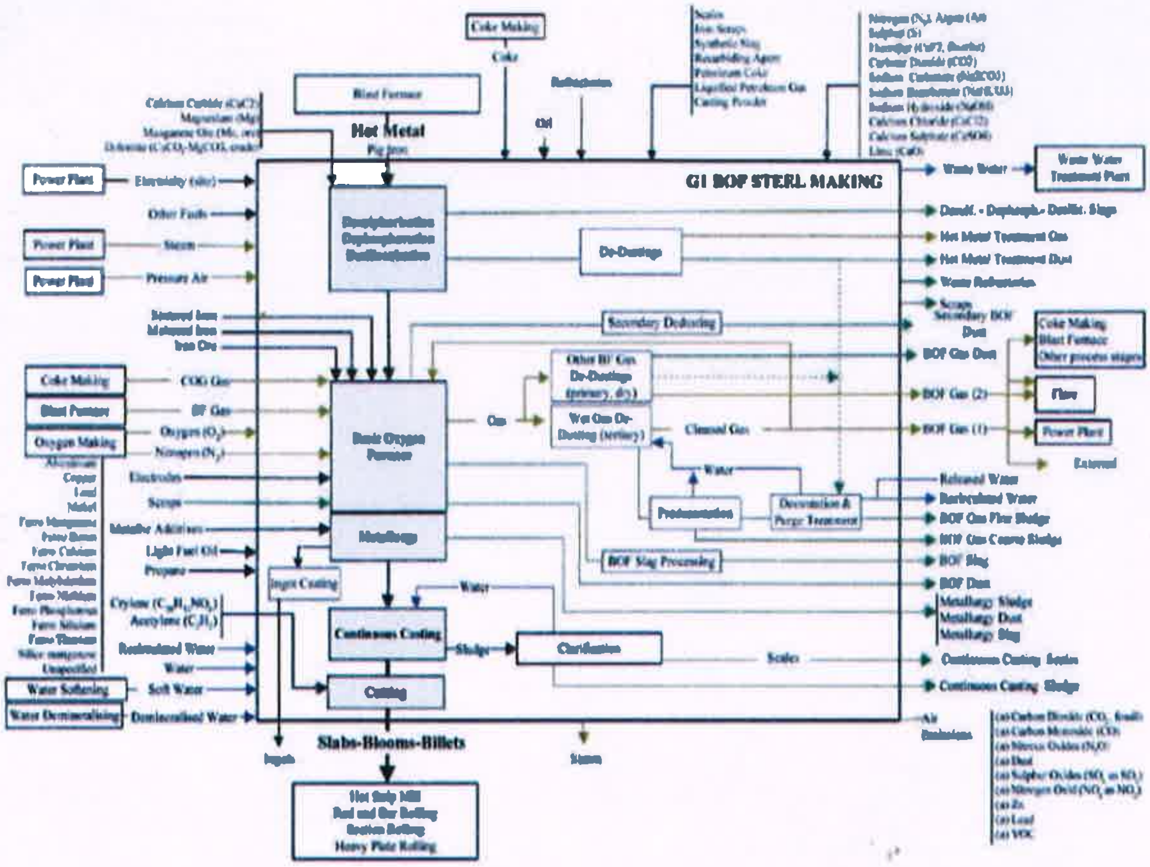
***Life Cycle Assessment***

Life Cycle assessment (LCA) is a process of compiling and evaluating the inputs, outputs and the potential impacts of a process cycle or product system through its life cycle. Impact analysis can include environmental impact, impact on natural resources, ecological impact, societal impact, economic impact etc. For any material, the life cycle as mentioned earlier will include the stages of mining, mineral processing, metal extraction or production, manufacturing, use and end-of-use.In each stage, there will be a large number of unit processes and product/material/energy flow between these unit processes. A process refers to the transformation of an input to an output and unit process is the smallest element considered in the life cycle analysis for which input and output data are quantified.*There is no single unique method for conducting LCA although 14040 series ISO standards provide guidelines*. The LCA procedure described below is largely based on ISO 14044 –2006 [3].

An LCA comprises of four phases"– the establishmentof the goals and scope of the assessment, the drawing up of materials inventory and energy balance for each unit process and for all stages of the life-cycle, evaluation of emissions and discharges for each unit process and for all stages of the process/product life cycle, an assessment of the impact and the identification of actions for improvement".LCA studies are relative in nature and based on a functional or reference unit. The functional (reference) unit can be a unit product, unit mass, unit length or any other physical parameter depending on the goal and scope of the LCA.




Definition of goal includes defining the intended application (eg., product development, strategic planning, public policy making, import-export decisions, marketing etc.) and objective, intended audience and whether the results are to be put up in public domain. The scope would include the description of the product system to be studied, the performance characteristics of the product system, the functional unit, the system boundary, procedures & methodologies to be used, interpretation methods and data requirements. Defining the system boundary involves specifying the unit processes of the system under consideration and the flow between the unit processes in the form of process flow charts. Although, it would be ideal to carry out such a study over the full life cycle ie., from cradle-to-cradle or even cradle-to-grave, in practice because of large differences in the time cycles of the various stages and geographical spread over which the various stages of the product cycle occur, this becomes virtually impossible. Whereas the time taken for the stages of mining, mineral processing, metal extraction and product manufacturing are in days, the use stage can be for tens of years and the resource formation stage takes millions of years. Further, the geographical locations where each of these stages is carried out are different and widely spread. Because of the difficulty in data collection over the vast geographical space and long time cycle, the studies are generally restricted up to the exit gate of the product, leaving out the "Use" and "End-of-Use" stages. It could be either a Cradle-to-Gate analysis or a Gate-to-Gate analysis. A typical "System Boundary" for a Gate-to-Gate analysis of Steel Making through the Blast Furnace – Basic Oxygen Furnace (BF-BOF) route reproduced from a LCA study by World Steel Association [4] is depicted below:




Even a simplified Gate-to-Gate analysis such as the one shown abovehas close to 270 unit processes [4] and one can imagine the level of complexity. Further, as mentioned earlier, the material life cycle has so many stages and each stage has several degrees of freedom as shown below:


Since each stage has several degrees of freedom, any one of them can be used for a life-cycle assessment. Therefore for the same material several LCA's are possible

The life cycle assessment is dependent on location, time, nature of technologies (mining, mineral processing, production and manufacturing technologies), nature of use and the end-of-use option exercised; carrying out a realistic life cycle assessment for the whole cycle from cradle-to-grave becomes virtually impossible.

