Graphene shines a light on surface-enhanced spectroscopy

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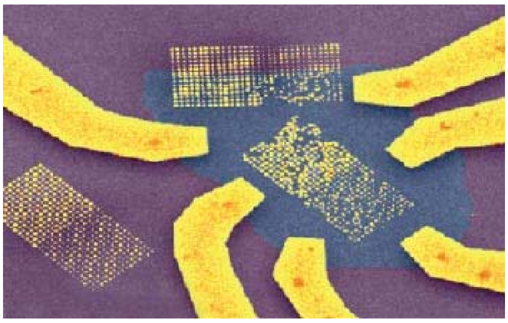

False-colour SEM images of SERS sample

Surface-enhanced Raman scattering (SERS) is a powerful way to identify molecules at very low concentrations – a technique that has proven very useful in forensics, medical diagnostics and identifying new drugs. But despite its success, scientists have struggled to understand the physics behind how SERS works.

Now researchers in the UK and Greece have developed a new model that shows how tiny metal discs can greatly enhance SERS signals. They claim their work could lead to a better understanding of the physics underlying SERS.

In recent years researchers have discovered that they can boost interactions between light and matter by harnessing collective oscillations of surface electrons called surface plasmons. Light fields are enhanced when they are resonant with these plasmons, leading to SERS and other surface-enhanced techniques. Indeed, scientists have already succeeded in boosting Raman-scattering signals by as much as 10^{14} when molecules sit on random nanostructure "hot-spots" on metal surfaces.

However, scientists don't fully understand which nanostructures make the best hotspots or how to create SERS substrates with uniform enhancements over large areas. This is because most SERS systems studied before now were based on random nanostructures, whose properties varied from experiment to experiment. This non-uniformity also made quantitative comparisons between theory and experiment difficult.

To overcome these problems, Andrea Ferrari and colleagues at the University of Cambridge along with researchers at the University of Manchester and the University of Ioannina have studied SERS using metal nanostructures grown on graphene. A sheet of carbon just one atom thick, graphene was chosen because it provides large, uniform and virtually defect-free surfaces. Furthermore, the Raman spectrum of graphene is well known.

The team created square arrays of gold dots on the graphene with a separation between dots of 320 nm. The dots were about 80 nm thick and had a radius of 210 nm in some arrays and 140 nm in others. The researchers then compared the Raman spectrum of bare graphene to the spectrum of graphene with dots, and found a significant enhancement when dots are present.

Modelling SERS

To gain a better understanding of why the enhancement was occurring, the team modelled its system by considering metal dots of various sizes placed on the graphene. They then solved Maxwell's equations for each sample using the "finite difference time domain method".

Ferrari and colleagues observed significant enhancements of the Raman signal and found that the enhancement is inversely proportional to the tenth power of the distance between graphene and the centre of a metal nanoparticle. "These results could help us better understand SERS physics of 2D materials," added Ferrari. "The work also proves that plasmonic nanostructures can enhance light absorption and scattering from 2D materials, like graphene, something that could have direct applications for photodetectors and sensors."

Spurred on by these findings, the team will now try and optimize the SERS substrate to achieve even bigger enhancements by using different metals and dot shapes. "We will also implement plasmonic nanostructures on various devices made from graphene," revealed Ferrari.

"We are confident that this research will become a key reference in the SERS field and will stimulate follow-up studies," team leader Andrea Ferrari said.

The work was reported in *ACS Nano*.

About the author
Belle Dumé is a contributing editor to *nanotechweb.org*.

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