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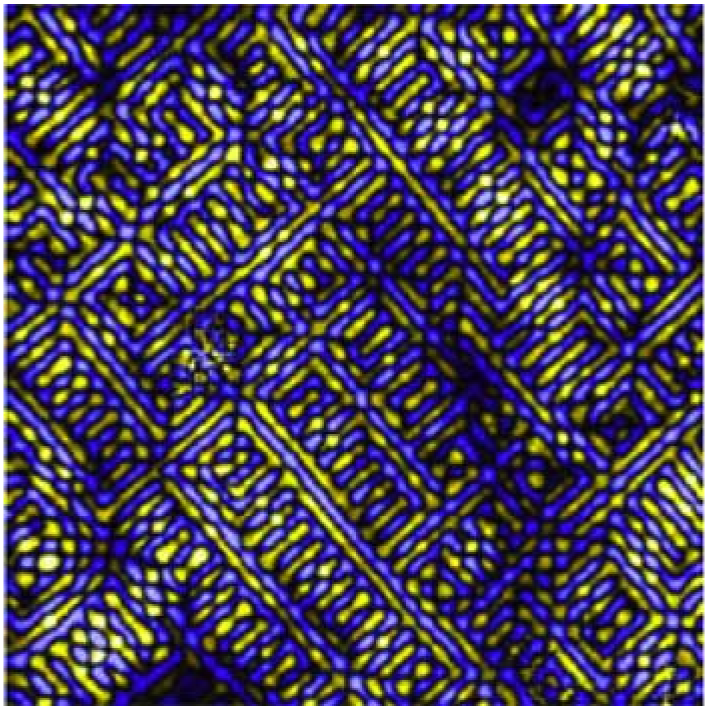
New superconductor theory may revolutionize electrical engineering

Dec 06, 2013 by Bill Steele



"Nanostripes" of alternating electrons and holes (spaces where electrons should be that appear as positive charges) appear in this scanning tunneling microscope image of a copper-oxide superconductor, just one of many odd patterns seen in years of observations of high-temperature superconductors. Credit: Davis Research Group

(Phys.org) —High-temperature superconductors exhibit a frustratingly varied catalog of odd behavior, such as electrons that arrange themselves into stripes or refuse to arrange themselves symmetrically around atoms. Now two physicists propose that such behaviors – and superconductivity itself – can all be traced to a single starting point, and they explain why there are so many variations.

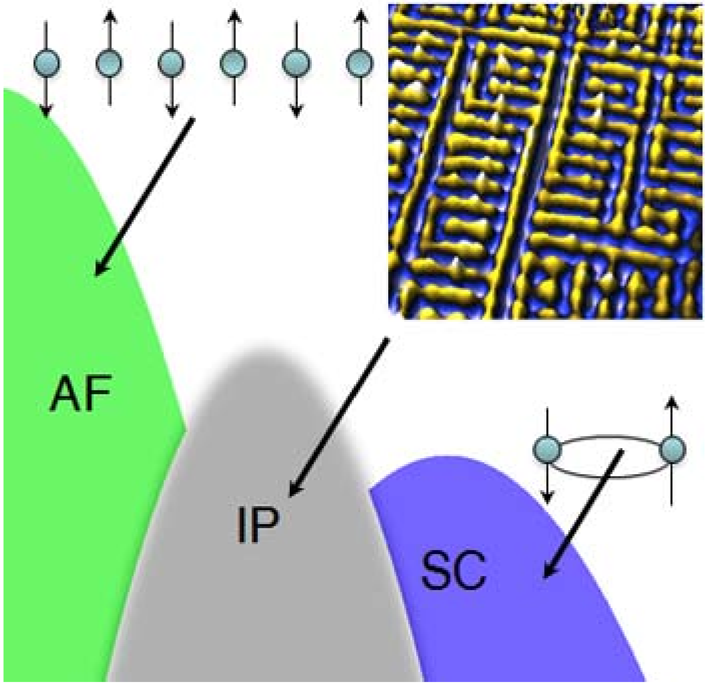
This theory might be a step toward new, higher-temperature superconductors that would revolutionize electrical engineering with more efficient motors and generators and lossless power transmission.

J.C. Séamus Davis, the James Gilbert White Distinguished Professor in the Physical Sciences at Cornell and director of the Center for Emergent Superconductivity at Brookhaven National Laboratory, and Dung-Hai Lee, professor of physics at the University of California-Berkeley and faculty scientist at Lawrence Berkeley National Laboratory, describe their theory in the Oct. 7 issue of the *Proceedings of the National Academy of Sciences*.

