Tech

One-dimensional quantum nanowires for Majorana zero mode fertile ground

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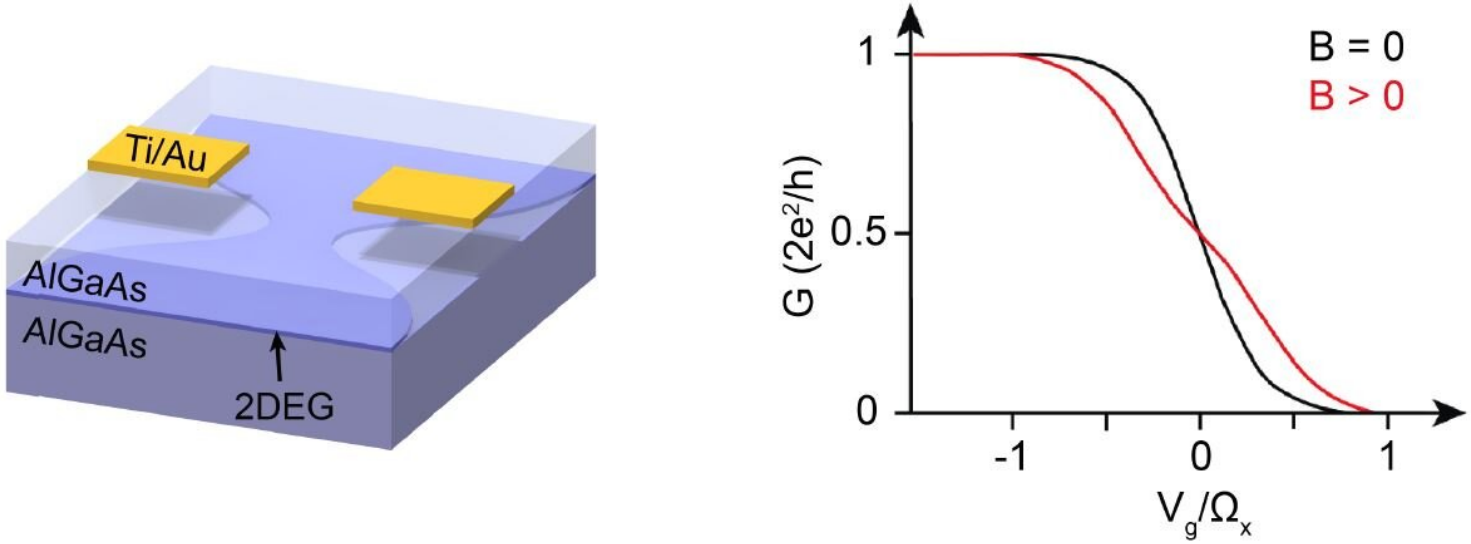

A quantum point contact structure (left) in which the applied voltage limits the movement of electrons to one dimension and the conductance (right) shows the effect of the applied magnetic field (red). Credit: UNSW

Why is it important to study the spin properties of one-dimensional quantum nanowires?

Quantum nanowires, which are long but have no width or height, provide a unique environment for the formation and detection of quasiparticles known as Majorana zero mode.

The new UNSW-led research overcomes the previous difficulties of detecting Majorana Zero mode and significantly improves device reproducibility.

Potential applications for Majorana zero mode include fault-tolerant topological quantum computers and topological superconductivity.

Majorana fermion of one-dimensional wire

Majorana fermions are composite particles that are antiparticles of their own.

The academic and commercial interest in such anomalous particles stems from their potential use in topological quantum computers, which are predicted to be unaffected by decoherence, which randomizes valuable quantum information.

Majorana zero mode can be created with quantum wires made of special materials that h
electrical and magnetic properties.

In particular, Majorana zero mode can be created with one-dimensional semiconductors (such as semiconductor nanowires) by combining with superconductors.

Quantum effects predominate in one-dimensional nanowires whose dimensions perpendicular to length are so small that they do not allow the movement of elementary particles.

Antimatter Description: Every elementary particle has a corresponding antimatter particle with the same mass and opposite charge. For example, an electron antiparticle (charge -1) is a positron (charge +1). Credit: UNSW

A new way to detect the required spin-orbit interaction

Due to its potential application to topological quantum computing, one-dimensional semiconductor systems with strong spin-orbit interaction are attracting a great deal of attention.

The magnetic “spin” of an electron is like a small bar magnet whose orientation can be set by the applied magnetic field.

In materials with “spin-orbit interaction”, the spin of an electron is determined by the direction of motion, even when the magnetic field is zero. This allows for all electrical manipulation of magnetic quantum properties.

When a magnetic field is applied to such a system, an energy gap opens, all forward electrons have the same spin polarization, and backward electrons have opposite polarizations. This “spin gap” is a prerequisite for forming the Majorana Zero mode.

Despite intense experimental research, this spin gap in semiconductor nanowires has proven to be very difficult to detect clearly. The characteristic feature of the spin gap (decrease in conductance plateau when a magnetic field is applied) is very difficult to distinguish from the inevitable ones. Nanowire background failure.

New studies have discovered new and distinct features of spin-orbit interaction that are u

plague previous studies.

“This signature will become the de facto standard for detecting spin gaps in the future,” s

A unique antiparticle, the Majorana fermion, has been theorized since 1937, but has only been experimentally observed over the last decade. Majorana fermion’s “tolerance” to decoherence offers potential applications for fault-tolerant quantum computing. Credit: UNSW

Reproducibility

Using Majorana Zero mode on a scalable quantum computer faces additional challenges due to the random disorder and imperfections of the self-assembled nanowires that host MZM.

Previously, it was nearly impossible to manufacture a reproducible device, and only about 10% of the devices worked within the desired parameters.

The latest UNSW results show significant improvements, with reproducible results among six devices based on three different starting wafers.

“This work opens up a new route for creating fully reproducible devices,” said corresponding author Alex Hamilton, UNSW Professor.

“New features of spin gap in quantum point contact” *Nature Communications* January 2021.

Ultra-thin designer material unleashes quantum phenomena

For more information:

KL Hudson et al. New features of spin gap in quantum point contact, *Nature Communications* (2021). DOI: 10.1038 / s41467-020-19895-3

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