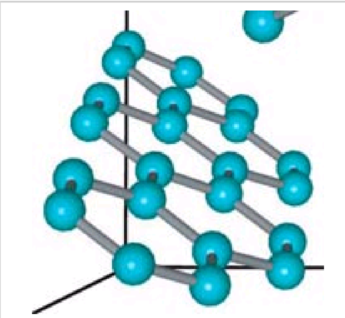
Hydrocarbon superconductor is a first

Mar 3, 2010 1 comment

Researchers in Japan have made the first superconducting hydrocarbon material by adding potassium atoms to picene ($C_{22}H_{14}$). The material becomes superconducting at temperatures below 18K – something that has surprised physicists and could provide clues about the physical origins of superconductivity.



The first hydrocarbon superconductor

An important challenge facing physicists is understanding exactly why some materials conduct with zero electrical resistance at relatively high temperatures (up to 138K in cuprates), while others must be chilled to near absolute zero before this superconductivity occurs. To solve this problem, scientists have been very busy making as many different kinds of superconductor as possible, in order to make systematic studies of material properties that affect superconductivity.

Two years ago Kosmas Prassides at the University of Durham, Matt Rosseinsky at Liverpool University and colleagues showed that a solid made of carbon-60 molecules (buckyballs) and caesium was a superconductor below 38K. These materials differed from other carbon-based superconductors because the superconductivity involves carbon's p-electrons – opening up a new avenue for systematic studies.

Picene, potassium and p-electrons

Now, Ryoji Mitsuhashi and colleagues at Okayama University in Japan have found that crystals made from the hydrocarbon picene and potassium atoms are superconductors at temperatures up to 18K.

The team begin with an ultrapure picene crystal that is then heated in the presence of potassium for several days. The critical temperature for superconductivity (Tc) is then measured by cooling the sample to a few degrees Kelvin and applying a magnetic field. The magnetic field induces currents in the superconductor, which exactly cancel out the applied field – a property described as negative magnetic susceptibility

The sample is then heated slowly and its magnetic susceptibility measured as a function of temperature. The transition from the superconducting state is heralded by a rapid change switch in the susceptibility from a negative to positive value, which the team saw in many of their samples.

The team studied crystals with a range of potassium concentrations from one potassium atom per picene molecule to 5.1 per molecule. Superconductivity was seen in samples with concentrations in the 2.6–3.3 range, with Tc ranging from 6.5K at 2.6 to 18K at 3.3.

Mitsuhashi and colleagues also looked at several samples doped with sodium, rubidium and caesium – all alkali metals like

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potassium. Only one sample – containing 3.1 rubidium atoms per picene molecule – was superconducting with a Tc of about 7K.

Wrong kind of symmetry

Like the carbon-60 crystals, superconductivity in picene is believed to be related to p-electrons. But according to Prassides, the superconductivity comes as a surprise because picene molecules arrange themselves in 2D planes much like graphite. This is unlike carbon-60 crystals, which have a cubic structure that matches the cubic symmetry of the p-electron orbitals. This means that a carbon-60 crystal has several different electron energy states with the same energy – and this "degeneracy" is expected to play a role in its superconductivity.

Picene does not have this cubic symmetry and therefore should not have the required p-orbital degeneracy. It turns out, however, that by pure coincidence, picene has two p-electron states with the same energy. Prassides believes that this "accidental degeneracy" could be related to the superconductivity.

One major stumbling block to interpreting these latest results is that Mitsuhashi and team were unable to determine the crystal structure of their samples in the superconducting phase. In particular, they don't know whether the potassium atoms lie within the picene planes or between the planes – although they believe the former to be more likely.

Prassides told *physicsworld.com* that determining the positions of the potassium atoms is needed gain a better understanding of the superconductivity. He also said that such hydrocarbon materials could provide a new family of superconductors for study. New materials could be created, for example, by doping similar "acene" materials with alkali metals.

The work is reported in *Nature* **464** 76

About the author

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1 comment

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1 **Ragtime**
Mar 3, 2010 11:10 PM
Prague, Czech Republic

It's not so bad, but the resulting compounds

will be extremelly sensitive to air and as such unusable. BTW what about Hendrik Schön's superconductor research in this connection? Wasn't he right at the very end?

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