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Scientists developed super-sensitive magnetic sensor

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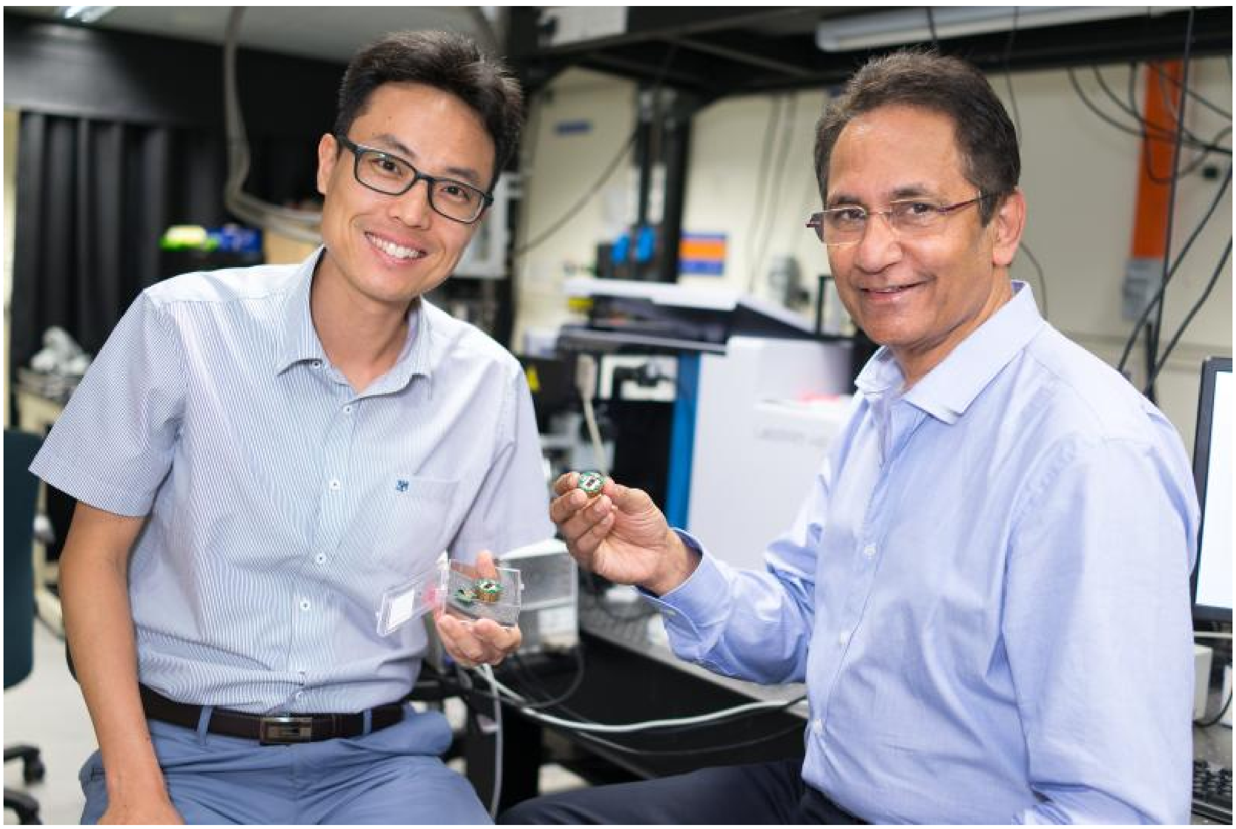

Credit: National University of Singapore

Researchers from the National University of Singapore (NUS) have developed a new hybrid magnetic sensor that is more sensitive than most commercially available sensors. This technological breakthrough hails opportunities for the development of smaller and cheaper sensors for various fields such as consumer electronics, information and communication technology, biotechnology and automotive.

The invention, led by Associate Professor Yang Hyunsoo of the Department of Electrical and Computer Engineering at NUS' Faculty of Engineering, was published in the journal *Nature Communications* in September 2015.

