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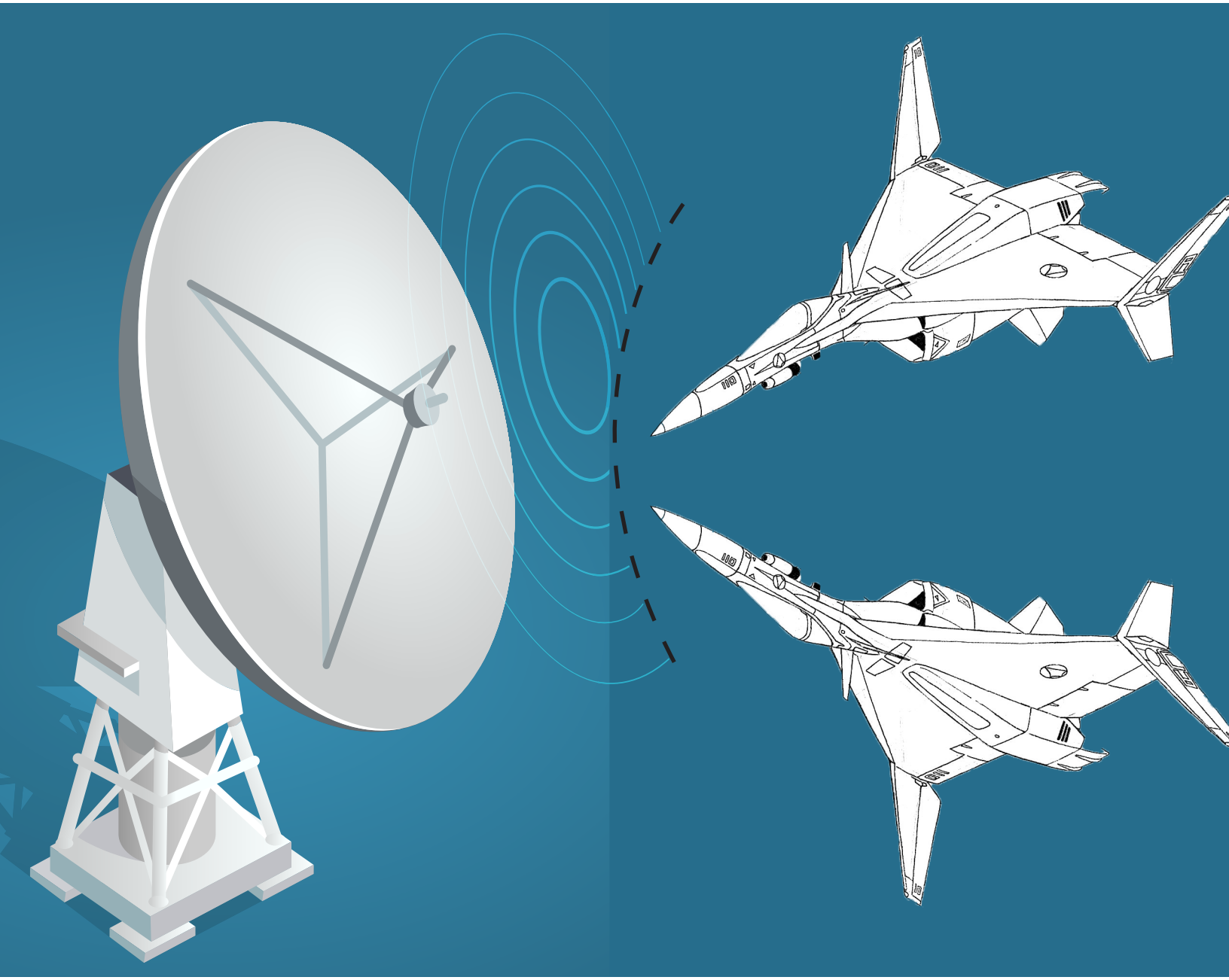


Polymeric Nanocomposites as Radar Absorbing Materials

Science of Disguise

leader

Dr. Rajiv Kumar Tayal
Secretary
Science & Engineering Research Board

Science and Engineering research has a major role to play for country as vast as India to meet its current and future needs without the traditional dependence on imported products, technologies, raw materials. The Make in India paradigm ushered by the nation's leadership has added a new sense of urgency to develop and commercialize technologies and processes that strengthen the nation's preparedness and ability to meet its unmet needs. SERB is making concerted efforts to help nation meet its avowed objectives in this context.

Stealth technology is now become the mainstay of air/naval defence strategies of all major armies. Radar Absorbing Materials are at the core of stealth technology as they make it possible to minimize/ erase the radar signatures of aircraft and naval vessels thus helping them avoid radar detection. As the leading piece of this issue we cover the development of polymer nano-composite based light-weight flexible and heat stable radar absorbing materials in India. This important work is being carried out by a team of researchers at the Indian Institute of Science with financial support from SERB.

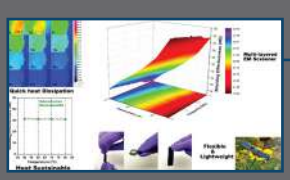
In the era of rapid and unprecedented climate change that threatens the sustainability of ecosystems that form the basis of human existence on the planet, biofuels are recognized for their key role in reducing the extent of anthropogenic carbon emissions in the times to come.

Given its abundance in nature, Algae can be major source of biofuels for fast growing needs of an increasingly energy intensive world. However, there are significant techno-economic challenges in the area of recovery of algal biomass from culture medium or wastewater. We bring to you in this issue, salient aspects of a project supported by SERB aimed at enhancing efficiency of algal biomass harvesting. The project is being executed at IIT Delhi.

In the context of biofuels, gasification technology has a key role to play in harnessing the potential of agricultural waste for producing heat energy. An SERB supported project, being implemented by IIT-Patna in association with M/s New Leaf Dynamic Technologies-New Delhi has resulted in the development of a novel thermally integrated biomass-gasification based hot water generation system. We highlight the prominent dimensions of this effort that has significant potential to not only energize rural India but also to augment farm incomes.

Your feedback on above-mentioned and other articles/features of this issue will be sincerely appreciated. Before I close, I would like to wish all our readers and well wishers a very happy and prosperous 2019. May all our collective efforts take our nation towards achieving its full potential as a S&T powerhouse of the world.

inside



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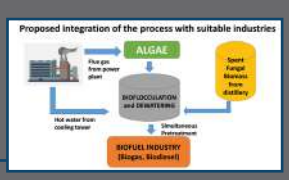

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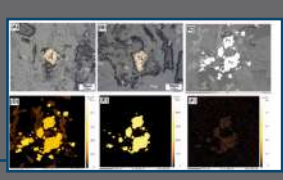

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Polymeric Nanocomposites as Radar Absorbing Materials

Science of Disguise

Radar Absorbing Materials (RAMs) is used in stealth technology to disguise a vehicle or structure from radar detection. Polymer nanocomposites and coatings offer a unique and efficient strategy which can replace metals in stealth technology due to their corrosion resistance and light weight attributes.

A team of researchers led by Dr. Suryasarathi Bose at the Indian Institute of Science has developed polymer nanocomposite based light weight, flexible and heat stable RAMs using a core-multi-shell heterostructure based approach.

Ever wondered why it is advised to switch off your mobile phones and other electronic devices during take off and landing of a flight? Or why your microphones (connected to your cell phone) create a buzzing noise due to an incoming call? In scientific terms, this phenomenon is termed as Electromagnetic Interference (EMI). It results in the disruption of operation of an electronic device when it is in the vicinity of an electromagnetic field. This affects the performance of a device, transmission channel, or system. Electromagnetic shielding is the practice of reducing the electromagnetic field in a space by blocking the field with barriers made of conductive or magnetic materials. Shielding is typically achieved using enclosures to isolate electrical devices from their surroundings, and to cables to isolate wires from the environment through which the cable runs. The door of a microwave oven has a screen built into the window. From the perspective of microwaves (with wavelengths of 12 cm) this screen finishes a Faraday cage formed by the oven's metal housing. Visible light, with wavelengths ranging between 400 nm and 700 nm, passes easily through the screen holes.

