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NEWS AND OPINIONS

Nanoscience provides new tips on probing cells

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One of the great promises of nanoscience is the potential to probe, investigate, and manipulate living cells. Two recent reports demonstrate new ways of doing just this.

In the first, Peidong Yang and colleagues at Lawrence Berkeley National Laboratory, University of California, Berkeley and Korea Advanced Institute of Science and Technology describe a nanowire-based endoscope that can provide high-resolution optical images of the interior of cells, as well as delivering drugs or other cargo like genes or proteins [R. Yan et al., Nature Nanotechnology (2011), doi:10.1038/NNANO.2011.226].

The endoscope consists of a nanowire waveguide attached to the tapered tip of an optical fiber. Because the SnO_2 nanowire is mechanically flexible and small in dimension (~100—250 nm), it does not damage the cellular structure or induce any significant toxicity. Yet the device is mechanically robust and can endure bending and buckling during repeated use. The nanowire-based endoscope can both guide light into specific intracellular compartments and detect optical signals from subcellular regions with high spatial resolution (Fig. 1).

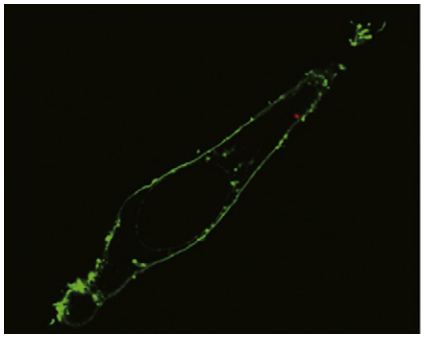

Figure 1 Fluorescence confocal image of a single living HeLa cell showing that a quantum dot cluster (red dot) has been delivered to the cytoplasm within the membrane (green) of the cell. (Credit: Berkeley Lab.)

''By combining the advantages of nanowire waveguides and fiber-optic fluorescence imaging, we can manipulate light at the nanoscale inside living cells for studying biological processes within [those] cells with high spatial and temporal resolution,'' explains Yang.

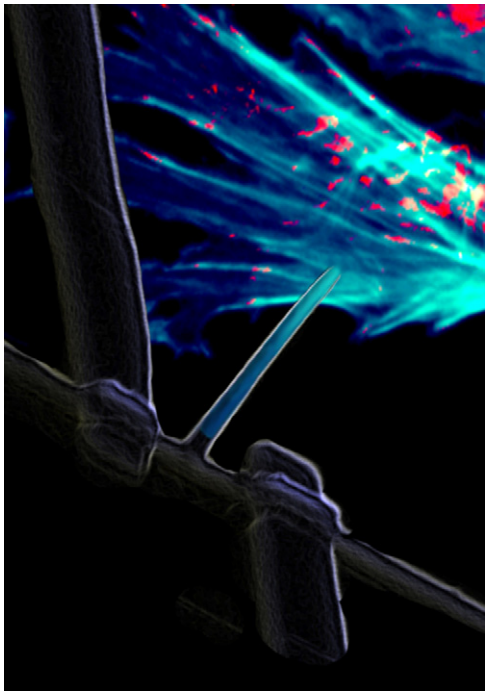

Figure 2 A false color scanning electron micrograph of a branched intracellular nanotube field-effect transistor (BIT-FET) device overlaid with an image of a cluster of cardiomyocyte cells illustrating how intracellular action potentials are recorded by the device. (Credit: Xiaojie Duan and Brian Timko, Harvard University and Opusdesign.)

The researchers also show that by functionalizing the surface of the nanowire with photo-cleavable linkers they can create a system that is capable of delivering a payload of cargo — in the current case quantum dots, but could be drugs, proteins or genes — when exposed to low-power UV radiation.

''In the future, in addition to optical imaging and cargo delivery, we could also use this nanowire endoscope to electrically or optically stimulate a living cell,'' says Yang.

Meanwhile, it is the electrical signals inside cells that are the focus for Charles M. Lieber and colleagues at Harvard University, who have reported a completely new way of recording these signals at an unprecedented scale [X. Duan et al., Nature Nanotechnology (2011), doi:10.1038/NNANO.2011.223].

