Subgap Leakage in Nb/Al-AlO_x/Nb Josephson Junctions and Run-to-Run Reproducibility: Effects of Oxidation Chamber and Film Stress

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Abstract - Many applications of Nb/Al-AlO_x/Nb Josephson junctions (JJs) in superconducting electronics require high quality tunnel barriers with low subgap leakage that is usually characterized by figure of merit $V_m=I_cR_{sg}$, where I_c is the critical current and R_{sg} is the subgap resistance at 2 mV and 4.2 K. It is widely believed, and there is considerable literature suggesting, that quality and reproducibility of JJs depends critically on the intrinsic stress in Nb/Al-AlO_x/Nb trilayers, and the stress therefore should be carefully minimized and controlled. Contrary to this belief, we show that JJ quality (V_m) and reproducibility do not depend on the stress in the trilayer, at least in the studied range from -300 MPa to 300 MPa. In this range, V_m neither depends on the stress in Nb/Al base electrode nor in Nb counter electrode. We have found, however, that V_m crucially depends on the way the tunnel barrier formation by thermal oxidation of Al is done. For instance, room-temperature dynamic oxidation (in O_2 flow at low pressures) in a cryopumped chamber leads to poor run-to-run reproducibility of V_m and reduced V_m values, whereas dynamic oxidation at the same parameters but in a chamber with turbomolecular pump results in high V_m values and excellent run-to-run reproducibility.

Keywords - Nb/Al-AlO_x/Nb Josephson junctions, AlO_x tunnel barrier, subgap leakage, intrinsic stress, hydrogen in Nb, hydrogen chemisorption, superconducting digital circuits.

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