



IIT Gandhinagar

RESEARCH SPECTRA

Collaboration • Innovation • Impact

www.iitgn.ac.in





RESEARCH SPECTRA

Collaboration • Innovation • Impact

Disclaimer

The material presented in this document has been prepared and compiled in accordance with explicit publication rights resting with the Indian Institute of Technology Gandhinagar. This document is intended for pure academic use by individuals and institutions without any bias or judgement towards its contents. The editors and IIT Gandhinagar will not be responsible for any direct, accidental, or consequential misinterpretations arising from the use of material contained in this document.

Development of this document was supported by the Indian Institute of Technology Gandhinagar, Gujarat, India.

The material presented in this document can be reproduced while giving appropriate credits to the creators of this work.

CREDITS

CONTENT

Tanumita Misra

EDITORS

Prof Sharada CV and Vandana Yadav

PHOTOS

Gaurav Shukla, Devarsh Barbhaya, and Hatim Sham

ILLUSTRATIONS

The scientific drawings and graphic material were prepared by students or research group labs at IIT Gandhinagar.

LAYOUT & DESIGN

Gaurav Shukla and Hatim Sham

COPYRIGHT

Indian Institute of Technology Gandhinagar, 2021

Indian Institute of Technology Gandhinagar

Email: dean.rnd@iitgn.ac.in

Website: www.iitgn.ac.in

What's Inside

'To go about seeking' or *recherché* is one of the primary interest areas and pursuits of the Indian Institute of Technology Gandhinagar (IITGN). The euphoria of research lies in the opportunity to quench one's curiosity, leading to unexpected avenues of discovery. It is exciting indeed when these avenues give rise to broader impacts benefiting society.

The Research Spectra published by the Office of Research & Development at IITGN presents a diverse array of research stories with the aim to inform and inspire the IITGN community and beyond. We hope that this publication will also serve as a useful educational tool for students and young professionals. The pioneer volume of this compendium incorporates stories from a plethora of research activities and discoveries across disciplines at IITGN. It extends a run-through of the published research findings in cutting-edge areas of discovery, initiatives, experiences, and achievements made by the faculty and students.

The focus of our endeavour is to bring to the fore and share the ideas and perspectives of the teams behind these researches. The research community continues to strive for innovation with a focus on changing lives for the better. With excellent research facilities on our campus, outstanding faculty from some of the world's best educational institutes, and a committed team of staff and scholars, we believe we have the potential to undertake novel discoveries. But, what we discover can materialise and become fruitful only when communicated to a larger audience. Through the medium of the Research Spectra, we aspire to keep all our readers and well-wishers informed about our objectives, the impact they are creating, and the many research stories that are yet to be told.

Enjoy the read!



Contents

8

*A Step Closer to Developing
Antibacterial Drugs*
Prof Abhijit Mishra

10

*A Way Forward on
Understanding Black Holes*
Prof Anand S Sengupta

12

*Is there a Parallax in the Mind?
An Investigation into Beckett*
Prof Arka Chattopadhyay

14

*Fibre Optic Sensor-Based
Glove for Stroke Rehabilitation
Monitoring*
Prof Arup Lal Chakraborty

16

*Over 60-Year-Old Unstudied
Mathematical Masterpiece
Uncovered*
Prof Atul Dixit

18

*Low-Cost, Non-Electric, and
Point-Of-Use Water Filter*
Prof Chinmay Ghoroi

20

*DNA Nanodevices Designed to
Function as Smart Therapeutics*
Prof Dhiraj Bhatia

22

*Unique Surface Coating that
Inhibits Viral Activity*
Prof Emila Panda

24

*Study Explains Potential Severity
of Fire in Modern Buildings*
Prof Gaurav Shrivastava

26

*Researchers Synthesise
Compound for Anti-Cancer
Applications*
Prof Iti Gupta

28

*Coupling Solvents to Achieve
a Sweet Spot for Synthesising
Nanosheets*
Prof Kabeer Jasuja

30

*A New Class of Nano-Additives
for Fuels Used in Space and
Defence Applications*
Prof Kabeer Jasuja

32

*Studying Gandhian Literature,
the New User-Friendly Way*
Prof Mayank Singh

34

*Studying Surface Patterning for
Enhanced Enzyme Activity*
Prof Mithun Radhakrishna

36

*A Switch to Decentralised
Energy Access: Prosumer-Driven
Integrated Smart Grid*
Prof Naran Pindoriya

38

*New Lead for 'Make in India'
Technology, Manufacturing
High-Voltage Devices*
Prof Nihar Ranjan Mohapatra

40

Why is my Electricity Bill so High?

Prof Nipun Batra

42

Vartalaap: Understanding the Public Perception on Air Pollution

Prof Nipun Batra and Prof Udit Bhatia

44

Uncovering Neural Mechanisms Underlying Limb-Independent Motor Memories for Stroke Rehabilitation

Prof Pratik Mutha

46

Double-Layered Microbubbles for Effective Drug Delivery

Prof Sameer Dalvi

48

Exploring Effectiveness of 'Curcumin' as an Anti-Cancer Compound

Prof Sameer Dalvi and Prof Dhiraj Bhatia

50

Enhanced Molecular Fluorescence by Ordered Gold Nanostructures to Benefit Single-Molecule Imaging

Prof Saumyakanti Khatua

52

How Neurons Uptake Different Nanosized DNA Cages

Prof Sharad Gupta and Prof Dhiraj Bhatia

54

A 'Made in India' Molecule that could be a Potential Cure for Cancer

Prof Sivpriya Kirubakaran

56

Forging Ahead with Targeting Mitochondria in Cancer Therapy

Prof Sudipta Basu

58

Smart Shoe Insole, a Gait-Analysis Device

Prof Uttama Lahiri and Prof Manasi Kanetkar

60

Virtual Reality Platform for People with Autism

Prof Uttama Lahiri

62

Wearable Robotic Suit to Facilitate Normal Walking in Stroke Patients

Prof Vineet Vashista

64

Research Blurb

**Prof Arpan Bhattacharyya
Prof Raghavan Ranganathan
Prof Karla Mercado-Shekar
Prof Prasanna Venkatesh**

66

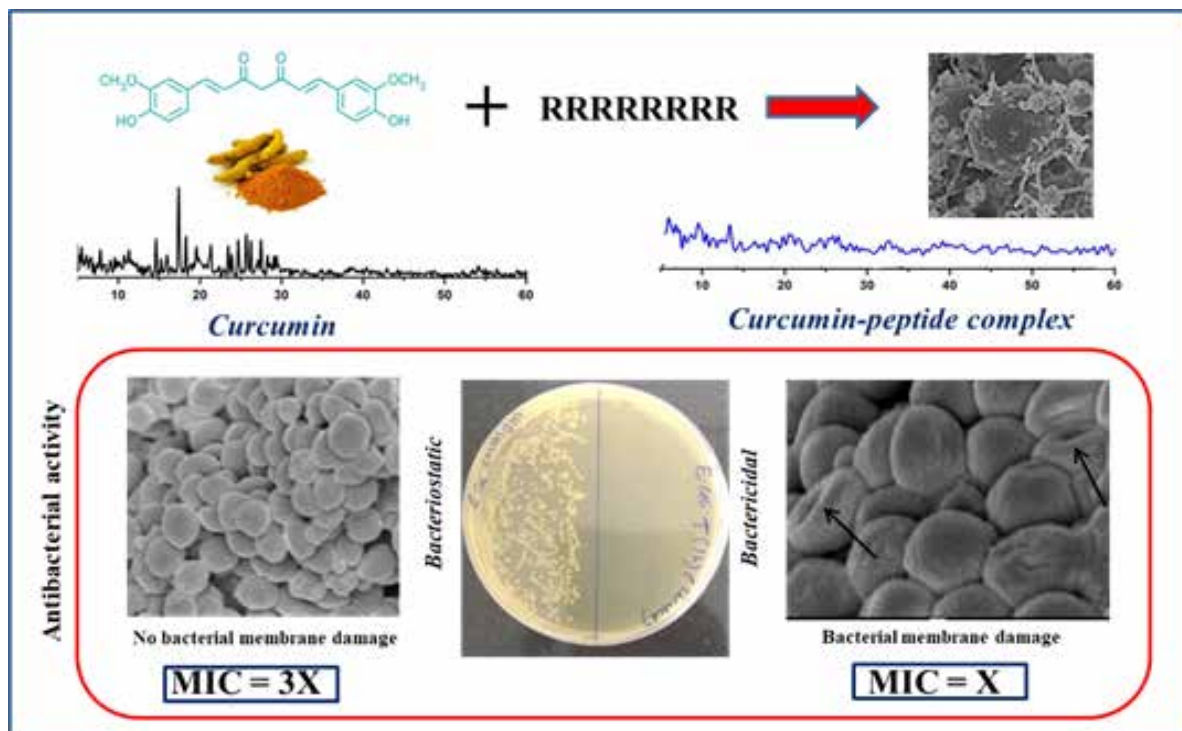
The Research Park at IIT Gandhinagar

68

IIT Gandhinagar Innovation and Entrepreneurship Center

70

Bibliography



A STEP CLOSER TO DEVELOPING ANTIBACTERIAL DRUGS

Research reveals the potential of a complex as an antibacterial and anticancer drug

Bacteria are everywhere. Although they are vital to the ecosystem, some of them cause infections and diseases. The imperviousness of bacteria towards antimicrobial drugs is a global threat to human health. Recent research has devised novel pathways for designing antimicrobial drugs based on combination therapy, which involves administering separate pharmacological agents to treat diseases.

Poonam Ratrey, a PhD scholar at IITGN, has developed a complex/hybrid of curcumin and a cell-penetrating peptide – octaarginine (R8) that could target the cell membrane of bacteria. This complex kills the bacteria rapidly within 0.5 hours and penetrates the bacterial cell membrane. The study was led by **Prof Abhijit Mishra**, Associate Professor, Materials Engineering.

Curcumin is a yellow-colored compound obtained

from the plants of *Curcuma longa* species. It is the principal bioactive substance found in turmeric, an Indian spice, and is known for its anti-inflammatory, antibacterial, and anticancer properties. It has thus gained worldwide interest for its potential multiple medicinal applications. However, owing to its low aqueous solubility and low membrane permeability, its clinical application is hindered.

Cell-penetrating peptides (CPPs) are short chains of amino acids that deliver biologically active molecules into cells. Over the past years, the potential of CPPs has broken new ground for effective drug delivery. Conjugate of biomolecules with CPPs acts as drug delivery vehicle for transporting biomolecules across the cell membrane.

The team greatly enhanced the aqueous solubility and stability of the potential wonder drug, curcumin, by linking it non-covalently with octaarginine. They



It is the first-ever approach in the literature wherein we are using a cell-penetrating peptide for antibacterial drug delivery while improving the original antibacterial property of raw curcumin.

-Prof Abhijit Mishra



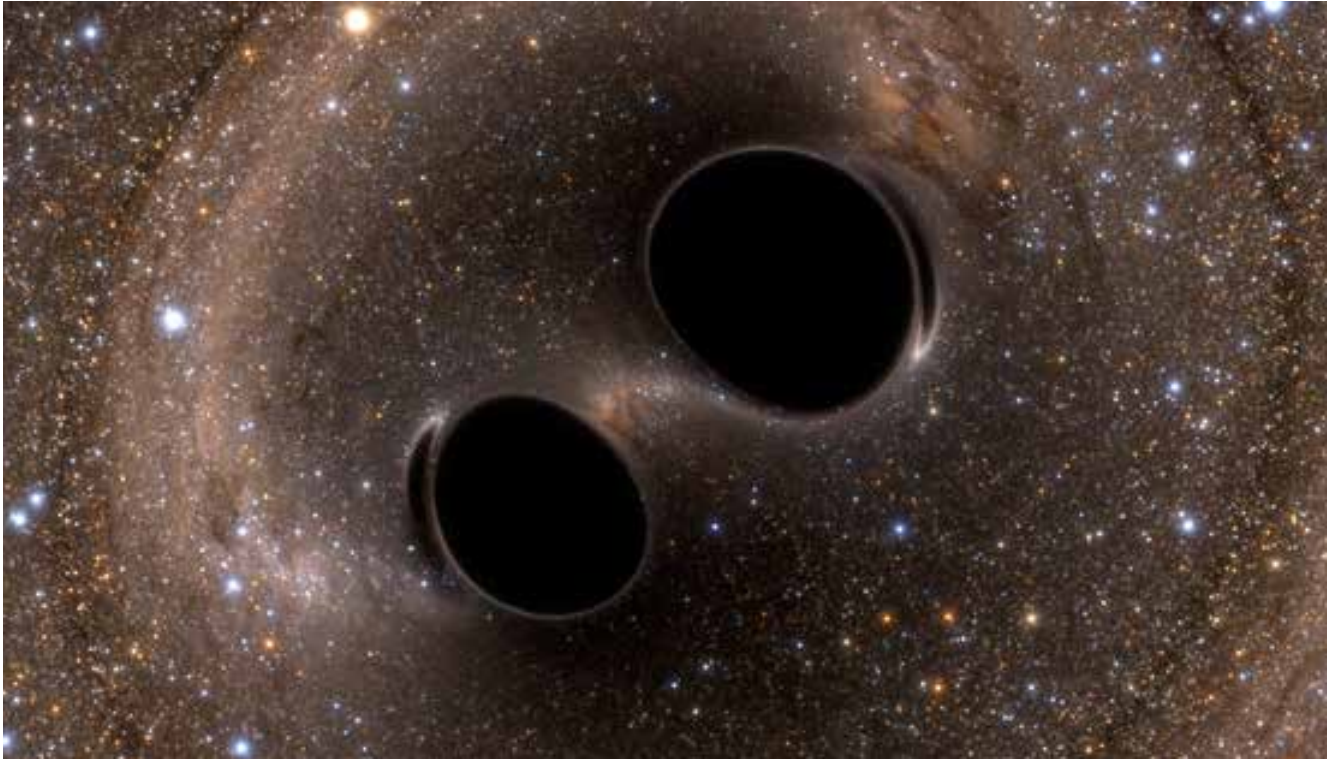
carried out dropwise mixing of ethanolic curcumin and aqueous peptide solutions to prepare peptide-curcumin complexes. These complexes had 1 mg of curcumin and varying amounts of peptides in them. The team observed the antibacterial activity of the complexes against bacteria and found that they could target and rupture the bacterial cell membrane, enhancing the antibacterial activity of curcumin in parallel.

“The ability of the complex to target membranes, something that raw curcumin cannot do, not only improves antibacterial efficiency but also makes it harder for bacteria to develop resistance,” says Professor Mishra. “The peptide-curcumin complex also displayed anticancer activity against cancerous HeLa

cells, and was able to penetrate into mammalian cells.” The work finds application in medicine and human health. Since bacterial organisms are the focal point of the study, it can be used in the development of effective antibacterial drugs. “Resistance to conventional antibiotics offered by disease-causing bacteria is a huge and ever-growing challenge to the clinical science and healthcare industry. Our study, observations, and findings are an effort directed towards the endeavour of finding alternative and suitable approaches to combat the resistance crisis and improve the efficacy of the presently available drug through a novel strategy,” he explains.

The study was published in the *ACS Omega Journal*.





A WAY FORWARD ON UNDERSTANDING BLACK HOLES

Detecting higher-order modes of gravitational waves could lead to precise measurements of black holes' properties

Did you know that the merger of a pair of black holes, called a binary, produces gravitational waves (GWs) which can actually be detected? These GW signals from binary black holes can be broken into different pieces called 'modes'.

A research team at IITGN, led by **Prof Anand S Sengupta**, Associate Professor, Physics, has introduced a new method for detecting the higher-order modes of GW signals from a single isolated merger event.

GWs are ripples in space-time caused by the acceleration of masses. In 1916, Albert Einstein predicted the existence of GWs as a part of his theory of general relativity. It was for the first time in 2015, when a team of scientists working on the Laser Interferometer Gravitational-wave Observatory (LIGO) detected GWs, which propagate outward from their

source at a speed of light, expelled by two colliding neutron stars. This discovery earned LIGO, the most sensitive detector, a Nobel Prize in Physics in 2017.

The GW detectors detect the GW generated by the inspiraling compact binary systems – the systems of two compact black holes spiraling swiftly past each other in their latter stage of evolution. Such observations of GW signals made by LIGO provide a precise understanding about the properties of the expanding universe and its components.

The higher-order modes of the GW signals are weak and hence difficult to detect. However, the higher-order modes in signals can open the door to new tests of Einstein's theory of general relativity and provide insight into the origin of black holes and extreme conditions inside them. Although the present generation of interferometric GW detectors



Even if the higher-order modes of gravitational waves are too faint to be deciphered in observed individual signals, our method can combine several such observations to tease out the faint modes.

-Prof Anand S Sengupta



are incapable of detecting higher-order modes from a single observation, a combination of several observations could tease out the weak signals.

“Each mode of the GW signals carries a certain fraction of the total energy emitted during the merger of two in-spiraling black holes. Detecting these pieces separately in GW detectors is a challenge, but can lead to precise measurements of the black holes’ properties,” explains Professor Sengupta.

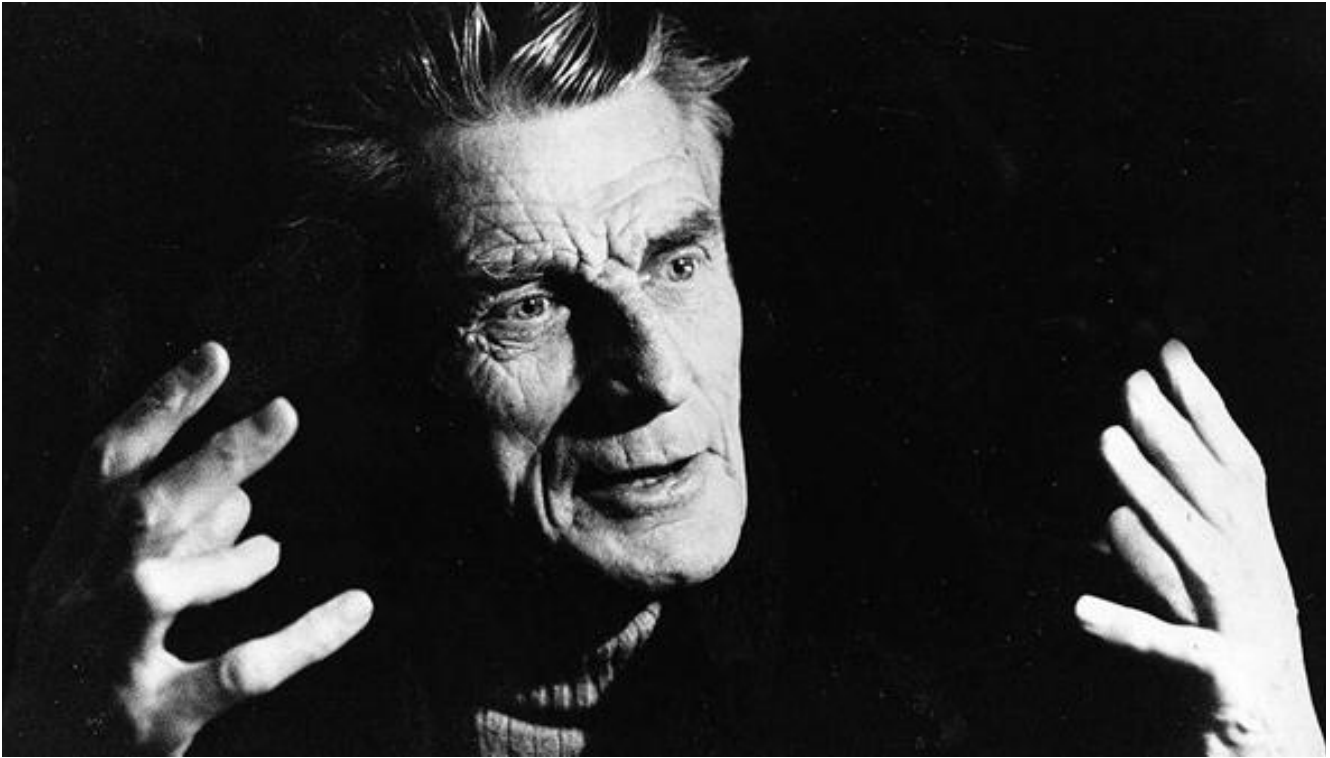
The IITGN researchers came up with a new method to detect the higher-order modes by combining multiple events observed in the interferometric GW detectors. “So far, we are unaware of any work in literature that deals with the problem of combining multiple events detected, probably due to the difficulty posed by their time-varying instantaneous frequency, especially in the latter in-spiraling stages,” he says.