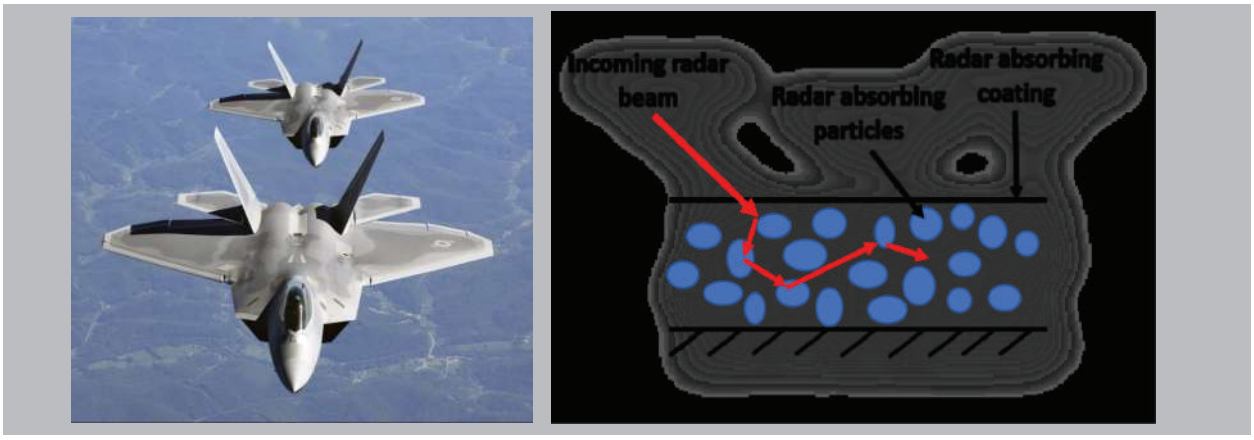


Figure 1 : Illustrates the mechanism of RF wave attenuation by a typical stealth plane

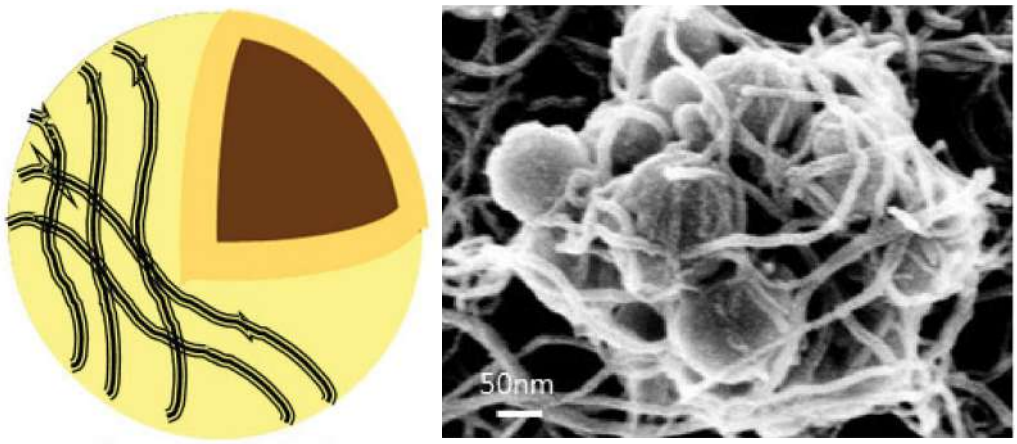


Figure 2 : Core-multi-shell nanoparticle-based system

Typical materials for EMI shielding include metals which shield incoming waves by reflection which is highly undesirable since the reflected waves can interfere with some other unshielded device. Meanwhile, magnetic materials like Iron, Nickel, Cobalt and Ferrites absorb the incoming waves. In spite of being so versatile the use of metals in the form of sheets and screens possess several challenges owing to their high density and poor corrosion resistance. Recent times have seen the increasing use of polymer nanocomposites for EMI shielding applications attributed to their light weight, flexibility and corrosion resistance. Different types and combinations of conducting, magnetic and dielectric nanoparticles can be incorporated in the polymer matrix to achieve the desired properties. In this context, carbonaceous fillers (like multiwalled carbon nanotubes, graphene and carbon fibres) are being increasingly researched upon due to their high aspect ratio and conductivity.

One of the most important applications of EMI shielding is in the area of stealth technology. Radiation-absorbent material, usually known as RAM, is a material which has been specially designed and shaped to absorb incident RF radiation (also known as non-ionising radiation), as effectively as possible, from as many incident directions as possible. A stealth aircraft, on the other hand, is made up of completely flat surfaces and very sharp edges. When a radar signal hits a stealth plane, the signal reflects away at an angle. In addition, surfaces on a stealth aircraft can be treated so they absorb radar energy as well, with the use of RAM. Figure 1 illustrates the mechanism of RF wave attenuation by a typical stealth plane. Typically, RAMs are made up of polymeric coatings and foams in which some absorbent magnetic/conducting particles have been incorporated. One of the most commonly known types of RAM is iron ball paint. It contains tiny spheres coated with carbonyl iron or ferrite. Radar waves induce molecular oscillations from the alternating magnetic field in this paint, which leads to conversion of the radar energy into heat. The heat is then transferred to the aircraft and dissipated. Similarly, neoprene rubber sheets with ferrite grains or conductive carbon black particles are also widely used.

A team of researchers led by Dr. Suryasarathi Bose at the Indian Institute of Science, Bangalore have extensively explored the use of polymeric nanocomposites as potential RAMs. Instead of using the conventional technique whereby the conducting and magnetic nanoparticles are incorporated separately in the polymer matrix to design RAMs, they have developed a core-multi-shell nanoparticle-based system (as seen in Figure 2) whereby nanoparticles with a magnetic core i.e Iron Oxide (Fe_3O_4) and conducting outer shell (carbon nanotubes) supported on a dielectric spacer here Silicon Dioxide (SiO_2) have been synthesised by a very simple industrially viable technique.

This unique Core-multishell heterostructure is designed to shield microwave frequencies.

