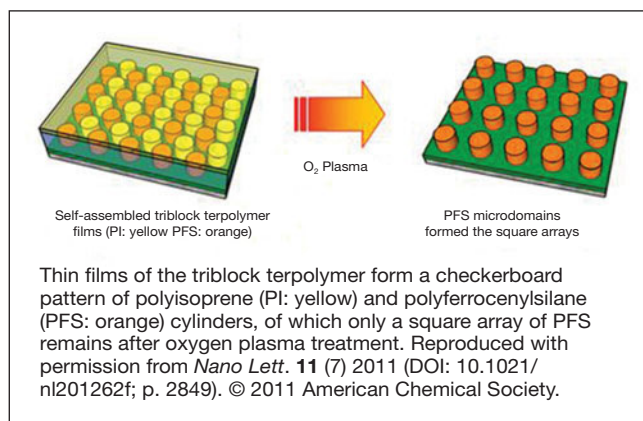


dicular to the surface. The extent of order in the resulting checkerboard pattern was honed by carefully adjusting the film thickness, the type of polymer brush, and solvent annealing. Swelling the film with the appropriate amount of chloroform allowed a relatively hydrophilic polyethylene oxide (PEO) brush to be used, whose similar interaction with all three components promoted large ordered domains of up to 1.75 μm in size. The films were then etched with an oxygen plasma, which preferentially removes the PS and PI regions to leave only a square pattern of PFS posts which etch more slowly due to their iron and silicon content.

The long-range order of the pattern was further improved by forming the block copolymer film on substrates which had been pre-patterned with walls

and posts using electron beam lithography. The substrate pattern then acted as guiding surface features. While a more neutrally interacting flat surface promotes order, these vertical features are most beneficial when selectively interacting with the PFS block, and so were coated separately with a PFS brush. In this way, posts placed sparsely throughout the grid act as surrogate PFS cylinders and enforce order on the pattern over longer distances. Square arrays



such as these are useful as etch masks through which a Cartesian grid can be transferred onto functional materials, providing a layout for minute circuitry or other nanoscale devices.

Tobias Lockwood

Two-state dynamics achieved on amorphous silicon surface

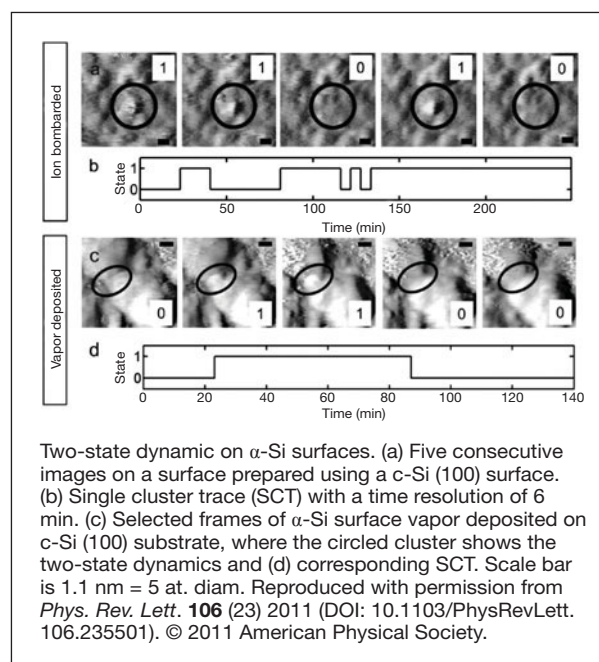
Amorphous silicon (α -Si) is widely used in the semiconductor industry for a range of device applications due to its low cost and because it is much easier to form flexible thin films than crystalline silicon. In an effort to settle the continuing debate over whether α -Si is a glass or simply an amorphous solid, M. Grubele, J. Lyding, G. Scott, and S. Ashtekar from the University of Illinois at Urbana-Champaign have attempted to observe the two-state dynamics of α -Si clusters which is characteristic of glass.

As reported in the June 10 issue of *Physical Review Letters* (DOI: 10.1103/PhysRevLett.106.235501), the researchers used low energy ion implantation and chemical vapor deposition (CVD) to create an amorphous silicon surface from a Si substrate, generating the two-state dynamics. A scanning tunneling microscope (STM) was utilized to directly observe the hopping between the two states at a temperature of 295 K (see figure). This temperature lies above the tunneling regime and below the glass transition temperature of α -Si as reported at 900 K, a universal observation of glassy behavior.

Since α -Si surfaces are normally grown with hydrogen incorporated into the structure, the researchers passivated the α -Si surfaces with 1% hydrogen. With the addition of hydrogen, a two-state motion was not observed, which was attributed to the fact that hydrogenation quenches the two-state dynamics by relaxing the surface to lower energy structures. Hydrogen passivation caps the most strained, least-bonded Si atoms to lower the surface free energy, thereby reducing two-state dynamics. Furthermore, the surface showed signs of crystallization including larger clusters, cracks, and highly structured patches. Cracks indicate that the density of the remaining α -Si surface increased, as expected if strain is relieved. The crystalline patches ranged from just a few atoms to hundreds of atoms in surface area, consistent with a Si(111) surface structure, the lowest energy surface

structure for Si. Blobs observed on the surface indicated the merging and undercutting of the surface structure as a result of a reaction with hydrogen. Thus hydrogen passivation has major structural and dynamical consequences.