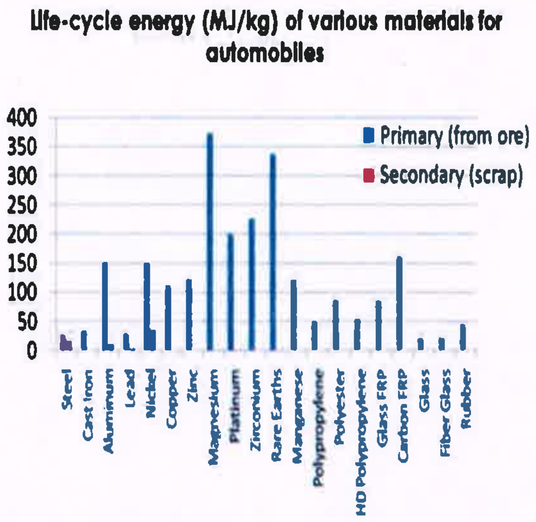
The heart of an LCA study is the creation of a Life Cycle Inventory (LCI) and the impact assessment protocols. In the Life Cycle Inventory phase, an inventory of input/output data is created for each unit process and for all the stages of the life-cycle. It involves the collection of the data for each unit process and the data is normalised against the functional unit. The input data for each unit process includes amount, composition and energy content of all raw material inputs, energy inputs, ancillary inputs and other physical inputs (such as air and water). The output data includes similar information on products & co-products, intermediate products, wastes, releases to air, water & soil and any other form of energy output. Depending upon the nature of the impact analysis carried out, one may require other data such as land use in each unit process, costs of inputs and outputs, noise and radiation generated if any during the process. The life cycle inventory stage includes data collection, data validation, normalising the data against the functional unit, relating the data to each unit process, and data aggregation. Data collection for each unit process can be through measurement, calculation, estimation or taken from literature. Data validation of each unit process can be accomplished through elemental mass balances, energy balances and/or by comparison with literature data. The input and output data if aggregated must also be related to each unit process, allocation of inputs and outputs made to the products & co-products and normalised against the functional or reference unit.

The objective of the Life Cycle Impact Assessment (LCIA) phase is to comprehend and assess the magnitude and significance of the potential impacts of a process/product system through the life cycle of the process/product. Although the most common and relevant impact is the Environmental Impact, life cycle impacts on climate change, human toxicity, eco-toxicity, depletion of natural resources, depletion of energy resources, on land degradation, on water resources and on cost can as well be evaluated based on the life cycle inventory data. The LCIA phase comprises of selecting impact categories, assignment of the LCI results to the selected impact categories, selection of category indicators and characterization models, calculation of the category indicator results and the final impact.After the selection of the impact category, the next step is to assign the LCI results to impact categories. There are LCI results that are exclusive to one impact category and there are LCI results that relate to more than one impact category. For example, concentrations of $CO_2$ and methane can be assigned exclusively to Global Warming Potential whereas $SO_2$ contributes to both Acidification and Eutrophication potential and CFC's contribute to both Global Warming Potential and Stratospheric Ozone Depletion Potential. In the assignment of LCI results, distinction must be made between parallel mechanisms (e.g. $SO_2$ is in parallel apportioned between the impact categories of human health and acidification) and serial mechanisms ($NO_x$can be classified partly to contribute to ground-level ozone formation and partly to acidification). The category indicators are quantified representation of the impact category. There are mid-point category indicators that are relevant in the short run and end-point category indicators that are relevant in the long run. For example, if the selected impact category is "Climate Change" reflected by Global Warming, the mid-point category indicator can be Infra Red radiative forcing ($W/m^2$) and end-point category indicator could be loss of life in years or fraction of species that has disappeared. The relevant LCI data for this purpose would be the output concentrations of $CO_2$, methane, CFC's and halogens for all the unit processes within the system boundary. Similarly, if one were analyzing the "Environmental Impact" of which one of the parameters is the Acidification potential, then the mid-point category indicator would be pH and end-point category indicator can be disappearance of plant species and the relevant LCI data are concentration of nitrogen oxides, sulphur di oxide, halogens, $H_2S$ etc. The calculation of indicator results or characterization involves the conversion of LCI results to common units and the aggregation of the converted results within the same impact category. For example, for the impact category of "Global Warming Potential", all the output data on $CO_2$, methane, CFC's and halogens is converted to kg-equivalent of $CO_2$. Similarly, for the impact category of "Acidification Potential", all the output data on nitrogen oxides, sulphur di oxide, halogens, $H_2S$ etc is converted to kg-equivalent of $SO_2$. This conversion uses characterization factors. Characterisation models describe the relationship between the LCI results, category indicators and, in some cases, category endpoint(s). Characterisation models have been developed and reported in the literature for most of the impact categories [5-7]. Some of the sources have a collection of characterisation models [8-14].For measuring climate change, there exists a characterisation model developed by the Intergovernmental Panel on Climate Change (IPCC) [5].

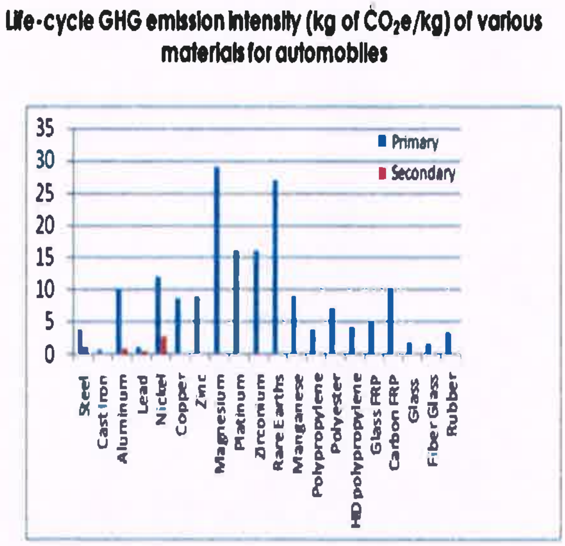
The Life Cycle Interpretation phases comprises of identification of the significant issues based on the results of LCI and LCIA, an evaluation of the completeness, consistency and sensitivity of LCI & LCIA, flagging the limitations and drawing up of conclusions and recommendations. The results are clearly sensitive to the exact assumptionsmade and the LCA results are context specific, place specific, time specific and technology specific.

Among the several types of impact analysis that can be carried out, the most relevant ones from an Engineer or Material Scientist's point of view is Environmental impact, Embodied Energy Analysis, Exergy Analysis, Material Flow Accounting, Embodied water Analysis and Life Cycle Costing.

**Embodied Energy** is the sum of all the primary energy consumed to produce any goods or services, considered as if that energy was incorporated or 'embodied' in the product itself ie., the primary energy consumed to mine, beneficiate, extract, process, transport, and produce a good (or service). It implies all the energy requirements associated with the production of the good or service. That includes the sum of the direct and indirect energy associated with the product or activity, i.e., all energy must be primary and traced upstream to their origin.One can similarly define embodied water for any product. The life cycle embodied energy of various materials used in automobiles and the GHG emission impact thereof is given below [15]:




Data from Keoleian & Sullivan, MRS Bulletin, 37, 2012, p.368




Data from Keoleian & Sullivan, MRS Bulletin, 37, 2012, p.368

Note that steel has one of the lowest life cycle embodied energy among all the materials used in automobiles including Al and Mg. Although light alloys of Al and Mg consume less energy in the "Use" stage compared to Steel, they consume four to six times the energy as Steel in the production and manufacturing process.

