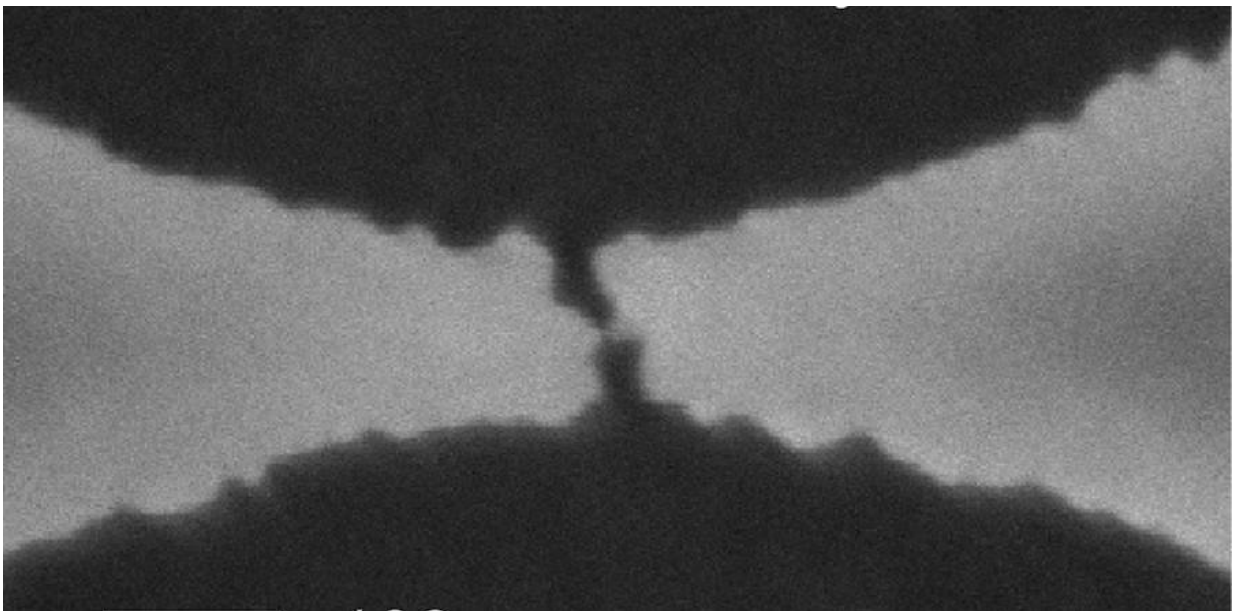


Molecular semiconductors could be the future of electronics, and this new technique offers a way to mass produce them

October 16 2018



A close-up look at a molecular junction formed with the new, scalable method.
Credit: KTH The Royal Institute of Technology

Visions for what we can do with future electronics depend on finding ways to go beyond the capabilities of silicon conductors. The experimental field of molecular electronics is thought to represent a way forward, and recent work at KTH may enable scalable production of the nanoscale electrodes that are needed in order to explore molecules and

exploit their behavior as potentially valuable electronic materials.

A team from the Department of Micro and Nanosystems at KTH recently tested a technique to form millions of viable nanoscale molecular junctions – extremely small pairs of electrodes with a nanometer-sized gap between them, where molecules can be trapped and probed. The findings were published in *Nature Communications*.

The KTH researchers reported that with a 100 mm diameter wafer of thin materials, they can produce as many as 20 million such electrodes in five hours' time, using gold film on top of a brittle material that forms cracks. In addition, working with the van der Zant Lab at TU Delft, the team trapped and studied a widely-used reference molecule in the nanometer-wide space between the electrodes to ensure that the fabrication method didn't hinder the formation of molecular junctions.

Shyamprasad Natarajan Raja, one of the co-authors, says this "crack-defined break junction" method offers a breakthrough to the impasse of scalable production of structures that could one day enable electronic devices made of single molecules.

The key is to produce gaps that enable a phenomenon called tunneling, in which electrons overcome the break in a circuit. A break junction has a gap the size of a few atoms, which breaks the flow of electrons through it. However, because the gap is so small, electrons with sufficient energy can still jump across this expanse. Tunneling electrons sustain a small but measurable current that is extremely sensitive to the size of the gap – and to the presence of nano-objects inside it.

"Break junctions are the best means available to make [single molecules](#) part of a larger electronic circuit that can probe [molecules](#)," Raja says. They could also one day enable ultra-sensitive high-speed detectors using quantum tunneling, he says.

However, tunneling break junctions are produced one gap at a time, which has been a major roadblock in developing any application involving tunneling junctions outside a research laboratory," Raja says.

The method begins with using photo lithography to pattern a stack of gold on titanium nitride (TiN). This stack is set on a silicon wafer, and the notched structures that are formed then concentrate stress. So, when the silicon directly underneath the stack is removed (a process called release etching), tiny cracks form at the pre-determined locations in the TiN to release the stress. This in turn deforms the gold, stretching it into atomically thin wires running across these cracks, which upon breaking form gaps as small as a molecule.

Raja says that the method can be used for other conductive materials, besides gold, which offer interesting electrical, chemical and plasmonic properties for applications in [molecular electronics](#) and spintronics, nanoplasmonics and biosensing.

More information: Valentin Dubois et al. Scalable Manufacturing of Nanogaps, *Advanced Materials* (2018). [DOI: 10.1002/adma.201801124](https://doi.org/10.1002/adma.201801124)

Valentin Dubois et al. Massively parallel fabrication of crack-defined gold break junctions featuring sub-3 nm gaps for molecular devices, *Nature Communications* (2018). [DOI: 10.1038/s41467-018-05785-2](https://doi.org/10.1038/s41467-018-05785-2)

Provided by KTH Royal Institute of Technology

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