measured resistance of the NT devices at room temperature. An applied positive gate voltage U_g would polarize the NT-electrolyte interface by the attraction of cations. The gate capacitance C_g, formed by the double-layer capacitance, can be very large.

The researchers observed that while the initial gate-induced resistances $R(U_g)$ at $U_g = 0$ are comparable between liquid-ion gating and its BG counterpart, $R(U_g)$ has a maximum at $U_g = U_0$ in the electrolyte in the former, which is not observed in BG. This suggests that the NT has a *p*-type behavior for $U_g < U_0$ and *n*-type otherwise. The liquid-ion gating was also more effective than BG by a factor of more than 200. Time-independent measurements were carried out cyclically by sweeping U_g slowly (10 min/sweep); R change of about 20% with a small hysteresis was observed. Time-dependent measurements showed a much larger R change. In either case, U_0 was about 1 V in equilibrium.

According to the researchers, the MWNTs in air are hole-doped with a doping concentration of ~10^{13} cm^{-2} due to the adsorption of oxygen, leading to Fermi energy E_F of about 0.3–0.5 eV. The electrolyte induces further doping, most likely due to adsorption of the (weakly) oxidizing species (in this case, the perchlorate ion ClO_4^-), leading to a charge transfer which partially oxidizes the NTs. The oxidation is weak in the sense that the NT carbon network is still preserved. The use of a stronger oxidizing electrolyte would shift the curve $R(U_g)$ farther to the right, while a reducing solvent would shift it to the left. The doping magnitude also depends on the electrolyte concentration. Polarizing the NT by an electrolyte allows E_F to move over a wide range, resulting in a large resistance change. NTs are possibly the most sensitive FETs for environmental application because the mobile NT carriers are in intimate contact with the environment—in this case, the electrolyte. In their report published in the February 19 issue of *Applied Physics Letters*, the researchers also present a model to explain the physics of this experiment.

WIRAWAN PURWANTO

Naturally Occurring Vacancies Shuffle Low-Index Metal Surfaces

R. van Gastel, E. Somfai, S.B. van Albada, W. van Saarloos, and J.W.M. Frenken of Universiteit Leiden have reported in the February 19 issue of *Physical Review Letters* that atoms on the surface of low-index metal surfaces are in motion due to an ultralow density of surface vacancies that rapidly diffuse throughout the surface. Since no experimental techniques are available with both the spatial and the temporal resolution necessary to follow the diffusion of naturally occurring vacancies in a low-index metal surface, the researchers employed embedded indium "tracer" atoms on a copper surface to visualize the diffusive motion of surface atoms. They concluded

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that surface vacancies are responsible for the mobility of the indium, and that this metal surface is far from static, even at room temperature.

A single crystal of Cu (99.999% pure) was polished parallel to the (001) plane. It was cleaned by heating in Ar/H_2 to remove sulfur impurities, sputtering with 600-eV Ar ions in ultrahigh vacuum (UHV) with periodic exposure to a few Langmuir of O_2 to remove carbon, and annealing to 675 K. A 3% monolayer of indium was deposited on the Cu(001) surface from a Knudsen cell. The experiments were performed with a variable temperature scanning tunneling microscope (STM) in UHV. The diffusion of the indium atoms embedded in the copper terrace was followed by making a series of images of the same area on the copper surface to form an STM-movie of the motion (viewable at http://lion.leidenuniv.nl/wwwhome/gastel/measurement.gif).

The researchers discovered that the indium atoms move by long jumps of more than a single lattice spacing, separated by long time intervals, and that nearby indium atoms tend to jump at the same time. The researchers said this strongly suggests that the diffusion of the indium is mediated by vacancies, which diffuse so rapidly that they remain undetectable by STM. The length of the long jump depends on the average number of times that a single vacancy changes places with the indium atom as the vacancy performs a biased random walk. The root-mean-square jump length of the indium atoms is 3.5 nearest-neighbor spacings, and it can be reproduced accurately in calculations if the chemical difference between indium and copper atoms is taken into account. Van Gastel favorably compares the continuous reshuffling of the surface to an atomic version of a slide puzzle.

ERIN S. CARTER

Nanoscale Patterning of Magnetic Recording Media Allows High-Density Data Storage

With the explosion of the Information Age, the demand for disk space keeps growing; however, magnetic-media manufacturers foresee the limits of the traditional scaling approach to achieving higher area densities where the signal-to-noise ratio is maintained while increasing bit density by reducing the grain size and preserving the number of grains per bit to several hundreds. In this approach, the grains will ultimately become small enough to become thermally unstable and undergo spontaneous reversals of their magnetization direction. One method for alleviating this effect is to create patterns of single-bit domains that have increased thermal stability due to the increased magnetic-switching volume. A group of researchers at the IBM Almaden Research Center in San Jose, California, reported systematic write-and-read experiments on magnetic media patterned at densities as high as 100 Gb/in^2.

As reported in the February 12 issue of *Applied Physics Letters*, the researchers used a focused Ga^+ ion beam to cut 20-nm-wide trenches into 20-nm-thick perpendicular granular $Co_{70}Cr_{12}Pt_{18}$ recording media in order to create islands with lengths from 60 nm (100 $Gb/in.^2$) to 230 nm (10 $Gb/in.^2$). Using a static write-read tester, they have written square-wave bit patterns on these arrays of islands and found that

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