Hole Mobility and Antiferromagnetic Correlations in Underdoped $La_{2-x}Sr_xCuO_4$ High-T_c Cuprate Explained

In order to better understand the origin of high-T_c superconductivity, researchers at the Central Research Institute of Electric Power Industry in Tokyo, Japan, have systematically studied the doping dependence of the mobility of holes in underdoped high-T_c cuprates. Specifically, the research group has examined the moderately to heavily underdoped region of the $La_{2-x}Sr_xCuO_4$ (LSCO) cuprate system. Unlike other superconductors, the underdoped region of high-T_c cuprates has many unusual properties such as log $(1/T)$ insulating behavior, charged-stripe instability, and the presence of a pseudogap. The experiments indicate that the x-dependence of the hole mobility, μ, at 300 K is strikingly similar to that of the inverse antiferromagnetic (AF) correlation length, ξ_{AF}^{-1}, which is known from neutron experiments. The researchers discuss both an incoherent-metal picture and a charged-stripe scenario as possible theories to account for the observation.

As reported in the July 2 issue of *Physical Review Letters*, the researchers prepared a series of LSCO samples using the traveling-solvent floating-zone technique. The samples were carefully annealed to remove the excess oxygen and ensure that the hole doping is identical to x. The crystallographic axes were determined, and the samples were shaped into platelets with the *ab* plane parallel to the wide face. Metallic charge transport in high-quality single crystals of LSCO was examined from lightly to optimally doped samples (x = 0.01–0.17), employing both in-plane resistivity and Hall coefficient measurements. At 300 K, the researchers found that the inverse mobility, μ^{-1}, exhibits a metallic temperature dependence, throughout the underdoped region, down to x = 0.01 and is weakly dependent upon x, changing by only a factor of three from x = 0.01 to x = 0.17. The researchers said that this result is interesting since a superconductor-insulator transition occurs at approximately x = 0.05. Moreover, the researchers discovered that the x-dependence of μ^{-1} is analogous to that of ξ_{AF}^{-1} in the whole underdoped region. According to the researchers, this is a notable similarity since there exists in this region a significant change in the ground state. This implies that the mechanism which governs the charge transport is the same from x = 0.01 to x = 0.17 and is related fundamentally to the background AF correlations. Although the idea of an incoherent metal accounts for some of the observed results, the connection between the x-dependence of μ^{-1} and ξ_{AF}^{-1} is better explained within the charge stripe scenario.

"Actually, the lightly doped LSCO crystals show a number of surprising features in both the transport and the magnetic properties," said Yoichi Ando, leader of the group, "and the result we report here suggests that the physics responsible for the lightly doped region is also responsible for the high-T_c superconductivity at x = 0.17."

JENNIFER L. BURRIS

Ab Initio Calculations Explain Differences in (111) Surface Reconstructions of Diamond, Silicon, and Germanium

Friedhelm Bechstedt and co-workers at the Institut für Festkörpertheorie und Theoretische Optik at Friedrich-Schiller-Universität have performed an *ab initio* investigation of the (111) surface reconstructions for carbon, silicon, and germanium in order to explain their differences. As reported in the July issue of *Physical Review Letters*, using a plane-wave, pseudopotential implementation of density-functional theory within the local-density approximation, the researchers provide insight into the nature of the reconstructed surfaces by comparison of relative energetics, optimized surface geometries, and analysis of the electronic structure for each system.

The researchers studied the structures of the 2×1, $c(2\times8)$, and 7×7 reconstructions of the (111) surface for each of diamond, silicon, and germanium. They performed calculations for all three elemental solids on an equal theoretical footing, allowing direct identification of the differences in surface properties and providing the first-known reported comprehensive understanding of the underlying driving forces leading to the observed differences in reconstruction behavior with diamond favoring 2×1, silicon favoring 7×7, and germanium equally favoring 7×7 and $c(2\times8)$. Carbon, silicon, and germanium have the same valence electron configuration. Nevertheless, carbon's strong localized bonds and lack of p and d core electrons result in markedly different reconstruction properties. The strong bonds of carbon inhibit the long-range reconstructions induced by adatoms that are energetically favorable for both silicon and germanium. As expected, silicon exhibits behavior intermediate to that of carbon and germanium.

"Although certain aspects of these surface reconstructions have been understood for decades, it is satisfying to uncover aspects of the underlying mechanisms leading to the most energetically favorable surface structures in each case," said Bechstedt. "This work provides a succinct foundation for understanding differences in the important (111) surface reconstructions for elemental semiconductors, a subject of interest to both fundamental physical understanding and practical application."

EMILY JARVIS

Dendrimers Facilitate Two-Photon Absorption Applications

Two-photon absorption (TPA) is a third-order nonlinear optical process which could be used for various optical applications, including optical memory or optical power limiting, if the available nonlinear optical materials such as organic molecules could offer higher values of nonlinear absorption cross section (σ_2) than currently observed. A team of researchers from Montana State University has reported in the July 15 issue of *Optics Letters* that dendrimers based on 4,4′-bis(diphenylamino)stilbene (DPAS) repeating units have a TPA cross section of 11×10^3 GM (1 GM = 10^{-50} cm^4 s molecule^{-1} photon^{-1}), which is the highest recorded for a monodisperse organic macromolecule. The researchers said that the TPA cross section is a factor of three larger than the previous largest TPA cross section and is a factor of 1000–10,000 times those of conventional organic dyes.

DPAS is a D-π-D-type TPA active chromophore in which D symbolizes electron donating and π stands for π conjugation. Three generations of dendrimer macromolecules with 5, 13, and 29 DPAS units were fabricated. The dendrimer's three-dimensional structure affords a high-packing density of chromophores per unit volume and stable photochemical and thermal performance, as well as the possibility for chemical modification.

Femtosecond fluoresence spectroscopy was used to measure both single-photon and two-photon absorption properties of the dendrimers. From the TPA spectra in the three consecutive generations of DPAS dendrimer macromolecules, the researchers observed that at the wavelength of 714 nm, the dendrimers' intrinsic σ_2 values increased linearly with the total number of stilbene chromophores. Most significantly, for the second generation of the dendrimer possessing 29 stilbene chromophores, σ_2 reached the value of 11,000 GM. The researchers also reported that DPAS dendrimers had high quantum yields of fluorescence, which would be important for the application of TPA.

The researchers speculate that larger σ_2 values in higher generations of this den-

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