Temperature Dependent Mechanical Loss Measurements of TiO_2-doped GeO_2 thin films

GWADW
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Motivation

TiO_2- doped GeO_2 is being studied as a prospective coating for A+

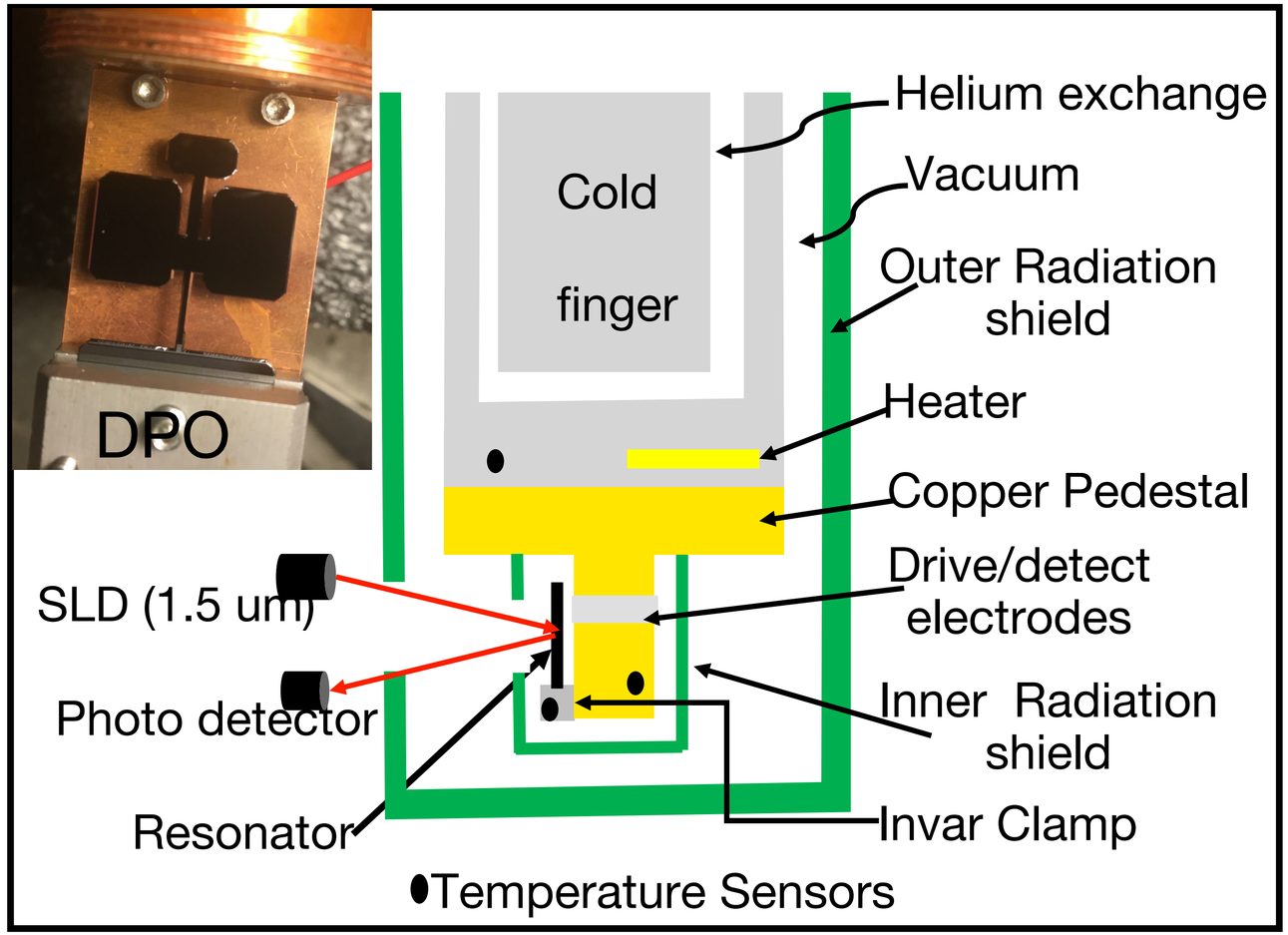
- Atomic structure studies showed that GeO_2-based coatings could have low RT loss (**Phys. Rev. Lett. 123, 045501**); TiO_2-doped GeO_2 coating emerged as possible coating solution for A+
- Latest RT loss measurements/ thermal noise estimates of TiO_2-doped GeO_2 are encouraging (See Vajente *et. al*, P2100075)
- Room for further improvement

Temperature dependence of mechanical loss is important

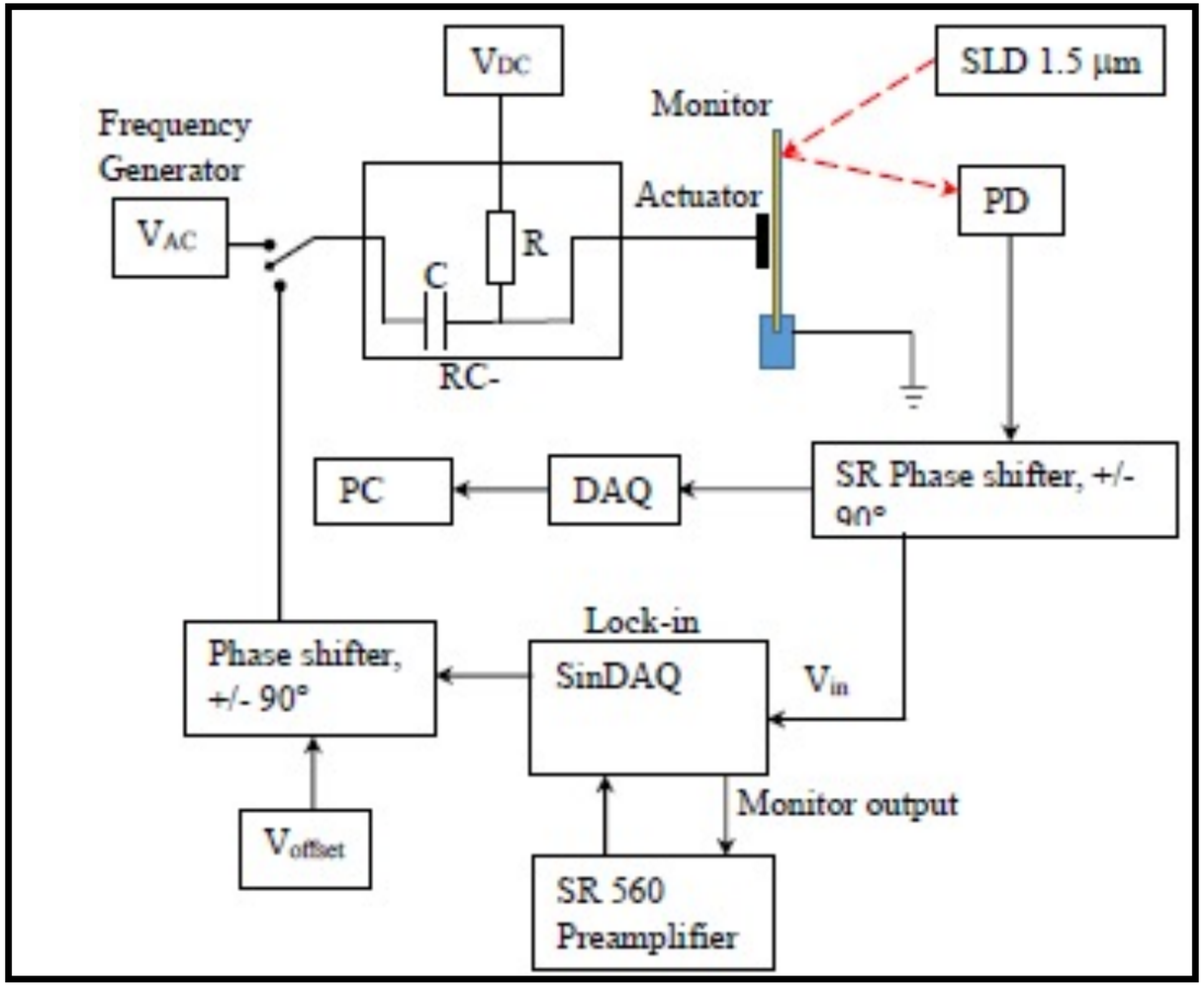
- Helps design a better RT coating by elucidating the underlying loss mechanisms, two level system (TLS) distributions etc.
- Informs future coating designs for cryogenic detectors