The oddities, known as intertwined ordered phases, seem to interfere with superconductivity. "We now have a simple way to understand how they are created and hopefully this understanding will help us to know how to get rid of them," said Lee.

Superconductivity, where current flows with zero resistance, was first discovered in metals cooled almost to absolute zero. Recently, complex crystals of copper, iron and some other metals combined with trace elements have been found to superconduct at temperatures up to around 150 Kelvins (degrees Celsius above absolute zero). For the last 10 years, Davis has examined these materials with scanning tunneling microscopes so well insulated from vibration that they can scan a surface in steps smaller than the width of an atom, while measuring the energies of electrons under their probes. He has discovered several of the intertwined phases of high-temperature superconductors, which appear in scans as unexpected arrangements of the electronic structure, and found them to vary widely from one material to another.

"[Our work] was not random; we were trying to map out all the known phenomena," Davis said.



An "antiferromagnetic" state, where the magnetic moments of electrons are opposed, can lead to a variety of unexpected arrangements of electrons in a high-temperature superconductor, then finally to the formation of "Cooper pairs" that conduct without resistance, according to a new theory. Credit: Davis Research Group

Most subatomic particles have a tiny magnetic field – a property physicists call "spin" – and electrical resistance happens when the fields of electrons carrying current interact with those of surrounding atoms. Two electrons can join like two bar magnets, the north pole of one clamping to the south pole of the other, and this "Cooper pair" is magnetically neutral and can move without resistance. Lee and Davis propose that this "antiferromagnetic" interaction is the universal cause not only for superconductivity but also for all the observed intertwined ordering. They show how their "unified" theory can predict the phenomena observed in copper-based, iron-based and so-called "heavy fermion" materials.

But if the cause is always the same, why do different materials exhibit different oddities? The difference, they say, is in the varying energy levels of the electrons that are free to carry current, which can be described by a mathematical structure called the "Fermi surface."

The new high-temperature superconductors are derived from orderly crystals where the same arrangement of atoms is repeated over and over and the spins of electrons alternate up and down from one unit cell to another. Although this favors antiferromagnetic interaction, electrons are not free to form Cooper pairs. Doping with trace elements distorts the crystal structure and removes some electrons, changing the Fermi surface. Whether Cooper pairing or some other ordering will take place depends on the shape of the Fermi surface, the researchers said.

Heat makes atoms move and can shake Cooper pairs apart, so the holy grail is to design a material where the pairs are bound together so strongly that superconductivity can happen even up to room temperature. It might be possible to describe a Fermi surface that would create that condition, and perhaps then imagine what crystal structure it would require. "Ideally we would like to be able to tell the materials scientist to put elements X, Y and Z together," Lee said. "Unfortunately we can't do that yet."

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QuixoteJ

-

3.4 / 5 (5) Dec 06, 2013
Seeing the alternating holes/electrons in the lattice in those pictures is intriguing and stirs up all kinds of neat ideas about the fundamental underlying reason why that charge structure is the way it is. I know it has to do with the doping etc., but something about it begs more.

Also, the article grammar and punctuation is wicked tight. Thank you, Bill Steele.

antialias_physorg

-

5 / 5 (2) Dec 06, 2013
Interesting. So the key is in making very ordered structures (or very ordered doping).
Maybe find a way to counteract the vibration energy in very small parts of a material (sort of like noise-cancelling headphones can create small areas of perfect silence). Thogh that should be hard as it's a stochastic process.

no fate

-

2.3 / 5 (6) Dec 06, 2013
"...so the holy grail is to design a material where the pairs are bound together so strongly that superconductivity can

happen even up to room temperature."

It's called diamond. Johan Prins did this experimentally 13 years ago.

indio007

-

1 / 5 (3) Dec 06, 2013
He does this jibe with the fact that current does not flow within a conductor.

