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Search for elastic interactions in amorphous silica

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Abstract

Internal friction measurements were made above 6 mK for a sample of a-SiO_2 at 90 kHz using the torsional oscillator method. Since the internal friction is rather sensitive to nonlinear effects, strain amplitudes smaller than $\varepsilon_A < 10^{-8}$ were used to remain in the linear regime. Excellent agreement with the prediction of the Tunneling Model was observed.

Keywords: a-SiO_2; Internal friction; Low energy excitations; Tunneling model

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The low temperature acoustic properties of amorphous solids have long been successfully described by the Tunneling Model. Previous measurements of the internal friction on a-SiO_2 in our lab using the torsional oscillator technique at 66 and 160 kHz also showed excellent agreement with the model down to 50 mK. However, measurements of a double-paddle oscillator etched out of an amorphous silica wafer at 4.5 kHz showed deviations to the Tunneling Model below 40 mK [1]. Further disagreements were observed in other experiments in the speed of sound and sound attenuation measurements below 100 mK [2,3] and interpreted as indications of defect interactions [4].

The internal friction measurements on a-SiO_2 (Suprasil W) to be reported here show no deviations from the Tunneling Model to 6 mK at 90 kHz. The measurements were taken below 100 mK using a torsional oscillator [5] in a vibrationally isolated dilution refrigerator cryostat with a demagnetization stage [6]. In order to shield the sample from residual magnetic fields except for the earth's magnetic field in the lab (< 0.5 G), it was surrounded with a Nb tube.

Fig. 1 shows the resonance curves versus frequency for increasing strain amplitudes, ε_A, at 15 mK. Extreme care was taken to use very small strain amplitudes. Internal frictions were only determined when the frequency dependence of the oscillator was clearly in the linear regime, that is fit a Lorentzian curve well (solid curves in Fig. 1). In the linear regime, the internal friction was found to be independent of the driving voltage, V_{input}. Attempts to determine some internal friction in the nonlinear regime, e.g. by determining a half-width of the non-Lorentzian curves in Fig. 1 led to larger internal frictions.

The internal friction of a-SiO_2 at 90 kHz along with 4.5, 66, 160 kHz and the background are plotted in Fig. 2. The background of the torsional oscillator technique was

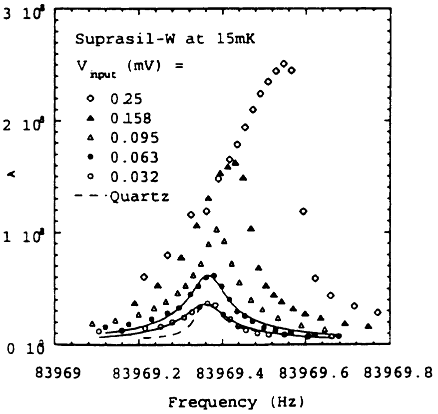

Fig. 1. Resonance curves of a driven a-SiO_2 (Suprasil W) rod at 15 mK and at different drive voltages. Solid curves are Lorentzian fits and the dashed curve is the response of the oscillator carrying a crystal quartz sample, i.e. background.

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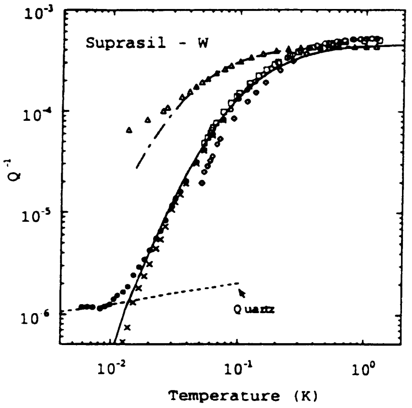

Fig. 2. Internal friction measurements of a-SiO_2 (Suprasil W) at 4.5, 66, 90, 160 kHz and the background. Solid circles, 90 kHz in demagnetization cryostat; *x*'s, 90 kHz after subtraction of the background; open circles, 90 kHz in a different dilution fridge; solid curve [5], Tunneling Model prediction with parameters from sound velocity measurements; diamonds, 160 kHz [1]; squares, 66 kHz [1]; triangles, 4.5 kHz on a vitreous silica double-paddle oscillator; dash-dot curve, Tunneling Model prediction; dashed curve, background of the technique. Note the excellent agreement between theory (solid curve) and experiment (*x*'s) for the 90 kHz torsional oscillator.

measured by replacing the a-SiO_2 with a crystalline quartz sample [5]. Below approximately 10 mK, the 90 kHz internal friction measurements approach that of the background (mounting losses). Subtracting these losses results in an internal friction that is in excellent agreement with the solid curve which is the Tunneling Model prediction based only on sound velocity measurements. The data show none of the disagreement observed previously on the silica double-paddle oscillator vibrating at 4.5 kHz in its antisymmetric mode. Also, from power dissipation measurements on a spectrum analyzer, we conclude this disagreement had been caused by an experimental artifact, either by sample heating or by nonlinearity. In the work reported by Burkert et al. [7] at this conference, the authors report results which disagree with the Tunneling Model at an order of magnitude of frequencies lower than our own. They argue that the measuring frequency has a major influence on the results. These results are very interesting but experimental artifacts need to be ruled out.

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