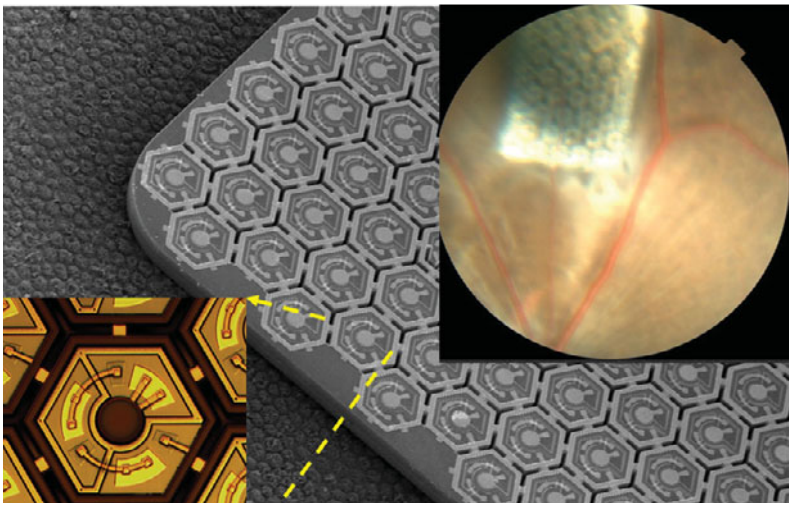


Subretinal photodiode array with triple-diode pixels arranged in a hexagonal pattern. Pixels of 70 µm and 140 µm in size were made. Left inset: Central electrodes are surrounded by three diodes connected in series, and by the common return electrode. Right inset: The subretinal implant.

photosensitive pixels but they depend on an external power source. Recently, however, researchers from the Palanker group at the Hansen Experimental Physics Laboratory and the Department of Ophthalmology at Stanford University designed a photovoltaic retinal prosthesis where video goggles were used to deliver both power and visual information through pulsed NIR illumination, preserving the natural link between image perception and eye movement without complex electronics and wiring.

In an article published in the June issue of *Nature Photonics* (DOI: 10.1038/nphoton.2012.104; p. 391), Keith Mathieson, James Loudin, and co-researchers from Stanford University and the University of California–Santa Cruz, describe their prosthesis design in which video images captured by a head-mounted camera are processed by a portable computer. The video goggles use a liquid-crystal display (LCD) illuminated by pulsed near-infrared light (880–915 nm) to project the images onto a subretinal photodiode array (consisting of 70 µm pixels, each with ~20 µm stimulating electrodes), which converts the light to local currents that stimulate the nearby neurons in the inner nuclear layer of the retina.

The researchers fabricated silicon photodiode arrays consisting of pixels with single diodes as well as those consisting of pixels with three diodes connected in series. These triple-diode pixels can produce 1.5 V, which triples the charge injection on the sputtered iridium oxide film electrodes (from 0.5 mC cm^{-2} for a single-diode pixel to 1.5 mC cm^{-2}). The triple-diode pixels require light intensities three times higher than single-diode pixels because the photosensitive pixel area is divided into three subunits. However, the researchers found that their single- and triple-diode devices had very similar thresholds for eliciting retinal responses.

The researchers tested their design concept by stimulating healthy and degenerate rat retinas *in vitro* with NIR light intensities at least two orders of magnitude below the ocular safety limit. They showed that the elicited retinal responses can be modulated by both light intensity and pulse width, although their current optical design allows only for intensity modulation within each video frame. However, if the retinal response is modulated by varying the pulse width, the researchers said that digital light processing technology can also be used, adding, "Such a device would allow both the duration and timing of exposure to be precisely controlled on the scale of individual pixels. In addition to higher throughput compared to an LCD, this high-speed control would allow the sequential activation of nearby pixels to further reduce pixel crosstalk—interference of currents from nearby pixels."

Steven Trohalaki

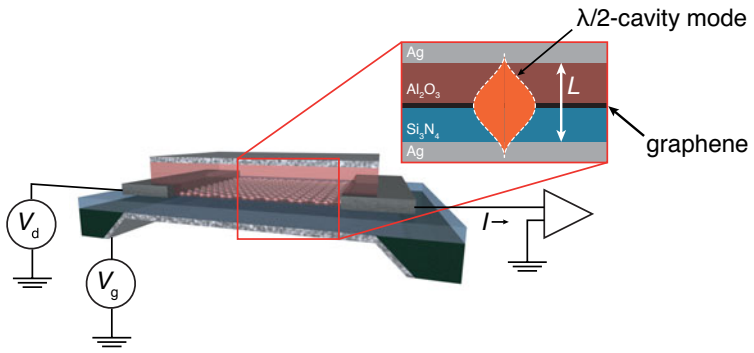
Nano Focus

Optical confinement modifies graphene transistor characteristics

The interaction between light and matter can be greatly enhanced within an optical cavity in which the spacing of two mirrors defines a standing electromagnetic wave. Placing a sheet of graphene in such a cavity can therefore have profound effects on its optoelectronic properties, as shown by M. Engel of the Karlsruhe Institute of Technology, M. Steiner of the IBM T.J. Watson Research Center in New York, A. Lombardo of the University of Cambridge, and their colleagues. Their article in the June 19 issue of *Nature Communications* (DOI: 10.1038/ncomms1911) describes how such optical confinement of a graphene transistor allows spectrally selective generation of photocurrent and even alters the electrical transport properties of the material.