This research provides an improved understanding of the glassy behavior of amorphous silicon. Although two-state dynamics hopping has been pre-





dicted by theory, and many researchers have inferred it indirectly from measure-

ments, this is the first time this type of two-state dynamics has been visualized,

said the researchers.

Jean Njoroge

Nano Focus

At small scales, tug-of-war between electrons may lead to magnetism

Magnetism plays a central role in the development of many exciting new technologies including lasers, medical imaging devices, and computers. As such, there is a continued need to further understand and exploit this phenomenon. Now, R. Oszwaldowski and I. Zutic of the University at Buffalo and A. Petukhov of the South Dakota School of Mines and Technology have proposed that, at very small scales, it may be possible to create a quantum dot that is magnetic under surprising circumstances.

As reported in the April 29 issue of *Physical Review Letters* (DOI: 10.1103/

PhysRevLett.106.177201), the researchers describe a theoretical scenario involving a quantum dot that contains two mobile electrons with opposite spins, along with manganese atoms fixed at precise locations within the quantum dot. The mobile electrons act as “magnetic messengers,” using their own spins to align the spins of nearby manganese atoms.

Under these circumstances, conventional thinking would predict that each electron would exert an equal (but of opposite sign) influence over the spins of the manganese atoms such that neither is able to “win.” However, the researchers show that the quantum dot’s two mobile electrons actually influence the manganese spins to different degrees.

This occurs because while one mobile electron prefers to stay in the middle

of the quantum dot, the other prefers to locate further toward its perimeter. As a result, manganese atoms in different parts of the quantum dot receive different messages about which way to align their spins.

In the “tug-of-war” that ensues, the mobile electron that interacts more intensely with the manganese atoms aligns more spins, which causes the entire quantum dot to become magnetic.

This prediction, if proven, could “completely alter the basic notions that we have about magnetic interactions,” Zutic said. Studying how magnetism works on a small scale is particularly important, Zutic said, because “we would like to pack more information into less space.”

Mid-infrared single-mode waveguides may allow detecting Earth-like exoplanets that show biological activity

Nulling interferometry operating in the mid-infrared (IR) range is one of the techniques being considered for the search of Earth-like exoplanets that may show biological activity. At these wavelengths many life-marker gases present absorption bands, and at the same time, the overwhelming flux of the parent star can be minimized. However, single-mode waveguides need to be used in this approach since they allow high angular resolution while reducing the star flux by ~50 dB. This may allow high spatial resolution measurements of the weak signals from biological activity to be observed against the high background of the light from the star. With this objective in mind, C. Vigreux, E. Barthélémy, and A. Pradel from the Université Montpellier II, in collaboration with L. Bastard and J.-E. Broquin from

Minatec-INPG (Grenoble), M. Barillot and S. Ménard from Thales Alenia Space (Cannes), and G. Parent from Nancy-Université, France, fabricated single-mode waveguides operating in the 10–20 μm range based on Te-Ge-Ga glasses.

As reported in the August 1 issue of *Optics Letters* (DOI: 10.1364/OL.36.002922; p. 2922), the researchers selected this family of glasses because they are transparent between 6 μm and 20 μm wavelengths, films of these materials can be produced by thermal evaporation, their refractive index can be tuned according to their chemical composition, they present good stability, and they do not involve highly toxic or very volatile elements. In particular, the researchers chose $\text{Te}_{75}\text{Ge}_{15}\text{Ga}_{10}$ as the substrate due to its thermal stability and its relatively low refractive index (3.3960 ± 0.0015 at 10.6 μm), and $\text{Te}^{82}\text{Ge}^{18}$ as the waveguide core layer, since it provides a refractive index difference with the substrate of $\Delta n = 4 \times 10^{-2}$ and allows design of an efficient aperture for the coupling optics of 1.

With these components, the researchers designed single-mode rib waveguides operating in the 10–20 μm range, that they fabricated by depositing the $\text{Te}_{82}\text{Ge}_{18}$ core layer on $\text{Te}_{75}\text{Ge}_{15}\text{Ga}_{10}$ polished glass disks using thermal co-evaporation. They then used standard UV photolithography to define the rib waveguides, and transferred the pattern to the core layer by reactive ion etching under an atmosphere of a mixture of CHF_3 , O_2 , and Ar to achieve a depth of 9 μm . Finally, they polished the input and output facets to obtain the waveguide.

The researchers reported that the overall transmission of these waveguides varies between 15% and 35% for a 1-cm-long device, after correcting from coupling and Fresnel losses, a value they considered very promising to prove the potential of the technology developed. In the future, the research team plans to use these waveguides as a wavefront filter on a nulling interferometer.

Joan J. Carvajal