Research Newsletter of
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# KERNEL

## Editorial

Is India ready for the 5G revolution? Researchers at IISc and institutes across the country are developing and testing new technologies that could fundamentally transform the way we communicate with each other. Read more about their efforts in this issue of *Kernel.*

Also featured are a new treatment approach for a chronic joint condition, insights from studies tracking aerosols during eye surgeries, and a snapshot of research related to data storage technologies at IISc.

## RIDING THE 5G REVOLUTION


Image: Pixabay/ADMC

**RADICALLY IMMERSIVE VIRTUAL REALITY EXPERIENCES. SELF-DRIVING CARS STEERED OVER MOBILE NETWORKS. ROBOTS THAT SEAMLESSLY TALK TO EACH OTHER ON A FACTORY FLOOR. THIS IS THE WORLD THAT 5G, THE NEXT GENERATION OF WIRELESS TECHNOLOGY, PROMISES – A WORLD WHERE EVERYTHING AND EVERYONE IS CONNECTED.**

The 5G revolution is already here. Last year, South Korea and the US rolled out the first full-fledged 5G networks, and many other countries are starting to put in place guidelines to regulate their use. 5G devices, especially smartphones, are also beginning to flood the market.

To ensure that India does not fall too far behind, the Department of Telecommunications, Government of India, established a "5G test bed" in 2018 with a budget of about Rs 220 crore. Several institutions, including IISc, are part of this project.

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Transmission of 5G new radio signals at 28 GHz (Photo: Sudhakar Balijepalli)

Its goal is not just to develop and test new technologies within the country, but also train students and work closely with companies to plug in their solutions, says Chandra Murthy, Professor in the Department of Electrical Communication Engineering (ECE), who leads IISc's efforts.

After voice calls, SMS and data services, 5G represents the next leap forward in mobile communication. Besides faster downloads (an entire HD movie can be downloaded in just a few seconds), it offers an almost instantaneous response – to relay a brake command to a remotely-driven car, for instance – and better connectivity for applications like telesurgery.

Like 3G and 4G before it, a 5G network transmits data between users and base stations ("cell towers") using radio waves, which occupy the low frequency end of the electromagnetic spectrum. With 4G, users can still stream high quality videos, and make calls while moving fast. But the bandwidth or portion of the spectrum available is tightly controlled by governments, and split among an increasing number of service providers vying with each other to recruit more subscribers. This congestion can restrict data speeds.

5G networks, on the other hand, are expected to be over 100 times faster. One of the technologies driving this, which is being explored at IISc, is called massive MIMO (Multiple Input Multiple Output). It uses a larger array of antennas at both the base station and the device, opening up multiple paths for a signal to travel and allowing many different signals to flow simultaneously.

5G technology also seeks to exploit higher frequencies of the electromagnetic spectrum, large swathes of which are unused. While 4G networks typically use frequencies in the range of 700 MHz-2,500 MHz, 5G frequencies could potentially go up to 100 GHz.

Of particular interest are waves with frequencies above 24 GHz, called millimeter waves, which can support very high data speeds. "We are trying to build hardware that can work in these frequencies," says KJ Vinoy, Professor in ECE. He and his team have been able to use these waves to stream high quality gigabit-sized videos simultaneously on multiple devices in the same room. This could prove useful in a digital classroom or meeting room, or even a flight cabin. Because these waves dissipate fast in the atmosphere, they are currently best suited for indoor settings, says Vinoy.

Another area of research is using visible light instead of radio waves to transmit data. This could be useful in places like power plants or hospitals where wi-fi cannot be used due to electronic interference, but LED lights can. "The visible light spectrum comes with a larger bandwidth. It is also unlicensed so nobody is trying to slice it up and sell it," explains Varun Raghunathan, Assistant Professor in ECE.

