4K でのミリ波超伝導薄膜共振器を用いたアモルファス SiO_2 の 2 準位系損失の測定

Two-level System Loss of SiO2 Measured at 4 K with Millimeter Superconducting Thin-film Resonators

国立天文台 [1], ○単 文磊 [1], 江崎 翔平 [1]
NAOJ[1], Wenlei Shan[1], Shohei Ezaki[1]
E-mail: wenlei.shan@nao.ac.jp

Two-level system (TLS) loss inherited in amorphous dielectric materials have been intensively investigated at millikelvin temperatures for its importance in limiting the performance of superconducting qubit devices and incoherent detectors based on superconducting resonators. In contrast, the experimental evidence of TLS loss in superconducting transmission lines at liquid helium temperatures and its relative significance with respect to other losses are not fully revealed. We investigated the loss of amorphous SiO_2 at liquid helium temperatures in a frequency range of 130-170 GHz by measuring Q factors of niobium microstrip and coplanar waveguide resonators. The measured losses show remarkable power and frequency-dependence, which is consistent with that modeled by TLS with a weak-field loss of about 3-7x10^{-3} depending on fabrication methods. The TLS loss and the quasiparticle loss exchanges the leading role at about 4 K in the measured frequency range, and this relationship is expected to hold in sub-millimeter wavelengths as well.

This work is partially supported by KAKENHI under Grant Number 23K20871.

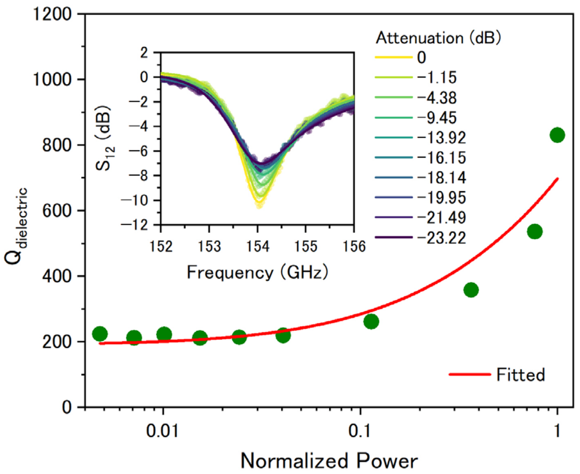

Fig. 1. Dielectric Q of SiO_2 measured as a function of signal power with a microstrip resonator under an ambient temperature of 3.3 K. The SiO_2, as the dielectric layer of microstrip line, was fabricated with PECVD. The signal power is normalized by the maximum output power of the signal source, which is about 3 μW. The fit was carried out by using the TLS model:

$$Q^{-1}(T,\omega,P) = Q_0^{-1}(\omega)\frac{\tanh\frac{\hbar\omega}{2k_BT}}{\sqrt{1+\frac{P}{P_c}}}.$$

Q_0 is the low-power quality factor at 0 K. P_c is TLS saturation power. T and ω are ambient temperature and angular frequency respectively. The inset shows the resonance curves measured at various signal attenuation.