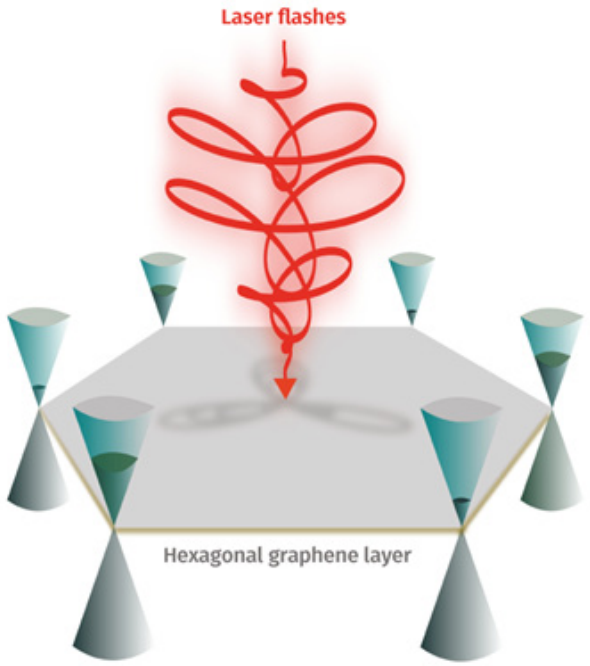
Can Graphene Valleytrionics Pave the Way to Household Quantum Computers?



Visualization of valley polarization
Short flashes of laser (shown in red) shine on a single layer of hexagonal graphene (shown by the hexagonal plane in grey). Due to the light-matter interaction, graphene exhibits different electronic populations at the alternate corners of the hexagon (indicated by the filled cones at the corners). These different populations, known as valley polarization, can be treated as 0 and 1: the basis of a qubit.
(Image credit: Dr Gopal Dixit from IIT Bombay)

QUANTUM computers that often make the news — such as those at Google, IBM, or Microsoft — are large, complex, and expensive, and can only operate at ultra-low temperatures of nearly –200°C. This makes them very impractical for use on a large scale. Now, researchers from the Indian Institute of Technology (IIT) Bombay have found a way to use pristine graphene for encoding, processing, and storing quantum information, opening doors to much simpler, small-sized quantum computers that can operate at room temperature.

Quantum computers have recently become a hot-button topic because of their theoretical potential to outperform conventional computers by several orders of magnitude in terms of speed. Quantum Computing will enable the faster execution of molecular simulations, big data analysis, deep learning, and other computationally intensive tasks, in turn, accelerating molecular research and the development of new drugs, helping in the search for cures to complex diseases, including COVID-19, not to mention the ways in which it can create uncrackable cybersecurity measures and revolutionise artificial intelligence.

A quantum computer can achieve these feats because it encodes information in quantum bits rather than the binary "0" or "1" that regular electronics use. Quantum bits are superpositions of "0" and "1", and can therefore take intermediate values, making computations much faster. Sadly, such quantum computation is not yet possible at room temperature; and existing computers, such as those owned by Google, IBM, and Microsoft, have to be kept at ultra-low temperatures below –196.1°C, which makes them costly and impractical to operate.

Fortunately, a very promising novel approach for encoding quantum information is actively being explored to overcome these challenges: *valleytronics*.

Aside from their charge, electrons have another parameter that can be manipulated: their "valley pseudospin," which are the local minima in the energy bands of solids that can be occupied by electrons. By manipulating how many electrons occupies each of the valleys, quantum information can be encoded, processed, and stored at less restrictive temperatures.

A team of scientists from the Indian Institute of Technology (IIT) Bombay, and Max-Born Institut, Germany, have achieved a breakthrough in valleytronics that opens up the road to taking quantum computers all the way to room temperature operation. Their findings, published in *Optica*, describe a way to perform valley operations in single-layer (one atom thick) or pristine graphene (carbon atoms arranged in a hexagonal sheet structure), which was hitherto assumed to be impossible — atomically thin layers of graphene have electron valleys but, due to the material's inherent symmetry, they were deemed useless for valley operations.