**Exergy** of a system is the maximum useful work possible during a process that brings the system to equilibrium i.e., utilizable energy of the system. After the system & surroundings reach equilibrium, the exergy is zero. Each input to the system is accounted for in terms of its exergy content and each output is evaluated for its exergy content. The ratio of the exergy content of the system's output to the sum of the input exergies is a measure of the maximum conversion efficiency attainable under reversible conditions.

**Material input per unit of service (MIPS)** is a measure of eco-efficiency of a product or service. The calculation takes into account materials required to produce a product or service. The total material input (MI) is divided by the number of service units (S). The whole life cycle of a product or service is measured when MIPS values are calculated. MIPS method can be used to measure natural resource consumption in 5-categories, viz. abiotic and biotic resources, earth movements in agriculture & silviculture, water and air. Abiotic resources refer to non-renewable resources like minerals, fossil energy sources and soil excavations. Biotic resources refer to renewable resources like plant biomass. Earth movements include mechanical movements and erosion. Water includes surface, ground and deep ground water used by humans. Air is calculated when it is used in combustion processes or chemically or physically transformed.

The life-cycle assessment techniques are in the stages of development as a scientific discipline. However, rapid progress is being made in this field with respect to development of softwares for a complete life cycle assessment, comprehensive Life Cycle Inventory database development, data validation through mass and energy balances, data analysis etc. Today, several softwares and programs including databases such as GABI, SIMAPro, GREET (Greenhouse Gases, Regulated Emissions and Energy Use in Transportation Model), TRACI (Tool for the Reduction and Assessment of Chemical and other Environmental Impacts), BEES (Building for Environmental & Economic Sustainability developed by NIST, US), GEMIS (Global Emission Model for Integrated Systems), USETox etc. are available for Life Cycle Assessment of materials and processes in various applications. However, since the LCI data for any unit process depends on the geography, time at which the data was collected, the nature of technology, the energy mix (extent of renewable&non-renewable energy) in the various countries etc., one can't readily use these databases either out of place or out of context or at a different time. Many countries such as Japan, Korea, USA, Thailand, Germany and Canada have national level LCA programs and/or national level databases which can be used for conducting a LCA study. Analyses such as Embodied Energy Analysis, Life Cycle Emissions Analysis, Embodied Water Analysis, Exergy Efficiency etc. are extremely useful in decision making on technology selection, strategic planning, public policy making and import-export decisions for the government.

India has set itself an ambitious growth rate target in double digits which also includesa significant increase in the growth rate of the manufacturing sector. Any growth in the manufacturing sector will have to be sustainable in terms of the impact on natural resources including energy resources, utilities such as air and water, environmental impact and socio-economic impact. As a country, we should be able to scientifically quantify these to enable decision making on a scientific basis and based on data. It is therefore imperative that India as a country launches a National Life Cycle Assessment Initiative as also creates a country-specific database that will enable a comprehensive life cycle assessment study as a basis of decision making on priority.

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## Civil Engineering

### 1. Sensing Trouble: New Way to Detect Hidden Damage in Bridges, Roads

*Engineers devise new method for monitoring structural health*

*University of Delaware engineers are leading research on a new technique to monitor the health of structures including roads and bridges*

Aging, deterioration and extreme events like earthquakes and hurricanes can take a toll on roads, bridges and other structures. With damage and defects often invisible, the search is on for systems that can monitor the health of structures and alert their owners to potential problems and even impending catastrophic failure. Several years ago, Erik Thostenson and Thomas Schumacher, both affiliated faculty members in the University of Delaware's Center for Composite Materials, began to explore the use of carbon nanotube composites as a kind of "smart skin" for structures. Now, they have improved on this approach with the addition of another technique called electrical impedance tomography (EIT), which uses surface electrode measurements to create an image of the conductivity of a material or structure. While EIT has been used as a noninvasive medical imaging technique since the 1980s, it has largely been overlooked by the structural health monitoring community. The UD team's development of the new approach applies EIT to a distributed carbon-nanotube-based sensor. "While the feasibility of employing carbon-nanotube-based composites as sensors has been validated, the typical approach is to use a series of one-dimensional measurements collected from a two-dimensional sensing area," says Thostenson, whose expertise lies in processing and characterization of composites for sensor applications. "The problem is that this confines the possible damage locations to the grid points of the measurements. EIT, on the other hand, is a true 2-D algorithm." The nanotube composite sensor can be adhered to virtually any shape to detect damage and to show its location within the material or structure. Other advantages are that it is mechanically robust and that its electrical properties are isotropic, or the same in all directions. For Schumacher, a structural engineering researcher who envisions using the technique on in-service structures, major benefits of the new sensing technique are that it can be scaled up and that it is relatively inexpensive, as it doesn't require a large quantity of carbon nanotubes. The work includes initial evaluation of the methodology, first by introducing well-defined damage and then by investigating a more realistic damage scenario to show the capability of the approach to detect impact damage on a composite laminate. The resulting EIT maps were then compared to visual inspection and thermograms taken with an infrared camera. "Although we did encounter some issues with the size of cracks being overestimated and their shapes not being well represented, overall our EIT methodology was able to detect the initiation of damage well before it was visible with infrared thermography," Schumacher says. "We are in the process of making improvements to the EIT algorithm to increase its accuracy. After that, we plan to demonstrate it in the laboratory, with an aim toward scaling it up for future monitoring of real structures."

