

Electrochemical and Morphological Study of Rhenium Electrodeposition on PVD-Mo Substrates

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A superconducting quantum computer consists of electronic circuits made from superconducting materials and employs qubits that can exist in a superposition of both 0 and 1 states simultaneously, which allows quantum computers to perform more complex computations compared to classical computers. High-critical temperature (T_c) superconductors are attracting significant attention in the electronics industry, particularly for their applications in superconducting quantum computers utilizing Josephson junctions. While low- T_c superconductors require helium-based cooling systems to maintain temperatures of 1–4 K, high- T_c superconductors provide enhanced stability and reliable performance over a broader temperature range. [1]

Superconducting materials commonly used in quantum computing include Nb, Nb-based alloys, Sn, and Ti. These materials are prone to oxidation and pose challenges in soldering. [2] Additionally, Pb exhibits a T_c of 7.2 K, however, its use is limited due to environmental concerns. [3] Rhenium (Re), on the other hand, has a remarkably high melting point of 3186°C and demonstrates excellent resistance to electromigration, making it a reliable material for circuit applications.

Re powder obtained by heating rhenium salts, such as ammonium perrhenate, in a hydrogen atmosphere at high temperatures exhibits a T_c of approximately 1.7 K. In contrast, Re thin films formed through electrodeposition demonstrate a significantly higher T_c of up to 6 K compared to the previous method. [4] Re electrodeposition occurs at potentials lower than the potential at which the hydrogen evolution reaction (HER) sets on. Consequently, hydrogen gas is generated during the deposition process which induces hydrogen embrittlement, resulting in cracks that can significantly degrade device performance. [5]

In this study, polyethylene glycol 20000 (PEG 20000) and sodium dodecyl sulfate (SDS) were employed as additives to prevent crack formation caused by the HER during Re electrodeposition on PVD-Mo substrates. Constant potential electrodeposition was conducted using PEG 20000, SDS, and a combination of PEG 20000 and SDS. Scanning electron microscopy (SEM) confirmed that the addition of PEG 20000, SDS, and the simultaneous use of PEG 20000 and SDS effectively eliminated cracks in the deposited films. Furthermore, atomic force microscopy (AFM) analysis was used to investigate the influence of the additives on nucleation and growth mechanisms (instantaneous nucleation or progressive nucleation) throughout the initial stages of electrodeposition on PVD-Mo substrates. Through electrochemical quartz crystal microbalance (EQCM) and Rutherford backscattering spectrometry (RBS) analyses, the amount of deposited Re was quantified and compared under additive-free conditions, with PEG 20000, with SDS, and with a simultaneous use of PEG 20000 and SDS. The combined use of PEG 20000 and SDS resulted in the highest deposition amount after 50 seconds at a potential of -0.7 V vs. Ag/AgCl.

References

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