Specifically sized gold nanoparticle spheres increase sensitivity of light-based chemical detector

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A sensor that relies on reflected light to analyze biomedical and chemical samples now has greater sensitivity, thanks to a carpet of gold nanoparticles. Xia Yu of the A*STAR Singapore Institute of Manufacturing Technology, along with her students and colleagues, has determined the ideal size of nanoparticle to improve surface plasmon resonance (SPR) sensors.

Such sensors contain a prism with one face covered in a thin film of gold. As laser light shines through the prism, it mostly reflects off the gold into a detector. However, if the light hits the gold at a particular angle, some of it couples with electrons in the metal to produce electromagnetic waves called surface plasmon polaritons. Stronger coupling leads to less light being reflected towards the detector.

When a liquid sample flows across the gold film, it changes the refractive index in that region and slightly alters the angle at which the light arrives at the metal. This hampers the formation of polaritons meaning that more of the light is reflected toward the detector. Varying the angle of the laser beam and monitoring the intensity of the reflected light reveals the composition of samples flowing over the metal surface.

Other researchers have shown that gold nanoparticles can enhance the sensor's responsiveness. Incoming light sparks localized plasmon resonances around the nanoparticles that couple to the sensor surface, which causes larger changes in the intensity of the reflected light. This makes the device more sensitive to the light's angle of arrival and therefore able to detect lower concentrations of the chemicals being tested.

Yu's team calculated the optical responses of four different gold nanoparticles—ranging in diameter from 40 to 80 nanometers—determining that they would be most effective when held about 5 nanometers above the gold surface. The researchers then mounted the different nanoparticles onto gold films using a sulfur-containing molecule called dithiothreitol, which provided the optimum 5-nanometer gap.

The team's calculations had suggested that the electric field of the surface plasmon polaritons would be hundreds of times greater when 40-nanometer particles were added to the surface. "The stronger the electric field, the more sensitive the sensors," says Yu. Tests using different concentrations of glycerin and formamide solutions confirmed that the 40-nanometer particles did offer the greatest increase in sensitivity. "The detection limit is at least three orders of magnitude higher than current commercial SPR sensors," says Yu.

Yu now hopes to apply this discovery to ultrasensitive sensors that can detect traces of cancer biomarkers.

More information: Zeng, S. et al. Size dependence of Au NP-enhanced surface plasmon resonance based on differential phase measurement. *Sensors and Actuators B: Chemical* 176, 1128–1133, 2013. www.sciencedirect.com/science/ … ii/S0925400512009860

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