Mechanical loss measurement setup

Schematic of flow cryostat

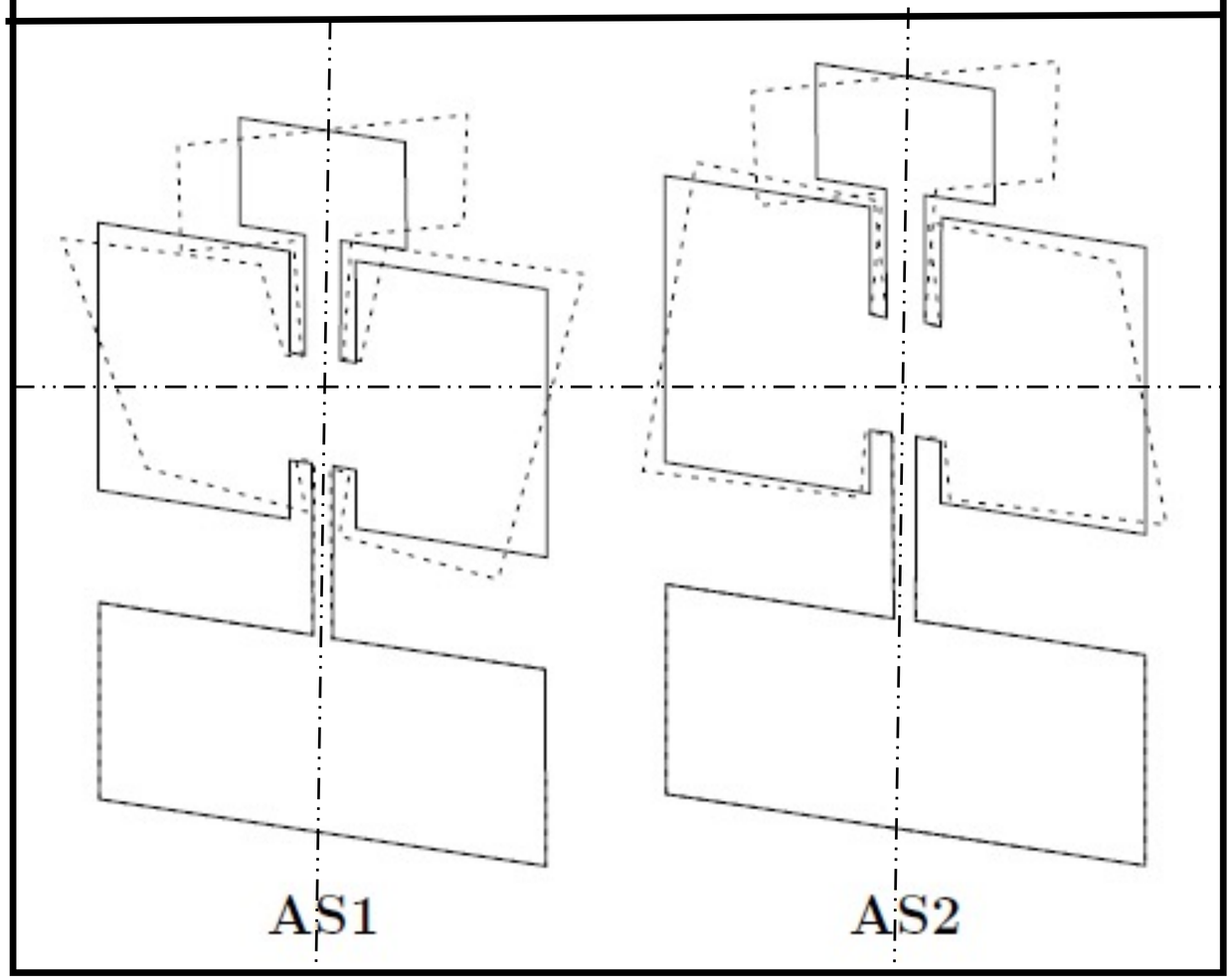


Block diagram of the measurement process



Resonator used for loss measurement

Double paddle Oscillators (DPO)



Extracting mechanical loss of coatings using ringdown of a DPO

For AS2 Mode (2nd Anti-Symmetric) Torsional mode

$$\varphi_{coating} = \frac{G_s\, t_s}{3 G_c\, t_c} \left(\varphi_{coated} - \varphi_{uncoated}\right)$$

G_s = shear modulus of substrate (Si)

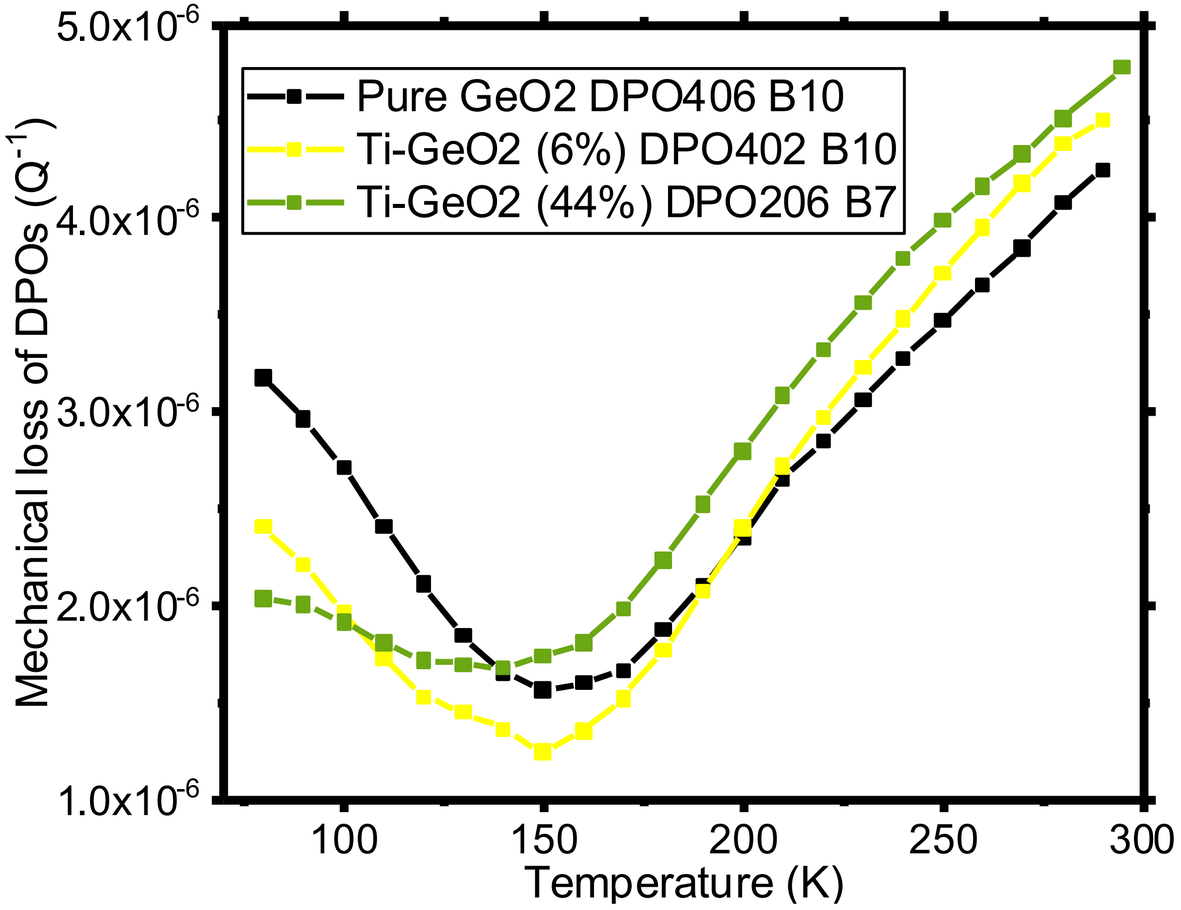
G_c = shear modulus of coating

t_s = thickness of substrate (Si)