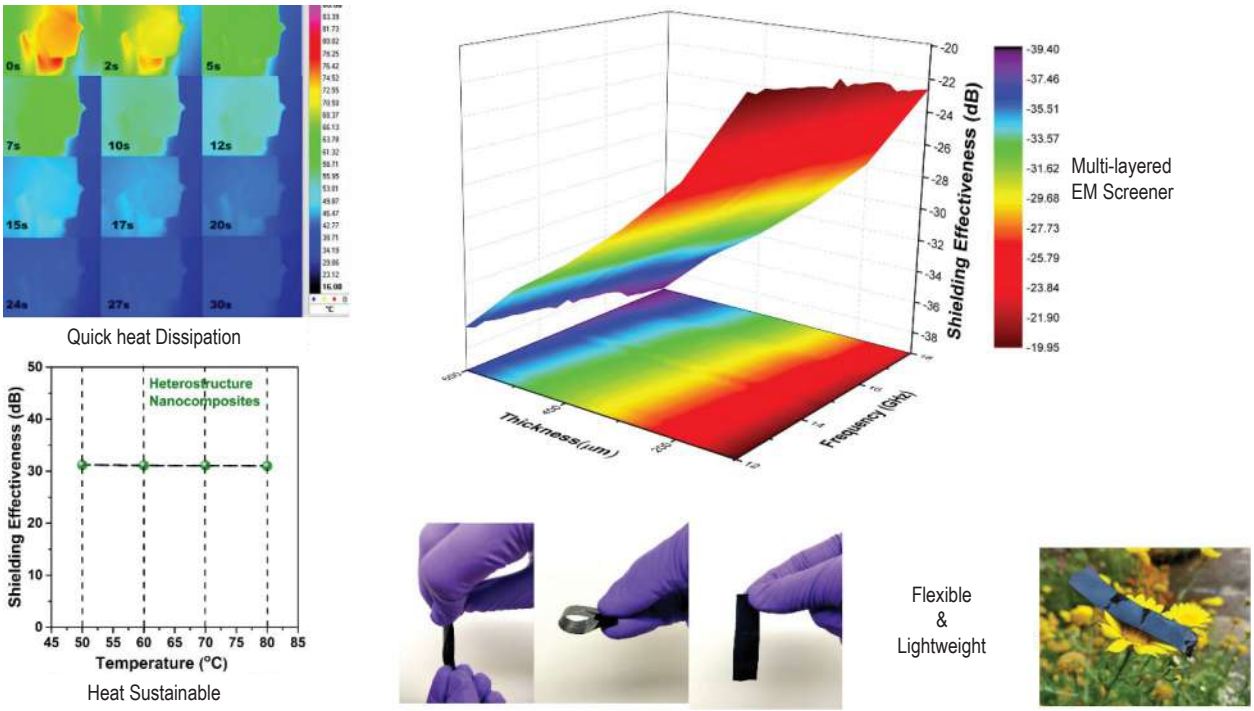


Figure 3 : Various attributes of the designed composite material - flexibility, lightweight and sustainability

Incorporation of this heterostructure in a polymer matrix (here Polyvinylidene fluoride - PVDF) creates multiple interfaces in the system due its unique morphology and thereby leading to excellent radar wave attenuation (40 dB i.e. nearly 99.99% attenuation) dominated by absorption (80%), which is highly desirable in the current market scenario.

In addition to EMI shielding capability, this composite material exhibited outstanding heat dissipation ability (72 °C to room temperature in less than 90 seconds). PVDF is an insulator and its degradation temperature is around 350 °C, making it capable of being heat stable for application in stealth technology. In order to study the fate of the material under different thermal cycles, an experiment was conducted wherein thin films of the composite samples were put in a programmable environmental chamber. Each film was kept at four different temperatures (50, 60, 70, and 80 °C) in the chamber with a hold time of 10 min at a particular temperature. The EMI shielding values were measured after each temperature ramp, and no observable change in the shielding values was recorded, which confirmed that these materials can sustain their EMI shielding capability even at high temperature and past thermal history. This work provides advancement in the field of RAMs in terms of material design and its suitability for real life sophisticated applications owing to its low thickness (~ 600 micron) and flexibility. Figure 3 describes various attributes of the designed composite material like flexibility, lightweight and sustainability.

One of the prevalent issues with polymeric RAM coatings is their peeling off and poor durability, since they are often exposed to harsh weather conditions. The team also focuses on development of "self-healable" RAM coatings. These coatings can repair themselves on the application of a suitable "thermal trigger" (temperature) and their radar absorbent property is restored, thus improving their long-term durability.

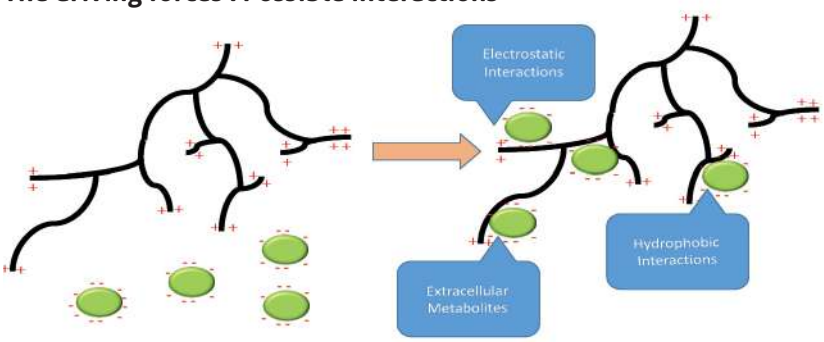
The details of this work can be found in the article, Yudhajit et.al ACS Applied Materials and Interfaces 10, 30762 (2018). https://pubs.acs.org/doi/abs/10.1021/acsami.8b10819. This work is supported by SERB (Grant number: SB/S3/ME/032/2015).

Trapping Microalgal Cells on Fungal Highways

Solving the Algal Biofuel Dilemma

Given its abundance in nature, Algae can be major source of bio-energy for meeting fast growing energy needs of increasing energy intensive world. However, there are significant techno-economic challenges that need to be overwhelmed in the area of recovery of algal biomass from the culture medium or wastewater.

The driving forces : Possible interactions



(a)

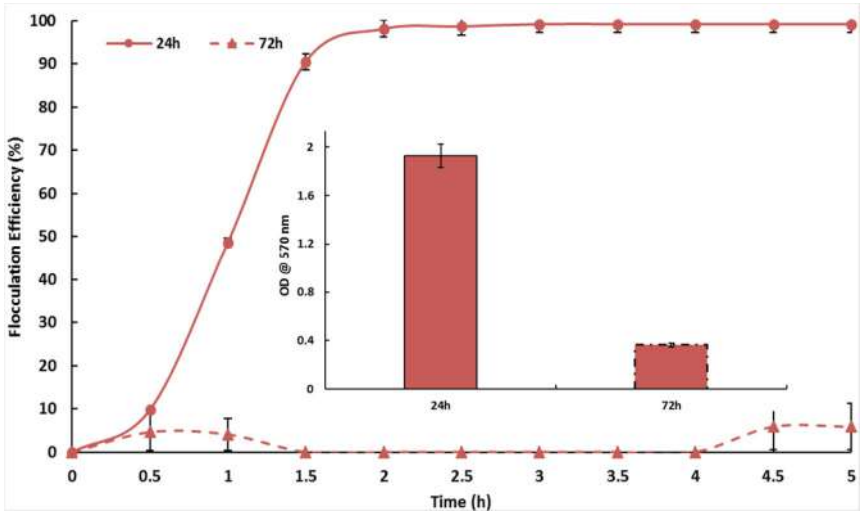
Microscopic images of Algal-Fungal Pellets

(b)

Figure 1 (a) : Possible interaction mechanism of algae and fungi **(b)** Microscopic images of algal-fungal pellet

In nature, algal fungal interactions are ubiquitously seen due to the nutritional interdependency in both the species. Lichens are well known example of a highly complex algal-fungal symbiosis. Other natural fungal populations are being benefited by algae due to their host-parasite kind of relationship. These interactions drive us to mimic such interactions in artificial system, which can be applied for algal biomass harvesting (Figure 1).

