ciency of these organic PV cells, the researchers found "that materials choice is an important route to cell optimization." Hence, not only has efficiency been improved, but also the understanding of these devices.

PAMELA JOHNSON

### The Femtosecond Transient Absorption Signal of UV-Grade Fused Silica Contains Third- and Fifth-Order Nonlinearities

Femtosecond transient absorption pump-probe spectroscopy and numerical simulations show interference between the third- and fifth-order nonlinear susceptibilities ($\chi^{(3)}$, $\chi^{(5)}$) of ultraviolet (UV)-grade fused silica. Katrin Ekvall of the Royal Institute of Technology in Stockholm and Cecilia Lundevall and Peter van der Meulen of Stockholm University have obtained values for the second-order nonlinear refractive index and the three-photon absorption (3 PA) coefficient from $\chi^{(5)}$.

As reported in the June 15 issue of *Optics Letters*, a compact Ti:sapphire amplified fs laser system produced ~850 μJ, 160 fs pulses centered at 775 nm. A 0.2-mm-thick Type I β-barium borate second-harmonic generation crystal frequency doubled the fundamental pulse to produce a pump pulse with $\lambda = 387.5$ nm.

White light continuum probe and reference pulses were obtained by focusing a small fraction of the fundamental pulse in a thin rotating fused-silica plate. Both the third- and fifth-order material responses produce large signals in the detected region.

The intensity of the pump pulse was varied from 90 to 160, 210, and 270 GW/cm$^2$ by rotating a zero-order half-wave plate in front of the β-barium borate crystal.

At the lowest intensity, the transient absorption signal was W-shaped. At higher intensities the curve developed an extra dip and the signal increased. The researchers describe the signal as a superposition of three contributions: the real part of $\chi^{(3)}$, dominant at the lowest intensity; a similarly shaped effect with opposite sign from the real part of $\chi^{(5)}$, which produces the dip at higher intensities; and the imaginary part of $\chi^{(5)}$, corresponding to 3 PA.

The researchers numerically solved the probe propagation equation in the presence of third- and fifth-order nonlinearities, obtaining the probe amplitude after propagation through the sample. They calculated the pump-probe signal as a function of probe wavelength and the delay time between the pump and the probe.

A comparison with the experiment gave the real and imaginary parts of $\chi^{(5)}$. The real part is $-5.1(\pm0.7) \times 10^{-41}$ m$^4$/V$^4$, which gives for the second order nonlinear refractive index $-3.3(\pm0.4) \times 10^{-41}$ m$^4$/V$^4$. The error is due to the uncertainty in pump intensity. The imaginary part of $\chi^{(5)}$ is $2.1(\pm0.3) \times 10^{-41}$ m$^4$/V$^4$, which gives for the 3 PA coefficient $5.2(\pm0.7) \times 10^{-29}$ m$^3$/W$^2$. The simulations did not accurately reproduce the measurements at the highest optical pump intensity, indicating the possibility that even higher order processes may play a role in the nonlinear optical response of this glass.

ELIZABETH A. SHACK

### Photopatterned Films of Discotic Liquid Crystals Demonstrate Polarized Photoluminescence

The ability to control the orientation of liquid crystals (LCs) is needed to optimize their properties for use in display devices. As reported in a communication for the May issue of *Chemistry of Materials*, in a collaborative effort led by Kunihiro Ichimura of the Tokyo Institute of Technology, researchers used a micropatterned film of discotic liquid crystals (DLCs) to demonstrate the first observation of their polarized photoluminescence (PL).

To date, research in the field of DLCs trails that of calamitic liquid crystals (CLCs) due to the relative difficulties of assembling well-defined DLCs. This is due to the high viscosity of DLCs, and their high mesophase temperatures. To overcome these obstacles, the researchers first assembled a thin film that aided orientation, followed by a heating method which aided in the ordering of the liquid crystals (DLCs).

The researchers first assembled a thin film (25 nm) by spin-coating a 1.0 wt% solution of poly[4-(4-cyanophenylazo) phenoxyl methacrylate] (**A**) on a silica plate. This thin film was then subjected to nonpolarized 436-nm light of 3.0 J cm$^{-2}$ fluence with an angle of 45°, which induced photodichroism. Annealing **A** at 240°C for 30 minutes then enhanced the anisotropy of the film. Micropatterning of the DLCs was achieved by photoirradation through a photomask upon **A** before the addition of DLCs.

