Study shows nanoshells ideal as chemical nanosensors

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'Nanoshells' enhance sensitivity to chemical detection by factor of 10 billion

New research published in the Proceedings of the National Academy of Science finds that tailored nanoparticles known as nanoshells can enhance chemical sensing by as much as 10 billion times. That makes them about 10,000 times more effective at Raman scattering than traditional methods.

When molecules and materials scatter light, a small fraction of the light interacts in such a way that it allows scientists to determine their detailed chemical makeup. This property, known as Raman scattering, is used by medical researchers, drug designers, chemists and other scientists to determine what materials are made of. An enormous limitation in the use of Raman scattering has been its extremely weak sensitivity. While it was discovered almost three decades ago that roughened metallic surfaces could enhance Raman scattering signals by factors of 1 million, this "surface-enhancement" effect has been difficult to control, predict, and reproduce for practical sensing applications. Now, Rice researchers have shown that nanoshells can provide large, clean, reproducible enhancements of this effect, opening the door for new, all-optical sensing applications.

"Not only did we find that nanoshells are extremely effective at magnifying the Raman signature of molecules, we found each individual nanoshell acts as an independent Raman enhancer," said lead researcher

Naomi Halas, the Stanley C. Moore Professor of Electrical and Computer Engineering, Professor of Chemistry and Director of Rice's Laboratory of Nanophotonics. "That creates an opportunity to design all-optical nanoscale sensors -- essentially new molecular-level diagnostic instruments -- that could detect as little as a few molecules of a target substance, which could be anything from a drug molecule or a key disease protein to a deadly chemical agent."

About 1/20th the size of a red blood cell, nanoshells are about the size of a virus. They are ball-shaped and consist of a core of non-conducting glass that is covered by a metallic shell, typically either gold or silver. The metal shell "captures" passing light and focuses it, a property that directly leads to the enormous Raman enhancements observed. Furthermore, nanoshells can be "tuned" to interact with specific wavelengths of light by varying the thickness of their shells. This tunability allows for the Raman enhancements to be optimized for specific wavelengths of light.

Discovered by Halas at Rice in the 1990s, nanoshells are already being developed for applications including cancer diagnosis, cancer therapy, diagnosis and testing for proteins associated with Alzheimer's disease, drug delivery and rapid whole-blood immunoassay.

In the current study, Halas and former graduate student Joseph B. Jackson, now with Nanospectra Biosciences, Inc., created thin films of nanoshells deposited atop plates of glass. Films with various densities were studied, as were films containing both silver and gold nanoshells.

Through painstaking analysis, Halas and Jackson showed that the nanoshells' 10 billion-fold increase in Raman effect was due entirely to the interactions of light with individual nanoshells. This is markedly different from the pattern exhibited by pure gold or silver nanoparticle films. In that case, the Raman enhancement is an aggregate effect, due to the presence of localized "junctions" or "hot spots" between metallic regions of the metallic film substrate.

The finding that individual nanoshells can vastly enhance the Raman effect opens the door for biosensor designs that use a single nanoshell, something that could prove useful for engineers who are trying to probe the chemical processes within small structures such as individual cells, or for the detection of very small amounts of a material, like a few molecules of a deadly biological or chemical agent.

Source: Rice University