Commercially important products like lipids, proteins, nutraceuticals, food/feed, biofuel and various other bioactive compounds are obtained from microalgae. In a recent newspaper report it has been stated that women in rural areas of coastal states of India (like Andhra Pradesh, Tamil Nadu and Gujarat), organised under self help groups, are successfully



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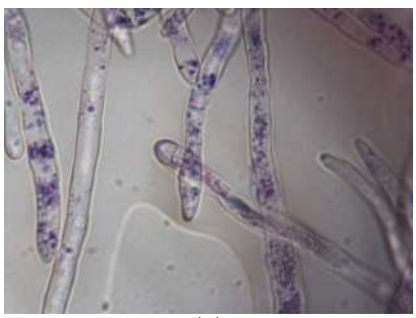

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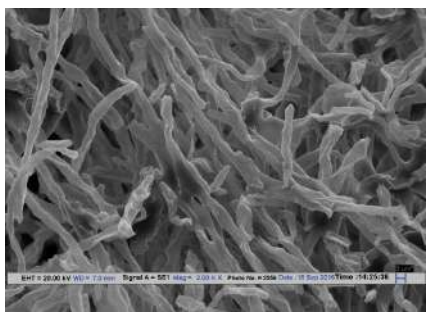

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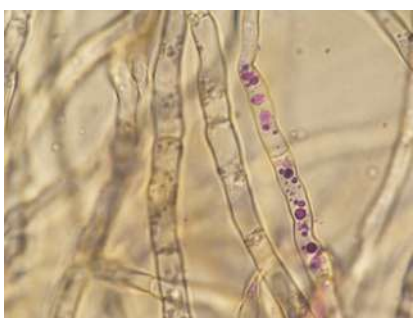

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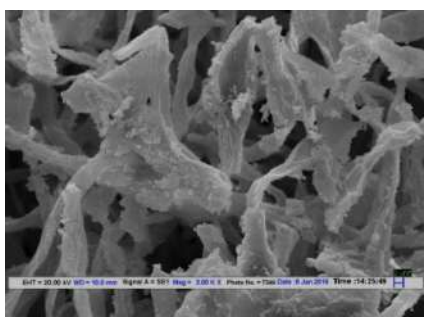

(e)

Figure 2: Effect of cultivation time on fungus (a) Harvesting efficiency of 24 hours and 72 hours grown fungus; the graph in inset shows the viability fungal pellets in terms of optical density at 570nm after MTT assay; (b) Intense purple color is seen in the fungal hyphae showing highly metabolically active fungi (c) Scanning electron microscopy (SEM) image of 24 h pellets of ***Aspergillus fumigatus*** showing intact hyphae. (d) MTT assay of 72 h pellets of ***A. fumigatus.*** **(e)** SEM image of 72 h pellets of ***A. fumigatus*** showing visible signs of disintegration and inactive fungi.

practicing algae farming. After the cultivation of algae by suitable method, the dewatering from the microalgal cells is the most important step to move ahead for its application. The recovery of algal biomass from the culture medium or wastewater is much more expensive than its cultivation. This is because of very small size of microalgal cells, ranging from 2 to 6 µm. This results in a situation that 40% of the total cost of algae biomass production is attributable to its cultivation compared to 60% in case of biomass recovery. This disturbs the overall economics of biofuel production. Therefore, comparative knowledge of existing harvesting methods, the advancements already made by the scientific community in this area and scope for improving these techniques may influence researchers to optimize the critical conditions best suitable for maximum biomass recovery.

In the present study, a method for rapid flocculation of ***Chlorella pyrenoidosa*** cells with ***Aspergillus fumigatus*** fungal pellets was developed. The process could flocculate 99% algal cells within 3 h (Figure 2(a)). **This is the fastest reported process of algal harvesting using this method and has been filed for a patent.** However, the question was how the fungus was able to carry out this phenomenon. Was there any specific physical or biological conditions necessary for this process? To answer these questions the effect of cultivation time and various pretreatments (autoclaving, cycloheximide exposure) on ***A.fumigatus*** was investigated. Results revealed that 24 h old fungal pellets flocculated at 38°C at 1:5 fungal-algal ratio gave the best flocculation efficiency. The cell viability assay showed that a viable and metabolically active fungal pellet is a prerequisite for flocculation. Scanning electron microscopy (SEM) studies confirmed that in addition to viability, an intact

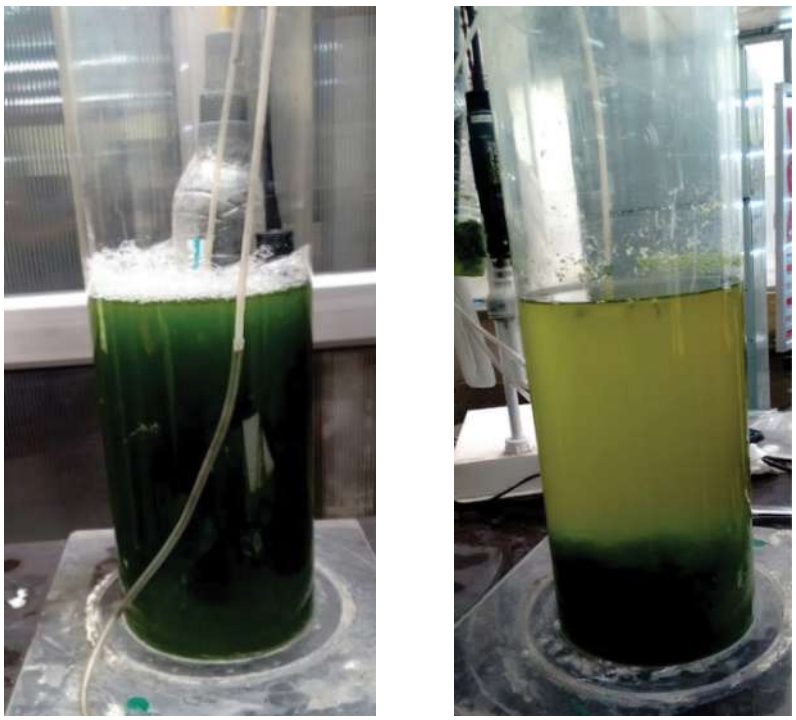

Figure 3 : Photo bioreactors used for flocculation of *C.pyrenoidosa* using *A.fumigatus*

and undamaged hyphae is also required for algal attachment (Figure 1(b) to (e)). These results necessitated the need for investigation of the changes in surfaces properties of the algae, fungus and the algal-fungal pellet. Fourier transform infrared spectroscopy (FTIR) of the algae, treated fungi, and algal-fungal pellet indicated sharp change in peak intensity at 1024 cm^{-1} and 1370 cm^{-1} indicating the involvement of specific groups in algal-fungal interaction. Finally, this method was tested on wastewater grown algae, and 95% flocculation was achieved within 3.5 h.*

The algal-fungal pellets (1650 µm diameter) could be easily separated from the culture. Hence, this process could serve as an alternative for concentrating microalgal cultures for biofuel production in a cost-effective way. The above results indicated that the fungus was the driving force behind this phenomenon. However, to understand the need for a live and metabolically active fungus for the process, mechanism of this interaction was studied. The mechanism study of the flocculation process revealed that neither algae nor fungi had any surface molecules which caused the interaction. Hence, it suggested that either the fungus or the algae secreted some molecules which were triggering this process. Analysis of the fungal spent medium showed that there was some extracellular factor which aided in the flocculation process. Microscopic examination of fungal spent medium incubated algal cells showed the formation of pilus-like structures on the algal cell surface. Biochemical analysis of the fungal spent medium indicated that the active molecule might be sugar like molecule. High-resolution liquid chromatography-mass spectrometry (HR-LC-MS) analysis of the fungal spent medium led to the identification of N-acetyl glucosamine (GlcNAc) which had a role in the flocculation process. Further studies with GlcNAc incubated algal cells confirmed its role in the flocculation process.

Although numerous studies have been reported in the recent time, no workable mathematical model has been developed for the same. For the first time, researchers proposed a mathematical model for this type of system. The model shows that the process is not a second-order process, unlike other flocculation models. The process is also dependent on the radius of the algal cells and fungal pellets. Moreover, the flocculation process is affected by the velocity gradient of the system. The model was validated using different experiments viz. different fungal-algal ratio, variation in rpm, different algal strains, algae grown in different wastewaters and finally in a 10 L photobioreactor (Figure 3). The proposed model is found to be in agreement with the experimental results along with $r^2 > 0.90$ in most of the cases.