Source https://www.sciencedaily.com/releases/2016/07/160707151127.htm

Computer Engineering and Information Technology

## 2. Researchers Storing Information Securely in DNA


Experiments at CERN's Large Hadron Collider generate 15 million gigabytes of data per year. That is a lot of digital data to inscribe on hard drives or beam up to the "cloud." George Bachand, a Sandia National Laboratories bioengineer at the Center for Integrated Nanotechnologies, is exploring a better, more permanent method for encrypting and storing sensitive data: DNA. Compared to digital and analog information storage, DNA is more compact and durable and never becomes obsolete. Readable DNA was extracted from the 600,000-year-old remains of a horse found in the Yukon. Tape- and disk-based data storage degrades and can become obsolete, requiring rewriting every decade or so. Cloud- or server-based storage requires a vast amount of electricity. The key is how do you go from text to DNA and do that in a way that is safe and secure. Bachand was inspired by the recording of all of Shakespeare's sonnets into 2.5 million base pairs of DNA—about half the genome of the tiny E. coli bacterium. Using this method, the group at the European Bioinformatics Institute could theoretically store 2.2 petabytes of information in one gram of DNA. Marlene Bachand, a biological engineer at Sandia added that they are taking advantage of a biological component, DNA, and using its unique ability to encode huge amounts of data in an extremely small volume to develop DNA constructs that can be used to transmit and store vast amounts of encrypted data for security purposes. The project has successfully moved from the drawing board to letterhead. Using a practically unbreakable encryption key, the team has encoded an abridged version of a historical letter into DNA. They were able to extract the DNA out of the paper, amplify and sequence the DNA, and decode the message in about 24 hours at a cost of about $45. To achieve this proof-of-principle, the first step was to develop the software to generate the encryption key and encrypt text into a DNA sequence. DNA is made up of four different bases, commonly referred to by their one letter abbreviations: A, C, G and T. Using a three-base code, exactly how living organisms store their information, 64 distinct characters—letters, spaces and punctuation—can be encoded, with room for redundancy. For example, spaces make up on average 15 to 20 percent of the characters in a text document, an encryption key could specify that TAG, TAA and TGA each code for "space" while GAA and CTC could code for "E." This would reduce the amount of repetition and make hacking more difficult. The team's first test was to encode a 180-character message, about the size of a tweet. Encoding the message into 550 bases was easy; actually making the DNA was difficult. The initial approach was very expensive, very time consuming and didn't work. However, they used a new technology to take synthetic DNA or gene blocks, and stitch them together into these artificial chromosomes. Two possible applications identified are storing historical classified documents and barcoding/watermarking electromechanical components, such as computer chips made in the Microsystems and Engineering Sciences Applications complex, prior to storage. They imagine encoding each component's history—when it was manufactured, the lot number, starting material, even the results of reliability tests—into DNA and spotting it onto the actual chip. Instead of having to find the serial number and look up that metadata in a digital or paper-based database, future engineers could swab the chip itself, sequence the DNA and get that information in a practically tamper-proof manner. DNA spotted onto electronic components and stored in cool, dark environments could be recoverable for hundreds of years. Another application for the DNA storage method would be for historical or rarely accessed classified documents. DNA requires much less maintenance than disk- or tape-based storage and doesn't need lots of electricity or tons of space like cloud- or paper-based storage. Making the DNA is the most expensive part of the process, but the cost has decreased substantially over the past few years. Given all of the issues of broken encryption and data breaches, this technology could potentially provide a path to address these security problems.

Source http://phys.org/news/2016-07-dna.html

## Mechanical Engineering

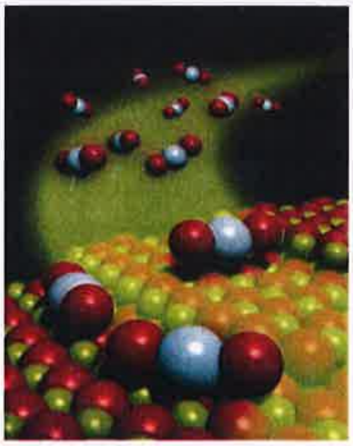
### 3. Trial by Ice a Next-Generation Ocean Robot Explores the Arctic's Deepest Secrets.



Getting a good look at life under the ice is very hard to accomplish. Scientists have to approach the region via icebreakers, which disturb the habitat. To get a true picture, they have to get away from the ship. That means robots, particularly advanced ones able to travel long distances while still transmitting back images and sounds. Standard ocean robots come in two types, neither of which are well-suited to the task. Remotely operated vehicles (ROVs) rely on human control to accomplish their missions and so need a constant connection to their operators via cables. The lengths and weights of those cables limit the ROV's mobility, and in Arctic conditions, those cables can be broken easily by drifting ice floes, leaving the million-dollar equipment lost at sea. The other type of robot, autonomous underwater vehicles (AUVs), have more intelligence than ROVs, but usually only enough for a few pre-programmed tasks like taking samples and photos, but not for weaving through protruding ice parts and hovering under icecaps. ***Nereid Under Ice*** was designed specifically for exploring the underside of Arctic sea ice, an area so far off-limits to scientists and launched from the German icebreaker RV *Polarstern*. During the trial run, as the two ton, bright orange vehicle lowered into the water, two other important components followed: a tow body and a depressor, which would quickly drag Nereid down. Once Nereid was under the keel of the ship, safe from dangerous ice floes or currents beating against the hull, the depressor and tow body were to decouple. The tow body would trail behind the robot as it swam away, unspooling as much as 20 km worth of hair-thin fiberoptic Gigabit Ethernet cable through which the robot would transmit video and other data. In order for Nereid to successfully move and work under ice and glaciers, the team designed it as an ROV-AUV hybrid, able to switch between the two modes as necessary. Maneuvering and landing on the ice ceiling would require human navigation. As Nereid sent real-time visual data to the computer screen through the lightweight fiber tether, the team would direct it to look into cracks and crevasses, photograph algae pools, or slowly ascend onto its landing skids to take water samples underneath ice. The thin fiber cable could still be its Achilles' heel, but if it got snagged and broken, Nereid was programmed to turn on its AUV mode and return to the ship. That's no simple task. Unlike the so-called blue-water vehicles that operate in the open ocean, Nereid couldn't just head straight to the surface. One would need to break the ice, which is difficult and may hurt the robot. To find its way back, Nereid not only had to remember the path it had taken, but also know where to turn or dive to avoid protruding ice pieces or other obstacles. And because ice floes drift continually, Nereid's navigational software had to keep track of their movements, adding error corrections to its homeward path. To maximize the vehicle's reliability in the event of the communication fiber breaking, the team implemented a variety of recovery features and levels of redundancy. If the fiber got cut, they could guide the robot from under the icecap by radio signals. If Nereid got stuck under ice, they would find it using an avalanche beacon. And if all else failed, the team had an emergency ice-breaking procedure devised. They would drill holes in the ice and deposit heavy weights on Nereid's top, sinking it to the depths safe from the *Polarstern*'s massive ice breakers—and then float the robot back to the ship. Nereid also has to withstand extreme Arctic temperatures, so its materials had to be tested even before it was assembled. Nereid's upper shell, for instance, is made from blocks of orange-colored syntactic foam made from tiny hollow glass spheres coated with epoxy glue. Before fabricating the shell, they had to ensure that the foam could hold up to the Arctic cold. At the end of the first exploratory sortie, engineers turned Nereid around to head back to the ship. The water currents had shifted the communication fiber into the vehicle's path and the robot ran over it, cutting it and severing communications with the ship. The team added extra software features to avoid this in the future, but it did provide a field test for Nereid's homing ability. It worked perfectly. The robot returned without a hitch.