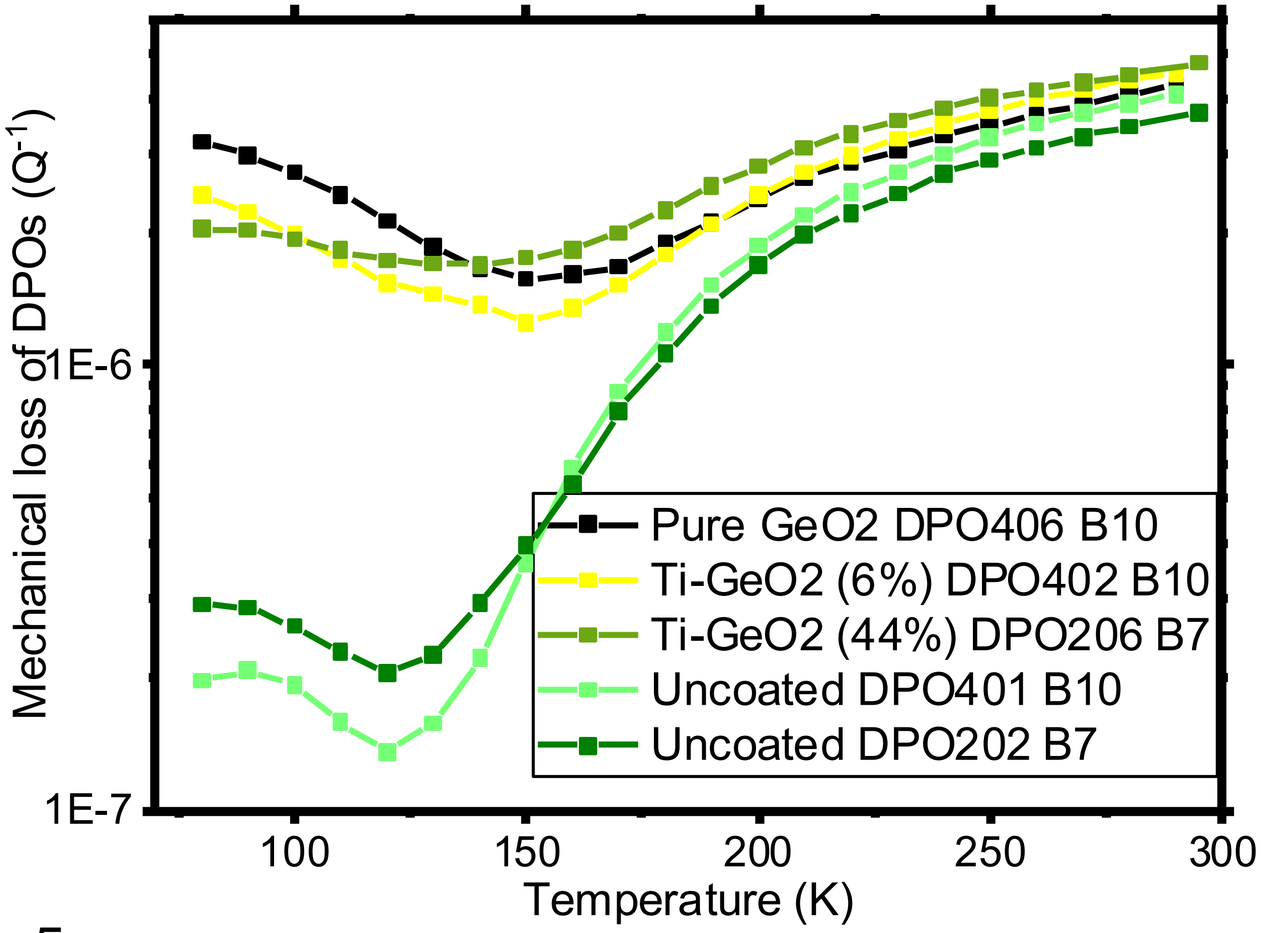
t_c = thickness of coating

Mechanical loss of as-deposited TiO_2-GeO_2 (295K- 80K)