The flocculation process was then carried out in a 10 l photobioreactor. The results showed that 85% of the algal cells were harvested within 4 h (Figure 3). The mathematical model developed using

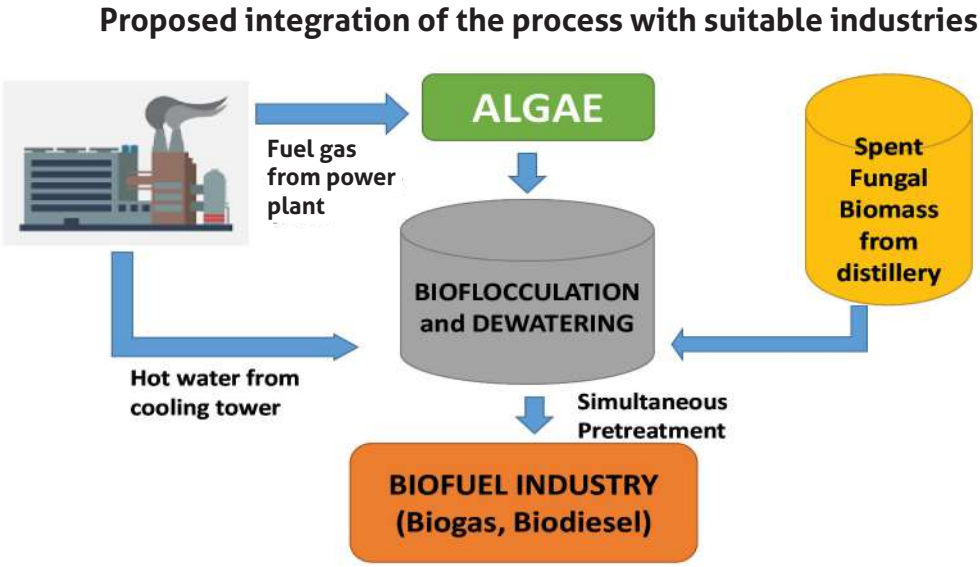

Figure 4 : Proposed integration of the process with suitable industries

batch studies also held true for the flocculation in the photobioreactor. Theoretical calculation of energy requirement for the flocculation process was done, and it was calculated to be 1.50 kW h kg^{-1} of algal biomass. The cost of the process could be brought down by suitably integrating with different industrial processes (Figure 4).

The process could be further tweaked to couple phycoremediation with energy generation apart from managing the eutrophic conditions, especially in rural ponds. The algae harvested using this method could be co-digested with cow dung to yield a higher amount of biogas which could of substantial value. Due to the ease of operation and rural application, biogas as a source of energy has been established to be the most feasible route of bioenergy. However, the use of algal biomass for biogas generation has been limited due to its problems like poor digestibility and harvesting. Hence, the current study addresses this problem by harvesting the biomass using fungal biomass and simultaneously pretreating that algal biomass by fungal enzymes produced during their simultaneous incubation. This exercise was done by two methods. Initially the fungal crude enzyme was produced using an external substrate, i.e. sugarcane bagasse for cellulase production by both the fungal strains. The enzyme assays of crude extract indicated high cellulase activity with COD solubilization and complete cell death when exposed to algal biomass. The biomethane potential increased almost 20-30% from the pretreated algal biomass as compared to the untreated biomass.

To make the process more techno-economically feasible, simultaneous harvesting and pretreatment of algal biomass were done. **This study has been filed for a patent (Application no. 1593/DEL/2015).** The algal-fungal pellets were tested for simultaneous harvesting and pretreatment under different conditions like high-temperature incubation (55°C) and were compared with the conventional method i.e. incubation at 38°C. The enzyme activity was highest after 24 hours of incubation at 55°C, and it also showed 30% increased biomethane production*. The process could also be extrapolated to harvest freshwater grown algae for food, feed or nutraceutical purposes. The existing potholes regarding the feasibility of the process could be assessed further by actually integrating the system with the industrial processes.

*The details of this work could be found out in Prajapati et.al (2017)., Green Chemistry 18 (19), 5230-5238.The present work was carried out with financial support from Science and Engineering Research Board (SERB), Department of Science and Technology, Government of India under grant no. SB/S3/CEE/0002/2014.

Agricultural Waste Based Gasifier Heating System

Energising the Waste

Under the aegis of a project under SERBs Uchchatar Avishkar Yojana (UAY), Indian Institute of Technology, Patna (PIs: Dr. Rishi Raj and Dr. Ajay D. Thakur) along with an industry partner (New Leaf Dynamic Technologies, New Delhi) has developed a novel thermally integrated biomass-gasification based hot water generation system. The technology holds tremendous promise in process industries with hot water requirements (paper & pulp, food & dairy, textile, chemical and refrigeration & air-conditioning etc.).

The hot water generation system developed under the project is now being used with New Leaf's product GreenCHILL™, an adsorption based refrigeration system (cold storage) for agricultural and dairy produce in areas not connected with the grid. While developmental work on atmospheric water harvesting is in progress. The team has plans for off-grid data center cooling applications in near future.

Agriculture contributes a lion's share to the Gross Domestic Product (GDP) of India. A significant portion of this includes vegetables and fruits that require robust preservation systems. Farmers witness post harvest losses and exploitation due to unavailability of cold storage units at source (i.e. on-farm). The inadequacies in the logistics systems includes lack of inexpensive physical infrastructure and insufficient and expensive grid power. In addition, the unavailability of adequate cold storage chains leads to high wastage and bunched-up supply. Hence there is an urgent need with a viable market for small off-grid cold storage facilities that can store the farm produce till it is sent higher up in the supply chain. Cold storage units employing the adsorption refrigeration cycle is a viable solution. However, these

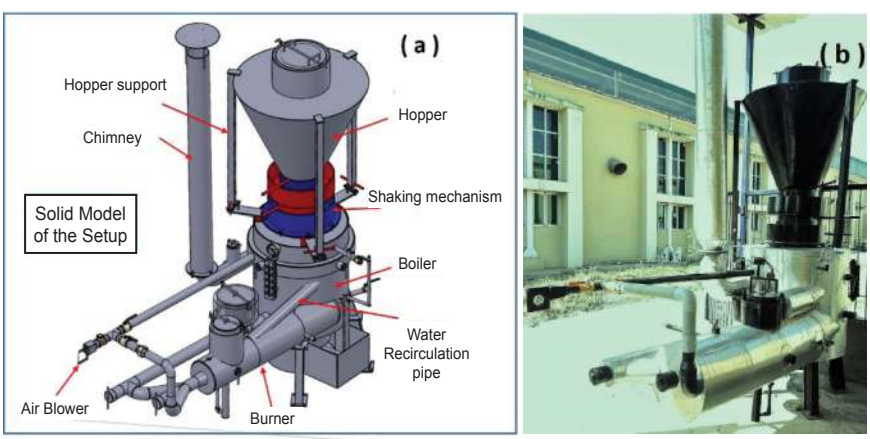

Figure 1 : Developed Heating Setup at IIT Patna

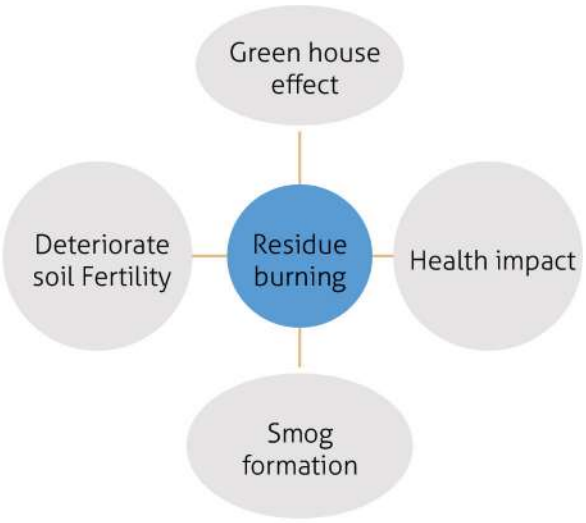

Figure 2 : Impacts of field burning of biomass

require hot water to run the thermodynamic cycle. It is possible to obtain hot water through various off-grid modes (both renewable and non-renewable). The dependency on sunlight is not very reliable in various parts of our country. In addition, the usage of fossil fuel like diesel/petrol is avoidable. To address this key problem, an agriculture waste based gasifier heating system was developed by the team at IIT Patna in collaboration with their industry partner New Leaf Dynamic Technologies.

