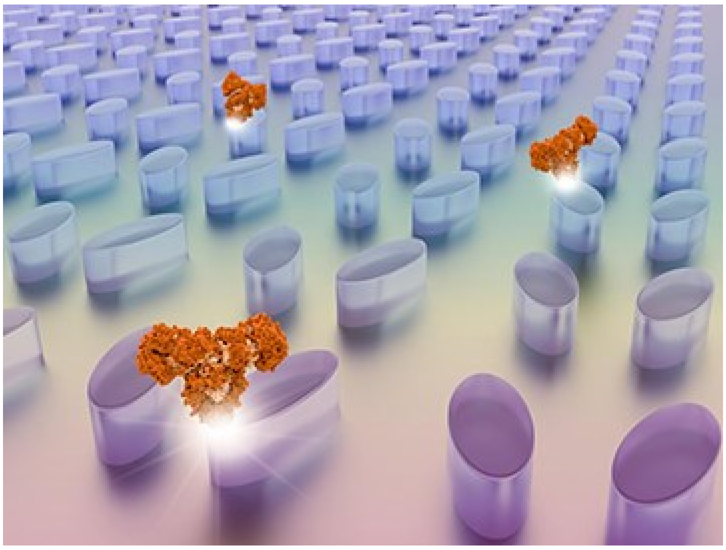
Biosensor Could Scale New Sensitivity Heights

Researchers in Switzerland and Australia have brought together the physics of dielectric metasurfaces and hyperspectral imaging to create an ultrasensitive, label-free biosensing platform. The team believes that the platform—reportedly capable of detecting and analyzing samples at spatial concentrations of less than three molecules per square micron—could ultimately enable compact portable diagnostics for personalized medicine. It could also, according to the researchers, offer a route to high-throughput, high-resolution optical characterization of single-atom-thick, 2-D materials such as graphene, a key requirement for advancing the technical development of those much-ballyhooed materials.



The detection platform demonstrated by scientists in Switzerland and Australia, which combines a high-*Q*-factor dielectric surface and hyperspectral imaging, can reportedly detect biomolecules at a density of less than three molecules per square micron of detector.

The dielectric difference

Sensors that operate via surface plasmon resonances—the subwavelength concentration and amplification of light on surfaces decorated with nanoscale metallic antennas—already have a long pedigree in biomedical diagnostics. As cells or biomolecules bind to the nanostructures, they change the local refractive index by an infinitesimal amount, which in turn leads to sharp changes in the peak wavelength of the surface plasmon resonance. Those wavelength changes can be read to track the presence, concentration and growth of the biological agent under study.

Bound states in the continuum

Originally a concept from quantum mechanics, BICs are confined waves that remain localized within a continuous spectrum of radiating waves. (More precisely, they represent discrete solutions of the single-particle Schrödinger equation from quantum mechanics, embedded within a continuum of positive energy states.) In principle, such bound states would be perfectly localized and would have an infinite quality (Q) factor. In practice, for device design, one can mathematically engineer a subwavelength optical “supercavity” that supports a “quasi-BIC” with an extremely high Q and an extremely narrow resonance width.

High Q response with a

hyperspectral kicker

The researchers behind the new work realized that, by virtue of those characteristics, a surface that exploited such supercavity-enabled BICs would be very responsive to local refractive-index changes—and, thus, could enable a very sensitive biodetection platform. So they set about building one. To do so, they used electron-beam lithography to pattern a 100-nm-thick layer of amorphous silicon (on a fused-silica substrate) with an array of tilted silicon “nanobars” around 100 nm wide and 280 nm long. The specific configuration and tilting angle of the bars had been mathematically calculated to take maximum advantage of quasi-BIC states—and the high *Q* factors and spectrally isolated resonances they enable—in the near-infrared region. That set up a metasurface that, when illuminated with a laser of the right wavelength, was primed to respond dramatically, via changes in resonance peak, to refractive-index changes due to individual biomolecules clinging to the surface. Next, the team supercharged this dielectric-metasurface platform by combining it with another hot technique: hyperspectral imaging. To obtain the hyperspectral data from the metasurface sensor, the team used a supercontinuum laser source to illuminate the sensor, sweeping the laser through multiple, narrow-linewidth frequencies by means of a laser line tunable filter. At each frequency of incident light, a high-resolution CMOS camera captures a new image of the resonant response of the sensor.

The team believes that the combination of high-*Q* resonant dielectric metasurfaces and high-throughput, imaging-based data acquisition amounts to “a superior and versatile sensing platform.” And the researchers suggest that further explorations—leveraging alternative materials, other dimensions such as incident-light polarization, and machine learning—could expand the system's flexibility still further, potentially enabling "a field-deployable high-throughput single-molecule detector for biomedical applications."

For more information: doi: 10.1038/s41566-019-0394-6