This prepared film aided in the organized assembling of the DLCs. Next, two DLCs were spin-cast onto the thin film **A**: both pentakis[(4-alkylphenyl)ethyl]benzene derivatives, labeled as **DLC-1** and **DLC-2**. The films were heated and supercooled, which preserved and aided in the orientation of both **DLC-1** and **DLC-2**. A study of the three-dimensional orientation revealed that both DLCs have homeotropic alignments, with angles of 70° from the surface **A**. This was demonstrated by monitoring the azimuthal retardation as a function of the angle of incidence of the probe light, which yielded asymmetrical plots.

To further probe the alignment of the DLC films, PL measurements illustrated the outermost DLCs' alignment at a microscopic level. This alignment was found to be an opposite tilt to the actinic light propagation. When **DLC-1/A** was irradiated under nonpolarized 340-nm excitation at 20° to the surface normal, distinct *s*-polarized, and *p*-polarized PL absorbances were demonstrated. Both intensity peaks were at ~460 nm, despite the nonpolarized excitation. The *s*-polarized/*p*-polarized intensity ratio was ~3. These results show that the 3D ordering of the preliminary **A** film was transferred to the DLCs' surface.

Also included in this report is an image of the micropatterned DLC films under PL, demonstrating both *s*-polarized and *p*-polarized PL, while visually demonstrating the propensity for applications in display devices. These DLCs were shown to be stable in ambient conditions for greater than six months. This communication demonstrates an investigation into the orientation of DLCs via PL, and a possible fabrication technique that results in better control of such orientation. Better orientational control of DLCs will enhance the performance of DLC-based devices such as thin film displays.

MATHEW M. MAYE

### $SrTiO_3$ Single Crystals Achieve 8% Plastic Strain When Tested in Compression at Room Temperature

Ceramic oxides tend to fail mainly by brittle fracture at ambient or low-temperatures, due to the ionic and covalent nature of the atomic bonding. However, a group of researchers from the Max Planck Institute in Stuttgart has obtained plastic deformation in compression from $SrTiO_3$, a ceramic oxide with a perovskite structure. The researchers observed a ductile–brittle–ductile transition when testing in a range of temperatures from 78 K to 1800 K, as reported in the May issue of the *Journal of the American Ceramic Society*. The samples were ductile in the temperature ranges from 78 K to 1050 K and between 1500 and 1800 K, and brittle between 1050 K and 1500 K.

In order to gather basic information about the nature of the deformation mechanism on this material, the researchers tested single crystals of $SrTiO_3$ oriented with the ⟨001⟩ axis parallel to the compression axis. Tests were conducted in air



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above room temperature. For lower temperatures, alcohol cooled by dry ice ($CO_2$) or liquid nitrogen were used to lower the temperature of the samples.

Samples tested at temperatures above ~1500 K showed ductilities up to 7%, and no work hardening. The yield stresses in that range increased with decreasing temperature. At ~1500 K there was a transition to a brittle behavior, and the fracture stresses decreased with decreasing temperature until ~1050 K. Below ~900 K down to room temperature, ductilities up to 8% were again observed, but the flow stress remained constant in all tests. At lower temperatures, a continuous increase in the flow stress with decreasing temperature appeared, but not as accelerated as in the tests at high temperature. The researchers observed that this behavior is similar to that of $Mg_2GeO_4$ olivine and some intermetallics with an $Ll_2$ structure.

Observations of a sample tested at room temperature under transmitted polarized light showed evidence of birefringence bands. Plastically deformed samples tested below ~900 K typically exhibit these bands. These features were not detected in samples tested above 1500 K.

Studies about the slip systems acting in this ceramic are limited, and subsequent transmission electron microscopy (TEM) observations become necessary to determine the characteristics of the dislocation activity and its relationship with the flow process. Preliminary observations from this investigation show dislocation dipoles and stacking faults. The researchers expect to later present their results on extensive TEM observations performed in these specimens.

