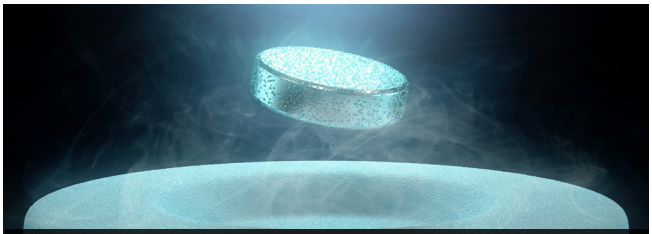
An iron grip on superconductivity

Layered iron selenides promise HIGHER TEMPERATURE SUPERCONDUCTIVITY.



Superconductors usually provide zero electrical resistance at low temperatures.

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Xian-Hui Chen's team has been creating iron-based materials that perform as superconductors at relatively high temperatures, bringing the cooling of superconductors tantalizingly close to cost efficiency.

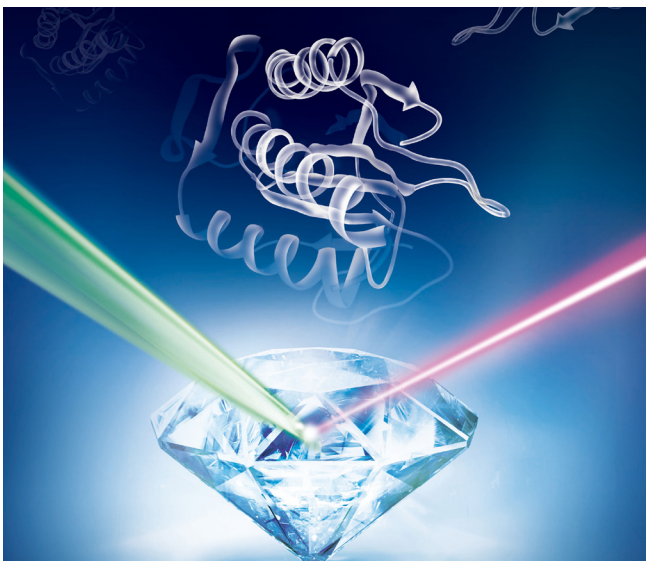
In 2008, Chen's group reported superconductivity above 40 Kelvin (-233 degrees Celsius) in an iron pnictide in *Nature*, suggesting iron-based superconductors form a second family of high-temperature superconductors, next to cuprates. Since then, Chen's group has hunted for new iron-based materials and hopes to raise superconducting temperatures higher than 77 Kelvin (-196 degrees Celsius), the temperature of more affordable cooling element, liquid nitrogen. In 2015, Chen's group reported superconductivity above 40 Kelvin in another iron-based material – layered iron selenides – in *Nature Materials*.

In 2020, the group successfully raised the superconducting pairing temperature of a new type of layered iron selenide, intercalated with tetrabutyl ammonium, an organic ion, to 65 Kelvin (-208 degrees Celsius). However, only one of two necessary conditions for superconductivity was boosted to higher temperature: the phenomenon in which electrons form pairs, known as Cooper Pairs. In this case, the real superconducting temperature is affected by the coherence among preformed Cooper Pairs.

"If we can increase the carrier density to raise the superfluid density enough, hopefully we can push it to 80 Kelvin (-193 degrees Celsius), which has been suggested is possible by recent measurements of the superconducting gap in iron selenide films," says Chen. This would open up the use of the liquid nitrogen. ■

Diamond quantum sensors

Defects in diamond provide atomic-scale information on BIOMOLECULES AND QUANTUM SYSTEMS.



Sensors based on nitrogen-vacancy centres could reveal key molecular structures.

Quantum sensors based on nitrogen-vacancy (NV) centres, a defect found in diamonds, are sensitive detectors of single spins. Jiang-Feng Du's group uses them to gain new understanding of systems that range from molecules within a cell, to exotic quantum systems.

Imaging molecules in their natural environment allows researchers to understand how structure determines function. "Our goal is to put nanoscale quantum sensors into cells to perform magnetic resonance spectroscopy and imaging on single biomolecules, so we can observe what they look like and how they work," explains Du. In 2015, his group reported results using NV-based sensors to measure single proteins at room temperature in *Science*, the first single-biomolecular spin resonance spectroscopy, and, in 2018, single DNA molecules in solution in *Nature Methods*.

Du's team also uses NV centres to investigate non-Hermitian systems, quantum systems that exhibit exotic behaviour. Non-Hermitian phenomena have so far not been studied in quantum systems, only in classical systems simulating quantum behaviour.

In a 2019 *Science* paper and in a 2021 *Physical Review Letters* paper, Du's team detail the use of a single NV centre to realize non-Hermitian quantum systems.

Beyond fundamental physics, NV centres are used to study 2D materials and nanomagnetism; in China and Europe, commercial equipment is already available. "In my opinion, quantum sensors are the closest quantum technology to real-world use," concludes Qi Zhang, a researcher in the group. ■

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