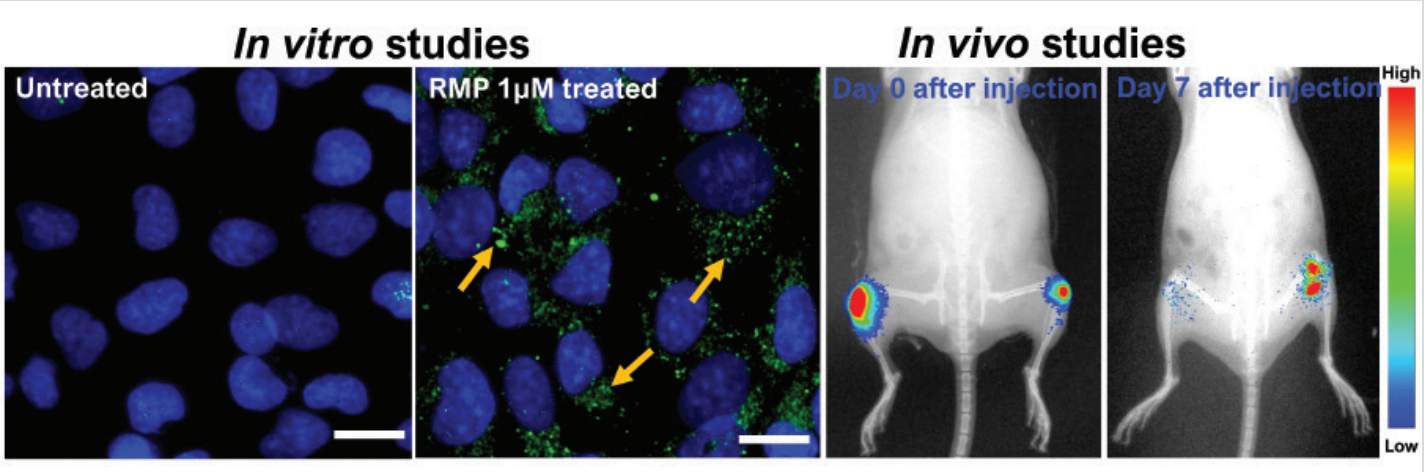
In the context of 5G, "li-fi" routers that transmit light could theoretically replace current wi-fi routers and link up with 5G mobile networks to expand coverage. "One of my students is looking at how to seamlessly hand over from a visible light communication setup to a 5G radio frequency link," says Raghunathan. His team is also exploring the use of lasers instead of LEDs – which could increase the data speeds – while at the same time ensuring that they are safe for the eyes in indoor settings.

Developing such technologies in India, however, isn't without challenges. Vinoy explains, "We don't have the ecosystem around us to even build printed circuit boards to the kind of accuracy and precision we will need."

Moving from 4G to 5G is also an expensive affair, says Murthy. Millions of new smartphones and devices which can work with 5G networks will need to be manufactured. Antennas and base stations will have to be completely overhauled. "It may take another 5 years for it to become available throughout the country," he adds.

*- Ranjini Raghunath*

Image: Kaamini M Dhanabalan




# A STEP CLOSER TO A MORE EFFECTIVE TREATMENT FOR OSTEOARTHRITIS

## A DRUG DELIVERY SYSTEM THAT ALLOWS SUSTAINED RELEASE OF DRUGS COULD HELP MANAGE INFLAMMATION ASSOCIATED WITH OSTEOARTHRITIS MORE EFFECTIVELY

Researchers at IISc have developed a microparticle formulation that allows sustained release of drugs to treat osteoarthritis, a chronic joint condition.

They have designed a polymer matrix made of poly (lactic-co-glycolic acid) or PLGA, an FDA-approved biomaterial, to encapsulate rapamycin, an immunosuppressant drug. Preliminary studies on cells cultured in the laboratory as well as in mice models have shown promising results indicating reduced inflammation and cartilage repair due to sustained drug release.

"In cell studies, rapamycin-loaded PLGA microparticles could release the drug for up to 21 days, and in animal studies, PLGA microparticles showed residence time up to 30 days after injecting the microparticles in the mice knee joint," says Kaamini M Dhanabalan, PhD student at the Centre for BioSystems Science and Engineering (BSSE), IISc, and first author of the study published in the journal *Biomaterials Science.*

Osteoarthritis is associated with the wear and tear of the cartilage – the smooth tissue that protects bone joints – caused due to stress or aging. Existing treatment revolves more around managing pain and inflammation than treating the disease. Although several classes of drugs seemed promising in preclinical trials, low drug retention and rapid clearance from the target site have made clinical translation difficult.

