

Towards Single-Crystalline Tunnel Barriers on Epitaxial CoSi₂/Si for Low Loss Superconducting Circuits

J. J. Choi,¹ T. A. J. van Schijndel,² Y. Wu,² C. J. Palmstrom^{2,3}

¹ Physics Department, University of California, Santa Barbara, CA, USA

² Electrical and Computer Engineering Department, University of California, Santa Barbara, CA, USA

³ Materials Department, University of California, Santa Barbara, CA, USA

Conventional Josephson junctions (JJs), superconductor/tunnel barrier/superconductor structures, are created using polycrystalline and amorphous materials. Typically, the superconducting metal layers are polycrystalline, and the tunnel barrier is amorphous, which leads to dangling bonds at the superconductor/tunnel barrier interfaces and in the tunnel barrier itself. These dangling bonds are believed to house two-level energy loss systems (TLS) that limit qubit and other quantum device performance.

Thus, one way to make progress in this field is to carefully select materials that minimize this loss. Cobalt disilicide (CoSi₂) can be grown epitaxially on silicon (Si), and its close lattice match with Si also enables the growth of single-crystalline Si tunnel barriers directly on the superconducting CoSi₂ layer [1, 2]. This prospect makes CoSi₂ particularly interesting for superconducting circuits because it eliminates the usage of amorphous or polycrystalline materials, which could potentially reduce loss. The vertical Josephson junction can then be completed by depositing another superconducting layer. In this talk, we demonstrate the growth and characterization of aluminum (Al)/Si/CoSi₂/Si(111)

structures using molecular beam epitaxy. The reflection high-energy electron diffraction (RHEED) shows the signature 1×1 surface reconstruction for CoSi₂, 7×7 surface reconstruction post Si growth, and a 1×1 surface reconstruction following Al deposition.

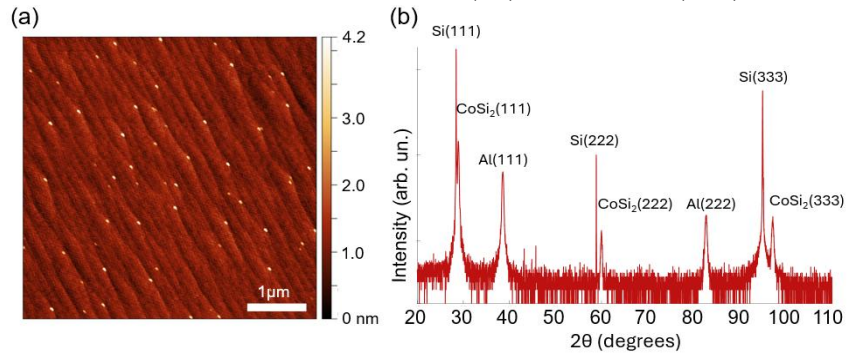


Fig 1: (a) Atomic Force Microscopy image of CoSi₂ on Si(111). (b) X-ray diffraction measurement on Al (40 nm)/Si (6 nm)/CoSi₂ (40 nm)/Si(111)

Following synthesis, atomic force microscopy of the CoSi₂ shows a smooth surface with terraces, which is indicative of a high-quality, epitaxial surface and suggests that the film grows in a well-ordered manner (Fig. 1 (a)). Additionally, the films exhibited sharp peaks in X-ray diffraction (Fig. 1 (b)) and oscillations in X-ray reflectivity, indicating well-defined crystalline structure and interfaces. Correlation of the growth parameters to the superconducting critical temperature of CoSi₂ were also investigated, with the highest critical temperature of 1.25 K.