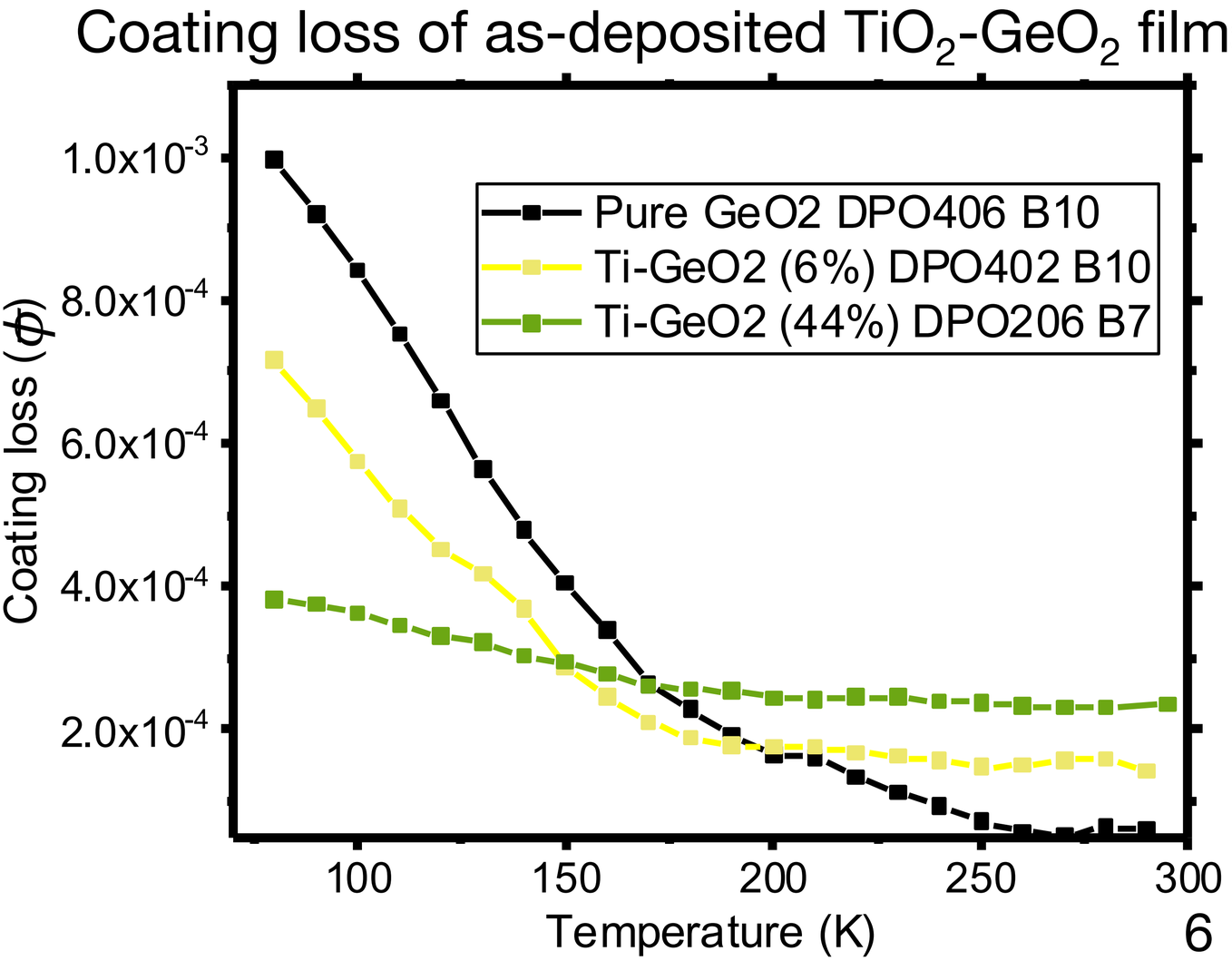
Mechanical loss of Coated DPOs



Mechanical loss of Coated and Uncoated DPOs

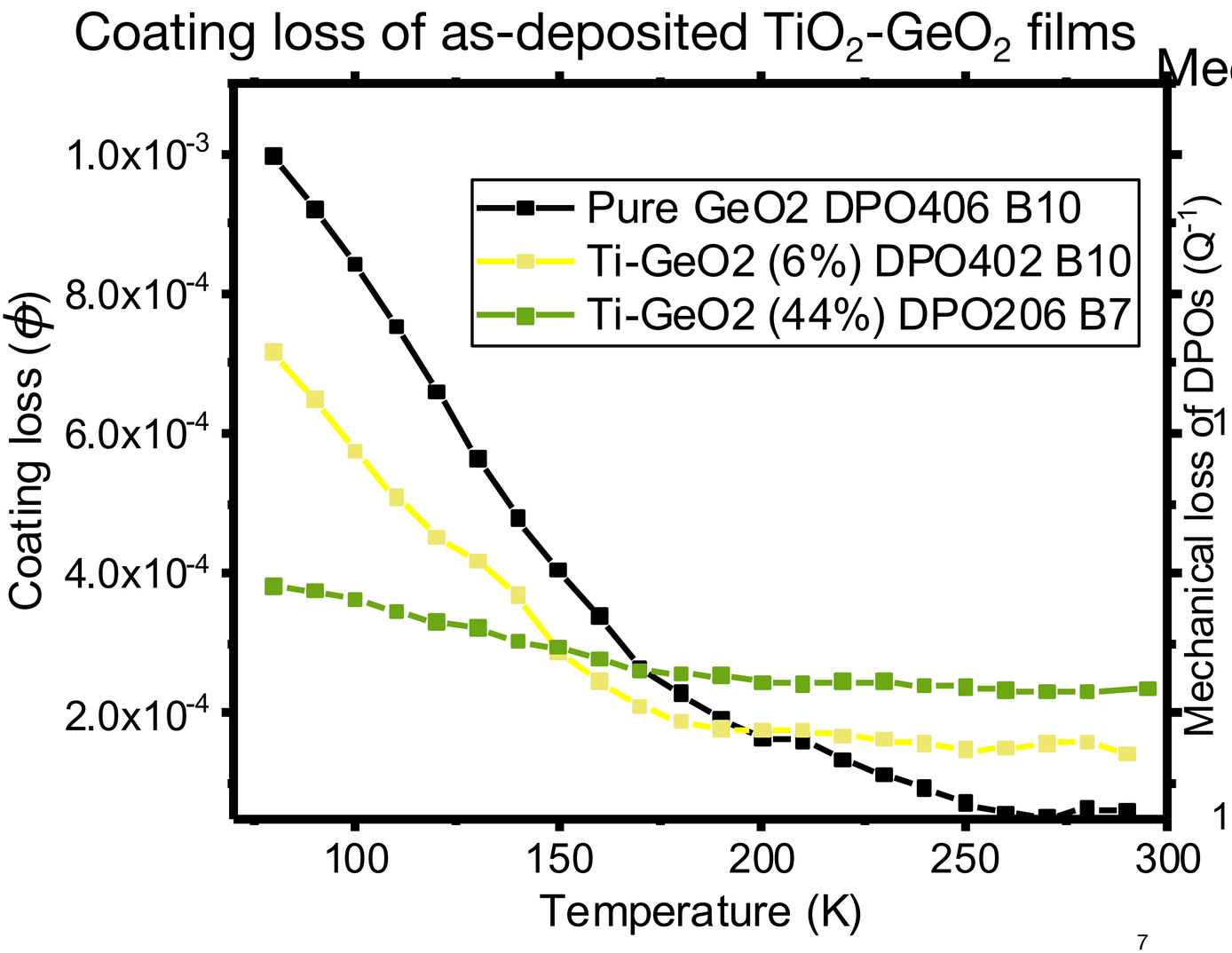


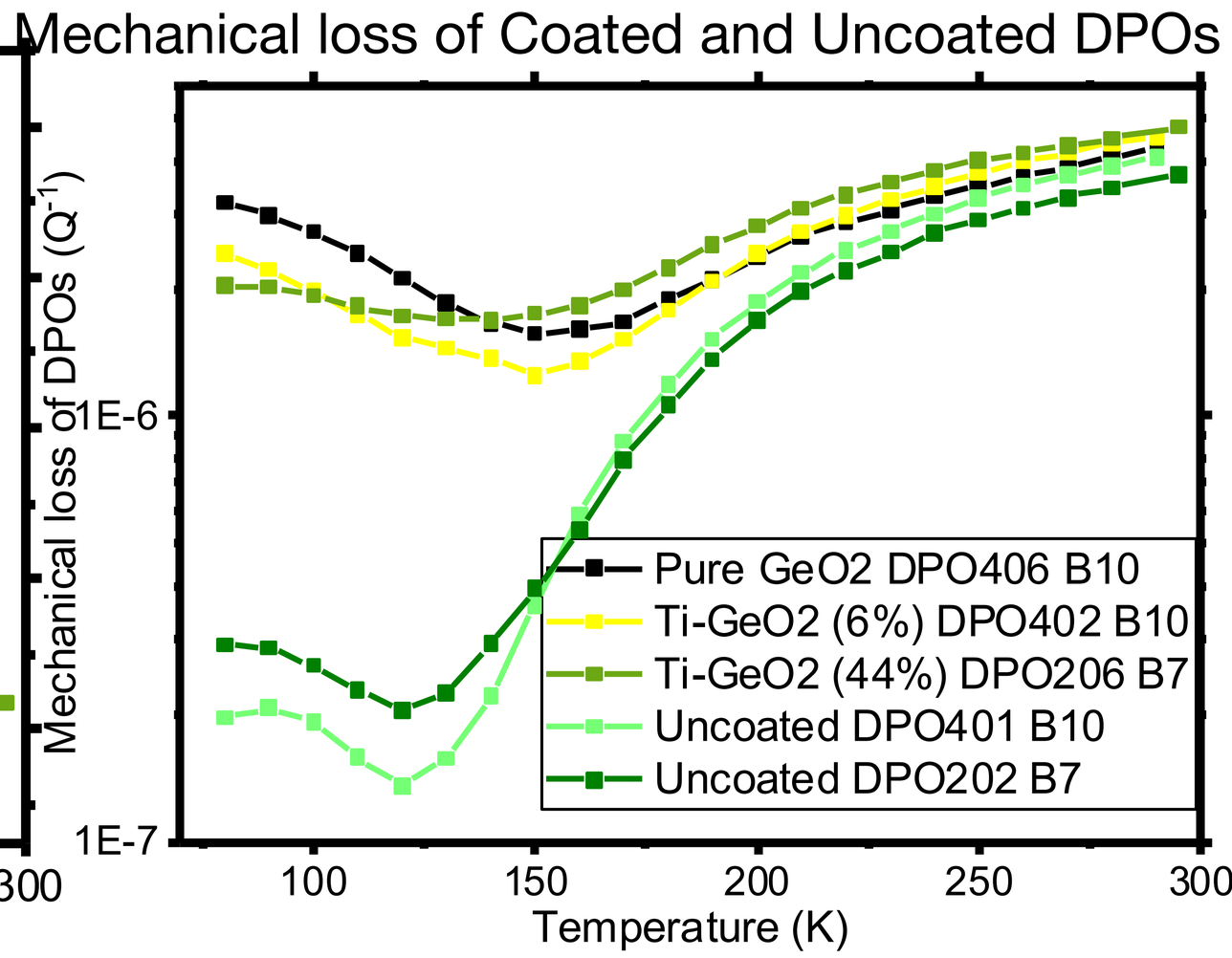
Mechanical loss of as-deposited TiO_2-GeO_2 (295K- 80K)



Samples	As-deposited coatings	Loss at 295K	Loss at 80K
DPO406	Pure GeO_2	$6.12e^{-5}$	$9.95e^{-4}$
DPO402	Ti-GeO_2 (6%)	$1.43e^{-4}$	$7.16e^{-4}$
DPO206	Ti-GeO_2 (44%)	$2.35e^{-4}$	$3.81e^{-4}$