High performance magnetic sensors in demand

When an external magnetic field is applied to certain materials, a change in electrical resistance, also known as magnetoresistance, occurs as the electrons are deflected. The discovery of magnetoresistance paved the way for magnetic field sensors used in hard disk drives and other devices, revolutionising how data is stored and read.

In the search for an ideal magnetoresistance sensor, researchers have prized the properties of high sensitivity to low and high magnetic fields, tunability, and very small resistance variations due to temperature.

The new hybrid sensor developed by the team led by Assoc Prof Yang, who is also with the NUS Nanoscience and Nanotechnology Institute (NUSNNI) and the Centre for Advanced 2D Materials (CA2DM) at NUS Faculty of Science, may finally meet these requirements. Other members of the interdisciplinary research team include Dr Kalon Gopinadhan of NUSNNI and CA2DM; Professor Thirumalai Venkatesan, Director of NUSNNI; Professor Andre K. Geim of the University of Manchester; and Professor Antonio H. Castro Neto of the NUS Department of Physics and Director of CA2DM.

More than 200 times more sensitive than

commercially available sensors

The new sensor, made of graphene and boron nitride, comprises a few layers of carrier-moving channels, each of which can be controlled by the magnetic field. The researchers characterised the new sensor by testing it at various temperatures, angles of magnetic field, and with a different pairing material.

Dr Kalon said, "We started by trying to understand how graphene responds under the magnetic field. We found that a bilayer structure of graphene and boron nitride displays an extremely large response with magnetic fields. This combination can be utilised for magnetic field sensing applications."

Compared to other existing sensors, which are commonly made of silicon and indium antimonide, the group's hybrid sensor displayed much higher sensitivity to magnetic fields. In particular, when measured at 127 degree Celsius (the maximum temperature which most electronics products are operated at), the researchers observed a gain in sensitivity of more than eight-fold over previously reported laboratory results and more than 200 times that of most commercially available sensors.

Another breakthrough in this research was the discovery that mobility of the graphene multilayers can be partially adjusted by tuning the voltage across the sensor, enabling the sensor's characteristics to be optimised. This control gives the material an advantage over commercially available sensors. In addition, the sensor showed very little temperature dependence over room temperature to 127 degree Celsius range, making it an ideal sensor suitable for environments of higher temperature.

Meeting industry demand

The magnetoresistance sensor industry, estimated to be worth US$1.8 billion in 2014, is expected to grow to US$2.9 billion by the year 2020. Graphene-based magnetoresistance sensors hold immense promise over existing sensors due to their stable performance over temperature variation, eliminating the necessity for expensive wafers or temperature correction circuitry. Production cost for graphene is also much lower than silicon and indium antimonide.

Potential applications for the new sensor include the automotive industry, where sensors in cars, located in devices like flow meters, position sensors and interlocks, are currently made of silicon or indium antimonide. For instance, when there is a change in temperature due to the car's air-conditioner or heat from the sun, properties of the conventional sensors in the car change as well. To counter this, a temperature correction mechanism is required, incurring additional production cost. However, with the team's new hybrid sensor, the need for expensive wafers to manufacture the sensors, and additional temperature correction circuitries can be eliminated.

"Our sensor is perfectly poised to pose a serious challenge in the magnetoresistance market by filling the performance gaps of existing sensors, and finding applications as thermal switches, hard drives and magnetic field sensors. Our technology can even be applied to flexible applications," added Assoc Prof Yang.

The research team has filed a patent for the invention. Following this proof-of-concept study, the researchers plan to scale up their studies and manufacture industry-size wafers for industrial use.

More information: Kalon Gopinadhan et al. Extremely large magnetoresistance in few-layer graphene/boron–nitride heterostructures, *Nature Communications* (2015). DOI: 10.1038/ncomms9337

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