The method introduced by them is unique as they used a different signal processing strategy to disentangle various modes of the GW signal using time-frequency representations. “It is a particularly effective method as one can detect multiple weak

signals and obtain higher-order modes even if they are too faint to be deciphered in individual signals. This is done by improving their signal-to-noise ratio which is the ratio between the desired signal and the background noise,” he adds.

Researchers in the international LIGO scientific collaboration used this method to demonstrate the presence of higher-order modes in two recent events. The proposed method is one of the four techniques capable of detecting these signals and appeared in the *Astrophysical Journal Letters*. The research paper is co-authored with **Dr K G Arun**, Professor at The Chennai Mathematical Institute, and **Dr Soumen Roy**, former PhD scholar at IITGN and now a postdoctoral fellow at Utrecht University, Utrecht, Netherlands.





IS THERE A PARALLAX IN THE MIND? AN INVESTIGATION INTO BECKETT

Study shows parallax as a tool to activate the psychic archive by seeking to grasp the materiality of the immeasurable

Between the maddening pathos and the taunting wit of *Waiting for Godot*, the effect left behind by the genius of Samuel Beckett, an Irish writer during the 20th century, is astounding in its self-reflexive craftsmanship. The existential interludes and anxieties shimmering in Beckett's works are not just reserved for deep dives in literary criticism. His craft, the art, and his persona are together and individually a treasure trove.

In his recent exploration of Beckett, Prof Arka Chattopadhyay, Assistant Professor in Humanities & Social Sciences, of IITGN has examined the speculative presence of a psychic parallax, as it is mapped in Beckett's works. In this study, he amalgamates caveats on psychic immeasurability from the psychoanalytic perspectives of Jacques Lacan and Žižek, alongside Derrida's archival perspective to ascertain the presence and function of

the parallax in Beckett's TV play ...but the clouds... and prose text, *Stirrings Still*.

The Merriam-Webster dictionary defines parallax as the "the apparent displacement or the difference in apparent direction of an object as seen from two different points not on a straight line with the object." Professor Chattopadhyay in his study published in the *Textual Practice*, frames parallax as a specific mode of operation, governed by a mathematical logic that proffers a materialist form to the mind as a trope in the literary text.

The parallax is situated as an ineffable psychic distance that tinkers with our knowing of things in the real world. Such an understanding is siphoned through the Lacanian articulation of the real as an inexpressible matter that can only be presented via impasses in mathematical forms. Professor



There are not too many works on these late and relatively little discussed texts of Samuel Beckett and the paper moreover brings in a new angle of Beckett's interest in mathematics to deal with psyche as an archive and eventually as a distance.

-Prof Arka Chattopadhyay



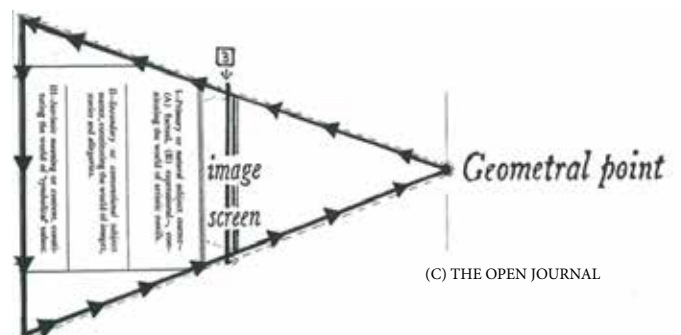
Chattopadhyay, using the Lacanian accent on the Real, constructs and presents a case for the psyche as distance by juxtaposing it with Beckett's works, so as to introduce parallax as a mathematical mode of grasping psychic distance.

Citing Slavoj Žižek, Professor Chattopadhyay articulates that the Lacanian real has no ontological substance — what we understand as the real is referential to the gap between multitude of perspectives and not existent by itself for us. In such a framework, parallax perceives the same object from different points that have no shared ground. So by using Žižek's approach that endears the real to the mathematical notion of parallax, he argues that the parallax, in housing both sameness and difference in a visually perceived object, is a figure of impasse.

Sensitive to the emergent aporia, Professor Chattopadhyay turns to Derrida's conceptualisation of the psychic archive as a dynamic matrix of what we remember and what remains irreversibly forgotten. He explains, "the Real in the psychic archive is the spectral trace of the unknowable." In such a parameter of the psychic archive that grounds the play between memory and forgetting, he posits parallax as a mnemotechnical supplement that precipitates the real as immeasurable and yet indispensable to perception.

"Having established how the parallax is manifested in perception and the psychic archive, I analyse the aforementioned works of Beckett delineating evidence that indicates awareness and manipulation of the parallax as both a textual trope and in the unpublished manuscript as a textual archive," he says. He showcases the play of parallax in the stage directions of ...but the clouds... and in the unpublished drafts of *Stirrings Still*.

With evidence on how Beckett has operationalised parallax, his investigation concludes that the parallax operates as a tool to activate the psychic archive by seeking to grasp the materiality of the immeasurable. Using parallax, the study breaks the image-driven idea of the psyche and reconfigures it as one of intractable self-distance, disclosing the possibility to mathematicize the psychic archive. From his argumentative standpoint, Professor Chattopadhyay makes an impassioned call for more efforts to find the exact distances in the psyche to understand its defiant self-distance.



(C) THE OPEN JOURNAL



FIBRE-OPTIC SENSOR-BASED GLOVE FOR STROKE REHABILITATION MONITORING

A fibre-optic sensor-based glove that could help in monitoring the rehabilitation of stroke patients.

Researchers at the **Photonic Sensors Lab**, IITGN have designed a fibre optic-sensor based glove that could be useful in monitoring the rehabilitation of stroke patients. The glove can record the flexing of fingers with a very high accuracy and offers the possibility of quantitative assessment of the recovery.

The first Stroke Summit, organized in December 2019 by the health think tank Integrated Health and Wellbeing (IHW) Council and endorsed by World Stroke Organization, addressed the issue of growing prevalence of stroke in India. It highlighted the fact that stroke is one of the leading causes of disability and deaths in India with an estimated 1.8 million people being affected every year.

Residual spasticity is a common and major post-stroke problem. The stroke survivors require

rehabilitation therapy to recover and relearn the basic skills lost/forgotten during the stroke. The rehabilitation exercises commonly recommended by physiotherapists are repetitive and monotonous. More importantly, the conventional techniques of determining the extent of recovery in stroke survivors are largely subjective, time-consuming, and prone to measurement errors.

“We wanted to turn this around and decided to explore a quantitative and engaging approach that could be customised to a person’s comfort level and interests,” says **Prof Arup Lal Chakraborty**, Associate Professor, Electrical Engineering. “We have developed a glove that uses an optical fibre-based sensor known as a fibre Bragg grating that is extremely sensitive to microscopic elongation of the fibre. The glove has the potential to quantify the improvement in post-stroke rehabilitation. The glove is interfaced with a



virtual reality (VR) environment in which immersive and customised tasks can be designed. The tedium of conventional exercises can be significantly reduced and people could perhaps even enjoy a rehabilitation session. We do believe that is possible.”

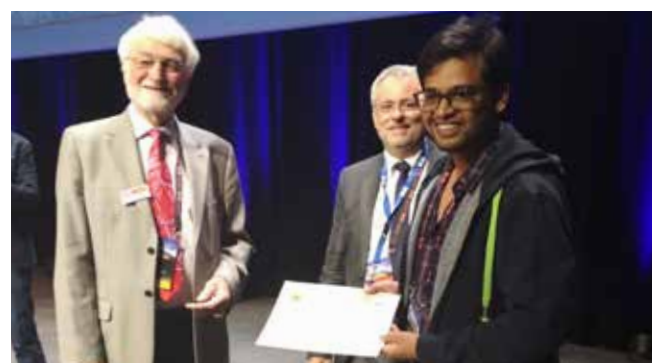
Chandan Kumar Jha, the PhD scholar who developed the glove, explains, “We can accurately measure the strain induced in the fibre Bragg grating when a patient wears the glove and bends fingers. The angle by which the joints of the fingers are rotated can then be calculated rapidly, thereby making it possible to monitor the movement of fingers in real-time. Currently we can monitor 10 joints simultaneously. We have interfaced the glove with a VR environment, and one can watch a virtual hand mimic the movement of your hand. One can also play games by moving one’s fingers. The combination of the glove and VR has the potential to incentivise post-stroke rehabilitation for the patient while also providing real-time data on the movement of fingers to the doctor.”

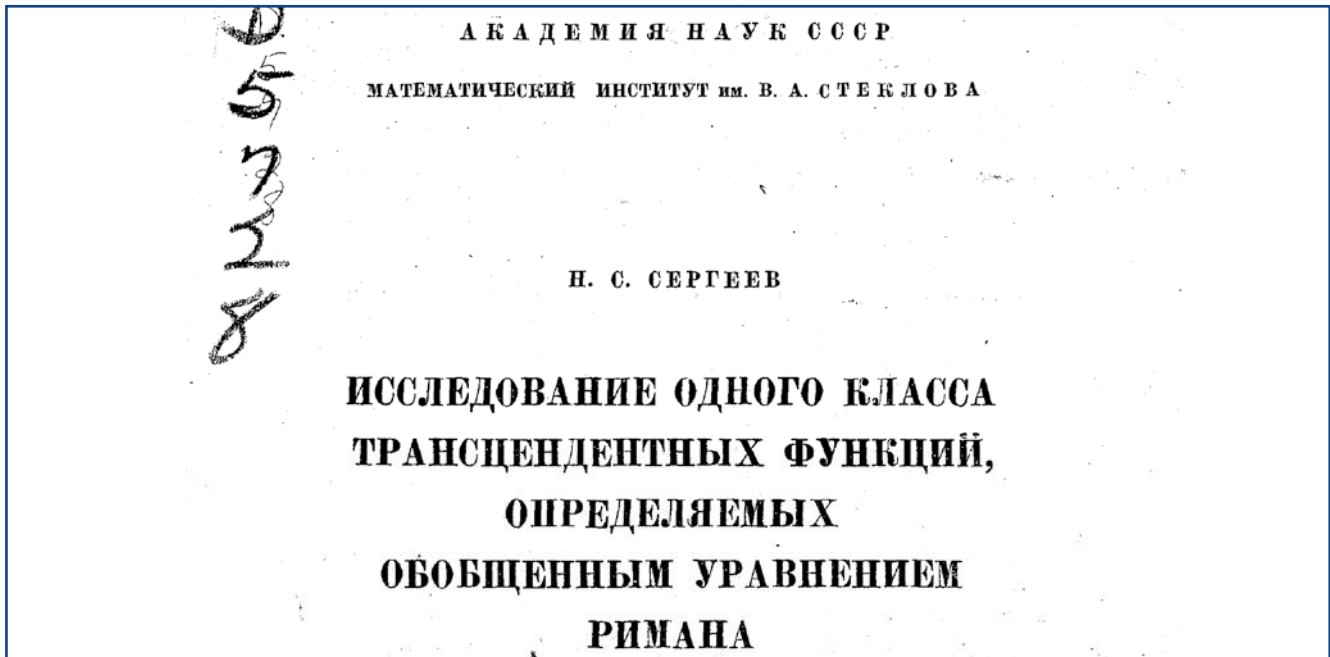


The research team is currently focusing on making the glove robust so it can be operated by a technician without the intervention of doctors, and on setting up automatic data logging and visualisation methods.

“We have engineered the glove carefully to make it robust so that repeated wearing and removing of the glove does not affect its performance. There are no electrical hazards because there is only light travelling through the optical fibre. We will soon have a battery-powered, light-weight system that can be strapped on to the arm,” says Professor Chakraborty. In the next phase of this work, the team looks forward to conducting field trials on multiple stroke patients. “Conducting field trials will be a very important phase during which we would engage with medical experts for their feedback on the design and functionality. We are optimistic and quite confident about the glove’s capabilities.” he says.

The work appeared in the *IEEE Sensors Journal* and *IEEE/OSA Journal of Lightwave Technology*.





OVER 60-YEAR-OLD UNSTUDIED MATHEMATICAL MASTERPIECE UNCOVERED

*Researchers uncover and examine the long-lost manuscript
that could find applications in science and engineering*

Prof Atul Dixit, Associate Professor of Mathematics, along with his PhD student, Rajat Gupta, has brought to light a manuscript that sank into oblivion during the aftermath of World War II. The manuscript was written by Nikolai Sergeevich Koshliakov, an outstanding Russian mathematician who made seminal contributions to analytic number theory and differential equations. In 1949, he published this manuscript of over 150 pages written in Russian. Literature has a fascinating account of the adverse conditions in which the manuscript was written and how it became available to the mathematical community.

While harking back to his journey towards uncovering the manuscript, Professor Dixit said, “In 2010, during my fourth year of graduation at the University of Illinois at Urbana-Champaign, I came across an article written on the centenary of Koshliakov’s birth which had a reference to this manuscript. I was fortunate

to get a copy of the whole document from the Center for Libraries (CRL), Chicago. It didn’t take me long to realise that it is indeed a mathematical gem.”

Their paper, accepted for publication in *Advances in Mathematics*, is the first of a series of papers that they plan to write on this subject. The second paper is in the making. “I am happy to have played a modest role in uncovering this extremely significant masterpiece of Koshliakov,” he exclaimed. “In addition to the mathematical research, there is the historical aspect intricately woven in our paper.” The study builds further the Koshliakov theory that contains the theory of the Riemann Zeta function as a special case.

What is the Riemann Zeta function?

You’ve probably heard about ‘function’ in mathematics. It is defined as a relationship between two sets wherein each element of the first set is



It may, sometimes, happen that a manuscript so important as this falls through the cracks. I feel it's our responsibility to try to uncover such works, if we can. Who knows what valuable information they may contain!

-Prof Atul Dixit



associated with exactly one element of the other. The Riemann Zeta function is one of the most important special functions of Mathematics. It is an infinite series for all complex numbers (of the form $x + yi$, wherein $x > 1$ and y are real numbers and i is the imaginary number). It is defined by means of other representations for all other complex numbers (except when $x=1, y=0$).

What did the mathematicians find?

Rajat undertook and efficiently accomplished the daunting task of translating the more than 150-page manuscript that remained unveiled for over 60 years after getting published, from Russian to English. He and Professor Dixit coined the term 'Koshliakov zeta functions' for the two functions whose study forms the crux of Koshliakov's manuscript. "We have merely scratched the tip of the iceberg by obtaining a couple of new results in the theory of Koshliakov zeta functions which lay dormant in the mathematical community for about 60 years," said Professor Dixit.

They have used the Koshliakov theory to obtain two modular relations generalizing two famous formulas of Ramanujan. Loosely speaking, a 'modular relation' is an identity which relates $F(x)$ with $F(1/x)$ for a certain function F in a 'nice' way. In some cases, we simply have $F(x)=F(1/x)$. The first one of the two modular relations obtained is a generalization of Ramanujan's famous formula for odd values of the

Riemann zeta function. The Riemann zeta function at even positive integers is known to be irrational. Unlike this, the arithmetic nature of the odd zeta values (special values of the Riemann zeta function at odd arguments) is far from being known. So far, one only knows that $\zeta(3)$ is irrational. Ramanujan's formula for odd zeta values is important not only from this perspective but also from the fact that it encodes modular properties of significant objects called 'Eisenstein series'. Their second result is a generalization of a curious formula in Ramanujan's Lost Notebook, which is the 138-page manuscript in which Ramanujan recorded the discoveries of the last year of his life. This came to them as quite a surprise that the obtained generalized modular relations gave new results even in the theory of the Riemann zeta function.

The theory of the Riemann zeta function, a special case of Koshliakov's theory, has applications in variegated fields such as Random Matrix Theory, Probability Theory, Applied Statistics, and in the distribution of prime numbers. Therefore, the researchers anticipate novel applications of Koshliakov's theory, now from a more general perspective. "The theory of any generalization of the Riemann zeta function so far has always been fruitful. This is why we hope that Koshliakov zeta functions and their theory will eventually find applications in Science and Engineering.," Professor Dixit said.



LOW-COST, NON-ELECTRIC, AND POINT-OF-USE WATER FILTER

A point-of-use water treatment system that could possibly cost less than the existing commercially available ones

A team of researchers at IITGN has designed a surface-engineered particles (SEP) based water purification system which can remove 99.5% bacteria from 300 million cells per millilitre of water.

“This is a major achievement because as per the literature, the water purifiers developed so far have not been able to achieve more than 60% bacterial removal,” says Dr Deepa Dixit, a PhD graduate from Prof Chinmay Ghoroi’s lab, who worked on this project.

Recent reports from the Ministry of Drinking Water and Sanitation says that more than 40 million people in rural India consume contaminated water. The 2018 WaterAid Global Report states that approximately 163 million Indians face dearth of safe drinking water near their homes. India’s Central Bureau of Health

Intelligence (CBHI) and Ministry of Health and Family Welfare revealed figures showing polluted water being matter of grave concern as it leads to birth of various water-borne diseases. The data collected suggests that 2,439 deaths in India in 2018 were caused due to major water-borne diseases such as cholera, typhoid, acute diarrhoeal diseases (ADD) and viral hepatitis.

“The objective of our research was to develop a cost-effective, non-electric water purifier which can be made accessible to the urban slums and rural populations which cannot afford the commercial options available,” says Deepa. “Our water purification system based on surface-engineered particles is a low-cost, gravity-driven and non-electric purifier, unlike the currently available ones. It will be accessible by the rural habitants even in remote areas where potable water is scarce.”



We report an inexpensive method to develop surface engineered particles (SEPs) which have potential to remove bacteria in a continuous mode without using any disinfecting agent like silver nanoparticles for point-of-use application.

-Dr Deepa Dixit



The SEPs in the water disinfection filter are micron-size hydrophobic particles that are capable of attracting bacteria present in contaminated water. “We have engineered the surface of the particles in such a way that it possesses nanoscale roughness which can attract the bacteria having nanoscale-level outer morphology,” she adds. The bacterial membrane is damaged by these engineered particles as soon as bacteria contacts the surface and we obtain pure water, without traces of dead bacteria or disinfectants.

This point-of-use water filter can efficiently replace the conventional water purification processes like boiling and chlorination which often result in foul odour and harmful byproducts, making long-term storage inconvenient and unhygienic. The filter can be used in water bottles or directly attached to the

taps at homes, schools, and hospitals. It can be of benefit to the military deployed at remote locations and during the time of calamities and natural disasters.

Deepa says, “We are working towards adding more features to the filter and improving its prototype design.” The research was published in the *Scientific Reports* and was later funded by **Wheels India Niswarth Foundation (WINSAT)** for developing the deployable prototype of SEP-based filters. More recently, the work was selected for “**SITARE – Gandhian Young Technological Innovation Awards 2020.**”

The work got published in the *Nature Springer Scientific Reports*.