The formulation developed by the IISc team, however, has a residence time of upto 30 days at the target site, with no evident signs that it may cause discomfort to patients. Such a sustained release system can improve patient compliance and reduce hospital visits.

PLGA is widely used for drug delivery applications and several drug formulations are currently used in clinics. Rapamycin is commonly used to suppress immune response in patients undergoing surgery for organ transplant to prevent organ rejection. Preclinical studies have shown its potential for treating osteoarthritis by preventing cell loss and cartilage damage, thereby reducing inflammation. However, the short drug retention time of about 1-4 hours demands frequent injections to maintain the therapeutic window in the joints.

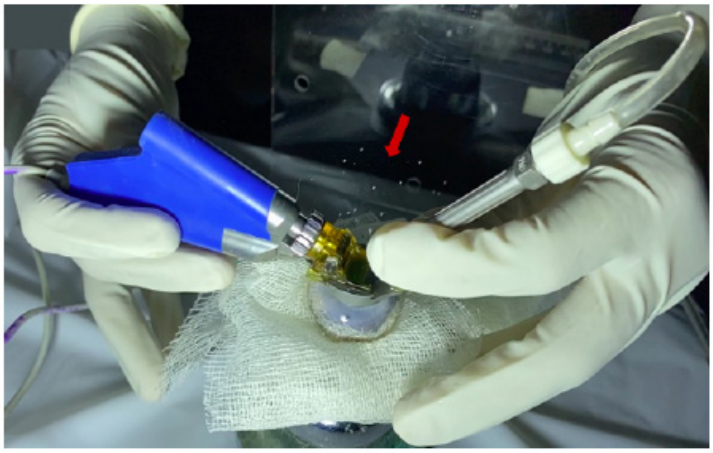
Therefore, Dhanabalan and her colleagues combined the advantages of PLGA and rapamycin to create a system that would allow sustained release of the drug. This was achieved by encapsulating rapamycin in PLGA microparticles.

To evaluate the effectiveness of this formulation, chondrocytes or cartilage cells were cultured and subjected to various stresses to recreate osteoarthritis-like conditions under laboratory settings. This resulted in ailing chondrocytes with the hallmarks of osteoarthritis. These damaged chondrocytes recovered from osteoarthritis when treated with rapamycin-loaded PLGA microparticles.

"Preliminary studies using this newly-designed formulation can potentially reduce the frequent medical intervention to once a month. Detailed studies are in progress to explore the functional potential in mouse models of osteoarthritis," says Rachit Agarwal, Assistant Professor at BSSE, and senior author of the study.

*- Edna George*

Photo: Narayana Nethralaya Foundation



# TRACKING AEROSOLS DURING EYE SURGERIES

**ARE THE AEROSOLS GENERATED DURING ROUTINE EYE PROCEDURES POSING A RISK TO HEALTHCARE WORKERS? DOCTORS AT NARAYANA NETHRALAYA WORKED WITH IISc RESEARCHERS TO INVESTIGATE**

There is growing evidence that the novel coronavirus, SARS-CoV-2, could spread through aerosols – tiny droplets that can remain suspended in the air for hours in closed spaces. Aerosols can be generated during surgeries and out-patient procedures, lingering in the work environment of healthcare workers.

To investigate how aerosols are generated during routine eye procedures, doctors at Narayana Nethralaya, an eye hospital in Bengaluru, collaborated with researchers at IISc. They used high-speed imaging and aerodynamic models to visualise the generation of droplets during procedures such as cataract and LASIK surgeries.

"We identified the size of the droplets, and also calculated the speed and distance to which they travel," says Saptarshi Basu, Professor at the Department of Mechanical Engineering, and co-author of two papers published in the *Journal of Cataract and Refractive Surgery.* The studies showed that during most procedures, aerosols are not generated, he adds.

The first study focused on phacoemulsification, a type of cataract surgery in which an ultrasonic needle is used to break up the cataract. The fluids are then suctioned out and the eye is rehydrated with a balanced salt solution. The needle and a sleeve carrying the salt solution are usually combined into a single disposable probe. In the study – conducted during surgeries on humans and animal eyes in a closed chamber – the researchers employed a technique called shadowgraphy, which uses a light source such as pulsed laser or LED to cast shadows of fast-moving droplets onto the sensor of a high speed camera.

