Precursor to lithography: Electron-induced etching with the STM on CVT Grown TaS_2 Crystals

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The integration of transition metal dichalcogenides (TMD) in electronic and photonic devices will require the means to lithographically pattern and contact on small length scales. TaS_2 is metallic and as such a candidate for 2D contacts, and shows a multitude of charge density waves (CDW) reconstructions of significant interest. The TaS_2 samples used in our experiments were CVT grown with iodine as a transport agent in a four-zone furnace yielding bulk crystals with 2H-TaS_2 structure project ID# S0112 with 2DCC). Transport measurements and STEM imaging confirm the 2H structure and show the characteristic phase transitions with temperature. Traces of iodine are still present in the sample. The imaging of the bulk crystal surfaces with scanning tunneling microscopy (STM) reveals tracks which resemble drainage patterns and are attributable to the transport agent motion on the surface. The track density diminishes with distance from the edge. We will present a statistical image analysis for the growth tracks.

Imaging the TaS_2 surface with STM introduces artificial defects through the injection of electrons or holes, and specifically leads to the nucleation of vacancy islands (VI). The nucleation and growth of many VIs is observed through image acquisition over extended timescales (up to several hours) and with variable imaging conditions with respect to bias voltage and tunneling current whereas the sign of the bias voltage is not important. We propose that intrinsic defects such as S-vacancies can serve as nucleation sites for the Vis. Image analysis and segmentation delivers detailed growth kinetics including VI generation and coalescence events. Tracks can act as pinning sites and modify the shape of the VIs. We propose that the presence of traces of water and the electron or hole injection from the tip during imaging are relevant for localized etching events. The edges of VI are more susceptible to bond breaking and hence growth of the VI is initiated. We will present a full statistical analysis of VI growth kinetics including its dependence on layer designation, and crystallographic direction, and a chemical model of the etching process. Next experiments will explore the introduction of vacancies via electron or ion irradiation to achieve a controlled introduction of VIs as a first step in TMD lithography. We hypothesize that it is possible to program VI formation and couple this process with deposition of insulators or semiconductors for a bottom up fabrication of TMD devices.