Source https://www.asme.org/engineering-topics/articles/technology-and-society/trial-by-ice

## 4. Catalyst Efficiency Improved for Clean Industries



*Method reduces use of expensive platinum. Mobile platinum oxide species trapped on a cerium oxide surface. The bonding of the platinum to surface oxygen creates isolated platinum atoms that are thermally stable, and active for treatment of automotive exhaust pollutants.*

Researchers have developed a way to use less platinum in chemical reactions commonly used in the clean energy, green chemicals, and automotive industries. Led by the University of New Mexico in collaboration with Washington State University, the researchers developed a unique approach for trapping platinum atoms that improves the efficiency and stability of the reactions. Platinum is used as a catalyst in many clean energy processes, including in catalytic converters and fuel cells. The precious metal facilitates chemical reactions for many commonly used products and processes, such as converting poisonous carbon monoxide to less harmful carbon dioxide in catalytic converters.Because of its expense and scarcity, industries are continually looking to use less of it and to develop catalysts that more efficiently use individual platinum atoms in their reactions. At high temperatures, however, the atoms become mobile and fly together into clumps, which reduces the catalyst's efficiency and negatively impacts its performance. This is the primary reason why catalytic converters must be tested regularly to ensure they don't become less effective over time. "Precious metals are widely used in emission control, but there are always the issues of how to best utilize them and to keep them stable," said Yong Wang, Voiland Distinguished Professor in the Gene and Linda Voiland School of Chemical Engineering and Bioengineering. "You want to use as little as possible to achieve your objectives, but it's normally hard to keep the atoms highly dispersed under working conditions." The University of New Mexico and WSU research team developed a method to capture the platinum atoms that keeps them stable and lets them continue their catalyzing activity. The researchers used a commonly-used and inexpensive manufacturing material, known as cerium oxide, to create a tiny, nano-scale trap. They shaped the cerium oxide into nanometer-sized rods and polyhedrons, which look like tiny pieces of rock candy, to capture the platinum atoms. With their large surface areas and sufficiently high number of defects, the cerium oxide nano-shapes are able to capture the platinum atoms on their surfaces and keep them from clumping together, so that the platinum can continue to do its work. "The atom-trapping technique should be broadly applicable for preparing single-atom catalysts," said Abhaya Datye, a Distinguished Regents' Professor of Chemical and Biological Engineering at The University of New Mexico, who led the study. "It is remarkable that simply combining the ceria with a platinum catalyst was sufficient to allow trapping of the atoms and retaining the performance of the catalyst. "Even more surprising is that the process of trapping occurs by heating the catalyst to high temperatures -- precisely the conditions used for accelerated aging of these catalysts," he added. Adding the cerium oxide to the catalyst is a simple process, too, with no exotic precursors needed. "This work provides the guiding principles, so that industry can design catalysts to better utilize precious metals and keep them much more stable," added Wang.

Source https://www.sciencedaily.com/releases/2016/07/160707151001.htm

## Electrical Engineering

## 5. For Best Results, Send Molecular Messages Using MIMO

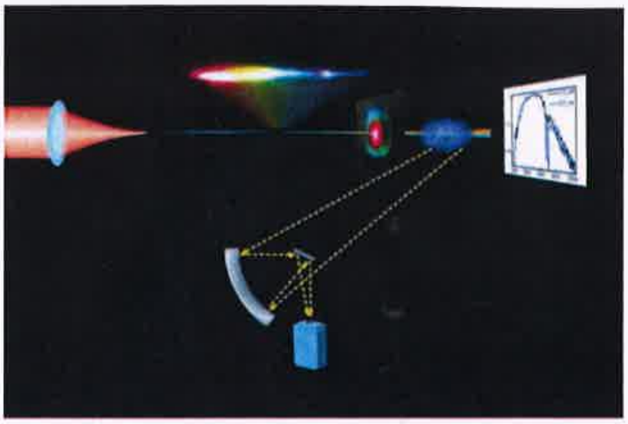
*Researchers used this experimental set-up to test MIMO for molecular communications. It consists of two mechanized spray nozzles (left) and two breathalyzer sensors (right).*

Just as cell phones propagate radio waves to connect users, it's also possible to transmit messages by emitting molecules. A sender can compose a message by diffusing bursts of a specific type of molecule, so long as a recipient can detect that molecule and interpret the pattern. Using this method, nanodevices could create a digital signaling system within the body, a locale where radio waves are quickly absorbed and where there is little space for bulky antennas. Neurons and other cells in the body already communicate through the transfer of neurotransmitters, hormones, and other signaling molecules. And researchers have shown in early experiments that molecular digital communications through the air works but only with a fairly low data rate. Now, a team from Toronto's York University and Yonsei University in Seoul, South Korea found that they can nearly double that data rate by applying multiple-input multiple-output (MIMO) technology. MIMO is a technique more commonly applied to radio antennas. It boosts data rates by using at least two transmitters and two receivers to exchange messages, rather than a single pair. Using the traditional setup of just one transmitter and one receiver—placed 1 meter apart— the Yonsei-York group transmitted data at a rate of 0.2 bits per second (bps). But with two sets, they achieved a rate of 0.34 bps, spelling "YONSEI" in 88 seconds. For comparison, today's LTE networks can reach peak download speeds of 50 Mbps. This group was working with alcohol molecules instead of radio waves, so they used motorized spray nozzles as transmitters, and cheap breathalyzer sensors as receivers. A tank of compressed air provided the force required to expel alcohol molecules from both nozzles at once, while a microcontroller coordinated the timing of these spritzes over 4 second intervals. As the alcohol molecules from both sprayers spread through the air, the sensors recorded their presence after each timed spritz. If there were no alcohol molecules in the air, the sensors recorded a pause. As the system spritzed away, two more microcontrollers hooked to the sensors fed these logs to a computer for processing. The entire set-up would cost around $400 to build from scratch, says Andrew Eckford, a co-author and electrical engineer at York University. He was part of a team that used molecular communications to transmit "O CANADA" in 2013 in one of the first live demonstrations of the technology. In any molecular communications system, the receiver uses the concentration of alcohol molecules to interpret messages based on a code similar to Morse Code. Each letter in the alphabet is represented by a five-bit number sequence. For example, an "a," is 11000. Each spritz of molecules represents a "1" and each non-spritz represents a "0". By spritzing twice and then pausing for three beats, a sender can transmit an "a." It may seem like a laborious way to text a friend, but Chan-Byoung Chae, a co-author and communications researcher at Yonsei University, says that process wouldn't be so painful for tiny sensors that merely need to communicate basic concepts, such as whether or not a heart monitor was working properly. With a single spritz or pause, a nanodevice placed inside the body could alert physicians to a problem if it were somehow connected to the outside world. The most successful examples of molecular messaging today are those that occur naturally. Neurons and cells rely on chemical messengers to carry information and trigger reactions throughout the body. Alarcon says one of the next logical steps for researchers is to deploy molecules through massive MIMO, a technology in which many transmitters and receivers exchange molecules at once. But even with that possibility, he says this method will likely remain a low bandwidth form of communication for the near future.