The team, led by Associate Professor Gopal Dixit from IIT Bombay, came up with a strategy to break graphene's valley symmetry using light. Dr Dixit explains: "By tailoring the polarization of two beams of light according to graphene's triangular lattice, we found it possible to break the symmetry between two neighbouring carbon atoms and exploit the electronic band structure in the regions close to the valleys, inducing valley polarization."

In other words, this enables the use of graphene's valleys to effectively "write" information.

Reference

M.S. Mrudul, Álvaro Jiménez-Galán, Misha Ivanov, and Gopal Dixit, "Light-induced valleytronics in pristine graphene," *Optica* 8, 422-427 (2021).
DOI: https://doi.org/10.1364/OPTICA.418152

Source: Press Release, IIT Bombay

AI may Spot Unseen Signs of Heart Failure

MOUNT Sinai researchers have created a special artificial intelligence (AI) based computer algorithm that was able to learn how to identify subtle changes in electrocardiograms (also known as ECGs) to predict whether a patient was experiencing heart failure. Ordinarily, diagnosing these types of heart conditions requires expensive and time-consuming procedures. The researchers hope that this algorithm will enable quicker diagnosis of heart failure.

The researchers, led by Benjamin S. Glicksberg, Assistant Professor of Genetics and Genomic Sciences, a member of the Hasso Plattner Institute for Digital Health at Mount Sinai, said that deep-learning algorithms can recognize blood pumping problems on both sides of the heart from ECG data.

The study, published online in *Journal of the American College of Cardiology: Cardiovascular Imaging* on 13 October 2021, was led by Akhil Vaid, a postdoctoral scholar who works in both the Glicksberg lab and one led by Girish N. Nadkarni, Associate Professor of Medicine at the Icahn School of Medicine at Mount Sinai.

Heart failure, or congestive heart failure, occurs when the heart pumps less blood than the body normally needs. For years doctors have relied heavily on an imaging technique called an echocardiogram to assess whether a patient may be experiencing heart failure. While helpful, echocardiograms can be labour-intensive procedures that are only offered at select hospitals.

However, recent breakthroughs in artificial intelligence suggest that electrocardiograms – widely used electrical recording devices – could be a fast and readily available alternative for diagnosis in these cases. For instance, many studies have shown how a "deep-learning" algorithm can detect weakness in the heart's left ventricle that pushes freshly oxygenated blood out to the rest of the body. The researchers have described the development of an algorithm that not only assessed the strength of the left ventricle but also the right ventricle, which takes deoxygenated blood streaming in from the body and pumps it to the lungs.

"Although appealing, traditionally it has been challenging for physicians to use ECGs to diagnose heart failure. This is partly because there have been no established diagnostic criteria for these assessments and because some changes in ECG readouts are simply too subtle for the human eye to detect," says Dr Nadkarni. "This study represents an exciting step forward in finding information hidden within the ECG data which can lead to better screening and treatment paradigms using a relatively simple and widely available test."

Typically, an electrocardiogram involves a two-step process. Wire leads are taped to different parts of a patient's chest and a specially designed portable machine is used to print out a series of waveforms, representing the heart's electrical activity. These machines require minimal training to operate.

For this study, the researchers programmed a computer to read patient electrocardiograms along with data extracted from written reports summarizing the results of corresponding echocardiograms taken from the same patients. Here, the written reports acted as a standard set of data for the computer to compare with the electrocardiogram data and learn how to spot weaker hearts.

Language processing programs helped the computer extract data from the written reports. Meanwhile, special neural networks capable of discovering patterns in images were incorporated to help the algorithm learn to recognize pumping strengths.

Dr Vaid says, "We wanted to push the state of the art by developing AI capable of understanding the entire heart easily and inexpensively".

The computer was then used to read more than 700,000 electrocardiograms and echocardiogram reports obtained from 150,000 Mount Sinai Health System patients from 2003 to 2020. Data from four hospitals was used to train the computer, whereas data from a fifth one was used to test how the algorithm would perform in a different experimental setting.

Dr Nadkarni says, "A potential advantage of this study is that it involved one of the largest collections of ECGs from one of the most diverse patient populations in the world".

