SURFACE-ENHANCED RAMAN SPECTROSCOPY

## Curved space for fast analysis

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The electric field intensity near a silver nanoparticle is enhanced by virtue of surface plasmons. When a molecule experiences such a high electric field, it gives out an intense Raman spectrum, and this effect has been used for spectroscopic and analytical purposes. So effective is this surface-enhanced Raman spectroscopy (SERS) effect that detection limits up to the single-molecule level have been demonstrated. A common drawback, however, is the fact that the analyte must be very close to the silver nanoparticle; and it may take hours for molecules to diffuse from bulk solution. Now Mao et al. have demonstrated a strategy to reduce the preparation time for a SERS analysis to 60 seconds while maintaining a single-molecule detection limit.

The researchers start with the consideration that the electric field enhancement is due to a spatial variation of the refractive index of the medium. On a flat substrate, the refractive index can only vary in the proximity of the nanoparticle. Instead, Mao et al. design a curved substrate composed of silver nanoparticles inside tiny gold bowls. The curved substrate induces the electric field intensity to be confined within the space of the bowl and towards the bulk solution. As a result, a relatively constant enhancement is induced near the surface, with the outcome that it takes only 60 seconds of soaking time to achieve the single-molecule detection limit for a rhodamine 6G molecule. *AM*

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QUANTUM OPTICS

## A quantum typewriter

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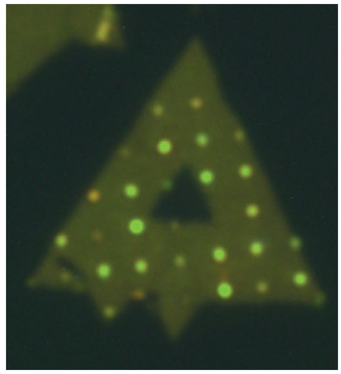

Credit: American Chemical Society

Good single-photon emitters (SPEs) should produce single, indistinguishable photons on demand and at a high rate, from well-defined positions in a device. Two-dimensional materials are attractive hosts for SPEs because they conveniently integrate with photonic circuits and enable efficient coupling into photonic waveguides or cavities. Furthermore, in transition metal dichalcogenides, local strain can induce SPEs. But precise positioning is a challenge.

Rosenberger et al. now use an atomic force microscope (AFM) to induce SPEs in a $WSe_2$ monolayer with submicrometre precision. They place the $WSe_2$ on a polymer layer on a $SiO_2$/Si substrate and indent the tip of the AFM into this sample at predefined positions. The plastic deformation of the polymer stabilizes the indentation in the $WSe_2$ after the tip has been retracted because the $WSe_2$ monolayer adheres to the polymer layer below. Subsequent AFM measurements confirm the creation of notches, whose shape and size depend on the applied force and the tip shape.

The researchers then perform photoluminescence experiments. They detect increased photoluminescence intensity, sharp emission lines and antibunching behaviour up to a temperature of 60 K. These experiments unveil the SPE character of the indents; the exact nature of the emitter, however, remains obscure at this stage. *BH*

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2D MATERIALS

## Edge state mitigation

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Graphene quantum dots (GQDs), a relatively new addition to the nanocarbon materials family, have a number of advantageous tunable opto-electronic properties. However, the presence of localized edge states in GQDs, which inevitably occur during their formation, adversely affects the charge transport. Moreover, the fabrication of tunnelling contacts to GQDs with reproducible contact resistances has proved challenging. Now, G. Kim and colleagues have shown how to circumvent these issues by using a combination of in-plane and vertical heterostructures to build vertical single-electron tunnelling transistors.

The researchers synthesize the GQDs on top of an array of platinum nanoparticles embedded inside a hexagonal boron nitride (hBN) matrix through catalytic substitution of boron and nitrogen atoms by carbon. The GQD/hBN layer is sandwiched between two thin hBN layers to isolate the quantum dots from the contacts: this ensures a long lifetime of electrons and reduces the number of localized states. Next, multichannel single-electron tunnelling transistors are prepared by capping the GQD/hBN structure with graphene electrodes. Differential conductance measurements performed using tunnelling spectroscopy reveal the observation of multiple Coulomb diamonds originating from a Coulomb blockade regime in one particular GQD. *KS*

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BIOHYBRIDS

## Bioactive vesicles made from human cell membranes

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Vesicles self-assembled from Janus dendrimers (JDs) are much more stable at room temperature than liposomes formed by phospholipids. And JDs can coassemble with Gram-negative bacterium *Escherichia coli* membranes. Now Yadavalli et al. have found that JDs can also stabilize fragile human cell membranes, forming stable cell-like hybrids from human membrane vesicles and dendrimersomes.

They first prepare giant dendrimersomes from selected JDs and create human membrane vesicles by simple centrifugation of human cells. A dehydration–rehydration procedure is then applied to coassemble the prepared giant dendrimersomes with the human membrane vesicles. Successful formation of hybrid vesicles is evidenced by dual-colour imaging using fluorescence microscopy. The giant hybrid cells can be stored in buffer at room temperature for more than a year. Moreover, the hybrid vesicles with both bacterial membranes and human cell membranes are very biocompatible, so the authors further explore their bioactivity. By expressing adhesion protein YadA in bacterial membrane, they fabricate hybrid cell-like vesicles made from dendrimersome and bacterial membrane that can be recognized by HeLa cells and delivered into the cytoplasm. Hybrid vesicles containing dendrimersomes and human cell membranes are also bioactive, capable of binding and aggregating *E. coli* cells with YadA proteins. These hybrid platforms may prove useful in recognition, signalling and delivery applications. *WS*

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