Source http://spectrum.ieee.org/tech-talk/telecom/wireless/for-best-results-send-molecular-messages-through-mimo

**Electronics and Communication Engineering**

## 6. New Mid-Infrared Laser System Could Detect Atmospheric Chemicals



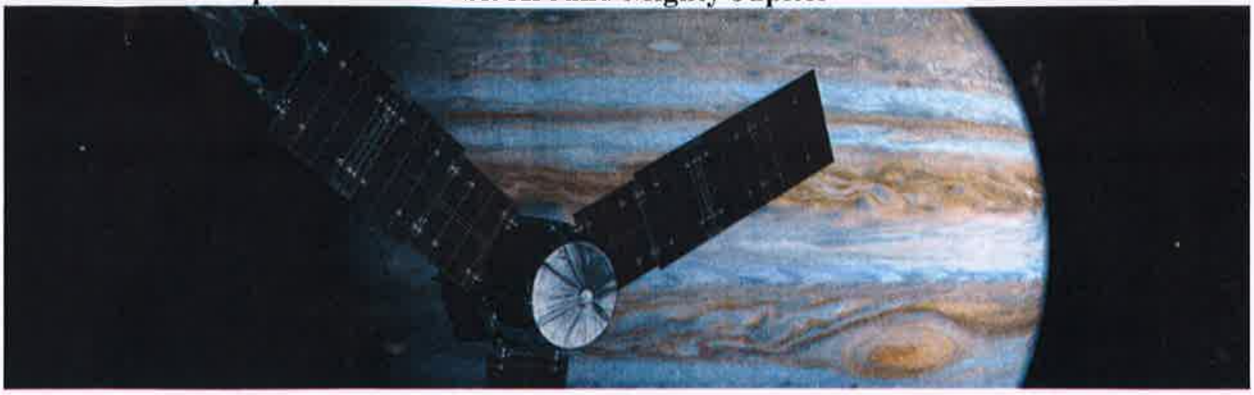
*This diagram depicts the way a mid-infrared laser (red cylinder, left) can send a beam through the atmosphere that generates filaments of ionized air molecules (multicolored beam, center, shown with magnified view). These filaments, which can be kilometers long, help to keep the beam concentrated enough to generate mid-infrared light in air (blue cloud, right) that can reveal detailed chemical composition through spectral analysis (chart at right) of the light picked up by a mid-infrared detector (bottom).*

Researchers at MIT have found a new way of using mid-infrared lasers to turn regions of molecules in the open air into glowing filaments of electrically charged gas, or plasma. The new method could make it possible to carry out remote environmental monitoring to detect a wide range of chemicals with high sensitivity. The new system makes use of a mid-infrared ultra-fast pulsed laser system to generate the filaments, whose colours can reveal the chemical fingerprints of different molecules. Researchers explain that such filaments, as generated by lasers in the near-infrared part of the electromagnetic spectrum, have been widely studied already because of their promise for uses such as laser-based rangefinding and remote sensing. The filament phenomenon, generated by high-power lasers, serves to counter the diffraction effects that usually take place when a laser beam passes through air. When the power level reaches a certain point and the filaments are generated, they provide a kind of self-guiding channel that keeps the laser beam tightly focused. But it is the mid-infrared (mid-IR) wavelengths, rather than the near-IR, that offer the greatest promise for detecting a wide variety of biochemical compounds and air pollutants. Researchers who have tried to generate mid-IR filaments in open air have had little success until now, however. Only one previous research team has ever succeeded in generating mid-IR laser filaments in air, but it did so at a much slower rate of about 20 pulses per second. The new work -- which uses 1,000 pulses per second -- is the first to be carried out at the high rates needed for practical detection tools, the researcher says. "People want to use this kind of technology to detect chemicals in the far distance, several kilometers away," researcher says, but they have had a hard time making such systems work. One key to this team's success is the use of a high-power femtosecond laser with pulses just 30 femtoseconds, or millionths of a billionth of a second, long. The longer the wavelength, the more laser peak power is needed to generate the desired filaments, due to stronger diffraction, he says. But the team's femtosecond laser, coupled with what is known as a parametric amplifier, provided the necessary power for the task. This new laser system has been developed together with Franz X. Kaertner in Hamburg and other group members for last several years. At these mid-IR wavelengths, Hong says, this device produces "one of the highest peak-power levels in the world," producing 100 gigawatts (GW, or billion watts) of peak power. It takes at least 45 GW of power to generate the filaments at these mid-infrared wavelengths, he says, so this device easily meets that requirement, and the team proved that it did indeed work as expected. That now opens up the potential for detecting a very wide range of compounds in the air, from a distance. Using spectrally broadened mid-IR laser filaments, "we can detect virtually any kind of molecule you want to detect," he says, including various biohazards and pollutants, by detecting the exact colour of the filament. In the mid-IR range, the absorption spectrum of specific chemicals can be easily analyzed.