Initial results suggested that the algorithm was effective at predicting which patients would have either healthy or very weak left ventricles. Here strength was defined by left ventricle ejection fraction – an estimate of how much fluid the ventricle pumps out with each beat as observed on echocardiograms. Healthy hearts have an ejection fraction of 50 percent or greater while weak hearts have ones that are equal to or below 40 percent.

The researchers say the algorithm was 94 percent accurate at predicting which patients had a healthy ejection fraction and 87 percent accurate at predicting those who had an ejection fraction that was below 40 percent.

Further results suggested that the algorithm also learned to detect right valve weaknesses from the electrocardiograms. In this case, weakness was defined by more descriptive terms extracted from the echocardiogram reports. Here the algorithm was 84 percent accurate at predicting which patients had weak right valves.

"Our results suggested that this algorithm may eventually help doctors correctly diagnose failure on either side of the heart," Dr Vaid said.

Finally, additional analysis suggested that the algorithm may be effective at detecting heart weakness in all patients, regardless of race and gender.

The researchers are in the process of carefully designing prospective trials to test out its effectiveness in a more real-world setting.

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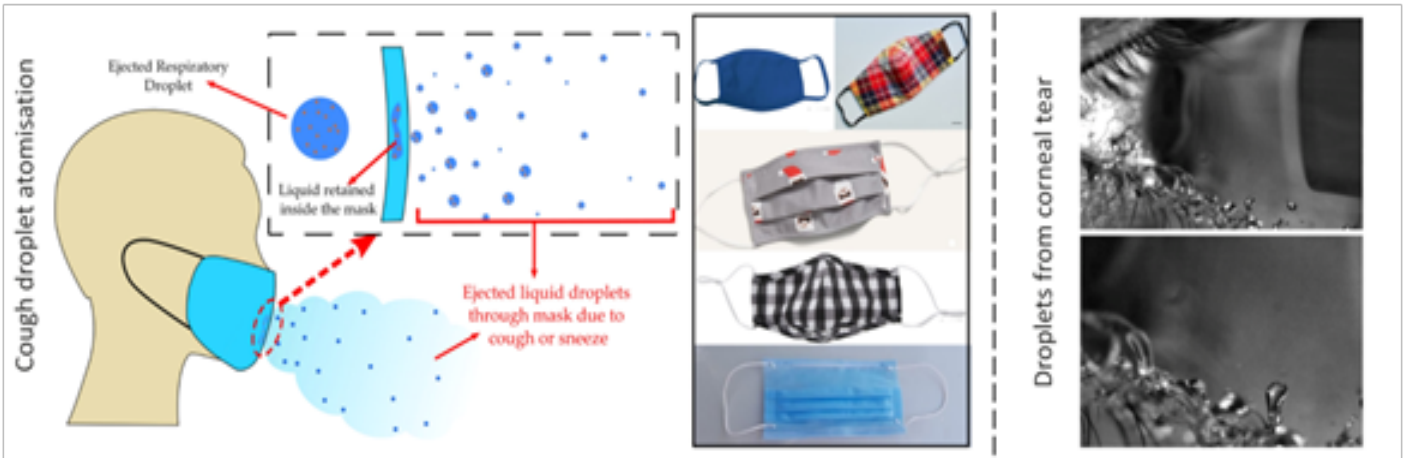
Fluid Dynamics Studies on Homemade Facemasks and Non-invasive Eye Procedures



(a) Cough droplet atomisation and various homemade facemasks (b) Droplet generation from corneal tear film during the non-contact tonometry process

SINCE the start of the COVID-19 pandemic, the use of homemade facemasks has been advised as a possible substitute for commercially available surgical or N95 masks.

Researchers at IISc (Indian Institute of Science) have carried out a detailed study on the fate of a large-sized surrogate cough droplet impinging at different velocities (corresponding to mild to severe coughs) on various locally procured cloth fabrics (stole, handkerchief, cotton towel, and surgical masks), specifically those which are convenient for people to use every day. A single quantity has been formed by combining the individual effects of pore size and porosity, giving a better insight into the correlation between liquid penetration and fabric properties.

