about the perpendicular bisecting plane.

When an extra CO molecule is added to CuCO and FeCO, the topographical images displayed symmetry. However, the plane containing the $Fe(CO)_2$ molecule is orthogonal to the plane containing the $Cu(CO)_2$ molecule.

Detailed information of chemical bonding was provided by single-molecule vibrational spectroscopy using the STM. Different stretched and hindered rotation energies of CO molecules were obtained by using different C and O isotopes. This way, a basis of Cu/Fe comparison was established.

The Cu/Fe carbonyl molecules may be deconstructed the same way they are made. Deconstruction, however, is a less controlled procedure. In the case of $Cu(CO)_2$, the tip picked up one CO molecule (at 100 nA and 250 mV) and dropped it off. When the tip returned for the second CO molecule, however (at 100 nA and 500 mV), the molecule's whereabouts were less precise. For the case of $Fe(CO)_2$ and FeCO, the tip had difficulty picking up the CO molecule, even at 1 V and 100 nA.

According to the researchers, this study demonstrates the utility and versatility of the STM. In addition, atomic-scale manipulation of molecules using the STM can provide a new means of nanofabrication.

JUNE LAU

Accelerated Aging of Concrete and Triaxial Test Provide Insight for Long-Term Safety of Nuclear-Storage Containers

At a meeting of the American Society of Civil Engineers held in May in Austin, Texas, Franz-Josef Ulm of the Massachusetts Institute of Technology (MIT) presented the work of his team on determining the long-term safety of concrete for holding nuclear waste. The current laboratory test can predict aging to about 300 years. While this accelerates concrete aging by a factor of 3 over what other researchers have achieved, Ulm, the Gilbert T. Winslow Career Development Associate Professor of civil and environmental engineering, is confident that the work can be further extrapolated to over 1,000 years.

Concrete weakens over time when water leaches calcium from the material, and calcium is what gives concrete its strength. To accelerate the leaching process, the researchers from MIT and the Commissariat à l'Energie Atomique in France replaced the water with a highly concentrated solution of ammonium nitrate, which caused the calcium to leach at a much higher rate. They coupled this with an oscillating table that ensured an even concentration of solution around each sample.

To expose the weathered materials to stress, the team placed samples into a triaxial high-pressure steel chamber that applied pressures up to 10 MPa from all sides. When they applied a shear, or slightly larger stress from one side, slivers of the material slipped apart.

The researchers found a significant loss of frictional performance in the artificially aged cement paste. The leached calcium left large pores that collapsed under the pressure, allowing the material to slip apart.

Ulm said that the microstructure of the leached cement paste, as visualized with an environmental scanning electron microscope, "showed a strong similarity to that of osteoporotic trabecular bones."

Photo-Induced Densification Causes Refractive-Index Modulation in Ge-Doped Silica Fibers

The photosensitivity effect is a nonlinear optical phenomenon that has been used to describe the alteration of the refractive index of an optical fiber when exposed to ultraviolet (UV) radiation. Two mechanisms have been proposed to explain the effect: the creation of color centers and structural transformations resulting from densification of the optical fiber. While both mechanisms have been observed experimentally, their relative importance in a given optical system has been a subject of much discussion. In the June 15 issue of *Optics Letters*, A.I. Gusarov of the Faculté Polytechnique de Mons in Belgium and D.B. Doyle of the European Space Research and Technology Center in The Netherlands have come down firmly on the side of UV-induced densification in the Ge-doped silica fiber system.

Observing that the effect of density variation on the refractive index results from a combination of inelastic structural transformations and photoelastic transformations, the researchers first performed analytical calculations to model the stress distribution, resulting from inscription of a fiber grating, in an optical fiber. They then compared the model with experimental measurements to determine the contribution of densification to the changes in refractive index. By scanning a 3-μm-diameter laser probe across the fiber to measure stress-induced birefringence parallel and orthogonal to the fiber axis, they obtained axial stress values averaged over the grating period. Experimental values of $(0.8 \pm 0.2) \times 10^{-11}$ m^2 N^{-1} compare favorably with the calculated value of 0.96×10^{-11} m^2 N^{-1}. The slightly higher computed value was attributed to the saturation effect. The experimentally induced axial stress of 124 MPa corresponds to a mean densification of 0.82%, yielding a calculated mean value of 0.99×10^{-3} for the index-modulation amplitude versus a measured value of 0.96×10^{-3}. The researchers conclude that this correlation clearly demonstrates that density changes account for the majority of the photosensitivity effect in the Ge-doped silica system, with color-center creation having little or no contribution.