As long as the probe was restricted to the inner layer of the eye called anterior chamber – a protocol normally followed – no aerosols were generated. Aerosols were formed only when the probe was exposed to the salt solution on the eye's outer surface called cornea. Therefore, replacing the salt solution with more gelatinous or viscous materials can prevent fluid spurting and aerosol generation, the researchers say.

The second study investigated LASIK surgery, performed to correct near- or far-sightedness. It uses an oscillating blade to cut and lift a thin flap from the cornea's top layer to reshape the inner layer called stroma. As the blade cut through to the stroma, some droplets were generated, likely due to the balanced salt solution used as a lubricant prior to the procedure. However, most of them were large in size (>90 micrometers) and therefore likely to settle down fast, reducing the risk that they will become aerosolised. Because the droplets were found to travel up to 1.8 m in a simulated surgery setting, adequate precautions should be adopted by doctors, the researchers suggest.

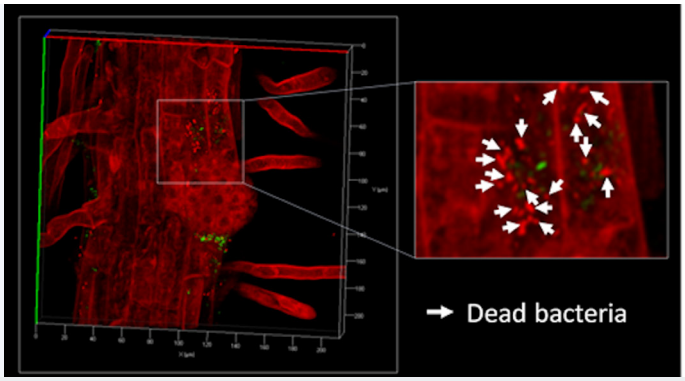
Based on these findings, the hospital has identified and implemented specific safety protocols, says corresponding author Abhijit Sinha Roy, Chief Scientist at Narayana Nethralaya Foundation. It has also put together videos to educate patients, medical staff and the general public, to make them feel more comfortable about resuming routine procedures.

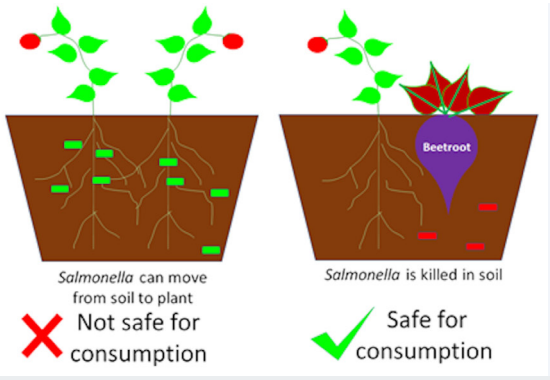
"Because of COVID-19, a lot of other surgical procedures are getting delayed. Our concern is that patients should not end up compromising their vision just because they delayed getting the appropriate healthcare they needed. They should feel at ease after seeing these robust studies and safety measures implemented in our eye clinics," he says.

Similar studies are also planned for orthopaedic and heart surgeries, says Basu.

*- Ranjini Raghunath*

Image: Kapudeep Karmakar




# BEETROOT AS BIOCONTROL IN MIXED-CROPPING SYSTEMS

Untreated sewage water and animal-based manure are a common cause of contamination in agricultural fields. Through this route, food-borne pathogens like *Salmonella* bacteria may cause infections in humans.

To address this problem, researchers from IISc and the University of Agricultural Sciences, Bengaluru, have developed a strategy to use beetroot as a cultivation partner with other vegetables to arrest the growth of *Salmonella* in them.