DNA NANODEVICES AS SMART THERAPEUTICS

Researchers design DNA nanodevices with DNA for programming cells from which all other cells with specialized functions are generated

Ever wondered how a single strand of DNA can fold itself into 2- or 3-dimensional structures at nanoscale to form programmable nanostructures? DNA is the hereditary material responsible for coding inherited genetic information. Researchers at IITGN are developing 2D as well as 3D designs of DNA and programming them with multiple cellular ligands which will program the right signal to stem cells to differentiate them into the desired celltype. **Prof Dhiraj Bhatia**, Assistant Professor, Biological Engineering, who leads the research, says it is first-of-its-kind in India. The project is sponsored by the **Department of Science & Technology, Government of India**.

Road accidents in India account for almost half of the spinal cord injuries every year. The idea is to make scaffolds with DNA on which the patient's stem cells will be seeded. As a result, they will differentiate into

functional neurons and further into 3D brain parts. "We could then use these brain parts and add them to the site of injury of the spinal cord to come up with spinal cord injury treatment," says Professor Bhatia. "These and many disease models are challenges that we're trying to solve using DNA nanotechnology."

The spatial arrangement outside the cell passes on specific signals to the nucleus of the cells. Stem cells respond to these signals which triggers a downstream gene expression resulting in their differentiation. "The biggest challenge before the science community in programming stem cells to differentiate into the desired tissue is to regulate this signal from outside the cells," he adds. DNA nanotechnology has simplified the process by programming DNA's surface with different cellular ligands not only in specific stoichiometry but also in a specific geometry.



The DNA nanodevices can be modified with any biological entity and can give rise to extremely homogeneously functionalised nanoparticles currently not achievable with similar biotech-based treatments.

-Prof Dhiraj Bhatia



The DNA nanodevices, too small to be seen with naked eyes, are designed by joining small pieces of DNA strands. Applying combinatorial techniques to DNA nanodevices, these are functionalised with different molecules capable of binding specifically to the human cells like metal ions, proteins, peptides, lipids, and carbohydrates. These devices are also capable of loading and unloading the drugs onto their surfaces in response to specific stimulus from cells and tissues. The drugs from the distinctly shaped and drug-laden nanodevices are then released at the targeted site, which is the diseased part of the body.

Professor Bhatia explains, “Like usual tablets and capsules, even these devices are simple capsules but they are made of DNA and function like the polymers. Similarly like many other polymers, DNA devices respond to external stimuli and while changing

their shapes or morphologies, they can secrete the encapsulated drug molecules.” He says the devices

have the ability to be modified with any biological entity like peptides, antibodies or small molecules and they can give rise to extremely homogeneously functionalised nanoparticles which are currently not achievable with similar biotech-based treatments. Also they are extremely safe, and do not trigger any immune response in the body.

“Our lab has started to make simple DNA-based robotic devices which could sense specific toxic molecules in the body,” says Professor Bhatia. “These devices immediately release the therapeutic molecules to protect the bodies from the attack of foreign toxic agents. This is called Theranostics (therapeutics + diagnostics) using DNA nanotechnology.”

The findings so far are published in the *Royal Society of Chemistry*.





UNIQUE SURFACE COATING THAT INHIBITS VIRAL ACTIVITY

Researchers develop non-toxic, anti-viral surface coating; could be a boon to health and environment

Viral infections are major public health hazards causing illnesses such as common cold, flu, measles, and chickenpox, among others. Sometimes, these viral infections can also lead to serious, possibly life-threatening complications such as dehydration, pneumonia, and other secondary infections.

With the aim to address the root cause of this health concern, a team of researchers at IITGN has successfully developed a thin anti-viral surface coating material that is highly effective against non-pathogenic viruses (the ones that do not cause diseases).

“The existing coating material that apparently inactivate the virus, are found to consist of toxic, opaque layers of copper and silver-based materials that are difficult to realize from the environmental

and design aspects,” explains **Prof Emila Panda**, Associate Professor, Materials Engineering and Principal Investigator (PI) of the research. “It is important to develop a material consisting of non-toxic elements having a higher presence in the Earth’s crust. This would enable sustainability of the developed technology for a longer duration.”

The coating, made of non-stoichiometric amorphous titanium oxide which makes it anti-viral, is also an economical, cost-effective, and eco-friendly material due to its abundance in the Earth’s crust. Apart from having shown promising results with its anti-viral activity, the coating distinguishes itself by virtue of its transparency and non-toxicity. This unique coating is synthesised using Radio Frequency (RF) magnetron sputtering fabrication system which is an equipment for thin film deposition of different materials like metals and ceramics onto various substrate materials.



The surface coating being transparent, cost-effective, and environment friendly, holds huge scope for commercialisation. The next step could be to prepare this at a large scale.

-Prof Emila Panda



The technique comprises vacuum coating process whereby the ejected target metal atoms deposit on the surface to be coated, forming a thin film. One of the advantages of using RF magnetron sputtering is an increased yield, resulting in a high deposition rate. “This makes it a cost-effective and scalable fabrication process for synthesising the anti-viral surface coating while ensuring its smooth transition from laboratory scale to industrial,” explains Professor Panda.

The coating is found to be durable, chemically stable and is strongly adhesive to various surfaces. We washed the coating 10 times after exposing it to viral strains and found that its anti-viral activity remained unaltered. However, we have not yet checked the exact durability of this coating,” she adds. This property can significantly contribute to improving the public health scenario by preventing viral infection and its transmission from frequently touched surfaces.

It can be coated easily on various indoor and outdoor surfaces different indoor and outdoor surfaces such as glass, metals, steel, silicon, and teflon, thus making it effective for use on objects like glass windows and doors, wooden and plastic furniture, doorknobs,

handles, household appliances, electronics, automobiles, etc.

While touching upon the usefulness of this innovation and its future applications, Professor Panda says, “The overall results shown by this material (for surface coating) are promising. Being transparent, cost-effective and environment friendly, this holds huge scope for commercialisation in the coming days. Our team is currently in the process of testing this coating on pathogenic viral and bacterial strains. The next step could be to prepare this at a large scale.”

The team has filed an Indian patent for this unique anti-viral surface coating and its coating process. The manuscript based on this work has been published in the *Journal of Alloys and Compounds (ELSEVIER)*, an international peer-reviewed journal. The co-authors include **Prof Abhay Raj Singh Gautam**, Assistant Professor, Materials Engineering; **Prof Virupakshi Soppina**, Ramalingaswami Fellow, Biological Engineering; **Nishaben M Patel**, PhD student, Biological Engineering; and **Ravi Teja Mittireddi**, PhD student, Materials Engineering.



STUDY EXPLAINS POTENTIAL SEVERITY OF FIRE IN MODERN BUILDINGS

Comprehensive study assesses the behaviour of real fires in modern buildings

Stop to think about the building you live in or the office you work at! Modernised buildings bespeak an upgraded lifestyle. However, they increase the risk of fire.

The past few decades in India have witnessed an advent and a rapid growth of new residential cultures and luxuries. Modern buildings sport amenities like plastic doors, partition walls, plastic roofs and maintain equipment like washing machines, refrigerators, air-conditioners and computer hardware. To understand the impact of these materials on the intensity of fire and its dire consequences, researchers at IITGN, under the supervision of **Prof Gaurav Srivastava**, Associate Professor, Civil Engineering, conducted a detailed survey covering 105 office rooms and 202 students' dormitories in Ahmedabad.

The higher risk of fire is due to changes in the composition of fuel load – the total amount of combustible material in a defined space. “The newer materials used in the present-day buildings are often more inflammable and have greater calorific values than the materials used earlier,” says Professor Srivastava.

The set of norms that specify the minimum standards for the construction of buildings, called building codes, do not account for these changes. Even today, many building codes stick to the representative fuel loads derived from the data collected in the 1970s and 80s. “Taking into consideration the new construction materials being used in the modern buildings, the use of data collected by the earlier surveys is questionable,” he says.



The IITGN team studied the total **Fire Load Energy Density (FLED)** – the calorific value of all combustible things divided by the given space – of office and dormitories. “Our study presents fire load estimates from surveys conducted in 2015 in Ahmedabad to further highlight this issue. We found the average FLED was 1,400 MegaJoules per square meter, which is about three times greater than the average value found in a study conducted at Kanpur in 1993.”

Besides assessing the total Fire Load Energy Density FLED, the team critically examined the distribution of combustibles and, interestingly, found that among all the combustibles, the proportion of cellulosic material like paper and wood decreased while that of plastics increased. The study also proposed probability distributions of fire loads in offices and dormitory buildings. They developed parametric design fire curves to quantify fire severity in modern dwellings, which revealed that the maximum expected temperatures in the first half were much higher as compared to those in the previous study.

“The structural components are given fire ratings as per the expected critical temperature levels. The safety of the buildings could be achieved by maintaining temperatures of structural components below critical levels,” adds Professor Srivastava. Earlier, the National Building Code of India (2005) had a table that provided guidelines about fire loads for typical dwellings. In the current version of the

code (2016), the table was removed due to lack of current data. “The study conducted here provided this data for the current times and since higher fire loads imply greater fire intensities, it becomes essential to undertake a comprehensive fire load assessment study for various dwellings in the country,” he explains.

The study was published in *Current Science*.





RESEARCHERS SYNTHESISE COMPOUND FOR ANTI-CANCER APPLICATIONS

Water-soluble zinc porphyrins, a group of organic compound present everywhere in biological system; could be used for anti-cancer and bio-imaging applications

Cancer, one of the greatest global health threats to humans, has attracted significant attention with respect to research and development of therapies and treatment.

Photodynamic therapy (PDT) is a light-based therapy used for a wide range of medical conditions including several types of malignant cancers like skin, brain, pancreatic, lung etc. PDT uses a combination of light, a light-absorbing chemical substance called photosensitiser, and molecular oxygen to destroy cancer cells.

Photosensitiser administered to the cancer site is activated by light to produce reactive oxygen species (ROS) in the presence of oxygen. The process induces cell death. Many of the second-generation photosensitisers used in PDT are designed using

porphyrins. Porphyrins, present in the blood of higher as well as in microbial organisms, tend to get accumulated more in the tumor cells as compared to the normal cells. By the virtue of this property of porphyrins, they act as promising photosensitisers and excellent transporters of active drugs into the tumour tissues.

Past several years have witnessed much research on the use of porphyrins as photosensitisers. The IITGN research team, led by **Prof Iti Gupta**, Associate Professor, Chemistry, has prepared a class of porphyrins for anti-cancer as well as bio imaging applications.

Their study reported the synthesis of a type of water-soluble zinc porphyrins (A2B2 type Thioglycosylated porphyrins) which have undergone controlled



The water-soluble zinc porphyrins are good photo-sensitizers for the Photo-Dynamic Therapy of cancer. They can also be used for bio-imaging of the tumor cells.

-Prof Iti Gupta



modification by addition of the sugar molecules. This is because the man-made glycoconjugates and oligosaccharides, a type of carbohydrate, have shown possible applications as bioimaging agents and drug-delivery systems in medicinal chemistry. “We have prepared water-soluble, sugar-linked porphyrins and their zinc complexes, and tested them for bioimaging and anti-cancer applications,” says Professor Gupta. They carried out in-vitro cellular investigations of these porphyrins in the lung cancer cells, in order to test their photodynamic therapeutic (PDT) activity.

“The PDT study revealed significant porphyrin cytotoxicities i.e. the toxicity caused due to the effect of certain chemicals on living cells,” she says. They found that the cell cytotoxicity assay, a test performed to measure the ability of certain chemicals to destroy living cells, on lung cancer cells showed good IC₅₀ value (4.6-8.8 microM) after light exposure. This value determines the measure effectiveness in inhibiting a biological or biochemical function.

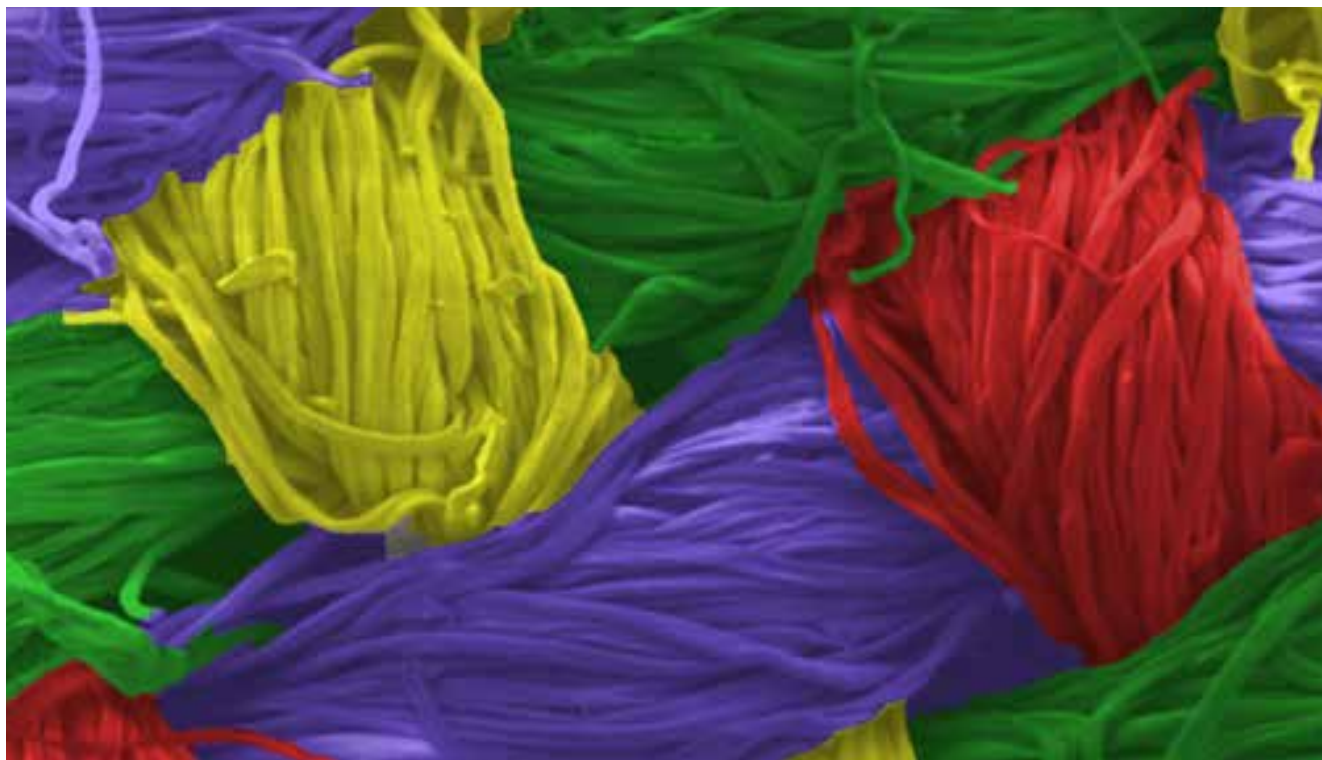
They conducted the flow cytometry analysis which is a cell analysis technique that is used to detect and measure the physical and chemical characteristics of cells. In the words of Professor Gupta, “The flow cytometry analysis that we conducted, showed decent cellular uptake and Reactive Oxygen Species (ROS) generation efficiency of the prepared porphyrins. It was higher as compared to those of the non-metalated porphyrins.” These water-soluble zinc porphyrins

were cell-penetrable and showed good localisation in endoplasmic reticulum, along with the mitochondria.

Explaining how this class of porphyrins is different from the previously reported glycosylated porphyrins, Professor Gupta says, “Most of the literature reported glycosylated porphyrins have four sugar units at their periphery; their globular shape hinders the cell penetration. Our paper described the synthesis of glycosylated porphyrins with only two sugar units with enhanced cellular uptake and ROS generation efficiency.”

The study appeared in *ACS - The Journal of Organic Chemistry*. The authors of the paper include Vijayalakshmi Pandey and Pooja Joshi from IITGN and Md Kausar Raza from IISc Bangalore.





COUPLING SOLVENTS TO ACHIEVE A SWEET SPOT FOR SYNTHESISING NANOSHEETS

*Simple chemistry to obtain a new class
of nanosheets from a ceramic*

In their study published in *Ceramics International*, a team of researchers at IITGN has presented an innovative approach that utilises the science of cosolvents to predict the synthesis of nanosheets – materials that are just a few-atom-thick. Cosolvents are routinely used in pharmaceutical research – often, one solvent is added to another to increase the solubility of a poorly soluble compound.

Researchers at IITGN utilised this science in an innovative manner in their pursuit of exploring a new family of boron-rich nanosheets that they have discovered. When the team faced the challenge of delaminating titanium diboride (TiB₂), a ceramic material traditionally known to be chemically inert, they thought of utilising the chemistry of cosolvents. When they tested the delamination of these inert

crystals in a cosolvent of water and alcohol, they were pleasantly surprised that not only were they able to form nanosheets but the resultant nanosheets were also pure and retained their native chemistry. The team led by Prof Kabeer Jasuja, Dr Dinesh O Shah Chair Associate Professor in Chemical Engineering, also showed that this approach can be used as a guide to predict the fate of delaminating tightly bonded crystals. It is a first-of-its-kind attempt to obtain TiB₂-based nanostructures while utilising its inherent properties to the maximum. TiB₂, as a starting material, itself has significant properties well-suited for energy-storage devices like supercapacitors and new generational batteries. Mindful of the use of nanosheets in commonly used Lithium-ion batteries, they exfoliated this ionic material to synthesise the nanosheets.



We utilised the simple chemistry of combining two solvents to obtain a new class of nanosheets from Titanium Diboride, a ceramic known to be chemically inert.

-Prof Kabeer Jasuja



In general, two-dimensional materials perform exceptionally well in hosting positively charged ions (e.g., Lithium ions) reversibly, by virtue of their high surface area and large availability of sites for insertion of ions into materials with layered structure. The nanosheets, synthesised by the team are 2D in nature and have Titanium (Ti) and Boron (B) as constituents. Both Ti and B have an exceptional capability to serve as the high-capacity anode (positive electrode) for the Lithium-ion battery. In addition to this, the 2-D nature of these nanosheets is expected to result in faster delivery of stored charges. Such a battery can be charged or discharged for thousands of cycles without any significant capacity loss.

Hence, we shifted our focus towards organic solvents. We tried various solvents by utilising a theoretical concept which was never tested for metal diborides (ionic type material) and found IPA (Iso-propyl alcohol) as a suitable matching organic solvent.”

He further explains that since the concept used was never tested for metal borides, they tried generalising the experiments by an empirical approach — by using isopropanol (IPA)-water cosolvent mixtures. With this, they established that a 10% isopropanol-water cosolvent results in the formation of optimal nanostructures which were also later found out to be less functionalised as compared to the previous approach.

