stance. This could provide a powerful method to determine the identity of the substance, with applications ranging from industry and medicine to the military, says electrical engineering professor Stephen Y. Chou, who led the research.

In Raman scattering, the reflected light is typically too weak to be sensed, even with the most sophisticated equipment. Stronger signals can be obtained if the substance to be identified is placed on a rough metal surface or tiny particles of gold or silver — a technique known as surface-enhanced Raman scattering (SERS). However, the strong signals appear at only a few random points on the sensor surface, making it difficult to predict where to measure the signal, and resulting in a weak overall signal.

The new sensor relies on a completely new SERS architecture and fabrication technique. The device — a chip studded with uniform rows of tiny pillars made of metals and insulators — boosts faint signals generated by the scattering of laser light from a material placed on it. The sample can be as small as a single molecule, making this the most sensitive sensor of its kind, Chou says.

The pillar arrays developed by Chou's team are fundamentally different from those explored by previous researchers. The structure has two key components: a cavity formed by metal on the top and at the base of each pillar; and metal particles of about 20 nm dia. (known as plasmonic nanodots) on the pillar wall, with small gaps of about 2 nm between the metal nanoparticles. The particles and gaps significantly amplify the Raman signals, because the cavities serve as antennae by trapping light so it passes the plasmonic nanodots multiple times to generate the Raman signal, rather than only once.

Chou reports that in initial tests, the chip was a billion times more sensitive than was possible without SERS boosting of Raman signals. The sensor is uniformly sensitive, making it more reliable for use in sensing devices.

In addition to its unprecedented sensitivity, the Princeton chip can be manufactured inexpensively in large sizes and large quantities by a combination of nanoimprinting and self-assembly.

"The combination of a sensor that enhances signals far beyond what was previously possible, that has uniform sensitivity, and that is easy to mass-produce could change the landscape of sensor technology," Chou says.

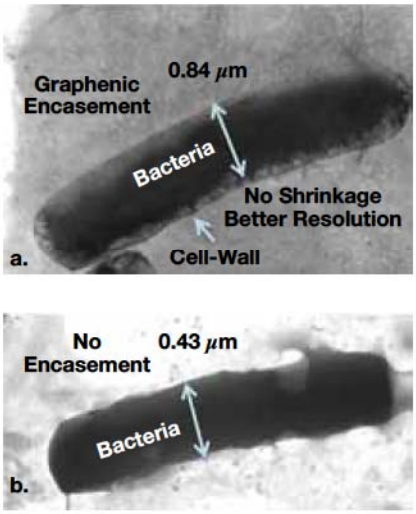
BIOTECHNOLOGY

Graphene Encasement Enhances Bacterial Image

Chemical engineers at Kansas State Univ. have developed a carbon cloak made of graphene that allows high-vacuum electron microscopes to image bacteria at their natural size and with high resolution. Cell imaging with an electron microscope is difficult because the strong vacuum required removes water from the cells (which typically contain 70–80% water) and causes them to shrink significantly. This makes it difficult for scientists to study the cells and their components in their natural wet state.

Graphene, a layer of carbon just one atom thick, has several advantageous properties: it is impermeable, is electron-transparent, has high thermal conductance, and is the strongest known nanomaterial. "Although only an atom thick, graphene does not allow even the smallest of molecules to pass through. Furthermore, it is strong and highly flexible so it can conform to any shape," says chemical engineering professor Vikas Berry, who led the research team.

The researchers coat bacteria with a protective layer of graphene, which encases the cells and acts as an impermeable cloak so that the cells retain water and do not shrink under the vacuum, allowing for imaging



▲ Top: A wrapped bacterium exhibits no shrinkage from the original size after 20 min inside the vacuum chamber, and the cell wall is visible. Bottom: An unwrapped bacterium exhibits 76% shrinkage after 20 min under vacuum. Image courtesy of Vikas Berry / ACS.

of wet bacterial cells at their natural size. They apply the graphene using one of two methods: in one, a sheet of graphene is placed on top of the bacteria, much like covering up with a bed sheet, while the other involves wrapping the bacteria with graphene so that the graphene sheets swaddle the bacteria. The graphene is then functionalized with a protein to enhance its binding to the bacterial cell wall.

When placed under the high vacuum of the microscope, the wrapped bacteria did not shrink for 30 min, giving scientists time to observe them. Berry notes that this is a direct result of the strength and impermeability of the graphene cloak.

Since graphene is a good conductor of heat and electricity, the local electronic-charging and heating is conducted away by the graphene cloak, providing a clear view of the bacterial cell wall. Conversely, unwrapped bacterial cells appear dark with an indistinguishable cell wall.

Berry believes that this technology may allow scientists to better view wet samples in a vacuum. He hopes that in the future it will be possible to use

graphene to keep a bacterium alive in a vacuum while its biochemistry is studied under a microscope. In addition, because wet proteins and dry proteins function differently, the research may lead to enhanced protein microscopy by allowing proteins to be observed in aqueous environments.

Cell-Carrying Spheres Aid in Tissue Repair

Scientists at the Univ. of Michigan (U-M) have created biodegradable polymers that can self-assemble into hollow, nanofiber spheres, which could serve as cell carriers for wound healing.

Success in repairing tissue is difficult to achieve because of the limited supply of donor tissue, explains Peter Ma, a professor in the U-M School of Dentistry and College of Engineering. The traditional approach to tissue repair is to inject the patient's own cells directly into the wound. However, the quality of this type of repair is not good, because the cells are injected loosely and are not supported by a carrier that simulates the cells' natural environment, Ma says. An injectable cell carrier is desirable to achieve accurate fit and to minimize surgery when repairing complex or oddly shaped tissue defects.

The U-M cell-carrier matrix is composed of biodegradable nanofibers that support the cells as they grow and form new tissue. The nanofibrous hollow microspheres are highly porous, allowing nutrients to enter easily. In addition, the nanofibers in these hollow microspheres do not generate many degradation byproducts that could harm the cells.

After the nanofibers are combined with cells and injected into the wound, the spheres provide an environment in which the cells naturally thrive. The fibers then degrade at the wound site.

In tests, the nanofiber repair group grew as much as three to four times more tissue than did the traditional cell matrix. The team plans to study the new cell carrier in larger animals and eventually in humans to repair cartilage and other tissue types.

NANOTECHNOLOGY

Ligand-Stabilized Nanoparticles Grow Better Carbon Nanofibers

Carbon nanofibers appear promising for use in technologies ranging from precise scientific measurement tools to