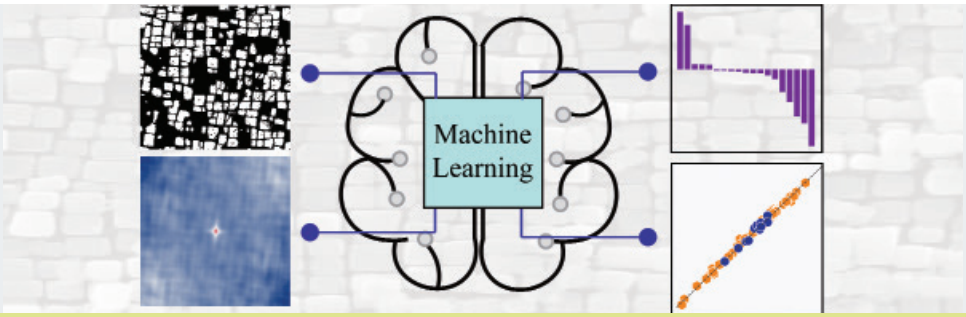
The team, led by Dipshikha Chakravortty in the Department of Microbiology and Cell Biology, found that some compounds released by beetroot plants had antimicrobial properties that reduce the growth of pathogens in food crops.

The researchers tested this using different approaches: treating roots with *Salmonella* and testing the effects of beetroot extract on them, cultivating beetroot in *Salmonella*-treated soil, and growing tomatoes and beetroot together in *Salmonella*-treated soil.

The compound secreted by the beetroot plants is water soluble and can spread across the field through irrigation, without any extra effort. Co-cultivating beetroot is also cost-effective and therefore of immediate importance to small-scale farmers.

*- Priti Bangal*

Image: Nikhil Khatavkar et al.



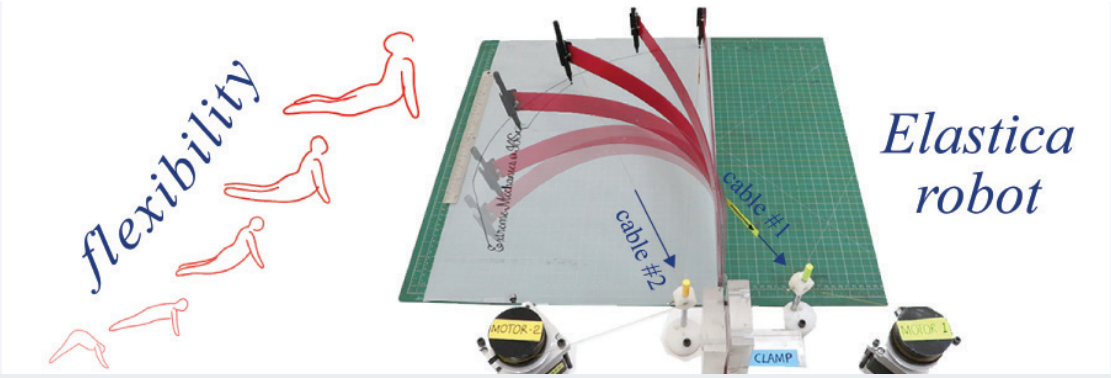

# MACHINE LEARNING FOR PREDICTING MATERIAL HARDNESS

Machine learning (ML) has accelerated the development of novel materials for various applications. In a new study, IISc researchers led by Abhishek Singh at the Materials Research Centre have developed highly accurate ML models to predict the Vickers hardness – an important material property – of nickel and cobalt-based superalloys. Superalloys are used widely in aerospace, marine, chemical and petrochemical industries.

To develop the ML model, a database was initially generated comprising the microstructures, compositions and Vickers hardness of several cobalt and nickel-based superalloys. Scanning electron microscopy images were processed to obtain binary microstructures, which were then used to calculate statistically derived parameters called 2-point correlations. Principal component analysis (PCA) was performed on these correlations to select the most dominant ones. These PCA-derived correlations along with composition of the superalloys were used as descriptors for building the ML models.

The approach developed in this study can be applied for any material property.

