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Errors on the Cryogenic Mechanical Loss Measurement in Cantilever Ring-down Method

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Abstract

We report here, based on our repeated measurements on various kind of thin film samples on silicon cantilevers, error patterns of cryogenic mechanical loss measurement in cantilever ring-down method from 10K to room temperature. We found that the measured cryogenic loss is highly repeatable with temperature re-cycling from 10K to room temperature. While on re-clamping, the measured loss is highly repeatable from 10K to ~100K, but less repeatable at elevated temperature; non-repeatable loss peaks appear with different clamping at the elevated temperature. With careful alignment during the sample-clamp assembling process, problem improved. Re-clamping with careful alignment is necessary to ensure that the peaks presented in the temperature range above ~100K are real.

Cryogenic loss measurement setup

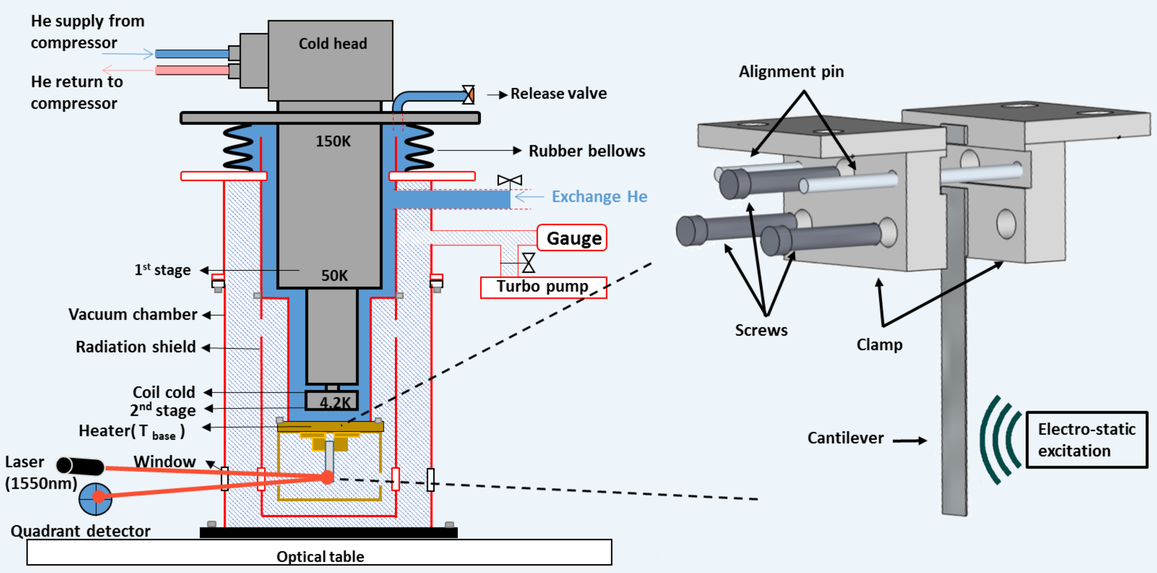
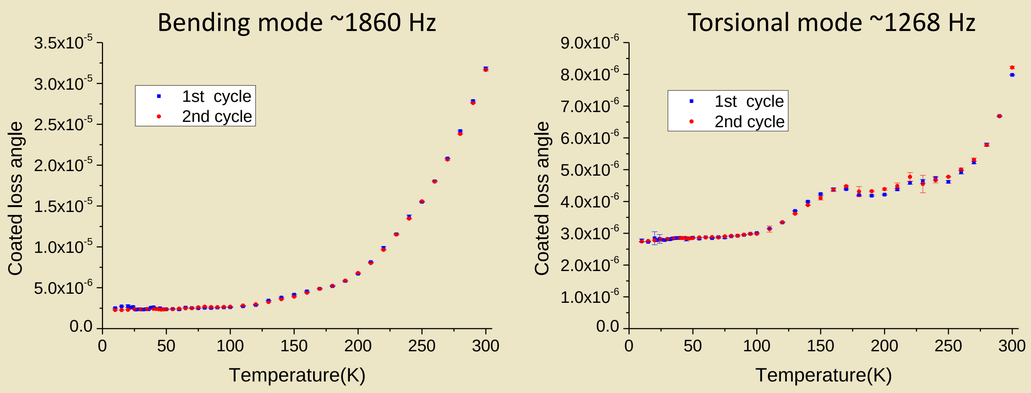


Fig. 1 Setup of cryogenic cantilever ring-down system in NTHU

- The cryogenic system is a JANIS SHI-4XG-15. It is a closed-loop system free of helium-replenishment.
- A proprietary rubber bellow is used to isolated the vibration from the compressor.
- Temperature range is from 5K to room temp. with pressure below 10^{-5} mbar[1].
- Stainless steel SUS-420J2 clamp design is shown above on the right.

