Supplemental Document

Thin film vacuum deposition of materials onto cryogenically cooled substrates, known as quench-condensation, provides a route to probe metastable disorder in films. This route often leads to different and desired electronic characteristics and can offer additional opportunities for optimization of such characteristics. In this work we apply quench-condensation to the vacuum deposition of bismuth films, experimentally studying the systematic effect of deposition temperature on the microstructure and on electronic properties, for deposition on three substrates covering a wide range of properties. Bismuth is chosen because it is known to develop noteworthy electronic properties when quench-condensed, including superconductivity at a relatively high transition temperature. Disorder in the films is quantified by observing morphology. The characterization of quench-condensed films shows surprising continuity and stability of the 110 orientation, especially when grown on van der Waals substrates. Electrical measurements proved the presence of a change in electronic properties between growth temperatures by showing higher resistance across all quench-condensed films.

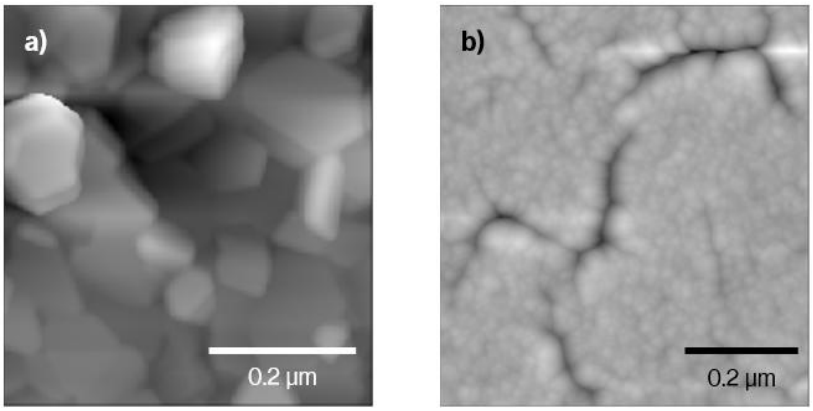

Fig.1. Atomic force micrographs of, a) room temperature growth and b) quench condensed (77 K) growth bismuth films on Al_2O_3(0001).

In Figure 1 AFM micrographs of both room temperature (a) and quench-condensed (b) films are shown. Room temperature film morphology presents larger grain clusters and columnar growth, while quench-condensed films have evenly oriented grain clusters and long cracks. Overall, this work provides clear visual and structural characterization of quench-condensed bismuth films, addressing a longstanding gap in the field.