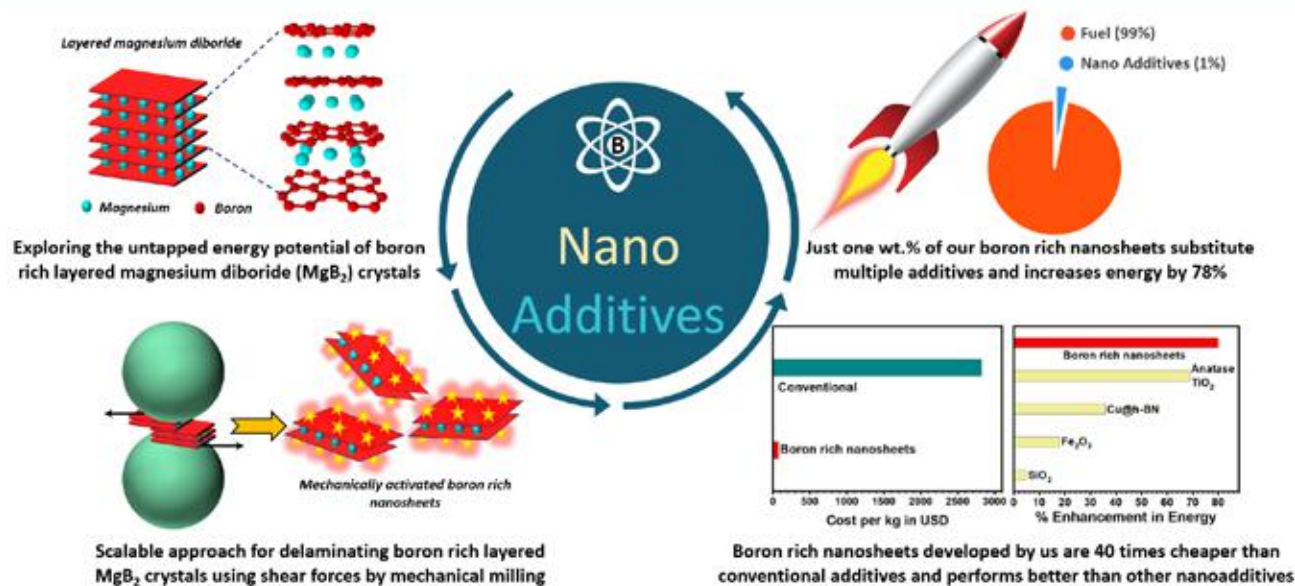


Explaining the process of exfoliation of nanosheets, **Rishabh Patidar**, the first author of the paper says, “Normally, the process involved in synthesising nanostructures

requires a solvent-based approach wherein the solvent is most commonly water. With our earlier research experience, we were aware that water is responsible for functionalisation that alters the properties of parent material and, therefore, limits its applications.

The group is presently utilising these nanosheets as electrodes for energy storage and is observing that these minimally functionalised nanosheets exhibit an inherent conductivity, which is a promising sign. These near-pristine nanosheets present a curious construct to assess how planar confinement in these nanostructures would affect the bulk properties of TiB₂. It would be promising to test this approach on other members of layered metal diborides (like MgB₂ and AlB₂) as well as on other ionic layered materials. They are now making efforts to see how this process can be scaled up such that the pristine chemistry of nanosheets is retained even when the production is on a large scale.

NOVEL BORON NANOADDITIVES FOR IMPROVING THE PERFORMANCE OF SOLID PROPELLANTS



NOVEL NANO-ADDITIVES FOR FUELS USED IN SPACE AND DEFENCE APPLICATIONS

Boron-based nano-additive, when added to rocket fuel, boosts its overall performance

Researchers at IITGN have discovered a new class of nano-additives for fuels used in space and defence applications, which would result in a superlative enhancement in the performance of solid propellants used in rocket propulsion systems.

Solid propellants are a mixture of fuel and oxidiser. Whether it is the Indian Space Research Organisation's famous polar satellite launch vehicle (PSLV) to lift satellites or the Defence Research and Development Organisation's AGNI intercontinental ballistic missile, all are powered by solid propellants. Ammonium Perchlorate (AP) is one such energetic fuel used widely in rocket propulsion systems. However, solid propellants usually need multiple additives to improve their burning rates and performance and also to maximise the energy of the fuel.

Conventionally, several additives are added to AP to improve its performance. These additives can take up to 30% of the total weight of the fuel. Boron is one of the fuel additives but it faces severe ignition delay and a low burning rate because of an inert boron oxide layer formation.

To overcome this issue, **Harini Gunda**, a PhD student working with **Prof Kabeer Jasuja**, Dr Dinesh O Shah Chair Associate Professor in Chemical Engineering, has developed a significantly efficient boron-rich nano-additive. It can be used as a single substitute for multiple additives conventionally required in propellants. What is more impressive is that this nano-material takes only 1% of the total weight.

This boron-based nano-additive is synthesised using a well-known superconductor, magnesium diboride (MgB_2). The simple method involves solid



This new class of nano-additives result in a superlative enhancement in the performance of solid propellants and offers a more efficient and economical single substitute for a group of conventional additives.

-Prof Kabeer Jasuja



exfoliation to form mechanically activated (MA)-MgB₂ nanosheets. In controlled experiments, adding just one weight percentage of these nanosheets enhances the energy release/fuel energy by nearly 80 % and reduces the fuel decomposition temperature by approximately 73 °C, which surpasses that of both conventional and other nano-additives.

The boron-based nanosheets play a dual role as catalyst and fuel. This is by virtue of uniquely rich chemistry of 2D boron honeycomb planes sandwiched with metal atoms (Mg in this case). According to the team, different additive variants can be obtained by simply tuning the recipe used to prepare the MA-MgB₂ nanosheets.

The method developed by them to synthesize this nanomaterial is simple and scalable. This makes these nano-additives more economical than the conventional ones.

Harini says that adding their nano-additive to solid propellant eliminates the dead mass associated

with other multiple additives. Decreasing the dead mass helps increase the active mass of the payload and improves the rocket's thrust. The payload in rockets varies from 16 to 140 metric tons. Reducing ~30 weight percentage of the payload will help carry additional satellites into orbit. Depending on the type of rocket, we can take from one to eight additional satellites than what we carry today in a single rocket.

Developing energy-efficient fuels for both defence and space applications is critical to meet our nation's targets and be among the top space-faring nations. The research team is now seeking a platform and resources for pilot-scale studies to bring their discovery from the lab to the market.

This discovery is valuable by virtue of its potential of being used in applications other than space and defence. These include energy storage in batteries and hydrogen production and storage.

The research findings were recently published in the journal *Thermochimica Acta* by Elsevier publishers. The research team had also filed an Indian patent in 2019.





STUDYING GANDHIAN LITERATURE, THE NEW USER-FRIENDLY WAY

An AI-based one-stop repository on vast volume of Gandhian literature

Mahatma Gandhi's life and work has touched the people globally to a great extent. Even today, his life and works act as a beacon for people and an interest in knowing more about him is alive eternally. Research teams at IITGN and IIT Kharagpur have collaborated to develop a web portal aimed at providing easy access and concise information about various aspects of his life in a single click.

They have come up with have come up with an Artificial Intelligence (AI)-enabled web portal called 'Gandhipedia'. It curates all works written or spoken by Mahatma Gandhi and presents them through interactive diagrams using AI. Anyone - whether an expert in Gandhian literature or a novice - can easily explore the vast volume of the literature. Some of the exciting features include an interactive timeline to explore letters written by Gandhi, a search feature to find the best matching books/speeches/letters, the

social network of famous personalities mentioned in the literature and more.

The already-existing Gandhian websites are static and it becomes difficult to pinpoint specific resources. The portal, built on python-based micro web framework, namely NGINX web server and Flask, represents the entire literature through graph visualisations, timeline display, gallery showcase, etc.

"The abundance of literature on various Gandhian platforms, including websites and digital libraries, results in information overload and makes it difficult to gather relevant information as per the user's interest, especially when life has become faster than ever and users tend to get disengaged very quickly," says **Prof Mayank Singh**, Assistant Professor, Computer Science & Engineering. "Gandhipedia is an extremely dynamic and interactive website.



The entire project is for real-world usage and digesting the vast volume of Gandhian literature. The visualisations are so simple that anyone with basic computer understanding can use this portal and navigate around.

-Prof Mayank Singh



People can look at various aspects of Gandhi's life, be it people or place, by selecting the respective node."

The information about a specific person or event in the Gandhian literature is displayed in a chronological order. This feature is unique to Gandhipedia. It makes the website extremely user-friendly. The users would not have to go through the complete biography of Gandhi to find the information. Instead, the website does it for them.

Unlike the available systems, the portal facilitates extensive multi-lingual search and provides detailed information on interaction among different personalities in Gandhian literature. The current version supports three languages namely, English,



Hindi, and Gujarati. The team intends to make the website available in Hindi too depending on the availability of the data.

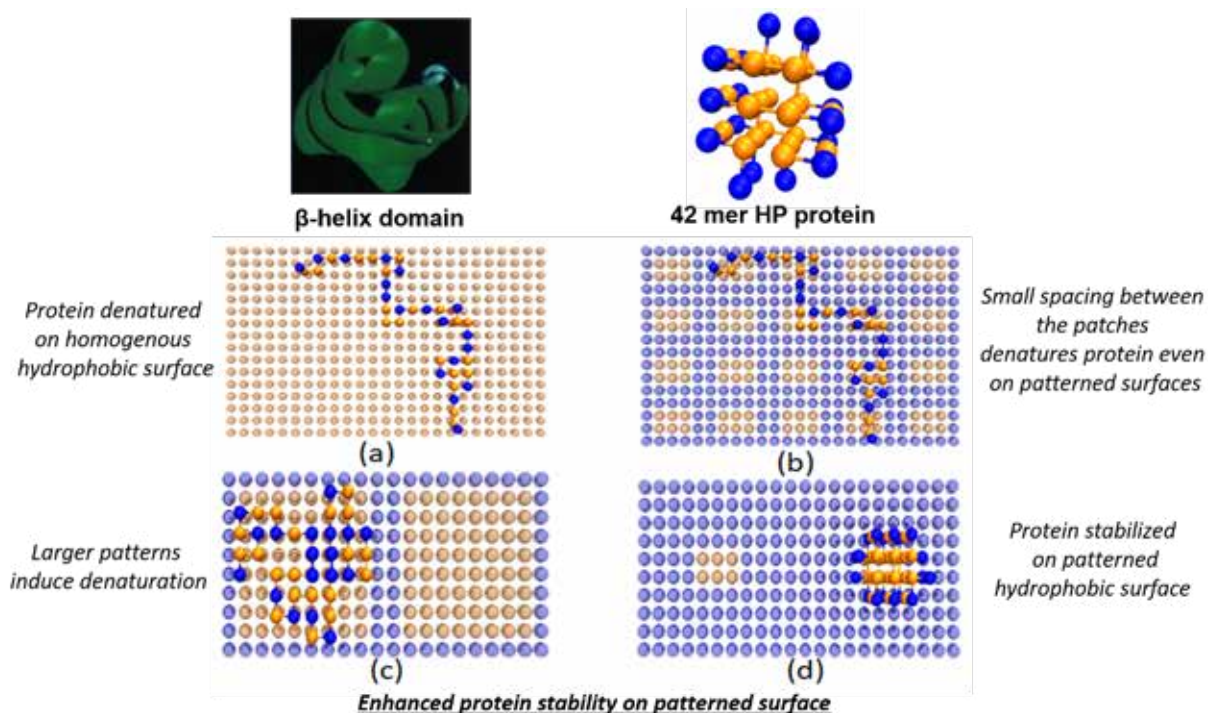
Gandhipedia is set to be launched by the Ministry of Culture. The collaborators of the project include **National Council of Science Museums, Sabarmati Ashram Preservation and Memorial Trust, Gandhi Smriti and Darshan Samiti, and Gandhi Heritage Portal.**

The authors of the work published in the *ACM/IEEE Joint Conference on Digital Libraries 2020*, include **Heer Ambavi, Shivam Patel, and Pritam Kadasi** from IITGN and **Atharva Vyas, Sayantan Adak, and Animesh Mukherjee** from IIT Kharagpur.



Key Contents

 <p>Key Texts Written by Mahatma Gandhi</p> <p>Study of seven key texts written by Mahatma Gandhi</p> <p>Visualisation of temporal networks from these texts</p> <p>Details about the individuals mentioned in these texts</p>	 <p>Collected Works of Mahatma Gandhi</p> <p>Category wise study of Collected Works of Mahatma Gandhi</p> <p>Statistics and timeline for each of the categories</p> <p>Visualisation of temporal networks</p> <p>Details about the individuals mentioned by CWMG</p>	 <p>Letters To Key Individuals</p> <p>Gokhale</p> <p>Amal Kumar</p> <p>Sushila Nayyar</p> <p>Top Responders</p> <p>Well Known Responders</p>
--	--	--



STUDYING SURFACE PATTERNING FOR ENHANCED ENZYME ACTIVITY

Effective surface patterning could help enhance enzyme activity, making it suitable for industrial utilisation through various biochemical reactions.

Enzymes are proteins that act as biological catalysts and are present in all living organisms. Besides, enzymes are used to carry out a wide array of industrial applications.

Enzyme immobilisation is the entrapment/confining of enzyme molecules within an inert and insoluble support material and has been broadly used in the industrial production of amino acids, beverages, jams, jellies, antibiotics etc. Moreover, immobilised enzymes are used extensively in biomedical applications and research activities. However, immobilisation reduces enzyme activity which is a major industrial challenge.

In a study published in *The Journal of Physical Chemistry B*, an IITGN-led team has investigated the role of various hydrophobic patchy support surfaces on the thermal and structural stability of proteins.

The findings can be rationalised to design novel surfaces for enzyme immobilisation while ensuring enhanced enzymatic activity.

“Our study underlies the physics behind protein stability on patterned surfaces,” says **Prof Mithun Radhakrishna**, Assistant Professor, Chemical Engineering, who supervised the research team. “We found the conditions under which the protein’s thermal stability increases.”

A glimpse into the science of enzyme immobilisation

Enzyme immobilisation aims at restricting the movement of the enzyme in space, such that its catalytic activity remains intact. The immobilised forms generate more benefits over their soluble forms. They increase enzyme stability, allow continuous production, enable reutilisation of



The novelty of the work lies in the fact the using a simple lattice model of proteins we are able to capture the physics of complex process like protein folding.

-Prof Mithun Radhakrishna



the catalyst, and reduce the cost of production significantly. Notwithstanding these advantages, immobilising enzymes on a support is challenging on an industrial scale as it leads to complete or partial loss of activity of the enzyme. This is due to the structural changes in the immobilised enzyme which occur as a result of interactions between the enzyme and support material and between the enzyme and other species. Therefore, the characteristics of the support material, enabling compatibility with the enzyme, are predominantly important for ascertaining the performance of the immobilised enzyme system.

Experimental studies in the past have explained that the patterned support surfaces can improve enzyme activity by enhancing the structural stability of intrinsically disordered proteins.

Here's what researchers have learnt

The work discusses protein adsorption on a hydrophobic surface driven by a hydrophobic effect. "The work is novel in its approach as we have studied the effect of surface patterning on protein stability and adsorption by using a simple lattice model of proteins," he says. "The results show that besides the shape and size of the patch, the distance between the patches is predominant in determining stability of proteins."

The researchers have shown that the protein's thermal stability increases when the surface pattern is complementary to the exposed hydrophobic domain of the protein, and when spacing between the patches is relatively large. The large hydrophobic patches always lead to unfolding of the protein's native structure, called protein denaturation, even on weakly hydrophobic surfaces due to protein-surface interactions.

He adds, "Our study aims to provide a rationale on three important aspects of enzyme immobilisation, including selection of best support material, type of surface modification that could enhance the enzymatic stability, and the existence of an optimum arrangement to immobilize enzymes on support material."

The study would aid favourable selection of surfaces for the immobilisation. This, consequently, would prevent the enzyme from interacting with the surface which causes protein denaturation and thus loss of its function. It would also be applicable to biosensors such as glucometers and pregnancy test kits, where the protein-surface interaction also has a significant role to play as it might lead to erroneous readings.

The research team includes PhD student **Deepshikha Ghosh** and MTech student **Avishek Kumar**.



A SWITCH TO DECENTRALISED ENERGY ACCESS: PROSUMER-DRIVEN INTEGRATED SMART GRID

An affordable, secure, and consumer-centric energy trading framework

A team of researchers at IITGN, in collaboration with IIM Ahmedabad, MSRIT Bengaluru, BSES Yamuna Power Ltd, and many other industry partners, is working on a research and development project titled “Development of the Prosumer-Driven Integrated Smart Grid”. The team is receiving financial assistance from the **Department of Science and Technology (DST)** under their **Mission Innovation** challenge on smart grids. The research team, mentored by **Prof Naran Pindoriya**, Associate Professor, Electrical Engineering, is developing a blockchain-integrated peer-to-peer (P2P) energy trading framework to realise the 3Ds – decentralisation, decarbonisation, and digitalisation in the smart grid.

The energy sector is undergoing a massive transformation. This is due to factors such as integrating renewables, improving operational

efficiency, leveraging smart grid infrastructure, and handling the dynamics of transactive energy, which requires ecosystem players to refine their roles in the ecosystem and try new business models. One such novel model is P2P energy trading which leverages the consumers with the energy resources to fulfill their energy demands locally. It transforms the big centralised power distribution system into small decentralised ones, turning passive consumers into active consumers, called prosumers, who can generate surplus power and sell electricity locally.

“With financial assistance from the DST, we have set up a test and demonstration rig at IITGN for showcasing the P2P energy trading application in a real-world environment,” says Professor Pindoriya, the co-principal investigator of the project. The setup comprises the following peers:



- » Peer-A has a solar PV system of 3 kWp and a battery energy storage system of 7.5 kWh catering to an electrical load demand of 2 kW.
- » Peer-B has an Electric Vehicle (EV) of 5 kWh Li-ion battery with a bi-directional charging port facility for V2G demonstration and an electrical load demand of around 2 kW.
- » Peer-C has an electrical load demand of approximately 2 kW.

This framework would revamp the existing power flow patterns, minimising consumption from the utility while uplifting the participation of renewable energy generation and energy storage. Besides encouraging an unconventional, decentralised, prosumer-driven open-access energy system, it would lead to transparency and energy affordability by improving the reliability of power system operation. The project, a part of the Smart Grids Innovation Challenge, envisions the development and demonstration of a blockchain-based energy trading platform.

The modernisation of technological changes at each layer of the energy system would introduce a secure

energy market and convert a mere consumer to a prosumer who could not only consume but also produce energy. The buildout of the rooftop solar PV system, EVs, and energy storage would promote a novel electricity system that would allow prosumer communities to generate, consume, and trade surplus energy produced to their peers within the grid.

The team aspires to develop and demonstrate a blockchain-based platform — which can facilitate and record a multitude of distributed transactions in a secure, transparent, and trustworthy manner — for P2P energy trading. Financial transactions, monitored through such a distributed database system inventorying all transactions, would take place within the network. “Net metering and open access are instrumental in facilitating such transactions through proper accounting and settlement,” says Professor Pindoriya.

The team, including Research Associates **Bables Jha** and **S Hari Charan Cherukuri** believes that such a transactive energy grid would serve as a bridge to an intelligent energy future and empower consumers/prosumers to manage their energy needs.



NEW LEAD FOR 'MAKE IN INDIA' TECHNOLOGY, MANUFACTURING HIGH-VOLTAGE DEVICES

An indigenous technology platform to enable fabrication of high-voltage and high-power metal-oxide-semiconductor (MOS) devices in India

A research group at Nanoelectronics Devices and Circuits Lab (NanoDC) at IITGN in collaboration with Semi-conductor Laboratory (SCL) and Space Application Centre (SAC), has developed a cost-effective semiconductor manufacturing technology platform for fabricating 10-40V devices in India. The study is done with support from the Advanced Manufacturing Technologies Program of the Department of Science & Technology.

India is one of the largest markets for electronic equipment such as portable devices, consumer and automotive electronics. To draw power, these devices rely on Power Management Integrated Circuits (PMICs). In modern PMICs, various devices (digital, analog and high-voltage power transistors) are

integrated monolithically on the same substrate in order to reduce the overall system cost. This requires a Bipolar-CMOS-DMOS (BCD) technology platform that can offer a wide voltage range of power devices with a high performance. The market for PMICs in India is forecasted to increase in coming years on account of continuously increasing production and sales of electronics goods. However, the Indian industries are facing a particular challenge i.e. lack of indigenous semiconductor manufacturing base and lack of availability of an indigenous BCD technology.

“My research group has augmented the already available CMOS technology with the capability to manufacture high-voltage semiconductor devices which are crucial for PMICs and the power electronics industry. This new augmented technology



This is the first BCD technology development activity in India and our team have demonstrated working devices within 3 years with achieved specifications better than target specifications.

