Contribution of dielectrics to frequency and noise of NbTiN superconducting resonators

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The low temperature microwave properties of superconducting resonators for kinetic inductance photon detectors [1] and quantum computation [2] are attracting increased attention. At low temperatures both a significant excess frequency noise and deviations in the resonance frequency from Mattis-Bardeen theory have been found. It has been suggested that these anomalies are caused by dipole two-level systems residing in dielectric layers near surfaces, which interact with the high frequency electric fields in the resonator [3-4]. In order to identify to what extent two-level systems in dielectrics affect the microwave properties of superconducting films we study NbTiN resonators with a 10, 40 or 160 nm thick SiO2 covering layer. We find that the resonance frequency of bare NbTiN resonators, unlike Nb, Ta and Al resonators, closely follows Mattis-Bardeen theory down to 350 mK. We demonstrate that deviations in the resonance frequency can be generated by covering the resonators with a thin amorphous SiO2 layer, and that these deviations scale with the layer thickness. In addition, we find that the frequency noise is strongly increased as soon as a SiO2 layer is present, but is, counter-intuitively, independent of the layer thickness. These observations show that the physical mechanisms causing the excess frequency noise are different from those responsible for the deviations in the resonance frequency.

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[4] J. Gao et al., arXiv:0802.4457.