Source https://www.sciencedaily.com/releases/2016/06/160628182626.htm

## Aerospace Engineering

### 7. NASA's Juno Spacecraft in Orbit Around Mighty Jupiter

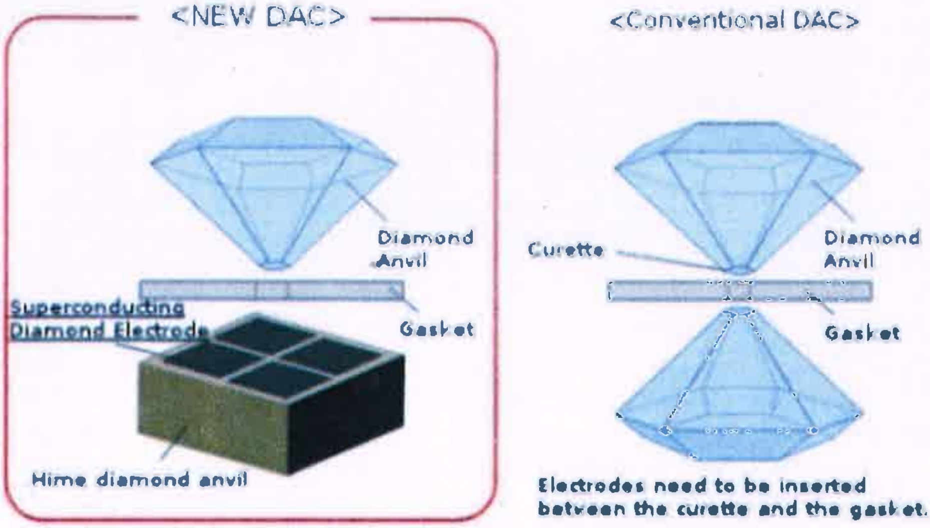


*Juno*

After an almost five-year journey to the solar system's largest planet, NASA's Juno spacecraft successfully entered Jupiter's orbit during a 35-minute engine burn. Confirmation that the burn had completed was received on Earth on Monday, July 4. Confirmation of a successful orbit insertion was received from Juno tracking data monitored at the navigation facility at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, as well as at the Lockheed Martin Juno operations center in Littleton, Colorado. The telemetry and tracking data were received by NASA's Deep Space Network antennas in Goldstone, California, and Canberra, Australia. Preplanned events leading up to the orbital insertion engine burn included changing the spacecraft's attitude to point the main engine in the desired direction and then increasing the spacecraft's rotation rate from 2 to 5 revolutions per minute (RPM) to help stabilize it. The burn of Juno's 645-Newton Leros-1b main engine began on time, decreasing the spacecraft's velocity by 1,212 miles per hour (542 meters per second) and allowing Juno to be captured in orbit around Jupiter. Soon after the burn was completed, Juno turned so that the sun's rays could once again reach the 18,698 individual solar cells that give Juno its energy. Over the next few months, Juno's mission and science teams will perform final testing on the spacecraft's subsystems, final calibration of science instruments and some science collection. "Our official science collection phase begins in October, but we've figured out a way to collect data a lot earlier than that," said engineers. "Which when you're talking about the single biggest planetary body in the solar system is a really good thing. There is a lot to see and do here." Juno's principal goal is to understand the origin and evolution of Jupiter. With its suite of nine science instruments, Juno will investigate the existence of a solid planetary core, map Jupiter's intense magnetic field, measure the amount of water and ammonia in the deep atmosphere, and observe the planet's auroras. The mission also will let us take a giant step forward in our understanding of how giant planets form and the role these titans played in putting together the rest of the solar system. As our primary example of a giant planet, Jupiter also can provide critical knowledge for understanding the planetary systems being discovered around other stars. The Juno spacecraft launched on Aug. 5, 2011 from Cape Canaveral Air Force Station in Florida. JPL manages the Juno mission for NASA. Juno is part of NASA's New Frontiers Program, managed at NASA's Marshall Space Flight Center in Huntsville, Alabama, for the agency's Science Mission Directorate. Lockheed Martin Space Systems in Denver built the spacecraft. The California Institute of Technology in Pasadena manages JPL for NASA.

Source https://www.nasa.gov/press-release/nasas-juno-spacecraft-in-orbit-around-mighty-jupiter

## 8. High-Pressure Generator Using a Superconducting Diamond Developed



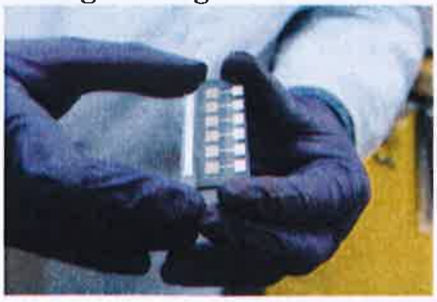

*Structures of diamond anvils. In the new DAC, a Hime diamond was used as a lower anvil and a superconducting diamond, which serves as electrodes, was fabricated on top of the anvil. In the conventional DAC, pressure is generated by two pointed curettes of the lower and upper diamonds pressing on each other. In this system, electrodes need to be inserted between the curette and the gasket.*

Researchers of National Institute of Materials Science and Ehime University, Japan, developed a new diamond anvil cell by micro-fabricating a superconducting diamond, which conducts electricity like metal and serves as electrodes, on the world's hardest and chip-proof nano-polycrystalline diamond. A research group led by Yoshihiko Takano, Environment and Energy Materials Division, NIMS, developed a new diamond anvil cell (DAC) by micro-fabricating a superconducting diamond, which conducts electricity like metal and serves as electrodes, on the world's hardest and chip-proof nano-polycrystalline diamond (Hime diamond). As a result, the conventional practice of skillfully attaching four electrodes to a small sample (of several dozen microns) was eliminated, and thus electrical resistance measurements under ultra-high pressure have become much easier. Furthermore, because diamond electrodes can be used repeatedly, physical property measurements have dramatically improved in terms of work and economic efficiencies. A typical DAC is a device to generate high pressure by pressing curettes of paired diamond anvils on each other. To increase the pressure generated by the device, it is necessary to make the areas of the curettes smaller. Specifically, to generate ultra-high pressure (several hundreds of thousands of atmospheric pressure), curettes need to be about 400 microns in diameter. Operation of such a device would be very difficult due to the requirement that the sizes of the samples to be studied need to be as small as about 100 microns. To generate a million atmospheric pressure or higher, the sizes of the samples need to be even smaller, making it extremely challenging to manually attach electrodes to the samples. Accordingly, the research group micro-fabricated superconducting diamond electrodes on the top of the anvil using the electron-beam lithography method. As it is convenient to use a plate-shaped diamond for the fabrication of electrodes using lithography, they combined a plate-shaped diamond and another diamond with a curette to form a diamond anvil cell. As a result, the research group succeeded in developing a new diamond anvil cell by combining the world's hardest diamond electrodes and the world's hardest diamond anvil. Because advanced experimental technologies are required, materials R&D under ultra-high pressure is still largely unexplored. As such, this field has great potential to offer opportunities for exploring novel materials and superconductors with extraordinary functions.

Source https://www.sciencedaily.com/releases/2016/06/160630180259.htm

## Energy Engineering

### 9. Engineering Researchers Strive to Create Cheaper, More Efficient Third-Generation Solar Cells



*Kennesaw State researchers develop third-generation solar cells*

A humming laboratory is making tiny solar cells as Kennesaw State researchers strive to develop better photovoltaic technologies. Sandip Das, assistant professor of electrical engineering in the Southern Polytechnic College of Engineering and Engineering Technology, along with researchers, has recently fabricated the delicate solar cells, which are about 100 times thinner than a human hair. The future of solar power generation is in these flexible solar cells, Das said. He and his research team are investigating various nano-materials to fabricate the third-generation solar cells. The researchers hope to develop a superior photovoltaic technology that produces cheaper and more efficient solar cells. "The most fascinating part of doing this research is the enormous potential that this new technology offers, such as integrating flexible solar cells on wearable electronics, backpacks and self-charging cell phones and electricity-generating layers on windows, especially on skyscrapers, and solar power's ability to supply a large amount of clean, renewable and cheap energy for the future," said David Danilchuk, a researcher. In the laboratory, the research team fabricated the solar cells' multiple nano-structured layers using a unique manufacturing process. Specialty instruments, like electron microscopes, as well as X-ray spectroscopy techniques and precision electronic measurement systems, enable the research team to investigate and better understand the cells' behaviour. Researchers explained that the fabrication process developed by the team can produce these solar cells on plastic substrates to create flexible solar cells -- one of the most advanced ideas in solar technology today. In practice, these flexible solar panels can be beneficial after catastrophic storms. Disaster relief personnel could transport rolled-up solar panels to produce portable power on site, Das explained. Commercial building developers in USA also are eyeing smart building applications, like transparent solar panels for windows, so skyscrapers can generate solar power and be more energy efficient. Current commercial solar panels use first-generation silicon solar cells, which are expensive, fragile and bulky, limiting their portability, according to Das. The most promising materials systems for future generation solar cells, according to Das, are the materials that his research team applies in their fabrication -- an ultra-thin hybrid Perovskite noncrystalline film. Rather than using expensive silicon, they fabricate their solar cells on cheap glass substrates like those in windows and beverage bottles. The team plans to explore the fabrication process so they can develop solar cells on flexible plastics or metal foils, without requiring expensive materials, million-dollar equipment or scientific-grade clean rooms. Researchers explained that silicon is not a good light absorber, and new technologies are needed to create high-efficiency cells at a lower cost. The new bandgap-engineered Perovskite crystals, which his team is investigating, can absorb a wider spectrum of sunlight compared to silicon, on a film that is 200 times thinner than silicon cells. A major goal for their research is to substantially reduce the cost of producing solar cells. Typically, solar cells are fabricated in a clean room, a controlled environment for manufacturing electronics that is free of dust or other contaminants. Even without a clean room, Das and his team are able to fabricate this next generation of solar cells and test their newly hatched cells. The raw materials used for the third-generation solar cells are less expensive than the electronic-grade silicon.