The crucial innovation includes developing a gasifier based boiler with a spiral heat exchanger. This not only reduces the emissions but also increases the efficiency of the gasification process two-folds. The developed technology has already been incorporated in an existing GreenCHILL™ off-grid cold storage developed by the industry partner New Leaf Dynamics under the aegis of the Ucchatar Aavishkar Yojana (UAY) project. At the moment, the system consumes less than 10 kg of biomass to generate cooling equivalent to 3 Tons capacity. Efforts at further improvement are underway. In addition to the demonstrated technology, there has already been a publication and a patent coming out of this work [1,2]. The team is currently looking into further issues to address a number of technological challenges related to scaling and environmental conditioning in further collaboration with the industry partner. Efforts at employing a modified system for atmospheric water harvesting applications is also underway. The team also plans to develop systems for off-grid data center cooling in near future.

Biomass as a resource is a useful waste to value concept. The demonstrated technology of gasification based heating has a potential to solve a number of problems arising due to field burning of biomass waste. In particular, issues related to green-house gas emission, soil quality degradation,

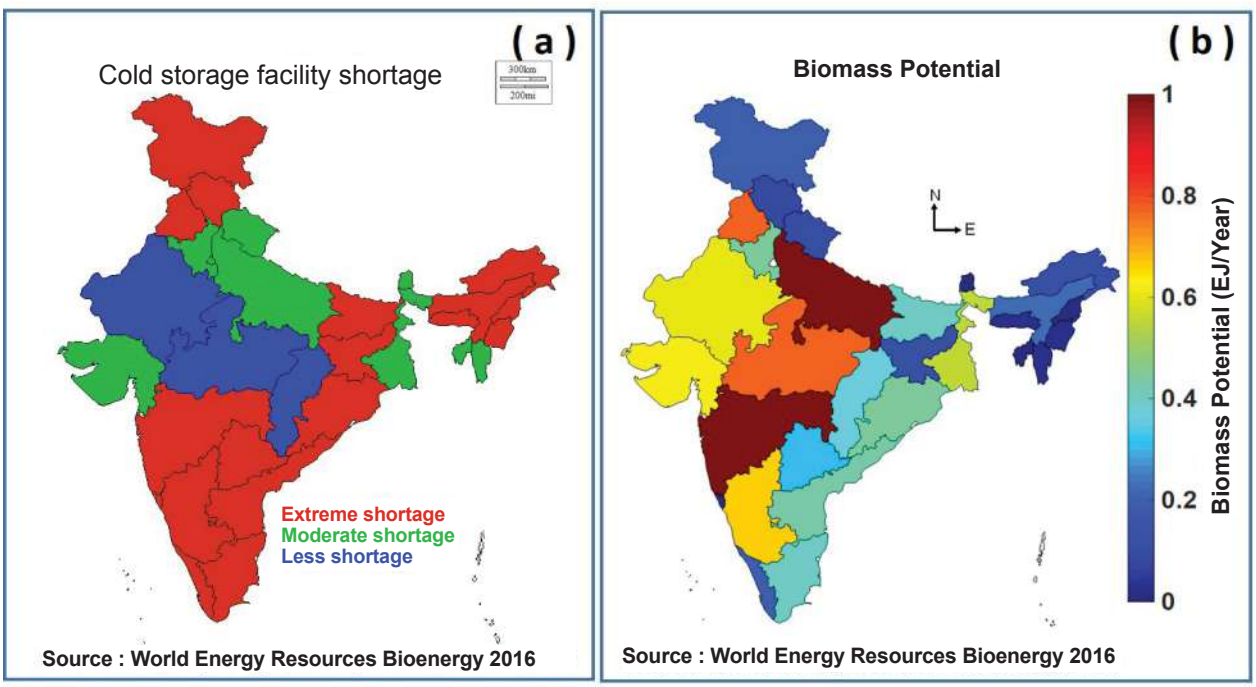

Figure 3 : A comparison between the demand for cold-storage and the biomass potential in India.

Figure 4 : The full system developed at IIT Patna in collaboration with industry partner (New Leaf Dynamic Technologies).

smog formation and associated health impacts are worrisome. The current problem of smog in and around NCR region is primarily due to the field burning of crop residues. This problem primarily arises due to the fact that the biomass residue from crops does not have an economic value and is a waste for farmers. Hence, before the start of a new season, farmers burn them in open air causing immense pollution, which is amplified due to wind patterns in winter and is primarily responsible for the smog problem we see in our country. While there is a great demand for cold storage within the country, the amount of biomass generated is also high and this can in turn feed into the economy as a resource. The technological developments in this domain at IIT Patna pave way for such end applications.

The demonstrated application of the gasifier based heating system in GreenCHILL™ off-grid cold storage utilizes biomass to produce refrigeration without any significant emissions. This creates a value and hence a market for biomass waste. While the system is primarily designed for off-grid refrigeration in remote locations, it can also be used to generate hot water for various process industries as well as normal household heating applications during winter, when refrigeration is not required. This product may therefore be critical for empowering our farmers while ensuring optimal usage of our energy resources without polluting our environment.

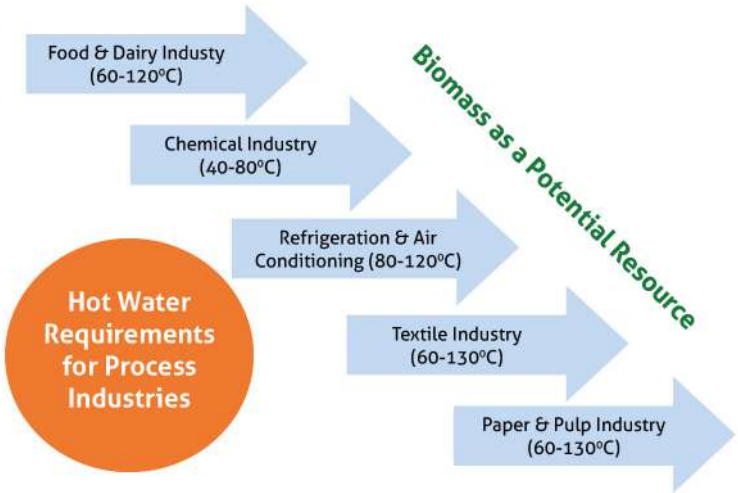

Figure 5 : Hot water requirement for process industries.

Moreover, the spin-offs of the innovation include the potential for developing off-grid data center cooling and heating ventilation and air-conditioning (HVAC) systems based on biomass utilization in addition to providing an approach for generating hot water for a number of process industries.

[1] Sunil, Raj, R., Thakur, A. D., Rajan, B. K., Chaitanya, B., Sinha, R., Agarwal, A., and Agarwal, A., "System and Method for Heat Recovery in Gasification Process," Application filed with the Indian Patent Office, Serial Number 201831011600, Application no. TEMP/E-1/12145/2018-KOL, Date 28/03/2018.

[2] Chaitanya, B., Bahadur, V., Thakur, A. D. and Raj, R., 2018, "Biomass-gasification-based atmospheric water harvesting in India," **Energy**, 165, pp. 610-621.

