Universität Basel

# Research Project

## Neue Einsichten in die Sonden-Proben-Wechselwirkung bei den Rastersondenmethoden

### Third-party funded project

**Project title** Neue Einsichten in die Sonden-Proben-Wechselwirkung bei den Rastersondenmethoden
**Principal Investigator(s)** Meyer, Ernst ;
**Project Members** Drechsel, Carl ; D'Astolfo, Philipp ; Hinaut, Antoine ;
**Organisation / Research unit**
Departement Physik / Nanomechanik (Meyer)
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This research proposal focuses on the progress in the study of local interactions by Scanning Probe Methods (SPM). The research in this field is only possible due to our longstanding experience and equipment:Nanolino: STM/AFM force microscopy in ultrahigh vacuumLT-SPM: Combined low temperature scanning tunneling and force microscopyThe following research topics will be addressed in this period:a) High resolution tunneling and force spectroscopy of Majorana bound statesIn this research, we pursue our investigations of magnetic chains on superconductors, grown by self-assembly or atom-by-atom via tip manipulations, with a particular focus on growing perfect chain structures. Their characterizations will be conducted with advanced SPM techniques in order to disentangle electronic properties, spin texture and atomic structure. We are acquiring a new ultra-low temperature tuning fork microscope operated at 900 mK under a variable magnetic field of ś 3T with He holding times of about 150 hours that will be set up during this research period. Beside the topological chains, we also investigate new condensed-matter systems to realize synthetic topological superconductors based on two dimensional materials and potentially hosting Majorana fermions (MFs). We thus focus on the on-surface synthesis of doped graphene nano-structures as well as the epitaxy of silicene atomic layers. Not appropriate for Pb substrates due to its low melting temperature, these synthesis will be transferred to atomically-cleaned niobium surfaces prepared in ultra-high vacuum.b) Pulling of molecular wires along surfacesOur main focus for this research period is on the pulling of single molecular wires with predefined mechanical properties. For this purpose, we will exploited the manipulation techniques developed in our group these last years. The metallic STM tip is approached to one end of the wire until a bond is formed. Then the tip is retracted in the vertical direction to detach the molecular wires unit after unit while recording its mechanical responses. These experiments are in analogy with our previous ones using graphene nanoribbons (GNRs) and poly-fluorene chains. In the case of poly-pyrenylene-chains, we are particularly interest in detecting and controlling the effects of steric hindrance between consecutive sub-units of the chains. From ab initio calculations, it is expected that the free poly-pyrenylene molecules naturally promotes large twists about the single C-C bonds of ś40ř, as a result of steric repulsions between adjacent hydrogen atoms. In a second phase, we wish to design new molecular chains with selected peripheral side groups or sub-units. The concept is to promote new mechanical dynamics upon lifting/sliding with different sub-units twist angles of the equilibrium form of the molecular chains. Consequently, we expect that cryo-force spectroscopic measurements observe different adhesive forces to detach the molecular units. In analogy to the pyrenylene case, we might observe variations of the maximum detachment force depending on the twisting direction (clock- vs. anti-clock wise).c) Friction and contact forces with large molecules prepared by electrospray depositionWe will use electrospray deposition to deposit large

molecules, such as the hexadodecylhexabenzo-coronene, and extend this study to graphylene-1, also called the spoked wheel molecule. Several questions are to be addressed: 1) Do the molecules assemble on metallic and insulating substrates? The assembly on insulators is of importance for applications in optics and molecular electronics, where optical and electronic decoupling of the molecules from metallic substrates are required. 2) How is the assembly depending on the temperature? First evidence is found that large molecules with alkyl chains have temperature dependent inter-molecular spacing, which correspond to very large thermal expansion coefficients of the order of 10-4/řK.In the second period, individual large molecules will be moved by the probing tip and the frictional forces will be determined as a function of orientation, adsorption location and loading force. How do the frictional forces scale with the size of the molecules? Can we heat the molecules by exposure to tunneling currents or laser light? Does this increase the mobility or reduce the frictional forces. In the same spirit, we will prepare carbon onions and graphene nanoribbons, which will continue some the previous experiments on larger scales.

**Keywords** kelvin force microscopy; STM; SFM; force microscopy; SPM; scanning tunneling microscopy; non-contact force microscopy; surface science; insulators; atomic friction; Atomic and molecular resolution; true atomic resolution by AFM in ultrahigh vacuum

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