Application Note CI08

# Multi-contact break junctions controlled mechanically by an ANPz100 positioner

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Break junctions have been established as one of the most common experimental techniques for the investigation of electrical transport properties on the atomic scale. In most of the setups realized so far, the whole substrate, carrying a thin contact between two leads, was carefully bent by a macroscopic rod. This technique enables a reversible opening and closing of a 'molecular switch' on the atomic level. Although the actual atomic configuration may differ due to local rearrangements from one cycle to the next, the technique very reproducibly shows a clear conductance quantization prior to the transition into the tunneling regime.

In this application we have used a novel approach, where small tips with a radius of 50-200 µm (made from either glass or graphite) were used in combination with thin silicon membranes and precise positioning units to locally stretch the substrate, allowing to individually address multiple break junctions.

Samples were produced by a complex process including electron beam lithography and reactive ion etching, yielding free-standing bridges made from either Al, Pt, or Au. After fabrication, samples were placed onto the breaking mechanism, consisting of a chip carrier, a micrometer screw-controlled x-y table and an attocube ANPz100 positioner, see Figure 1. The ANPz100 was used in slip-stick mode for coarse approach, and in scanning mode to adjust the deflection of the membrane with sub-nm precision. The motion of the tip was monitored with an optical profiler with integrated microscope and was recorded by a CCD camera.

The measurements nicely show that the displacement of the membrane needed for breaking the nanobridge strongly depends on the lateral position of the tip on the back side of the membrane (see Figure 2). As expected, the required deflection for breaking a junction increases with increasing distance from the junction. Hereby, larger deflections are required in case of a motion perpendicular to the electrical contacts compared to a motion along the latter.

The versatility of the setup was nicely demonstrated by a device containing two junctions placed perpendicular to each other. Figure 3 shows the time-dependent conductance of both junctions when opening and closing with constant speed for different positions in the x-y plane. When positioning the tip close to junction *A*, junction *B* is mainly unaffected and vice versa. Similar configurations could potentially be used for studying charging effects in metallic single-electron transistors with variable junctions.

In summary, this experiment demonstrates a novel break-junction setup using thin membranes. The technique overcomes the limitation of previous experiments by allowing to control more than one junction on the same circuit. This technique will be used for studying the influence of optical excitations onto the conductance and for controllable metallic single-electron transistors.

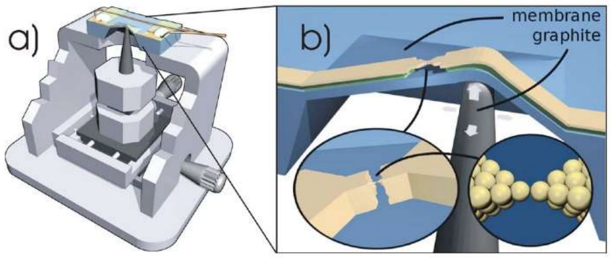


***Figure 1:*** *(a) Schematics of the breaking mechanism, showing the sample holder and a cut through the sample (not to scale). The image further depicts the tip, the mechanical x-y positioning stage and attocube's ANPz100 nanopositioner. (b) Zoom into panel (a), demonstrating the working principle of the setup. The typical membrane size is 0.6 x 0.6 mm² with a thickness of 340 nm.*

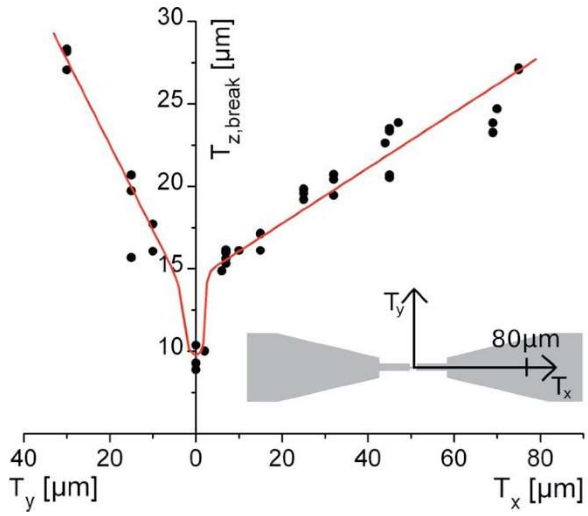


***Figure 2:*** *Sensitivity of the setup to lateral motion of the tip. The main panel shows the displacement in z-direction required to break a nanobridge as function of the lateral position of the tip. The directions x and y are defined in the inset.*



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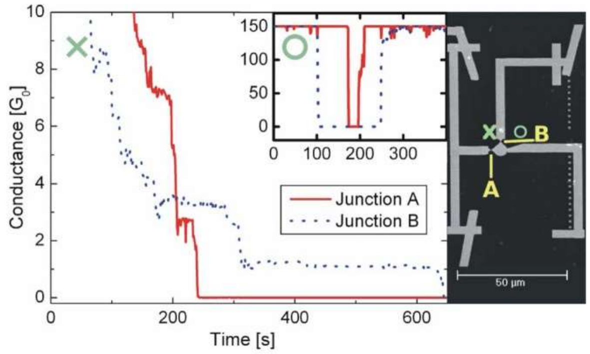


***Figure 2:*** *Time-dependent conductance of junctions A and B as depicted in the micrograph to the right. The tip was located at the position indicated by the green cross (the inset was recorded at the position indicated by the circle). At t = 160 s the motion direction of the tip is reversed.*