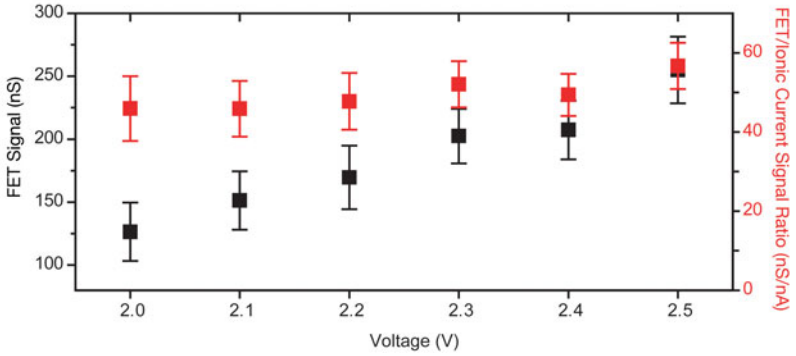
Nano Focus

Silicon nanowire FET-integrated nanopore sensor uses local electrical potential detection as a novel method for DNA sequencing

Current nanopore technologies for direct DNA sequencing are limited in their detection sensitivity by the fast translocation speed of DNA molecules (~1 μs base^{-1}). An international research group led by Charles M. Lieber of Harvard University has developed a silicon nanowire field-effect transistor-integrated nanopore sensor to tackle the challenge of providing high bandwidth detection to match the fast DNA translocation speeds. The novel nanowire-nanopore sensor exploits the localized electrical potential developed near the nanopore during DNA translocation, to provide a highly sensitive DNA sequencing method. Lieber, P. Xie, and Q. Qing of Harvard; Q. Xiong of Nanyang Technological University in Singapore; and Y. Fang of the National Center for Nanoscience and Technology in China published their findings in the December 11, 2011 issue of *Nature Nanotechnology* (DOI: 10.1038/NNANO.2011.217).

Chemical vapor deposition (CVD)-synthesized *p*-type silicon nanowires were deposited onto SiN_x membranes, with nickel contacts defined by electron-beam lithography. The nanopores were drilled with a focused electron beam in a transmission electron microscope. The FET-integrated sensor is electrically connected to a printed circuit board chip carrier, which in turn is sandwiched between two poly(dimethylsiloxane) (PDMS) solution chambers with buffer solutions. The double strand DNA molecule is then injected into the bottom PDMS chamber to translocate through the nanopore. However, the researchers had to change the relative ionic strengths of the top and bottom PDMS chambers, with the bottom chamber having a higher ionic strength, in order to successfully produce the localized potential and detect FET conductance signals correlated in time to the ionic currents.



Experimental values of the field-effect transistor (FET) signal (black data points) and FET signal/ionic current signal ratio (red data points) under different voltages. Reproduced with permission from *Nature Nanotech*, DOI: 10.1038/NNANO.2011.217. © 2011 Macmillan Publishers Ltd.

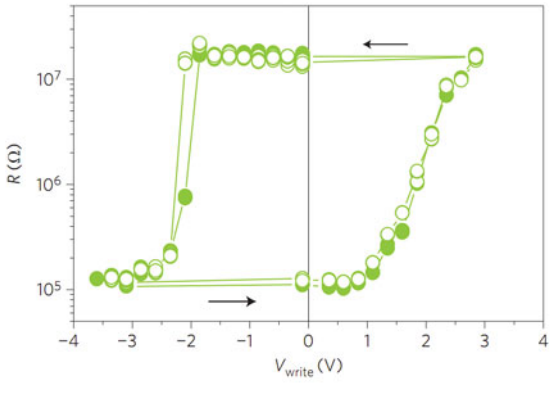
The researchers report a constant ratio between the orders of magnitude larger FET signal and corresponding ionic current signal. Such a correlation is a unique advantage of this new sensing method. This feature in principle ensures the compatibility of this much faster sensing scheme with all previous ionic current-based nanopore base-differentiation methods. Furthermore, the FET-integrated nanopore sensors have the potential to be integrated and multiplexed into large-scale DNA detection systems for higher throughput without complex microfluidics.

Rufina S.A. Sesuraj

Nano Focus

Functional ferroelectric tunnel-junction memories demonstrated

Quantum mechanical tunneling across an insulating barrier is the basis for the operation of magnetic tunnel junctions and other novel memories. However, current memory designs are hampered by poor resistance switching ratios and high power consumption. This problem could potentially be overcome by use of a ferroelectric tunnel barrier material which promises high OFF/ON resistance ratios with lower power consumption. Meeting this challenge, an international research group has recently described the design of a ferroelectric tunnel junction with exceptional tunneling electroresistance that may compete with traditional nonvolatile memories. A. Chanthbouala of the Unité Mixte de Physique CNRS/Thales, S. Fusil of CNRS and the Université d'Evry-Val d'Essonne, X. Moya of the University of Cambridge, S. Xavier of Thales Research and Technology, A. Moshar of Asylum Research in Santa Barbara, and their colleagues have reported their findings in the December 4, 2011 online



Magnetoresistance of a Au/Co/$BaTiO_3$/$La_{0.67}Sr_{0.33}MnO_3$ junction measured at 100 mV after the application of different write voltages using piezoresponse force microscopy. Reproduced with permission from *Nature Nanotech,* DOI: 10.1038/NNANO.2011.213. © 2011 Macmillan Publishers Ltd.

edition of *Nature Nanotechnology* (DOI: 10.1038/NNANO.2011.213).