The researchers have devised a sensitive nanoscale field-effect transistor (FET), which is coupled to the inside of a cell by an ultra-small diameter SiO_2 nanotube joined to a Si nanowire in a T-shape. When the device, dubbed a branched intracellular nanotube FET (BIT-FET), is used to probe a cell, the nanotube penetrates the cell membrane, bringing the fluid inside (the cytosol) into contact with the nanowire. If a voltage is then applied across the nanowire, the device operates as a FET and can record intracellular action potential signals, which the researchers demonstrate with embryonic chicken cardiomyocyte cells (Fig. 2).

Moreover, two BIT-FETs can be inserted into the same cell to independently record the action potential from different points within the cell, while multiple devices could be used to record action potentials from a network of cells. The small dimension of the nanotube probe, which can be as little as ~3 nm—much less than currently used micropipettes and microelectrodes, opens up completely new opportunities for electrophysiology measurements, says Lieber.

''The multiplexing capability [of our new tool] has great potential for new drug-cell screening assays, such as testing ion-channel blockers on the detailed behavior of cardiac cells,'' Lieber told Nano Today.

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Researchers unstick nanoparticle friction

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Multilayered, fullerene-like (IF) nanoparticles have the potential to be remarkable lubricants but the underlying friction mechanisms remain something of a mystery. Now researchers from the Weizmann Institute of Science in Israel have reported experimental estimations of the relative role of each of the main friction mechanisms — rolling, sliding and exfoliation [O. Tevet et al., Proc. Natl. Acad. Sci. USA (2011), doi:10.1073/pnas.1106553108].

Reshef Tenne and his colleagues investigated the role of each mechanism using IF WS_2 and MoS_2 nanoparticles decorated with Au nanoparticles as markers (Fig. 1). The nanoparticles were spread over a Si wafer wedge in a high resolution scanning electron microscope and subjected to axial compression and shearing forces using the cantilever from an atomic force microscope.

When the loading is below 1 GPa, the WS_2 nanoparticles roll, the researchers observe. But above that loading the nanoparticles become stuck and cannot roll, so they start to slide instead. And at even higher loadings, above 1.2 GPa, the nanoparticles collapse and start to shed layers like an onion — or exfoliate — which coat the surface allowing easy shearing. The WS_2 nanoparticles collapse completely at loads of 1.9 GPa or more. Meanwhile, less spherical MoS_2 nanoparticles show less rolling and more sliding friction, only failing at pressures of 2.5 GPa.

''The novelty of our findings is in the realization of all three main mechanisms of lubrication in the nanoparticles, which were assumed to exist but could not be verified unequivocally before,'' explains Tenne. ''The main implication is that the rolling friction mechanism cannot be discarded.''

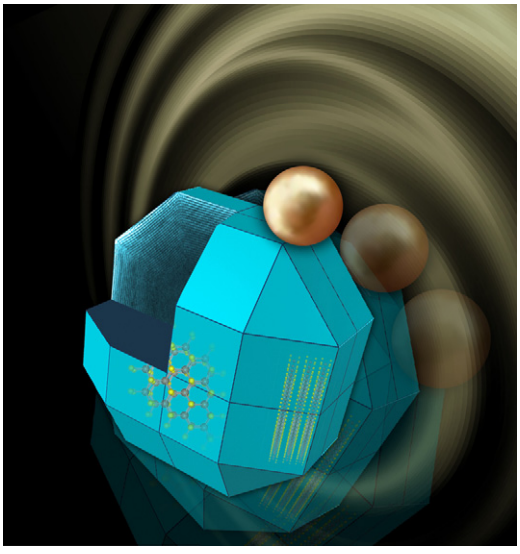

Figure 1 An artist's rendering of the rolling of nanoparticles. The Au nanoparticle (shown in yellow) decorates the IF-WS2 nanoparticle and serves as a marker for the rolling movement. (Credit: Ofer Tevet, Weizmann Institute of Science.)