Image: Darshan Bhandari and Poornakanta Handral




# MAKING ROBOTS FLEXIBLE

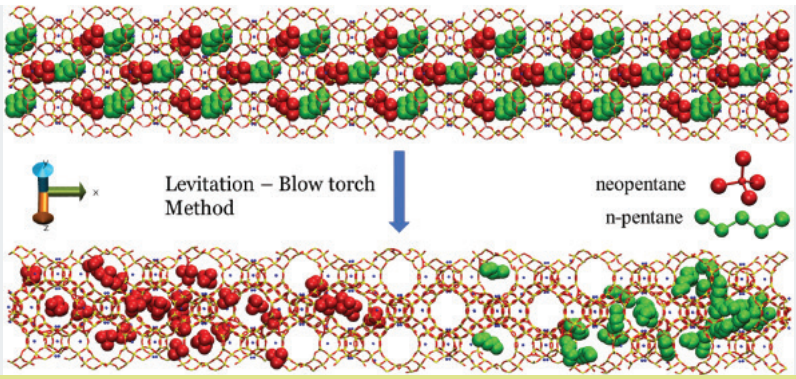
As applications of robotics continue to diversify, flexibility has emerged as one of the most desirable characteristics. Recent research in the lab of Ramsharan Rangarajan in the Department of Mechanical Engineering examines how to incorporate this literally: by building a flexible, bendy robot.

Using nonlinear mechanics and optimisation-based algorithms, they have developed a flexible, tendon-actuated arm that functions as a dextrous robot.

The "Elastica Robot" – named after the mechanical theory attributed to Euler – not only embraces flexibility but also relies on it as for functioning.

The researchers believe that such a flexible, remotely-operated and energy-efficient robot can have diverse applications. The fact that its functioning is independent of the length scale or the material means that it can, in principle, be miniaturised to design medical devices or enlarged for deployment in space-related applications.

Image: Shubhadeep Nag




# GREEN SEPARATION METHOD FOR HIGH PURITY COMPONENTS

A novel method to separate molecular mixtures to very high purity has been developed by IISc researchers led by S Yashonath in the Solid State and Structural Chemistry Unit.

Existing methods separate the components of a mixture by driving them to move at different speeds along the same direction in a column of porous solid such as zeolite. They usually lead to an impurity of 1 molecule in 100. The new method causes the molecules to move to opposite ends of the column, resulting in better than 1 in $10^{10}$ separation.

The method judiciously combines two well-studied phenomena: levitation effect and blow torch effect. The researchers used it to separate a mixture of a linear hydrocarbon called n-pentane and its branched isomer, neopentane, to very high purity. Such separations are routinely carried out in petroleum refineries, but consume large amounts of energy. This new method is more energy-efficient by several orders of magnitude. It will also be useful in green chemistry where high purity reactants are required.