Insights from Electron Probe Micro Analysis of Minerals

Analysing Earth's Mantle

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It is well known that the planet earth is made of three fundamental layers viz. crust, mantle and core, which contrast with respect to their physical and chemical properties. Evidence for such a stratification has come from seismological (earth quake) studies wherein P (primary) and S (secondary) waves generated from earthquakes travel with different velocities in different media. However, direct evidence regarding the nature of the deep earth comes from the study of rock types such as kimberlites, lamproites and lamprophyres and their entrained xenoliths (foreign material) which are formed from magmas originating from mantle depths ranging around 160 km or excess. The chemistry of the minerals found in these rock types and in their xenoliths can be utilized to extract information on the evolution of the sub-continental lithospheric mantle (that portion of the mantle which underlies the continental crust and coupled with it). Indian shield is made up of several cratons (ancient old blocks which got stabilized ~ 2500 Ma) and mobile belts (2000- 500 Ma old reworked terranes which garlands the cratons).

Before proceeding further, it is important to detail salient aspects of two major instruments procured and installed under this project viz., Electron Probe Micro Analyzer (EPMA) and Scanning electron Microscope (SEM) which are the national facilities and are capable of physico-chemical characterization of any solids (minerals in this case) with high accuracy and precision. Both these instruments deploy fast accelerating electron beam to excite the X-rays from the atoms of the elements hosted in minerals (solids). X-rays of different elements have characteristic wave-lengths and their intensities are used to carry out qualitative and quantitative analyses of minerals using both these instruments. Whereas EPMA is best suited for carrying out high precision and accurate quantitative analyses together with moderate to

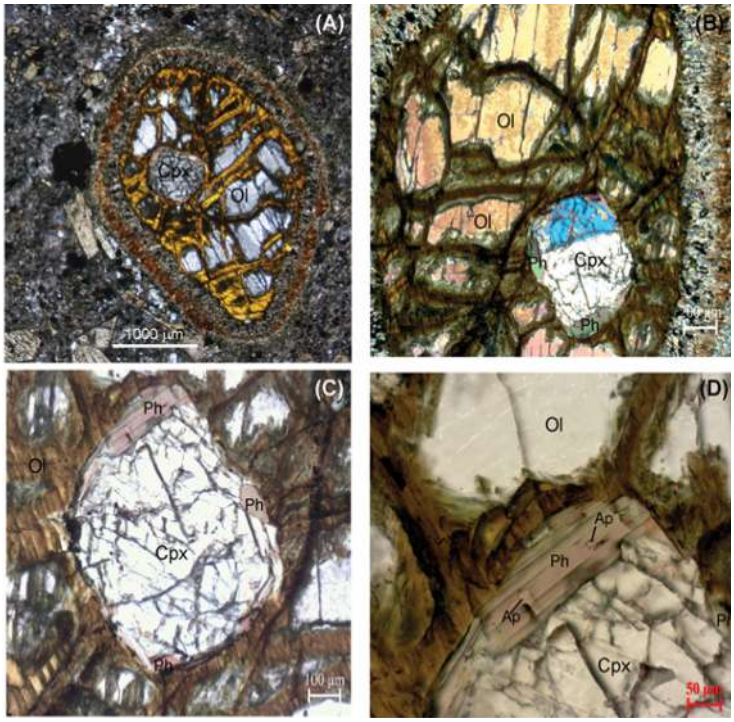

Figure 1 : Photomicrographs of the mantle xenolith encountered in the Dongargaon lamprophyre. (A) Oval shaped mantle xenolith showing olivine, and clinopyroxene. Note the reaction rim surrounding the xenoliths (XPL); (B) and (C) Rimming of phlogopite around the clinopyroxene in the mantle xenoliths (PPL); (D) A high magnification image showing the apatite inclusions within the phlogopite (PPL). Abbreviations: Ol= olivine; Cpx= clinopyroxene; Phl= phlogopite; Ap = apatite; XPL= Crossed polars; PPL= Plane polarized light.

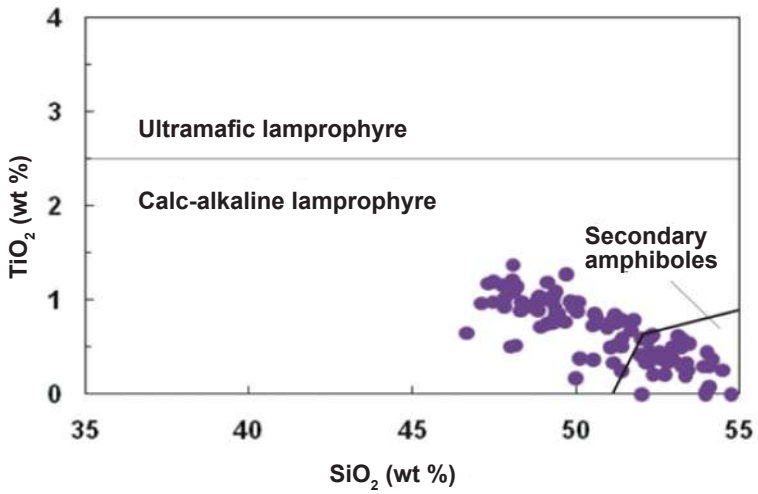

Figure 2 : TiO_2 (wt %) versus SiO_2 (wt %) plot for the amphibole suggesting its calc-alkaline nature of the lamprophyre.

good imaging, SEM is best meant for carrying out highest magnification (10,00,000 x) imaging and quantitative analyses with not so much precision and accuracy. A combination of results obtained from both these instruments can help in providing maximum physico-chemical information about the minerals.

Mineralogical and geochemical studies of kimberlites, lamproites and lamprophyres occurring in these cratons and mobile belts are being carried out in this project and some major inferences are summarized here.

- Presence of volatile-rich minerals such as phlogopite and apatite crystallized in an olivine + clinopyroxene bearing mantle xenolith entrained in a Eocene lamprophyre from the Dongargaon, Chhota Udepur area Chhota Udepur provides petrological evidence for hydrous modal metasomatism in the North Western India (Figure 1).
- Mineral chemistry of the clinopyroxene and amphibole from Mudigubba lamprophyres (western margin of the Cuddapah basin, southern India) provided supportive evidence for bulk rock geochemistry towards the discovery of Neoarchaean subduction processes in the evolution of the eastern Dharwar craton (Figure 2).
- Mineral chemistry data established the geochemical nature of the ultramafic variety of lamprophyre from Kutch Such types of lamprophyres are characteristic of rifted tectonic settings.
- An Island arc (ocean-ocean) tectonic setting has been brought from mineral chemistry of chromite grains from ultramafics of the Sonakhan greenstone belt, Bastar craton.
- Pre-Deccan lithosphere thickness estimated from pressure-temperature estimates of chrome diopside xenocryst from Late Cretaceous Mundwara complex, NW India
- Cobaltoan pyrite has been reported from a lamprophyre from the Mahakoshal belt, central India (Figure 3).
- Linkages of Mesoproterozoic lamproites from Vattikod area, eastern Dharwar craton, with Paleoproterozoic Columbia supercontinent brought out.

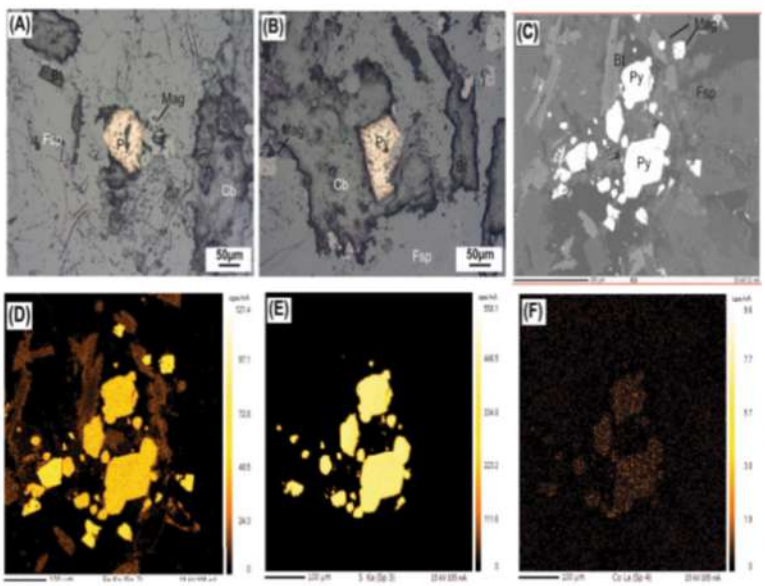

Figure 3 : Cobaltian pyrite in a lamprophyre from the lamprophyre from Sidhi, Mahakoshal belt, Central India.