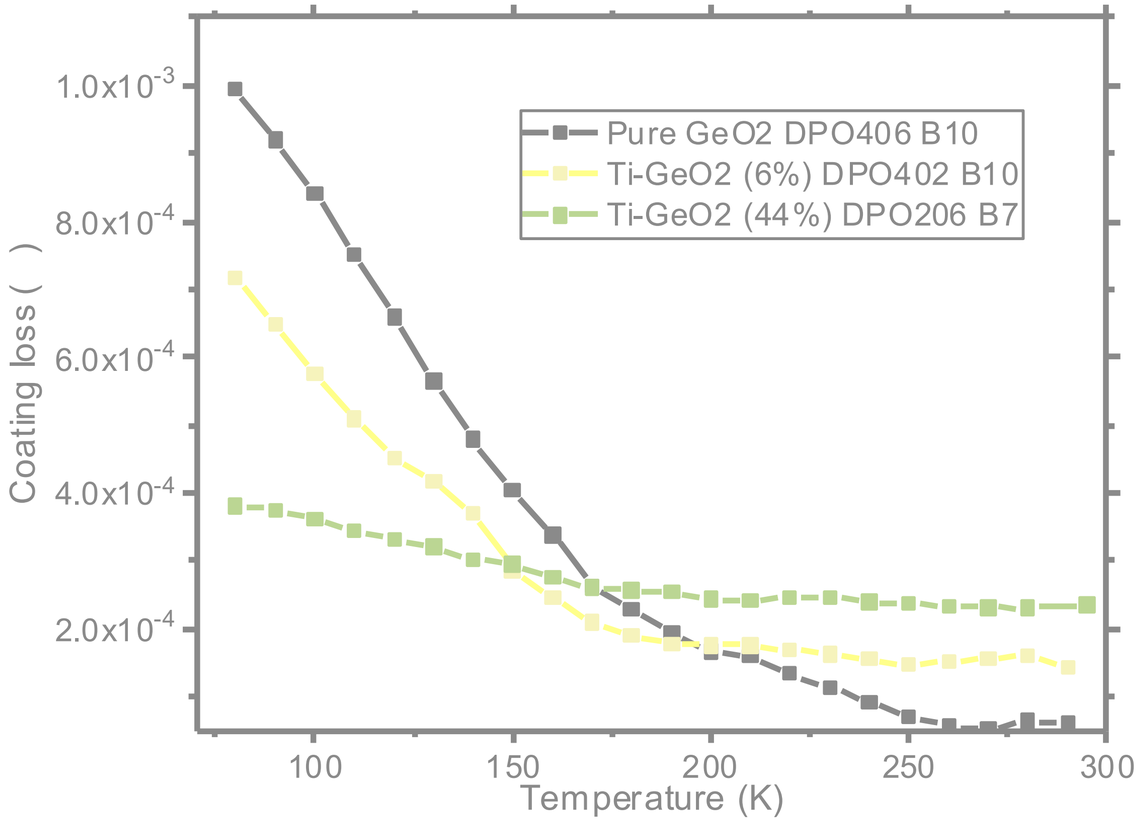
Mechanical loss of as-deposited TiO_2-GeO_2 (295K- 80K)



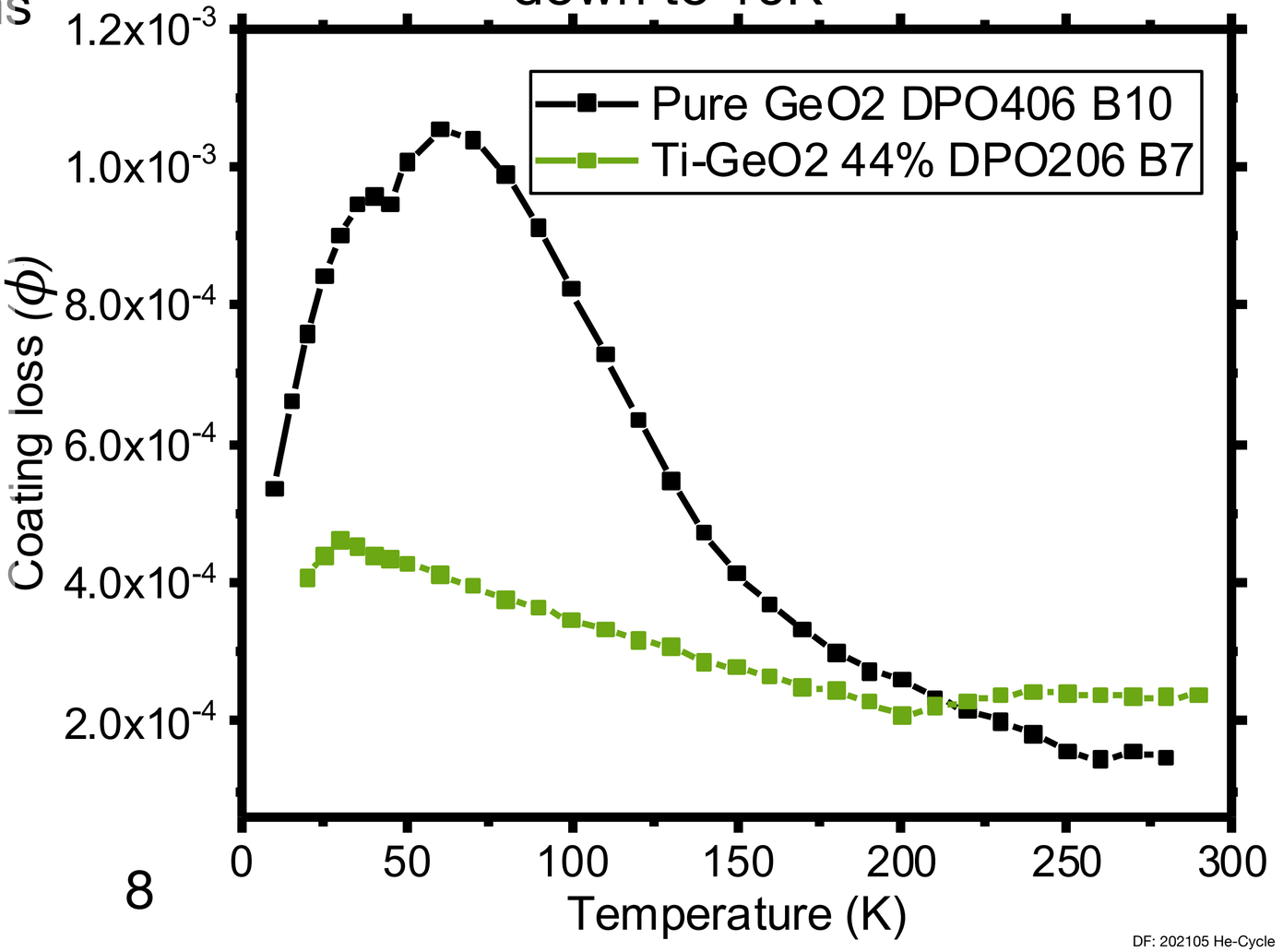


Mechanical loss of as-deposited TiO_2-GeO_2 (295K- 10K)

