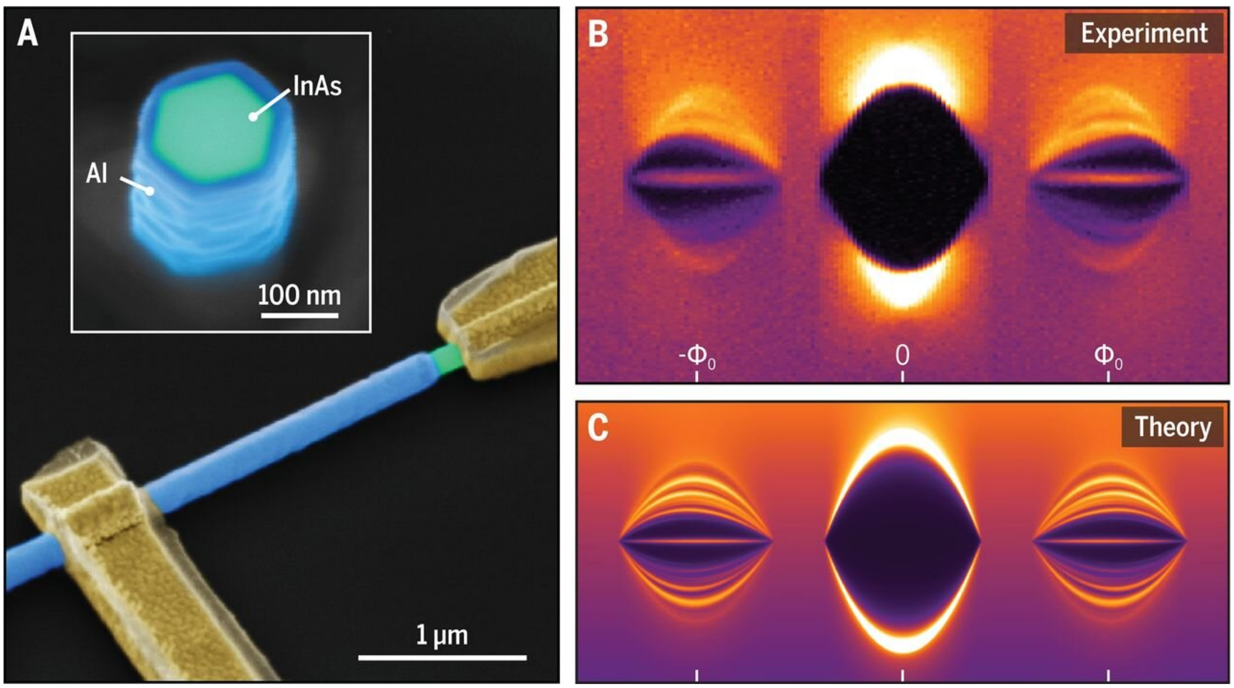
Quantum research unifies two ideas offering an alternative route to topological superconductivity

April 22 2020



Hybrid material nanowires with pencil-like cross section (A) at low temperatures and finite magnetic field display zero-energy peaks (B) consistent with topological superconductivity as verified by numerical simulations (C). Credit: Nbi

Researchers at the University of Copenhagen, in collaboration with Microsoft Quantum researchers, have used a pencil-shaped semiconductor measuring only a few hundred nanometers in diameter to uncover a new route to topological superconductivity and Majorana zero modes. The study was recently published in *Science*.

The new route that the researchers discovered uses the phase winding around the circumference of a cylindrical superconductor surrounding a semiconductor, an approach they call a conceptual breakthrough.

"The result may provide a useful route toward the use of Majorana zero modes as a basis of protected qubits for quantum information. We do not know if these wires themselves will be useful, or if just the ideas will be useful," says Charles Marcus, Villum Kann Rasmussen Professor at the Niels Bohr Institute and Scientific Director of Microsoft Quantum Lab in Copenhagen.

What they report appears to be a much easier way of creating Majorana zero modes, in which they can be switched on and off, according to postdoctoral research fellow Saulius Vaitiekenas, who was the lead experimentalist on the study.

Two known ideas combined

The new research merges two already known ideas used in the world of quantum mechanics: vortex-based topological superconductors and one-dimensional topological superconductivity in nanowires.

"The significance of this result is that it unifies different approaches to understanding and creating topological superconductivity and Majorana zero modes," says professor Karsten Flensberg, director of the Center for Quantum Devices.

The findings can be described as an extension of the Little-Parks effect, discovered by physicists 50 years ago. In the Little-Parks effect, a superconductor in the shape of a cylindrical shell adjusts to an external magnetic field, threading the cylinder by jumping to a "vortex state" in which the quantum wavefunction around the cylinder carries a twist of its phase.

The researchers needed a special type of material that combined semiconductor nanowires and superconducting aluminum. Those materials were developed in the Center for Quantum Devices over a few years. Notably, the superconducting shell fully surrounds the semiconductor in these wires. They were grown by professor Peter Krogstrup, also at the Center for Quantum Devices and Scientific Director of the Microsoft Quantum Materials Lab in Lyngby.

"Our motivation to look at this in the first place was that it seemed interesting and we didn't know what would happen," says Charles Marcus about the experimental discovery, which was confirmed theoretically in the same publication. Nonetheless, the idea may indicate a path forward for quantum computing.

More information: S. Vaitiekėnas et al, Flux-induced topological superconductivity in full-shell nanowires, *Science* (2020). DOI: 10.1126/science.aav3392

Provided by University of Copenhagen