Room temperature superconductivity: One step closer to the Holy Grail of physics

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Scientists at the University of Cambridge have for the first time identified a key component to unravelling the mystery of room temperature superconductivity, according to a paper published in today's edition of the scientific journal *Nature*.

The quest for room temperature superconductivity has gripped physics researchers since they saw the possibility more than two decades ago. Materials that could potentially transport electricity with zero loss (resistance) at room temperature hold vast potential; some of the possible applications include a magnetically levitated superfast train, efficient magnetic resonance imaging (MRI), lossless power generators, transformers, and transmission lines, powerful supercomputers, etc.

Unfortunately, scientists have been unable to decipher how copper oxide materials superconduct at extremely cold temperatures (such as that of liquid nitrogen), much less design materials that can superconduct at higher temperatures.

Materials that are known to superconduct at the highest temperatures are, unexpectedly, ceramic insulators that behave as magnets before 'doping' (the method of introducing impurities to a semiconductor to modify its electrical properties). Upon doping charge carriers (holes or electrons) into these parent magnetic insulators, they mysteriously begin to superconduct, i.e. the doped carriers form pairs that carry electricity without loss.

The essential conundrum facing researchers in this area has been: how does a magnet that cannot transport electricity transform into a superconductor that is a perfect conductor of electricity? The Cambridge team have made a significant advance in answering this question.

The researchers have discovered where the charge 'hole' carriers that play a significant role in the superconductivity originate within the electronic structure of copper-oxide superconductors. These findings are particularly important for the next step of deciphering the glue that binds the holes together and determining what enables them to superconduct.

Dr Suchitra E. Sebastian, lead author of the study, commented, "An experimental difficulty in the past has been accessing the underlying microscopics of the system once it begins to superconduct. Superconductivity throws a manner of 'veil' over the system, hiding its inner workings from experimental probes. A major advance has been our use of high magnetic fields, which punch holes through the superconducting shroud, known as vortices - regions where superconductivity is destroyed, through which the underlying electronic structure can be probed.

"We have successfully unearthed for the first time in a high temperature superconductor the location in the electronic structure where 'pockets' of doped hole carriers aggregate. Our experiments have thus made an important advance toward understanding how superconducting pairs form out of these hole pockets."

By determining exactly where the doped holes aggregate in the electronic structure of these superconductors, the researchers have been able to advance understanding in two vital areas:

(1) A direct probe revealing the location and size of pockets of holes is an essential step to determining how these particles stick together to

superconduct.

(2) Their experiments have successfully accessed the region betwixt magnetism and superconductivity: when the superconducting veil is partially lifted, their experiments suggest the existence of underlying magnetism which shapes the hole pockets. Interplay between magnetism and superconductivity is therefore indicated - leading to the next question to be addressed.

Do these forms of order compete, with magnetism appearing in the vortex regions where superconductivity is killed, as they suggest? Or do they complement each other by some more intricate mechanism? One possibility they suggest for the coexistence of two very different physical phenomena is that the non-superconducting vortex cores may behave in concert, exhibiting collective magnetism while the rest of the material superconducts.

Source: University of Cambridge

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