TIM PALUCKA

Elimination of Secondary Nucleation and Grain Coarsening May be Key to Controlled Thin-Film Morphologies

Controlling the morphology of molecular thin films on substrates is a key factor in determining the interfacial properties of the films and their possible technological applications. The currently preferred epitaxial growth of self-organizing molecules on crystal surfaces has some drawbacks: Mosaics of domains can form, and growth patterns can change from layered, two-dimensional structures to granular, three-dimensional ones with thickness. Such limitations have been attributed by various investigators to grain coarsening, Ostwald ripening, and secondary nucleation. In an article published in the June 15 issue of *Physical Review B*, researchers from the Consiglio Nazionale delle Richerche—Istituto di Spectroscopia Molecolare in Bologna, Italy, and of the Universitá della Calabria have reported the controlled growth of correlated droplet patterns of mesoscopic (100–1000 nm) dimension and narrow size distribution.

Thin films of the polar conjugated molecule tris(8-hydroxyquinoline) aluminum III (Alq_3) were grown onto passivated Si(100) crystal surfaces by high-vacuum sublimation. The substrate temperature was varied between 30°C and 150°C at a constant deposition rate; the thickness and morphology of the films were determined using scanning force microscopy.

Time-evolution studies of the deposition showed that the number of droplets per unit area is independent of time and therefore coverage, but is strongly dependent on the substrate temperature. This indicates the absence of secondary nucleation and coarsening phenomena. The investigators explain the results using the Capture Zone (CZ) model, in which a Voronoi mosaic forms, based on the initial distribution of nuclei on the substrate. The nuclei grow only by incorporating (that is, capturing) impinging molecules—since coarsening phenomena are absent—so the CZ mosaic is invariant. Good correlation

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between the area of a given droplet and the average area of its nearest neighbor indicates a narrow size distribution. Similar correlation between individual droplet radii and the corresponding distances to the nearest neighbor indicates a long-range repulsion between droplets that scales with droplet size. This repulsion may be responsible for the absence of coarsening effects. Further understanding and refining of this model could lead to better control of thin-film morphologies.

TIM PALUCKA

Method Developed for Ultraprecise Optical Frequency Measurements

Researchers from the National Institute of Standards and Technology (NIST) and Lucent Technologies/Bell Labs have produced an "ultraprecise" method for measuring the frequency of visible and infrared light. Reported in the April 28 issue of *Science*, the technique uses a single laser to measure optical frequency instead of a cumbersome and expensive multiple-laser system. The measurements made by the NIST/Lucent system have a higher level of precision than conventionally derived ones because they are directly compared to the well-defined primary frequency standard of a cesium-133 atomic clock.

The researchers "locked" an rf-clock-stabilized titanium-sapphire laser in a manner that generated a repetitive train of ultrashort optical pulses, referred to as a "repetition frequency." Each pulse contains only about 3 cycles of light. The output spectrum of such a laser is a series of sharply defined spectral lines separated by the repetition frequency. The scientists call this spectrum a "comb" because it has the appearance of a common pocket comb.

Ordinarily, there would be no fixed relationship between the envelopes of the pulses and the waves of the laser light, but in this work, the envelope and the waves are locked together with a controlled phase relationship. In addition, the repetition rate of the pulses is locked to the standard cesium microwave frequency (9.2 GHz). This makes it possible to determine the absolute frequency of each of the "teeth" of the comb and provides a means of measuring optical frequencies with a single laser.

A visible continuum of light-wave frequencies is generated within a novel fiber with an air/silica microstructure. Light is very tightly confined to the glass fiber's solid core by a ring of air holes surrounding the core. This unusual fiber creates an extremely small effective area, possesses characteristics for light dispersion, and keeps light loss to a minimum. This allows for the generation of a frequency continuum with only 1/1000 of the power previously needed.

A similar effort by the NIST/Lucent team in conjunction with a team from the Max-Planck-Institut für Quantenoptik is reported in the May 29 issue of *Physical Review Letters*, and the Max Planck group also has an article on this technique scheduled to be published in the July 15 issue of *Optics Letters*. □

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