Epitaxial Growth of Superconducting $CoSi_2$ for Advancements in Quantum Information Sciences

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Josephson junctions (JJs) are superconductor/insulator/superconductor structures crucial in superconducting quantum circuits due to their non-linear inductance creating an anharmonic oscillator that can be used as a qubit. They are often created using amorphous materials. The amorphous oxide and its interfaces with the superconductor are believed to result in two-level energy loss systems that limit performance. One way to progress in this field is to carefully select materials that best minimize this loss. In this context, $CoSi_2$ is particularly interesting for these systems because it has the potential to be fully epitaxial with silicon, thus eliminating any amorphous materials. This is due to the capability of growing a single crystalline Si barrier on $CoSi_2$, which is possible because of their similar crystal structures and small lattice mismatch of approximately 1.2% [1]. In this talk, we demonstrate the Si substrate preparation and epitaxial growth of superconducting $CoSi_2$ by molecular beam epitaxy (MBE). We systematically investigate the crystalline structure, topography, and superconducting properties of the resulting films. The reflection high-energy electron diffraction (RHEED) patterns after the cleaning process exhibited Laue arcs, indicating an oxide-free and smooth surface (Fig. 1(a)). During the growth, Co is deposited and $CoSi_2$ is formed through reaction with the Si substrate heated to at least 200 C. 2 x 2 diffraction patterns are visible in RHEED, which indicate epitaxial growth, later confirmed by high resolution X-ray diffraction (XRD) (Fig. 1(b)). Atomic force microscopy (AFM) shows grain formation on the surface (Fig. 1(c)) and measurements using an adiabatic demagnetization refrigerator show the superconducting transition temperature (T_c) of the $CoSi_2$ film as 0.58 K, which is lower than the bulk value of 1.4 K [2]. This T_c reduction suggests that the film is too thin or may not be completely single crystalline (Fig 1(d)). We then investigate the growth of $CoSi_2$ films at different temperatures, evaluate the impact of post-growth anneals, and determine how these factors influence their superconducting properties.

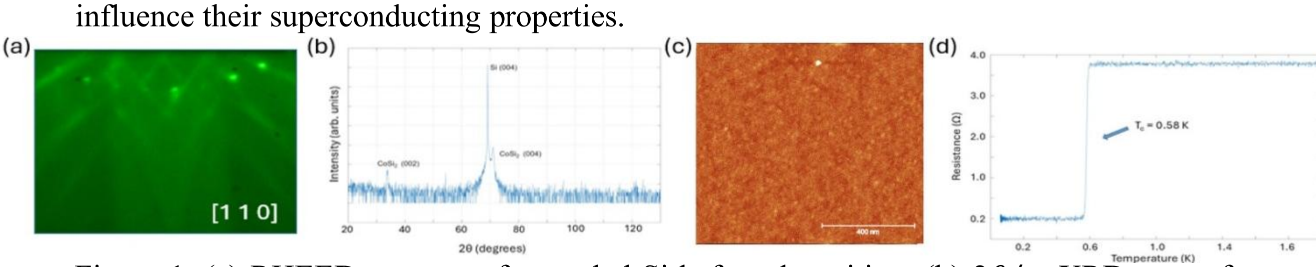

Figure 1. (a) RHEED patterns of annealed Si before deposition. (b) $2\theta/\omega$ XRD scan of $CoSi_2$ film. (c) AFM image of $CoSi_2$ deposited on Si. (d) Temperature dependent resistance measurement showing superconductivity

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