The team embedded a sheet of graphene between two optically transparent dielectric materials, Si_3N_4 and Al_2O_3, which are in turn enclosed by silver mirrors with a spacing equal to one-half of the resonant wavelength of the cavity. At the center of this optical cavity the anti-node in the optical field enhances the absorption or emission of photons by the graphene at the resonant wavelength, and inhibits it at other wavelengths. Applying a voltage across the graphene and illuminating the device with a laser generated 20 times more photocurrent at the

https://doi.org/10.1557/mrs.2012.212 Published online by Cambridge University Press



A schematic and cross section (inset) of the graphene transistor in an optical cavity. The separation L of the silver mirrors determines the resonant wavelength λ of the cavity, for which the intensity profile of the λ/2 mode is shown in orange; V_g, gate voltage; V_d, drain voltage. Reproduced with permission from *Nat. Commun.* **3** (2012), DOI: 10.1038/ncomms1911. ©2012 Macmillan Publishers Ltd.

resonant wavelength, providing a spectral selectivity not observed in unconfined graphene. Similarly, when a current is applied to unconfined graphene, it heats up and emits a featureless thermal spectrum, whereas the graphene in the optical cavity displays a strong emission peak at the resonant wavelength.

The researchers also found that confined graphene exhibited unusual electrical behavior. At low voltages the cavity inhibits the emission of the low energy thermal radiation with wavelengths longer than resonance, and the current therefore saturates. As the voltage is increased, this threshold for light emission is passed and the device resistance drops accordingly.

Graphene is an ideal material for this type of device because of its two-dimensional nature, which allows it to extend for micrometers across the center of the cavity, and easily tunable electrical properties. The degree of spectral selectivity provided by the optical confinement suggests a useful application in photodetection, while its influence on electrical transport could be exploited in nanoelectronic devices.

Tobias Lockwood

Bio Focus

Weakly charged cationic nanoparticles unzip DNA

Understanding the interaction between charged nanoparticles and double-stranded DNA has important implications for drug delivery schemes and DNA-templated metallization, in addition to other possible applications. While attempting to package DNA onto nanoparticles as a means of gene delivery into cells, Anatoli V. Melechko of North Carolina State University (NCSU), Timothy E. McKnight of Oak Ridge National Laboratory, and their colleagues discovered something completely unexpected. Some of the nanoparticles clumped together, and in the process pulled the double-stranded DNA apart, at least partially.

"This could be a new type of machinery that can be used for separating DNA into single strands," Melechko said, admitting that a lot more work will need to be done to understand and control the phenomenon.

In nature, negatively charged DNA wraps around protein cylinders with a positive charge of +220 to form a complex known as chromatin. A high positive charge on a protein or a nanoparticle causes DNA to bend and undergo compaction. Much work has been done with functionalized nanoparticles in this regime. Some research has been done with weakly positive charged nanoparticles, which typically have no effect on the conformation of DNA. In choosing gold nanoparticles (AuNPs) functionalized with thiolated alkane ligands bearing primary amines with a charge of +6, Melechko and his colleagues explored the lesser-known transition charge region between the weak and the strong regimes.

As reported in the August 16 issue of *Advanced Materials* (DOI: 10.1002/adma.201104891; p. 4261), gel electrophoresis experiments with the AuNP-DNA showed a "mystery band in a gel—an extra line [close to the 1000 base pair marker] that created the main puzzle for us," Melechko said. Though prior work by others might signify that this mystery line was the result of DNA compaction affecting gel mobility, Melechko and coworkers hypothesized that some denaturing—or unzipping—of the two-stranded DNA was occurring. UV spectroscopy showed that at least partial denaturing was occurring.

To better understand the phenomenon, co-researcher Yaroslava Yingling of NCSU ran molecular dynamics simulations involving single AuNPs with six charged ligands (AuNP−$6NH_3^+$), and compared them with other molecular dynamics simulations involving three of the AuNP−$6NH_3^+$ units. The single-particle simulations showed binding of the ligands to both the minor and major grooves of DNA, but little structural alteration in the double helix. Basically, the DNA just sticks to a single nanoparticle. But in the three-particle simulations, the nanoparticles bunch together. "You have hydrophobic groups that want to hide between themselves, and polar groups that grab on to DNA," Melechko said. "When they do this clumping and still hold on to DNA, they can rip it apart."

The researchers said that "particles acting in concert can produce effects not possible with single particles." A video of the molecular dynamics simulation can be viewed at http://youtu.be/9M-58niEOpU.

Tim Palucka

https://doi.org/10.1557/mrs.2012.212 Published online by Cambridge University Press