Coating loss of As-deposited TiO_2-GeO_2 films

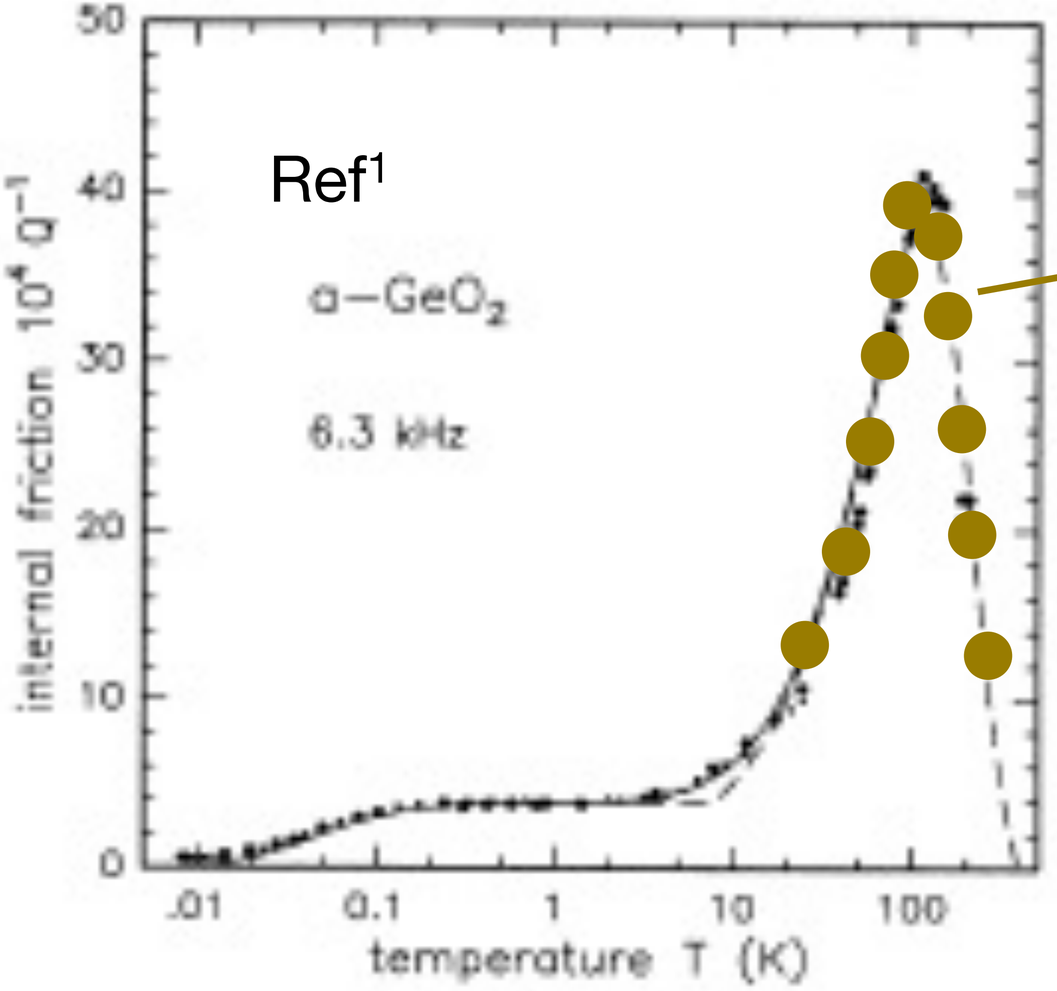


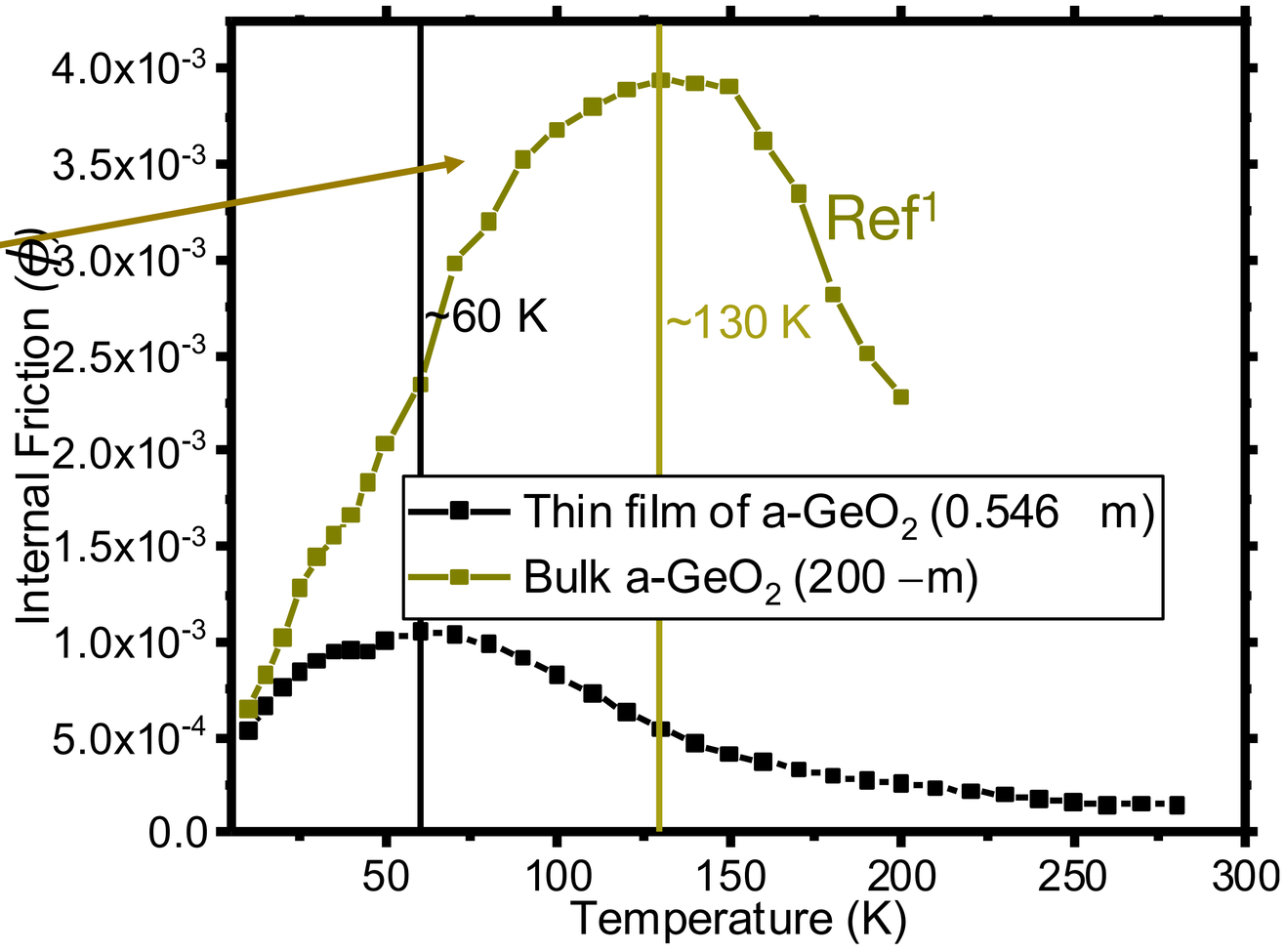
Coating loss of as-deposited Ti-GeO_2 thin films down to 10K



