The Importance of Synthesis and Single-Crystal Quality for Understanding High-Temperature Superconductivity in Cuprates

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Superconductivity is a propertyexhibited by certain materials, enabling the flow of electricity without dissipation. Understanding this phenomenon wherever it occursis not only crucial conceptually but also holds immense technological potential. Therefore, it is not surprisingthat high-T_c cuprates are among the most intensively studied correlated materials. Nonetheless, fundamental questions about their main phases and regimes, as well as the transitions between them, remain unanswered. This ismainly due to the complexity of these materials that renders the extraction of intrinsic properties difficult.

We addressed this challenge by identifying and synthesizing high quality crystals of, in many respects, model cuprate compound $HgBa_2CuO_{4+\delta}$. Comprehensive experimental studies, conducted on meticulously characterized materials, and through a comparison with data obtained for other cuprates revealed a set of remarkably simple universalities. The most important of them are that the effective mass and scattering rate of itinerant charges remain essentially unchanged across the phase diagram. This has led to a straightforward determination of carrier density, revealing a second localized electronic subsystem. The delicate balance between these subsystems is attributed to a change in the nature of the planar CuO3d-2pbond from ionic to covalent.

Finally, we established that the itinerant Fermi-liquid charges become superconducting, while the localized charge provides the superconducting "glue." With this, we have greatly demystified the physics of these fascinating compounds.

References:

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