ature (9–21 K) using electrochemically etched tungsten wires for analyzing tips, in order to record the diffusion of single copper adatoms on the close-packed Cu(111) substrate. They prepared their samples by evaporating ~0.01 monolayer of copper at 15 K, a temperature at which single copper atoms are mobile, on Cu(111) substrates that were previously cleaned by several sputter and anneal cycles.

The researchers analyzed STM images showing two Cu adatoms separated by distances of up to 70 Å. More than 65,000 Cu spacing distances from a total of 3400 images were analyzed. The researchers established an oscillatory behavior of the potential energy, with a periodicity of $\lambda_F/2$, and an envelope that decays as $\sim 1/d^2$ for large separation d. The method used to determine the interaction potential was to extract it from the measured pair distribution, obtained from the time-dependence of the distance between two adatoms, correcting for geometrical effects inherent to the measuring process. The discrepancies between their experimental results and the previous theoretical descriptions of the phenomenon will help to re-evaluate the assumptions made as well as neglected terms in theoretically describing the potential energy between adatoms, and will also help to understand the growth of Cu on Cu(111) at low temperatures.

CLAUDIU MUNTELE

Nucleation and Growth Mechanism Causes Switching of Exchange Bias in Double-Superlattice System

At interfaces of ferromagnetic and antiferromagnetic films, exchange coupling results in a process called "exchange bias," in which the ferromagnetic hysteresis loop shifts. Investigators at Argonne National Laboratory, studying the exchange bias in a "double-superlattice" system, have observed reversal of direction ("switching") of the exchange bias. They attribute the switching mechanism to a breakdown into domains of the antiferromagnetically coupled (AF) superlattice by nucleation and growth, followed by complete reversal of magnetization in the layers. They reported this result, which challenges the uniform rotation model, in the October 2 issue of *Applied Physics Letters*.

Using the Fe/Cr(211) system for their study, researchers S.G.E. te Velthuis, J.S. Jiang, and G.P. Felcher combined a ferromagnetically coupled (F) superlattice consisting of 50 Å Fe and 20 Å Cr with an AF superlattice of 14 Å Fe and 11 Å Cr to form a double superlattice with the layer sequence $[Fe(50\ Å)/Cr(20\ Å)]^{F}{}_{5}/[Fe(14\ Å)/Cr(11\ Å)]^{AF}{}_{20}$. A 20-Å layer of Cr was sandwiched between the F and AF superlattices to provide a ferromagnetic inter-superlattice coupling. An artificial exchange bias (uniaxial anisotropy) was built into the system by epitaxially growing the sample onto a single-crystal MgO(110) substrate.

Magneto-optic Kerr effect measurements were performed around two critical values (-406 Oe and -447 Oe) of the turning field in the field loop, H_{min}. The hysteresis loop obtained for the -406 Oe measurements is narrow, with a bias around -38.5 Oe; the magnetization in the F superlattice reverts to its original orientation at -33.6 Oe. However, with H_{min} at -447 Oe, the F superlattice magnetization does not revert to its original orientation until 40.7 Oe, indicating that the AF superlattice has reversed its direction. Polarized neutron reflectivity measurements confirm the reversal of the AF superlattice. The fact that the bias direction switches at a value of -447 Oe, which is much lower than the 14-kOe field required to saturate the AF superlattice, or the 2-kOe field needed to initiate spin-flop transitions, indicates that a different mechanism is at work. A nucleation and growth scenario is consistent with these results; further work is under way to determine the field-dependence of the magnetic layer structure more precisely.

TIM PALUCKA

Thin Films of α-Al_2O_3 Result from the Use of an Alternative Anhydrous Solution

Thin films of crystalline α-Al_2O_3 are obtained through an innovative sol-gel process developed by Naoufal Bahlawane and Tadahiko Watanabe at the Kyushu National Industrial Research Institute in Japan. This process has the advantage of reducing the transformation temperature for α-Al_2O_3, gaining more control over the final conditions of particle shape and size. Another advantage of this process is the accomplishment of a direct conversion to α-Al_2O_3 with the use of an anhydrous

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solution. Water shifts the conversion toward α-Al_2O_3, which is a transition structure.