DF: 202105 He-Cycle

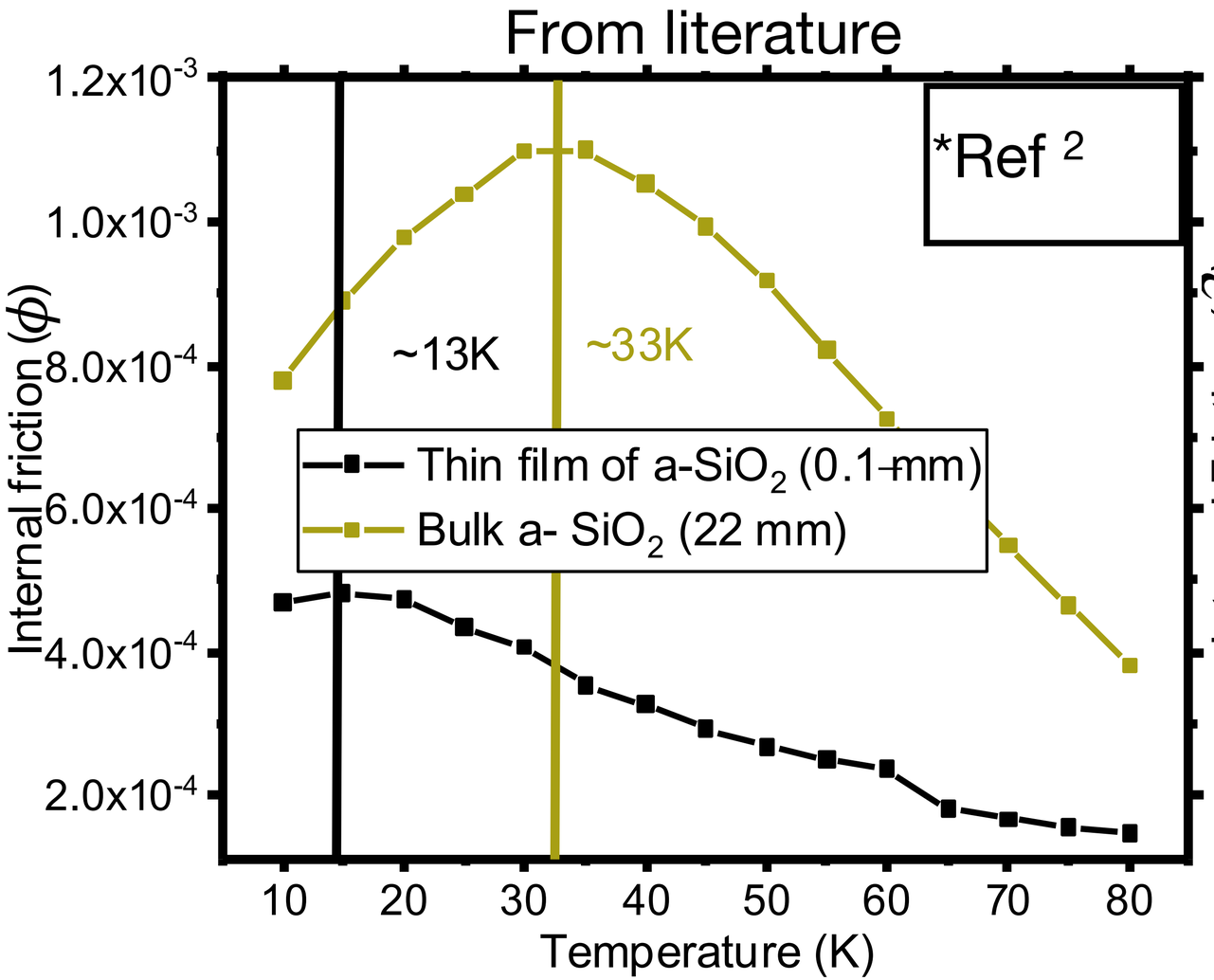
Loss curves of Bulk a-GeO_2 and Thin film of a-GeO_2

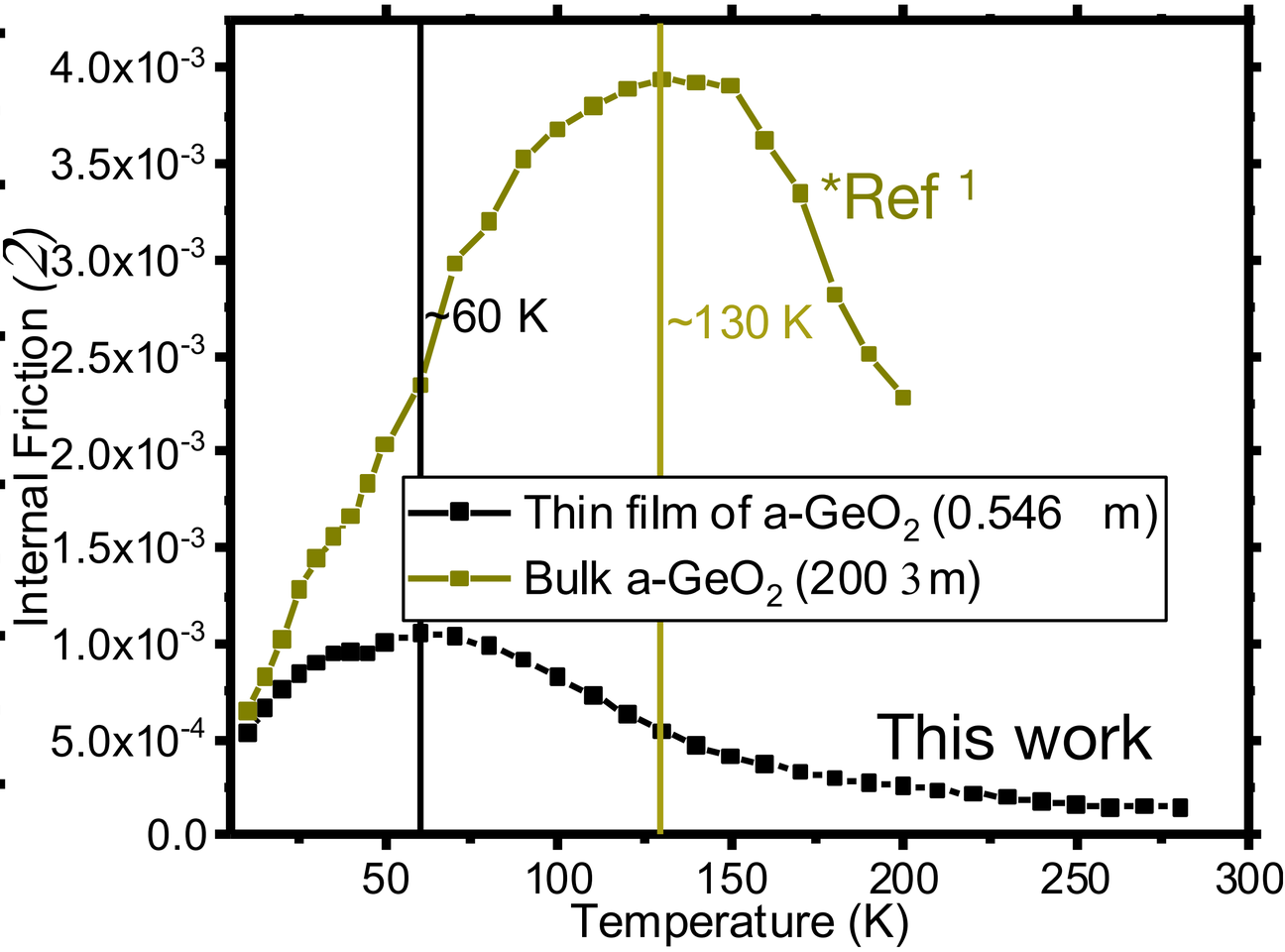




Ref[1]: Phys. Rev.B 52, 7179 (1995).

Bulk Vs Thin film loss behavior of a-SiO_2 and a-GeO_2



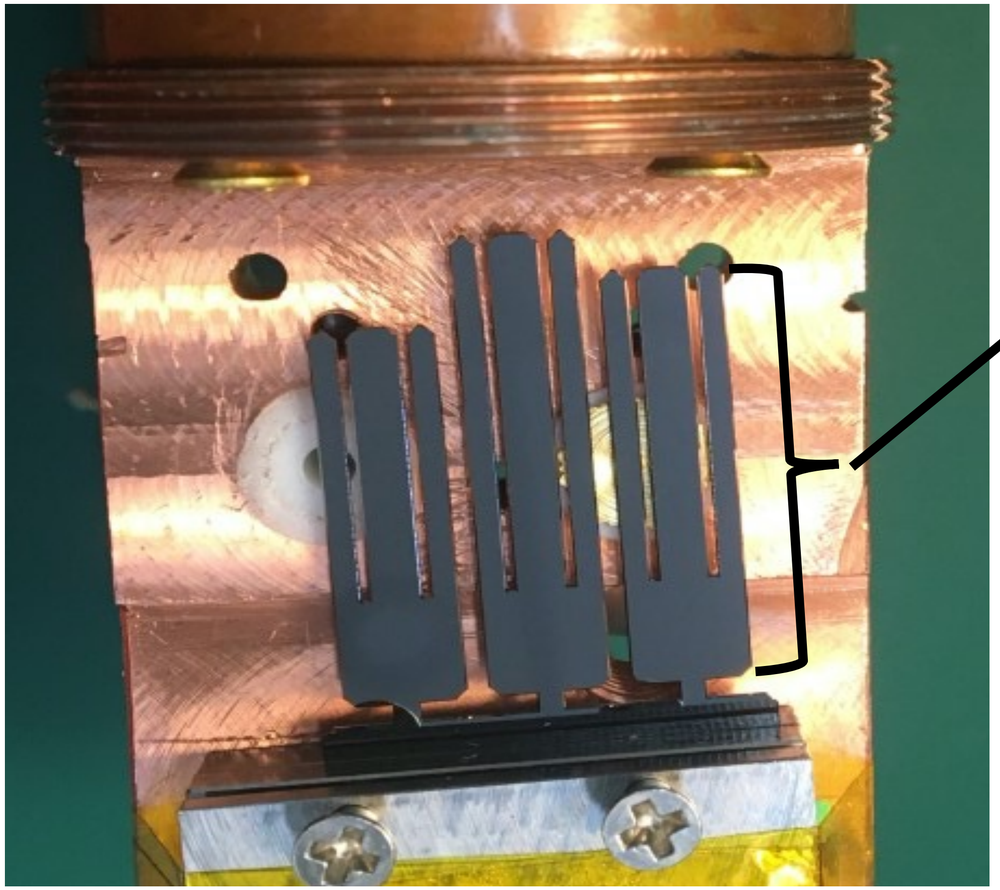


Ref[2]: I W Martin *et al* 2014 *Class. Quantum Grav.* **31** 035019

Ref[1] : Phys. Rev.B 52, 7179 (1995).