Dave_Price

-

1 / 5 (4) Dec 06, 2013
Paging Johan Prins... :)

Howhot

-

1 / 5 (2) Dec 07, 2013
Good article and I agree with QuixoteJ, I may never look at superconductivity the same.

johanfprins

-

1 / 5 (3) Dec 07, 2013

> Paging Johan Prins... :)

Here I am! I did generate a superconducting phase 13 years ago by extracting electrons from an n-type diamond surface which has a very high density of donor sites just below the surface.
By applying a positive voltage with an anode, electrons move out to form a layer of these extracted electrons outside the surface, thus leaving a positive depletion layer behind consisting of ionised donors: i.e. a dipole layer forms. For low applied voltages to the anode, this dipole layer cancels the applied electric-field within it. Dipole layers form to achieve this object.

If you have enough donors, one can, by increasing the applied electric-field, extract the electrons until they reach the anopde. A erratic current then starts to flow with the generation of Bremstrahlung which proves that electrons are being accelerated into the anode. By increasing the voltage further, the erratic current becomes steady state and the Bremstralung stops.

Continued below

johanfprins

-

1 / 5 (4) Dec 07, 2013
By applying the Solid State Physics which are used daily to design electronic chips, it is easy to prove that such an equilibrium-state can only exist when the electric-field within the dipole becomes zero. Even though electrons are flowing into the anode, the electrons between the diamond surface and the anode, and the depletion layer still forms a dipole layer, and if there are enough donors below the surface, the depletion-layer MUST increase until the electric-field becomes zero, in order to reach equilibrium. This means that the steady-state current that is being measured MUST be flowing without the presence of an electric-field.

When this happens, a black rod forms instantaneously forms between the diamond surface and the anode. It remains there even when one switches off the power supply. People have argued that this black rod must be contamination: Many experiments have proved IT IS NOT! There are only electrons within the gap

Continued below

johanfprins

-

1 / 5 (4) Dec 07, 2013
When the current starts flowing in an erratic way, the electron density within the gap immediately falls, since an electric-field accelerates these electrons into the anode; However, the depletion layer keeps on increasing by dumping more electrons into the gap in an attempt top cancel this electric-field.

Once the electron-density reaches a critical value so that the electrons in the gap can overlap in pairs (spin-up and spin down) the charge-carriers being accelerated becomes doubly charged.

With a further increase in electron density, these electron-pairs (which are NOT being bonded by phonons since there are no phonons in a vacuum) overlap by enough to entangle and thus form a single condensate: The black rod appears.

This black rod, however, does NOT consist of separate bosons since, by entangling to form the condensate, these bosons lose their distinguishability; as demanded by the statistics of Quantum Mechanics.

Continued below

Requiem

-

1 / 5 (3) Dec 07, 2013
Johan's magical diamonds not only operate as room-temperature superconductors, they also generate unlimited free vacuum energy! 2qV on the other side of the junction!

(nah, what really happened is that he predicated this entire notion of his on a 2qV condensate postulated by a theory that he outright rejects, then made several assumptions that blatantly ignore conservation from there to arrive at the imaginary conclusion that he was seeing superconductivity....)

I'm not gonna argue with you about it though, Johan. Don't even bother replying if it's just for my sake.

Requiem

-

1 / 5 (3) Dec 07, 2013
Oh, it's also worth noting that he himself will tell you that even if what he describes is happening, it's still not useful for anything aside from developing a theory that nobody will publish and a book that nobody will buy. It's not actually feasible to use for ANY superconducting application, so some of the posts before he chimed in are mischaracterizing anything that may be true.

johanfprins

-

1 / 5 (4) Dec 07, 2013
A covalent bond forms from the entanglement of two electrons (one pair); a double bond forms from the entanglement of four electrons (two pairs); and a triple bond follows from the entanglement of six electrons (there pairs). My black rod forms from thye entanglement of millions of paired electrons. It is thus a macro "chemical bond" that forms between the positive charges in the depletion-layer, and those in the anode.

Note that for as long as the pairs do NOT lose their individuality (so that they are distinguishable) you do not get a condensate that can superconduct. Cooper paisr do not do this. In fact within a material the superconducting condensate consists of separtae stationar loclaised states which transport the SC current by means of tunneling. For thsi one does not need pair-formation at all. In fcat I do not think that any such phase which has been discovered since 1911, the SC charge-carriers are pairs.

I will stop here: More info at www.cathodixx.com

johanfprins

-

1 / 5 (2) Dec 07, 2013

> Johan's magical diamonds not only operate as room-temperature superconductors, they also generate unlimited free vacuum energy! 2qV on the other side of the junction!

Where have I claimed this? It is an argument that can only come from a seriously demented mind; in this case your mind. I pity you.

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