Journal of Physics: Condensed Matter

Special Issue on Multiprobe Techniques

24 September 2018

Preface for JPCM

Special Issue on Multiprobe Techniques

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The multiprobe technique based on scanning tunneling microcopy (STM) has become very popular over the past few years and has demonstrated its capability to reveal fundamental nanoscale charge transport properties . Compared to conventional, i.e. lithographically-driven concepts, the four-tip STM technique can directly contact delicate nanostructures with upmost precision. Moreover, the reliable and individual positioning of the STM-tips allows the assembly and manipulation of such complex nanostructures. Together with the STM, STS, and potentiometry capabilities, an almost complete set of information with respect to the atomic structure, electronic states, and conductivity (even spin-polarized) can be gathered in-situ from emergent nanomaterials without the need for elaborate transfers.

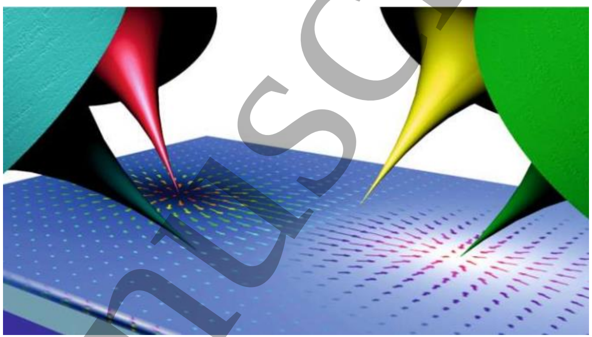

Figure 1: Artist view of a multiprobe system with 4 scanning tunneling tips approached to a surface. This image, "Scheme of a multi-tip STM", was created by the authors and originally used on the Wikipedia article "Multi-tip scanning tunneling microscopy" where it was made available under a CC BY-SA 4.0 licence. It is included within this article on that basis. It is attributed to Bert Voigtländer.

The invention of multiprobe STM is a result of a consistent further development of various multiprobe approaches used in the field of surface science. In the beginning, electric contacts with fixed geometries, realized by shadow masks or simply by clamps, were used in order to correlate surface conductivity with its morphology [1,2,3]. In the course of an increasing interest into precise surface conductance measurements, the first multiprobe systems were developed. In order to simplify the ex-situ sample preparation and to access now also the mesoscopic length scale, monolithic chip designs hosting various contact assemblies became available [4,5]. During this time, the first generation of multiprobe STM systems were developed, where all contacts could be navigated independently [6,7].
This special issue is a collection of papers, which maps the current research and application of multiprobe STM systems. For instance, two-probe transport experiments on a single 156 Ge dimer wire on H:Ge(100) demonstrate the truly atomic scale capability, which can be reached nowadays [8]. A major advantage compared to conventional transport experiments is that variable contact spacings and geometries can be easily realized in-situ. This mode is particular appealing for low dimensional electron gas systems like wires or films, as one has a direct access to the homogeneity and anisotropy, as greatly explored for atomic steps and grain boundaries in epitaxially grown Bi_2Se_3 films [9]. The in-situ capability allows the combination of high-resolution transport with complementary surface science techniques, e.g. XPS, as confirmed by the optimization of ZnO surfaces by light plasma treatments [10]. Moreover, the stability of state-of-the-art multiprobe instrumentations is impressive and allow to realize even measurements at freestanding nanowires. This was demonstrated for functionalized GaAs-nanowires grown by self-assembly on surfaces [11]. One strength of this technique is the probe-spacing dependent transport measurement, which gives a direct access to the dimensionality and environmental coupling of the system. In order to relate the measured resistance

with the resistivity of the system, highly symmetric tip geometries, e.g. equidistant and collinear assembly, are often used. Albeit theoretically more complex, a simplified 4-probe method was developed now in which only one tip needs to be navigated [12]. Besides such aspects, also application-driven research was performed. For instance, the connectivity of carbon nanofiber mats, which are used for lightweight construction, was analyzed by nanoscale transport [13]. Recently, the multiprobe technique was used for manipulation, i.e. contacting metallic wires in order to study failure processes in nanostructures and to use this technique to fabricate ultra-small junctions for single molecules [14].

The continuous and still ongoing improvement of this technique over the last years by many groups made it a reliable technique for surface science and nanotechnology. This includes also the development of new modes of operations, e.g., in order to simplify the setup or to be truly non-invasive. For instance, the surface potentials can be measured with a potentiometric manner within the tunneling contact, thus resistivities can be measured without being in contact to the sample [15].

We hope that the reader enjoys this special issue. We thank all contributors to this special issue and look forward to more experiments in order to elucidate the entire potential of this powerful technique.

Acknowledgements

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