Future Events

We are pleased to bring to your attention the following relevant and potential exciting scientific deliberations planned in the near future in India.

Event & Website	Organizer	Date & Place
INTERNATIONAL		
53rd Annual Convention of Indian Society of Agricultural Engineers (ISAE) and International Symposium on Engineering Technologies for Precision and Climate Smart Agriculture URL: www.iari.res.in/	Indian Agricultural Research Institute	January 28-30, 2019 Delhi, Delhi
International conference on Advanced Materials Chemistry at the Interfaces of Energy, Environment and Medicine (AMCI-2019) URL: https://www.msuniv.ac.in/	Manonmaniam Sundaranar University	January 30-31, 2019 Tirunelveli, Tamil Nadu
International Conference on Mathematical Modeling in Science and Engineering (ICMMSE – 2019) URL: www.buc.edu.in	Bharathiar University	February 01-02, 2019 Coimbatore, Tamil Nadu
International Conference on Recent Issues in Nuclear and Particle Physics (RINP2) URL: https://indico.cern.ch/event/763807	Visva-Bharati	February 03-05, 2019 Birbhum, West Bengal
International Symposium on 'Edible Alliums: Challenges and Opportunities' URL: www.dogr.res.in	Directorate on Onion and Garlic Research	February 09-12, 2019 Pune, Maharashtra
Fifth International Conference on Hydrology and Watershed Management with a focal theme on Urban Water Management for Sustainable Development URL: www.ichwam.org	Institute of Science and Technology, JNTUH	February 12-15, 2019 Hyderabad, Telangana
International Conference on Medicinal, Aromatic and Nutraceutical Plants from Mountainous Areas URL: https://acmap.geu.ac.in	Graphic Era University	February 14-16, 2019 Dehradun, Uttarakhand
Second International Conference on Advanced Computational and Communication Paradigms (ICACCP-2019) URL: http://www.icaccpa.in/	Sikkim Manipal Institute of Technology	February 25-28, 2019 East Sikkim, Sikkim
2nd International Conference On Innovations In Chemical, Biological & Environmental Sciences (Science & Technology For A Sustainable Future)(Icicbes-2019) URL: www.aryapgcollege.com	Arya P.G. College	February 27-28, 2019 Panipat, Haryana
The 13th International Conference and Workshop on Algorithms and Computation (WALCOM 2019) URL: http://www.iitg.ac.in/walcom2019/	Indian Institute of Technology Guwahati	Feb. 27-02 Mar., 2019 Guwahati, Assam
ISTH-ILBS Symposium on coagulopathy in Liver Diseases URL: https://www.ilbs.in/	Institute of Liver and Biliary Sciences (ILBS)	March 02-03, 2019 Vasant Kunj, New Delhi,
International IACMAG Symposium 2019 and Pre-symposium Workshop URL: http://events.iitgn.ac.in/2019/iacmag/	Indian Institute of Technology, Gandhinagar	March 04-07, 2019 Ahmedabad, Gujarat
Microbial Pathogenesis and New Frontiers URL: https://www.imtech.res.in/events/international-conference-on-microbial-pathogenesis-and-new-frontier	CSIR-Institute of Microbial Technology	March 20-22, 2019 Chandigarh
NATIONAL		
Contemporary Issues on Advanced Materials for Noise and Vibration Applications URL: chennai.vit.ac.in/	VIT University Chennai	February 01-02, 2019 Chennai, Tamil Nadu
सूक्ष्म पदार्थ एवं सम्बद्ध चेतन ऊर्जा पर राष्ट्रीय संगोष्ठी URL: https://www.periyaruniversity.ac.in/	Babasaheb Bhimrao Ambedkar University	February 01-03, 2019 Lucknow, Uttar Pradesh
31st Kerala Science Congress URL: http://ksc.kerala.gov.in/	Kerala State Council for Science, Technology & Environment	February 02-03, 2019 Thiruvananthapuram, Kerala
24th CRSI National Symposium in Chemistry (CRSI-NSC-24) URL: https://www.clri.org/	Central Leather Research Institute	February 08-10, 2019 Chennai, Tamil Nadu
Theoretical Chemistry Symposium 2019 (TCS-2019) URL: http://www.bits-pilani.ac.in/pilani/tcs2019/home	Birla Institute of Technology and Science (BITS)-Pilani	February 13-16, 2019 Pilani, Rajasthan
Climate Change Impacts, Vulnerabilities, and Adaptation: Emphasis on India and Neighbourhood (CCIVA 2019) URL: www.iitkgp.ac.in/	Indian Institute of Technology Kharagpur (IIT KGP)	Feb. 26-02 Mar., 2019 Midnapore, West Bengal
Waste Management for Greener and Cleaner Environment URL: http://www.klyuniv.ac.in/	University of Kalyani	March 01-02, 2019 Nadia, West Bengal
Belle Analysis Workshop (BAW) 2019 URL: https://sites.google.com/view/baw2019/home	Indian Institute of Science Education and Research, Mohali	March 01-04, 2019 Mohali, Punjab
Emerging Trends in Chemical Sciences (ETCS-2019) URL: http://www.cujammu.ac.in/	Central University of Jammu	March 14-15, 2019 Jammu, Jammu and Kashmir

Funding Schemes of SERB
A World of Possibilities

Core Research Grant (Formerly known as EMR)

Individual centric competitive mode of funding will be provided under the CRG, SERB supports potential scientists for undertaking research in frontier areas of S&T in Life Sciences, Physical Sciences, Chemical Sciences, Engineering Sciences, Earth & Atmospheric Sciences & Mathematical Sciences.

High Risk High Reward

The Scheme for Funding High Risk - High Reward Research aims at supporting proposals that are conceptually new and risky, and if successful, expected to have a paradigm shifting influence on the S&T. This may be in terms of formulating new hypothesis, or scientific breakthroughs which aid in emergence of new technologies.

Early Career Research (ECR) Award

This scheme aims to provide quick research support to the young researchers who are in their early career for pursuing exciting and innovative research in frontier areas of science and engineering.

Industry Relevant R&D (IRRD)

Supports joint academia-industry proposals that address a well-defined problem of industrial relevance.

Intensification of Research in High Priority Area (IRHPA)

Supports proposals in high priority areas that require multidisciplinary/ multi-institutional expertise.

Empowerment and Equity Opportunities for Excellence in Science

This scheme drives special programs to ensure enhanced participation of people from the marginalized sections of the society in the research and development field.

Women Excellence Award

This Award is given to young women scientists below 40, who have received recognition of any one of the national academies of the country. The scheme offers a research grant of Rs.5 lacs per annum for a period of 3 years.

Visiting Advanced Joint Research Faculty Scheme (VAJRA)

VAJRA Faculty Scheme is to bring a strong international connect to the R&D ecosystem of India. The scheme offers adjunct / visiting faculty assignments to overseas scientists, faculty members and R&D professionals.

International Travel Support (ITS)

International Travel Support (ITS) Scheme provides financial assistance to Indian researchers for presenting a research paper in an international scientific event (conference, seminar, workshop etc.) held abroad.

National Post Doctoral Fellowship (N-PDF)

To identify motivated young researchers and provide them support for doing research in frontier areas of science and engineering. The fellows will work under a mentor, and it is hoped that this training will provide them a platform to develop as an independent researcher.

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