dimensional impurity channel (2DIC) on the bottom side of the quantum well. The peaks observed in the IQHE regime of the 2DEG reflect the resistivity of the 2DIC (ρ_{xx}^{2DIC}). In that regime, the coupling between the two channels leads to a nonequilibrium charge distribution in the 2DEG with very long RC characteristic times, which causes the peak phenomena to last for a long time. The influence of the 2DEG nonequilibrium charge distribution on the 2DIC resistivity pattern is observed as the hysteretic peaks. The density of 2DIC, estimated at about 5.7×10^{10} cm^{-2}, can drop below the conducting limit when a negative bias is applied to the back-side gate, causing the hysteresis to disappear.

WIRAWAN PURWANTO

Lattice-Dynamics Properties May Explain Low Dielectric Constant of Thin Films

Soft-mode phonons are known to play a key role in the physics of ferroelectrics. The softening of one particular phonon usually results in a dramatic increase in the dielectric constant and an appearance of the ferroelectric phase. The relative variation of the soft-mode frequency with the dielectric constant is fully described by the Lyddane–Sachs–Teller (LST) formula.

Researchers from The Pennsylvania State University and Max Planck Institute for Solid State Research have reported in the March 23 issue of *Nature* the relationship between the lower dielectric constant of thin films and the reduced softening of the lowest optical-phonon mode. This research may explain the mechanism of low dielectric constant in thin films.

After applying the dead-layer model—which takes into account interface effects and results in a decrease of the average dielectric constant—to derive a temperature-dependent dielectric constant for thin $SrTiO_3$ (STO) films, the researchers found that the model was not able to accurately describe the measured dielectric constants. According to the researchers, lattice-dynamics studies are necessary for a better explanation of the lower dielectric constant of thin films.

The researchers used pulsed laser deposition to prepare the samples: They heated the substrate to 720°C in an oxygen pressure of 100 mTorr, then cooled the as-deposited film to room temperature in 400 Torr of oxygen. They then deposited STO films with thicknesses of 0.5, 1, and 2 μm on a 0.35-μm conducting oxide $SrRuO_3$ buffer layer.

Although the researchers observed optical-phonon peaks in STO films by means of conventional Raman scattering, the soft mode (the lowest optical mode) was not detected in this way. For this reason, they carried out far-infrared ellipsometry measurements at the National Synchrotron Light Source. Taking advantage of the high brightness of the synchrotron and Fourier transform infrared (FTIR) spectroscopy, the complex dielectric functions had been directly measured in the frequency range of 30–700 cm^{-1} and at a temperature range of 5–300 K.

From the plots of the real and imaginary parts of the measured complex dielectric constants versus wave numbers, the soft-mode optical TO1 (transverse) phonon has been clearly observed, as well as other TO modes. It proved the feasibility of the experimental method.

In order to acquire the frequency of the soft mode, the researchers fit the experimental spectra to the dielectric function that takes into account the contribution of the phonon broadening. They found that the eigenfrequency of the soft mode (TO1) decreases as the temperature is lowered and saturates at 13 cm^{-1} instead of 62 cm^{-1} for the bulk crystal. On the other hand, similar eigenfrequencies of other longitudinal (LO) and TO modes have been observed both in the thin film and the bulk.

By comparing the results with the LST formula, the researchers observed the correlation between the harder soft mode in the thin film and a lower static dielectric constant. The LST relation between the optical-phonon eigenfrequencies and the static dielectric constant has been found to be fully maintained in thin films like $SrTiO_3$ as well as in the bulk material. The researchers further said that "besides the dead-layer effect, the lower dielectric constant in STO thin films is due to their fundamental lattice dynamical properties—specifically, the soft-mode hardening."

In their discussion of the physical mechanisms for the soft-mode hardening, the researchers found that local strain and defects play key roles.

JIDONG HOU

Chiral Diarylethene Dopant Induces Large Photostimulated Pitch Change in Nematic Liquid Crystals

In an effort to explore photostimulated reversible phase changes in liquid crystals, researchers at Osaka Prefecture University, Kyushu University, and CREST have developed a new photoactive chiral chromophore—that is, a chiral cyclohexane containing two diarylethenes. In the April issue of *Chemistry of Materials*, the researchers refer to this compound as compound **1**. They explored the photoisomerization of compound **1** and its influence on the properties of a doped nematic liquid crystal and observed a large and stable photostimulated pitch change in a chiral nematic phase induced by this compound.

