Collaboration yields promising material for quantum computing

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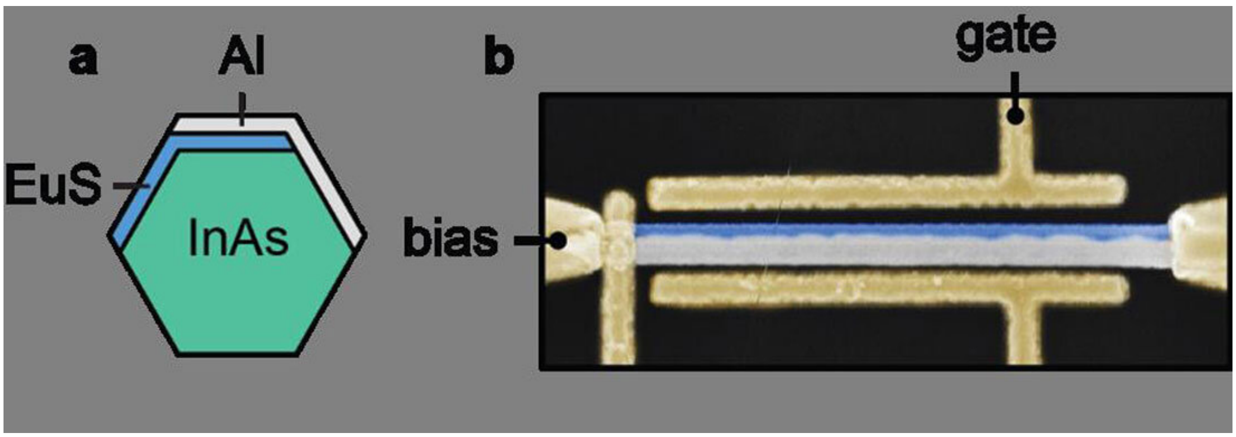

Illustration a: Graphic showing the three materials combined to form the new material. Al is aluminum – the superconductor, EuS is the new addition, europium sulfide – the ferromagnet, and InAs is indium arsenide – the semiconductor. In combination they allow for the existence of the desired Majorana zero modes, enabling the quantum wire device to be an integral component in a topological quantum computer. Illustration b: Electron micrograph showing the wire (blue/gray), between gate electrodes (yellow). The gate is necessary for controlling the density of the electrons, and electrons tunnel through the wire from the source (bias). The greatest advantage to this system is the fact that a large magnetic field has been made superfluous, as a magnetic field could have potential negative effects on other components close by. In other words, this result has made actual application much more likely. The length of the wire in the illustration is 2 micrometers = 0.002 millimeters and thickness 100 nanometers = 0.0001 millimeter. Credit: University of Copenhagen

Researchers at the Microsoft Quantum Materials Lab and the University of Copenhagen, working closely together, have succeeded in realizing an important and promising material for use in a future quantum computer. For this end, the researchers have to create materials that hold the delicate quantum information and protect it from decoherence.

The so called topological states seem to hold this promise, but one of the challenges has been that a large magnetic field had to be applied. With the new material, it has become possible to realize topological states without the magnetic field. "The result is one of many new developments needed before an actual quantum computer is realized, but along the way better understanding of how quantum systems work, and might be applied to medicine, catalysts or materials, will be some of the positive side effects to this research," Professor Charles Marcus explains. The scientific article is now published in *Nature Physics*

Topological states are promising—but there are many challenges along the way

Topological states in condensed-matter systems have generated immense excitement and activity in the last decade, including the 2016 Nobel Prize in Physics. There is a natural fault-tolerance of the so called Majorana zero modes, which makes topological states ideally suited for quantum computing. But progress in realizing topological Majorana zero modes has been hampered by the requirement of large magnetic fields to induce the topological phase, which comes at a cost: the system must be operated in the bore of a large magnet, and every topological segment must be precisely aligned along the direction of field.

The new results report a key signature of topological superconductivity, but now in the absence of an applied magnetic field. A thin layer of the material europium sulfide (EuS), whose internal magnetism naturally aligns with the axis of the nanowire and induces an effective magnetic field (more than ten thousand times stronger than the Earth's magnetic field) in the superconductor and semiconductor components, appears sufficient to induce the topological superconducting phase.

Professor Charles Marcus explains the progress this way: "The combination of three components into a single crystal—semiconductor, superconductor, ferromagnetic insulator—a triple hybrid—is new. It's great news that it forms a topological superconductor at low temperature. This gives us a new path to making components for topological quantum computing, and gives physicists a new physical system to explore."

The new results will soon be applied to engineering the qubit

The next step will be to apply these results in order to get closer to realizing the actual working qubit. So far the researchers have worked on the physics and now they are about to embark on engineering an actual device. This device, the qubit, is essentially to a quantum computer what the transistor is to the ordinary computer we know today. It is the unit performing the calculations, but this is where the comparison ends. The potential for the performance of a quantum computer is so large that today we are not even really able to imagine the possibilities.

More information: S. Vaitiekėnas et al, Zero-bias peaks at zero magnetic field in ferromagnetic hybrid nanowires, *Nature Physics* (2020). DOI: 10.1038/s41567-020-1017-3

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