Based on their findings, the researchers recommend using a cotton towel (with at least three layers) as a face covering if the person cannot use an N95 or a surgical mask. Masks with three or more layers are ideally recommended since they can suppress aerosolisation significantly. The team also analysed the effect of washing on mask effectiveness, and results show a negligible influence of washing on mask efficacy up to 70 wash cycles. This study was carried out by Bal Krishan, Dipendra Gupta, Gautham Vadlamudi and Shubham Sharma under the guidance of Prof Saptarshi Basu (Department of Mechanical Engineering) and Prof. Dipshikha Chakravortty (Department of Microbiology and Cell Biology).

In another study, Prof. Saptarshi Basu's group (Durbar Roy, Sophia M, Abdur Rasheed, Prasenjit Kabi) collaborated with Narayana Nethralaya Foundation (Dr Abhijit Sinha Roy and Dr Rohit Shetty). They provide a complete fluid dynamics interpretation of the unexplained droplet generation mechanism from corneal tear film during an eye procedure called non-contact tonometry (which involves an air puff) used routinely for glaucoma detection.

Droplets generated from the rupture of the tear film in the human eye may carry viruses like SARS-CoV-2, which can subsequently spread unnoticed through aerosols and fomites. The researchers also describe the size scales (0.1-3 mm) and velocity ranges (0.1-5 m/s) of droplets ejected during such procedures, which may help ophthalmologists and medical practitioners conduct these procedures more safely following proper protocols.

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D. Roy, M. Sophia, A. Rasheed, P. Kabi, A.S. Roy, R. Shetty, S. Basu, Fluid dynamics of droplet generation from corneal tear film during non-contact tonometry in the context of pathogen transmission, (2020). *Phys. Fluids*. (2021) 092109. https://doi.org/10.1063/5.0061007.

***Lab website*:** https://www.saptarshibasulab.com/

Source: IISc Press Release

Electronic Media Use Associated with Shorter Sleep in Children

Image credit: Wikimedia commons

USING phones, tablets and other electronic media has been associated with shorter sleep in children and adolescents, in a systematic review published in *BMC Public Health*.

Sleep has a major impact on the health and wellbeing of children and adolescents, and insufficient sleep has been linked to negative physical and psychological implications. A team of researchers at the University of Southern Denmark reviewed 49 studies published between 2009 and 2019, with the studies involving between 55 and 369,595 children. They assessed the potential association of electronic media use, including media type and duration, with sleep patterns. The authors considered bedtime and sleep onset, sleep quality (waking up at night), sleep duration and daytime tiredness.

They found that electronic media use was associated with shorter sleep duration and that the association was stronger in those aged between 6 to 15 years than in children aged five and under. In children aged five and under, media use and shorter sleep were associated mainly with television and tablet use, while in those aged 6 to 15 years, this association was present with a wide range of different electronic media such as video gaming, computer, mobile phone or smartphone, and internet use as well as television among those aged 6 to 12 years.

The authors also found evidence of an association between electronic media use in children aged 6 to 12 years and delayed bedtime and poor sleep quality. In adolescents aged 13 to 15 screen time was associated with problems falling asleep, and social media use with poor sleep quality.

The authors suggest that the interactive media predominantly used by adolescents may be overly stimulating, which may explain why there is more evidence for shorter sleep in this age group. In all age groups, exposure to blue light from screens may suppress the production of melatonin – the hormone that regulates sleep – thus leading to poorer sleep duration and disturbing the natural sleep-wake cycle.

Lisbeth Lund, the lead author, said, "It is important that children and adolescents get sufficient sleep to avoid negative health consequences. We also understand that media is an important part of our lives. Our findings suggest that parents may wish to regulate how much their children are engaging with electronic media to potentially improve sleep."

The 49 studies reviewed included participants from North America, Europe, Australia, New Zealand, and other Western countries. The authors highlight that the sample is specific to these countries and may not be generalisable to other countries with different attitudes towards electronic media use and parenting styles. The authors also acknowledge that most of the included studies were observational and therefore did not allow for conclusions about cause and effect or the direction between the association of media use and sleep quality.

Reference

Electronic media use and sleep in children and adolescents in western countries: a systematic review, *BMC Public Health 2021*,DOI: 10.1186/s12889-021-11640-9

BMC, Scientific Press Release