A different route to unconventional superconductivity: new spectroscopy on bismuth oxides

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A central challenge for understanding unconventional and/or high-Tc superconductors is elucidating how superconductivity emerges from adjacent phases whose interactions might foster or inhibit electron pairing. Addressing this question requires digging even deeper, since often those phases Mott insulator, spin/charge density wave, strange metal, and so on are complicated in their own rights. Our group has begun investigating a family of bismuth oxide compounds that can be doped to reach Tc just over 30 K [1]. Similar to, e.g., cuprates, the parent compound BaBiO3 is insulating, even though simple electron counting says it should be metallic. This insulating behavior is shockingly robust with respect to temperature, doping, and even structural transitions. Understanding the origin and nature of this phase and whether/how it is connected to superconductivity has led to various theories invoking phenomena such as charge ordering, attractive effective Coulomb interactions, reverse charge transfer effects, and bipolarons. It has been difficult to judge the merits of these models or answer any of the deeper questions, in part because the field has lacked a detailed experimental view of the electronic structure in any of the bismuthates. Thanks to a unique experimental toolkit, we have finally 50+ years after its first synthesis obtained the momentum-resolved band structure of BaBiO3 by performing angle-resolved photoemission spectroscopy (ARPES) in situ on freshly-grown thin films [2]. The pattern of Brillouin zone folding contrasts with core level measurements, showing that BaBiO3 lacks formal Bi charge ordering, despite a distorted structure that would suggest otherwise. We have been able to understand this by combining the photoemission data with density functional theory to uncover the orbital compositions of the bands. Our results confirm a model in which a negative charge transfer energy combines with structural distortions, driving hole pairs to condense onto molecular-like combinations of the oxygen p orbitals [3]. The findings carry implications for our understanding of the insulating phase and its doping evolution, as well as superconductivity in bismuthates. They also may shed light on other problems in oxide physics, such as the metal-insulator transition in rare earth nickelates.

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