Tailoring medium range order in amorphous oxides for coatings of gravitational wave interferometers

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120 Engineering (Hammond Auditorium)

Glassy amorphous oxides are fascinating materials in that their amorphous nature provides for enormous functionality. Amorphous oxides are ubiquitous in optics as they are transparent over a broad wavelength range spanning from the near ultraviolet to near infrared. In thin film form, vapor deposited amorphous oxides are the building blocks of interference coatings found in most optical systems. The suitable combination of a low refractive index material, as SiO_2, and a high refractive index material, as Ta_2O_5, makes it possible to tailor the optical response of interference coatings to the application. State-of-the-art interference coatings with absorption loss of parts per million at near infrared wavelengths are routine [1]. However, there are applications, as is the case of coatings for gravitational wave interferometric detectors (GWD), that in addition to a superior optical quality require the coatings to have ultra-low internal friction [2]. Internal friction results from the an-harmonic elastic behavior of the amorphous solids that leads to elastic energy dissipation.

In this talk I will describe the results of a journey in the identification of amorphous oxides with ultra-low internal friction. We investigated the structural and optical properties of a family of amorphous oxide thin films to identify structural modifications that occur in mixtures, such as those of TiO_2 and Ta_2O_5 that result in low internal friction [3,4]. TiO_2 doped Ta_2O_5 in combination with SiO_2 are used in the coatings of today's GWD as Advanced LIGO (Laser Interferometer Gravitational Wave Detector) [2, 5]. Using amorphous GeO_2 as an example, I will describe how the ordering that occurs at length scales of ~20Å (medium range order) affects internal friction [6]. These fundamental studies paved the way to engineer a new ternary alloy, TiO_2 doped GeO_2 which is very promising for reducing internal friction in interference coatings for GWD beyond the state-of-the-art [7].

This work is a collaboration among several groups of the LIGO Scientific Collaboration that include: LIGO Caltech, Stanford University, University of Montreal and Colorado State University. The work is supported by the National Science Foundation and the NSF/Moore Foundation Center for Coatings Research.

References

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Dr. Carmen S. Menoni is University Distinguished Professor in the Department of Electrical and Computer Engineering. She also holds appointments in the department of Chemistry, the School of Biomedical Engineering and the School of Advanced Materials Discovery. Prof. Menoni's research encompasses bridges optical science and material science. She uses spectroscopic and other material diagnostics to identify the structural organization of amorphous oxide at the nanoscale. Through a combination of fundamental understanding of the optical and structural properties of the thin films materials and device engineering, Prof. Menoni research is advancing the state-of-art in interference coatings for gravitational wave interferometers. Menoni is a member of the LIGO (Laser Interferometer Gravitational Wave Detector) Scientific Collaboration since 2017. Her work is described in over 300 archival publications and has been presented in 340 conference talks, including 100 invited presentations, at national and international conferences.

Prof. Menoni is Fellow of the Institute of Electrical & Electronic Engineers (IEEE), the American Physical Society (APS), the Optical Society of America (OSA), the American Association for the Advancement of Science (AAAS) and the International Society for Optics and Photonics (SPIE). Carmen Menoni is founding editor of IEEE Photonics Journal. Prof. Menoni was President of the IEEE Photonics Society in 2020-2021.