-Prof Nihar Ranjan Mohapatra



is an important resource for the nation,” says **Prof Nihar Ranjan Mohapatra**, Professor, Electrical Engineering, who led the research.

“India has spent a few thousand crores to buy the CMOS technology but unfortunately those technologies can support only 1.8-5V devices and not very high voltages required for some ICs and applications,” he adds. “We have indigenously designed, developed and qualified the BCD technology platform which can fabricate devices with voltage handling capability of up to 40V.” The team is making a headway with the project by enhancing the power handling capability of these devices and by developing devices operable at more than 50V to meet the industrial demands.

Through this first BCD technology activity in India, the group has demonstrated working devices by achieving specifications better than those targeted. The achieved specifications are comparable with the offerings from different CMOS foundries. The research has also been recognised in international journals and conferences, and aims at helping semiconductor fabrication units within the country, slashing the dependency on heavy imports.

The findings appeared in *IEEE Transactions on Electro Devices (IEEE TED)*, *IEEE Journal of Electron Devices Society (IEEE JEDS)*, and *IEEE Electron Device Technology and Manufacturing (EDTM) Conference*.



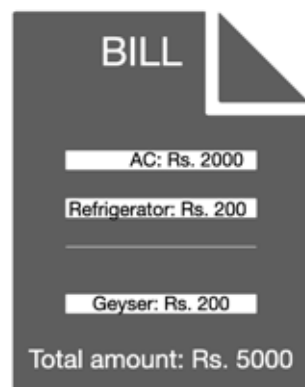


WHY IS MY ELECTRICITY BILL SO HIGH?

Study offers insight into developing better techniques for effective energy disaggregation systems

Think of an itemised electricity bill that could tell us about the exact energy usage of each appliance in our homes, similar to grocery bills. It could help us understand how much power our TV consumes in a month or exactly what we spend on our dishwasher and refrigerator.

This has been made feasible with the non-intrusive load monitoring (NILM) or energy disaggregation systems that estimate energy consumed by individual electric appliances in a household or a building by using various machine learning algorithms on the readings collected.



A team of researchers at the IITGN has proposed an approach to optimise state-of-the-art methods towards developing NILM systems for effective energy management. This work was presented by the team at **ACM Buildsys 2020**.

Owing to the mass rollouts of smart metres worldwide over the past few years, NILM has been an active area of research. Previous research shows that access to an itemised bill into individual appliances can potentially reduce energy consumption by up to 15%. It is because knowing the real-time energy consumption per appliance enables an understanding of electricity



Our work shows that strategically compressing a neural network can give us sufficiently high accuracy with very low computational requirements.

-Prof Nipun Batra



usage and smarter decision-making to not only save energy but also money.

“NILM is a relatively old field. Very recently, neural network (deep learning) based methods have been proposed to solve NILM. While these methods are accurate, they are computationally extensive and cannot be run on low-powered devices or edge devices,” explains **Prof Nipun Batra**, Assistant Professor, Computer Science & Engineering, who led the research.

Although deploying neural network-based architectures for NILM is a popular option, it generally requires large memory and extensive computation. This needs expensive infrastructure for doing the computation in real-time, and the data has to be sent to the cloud. Therefore, it becomes necessary to compress the neural network architectures to obtain a simplified model, smaller in size and with fewer parameters, from the original one.

The study, funded by **Cisco Research**, builds off the recent research that proposes various methods to compress neural networks without significantly impacting accuracy.

“If we do not compress these models, they require a lot of heavy computation. Imagine running a very complex machine learning code on a 15-year-old Nokia phone. Our work shows that strategically compressing a neural network can give us the best of

both worlds – very low computational requirements, and yet, sufficiently high accuracy,” he says. “The results are very exciting and surprising. We can compress these networks by a factor of 100 without significantly impacting accuracy.”

The team investigated various neural network compression schemes and their efficacy on the state-of-the-art neural network-based NILM method. They performed a comprehensive evaluation of these techniques on two publicly available datasets.

This is the first work to address the issue of running accurate neural networks on low-powered devices. “Existing work done in the field is either accurate or can be run on low-powered devices, but not both. This limits their applicability in bandwidth-constrained settings,” says Professor Batra. “Also, it does not preserve privacy as the data needs to be sent to the cloud for processing.”

The two work streams of the study include discussions about the kick-off of these technologies in Indian homes and making efforts towards developing better techniques to compress the algorithms, to run more efficiently while maintaining their accuracy, and preserving privacy.

The authors of the study include IITGN undergraduate students, **Rithwik Kukunuri, Anup Aglawe, Kratika Bhagtani, Rohan Patil, and Sumit Walia.**

VARTALAAP: UNDERSTANDING THE PUBLIC PERCEPTION ON AIR POLLUTION

Who drives air quality discussions in India?

Air pollution is lethal. And sadly, 99% of the people in the Indian subcontinent are exposed to air pollution that exceeds safety limits set by the World Health Organisation (WHO). In the wake of the rising levels of air pollution in India, the Centre launched the National Clean Air Programme (NCAP) across the country to develop city-level Clean Air Plans.

Besides implementing control measures, understanding the public perception related to air pollution is critical to curbing its levels and effects. A research team at IITGN, in collaboration with Dr Sarath Guttikunda, UrbanEmissions.Info, has conducted the first large-scale study and analysis on air pollution perception and proposed a scalable approach called 'Vartalaap'. The IITGN-led team includes Prof Nipun Batra, Assistant Professor, Computer Science & Engineering, Prof Udit Bhatia, Assistant Professor, Civil Engineering, and Prof Mayank Singh, Assistant Professor, Computer Science & Engineering. They chose Delhi, the national capital

with a dense population of nearly 35 million at a high risk of air pollution and often known as the most polluted city in the world, as the testbed for the study. A 2019 report declared India as an abode of 21 out of 30 most polluted cities in the world where Delhi held the top.

Air pollution is a major global health risk factor leading to an estimated 4.2 million deaths per year. In India, this estimate was 1.7 million for 2019.

Policymakers have been taking initiatives and proposing strategies directed towards improving air quality, like promoting electric vehicles, installation of smog towers, odd-even rule, etc. Their success largely depends on public participation and response. Hence, it becomes necessary to understand the public perception about air pollution, the associated health problems, and mitigation strategies.

Traditional perception studies using questionnaire-based surveys, do not incorporate changes in

Our work shows some ground realities as the public perception is largely supportive of untested strategies.

-Prof Nipun Batra





Owing to the domain expertise of our investigators, we limited our study to Delhi. However, in the future we plan to extend our analysis to multiple geographies.

-Prof Udit Bhatia



perception with time. Other sentiment analysis studies using data from social media have been limited to a small scale in terms of data. To analyse the perception of people on a large scale, the team curated more than 1.2 million tweets from 26,000 users, with accurate timestamps, discussing Delhi's air pollution. Additionally, they prepared a dataset containing daily air quality data from 2016 to 2019, using recordings from different monitoring stations across Delhi sourced via OpenAQ. "To derive meaningful observations from the enormous data collected, we used a combination of time series analysis and numerous machine learning techniques including Natural Language Processing (NLP)," explains Prof Nipun Batra, Assistant Professor, Computer Science & Engineering.

"We manually labeled a set of 1523 tweets representing two particular air polluting mitigation strategies and found that public sentiment towards both the strategies is supportive albeit unscientific. The untested strategies not only give the public a false sense of security but also are a waste of taxpayers' money," says Professor Singh who is an expert in natural language processing.

According to the study, although the air pollution level remained above safety limits almost throughout the year, public discussions on air pollution spiked only when the pollution was more visible and detrimental. In the tweets, the most discussed topics included traffic, public transport, Delhi smog, stubble

burning, Diwali, odd-even, etc. which increased when related events occurred in time. Influential users with a large following, like news outlets, politicians and celebrities seemed to have a larger impact on influencing public opinion.

"It seems that people largely care about the air pollution when it is extremely hazardous and visible, but air pollution is an invisible killer," says PhD scholar Rishiraj Adhikary. The observations made from this study would help policymakers to understand public opinion, educate the population effectively, and estimate the probability of success of a policy or action plan. Given its versatility and scalability, "Vartalaap" can be extended to any other part of the world to address similar issues.

He further adds that the team's outlook is to work with regional authorities and develop a real-time dashboard to monitor and analyse social media data.

"This project was a very interesting experience as we had multiple experts spanning different areas," says PhD scholar Zeel B Patel. Professor Singh, Professor Bhatia, and Dr Guttikunda from computer science, civil engineering, and atmospheric sciences played a key role with their expertise in language processing, climate change, and domain knowledge, respectively.

The authors have made the data set and code used in 'Vartalaap' publicly available on the code repository 'GitHub'.



NEURAL BASIS OF LIMB-INDEPENDENT MOTOR MEMORY ACQUISITION

Research has implications for rehabilitation of motor deficits following neurological injury

Skilled actions, from a ballerina's pirouette to playing a ghamak on a sitar, are based on the ability to learn new movement patterns and to adapt with new environments. This ability to learn, store, execute and continuously refine actions is broadly defined as motor learning, and is driven by multiple neural mechanisms. Just as learning the periodic table results in the formation of a memory that can be recalled later, motor learning also results in the formation of a "motor memory" that subsequently enables superior movement performance. Interestingly, motor learning comprises representations that are both limb-specific and limb-independent.

Limb-independent representations allow learning to generalise across different effectors. For example, a

basketball player who learns to dribble with his/her right arm might show gains in dribbling performance with the left arm though he/she might not be trained on the left side. Although the phenomenon of generalisation across effectors has been demonstrated over many studies, the neural mechanisms that encode limb-independent motor memory components have remained elusive.

In a study published in *PNAS*, **Prof Pratik Mutha**, Jibaben Patel Chair Associate Professor, Biological Engineering, and his team at the Centre for Cognitive and Brain Sciences probed how these limb-independent memories are acquired. Using a combination of behavioural experiments and computational modeling of healthy human participants learning of arm movements in a



We show that the limb-independent memory components are acquired via tacit, non-verbalisable learning mechanisms, and depend on intact processing within a region of the brain engaged in movement planning and decision-making.

-Prof Pratik Mutha



novel environment, they first found that effector-independent memories are forged through implicit learning, or learning that occurs without conscious realisation of how a skill is being learned. This mechanism contrasts, for instance, with learning using verbalisable or explicit strategies such as those employed when learning a list of words.

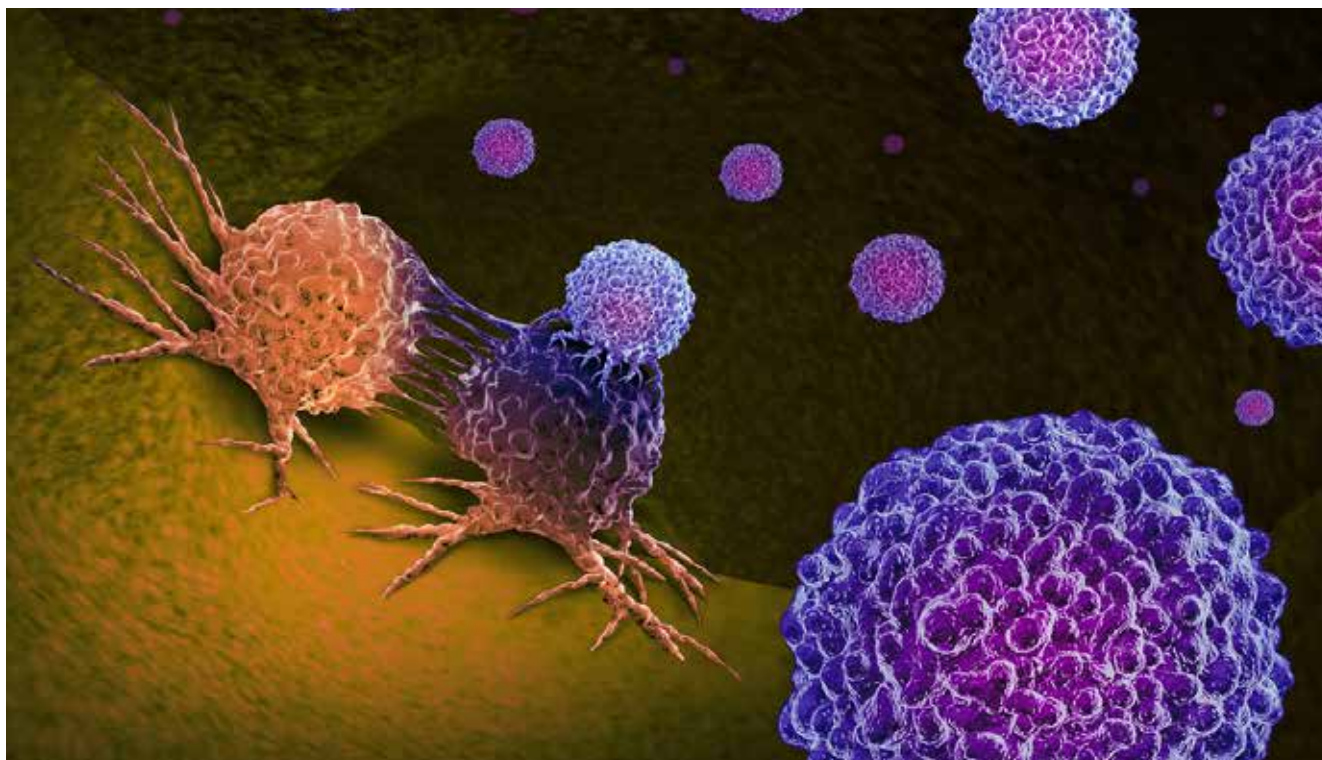
The team then delivered high-definition cathodal transcranial direct current stimulation over the posterior parietal cortex (PPC) to inhibit the underlying neural activity. They found that perturbing left but not right hemisphere PPC prior to learning blocked the operation of implicit process and prevented the acquisition of the limb-independent memory. Further, if the left PPC was perturbed after learning had been allowed to occur, the acquired memory was disrupted, and learning failed to generalise across effectors. This work thus established the PPC as an essential neural substrate for learning and storing effector-independent memories.

The work could potentially help physical therapists devise strategic training for stroke patients with significant weakness on one side of the body or for patients with other unilateral brain injuries. First, the fact that deficits in forming effector-independent memories are seen following left but not right

hemisphere disruption, suggests that rehabilitation following left versus right hemisphere damage needs to be different. Second, if patients with left hemisphere damage, particularly in the PPC, fail to learn using implicit mechanisms, explicit strategies to accomplish the task/goal may need to be provided to them in order to bring about improvements in their actions. Finally, the fact that learning can generalise from one effector to another, suggests that the “unaffected” limb could be trained during rehabilitation to bring about performance gains on the affected side.



The research team members include IITGN Cognitive Science PhD students **Adarsh Kumar** and **Gaurav Panthi**, and former JRF, **Rechu Divakar**.



DOUBLE-LAYERED MICROBUBBLES FOR EFFECTIVE DRUG DELIVERY

Drug-loaded microbubbles combined with ultrasound to treat triple-negative breast cancer (TNBC) cell lines and reduce cell proliferation from tumour

The rising number of cancer cases across India poses a serious threat to the human population. The Indian Council of Medical Research (ICMR) reported that there will be an increase of 12% in cancer cases across India over the next five years.

Conventional chemotherapy has been the mainstay of cancer treatment for decades. However, the therapy has certain drawbacks; non-specific targeting being one. To address this, the past two decades have witnessed growing research on the use of microbubbles as drug delivery vehicles. Microbubbles are spherical gas-filled bubbles with a size smaller than or equal to that of the red blood cells. They have been used in diagnosis and treatment, as a contrast agent due to their ability to respond to the incident ultrasound.

The team, led by Prof Sameer Dalvi, Smt. Meera and Prof Girish K. Sharma Chair Professor in Chemical Engineering, used microfluidic devices to synthesise the microbubbles. Microfluidic devices are fluid handling devices with at least one of the dimensions of the device on a micrometre scale. It is widely used for the formation of microdroplets, microbubbles, and micro-particles by contacting fluids in various schemes. “We used two microfluidic T-junctions, a device that allows cross-flow contact of fluid streams for microbubbles/droplet formation, to form double-layered microbubbles consisting of nitrogen gas core,” says Professor Dalvi.

Researchers at the Colloidal and Crystal Engineering Laboratory at IITGN, through their findings presented in *Langmuir (American Chemical Society)*, have proposed a novel method for the synthesis of double-layered microbubbles loaded with drugs for the inhibition of tumour progression.



Our work focuses on the synthesis of double-layered microbubbles that can load two different drugs on the microbubble surface. There are a handful of reports available in the literature on the synthesis of double-layered microbubbles, and even fewer on their use to treat cancer cell lines.

-Prof Sameer Dalvi



The synthesised microbubble has a sequential coating of silicone oil layer on the aqueous protein layer which encapsulates the nitrogen gas core. “The oil layer on the microbubbles allows loading of a hydrophobic drug (water-insoluble) on the microbubble surface. Unlike single-layered microbubbles, where the amount of drug loading is restricted by the size of the microbubble and the encapsulating material, the drug loading capacity in double-layered microbubbles can be enhanced due to the presence of an additional oil layer,” Professor Dalvi explains. “The drug thus loaded on the microbubble surface can be delivered at the tumor site upon exposure of ultrasound.”

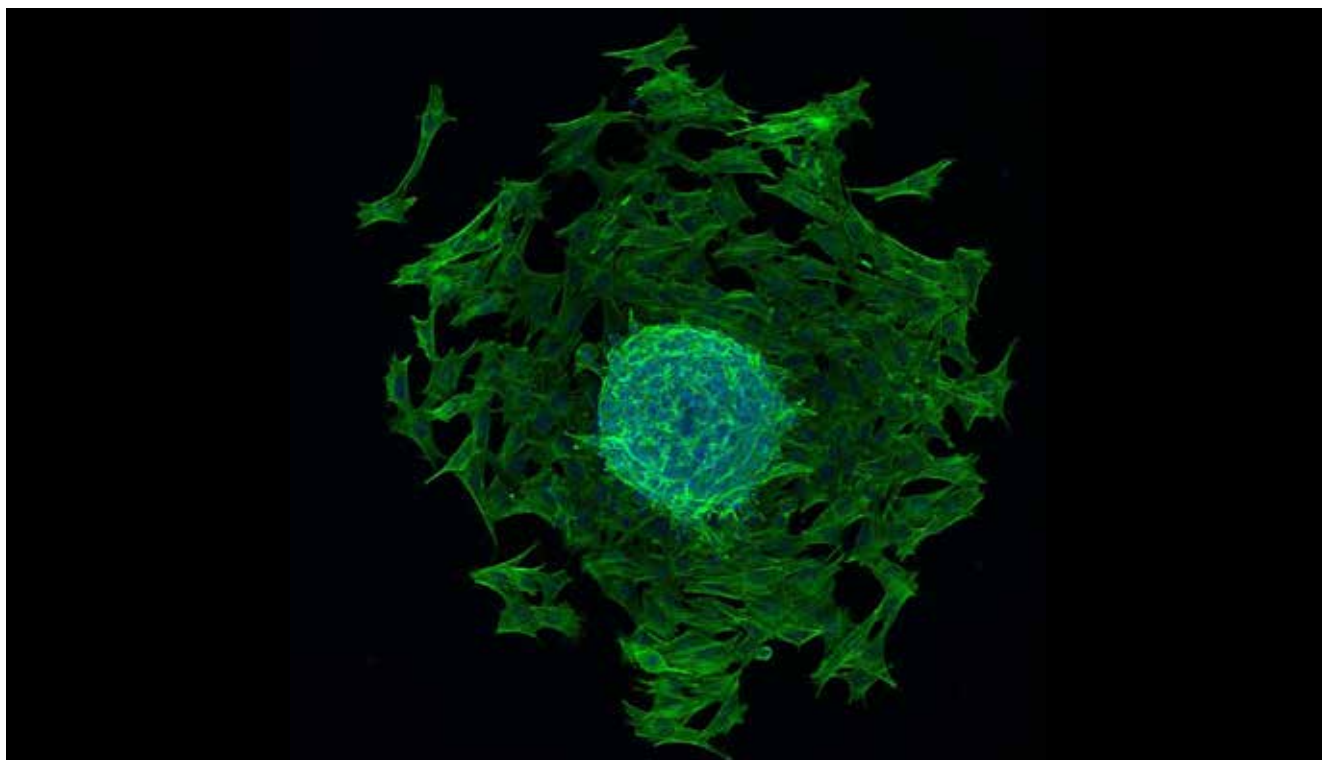
They loaded the double-layered microbubble with a combination of doxorubicin, a type of chemotherapy drug and curcumin, a yellow pigment which is found in turmeric — a common Indian spice. While doxorubicin is a Food and Drug Administration (FDA) approved drug which has been effectively used for treating cancer cells, curcumin has a variety of therapeutic properties, including antioxidant and anti-inflammatory properties. Moreover, there is a growing research interest in its usage for drug delivery owing to its anti-cancer properties. The team thereafter evaluated the effectiveness of the synthesised microbubble with the TNBC cell lines. In the words of Prof Dalvi, “We treated the TNBC cell lines with double-layered microbubbles and found that the incorporation of the two drugs, doxorubicin and curcumin, produced a synergic effect which leads to higher cell deaths. We also tested the efficacy of

drug-loaded microbubbles on the 3D spheroid models of TNBC cells and found that there was an efficient reduction of cell proliferation from tumours for cells treated with microbubbles in the presence of ultrasound.”