Tridents: Micro-resonators for frequency dependent loss measurements of optical coatings

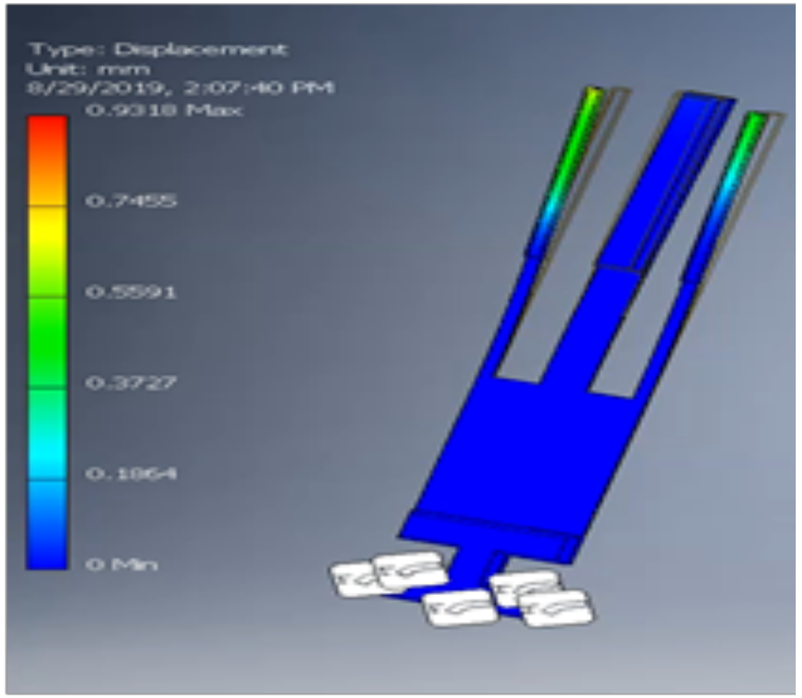
1 Chip with 3 Tridents



L= 15 mm

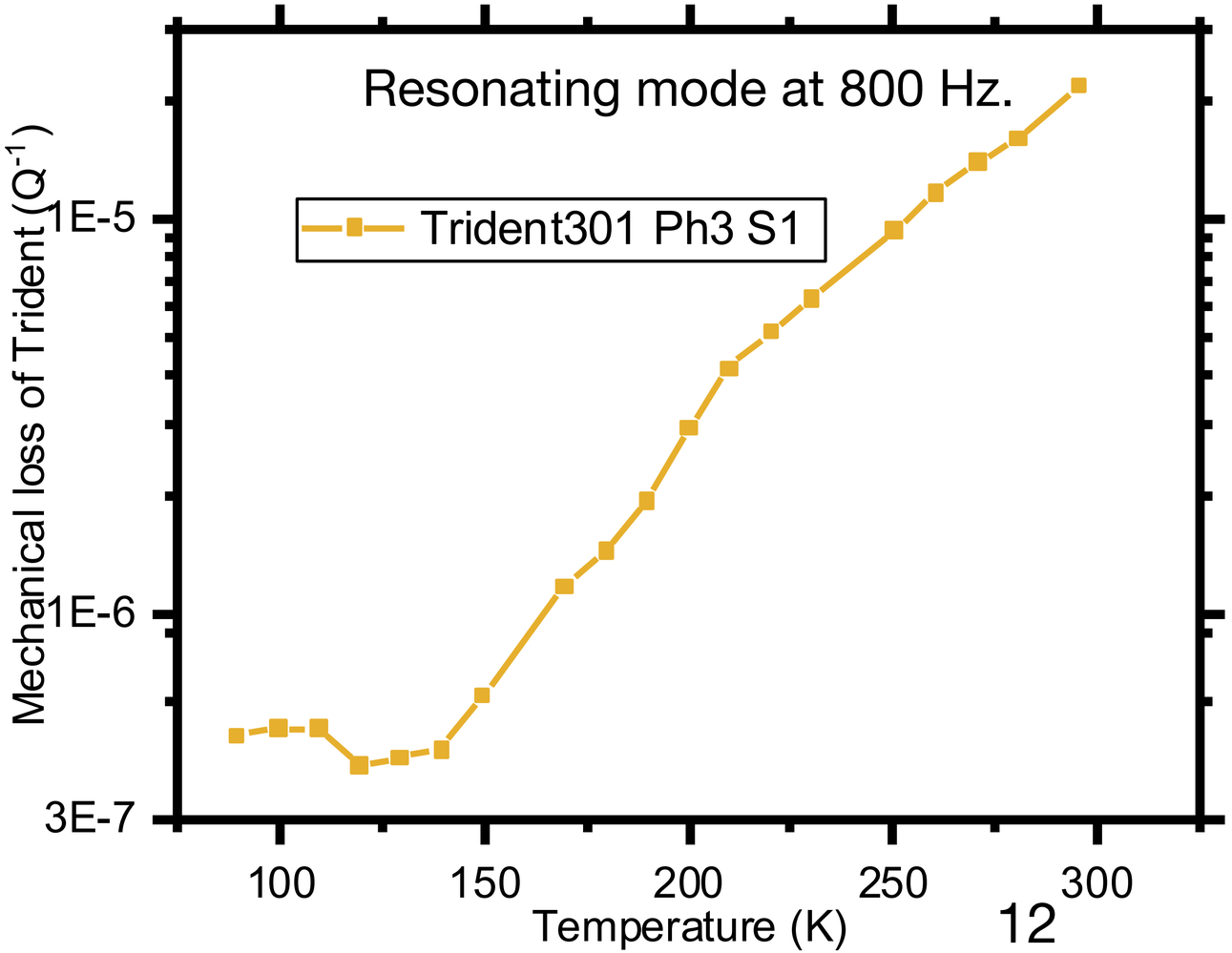
T = 130 mm

1 of its AS Mode



Tridents: Micro-resonators for frequency dependent loss measurements of optical coatings

Mechanical loss of an uncoated Trident from 295K down to 80K



Q^{-1} at 290K = 2.17 E^{-5} ± 2.8E^{-7}

DF: 202105 He-Cycle

Summary

➢ Temperature dependent loss measurements of GeO2 and Ti-GeO2 using DPOs.

1. For all IBS films studied in this work, cryogenic loss is found to be higher than RT loss.

2. Unlike the RT loss, cryogenic loss of thin film GeO_2 is lower than that of bulk GeO_2 (from literature).

3. RT loss is seen to increase with Ti concentration.

➢ Frequency dependent mechanical loss measurements using Tridents.

1. Temperature dependent Mechanical loss of the current Trident shows encouraging behavior for its applicability in the frequency dependent loss measurements of the optical coatings.

➢ Future works.

1. Continue the ongoing measurements as a function of Ti-concentration and annealing temperature using DPOs.

2. Start the frequency dependent measurements using the Tridents from Phase3.

3. Atomic structure measurements and modelling of Ti-GeO_2 are on-going (Stanford U., U. of Florida, and Sungkyunkwan U.) hence a more unified picture of atomic scale loss mechanisms could emerge.

Acknowledgments

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- Simon Tait, University of Glasgow.

SNF Stanford Nanofabrication Facility

LSC Center for Coatings Research

GORDON AND BETTY MOORE FOUNDATION

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