As reported in the September issue of the *Journal of the American Ceramic Society*, the investigators mixed high-purity aluminum isopropoxide with diethylene glycol monoethyl ether and acetic acid, and then produced the gel, which was deposited on silicon wafers. They compared two coating procedures: standard dip-coating and dip-coating combined with a fast thermal treatment.

A series of x-ray diffraction (XRD) patterns showed the development of the crystallization process in which the first crystalline phase to appear is γ-Al_2O_3 after annealing for 30 h at 700°C. Simultaneous formation of α-Al_2O_3 started after annealing for 30 h at 800°C. The amount of α-Al_2O_3 increased with temperature until it was 100% α-Al_2O_3 after annealing for 30 h at 950°C. Regarding the amount of time needed for complete conversion, the XRD pattern series showed that at 950°C, it was 10 h, at 1000°C it was 2 h, and at 1100°C it was only 1 h. These are very short times compared with standard procedures.

Concerning the differences in the applied coatings, crystallization occurs only in the coatings exposed to the rapid thermal treatment, as revealed by x-ray analysis. Bahlawane and Watanabe suggest that diffusion of Si on the film during the slow drying, observed after energy dispersive x-ray analysis of these films, prevents recrystallization of α-Al_2O_3, therefore leaving the amorphous film of Al_2O_3 and Si.

SIARI S. SOSA

Two-Dimensional Macroporous-Silicon Photonic-Crystal Waveguides with Large Mid-Infrared Transmission Bandwidth Fabricated

Researchers from the University of Toronto, the Max-Planck-Institute of Microstructure Physics, and the Massachusetts Institute of Technology have fabricated and demonstrated the operation of a new type of optical waveguide made in a photonic crystal. As they report in the October 15 issue of *Optics Letters*, their silicon waveguide efficiently guides and confines infrared light using a photonic bandgap.

A two-dimensional silicon photonic crystal was fabricated in macroporous silicon by lithography and wet etching techniques. A triangular lattice of 100-μm-long cylindrical pores, with a spacing of 1.5 μm, was formed in a silicon wafer. The resulting two-dimensional photonic crystal had a photonic bandgap (a spectral region over which the propagation of light is inhibited) spanning 3.1–5.5 μm in wavelength for light polarized along the axis of the pores. By leaving out a row of pores, a one-dimensional defect was created in the lattice, forming a narrow 1 μm waveguide cladded by the two-dimensional photonic crystal. Light from a parametric source was focused onto the entrance of the waveguide, and the transmission spectrum was measured over the bandwidth of the bulk crystal photonic bandgap.

The measured spectrum showed a very large transmission bandwidth nearly equal to that of the bulk crystal bandgap, in agreement with calculations. Furthermore, based on the agreement between theory and experiment, single-mode operation of the waveguide is predicted with a bandwidth of 10%. This bandwidth is significantly larger than that of current fiber-optic systems. These results demonstrate the use of photonic crystals to confine and guide light on the micrometer scale. Unlike traditional waveguides, which employ total internal reflection for light confinement, the photonic bandgap confinement mechanism allows for tight waveguide corners and a high density of optical integration. According to the researchers, photonic-crystal waveguides therefore represent an exciting technology for next-generation optical circuits.

JUNE LAU

Bohrium 267 Compound Found to be Volatile at 180°C

An international collaboration of radiochemists has determined the volatility of bohrium, element 107. According to their article published in the September 7 issue of *Nature*, the team, led by Heinz Gaggeler of the University of Bern and the Paul Scherrer Institute (PSI) in Villigen, Switzerland, created bohrium 267 at PSI's PHILIPS cyclotron. They used a beam of neon 22 to bombard a target of berkelium 249, which has a half-life of 320 days.

Immediately after bombardment, the reaction products were swept into an automated system where they formed molecules in oxygen-containing hydrogen chloride gas. These oxychlorides were then passed through a chromatography column, in which the more volatile species pass through at lower temperatures.

During the month-long experiment, about three atoms of bohrium were creat-

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