He also shares that as of today, there are a handful of reports available in the literature on the synthesis of double-layered microbubbles and even fewer reports on their use to treat cancer cell lines. “Since this work is in its early stage of development, the size of these microbubbles is large i.e. 200-250 μm , and hence cannot be administered intravenously. Although presently they can be used effectively to treat oral cancer cells in conjugation with ultrasound, different drugs effective for various other tumour cell lines can be loaded on the microbubble surface and used as potential drug delivery vehicles,” he says.

The team is working towards reducing the size of the microbubbles to 10-15 μm and looks forward to making advancements by using these microbubbles on animal models.





EXPLORING EFFECTIVENESS OF 'CURCUMIN' AS AN ANTI-CANCER COMPOUND

*Investigating the effect of curcumin, present in turmeric, on
triple-negative breast cancer (TNBC) cells*

Widely recognised for its anti-inflammatory, anti-microbial, and antioxidant properties, Turmeric is an all-pervasive and an essential spice used in Indian food. These properties of the spice are attributable to a yellow pigment called 'curcumin' present in it.

Curcumin (CUR), obtained from dried rhizome of *curcuma longa* (scientific name of Turmeric plant), is known to be a potential anticancer compound that can prevent cancer metastasis in patients. However, its poor bioavailability — the ability to be absorbed and used by the body — is still a major barrier in its therapeutic utilisation.

CUR is of wider interest worldwide for its multiple medical applications. Owing to its low aqueous solubility and low membrane permeability, it has

been classified as a class IV drug, based on the Biopharmaceutics Classification System (BCS). It, therefore, becomes necessary to fine-tune the solubility and bioavailability properties of CUR without affecting its intrinsic properties. The solubility of any poorly water-soluble active ingredient like curcumin, which can be used in the manufacture of drugs, can be significantly enhanced by converting the solid state of the ingredient to solvates, cocrystals, co-amorphous mixtures, and eutectics.

IITGN researchers, in a first-of-its-kind report, have investigated new non-covalent complexes of curcumin on TNBC cells. Guided by **Prof Sameer Dalvi** and **Prof Dhiraj Bhatia** of Chemical Engineering and Biological Engineering, respectively, **Indumathi Sathisaran**, a PhD scholar at IITGN observed a



combined and enhanced effect of curcumin and other highly water-soluble compounds on the direct extension and penetration of cancer cells into adjacent tissues.

Their findings appeared in the *International Journal of Pharmaceutics*.



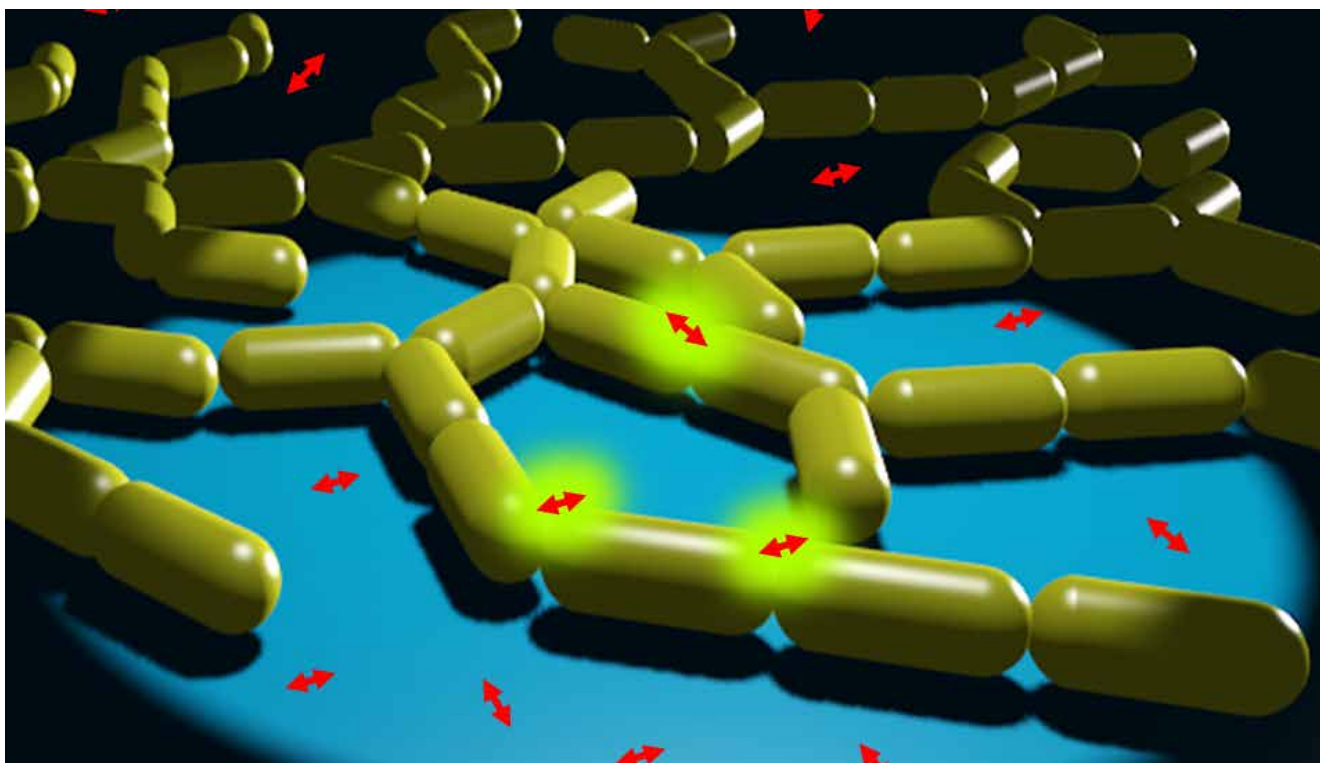
CUR exists in various polymorphic and in several multicomponent solid forms. Indumathi says, "Reports are available in the literature where

researchers have evaluated anti-cancer activity and anti-invasive activity of commercially available CUR (Form I CUR) in different 3D tumour models. But, no reports are available on understanding the impact of multicomponent solid forms of CUR against 3D tumour models. In this work, the CUR multicomponent solids were investigated on 2D and 3D tumour models."

The team employed slow cooling crystallisation and evaporative cooling crystallisation techniques to obtain crystal complexes of curcumin and tested them for effectiveness in 2D and 3D cancer cell models.

They discovered that the new crystal complexes of curcumin obtained possessed high solubility. "This is the first report in the literature where we have investigated the new non-covalent complexes of curcumin on TNBC cells and observed an enhanced effect of curcumin as well as other highly water-soluble compounds on the invasion activity of cancer cells," says Professor Dalvi. The team observed that among the various curcumin solid forms obtained, Curcumin-Hydroxyquinol (CUR-HXQ) and Curcumin-Trimesic Acid (CUR-TMA) cocrystals inhibited invasion of cells from the cancer cell models to the maximum. "We propose that the new CUR cocrystal and eutectic phases reported in this work showed effective anti-breast cancer activity. However, Curcumin-Folic Acid dihydrate co-amorphous solid encouraged the tumor cell invasion and is hence not suitable for cancer therapy by combinatorial drug treatment," he explains.

The findings provide an insight into fine-tuning the bioavailability of curcumin without impacting its inherent properties, thereby making curcumin suitable for its pharmaceutical applications. The study's sweeping results in TNBC are promising. However, the researchers plan to expand this further and conduct study in the animal model to check for the safety and efficacy of curcumin cocrystals before using it in humans as an anti-cancer drug.



ENHANCED MOLECULAR FLUORESCENCE BY ORDERED GOLD NANOSTRUCTURES TO BENEFIT SINGLE-MOLECULE IMAGING

*Novel method to develop end-to-end assemblies of gold nanorods;
could enhance a molecule's emission by 10,000-folds*

A team of IIT Gandhinagar researchers from the discipline of Chemistry, led by Prof Saumyakanti Khatua, Prof Saumyakanti Khatua, Associate Professor, Chemistry, has developed a novel method for the development of large assemblies containing thousands of rod-like gold nanostructures in end-to-end configuration with small gaps of approximately 1-2 nm. They showed that these end-to-end assemblies could strongly enhance the fluorescence signal of a weak light-emitting molecule by approximately ten thousand-fold. Enhancing such fluorescence could be useful for the detection of biomolecules and developing sensors where only extremely low concentrations can be detected.

The study is published in two parts in two journals: *Nanoscale Advances* (RSC publication) and *Langmuir* (ACS publication).

Plasmonic nanostructures exhibit a strong ability to absorb and scatter light. Owing to these properties, they have been used extensively in various surface-enhanced spectroscopies such as surface-enhanced Raman spectroscopy (SERS) or surface-enhanced fluorescence (SEF) spectroscopy. SERS is a sensing technique used to identify chemical and biological molecules in a vast range of fields. "Plasmonic nanostructures confine the incident electromagnetic field to a small area near their surface and hence act as antennas for optical frequencies," explains Professor Khatua. "A molecule placed near such a nanostructure experiences a strong electromagnetic



We believe that our new approach for making end-to-end assemblies of gold nanorods will contribute to push the boundary of single-molecule imaging beyond a few highly fluorescent dyes.

-Prof Saumyakanti Khatua



field which results in enhanced absorption and/or scattering processes.”

The magnitude of electromagnetic field enhancement, which determines the overall enhancement of fluorescence or scattering, can be significantly higher for nanorods than nanospheres. It is predicted to be even stronger at the nanogaps, commonly known as hot spots, between adjacent nanorods in end-to-end assemblies.

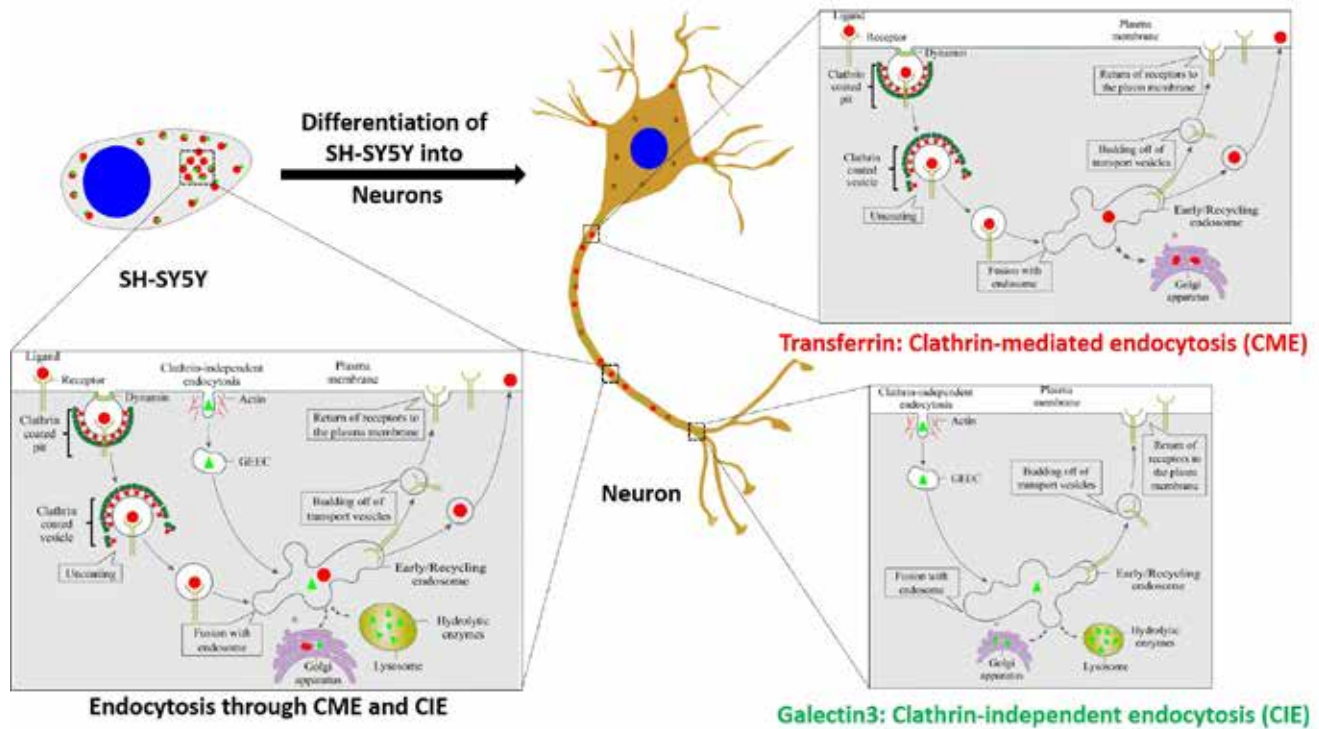
The team established the surface charge of nanorod as a key control parameter directing the growth of end-to-end attached gold nanorod assemblies linked via small molecules. “We demonstrated that tuning of nanorod surface charge drives the growth of dithiol linked end-to-end assemblies of gold nanorods from dimers (structure containing two identical units) to large polymer (substance made of repeating units) networks containing thousands of nanorods separated by narrow nanogaps of approximately 1 nm,” says Professor Khatua.

They achieved this long-range orientation ordering by increasing the surface charge of the nanorods during the assembly growth process. “Increased surface charge results in greater interparticle repulsion. This significantly reduces the possibility of binding at the sides of the nanorods and restricts attachment specifically to the tips,” he says.

The team further showed that an end-to-end gold nanorod network contains many plasmonic strong hot spots, which can enhance the fluorescence signal of a weak light-emitting molecule by 10,000-fold. “We used a crystal violet (CV) molecule which is a fluorescent chemical compound. It emits light when illuminated by other lights of different colours. However, it emits very less light i.e. emits weakly,” explains **Ashish Kar**, one of the authors of the study and a postdoctoral fellow. “The purpose of our work is to enhance light-emitting capability of such weakly emitting species.” The obtained enhancements are larger than the enhancements reported for end-to-end dimers of gold nanorods, prepared by lithography or by using DNA-origami. The enhancements are comparable to the largest reported fluorescence enhancements achieved in lithographically made in-plane antenna arrays.

The co-authors of the study include **Varsha Thambi**, and **Diptiranjana Paital**. The researchers believe that increasing the light-emitting capability of weakly emitting species will allow faster and efficient detection of such species. This would contribute towards detection of various (bio-) molecules that do not absorb and/or emit visible light.





HOW NEURONS UPTAKE DIFFERENT NANOSIZED DNA CAGES

Insights into pathways for the uptake of nanoparticles in cells would help in designing smart targeted biotherapeutics for targeting neuronal disorders.

Researchers at IITGN have explored pathways adapted by DNA nanodevices and the space-time dynamics of the fundamental cellular mechanism by which cells uptake different molecules outside the cell. Two prime routes of entry of molecules into the cells are direct fusion through the cell membrane and endocytosis. Endocytosis is an active transport mechanism through which particles such as large molecules, parts of cells, and other cells move into a cell. In the process, the cell membrane turns inside out forming a pouch that engulfs the target particle in the vesicle formed by the cell membrane.

Multiple pathways for endocytosis operate at any moment with diverse yet specific cellular functions. Understanding the uptake of synthetic nanoparticles and molecules with respect to endocytic pathways

is crucial to devising appropriate molecules for drug delivery into neurons and targeting neuronal diseases such as Alzheimer's, Parkinson's, and Huntington's, among others.

DNA in living systems has been widely exploited to design nanodevices that can be deployed in medicine as drug-delivery vehicles. The nanometre-sized objects called DNA nanocages are the nanocarriers that can be employed for cellular and *in vivo* delivery of small molecules such as peptides, antibodies, and oligonucleotides. "DNA nanostructures are programmable and can be created in different shapes, dimensions, and geometries," says Prof Dhiraj Bhatia, Assistant Professor, who led the study along with Prof Sharad Gupta, Associate Professor, Biological Engineering. "Those with well-defined geometries in sizes can be delivered to specific cells by triggering



chemical, molecular, and environmental signals to release targeted molecules and offer tunable cellular uptake profiles.”

For efficient internalisation in cells, many unmodified nanodevices require a transfection agent which allows external molecules to bypass cell membrane to enter into cells. However, there are few small-sized devices having specific geometries that show internalisation into cells and in vivo without the use of a transfection agent. Three-dimensional DNA nanocages like tetrahedral DNA nanocages (TDN) and icosahedral DNA nanocages (IDN) are such nanodevices. “Through this study, we explore which pathway is adapted by these DNA nanodevices at different stages of maturation of nerve cells and the space-time dynamics of two categories of endocytosis,” he adds.

The team studied in detail the clathrin-mediated endocytosis (CME) and clathrin-independent endocytosis (CIE) pathways in the model neuronal system where SH-SY5Y (a cell line model for neurodegenerative disorders) cells were differentiated into fully mature neurons. Various cellular ligands

(binding molecules) are established to mark these pathways. They used transferrin, an iron binding protein and galectin-3 (Gal-3) as endocytic probes to mark CME and CIE, respectively.

“We found specific patterns of multiple endocytic pathways during differentiation processes. We also showed that DNA nanodevices’ uptake in cells is dependent on the geometry of the binding molecule and the stage of neuronal differentiation,” says **Pravin Hivare**, a PhD scholar and the lead author of the study published in *ACS Applied Bio Materials*. “Our study revealed that the uptake of TDNs is more efficient than that of IDNs at all stages of neuronal differentiation and TDNs get endocytosed mostly via CME in fully mature neurons.”

Such insights into spatiotemporal dynamics of endocytic pathways and the uptake route of DNA nanocages would help in designing the smartly targeted biotherapeutics for targeting neuronal disorders.

Anjali Rajwar, PhD scholar is a co-author of the study.



A 'MADE IN INDIA' MOLECULE THAT COULD BE A POTENTIAL CURE FOR CANCER

New molecule shows great potency to completely reduce prostate cancer in 50 days

About 5,56,400 Indians die of cancer every year. But even more perturbing is the increasing resistance to anticancer drugs is also of grave concern. Prostate cancer, the second most commonly occurring cancer in men worldwide, needs a hormone called 'androgen' to grow. The standard treatment method is hormonal therapy or androgen-deprivation therapy (ADT) which provides respite from disease progression. However, it could fail when cancer spreads to other parts of the body leading to a terminal phase of the disease.

