Nano-switches for superconductivity

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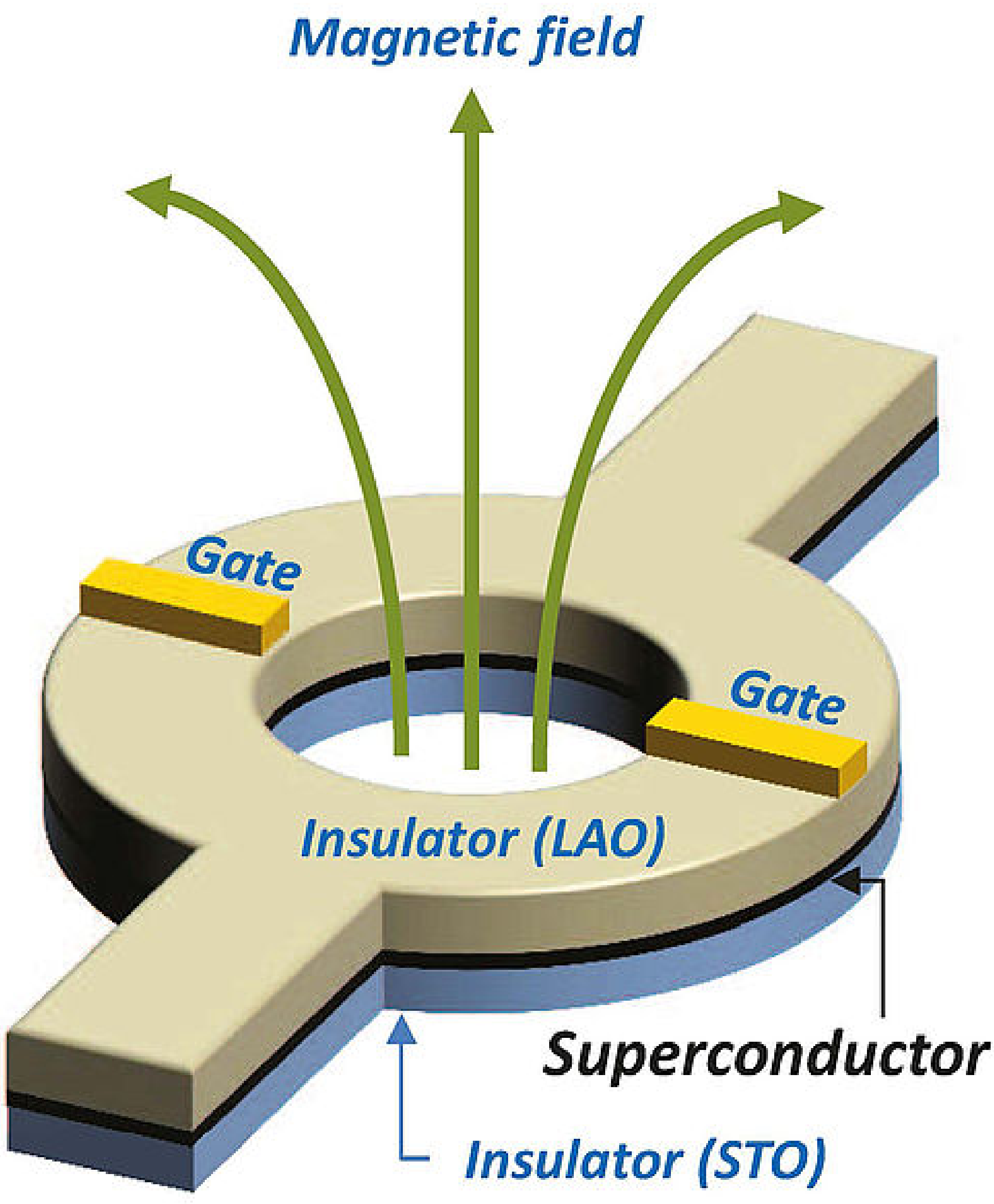

Credit: Delft University of Technology

Scientists at TU Delft, together with colleagues from the Tübingen University, have successfully created nano-electronic circuits using a recently discovered two-dimensional superconductor.

What makes this material unique is that its superconductivity can be turned on and off remotely, very much like the switching of electrical current in a transistor on a microchip. Utilizing this effect at the nanoscale, the researchers created superconducting circuits in a completely new way, which is impossible to achieve in other commonly known superconductors. Their work has been published in *Nature Nanotechnology*.

Creating a superconductor from insulators

To make the devices, researchers first create a ring composed of two insulators, lanthanum aluminate (LAO) and strontium titanate (STO). This is done through a combination of nanofabrication and precise atom by atom deposition of layers of LAO on STO. Finally, metallic gates are put on two small sections of this ring. When these structures are cooled down to low temperatures a ring-shaped sheet of superconductor appears at the boundary between the insulators. The reason for this unexpected emergence of superconductivity is still a mystery. Since its discovery in 2007, groups throughout the world have developed techniques to better understand why this superconductor appears and what its properties are. The devices created at TU Delft provide a new route to access crucial microscopic information about this superconductor, which has thus far been out of reach.

Doorways for superconductivity

The metal gates, as the name suggests, are like nanoscale doorways for superconductivity. When no voltage is applied to the gates this door is open and the superconducting ring is undisturbed. On the other hand, when large voltages are applied, the superconductivity just below the gates is turned off (the door closes completely) and two halves of the ring become disconnected from each other. "But something very special happens when these doors are only partially closed", says Srijit Goswami of the Kavli Institute of Nanoscience, Delft. "In this configuration, the resistance of the device begins to oscillate between zero and some high value, when small magnetic fields are applied. So, it appears as if the entire structure goes back and forth between a superconducting state (zero resistance) and a normal metal (high resistance)." This effect arises due to quantum effects in the superconductor, which are in principle very similar to what happens when two waves superpose to produce an interference pattern. Hence such devices are called Superconducting QUantum Intereference Devices (SQUIDs).

SQUIDs are used routinely in many applications, such as medical MRI machines, which require the detection of tiny magnetic signals. There are also efforts to use them in future quantum information processing circuits. Even the most advanced technologies for creating SQUIDs today do not allow one to tune the superconducting properties via electrical gates. Group leader Andrea Caviglia comments on this new discovery: "Using the strategy developed at TU Delft, it may become possible to create more complex superconducting circuits, where the functionality of the device is fully controlled via gate voltages". Whether such devices will eventually become technologically relevant is still an open question. However, they will certainly play an important role in answering fundamental questions about superconductivity at the nanoscale.

More information: Quantum interference in an interfacial superconductor. DOI: 10.1038/nnano.2016.112

Provided by Delft University of Technology