Source https://www.sciencedaily.com/releases/2016/07/160712073918.htm

## 10. Energy Saving Filters for Wastewater Treatment Created


*NTU's new nanofiltration hollow fibre membrane.*

Scientists at Nanyang Technological University (NTU Singapore) have invented a new type of nanofilter that could reduce the energy needed to treat wastewater by up to five times. Typically, for the last steps of water purification in a wastewater treatment process, an ultrafiltration (UF) membrane filters out small particles before a reverse osmosis (RO) membrane is used. In reverse osmosis, water is pushed through an extremely fine membrane at high pressure to separate water molecules from any remaining contaminants which are tiny -- about a thousand times smaller than the width of a human hair, such as salt, heavy metals and toxic chemicals like benzene. This high water pressure, typically 10 bars and above, means that the water pumps need a lot of energy. However, NTU's proprietary nanofiltration (NF) hollow fibre membrane does away with both ultrafiltration and reverse osmosis, combining the two processes. It also requires only 2 bars of water pressure, similar to the pressure found in a typical home pressure cooker, to filter out the same type of contaminants. Yet it produces water that is almost as pure as through reverse osmosis. This breakthrough technology took NTU's Nanyang Environment and Water Research Institute (NEWRI) about two years to develop and is now being commercialised by an NTU spin-off company De.Mem. De.Mem which owns over a dozen water treatment plants in Vietnam and Singapore, will be building a pilot production plant in Singapore to manufacture the new membranes. The researchers have addressed the ever increasing demand for clean water as what the world needs are innovative technologies like NTU's new nanofiltration hollow fibre membrane that allow them to treat and produce extremely clean water at a low cost, yet have high reliability and are easy to maintain. Researchers said they had designed the new NF membrane for commercial scale-up and production. "One of the main challenges faced by the industry is that current reverse osmosis processes are energy intensive, with down time needed for maintenance," explained Prof Wang, who is also the Chair of NTU's School of Civil and Environmental Engineering. "Our new membrane is also easy to manufacture using low-cost chemicals that are 30 times cheaper than conventional chemicals, making it suitable for mass production." Mr Andreas Kroell, Chief Executive Officer of De.Mem said the new membrane fills a gap in the current market for water treatment solutions. "We have seen in the labs that when we treat industrial wastewater with the new nanofiltration membranes, the quality of clean water produced is comparable to reverse osmosis but requires much lower pressure, hence lowering costs," Mr Kroell said. "Such an effective and efficient technology has significant market potential and can be used in many of De.Mem's projects that involve the treatment of industrial wastewater." De.Mem will test the new membrane modules in real world usage in its plants to verify its effectiveness and efficiency before scaling up to a full industrial production line.

Source https://www.sciencedaily.com/releases/2016/07/160707083312.htm

**Engineering Innovation in India**
**Gandhi Young Technological Innovation (GYTI) 2016 Awards**

The Gandhi Young Technological Innovation (GYTI) 2016 Awards were conferred on 13th March 2016 at Rashtrapati Bhavan. Brief details of two award winning projects are given below.

- **Wearable Drug Delivery Device Based On Microneedles For Efficient Management Of Chemotherapy Induced Nausea And Vomiting (cinv) And Nausea And Vomiting In Pregnancy (nvp)**

**Innovator:** Bhushan N Kharbikar **Guide:** Prof Rohit Srivastava **College:** Indian Institute of Technology Bombay

Prevention and control of emesis is of paramount importance in the treatment of cancer patients otherwise may result in serious health concerns. Hence the research is focused and oriented towards targeting cinv. The parenteral and enteral routes mentioned have several disadvantages such as poor patient compliance, painful injections, not feasible for self-administration, high cost, poor absorption, poor bioavailability, lack of programmability. administration of higher doses due to poor absorption results in many side effects ranging from less serious to more serious viz., fever, hearing loss, constipation, ringing ears, severe stomach pain, allergic reaction marked by swelling face or throat, CNS depression, disturbed cardiac conduction. The research is oriented towards the designing of novel and alternative approach for addressing the emesis by developing the novel wearable bioinspired microneedle based trans-epidermal drug delivery device which imitate the same mechanism of pharmacological actions exhibited by current mode of administration and doses of drugs used for treatment of emesis without any notified side-effects and better patient compliance. The device is convenient, saves time, and improves self-image. With wearable drug delivery device they are transforming how medicine is delivered and how people achieve their health goals through the convergence of optimized drug delivery, embedded sensor technology to monitor compliance, connected and personalized behavioral support. In order to determine the biosafety and amount of drug reaching the systemic circulation by developed microneedle and initial prototype device has to undergo stringent testing both in vitro and in vivo. Results from in vitro studies are sometimes hard to extrapolate for in vivo system. For this reason, the use of animal models is essential to judge clinical suitability of novel drug delivery method intended to be used to deliver antiemetic, prior to clinical use in humans. The promising scope of microneedles with sparse dose requirement reduces the major cost incurred. Painless trans-epidermal drug delivery with better patient compliance and behavioral support featured by wearable reduces the dependencies on trained nursing staff enabling users to self-administer and monitor the drug delivery. This tremendously curtails the cost incurred by patient on daily supportive/nursing care services. Possible mass production, low cost manufacturing, simple storage, handling and distribution may promote use of microneedles based wearable drug delivery device in mainstream healthcare.

- **Cost Effective Self-stabilizing Smart Hand Held Platform (spoon/pen) For Elderly Or Parkinson's Disease Patients**

**Innovator:** Debjyoti Chowdhury **Guide:** Dr. Madhurima Chattopadhyay **College:** Heritage Institute Of Technology

This work deals with development of cost an effective self stabilizing smart platform (spoon/pen) for bringing stability to the hands of elderly persons or for patients with parkinson's disease using MEMS tri-axial accelerometer. The developed prototype introduces an easy to adopt hand mount device that can be used to support the tremors in hands of old people or in persons with the said disease for day to day normal activities like writing with a pen, having food with a spoon and also holding crockery/knifes. The designed system is build around an 8-bit avr microcontroller along with a 6 dof (degree of freedom) tri-axis imu (inertial measurement unit) in a form of hand held hardware. The person's hand tremors are read by the system in form of acceleration data which is fetched from the imu and then are made to go through an embedded kalman filter which performs estimation on the data acquired from the acceleration sensor. In order to drive the system a custom designed electromagnetic (a servo) drive is designed to work with an embedded micro-controller based application. Every time there is a change in acceleration data the servo is actuated in a direction opposite to the recorded value from the person's hand tremor. This device uses six-point based sensor data calibration to eliminate discrepancies in senor output due to zero-g and installation errors.

Source http://gyti.techpedia.in