

temperature for 1 h. It was then ground and polished to 0.5 mm thick.

SHG was obtained by pulses of 3.6 ns at 1.064  $\mu\text{m}$  (beam  $\omega$ ) and 3 ns at 532 nm (beam  $2\omega$ ) from a Q-switched Nd:YAG laser. The samples were prepared with both beam  $\omega$  and beam  $2\omega$  incident. The samples were probed with beam  $2\omega$  blocked. Behind the sample, two heat-absorbing filters and a 532-nm bandpass filter allowed a photomultiplier to detect only the SHG signal with beam  $2\omega$  blocked. The signal was averaged by an oscilloscope.

The intensity of SHG, normalized by the maximum intensity of second-harmonic waves from 1-mm-thick Y-cut quartz, increased rapidly and saturated after 50 min. The maximum intensity was seven times larger than that of the quartz and four orders of magnitude larger than that of  $15\text{Nb}_2\text{O}_5\text{-}85\text{TeO}_2$  under the same optical poling conditions. As-made samples showed no SHG.

The signal from the chalcogenide glass was stable, unlike other glasses. The signal from  $\text{Bi}_2\text{O}_3$ -based glasses decreased to 80% after 10 min. For  $15\text{Nb}_2\text{O}_5\text{-}85\text{TeO}_2$ , the signal decreased to 5% after 10 min.

The researchers suggest that the non-linear coherent field of  $\omega + 2\omega$  creates free electrons that are trapped by active sites in the glass, which breaks the inversion symmetry of the microstructure and allows SHG.

Selecting the proper glass composition could increase the conversion efficiency and stability of the SHG, the researchers said. They believe that with their technique "it is possible to achieve practically useful nonlinear optical frequency-conversion devices with a chalcogenide glass fiber."

ELIZABETH A. SHACK

### Nonvolatile Memory Observed in Chromium-Doped $\text{SrTiO}_3$ Single Crystals

Materials that exhibit reversible resistive switching are potential candidates for random-access memory (RAM). Various metal-insulator-metal-oxide structures display switching and show memory retention of more than 18 months. Y. Watanabe and colleagues, members of the IBM research team at Zurich Research Laboratory, examined single crystals of one such oxide, Cr-doped  $\text{SrTiO}_3$ . Using these single crystals as a model system, the researchers determined that microstructural defects in the thin films are not a significant contribution to the switching effect. Instead, the researchers conclude that a bulk electronic change is necessary for memory switching to occur.

As reported in the June 4 issue of

*Applied Physics Letters*, at 4 K the crystal has an initial resistance of 1  $\text{G}\Omega$  up to 100 V. Sweeping to 200 V causes a drop in resistance leading to a hysteretic current-voltage characteristic. Stressing the crystal with pulsed or dc voltage causes an additional resistance drop by several orders of magnitude. This creates a conductive state which allows for memory switching. By applying a positive voltage pulse, the oxide is switched to a low-impedance state with a resistance of 500  $\Omega$ . Applying a negative voltage erases the "information" written to the device and switches the oxide back to a high-impedance state with a resistance of 5000  $\Omega$ . This effect is also seen at room temperature. Once the conductive state is established, the switching behavior of the single crystal is reproducible. After more than  $10^5$  read pulses, no change in the readout signal was seen, indicating that these single-crystal oxides have the potential to be alternative non-volatile RAM.

The conductive state is created by exposing the insulating crystal to high voltages. During temperature cycling experiments, the low state tended to change to the high state. This suggests to the researchers that the conductive state originates from an excessive amount of injected carriers. This was verified by Cr-doped  $\text{SrZrO}_3$  thin-film experiments. A good scaling of the current versus electrode area from 0.5 mm square to 100 mm square is observed, which indicates to the researchers that this is not a defect-dominated process. The researchers said that the high resistance of the single crystal at low voltage confirms that the bulk determines the current flow across the insulator and that the transition to the conductive state originates from a change in the bulk property.

JENNIFER L. BURRIS

### (Pb,Sr) $\text{TiO}_2$ Thin Films Prepared by LSMCD as Potential DRAM Materials

Researchers at the Department of Chemical Engineering at the Korean Advanced Institute of Science and Technology and Samsung Electronics Co. have prepared high-quality thin films of (Pb,Sr) $\text{TiO}_2$  (PST) on Si wafers and Pt-coated Si wafers by liquid source misted chemical deposition (LSMCD). Seong I. Woo and co-workers found that LSMCD produced high-quality films that exhibited a high dielectric constant, good paraelectricity, and low dielectric loss after annealing at a relatively low temperature of 550°C. According to the researchers, these properties make the "PST thin film a promising material for ULSI-DRAM [ultralarge-scale integration dynamic random-access memory] capaci-

tors and other microelectronic device applications."

As reported in the May 2001 issue of *Chemistry of Materials*, the researchers used lead acetate, strontium acetate, and titanium isopropoxide as the metallic precursors for the film. A solution of the precursors in acetic acid and 1-butanol was misted using an ultrasonic nebulizer and the mist transported to the deposition chamber by a stream of argon. The films were grown on Si(100) wafers and Si(100) wafers coated with 100 nm of Pt. The films were baked at 400°C for 10 min and annealed between 500°C and 700°C for 5 min. All heat treatment was performed in air. Films with thicknesses of 60, 90, and 130 nm were prepared.

Scanning electron micrographs of the PST films revealed smooth, dense, and uniform surfaces devoid of any gaps or cracks. X-ray diffraction and Auger electron spectroscopy also showed that the polycrystalline film exhibited uniform grain size and composition throughout its thickness. Wavelength dispersive spectroscopy was used to confirm that the composition of the film was identical to the composition of the precursor solution used for misting.

Measuring the capacitance and current as functions of applied voltage in the PST showed that the films exhibited paraelectric behavior, low leakage currents, and high dielectric constants. The researchers predict that the leakage current and paraelectricity in the films could be further improved by postannealing under oxygen and reducing the amount of Pb in the films, respectively. The electrical properties measured for the PST films compare favorably to those of (Ba,Sr) $\text{TiO}_2$  (BST) films, which are considered the most promising material for ULSI-DRAM capacitors. The BST films, however, must be annealed at 700°C while PST films can be annealed at 550°C. This reduction of annealing temperature is important in electronics fabrication because high annealing temperatures can damage sensitive electronic components.

GREGORY KHITROV

### Self-Assembled Diblock Copolymers Applied in Semiconductor Capacitor Fabrication

Advances in microfabrication technologies over the last few years have allowed reductions in the physical size of integrated-circuit (IC) components. Shrinking the size of the memory cell has facilitated dynamic random-access memory (DRAM) chips with near-gigabit storage capacities while maintaining similar sizes to their 1-MB