Superconductor breaks high-temperature record

Iron-based crystal regains conducting properties under pressure.

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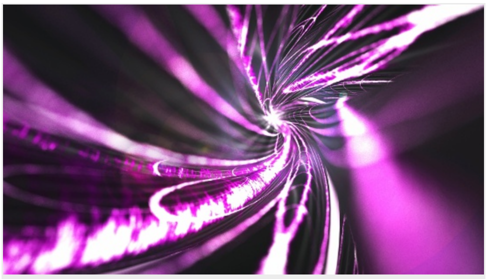
You just can’t keep a good superconductor down. An iron-based crystal has been found to regain the ability to conduct electricity without resistance when placed under pressure, breaking the record for the temperature at which superconductivity can survive in the process. But how it does this remains a mystery.

Most superconductors work only at temperatures close to absolute zero. So physicists have been puzzled about why certain materials can superconduct at temperatures approaching 70 kelvin. Liling Sun, a condensed-matter physicist at the Institute of Physics, Chinese Academy of Sciences, in Beijing, and her colleagues have investigated how a relatively new addition to the high-temperature superconducting family, iron selenide, behaves when placed under pressure. “Pressure is a way to tune basic electronic and lattice structures by shortening atomic distances, and it can induce a rich variety of phenomena,” says Sun.

Under normal pressure, iron selenide superconducts up to about 30 K, and Sun's team expected that raising the pressure would disrupt this. The researchers squeezed a single crystal of the material, measuring 100 micrometres in diameter and 50 micrometres thick, between two diamond-tipped anvils. At first, they found exactly what they predicted: superconductivity stopped as the pressure approached 10 gigapascals.



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Superconductors usually operate at nearly absolute zero, but a few can keep working as the temperature rises.

But as they increased the pressure above 11.5 GPa the sample began to superconduct again. “Pressure-induced re-emergence of superconductivity has been not found in any families of high-temperature superconductors.” says Sun. Furthermore, at pressures of about 12.5 GPa, the sample could superconduct at temperatures up to 48 K — setting a new record for iron-selenide superconductors[1]. “This really surprised us,” says Sun.

Those hoping to exploit iron selenides for practical applications will need to push its superconductivity transition temperature further — above 77 K, the temperature at which liquid nitrogen boils — but there are signs that this is possible, says Qi-Kun Xue, a physicist at Tsinghua University in Beijing. Xue and his colleagues raised the superconductivity transition temperature of a thin layer of a related iron-selenide compound to a similar level by growing it on a strontium-titanate substrate[2]. They are now studying the same material as Sun’s group and expect “a drastic increase in transition temperature”, says Xue.

Strange transitions

Subir Sachdev, a condensed-matter physicist at Harvard University in Cambridge, Massachusetts, says that the bizarre re-remergence effect may be related to the way that 'vacancies' — sites in the crystal that don't have any ions — are shuffled around when pressure is applied. Independent experiments have shown that at normal pressure, a thin iron-selenide sample exhibits a 'split personality', separating into regions that are highly magnetic and contain many ordered vacancies, and regions that are superconducting, but have no vacancies[3]. “There is already a very drastic contrast between these competing behaviours at ambient pressure,” says Sachdev. “Under high pressures, it looks like something happens to push the magnetic behaviour out, and let superconductivity take over.”

Sun and colleagues now plan to carry out neutron-scattering experiments to show how the structure of a sample changes under pressure, which should help to determine whether the ordering of vacancies, changes in magnetism or another effect is behind the change in behaviour.

The findings may confuse, rather than solve, the long-standing mystery of high-temperature superconductivity, says Andrew Green, a condensed-matter physicist at University College London, UK. He notes that although the first phase of superconductivity in iron selenide, seen at lower pressures, is related to the transition seen in other high temperature superconductors, the re-emergence of superconductivity at higher pressure is probably a new type of phase transition that follows a different mechanism. “This is a very nice result — but I think it raises more questions than it answers.”

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References

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