Effect of temperature re-cycling

sample : IBS TiO_2/Si-sub



sample : PECVD SiO_2/Si-sub

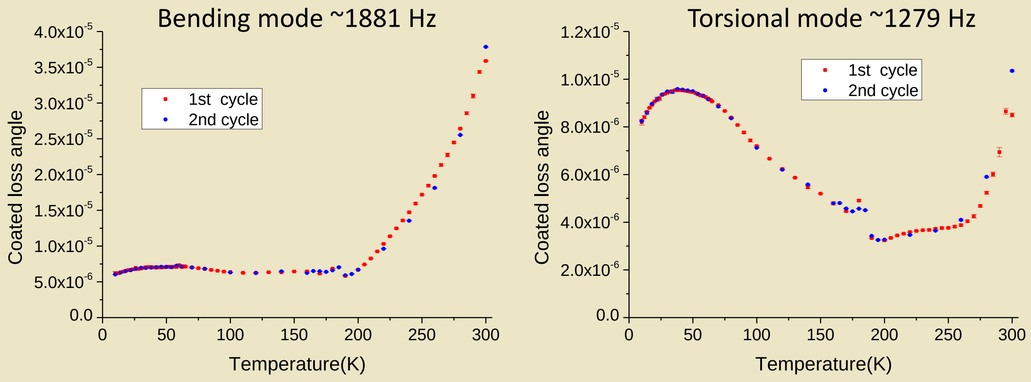
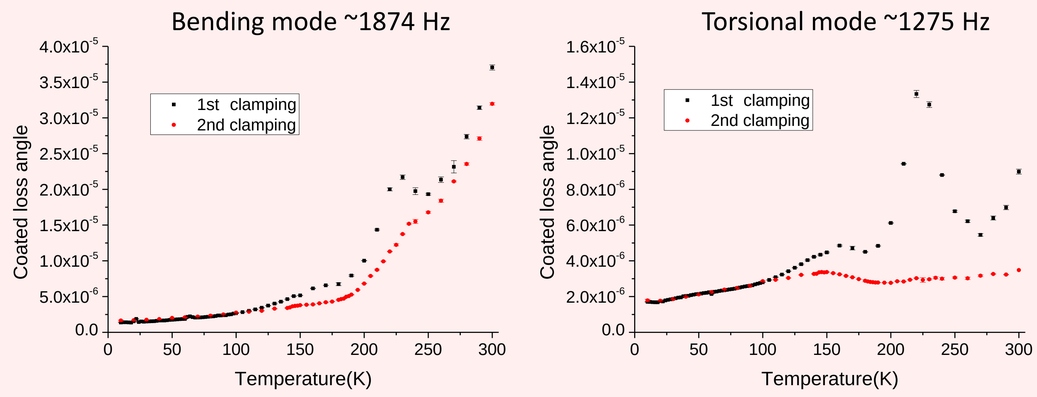


Fig.2 Loss angle for temperature re-cycling. Temperature was cooled down to 10K from room temperature then loss angle was measured at certain temperature increments up to room temperature. Without opening the chamber, the temperature was cooled down again to 10K and loss measurement for the 2nd temperature cycle was taken.

