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Diamonds not behaving like diamonds

With a tweak they can do more than just insulate.

Scientists may have found a way to make diamonds more like metal. That probably won't excite jewellers, but it could open up applications in everything from solar cells and LEDs to optical devices or quantum sensors.

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In a nutshell, they say they have discovered a way to tweak tiny needles of diamond in a controlled way to transform their electronic properties, dialling them from insulating, through semiconducting, all the way to highly conductive, or metallic.

This can be induced dynamically and reversed at will, with no degradation of the diamond material.

The concept has long been theorised, but it took a combination of quantum mechanical calculations, analyses of mechanical deformation, and machine learning just to get to the early proof-of-concept stage.

“The ability to engineer and design electrical conductivity in diamond without changing its chemical composition and stability offers unprecedented flexibility to custom-design its functions,” says Subra Suresh, from Nanyang Technological University in Singapore.

“The methods demonstrated in this work could be applied to a broad range of other semiconductor materials of technological interest in mechanical, microelectronics, biomedical, energy and photonics applications, through strain engineering.”

The research by Suresh, Ju Li from Massachusetts Institute of Technology (MIT) in the US, and other researchers from MIT and the Skolkovo Institute of Science and Technology in Moscow is described in a paper in *Proceedings of the National Academy of Sciences*.

Li and colleagues say they have spent years developing the concept of elastic strain engineering, which is based on the ability to cause significant changes in the properties of materials by deforming them. You put them under enough strain to alter the geometric arrangement of atoms in the material’s crystal lattice, but without disrupting that lattice.

Key to this work is a property known as bandgap, which essentially determines how readily electrons can move through a material. Diamond normally has a wide bandgap of 5.6 electron volts, meaning it is a strong insulator that electrons do not move through readily.

In their latest simulations, the researchers say, they showed that diamond’s bandgap can be gradually, continuously and reversibly changed, providing a range of electrical properties, from insulator through semiconductor to metal.

“We found that it’s possible to reduce the bandgap from 5.6 electron volts all the way to zero,” Li says. “The point of this is that if you can change continuously from 5.6 to zero electron volts, then you cover all the range of bandgaps.

“Through strain engineering, you can make diamond have the bandgap of silicon, which is most widely used as a semiconductor, or gallium nitride, which is used for LEDs. You can even have it become an infrared detector or detect a whole range of light all the way from the infrared to the ultraviolet part of the spectrum.”

It’s early days, and the work is not yet at the point where the researchers can begin to design devices. They are confident, however, that ongoing research will make practical applications possible.

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