PhD graduates Siddhant Bhoir and Javeena Hussain, led by Prof Sivapriya Kirubakaran, Associate Professor, Chemistry, in collaboration with scientists from Louisiana State University Health Center, USA and the University of Manchester, UK,

have discovered a new molecule called J54 which has shown great potency not only in cells but also in animals (mice model) to completely reduce tumour (prostate cancer) in 50 days (in male mice). (The median time for prostate cancer to shrink in human male patients is about 18 months, some quicker while others slower, depending on the size of tumour detected).

Recently, the researchers have published a paper in *Cell Press, iScience*, on a less-explored protein kinase called 'Human Tausled-like Kinase-1 (TLK1)' that is involved in DNA damage response pathway in cancer and discovered this new molecule - J54. This molecule is the first selective inhibitor of the protein that causes cancer initiation and growth, mainly in the prostate. J54 has also shown low toxicity in normal cells and animals.



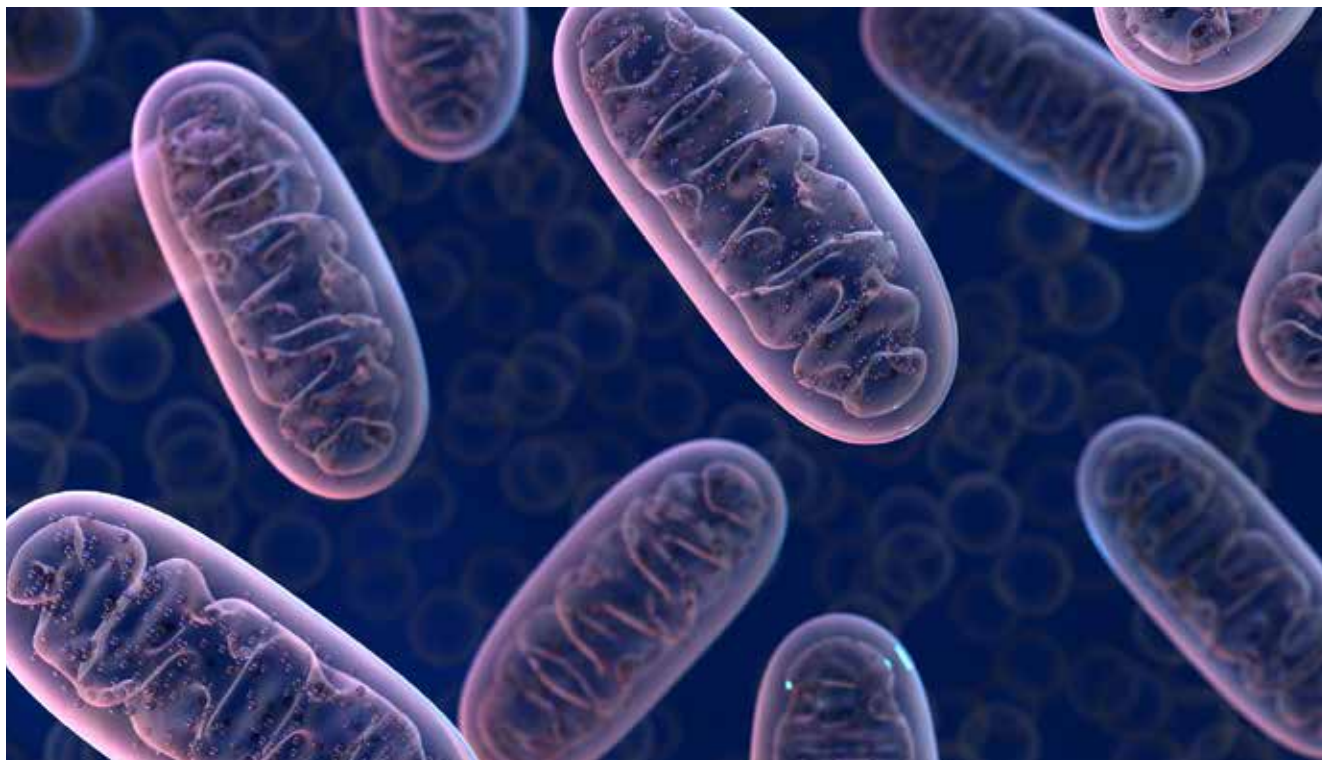
Professor Kirubakaran's laboratory at IITGN works on the chemical biology of cancer. They work on making small molecule drugs for inhibiting kinases, an important class of proteins which are important for the growth of cancer. The researchers used small molecule inhibitor approach to study this protein to develop new age cancer therapeutics.

Since J54 combination therapy is targeted to a specific protein, it is expected to be more effective and personalised for the treatment of a particular patient. It has not shown any side effects or toxicity

effects in normal cells and animals. The new molecule completely reduces prostate cancer in mice model while also considerably reducing the amount of drug used in known therapy.

The efficacy and potency shown by J54 molecule creates hope for a faster therapy of prostate cancer. Scientists are confident that the findings will pave the way for a new targeted therapy for prostate cancer with fewer side effects, if proved successful in clinical and human trials.





FORGING AHEAD WITH TARGETING MITOCHONDRIA IN CANCER THERAPY

Addressing manifold challenges in mitochondrial chemical biology by developing strategies to target mitochondria for a potential treatment of cancer

Studies suggest that the number of cancer cases in India would continue to double every 20 years. Of all the cancer research and therapeutics that have made rapid strides in the past decades, cell metabolic therapy is another treatment for the scourge which targets mitochondria, the energy source of the cancer cells, and inhibits their growth and spread.

The chemical biology group led by **Prof Sudipta Basu**, Associate Professor, Chemistry, has developed a multidisciplinary approach incorporating chemistry, biology and nanobiotechnology to target subcellular organelles as signaling hubs in cancer.

“Cancer cells use their metabolism to grow faster in an uncontrollable manner and a key player in

cellular metabolism or cancer cell metabolism is mitochondria, known to be the powerhouse of a cell. We aim to target and damage mitochondria residing in the cancer cells,” explains Professor Basu. “We have successfully developed some small molecules and nanoscale probes to specifically target organelles in cancer cells — this can be used in therapeutics in future.”

The major challenges were to target mitochondria selectively in cancer cells, keeping them unimpaired in the healthy cells, and to design nanoscale packages that could be sent to the mitochondria inside the diseased cell.

The idea that the group worked on was to develop a positively charged nanoparticle for sending



This strategy targets the effective organelles, hence less amount of drug carried by the nanoplatform will be more effective compared to the free drug which we need in high dosages for the same effect.

-Prof Sudipta Basu



it to the mitochondria which has a negatively charged membrane. They packaged Obatoclax, an experimental drug for various types of cancer, inside the positively charged nanoparticle. The nanoscale packages were engineered and made to pass through the pores in the tumour blood vessels which are comparatively larger than those in the healthy cells.

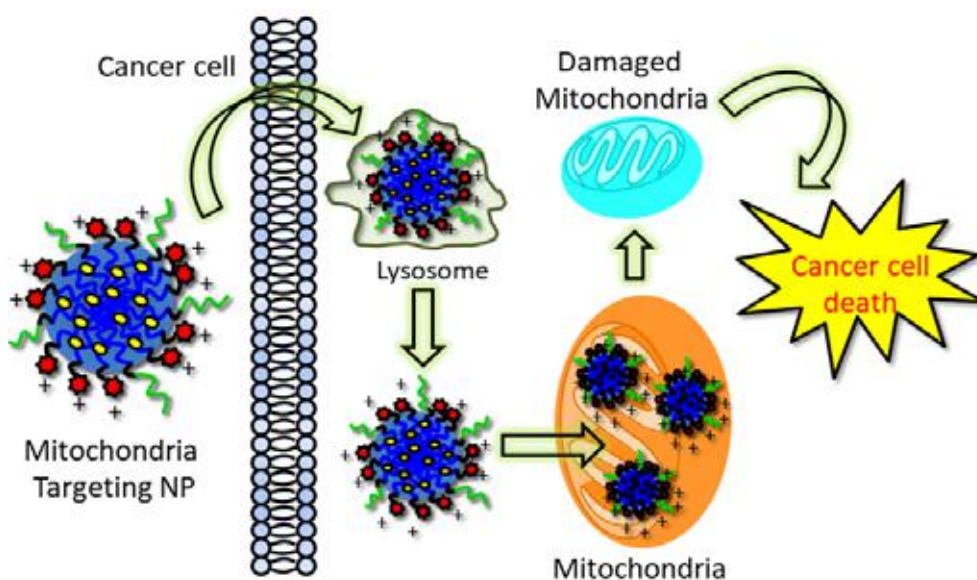
The nanoparticle would thus enter the cells and into the mitochondria to cause apoptosis — programmed cancer cell death. “These nanotechnology-based approaches have tremendous potential in next-generation cancer therapeutics and still a lot of work needs to be done towards achieving this. We are hopeful that this would work efficiently in the animal model and could thus be used in future to reduce the

pain of a large number of cancer patients,” explains Professor Basu.

The team has not explored the cost-effectiveness of this project as of yet. However, they anticipate that this strategy will be less expensive than the current treatment if translated into clinics.

“This strategy targets the effective organelle This strategy targets the effective organelles and, therefore, less amount of drug carried by the nanoplatform will be more effective when compared with the free drug needed in high dosages for the same effect,” he says.

The findings were published in *Applied Materials and Interfaces* (American Chemical Society)





SMART SHOE INSOLE, A GAIT-ANALYSIS DEVICE

A smart instrumented shoe insole monitors walking patterns; could be potentially used to help individuals with gait disorders

Walking is a natural process, isn't it? But did you know that it might need monitoring and correction? The experts say that wrong walking style or the foot impact can significantly alter one's blood supply to the brain and affect the heart and muscles. Monitoring and evaluating gait (walking pattern) characteristics over time thus makes it possible to diagnose and treat a disease and the associated complications early on.

A smart instrumented shoe insole, INSTROLE, developed by an IITGN research team, could be used to monitor and characterise the user's walking/running patterns. The team is led by Prof Uttama Lahiri, Professor, Electrical Engineering. INSTROLE can be used in rehabilitation centres by clinicians to help post-stroke patients restore their normal walk. Besides, it can be suitably used for monitoring walk or run by a healthy person, both overground and on a treadmill.





In the words of Professor Lahiri, “Instrole came up as a part of a bigger research project that took about five years. It is a gait characteriser or gait quantifier. It characterises one’s gait in terms of spatiotemporal indices which can infer a walking pattern.”

This instrumented insole, which is a smart piece of engineering has calibrated sensors placed in it for acquiring data on gait events reliably. While the carefully placed sensors record the walking pattern and provide real-time feedback for analysing change and improvement in one’s gait, wireless connectivity between sensors and data receiver ensures ease of human interaction. The chosen sensors do not interfere with one’s natural walking pattern and the wireless connection is stable enough for a long time and accurate communication over a fairly long range.

“The gait-related indices obtained can be presented, through a wireless connection, on a computer, cell phone, etc.,” she explains. “This allows tele-monitoring while facilitating diagnosis and aids careful observation of the rehabilitation outcomes. The shoe is also capable of issuing fall alerts through sensors thereby improving the quality of life for the elderly.” The designing of the insole is indeed the most interesting part that came into picture, once the underlying technology was successfully tested. The design team analysed various configurations for designing the insole without affecting the performance of the technology. “We designed a ‘structural packaging’ that housed the electronic

components and pushed it towards becoming an attractive, usable product that is also acceptable in the market,” says **Prof Manasi Kanetkar**, Assistant Teaching Professor in Design, who directed the designing of the insole.

Nirav Patel, an industrial designer working with Professor Lahiri’s team says, “Using the least amount of area for electronic components and by adding only the necessary elements to INSTROLE, we have maintained a composition of simple and compact design. The cushioning, texture and colours were picked in such a way that it improves the functionality of Instrole.”

Instrole can potentially change the diagnostic scenario for walking parameters and could be used for sportsmen with a purpose to gauge their gait pattern and map their stress level. However, this remains a future prospect. Professor Lahiri says, “**Intelligent Rehabilitation and Affective Computing Systems Laboratory (IRACS)** at IITGN is working on more technologies that will address not just biomechanical issues but also the cognitive issues. The devices will work in sync with Instrole to help the rehabilitation of those with impaired walking.” The team is hopeful of commercialising the idea soon and is looking for interested investors.

The study was published in the *Frontiers in Neuroscience*.



VIRTUAL REALITY PLATFORM FOR PEOPLE WITH **AUTISM**

A virtual reality-based storytelling platform that could help train autistic people

The use of virtual reality (VR) as a tool to explore autism and help individuals suffering from the disorder is a fast-developing area of research. The VR-based behavioural learning is now being adopted by counsellors, therapists, and teachers alike to help individuals with autism.



IITGN researchers have designed a **Virtual Reality-based Intelligent Storytelling Platform (VRISP)**, intended to teach some of the core skills of social communication to autistic children, by providing them with a fun and engaging experience of a gaming environment. It has received a positive response and feedback so far as the experiments conducted were able to impact the participants instantaneously.

“This sort of intervention and its transmission to real life helps raise social communication skills of the child. We carried out studies at Ahmedabad’s Pearl Special Needs Foundation and B M Institute of Mental Health and it worked out very well for participants from both the organisations,” says **Professor Uttama Lahiri**, Professor, Electrical Engineering, who led the project. Within this platform, two users are



It is an effort towards inculcating collaborative learning skills in individuals with autism through our story authoring virtual reality-based app.

-Prof Uttama Lahiri



provided with different screens connected with the same console, and pictorial representation of scenes (objects) are designed based on various environments like landscape, playground, restaurant or classroom. Once the objects present along the screen borders are dragged and dropped by the participants, they become populated in the form of a collage on the central canvas which is updated on both the screens simultaneously. The same story created on respective screens is observed by the duo.

While both the users try to understand each other's sentiments and preference and, accordingly, make selections to build a coherent story, it might also happen that they don't completely understand each other and end up creating unrelated (or incoherent) stories.

"We have an artificial intelligence-based engine that knits the objects to form a story. On completion of the storymaking by the players, the AI-based engine empowers an *avatar* to narrate the story to the children. In case the children make incoherent selections while framing the story, the *avatar* offers hints in the form of exception statements. Thereafter, the players are also awarded marks on the basis of their performance," she explains. The AI engine extracts the anxiety level from the physiology, such as the eye gaze-related measures of the child to get an estimate of the child's affective state while interacting with each other using VRISP.

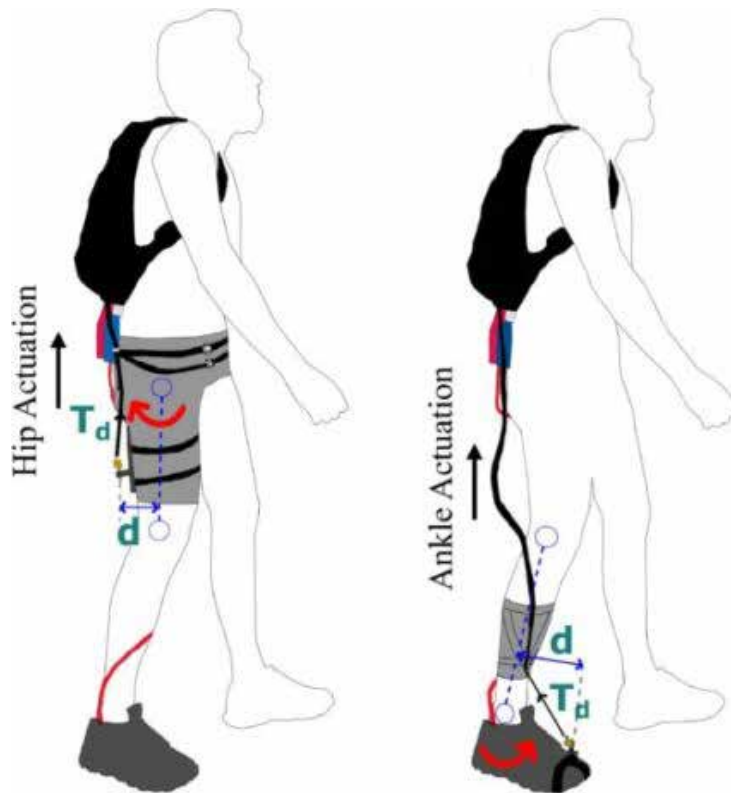
As autistic children experience difficulties in social communication, self-sustenance becomes a challenge. They avoid physical as well as eye contact, and become unresponsive to emotions like smile or scowl. Children with autism lack the ability to imagine what somebody else is thinking. Apart from core problems like repetitive behaviour and non-conventional responses, they might also have stereoscopic vision.

"Early diagnosis and various treatment therapies might be available but there's no known cure for autism. We can definitely lessen the symptoms and aid in inculcating collaborative learning skills in them through this story authoring VR-based app that we've developed," says Professor Lahiri.

The research paper is co-authored with the former PhD scholar of IITGN, **Pradeep Raj Krishnappa Babu** who is now a Postdoctoral Research Associate, Duke University Pratt School of Engineering.

The study appeared in the *IEEE Transactions on Neural Systems and Rehabilitation Engineering*.





WEARABLE ROBOTIC SUIT TO FACILITATE NORMAL WALKING IN STROKE PATIENTS

Wearable adaptive rehabilitation suit opens up a new approach for rehabilitation and retraining

Walking is one of the most essential activities for a person in day-to-day life but we take this skill entirely for granted. Don't we? However, a stroke can raze this capability within minutes.

About 88% of stroke patients suffer from weakness and lose the normal function in one limb. Although their mobility may recover with stroke rehabilitation, the majority can develop abnormalities in their walking patterns. Besides stroke and similar neurological disorders, age-related ailments may also result in the reduction of weight-bearing capacity and joint range of motion, which can lead to severe deterioration in human walking patterns and increase the risk of falling.

The traditional gait rehabilitation techniques which involve repetitive movement training of the affected limb could be tedious and time-consuming. Robotic devices, however, provide a solution; they can aid physical therapists in gait training and provide a quantitative measure of gait performance. In the past decade, body-weight support systems and robotic leg exoskeletons — which use rigid links to apply the required force to the appropriate joints to promote natural motion — have been developed for gait rehabilitation. These kinds of systems are, however, quite heavy and can restrain natural motion of the leg, leading to learning of undesirable walking patterns by the patient. In recent years, developers have created cable-driven systems that are lightweight, flexible, and do not interfere with the natural motion of the leg.



The emphasis is on extensive human studies to promote the effectiveness of cable-driven robots in improving the asymmetric gait of Stroke patients during overground and treadmill walking.

-Prof Vineet Vashista



At IITGN, Prof Vineet Vashista, Assistant Professor in Mechanical Engineering and his team have developed a portable **Wearable Adaptive Rehabilitation Suit (WeARS)** for the lower body (from the hip to the toes) which can be used for rehabilitation in patients suffering from gait abnormalities and to study gait patterns in elderly and the disabled.

The IITGN team used the WeARS system to study the adjustments in terms of modified gait patterns made by a healthy human body to compensate for reduced joint mobility. To mimic the abnormalities in hip and ankle joint motion, resistive force is applied to the backside of the thigh to resist the hip motion and on the toe to resist ankle motion, using the WeARS system.

“It was shown through the experiments that gait patterns do change when joint motion in the leg is restricted. This change was observed to be

compensatory in nature. When motion in one joint is restricted, the body compensates for this by changing the motion of other involved joints. This also proved that the designed system has the ability to alter a person’s walking pattern to a desired one,” he explains.

Further, the understanding of human locomotor adaptation in response to simple resistive forces drawn from the study can be used to develop personalised gait rehabilitation programmes.

