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Innovative High Energy X-ray characterization of interfaces for quantum application

Small layered junctions, integral to quantum applications, typically comprise thin films, often conductors or superconductors, separated by thin oxide layers. These junctions play critical roles in various quantum devices, including Josephson junctions, thermoionic devices and parametric amplifiers. However, characterizing these structures poses significant challenges due to their small dimensions and complex compositions. Traditional techniques like cross-sectional Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) offer limited insights and may be destructive. While X-ray Reflectivity (XRR) provides valuable out-of-plane electron density profile information for these junctions, it lacks the in-plane spatial resolution required for detailed analysis. Here we introduce a novel approach utilizing High Energy XRR Tomography (HEXRR-Tomo). Unlike conventional XRR, HEXRR-Tomo enables spatial mapping of the entire surface, allowing for the potential reconstruction of a high-resolution 3D electron density map of the junction. This technique promises to offer easily accessible and non-destructive insights into the thickness, density, and roughness of individual layers within the junction, thereby advancing our understanding of their structure and properties. In this contribution, we will present preliminary examples of the technique, demonstrating our ability to visualize the morphology and key features of various devices with specific applications. For instance, one example involves a thermoionic junction comprising complex layers of Si, SiO_2, Al, and V (Fig. 1), which is utilized as a cooling device for cryogenic temperatures. Another example features $NbAlAlO_xAlNb$ films and NbTiN structures on a Si wafer, which serve as Josephson junctions for quantum computing and as parametric amplifiers, respectively. Further analysis will provide information about the roughness and thickness of each individual layer.

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Instrumentation and methods

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