The researchers first deposited a 2 nm $BaTiO_3$/30 nm $La_{0.67}Sr_{0.33}MnO_3$ bilayer onto a (001)-oriented $NdGaO_3$ substrate using pulsed laser deposition. They then patterned an array of 10 nm Au/10 Co top contacts onto the bilayer. These contacts were then probed using a conductive atomic force microscope tip to measure the piezoresponse and electroresistance of each junction. A hysteretic behavior in the junction resistance was observed, which is consistent with ferroelectric polarization switching of the $BaTiO_3$ layer, and the tunnel resistance of the junction was shown to strongly depend on the write voltage, as shown in the figure. The magnitude of the OFF/ON ratio was also observed to change by over two orders of magnitude, which corresponds to a nearly 10,000% increase in junction resistance. This is a significant improvement over conventional tunneling magnetoresistive memories, which typically show only a fourfold OFF/ON ratio.

The researchers next measured the switching stability of over 50 junctions, and recorded an average switching ratio of 64 with little variation in *I-V* behavior over 900 read/write cycles. The power consumption of these devices (~10 fJ/bit) is also lower than that of other nonvolatile memory technologies, making these junctions appealing for a wide range of memory applications.

The research team believes that these devices can be optimized using strain engineering, electrical boundary conditions, and even magnetic electrodes to achieve further improvements in performance and could potentially compete with other nonvolatile memory technologies.

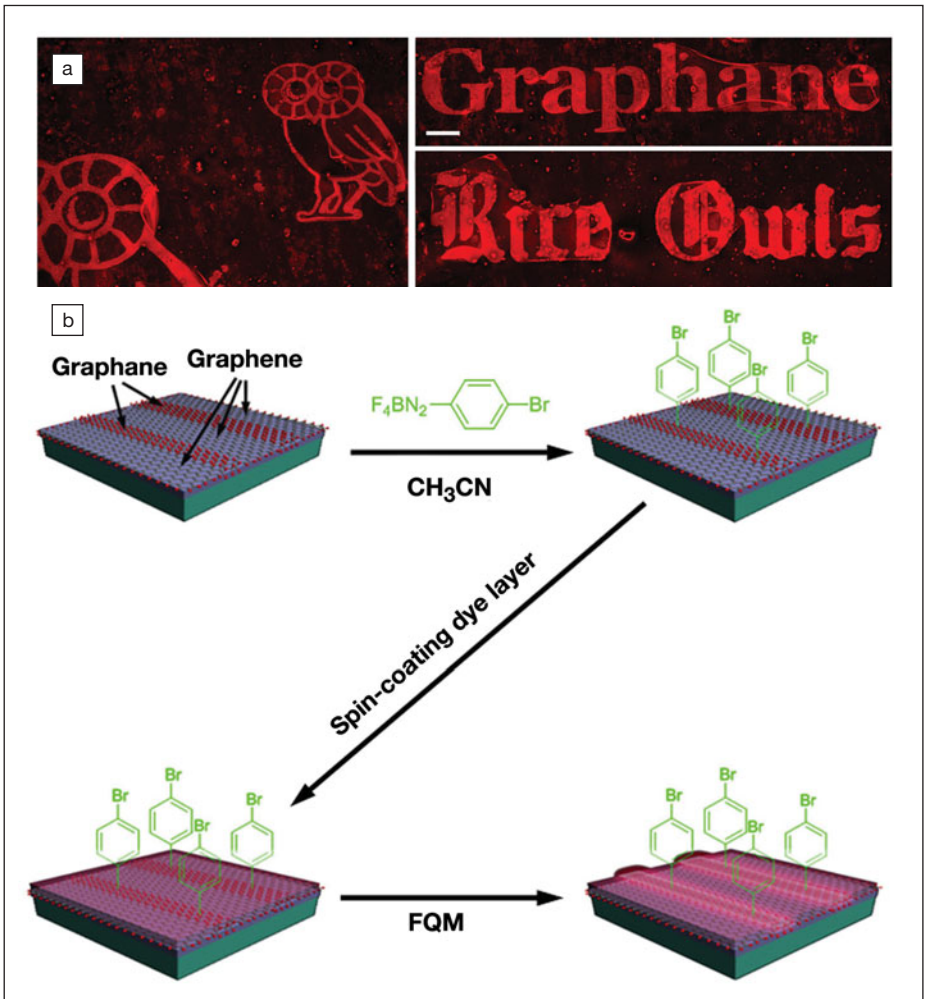
Steven Spurgeon

Nano Focus

Electronic properties of graphene modulated with chemical functionalization

Graphene, with its two-dimensional, hexagonal honeycomb lattice structure and semimetallic characteristics, has great potential for use in a diverse array of optoelectronic applications, especially now that synthetic routes for its large-scale synthesis have been demonstrated. One route to achieving this goal is through chemical functionalization, which can convert graphene, with its bandgap of zero, to a wide-bandgap semiconductor. In addition, patterned multifunctional regions could be used to form the superlattices required for devices such as chemical sensors and thermoelectrics. Toward these ends, J.M. Tour and colleagues at Rice University and Tianjin University have demonstrated a two-step process to first hydrogenate a pattern on the basal plane of graphene and then convert the hydrogens to a different functionality.

As reported in the November 29, 2011 issue of *Nature Communications* (DOI: 10.1038/ncomms1577), the researchers transferred graphene originally grown on Cu substrates to an insulating substrate (either quartz or SiO_2/Si) and then used conventional lithography to expose defined regions of the graphene to atomic hydrogen. Fluorescence quenching microscopy (FQM) was used to image



(a) Images of graphane/graphene patterns revealed with fluorescence quenching microscopy (FQM); the scale bars are 200 μm; (b) the fabrication of sp^3 C–C exchanged superlattices and subsequent FQM imaging is illustrated with a schematic diagram. Reproduced with permission from *Nat. Commun.* **2**:527, DOI: 10.1038/ncomms1531. © 2011 Macmillan Publishers Ltd.