With UV light irradiation (a mercury lamp, 254 nm, 10 W), the researchers converted open-ring isomers of compound **1** to stable closed-ring isomers. Irradiated by visible light (a halogen lamp, $\lambda > 480$ nm, 100 W), the closed-ring isomers were switched back to open-ring isomers. The researchers doped a 1.0 wt% open-ring isomer of compound **1** into a nematic liquid-crystalline material, 4-cyano-4'-pentylbiphenyl (K-15), at 26°C and achieved an apparent nematic phase. An induced cholesteric phase (chiral nematic phase) resulted at content higher than 5.0 wt%. When the doped liquid crystal (1.0 wt%) was irradiated with UV light for 3 min, the original stable nematic texture turned into a cholesteric fingerprint pattern (observed by a polarization microscope) and the pitch of the liquid crystalline phase decreased from longer than 40 μm to 11.8 μm (measured by the droplet method). When irradiated with visible light for another 3 min, the observed texture gradually returned to the stable nematic texture, and the measured pitch went back to longer than 40 μm. This switching cycle was performed more than 50 times without deterioration of the liquid-crystalline phase. The researchers said that the twisting power of the closed-ring isomers is much larger than that of the open-ring isomers and this accounts for the above photoresponsive behavior.

In addition, the researchers prepared an azobenzene derivative and compared its optical rotation value with that of compound **1**. They conclude that the large increase in the optical rotation value of compound **1** plays a role in the high efficiency of the phase change.

ZHENGMAO ZHU

Intraband Electron Energy Relaxation in CdSe Quantum Dots is Dominated by Coulombic Coupling Between Electrons and Holes

Femtosecond (fs) transient absorption measurements of CdSe quantum dots capped with either a ZnS layer or a pyradine layer indicate that electron intraband energy relaxation is dominated by Coulombic electron-hole coupling effects rather than by phonon-mediated processes (as is true of bulk materials) or Auger-assisted processes (i. e., electron-hole recombination with the excess energy given to a hole). Researchers at Los

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Alamos National Laboratory and the Massachusetts Institute of Technology prepared 1.15 nm diameter CdSe quantum dots using an organometallic precursor route and then capped them with either ZnS or pyradine.

As reported in the May 15 issue of *Physical Review B*, energy relaxation processes in the quantum dots were then studied using three-pulse pump-and-probe transient absorption spectroscopy. Absorption of a visible interband pump pulse coupling the hole $2s_{3/2}$ and the electron 1*s* states produced electron-hole pairs. A tunable infrared pump pulse was used to couple 1*s* electrons to a higher lying 1*p* state. Occupation of various states was measured by probing the excited dots with a fs white-light pulse spanning the energy range from 2.2 to 2.8 eV. Pump-and-probe measurements of sample response were performed with and without the influence of the infrared pump pulse for time delays of as much as 4 picoseconds (ps) between the visible pump and the white-light probe. Measurements of combined visible and infrared excitation were performed for various time delays of up to 600 fs between the visible pump and the infrared pump. Care was taken in the measurements to ensure that the interband excitation level was low enough (0.5 electron-hole pairs per dot) so that Auger relaxation mechanisms were unimportant.

For quantum dots capped with ZnS, the intraband energy relaxation was 270 fs, independent of time delays of as much as 600 fs between the visible and the infrared pump pulses. However, for the pyradine-capped quantum dots, the intraband energy relaxation was 250 fs for simultaneous visible/infrared excitation and slowed to more than 3 ps when the time delay between the visible and infrared pumps exceeded 430 fs. Longer time delays (at least to 600 fs) did not produce any further lengthening of the intraband energy relaxation time.

The researchers explain their results in terms of the effects of the different capping layers on the electron-hole coupling. For the ZnS-capped dots, the hole is confined to the dot, and the electron-hole coupling does not change significantly over the 600 fs time scale, that is, the maximum time delay between the visible and infrared pump pulses. Consequently, time delays between the visible and infrared pump pulses do not strongly affect the transient response. However, for the pyradine-capped dots, the hole rapidly (< 0.5 ps) transfers outside the quantum dot to the pyradine and the electron-hole coupling is reduced for a short time. These results are consistent with intraband energy relaxation mechanisms mediated by Coulombic interactions between electrons and holes.

Previous models of intraband energy relaxation in quantum dots invoked Auger-assisted or phonon-mediated relaxation. The low excitation levels eliminate Auger processes from dominating these results. Also, the observed differences between the ZnS-capped and pyradine-capped CdSe quantum dots indicates that models incorporating only phonon-mediated processes are unlikely to account for intraband energy relaxation in CdSe quantum dots.

YUHANG REN

Correction

In the article "From Simulation to Theory in the Physics of Deformation and Fracture," by M.L. Falk and J.S. Langer, in *MRS Bulletin*, May 2000, page 44, Equation 9 and the preceding text should be:

Also note that, for $s > s_0$, $\Delta \to s_0^2/\bar{\mu}s$,

$$\dot{\epsilon}^P \to \frac{1}{\tau\bar{\mu}s}(s^2 - s_0^2) \simeq \frac{2}{\tau\bar{\mu}}(s - s_0), \qquad (9)$$

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