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RESEARCH HIGHLIGHT

Electrons on deck

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Materials scientists have been in an age of discovery, as two researchers in IBM Zurich Research Laboratory discovered high-temperature superconductivity in a copper oxide in 1986.[1] New materials including superconductors have been synthesized one after another, which have given renewed vigor and enthusiasm to the community. As a current trend, different functions are merged into a single material to generate novel and unique properties. A prime example is multiferroics where magnetism and ferroelectricity mutually influence.[2]

Recently, Shi *et al.*[3] have combined ferroelectricity with metallic conduction. The ferroelectric material is a material that exhibits finite polarization without external electric field. They can accumulate charge at the surfaces and show substantial displacement in proportion to electric field. Thanks to these properties, they are used for various applications, such as ceramic capacitor, ultrasonic oscillator, micro-actuator etc.

The synthesized material is $LiOsO_3$. In this metallic oxide, the Li ions occupy either of the two stable sites randomly at high temperature. Below the transition temperature of 140 K, they regularly order by choosing one particular site, which is known as order–disorder transition. See Figure 1a, where the cards are completely disorganized where up and down cards are distributed fifty-fifty. The order–disorder transition is a transition to Figure 1b, where all the cards have the down face. The deck of the cards has now acquired the direction from bottom to top, as indicated by the arrow. In solids, this state is referred to as breaking of the inversion symmetry, which is a necessary condition for ferroelectricity.

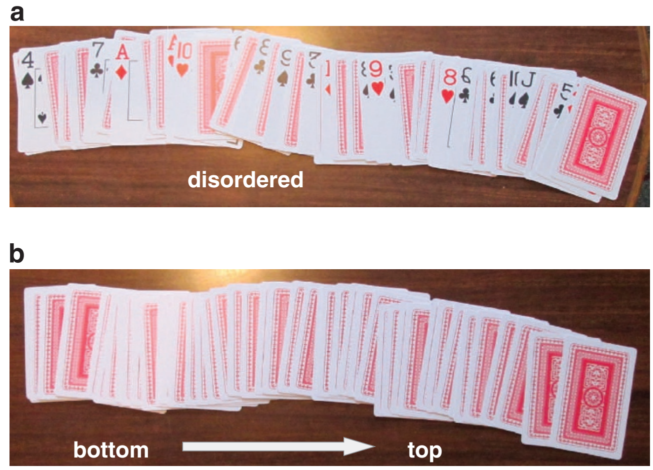

Figure 1 Schematic representation of order–disorder transition. (**a**) $T > T_c$ and (**b**) $T < T_c$. In (**b**), the direction from bottom to top can be specified in the deck of cards, as indicated by the arrow.

What will happen then, if mobile electrons are doped in the ordered deck? Well, at first glance, nothing special may occur, for electric field induced by the polarization is screened. However, the electrons feel the breaking of the inversion symmetry; they can identify 'top' from 'bottom' in the lattice. If they go superconducting, the superconductivity can be unconventional. The lattice vibration also changes significantly, and thereby it may cause high-temperature superconductivity, which was theoretically predicted half a century ago.[4] Although $LiOsO_3$ is not superconductive, the writer is certain that electrons in a ferroelectric lattice are now on deck to break a new ground in materials science.

1 Bednorz, J. G. & Müller, K. A. Possible high T_c superconductivity in the Ba-La-Cu-O system. *Z. Phys.* **B64,** 189 (1986).
2 Cheong, S.-W. & Mostovoy, M. Multiferroics: a magnetic twist for ferroelectricity. *Nat. Mater.* **6,** 13 (2007).
3 Shi, Y. *et al.* A ferroelectric-like structural transition in a metal. *Nat. Mater.* **12,** 1024 (2013).
4 Anderson, P. W. & Blount, E. I. Symmetry considerations on martensitic transformations: "Ferroelectric" metals? *Phys. Rev. Lett.* **14,** 217 (1965).

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