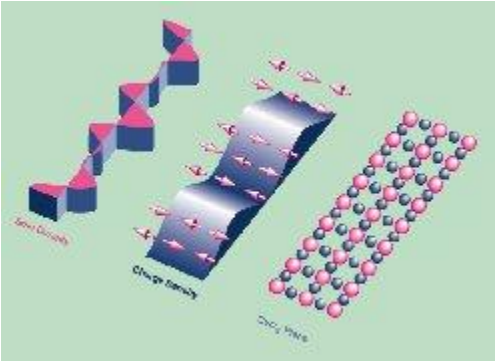
2.24 Unraveling the Mystery of High-Temperature Superconductivity



Stripe Formation. Picture of the spin and charge densities in the copper-oxygen planes where the conducting electrons are located. Lower density antiferromagnetic regions are seen to alternate with higher charge density regions. Such an effect is far more probable in two dimensional, i.e., planar, geometrical arrangements.

Since the discovery in the 1980s of high-temperature superconductors, the Office of Science has supported research designed to explain and improve the physical behavior of these materials and develop methods of making wires and other objects from them. These materials conduct electricity with virtually no resistance at temperatures high enough to be cooled by liquid nitrogen (-196 degrees C, or -321 degrees F) instead of more costly helium. Studies at various national laboratories have led to discoveries concerning, for example, the relationships between magnetic behavior and superconductivity, and between material layering and current-carrying capability. Argonne National Laboratory clarified the nature of several different phases of vortex matter (compounds often break down at the vortex, where the molecules of different materials meet), leading to new configurations that improve conductivity. Argonne also built the first superconducting motor and developed a process for welding lengths of wire in a way that maintains superconductivity. Other investigators have observed "charge stripes" in materials exhibiting colossal magnetoresistance, an unusual and powerful effect that may be exploited in future magnetic recording devices. Years of research at Oak Ridge National Laboratory led to the development of processes that may enable the manufacture of long lengths of superconducting wires and tape.

Scientific Impact: This research has greatly increased scientific understanding of high-temperature superconductors. As yet, there is no comprehensive theory that explains all of the experimental phenomena; this remains a key question in condensed matter physics.

Social Impact: Superconducting wires and tape can carry 100 to 200 times more electric current than conventional wires. These innovations could enable the widespread commercialization of more efficient types of power generation, transmission, and electrical equipment and devices, offering tremendous energy savings and emissions reductions.

Reference: S.L. Bud'ko, G. Lapertot, C. Petrovic, C.E. Cunningham, N. anderson, and P.C. Canfield. "Boron Isotope Effect in Superconducting MgB2," *Physical Review Letters*, February 26, 2001.

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