Scientists develop novel one-dimensional superconductor

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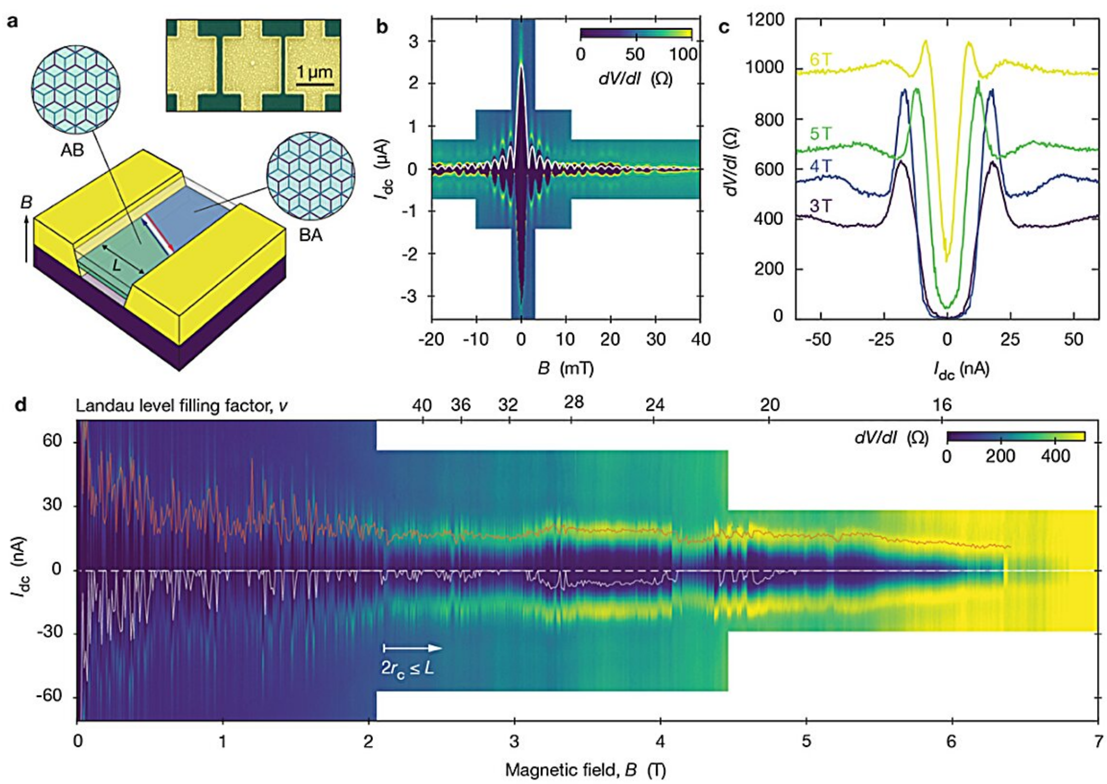

Josephson junctions incorporating domain walls in minimally twisted bilayers. Credit: Julien Barrier et al

In a significant development in the field of superconductivity, researchers at The University of Manchester have successfully achieved robust superconductivity in high magnetic fields using a newly created one-dimensional (1D) system. This breakthrough offers a promising pathway to achieving superconductivity in the quantum Hall regime, a longstanding challenge in condensed matter physics.

Superconductivity, the ability of certain materials to conduct electricity with zero resistance, holds profound potential for advancements of quantum technologies. However, achieving superconductivity in the quantum Hall regime, characterized by quantized electrical conductance, has proven to be a mighty challenge.

The research, published this week (25 April 2024) in *Nature*, details extensive work of the Manchester team led by Professor Andre Geim, Dr. Julien Barrier and Dr. Na Xin to achieve superconductivity in the quantum Hall regime. Their initial efforts followed the conventional route where counterpropagating edge states were brought into close proximity of each other. However, this approach proved to be limited.

"Our initial experiments were primarily motivated by the strong persistent interest in proximity superconductivity induced along quantum Hall edge states," explains Dr. Barrier, the paper's lead author. "This possibility has led to numerous theoretical predictions regarding the emergence of new particles known as non-abelian anyons."

The team then explored a new strategy inspired by their earlier work demonstrating that boundaries between domains in graphene could be highly conductive. By placing such domain walls between two superconductors, they achieved the desired ultimate proximity between counterpropagating edge states while minimizing effects of disorder.

"We were encouraged to observe large supercurrents at relatively 'balmy' temperatures up to 1 Kelvin in every device we fabricated," Dr. Barrier recalls.

Further investigation revealed that the proximity superconductivity originated not from the quantum Hall edge states propagating along domain walls, but rather from strictly 1D electronic states existing within the domain walls themselves.

These 1D states, proven to exist by the theory group of Professor Vladimir Fal'ko's at the National Graphene Institute, exhibited a greater ability to hybridize with superconductivity as compared to quantum Hall edge states. The inherent one-dimensional nature of the interior states is believed to be responsible for the observed robust supercurrents at high magnetic fields.

This discovery of single-mode 1D superconductivity shows exciting avenues for further research. "In our devices, electrons propagate in two opposite directions within the same nanoscale space and without scattering," Dr. Barrier elaborates. "Such 1D systems are exceptionally rare and hold promise for addressing a wide range of problems in fundamental physics."

The team has already demonstrated the ability to manipulate these electronic states using gate voltage and observe standing electron waves that modulated the superconducting properties.

"It is fascinating to think what this novel system can bring us in the future. The 1D superconductivity presents an alternative path towards realizing topological quasiparticles combining the quantum Hall effect and superconductivity," concludes Dr. Xin. "This is just one example of the vast potential our findings holds."

This research by The University of Manchester, 20 years after the advent of the first 2D material graphene, represents another step forward in the field of superconductivity. The development of this novel 1D superconductor is expected to open doors for advancements in quantum technologies and pave the way for further exploration of new physics, attracting interest from various scientific communities.

More information: Andre Geim, One-dimensional proximity superconductivity in the quantum Hall regime, *Nature* (2024). DOI: 10.1038/s41586-024-07271-w.
www.nature.com/articles/s41586-024-07271-w

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