# RESEARCH ON DATA STORAGE

## TECHNOLOGIES ON THE HORIZON

**Synthetic DNA**

Harnessing the power of genetic material to store data

**Memristors**

Stable, programmable devices for memory storage

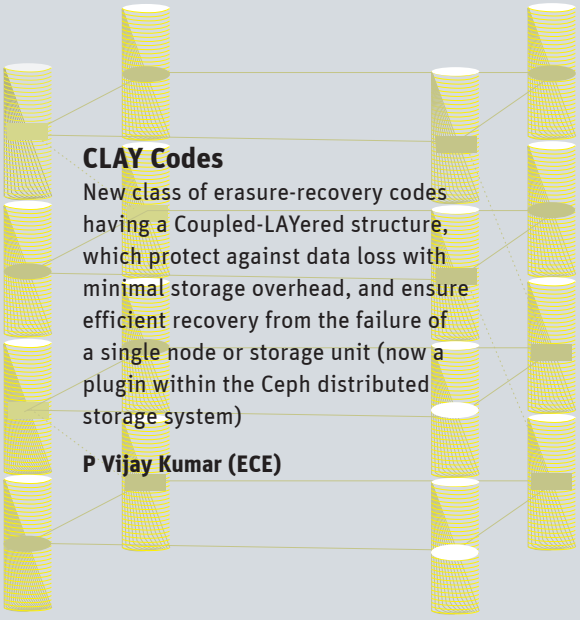
**Phase change memory**

Storing data by switching material states

**'Superman' memory crystals**

Nanostructured glasses for permanently storing 5D digital data

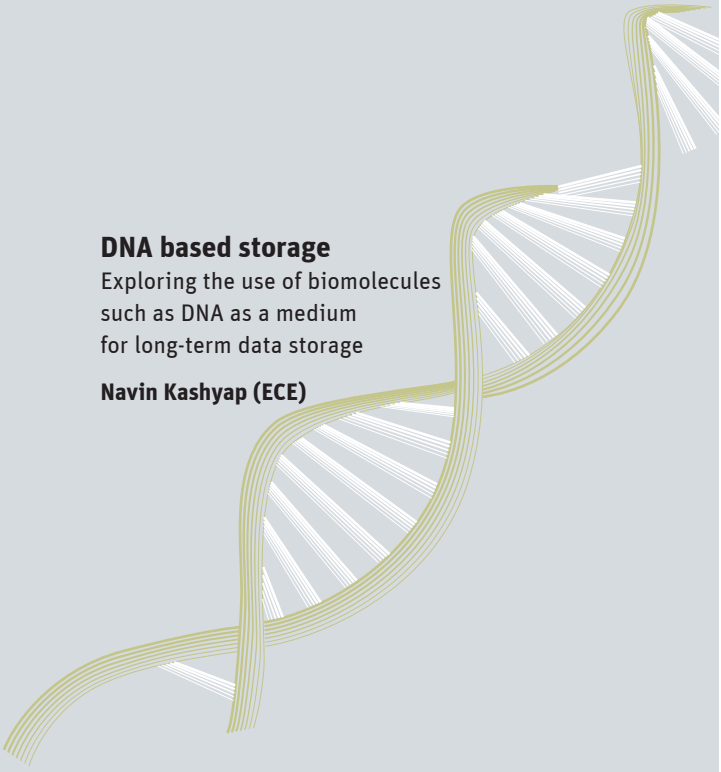
## RESEARCH AT IISc



**CLAY Codes**

New class of erasure-recovery codes having a Coupled-LAYered structure, which protect against data loss with minimal storage overhead, and ensure efficient recovery from the failure of a single node or storage unit (now a plugin within the Ceph distributed storage system)

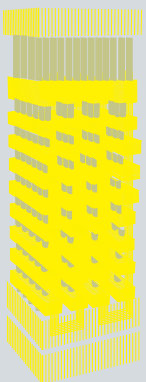
**P Vijay Kumar (ECE)**



**DNA based storage**

Exploring the use of biomolecules such as DNA as a medium for long-term data storage

**Navin Kashyap (ECE)**



**2D magnetic storage and NAND flash**

Innovative coding techniques, signal processing algorithms and efficient architectures towards reliably storing and retrieving data from physical media