SIARI S. SOSA

## Hassium Confirmed as Group VIII Member in Periodic Table

A team of researchers has established that element 108, hassium, forms a gaseous oxide similar to that of osmium, confirming that hassium, like osmium, is a member of Group VIII of the periodic table and should be placed directly under it. Heino Nitsche of Lawrence Berkeley National Laboratory, who is also a professor of chemistry at the University of California—Berkeley, directed the development of a very low temperature technique for separating and detecting oxides from Group VIII. The researchers used a heavy ion accelerator at the Gesellschaft für Schwerionenforschung (GSI) in Darmstadt, Germany.

Hassium does not exist in nature but must be created one atom at a time by fusing lighter nuclei. Energetic magnesium-26 projectiles bombarded targets of curium-248, a rare artificial isotope prepared for the experiment. Multiple curium targets were mounted in a rotating wheel system. The hassium atoms formed by impacts between target and beam reacted with oxygen to form hassium oxide molecules. The single molecules were carried through the detector by a stream of helium and immediately condensed on semiconductor diodes, arranged in rows and maintained at temperatures graded from -20°C to -170°C.

## Laser Beam with Spiral Interference Pattern Allows Controlled Rotation of Micro-Objects

By combining an annular-shaped laser beam with a reference beam, researchers from St. Andrews University in Scotland have devised a way to use optical forces to spin microscopic objects without damaging them. This system may give researchers an unprecedented amount of control for manipulating components of micromachines. So far, the scientists have demonstrated their technique with glass beads 1 µm across, a 5-µm-long glass rod, and a chromosome.

The technique devised by Kishan Dholakia and his colleagues relies on much of the same physics as do the well-established optical tweezers. In both cases, a particle gets trapped in the path of a light beam because some of the light refracts when it hits the object. This changes the momentum of the light, and, in turn, the momentum of the object, which gets attracted toward the spot in the beam where the light is most intense.

Instead of using a simple, single beam, Dholakia's group used two laser beams that combined (interfered with one another) to form a light beam with phase fronts in the form of a spiral. As reported in the May 4 issue of *Science*, this spiral "interference pattern" formed as the light waves that were in step with each other merged, while those out of step canceled each other out. The pattern is a spiral as the annular shaped beam had helical phase fronts. Driven by the same forces involved in optical tweezing, an object was trapped in an arm of the spiral (the brightest regions of the pattern).

The scientists then manipulated the orientation of one of the light beams, specifically changing the path length between them. This caused the spiral interference pattern between the two beams to rotate about its axis. Because the object was caught in the most intense part of the beam, it rotated as well. The researchers achieved rotation speeds over 5 Hz. The minimum optical power needed to rotate the objects is 1 mW.

"The beauty of our technique is that we can dictate how far we want the spiral pattern to go around and at what speed. That means we can fully control the rotation of that one particle," Dholakia said.

"Our technique could be used to drive motors, mixers, centrifuges, and other rotating parts in cheap, tiny, automated technologies of the future," he said.

## Noncontact Method Aligns Liquid Crystal Molecules

Researchers at IBM have demonstrated a noncontact method that uses ion beams to align the liquid-crystal molecules inside flat-panel liquid-crystal displays (LCDs) for the display industry. Praveen Chaudhari and his research team replaced the ubiquitously used polyimide film currently used by the industry with a diamond-like carbon (DLC) film and the rubbing roller by a directed atomic beam.

As reported in the May 3 issue of *Nature*, the first step in this method is to deposit a thin layer of DLC (3–4-nm thick). Next, low energy atoms are shot by an ion gun at an angle to the surface of the substrate. This introduces orientational order by a selective process in which the rings of the DLC film that are perpendicular to the ion beam are preferentially destroyed compared to those parallel. The net result is an excess amount of rings whose planes are parallel to the direction of the ion beam. These rings then produce alignment of the rod-shaped liquid crystals.

This noncontact method eliminates many problems associated with the current rubbing method. Rubbed displays must be removed from the clean room manufacturing line to avoid contamination from the velvet cloths used in rubbing. Then they must be washed and baked to eliminate contaminants before returning to the manufacturing line. Furthermore, worn velvet cloths are replaced periodically, interrupting the manufacturing process. Defects caused by the rubbing process cannot be detected until much later in the manufacturing process, when they are difficult or impossible to correct.

The noncontact method is built into the clean manufacturing line, eliminating those extra steps. A noncontact alignment process has been the goal of liquid-crystal display technologists for over two decades since the high-resolution displays were envisioned. □



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