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Many roads lead to superconductivity

September 10 2010

Since their discovery in 2008, a new class of superconductors has precipitated a flood of research the world over. Unlike the previously familiar copper ceramics (cuprates), the basic structure of this new class consists of iron compounds. Because the structure of these compounds differs from the cuprates in many fundamental ways, there is hope of gaining new insights into how the phenomenon of superconductivity arises.

In cooperation with an international research group, German researchers from Helmholtz-Zentrum Berlin (HZB) have now discovered a magnetic signature that occurs universally among all iron-based superconductors, even if the parent compounds from which the superconductors are made possess different chemical properties. Their findings are published in Nature Materials.

Superconductors are generally produced by "doping" so-called parent compounds, which means introducing foreign atoms into them. There is a strong correlation between magnetism and superconductivity here - both being properties of solids.

Conventional superconductors, such as those used in MRI machines in hospitals, do not like magnetism because it disturbs the interactions that lead to superconductivity within the crystal. It is quite a different story for the celebrated high-temperature superconductors, such as cuprates and iron-arsenic compounds. In these cases, the magnetic forces actually help, even promote the onset of superconductivity. These compounds feature magnetic orders which, if they occur in a crystalline structure, are a telltale sign that the material is suitable to be a high-temperature superconductor.

With the new iron-based superconductors, it turns out that the symmetry of a magnetic order corresponds exactly to the symmetry in the superconductivity signal.

Dimitri Argyriou (HZB) and his colleagues have produced iron-tellurium-selenium crystals and determined their chemical composition using X-ray and neutron diffraction. They measured the magnetic signals in the crystals by performing neutron scattering experiments on the research reactor BER II of HZB and on the research reactor of the Institute Laue-Langevin in Grenoble.

They discovered that the symmetry of the magnetic order is significantly different from that of other iron-based parent compounds, such as iron-arsenic compounds. Yet, surprisingly, this difference has no impact on the development of superconductivity as a property. It has been detected that the magnetic signal caused by superconductivity - often referred to as the magnetic resonance - has the same symmetry as that of the magnetic order. And this is the same in all iron compounds, and apparently follows a universal mechanism that causes superconductivity for all of these materials.

Dimitri Argyriou describes this property as follows: "Going by what we know about the magnetic order of iron compounds, the iron-tellurium-selenium materials ought not to exhibit any superconductivity. But the opposite is the case: Despite the differences in magnetism, the signature of their superconductivity is the same. If we were now to understand how superconductivity arises in light of different starting conditions, then we could perhaps develop materials that are superconductive at even higher temperatures."

More information: Paper online: DOI: 10.1038/NMAT280

Provided by Helmholtz Association of German Research Centres