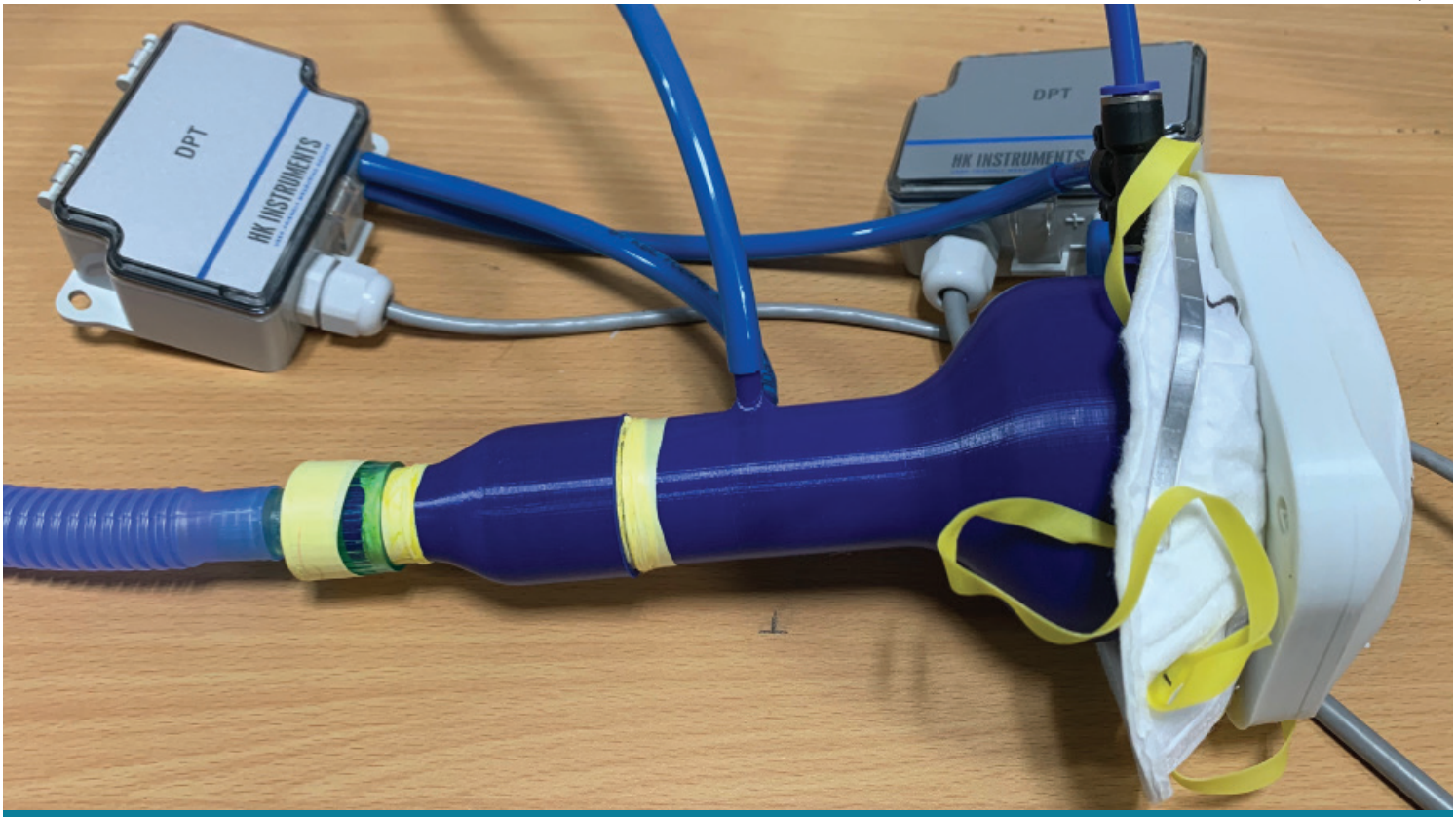
**Shayan Srinivasa Garani (DESE)**

**Storage systems design and realisation**

Layered, hierarchical and networked/distributed storage from feasibility, correctness and performance perspectives. Recent work on proposed melded pages for dense SSDs.

**K Gopinath (CSA)**

Photo: Akshay Naik




# TESTING MASKS FOR EFFICIENCY

To address the acute shortage of N95 masks due to COVID-19, our team at the Centre for Nano Science and Engineering (CeNSE), in collaboration with Manipal Hospital and KAS Technologies, decided to set up a system to test whether it is safe for healthcare workers to reuse their N95 masks after decontamination. This setup is now being used to test the efficiency of all kinds of masks.

Masks are tested on various parameters, but we focused mainly on two aspects: particle filtration efficiency and breathing resistance. Particle filtration tests indicate how effectively the masks filter out particles of various sizes. N95 masks, for instance, are expected to filter out 95% of particles of sizes 0.3 micron and above.

Breathing resistance, on the other hand, provides a measure of how easy it is to breathe through the masks. There are various standards that specify the acceptable breathing resistance of masks at different flow rates.

When we started in April, the nationwide lockdown made it extremely difficult to source equipment or parts. Using components and sensors that were readily available in CeNSE, we were able to set up a system to carry out the particle filtration test and the breathing resistance tests at different flow rates. We used a household vacuum cleaner, pressure sensors fabricated and packaged at CeNSE as well as some commercial ones, and a commercial particle counter readily available in the National Nano Fabrication facility. The rest of the components, including flow restrictors and components to fix the masks onto the setup, were 3D printed.

With this system, we have been able to help multiple faculty members from IISc who are keen on making materials for N95 masks, doctors with ideas to develop powered air-purifying respirators, and vendors who wanted to test imported N95 masks. Some indigenous N95 mask manufactures also got their masks tested with our system before sending it out for certification.

*- Akshay Naik*

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