Supplementary Pages

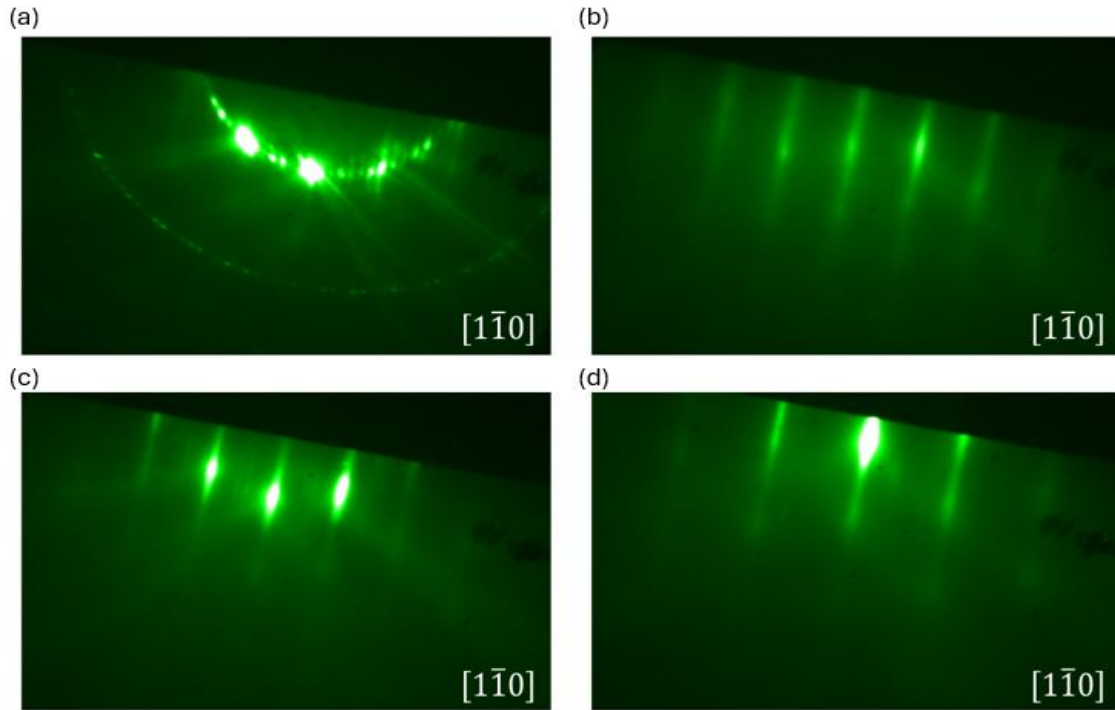


Fig 2: (a) RHEED of 7×7 Si(111) surface reconstruction before growth. (b) RHEED of 1×1 CoSi₂ surface reconstruction after codeposition of Co and Si. (c) RHEED of 7×7 Si surface reconstruction post deposition of Si. (d) RHEED of 1×1 Al surface reconstruction

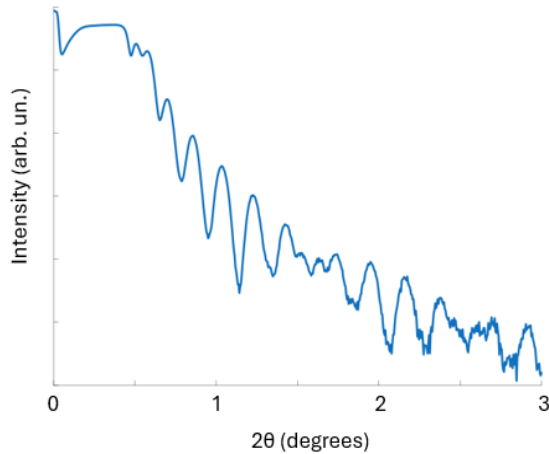


Fig 3: Oscillations in X-ray reflectivity measurement of Al/Si/CoSi₂/Si(111)

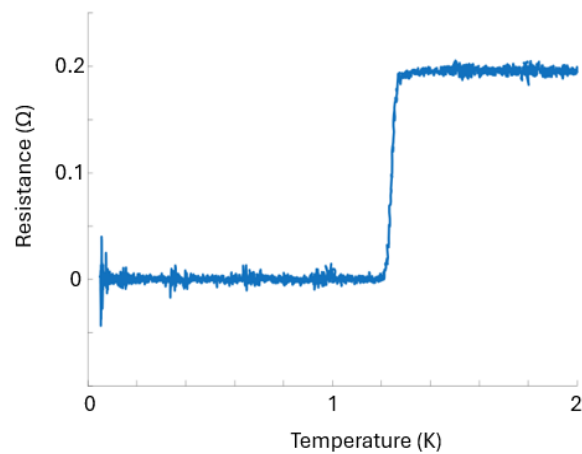


Fig 4: Resistance of CoSi₂ as a function of temperature, with superconducting critical temperature of 1.25 K