Application Note CI09

Mapping and Manipulation of Leakage Currents in a Nanostructure with ANP101 positioners

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Transport phenomena in nanostructures rely on charge flow of charge carriers in real space. In order to receive spatially resolved images of transport processes in certain nanostructures, we employ scanning gate microscopy (SGM). Here we show how this method has been used to spatially image and manipulate undesired electrical leakage currents in a nanostructure.

In this application note, attocube's smallest titanium positioners (ANPx51/RES and ANPz51/RES) are used as part of an atomic force microscope (AFM) inside a Janis ^{3}He cryostat with a base temperature of 280 mK (see Figure 1a). The setup is a combined low temperature AFM and scanning tunneling microscope (STM), which we employ to carry out SGM experiments on various nanostructures. In these measurements we use attocube systems' positioners to move the metallic tip directly above the nanostructure predominantly at 4.2 K but also as low as 280 mK.

In a SGM experiment, we use the tip as a flying nano-gate to locally induce a potential perturbation in the sample (see Figure 1b). Here we show how this method was used to investigate and manipulate the undesired leakage currents occurring between two insulating terminals of a nanostructure fabricated via local anodic oxidation [1] in a two-dimensional electron gas (2DEG) (see Figure 2a) when a voltage above a certain threshold is applied to one terminal of the structure [2].

To record a current map, we measure the current through the nanostructure in dependence of the tip position. When investigating the leakage currents in this nanostructure, we find that the current map is flat except for a single point of suppressed current (Figure 2b). We therefore conclude that the leakage current crosses the barrier not homogeneously along the whole extent of the barrier but rather at one single point. Crossings of two oxide lines are especially prone to the occurrence of leakage currents, as at those points the effective writing distance during sample processing is increased. By scanning the tip over the defected region in feedback mode, we can temporarily decrease the leakage current appearing at this point by more than a factor of two due to electrostatic alterations in the sample as shown in Figure 3.

In summary, attocube systems' positioners were used in a low temperature AFM-STM setup to coarse-position a metallic tip reliably close to the nanostructure under investigation. The setup was used to investigate the flow of leakage currents in a 2DEG-based nanostructure. We could show, that leakage currents cross oxide barriers at isolated points and how we can temporarily suppress these leakages. Additionally, the setup has successfully been used to investigate the positions of double dots in a 2DEG based structure, where we could use this technique to image and manipulate the apparent positions of both dots in real space [3].

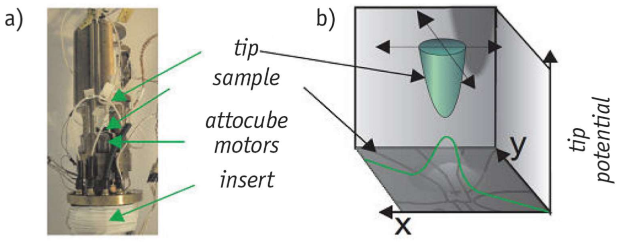

Figure 1: a) Photograph of the microscope head. b) Schematic principle of scanning gate microscopy.

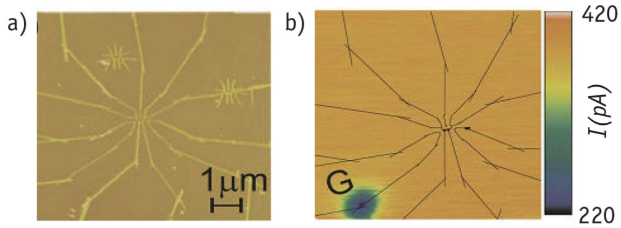

Figure 2: a) AFM scan of the sample. The bright protrusions correspond to the electrically insulating oxide barriers. The regions below the dark brown areas are electrically conducting. b) Current map of the leakage current when a large enough voltage is applied to the terminal labelled G. The oxide lines are indicated as black lines.

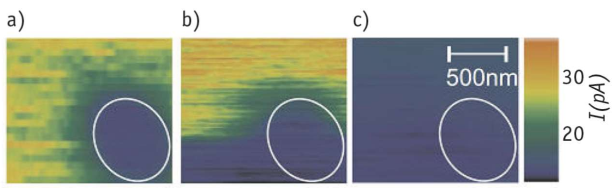

Figure 3: a) Current map to localize the leakage current occurring at one specific point. b) Current map recorded while scanning the tip in feedback mode over the same position. c) Current map recorded at the same setting and position as the map displayed in b) recorded after the current map shown in b).

References

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[2] M. Huefner, S. Schnez, B. Kueng, T. Ihn, M. Reinwald, W. Wegscheider, and K. Ensslin, Nanotechnology **22**, 295306 (2011).

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