The work was published in *IEEE, 2019* and *Frontiers in Neurorobotics, 2020*. It was presented at the *28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*.

Other authors include PhD scholars **Nakka S S Sanjeevi and Yogesh Singh**, MTech graduate **Srikesh Iyer**, and MSc graduate **Joel Joseph**.



RESEARCH BLURB

Prof Arpan Bhattacharyya



Prof Arpan Bhattacharyya did his PhD at the Indian Institute of Science, Bangalore in 2015. After completing his postdoc from the Physics Department, Fudan University, Shanghai, PRC and the Yukawa Institute of Theoretical Physics,

Kyoto, Japan, he joined IITGN in October 2019.

Quest for understanding the complex behaviour of nature has always generated unprecedented outcomes. For example, one needs to implement Einstein's General relativistic correction to make the global positioning system (GPS) work accurately. Recent observations from Gravitational-wave (GW) experiments: LIGO-VIRGO-KAGRA and Event Horizon Telescope (EHT) provide a platform for testing various classical aspects of gravity. Furthermore, Einstein's general relativity predicts objects like black holes, and

a complete understanding of such objects requires quantum gravity theory. AdS/CFT (Anti-de Sitter/Conformal Field theory) correspondence, popularly known as 'Holography', is perhaps the best theoretical framework to study perturbative quantum gravity theory. But, the inner workings of holography remain a mystery.

Professor Bhattacharyya, along with his students and team of postdocs, explores several observational signatures, e.g. black hole shadows and echoes of compact objects. These connect with the data coming from EHT and GW experiments and teach lessons about underlying gravity theory.

Apart from this, he tries to demystify the inner workings of AdS/CFT using tools of quantum information. In one of his recent papers with his collaborators, published in Physical Review Letters, he has pointed out an excellent connection between quantum circuit complexity and holographic renormalisation group flow.

Prof Prasanna Venkatesh

Prof Prasanna Venkatesh B did his PhD at McMaster University (Canada) in 2013 and a postdoc from the Asia Pacific Center for Theoretical Physics in Korea and the Institute for Quantum Optics and Quantum Information in Austria. He joined IITGN in 2018. We still have so much to learn about why things around us and in the biological systems work as they do. Quantum physics answers this by explaining how the universe behaves at the scale of the smallest things we know as atoms.

Professor Venkatesh's research interests and that of his research group at IITGN fall in the area of open quantum systems. "Specifically, there are two major directions in which we work," he explains. "The first one is the study of fascinating properties and exciting physics of specific open quantum systems, mostly drawn from the field of quantum optics such as collections of quantum emitters, ultracold atoms in optical cavities, etc. The second is focused on the growing field of quantum thermodynamics, which

has as its motivation a more general question - what sort of interesting and counter-intuitive behaviour emerges when one studies small quantum mechanical systems (dominated by quantum fluctuations) within the framework of thermodynamics?"



To illustrate the answers to such questions, his group studies the behaviour of thermodynamic heat engines made of quantum particles - the so-called quantum heat engines and other thermal machines. "On the more formal side, we are also interested in Fluctuation Theorems which generalise the second law of thermodynamics to situations far from thermal equilibrium," he adds.

Prof Raghavan Ranganathan

Prof Raghavan Ranganathan, who joined as an Assistant Professor in the discipline of Materials Engineering at IITGN in July 2019, leads the Computational Molecular Engineering Research Group at the institute. The group currently comprises two postdoctoral researchers, two PhD students, two postgraduate and five undergraduate students. Professor Ranganathan received his BTech in Metallurgical and Materials Engineering from IIT Madras and a PhD in Materials Science and Engineering from Rensselaer Polytechnic Institute in 2016. His research revolves around atomistic/molecular simulations to uncover structure-property relations in materials, with a focus on properties such as mechanical, thermal, mass transport and reactive processes in a host of materials.

“Some of our current projects include a systematic first-principles study of solid electrolyte interphase formation in Lithium (Li) batteries; mechanisms for viscoelasticity which is the property of materials to

exhibit both viscous and elastic characteristics when undergoing deformation, in multicomponent alloys; structure-property correlations in nature-inspired materials; and applications of machine learning in materials science, to name a few,” says Professor Ranganathan. Some of these projects are funded by research grants from the **Science and Engineering Research Board (SERB)** and the **Department of Science & Technology (DST)**.



While talking about his interests other than research, he says, “Besides research, I am passionate about teaching, cooking and playing the Carnatic flute. Also, I am always enthusiastic about discussing new ideas and meeting new people!”

Prof Karla Mercado-Shekhar



“Biomedical ultrasound is an interdisciplinary field and a satisfying area to work on, given its impact on healthcare. In the past decade, ultrasound has undergone several advancements which extend its capabilities beyond conventional

applications,” explains Prof Karla Mercado-Shekhar who joined IITGN on April 15, 2019 as an Assistant Professor in Biological Engineering.

Professor Mercado-Shekhar co-leads the **Medical Ultrasound Engineering (MUSE) Lab** at IITGN.

“The overall goal of my research team is to develop innovative ultrasound imaging approaches to facilitate diagnosis and clinical management of diseases,” she says.

Medical ultrasound incorporates diagnostic imaging techniques along with therapeutic applications of ultrasound, which is rapidly expanding due to its low cost, non-ionizing nature, and portability, and has the

potential to significantly impact healthcare delivery.

Professor Mercado-Shekhar’s work integrates the understanding of biological and physical mechanisms with technology to address healthcare challenges. Specifically, ongoing research efforts focus on developing ultrasound imaging approaches for delineating brain tumours and diagnosing oral cancer. Her team is also developing novel tissue-mimicking ultrasound phantoms for validating viscoelasticity imaging and tissue characterisation approaches. Her research is currently supported by the **Department of Science and Technology (DST)**, **Gujarat State Biotechnology Mission (GSBTM)**, and IITGN.

The **MUSE Lab** is equipped with facilities for research in biomedical ultrasound, including a programmable research ultrasonic system, which enables development of novel imaging techniques through full control of pulsing, beamforming, signal acquisition and processing. The lab also includes facilities for fabricating and characterising the acoustic properties of tissue-mimicking gel phantoms and tissue-engineered constructs.



THE RESEARCH PARK AT IIT GANDHINAGAR

The IIT Gandhinagar Research Park was established in 2017 as a Section 8, not-for-profit company. Located on campus, the Research Park seeks to accelerate translational and output-oriented (Lab to Market) research by bringing together industry, researchers, and academia.

The Research Park is in proximity to reputed academic institutions like the National Institute of Pharmaceutical Education and Research (NIPER - A) and the Indian Institute of Public Health (IIPH), among others. Also, its nearness to industrial zones like Gujarat Industrial Development Corporation (GIDC), GIFT City, and Infocity makes it a collaboration hub that facilitates interdisciplinary dialogue, impactful interactions, and sharing of facilities, space, and services.

It offers a state-of-the-art and ready-to-occupy office building of about 2,00,000 sq ft with warm shell structures, furnished offices, and dry and wet laboratories to suit different office and research requirements. The well-appointed office building of

the Research Park also houses ample meeting rooms, conference halls, board rooms, dining spaces, gyms, and space for recreational activities.

The Research Park invites corporate and industrial entities to become part of a vibrant community with access to world-class faculty, experienced R&D professionals, a creative and talented community of students, and properly outfitted laboratories at the Institute. It also offers resources aligned to support industrial partners, technology leaders, and startups alike. The unique and active ecosystem complements startups and helps them achieve their goals. It spurs translational research and innovations with the potential to promote the knowledge economy.

Over the years, twenty companies have operated at the Research Park. Present incumbents include entities like NASSCOM, GUVNL, D.P. Pulveriser, Everest Instruments, and Havi, among others. Their research work spans areas like water, sanitation, power, cognitive science, cloud, pharma, chemicals, IoT, pulverising equipment, agri-tech, biomedical, and manufacturing. Active engagement benefits immensely the industrial incumbents, who, among others, have been able to file several patents and achieve commercially beneficial outcomes.

The Research Park is all set and excited to welcome more such research-based collaborations in its new ready-to-occupy office.

The credit-based engagement model at the Research Park ensures an ongoing engagement that encourages regular, ongoing connections between the companies and the IITGN ecosystem, in general.

In addition, the Research Park offers:

- Professional work environment.
- Opportunity to be a part of IIT Gandhinagar's

interdisciplinary academic activities.

- The Incubation Center and technology startups as part of the current ecosystem.
- Active international collaborations with universities and industries.
- Industry-focused activities including
 - + Common Research and Technology Development Hub for Chemical Processes
 - + Fire testing lab in partnership with Underwriters Laboratories
 - + Industry-sponsored chairs with activities in multiple domains
 - + Maker Bhavan

Governance

A strong advisory board is chaired by **Shri Kris Gopalakrishnan**, co-founder, Infosys Ltd. The industry leaders on the board bring a wide range of experience, skills, and perspectives. They are committed to high-quality research, innovation, and supporting the Research Park.





IIT GANDHINAGAR INNOVATION AND ENTREPRENEURSHIP CENTER

IITGN has promoted IIEC with a mission to foster techno-entrepreneurship through innovative and creative thinking using an interdisciplinary approach, encouraging a strong link between technological research, innovation, and entrepreneurship.

IIT Gandhinagar Innovation and Entrepreneurship Center (IIEC), a technology business incubator located within the IITGN campus, was incorporated in December 2015 under Section 8 of the Companies Act 2013. IITGN has promoted IIEC with a mission to foster techno-entrepreneurship through innovative and creative thinking using an interdisciplinary approach, encouraging a strong link between technological research, innovation, and entrepreneurship.

IIEC provides a platform for nurturing and developing innovations and ideas into successful business companies. It has put in place a robust support ecosystem needed to build successful companies and technical prowess. The Center

connects incubated companies with the right mentors who guide startups, students, and existing entrepreneurs. The mentors help the incumbents develop and scale up their technology or products, identify their market, and understand legal and intellectual property-related matters. They also give guidance on building networks with relevant and emerging entrepreneurs, investors, and industry partners. In addition, early-stage financial support, generally, as per Government of India startup funding schemes, is also provided to eligible startups.

The incubation center provides vibrant operating surroundings with open co-working spaces, individual and shared offices, state-of-the-art conference rooms, and discussion areas. Backed

by highly reliable IT and computing infrastructure, IIEC strives to resemble some of the best expanses in the world. The Center brings unparalleled value by allowing its portfolio companies to access IITGN's R&D infrastructure such as labs, high-end equipment, and technical expertise.

The Center has successfully brought together entrepreneurs, academicians, and industry experts

to reshape the startup ecosystem. IIEC incumbents cover entrepreneurship areas, including Agri-tech, Health care, Automation, AR VR and 3D Printing, among others.

It has supported more than 40 startup companies so far and is open to partnering with incubating technology startups from outside the IITGN community.



Shashank Shekhar (Co-founder & CEO, MiCoB) (PhD, Civil Engineering, IITGN)

"IIEC has continuously provided us with the guidance and mentorship through its well-connected network of distinguished people in academia and industry. Mr. Anand Pandey, Mr. R A Venkitachalam, and Mr. Nirmal Jha have actively supported us since our inception. IIEC's support earned us various grants that assisted us in the product development. Also, the connection with the Angels and VCs has helped us commercialize the product and scale up. I am very grateful for IIEC's support and guidance."

Silky Agarwal (Founder at GeoCarte Radar Technology Pvt Ltd) (MTech/CE/2015)

"Being incubated at IIEC was a Kickstarter for our startup. We received a lot of handholding when we were taking baby steps towards this endeavour. IIEC has helped us structure our startup by providing mentor connections and other required support in different domains. Everyone's valuable support has been a catalyst for the successful completion of many prestigious projects. It has been a great place helping startups through their often challenging and perilous journey."



Chandan Kumar Jha (Founder, Galanto Innovations Pvt Ltd) (PhD/EE/2020)

"IIEC has been a very active and supportive institution at IIT Gandhinagar. As a researcher-turned-entrepreneur, I have reaped several benefits from the multiple activities undertaken by IIEC. The regular one-to-one mentorship sessions and the assistance provided in developing the right connections have particularly been very useful to me. IIEC has also been instrumental in encouraging the IIT Gandhinagar community to venture into entrepreneurship by organising several workshops, interaction sessions, and disseminating useful information."

Harini Gunda (PhD, Chemical Engineering, IITGN)

"IIEC-IITGN is giving me a platform to become an entrepreneur from a researcher. As my innovation is useful in both defense and space sectors, the IIEC team has helped me connect with the DRDO, ISRO, and the Indian Army. Besides facilitating the right connections, the team plays a major role in monitoring my progress, providing the necessary facilities, and guiding me by providing timely feedback. I am extremely thankful to the team for their continued support and encouragement in this pre-incubation journey."



BIBLIOGRAPHY

A step closer to developing antibacterial drugs
<https://pubs.acs.org/doi/abs/10.1021/acsomega.0c02321>

A way forward on understanding black holes
<https://arxiv.org/abs/1910.04565>

Is there a parallax in mind? An investigation into Beckett
<https://www.tandfonline.com/doi/abs/10.1080/0950236X.2020.1729850>

Fibre-optic sensor-based glove for stroke rehabilitation monitoring
<https://ieeexplore.ieee.org/document/8723618> & <https://ieeexplore.ieee.org/document/9302765>

Over 60-year-old unstudied mathematical masterpiece uncovered
<https://www.sciencedirect.com/science/article/abs/pii/S0001870821005326?via%3Dihub>

Low cost, non-electric, and point-of-use water filter
<https://www.nature.com/articles/s41598-019-54602-3>

DNA nanodevices designed to function as smart therapeutics
<https://pubs.rsc.org/en/content/articlehtml/2021/nr/d1nr04475c>

Unique surface quoring that inhibits viral activity
<https://www.sciencedirect.com/science/article/abs/pii/S0925838821020193?via%3Dihub>

Study explains potential severity of fire in modern buildings
<https://www.currentscience.ac.in/Volumes/115/02/0320.pdf>

Researchers synthesise compound for anti-cancer applications
<https://pubs.acs.org/doi/abs/10.1021/acs.joc.9b03491>

Coupling solvents to achieve a sweet spot for synthesising nanosheets
<https://doi.org/10.1016/j.ceramint.2020.07.336>

A new class of nano-additives for fuels used in space and defence applications
<https://www.sciencedirect.com/science/article/pii/S0040603120301830>

Studying Gandhian literature, the new user-friendly way
<https://dl.acm.org/doi/abs/10.1145/3383583.3398631>

Studying surface patterning for enhanced enzyme activity
<https://pubs.acs.org/doi/abs/10.1021/acs.jpcc.9b05663>

A switch to decentralised energy access: Prosumer-driven integrated smart grid
<https://ieeexplore.ieee.org/document/9331883> and <https://ieeexplore.ieee.org/document/9331873>

New lead for 'Make In India' Technology, Manufacturing High-Voltage Devices
<https://ieeexplore.ieee.org/abstract/document/8856264>
<https://ieeexplore.ieee.org/document/9355405>; <https://ieeexplore.ieee.org/document/9420971>

Why is my electricity bill so high?
https://nipunbatra.github.io/papers/2020/edge_nilm.pdf

Vartalaap
<https://nipunbatra.github.io/papers/2021/vartalaap.pdf>

Neural Basis of Limb-Independent Motor Memory Acquisition
<https://www.pnas.org/content/117/29/17338>

Double-layered microbubbles for effective drug delivery
<https://pubs.acs.org/doi/abs/10.1021/acs.langmuir.0c01557>

Exploring effectiveness of 'curumin' as an anti-cancer compound
<https://www.sciencedirect.com/science/article/pii/S0378517320306517>

Enhanced molecular fluorescence by ordered gold nanostructures to benefit single-molecule imaging
<https://pubs.rsc.org/-/content/articlehtml/2020/na/d0na00303d>

How neurons uptake different nanosized DNA cages
<https://pubs.acs.org/doi/10.1021/acsabm.0c01668>
A 'Made in India' molecule that could be a potential cure for cancer
[https://www.cell.com/iscience/fulltext/S2589-0042\(20\)30666-0#secsectitle0020](https://www.cell.com/iscience/fulltext/S2589-0042(20)30666-0#secsectitle0020)

Forging ahead with mitochondria in cancer therapy
<https://pubs.acs.org/doi/abs/10.1021/acsami.6b00263>

Smart shoe insole, a gait-analysis device
<https://pubs.acs.org/doi/abs/10.1021/acsami.6b00263>

Virtual reality platform for people with autism
<https://ieeexplore.ieee.org/document/9205891>

Wearable robotic suit to facilitate normal walking in stroke patients
<https://ieeexplore.ieee.org/abstract/document/8956397>

TEAMS

Research and Development

Prof Amit Prashant
Dean

Prof Sharad Gupta
Associate Dean

Prof Sameer Dalvi
Chairman, Central Instrumentation Facility

Prof Naran Pindoriya & Prof Chinmay Ghoroi
Faculty Coordinator, Industry Connect

Prof Uttama Lahiri
Faculty Coordinator, External Fellowships and
Entrepreneurship

Prof Pratyush Dayal
Faculty Coordinator, Continuing Education
Programme

Prof Superb Mishra
Faculty Coordinator, Post-doc and Project Staff Welfare

Prof Dhiraj Bhatia
Faculty Coordinator, Grant Opportunity Information

Prof Sharada Channarayapatna
Faculty Coordinator, R&D Communications

Mr Nirmal Jha
Advisor (Industry Partnerships)

Mr Anand Pandey
Assistant Manager (Commercialization)

Mr K S Murthy
Head, Marketing & Development (Research Park)

Ms Meena Joshi
Assistant Registrar

Mr Harshad Patel
Account Officer

Ms Sudarshini Jain
Junior Accounts Office

Mr Jitendra P Pawar
Junior Accountant

Mr Hemant K Gupta
Junior Assistant

Mr Kumar Ankit Saha
Junior Accountant Assistant

Ms Shraddha Jain
Project Accountant

Ms Rajani Pandey
Project Associate

Mr Jignesh Kapadiya
Project Associate

Mr Abhishek Karli
Junior Project Accountant

Ms Tanumita Misra
Content Developer and Writer

Ms Manasasri Muralidharan
Content Developer and Writer

External Communications

Prof S P Mehrotra
Professor-in-Charge, External Relations

Dr Ravikumar Bhaskaran
Honorary Advisor, External Relations

Prof Neeldhara Misra
Associate Dean, External Communication
Team Leader, Communication

Prof Achal Mehra
External Communications, Identity and Marketing

Prof Mayank Singh
External Communication, Website

Prof Akshaa Vatwani
External Communication, Newsletter

Prof Jooyoung Kim
External Communication, Social Media

Mr Gaurav Shukla
Superintendent

Mr Tej Gurung
Assistant, Web Developer

Ms Shivangi Bhatt
Communication and Media Officer

Mr Devarsh Barbhaya
Communication Assistant

Ms Dhara Vora
Executive

Mr Hatim Sham
Executive

Giving to IIT Gandhinagar

IIT Gandhinagar relies on the sustained generosity of its friends for support of many of its exciting and innovation initiatives.

IITGN partners share our dream and vision of excellence. The Institute has developed a reputation for thinking outside traditional disciplinary boundaries, experimenting with various facets of education and research and fostering a culture of free inquiry, innovation and excellence. We invite you to join us in this journey of a young Institute and its pursuit of developing into a world-class university.



For more information on giving to IIT Gandhinagar, please see donate.iitgn.ac.in

Donations are 100% tax deductible in India.

Donations to the IIT Gandhinagar Foundation in the US are 100% tax deductible in the USA



RESEARCH AND DEVELOPMENT OFFICE

Indian Institute of Technology Gandhinagar
Palaj, Gandhinagar - 382 055, Gujarat