Effect of re-clamping

sample : PECVD $SiN_{0.40}$/Si-sub



sample : PECVD $SiN_{0.87}$/Si-sub

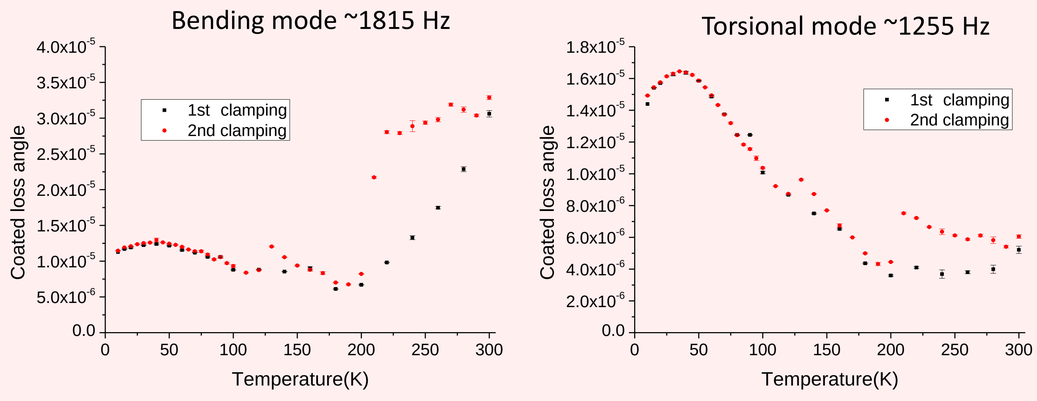
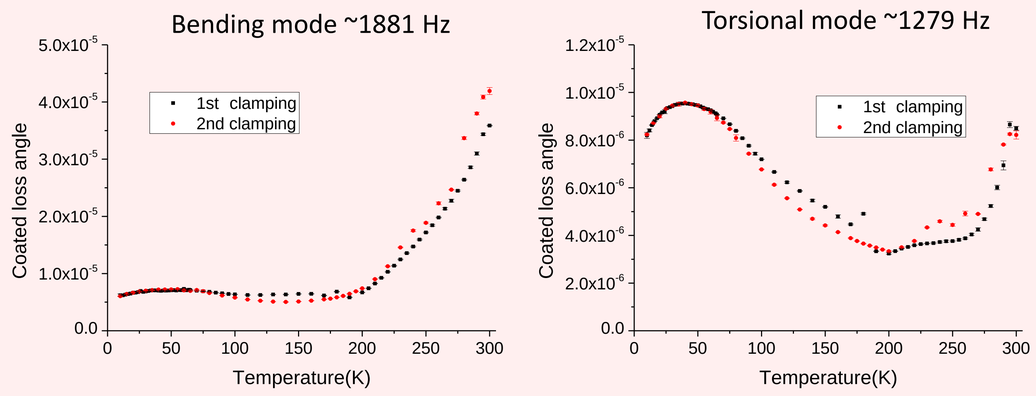


Fig.3 Loss angle with re-clamping. Temperature was cooled down to 10K from room temperature, then loss was measured at certain temperature increments up to room temperature. The chamber was opened and the sample was re-clamped. The measurement process was repeated for the 2nd clamping. False peaks appeared from above ~ 100K to room temperature depending on clamping.

sample: PECVD SiO_2/Si-sub



sample: PECVD QW stack $SiN_{0.4}/SiO_2$/Si -sub

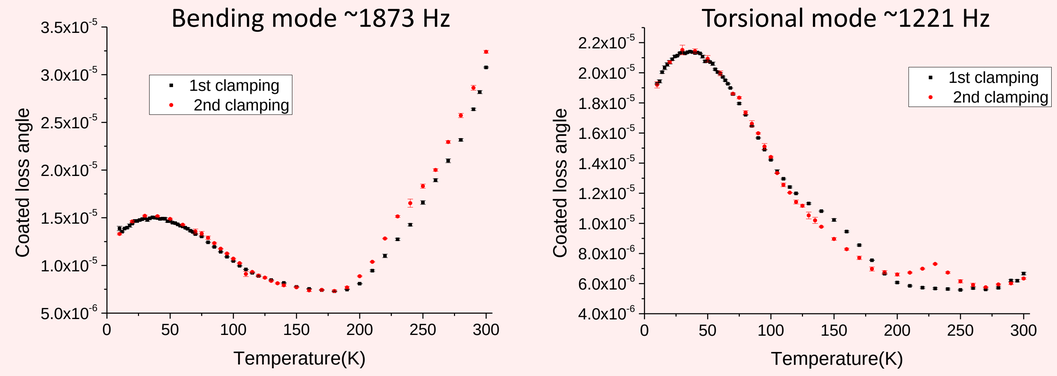


Fig. 4 Loss angle measured with improved clamp alignment. The sample-clamp assemble was considered well-aligned when the alignment pins were pulled out easily without friction after the screws were tightened. This improvement in alignment reduced the false peaks in comparison to Fig. 3.

Conclusion

- Temperature re-cycling gives highly repeatable loss value through out the temperature range. This implies that coarse scan through the temperature range could be performed at first to identified the temperature region within which fine scanning should be performed and be accomplished by subsequent directly cooling back.
- False peaks may appear from above ~ 100K to room temperature on re-clamping. If temperature range above ~100K is of interest, re-clamping with careful alignment is critical to ensure that no false peaks are presented.
- For temperature region below ~100K, the loss value is highly repeatable regardless of the re-clamping. One clamping should be confident enough to determine the loss value when the interested temperature range is below ~100K.

Reference:

[1] S Chao et al., “A closed loop cryogenic mechanical loss measurement system for cantilever samples”, LIGO document: G1501048 (2015)