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Investigating Crystalline Corundum Coatings for Low-Noise Cryogenic Interferometers

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To further reduce the mirror coating thermal noise for the Einstein Telescope (ET) and other third-generation gravitational wave detectors, a substantial improvement in the coating technology and material is necessary. Employing crystalline coatings is one of the new promising directions of the scientific endeavor to replace SiO₂ and Ti:Ta₂O₅ for interferometric measurements at cryogenic temperatures. So far, the most promising epitaxial coatings taken into consideration are III-V compounds multilayers, such as GaAs/Al_{1-x}Ga_xAs on a GaAs substrate. Despite these coatings' high optical and mechanical performance, significant concerns involve their upscaling to the desired mirror size for the ET. In this study, we propose crystalline corundum materials (crystal structure X₂O₃ as sapphire) as an upscalable alternative to III-V compounds for high-reflectivity multilayer coatings in cryogenic detectors. As proof of concept, we started studying Cr₂O₃ coatings deposited epitaxially via oxygen-assisted MBE on Al₂O₃ substrates. Mechanical losses measurements via GeNS system show losses of the chromia coating as low as 5·10⁻⁶ between 5K and 55K, 1-2 orders of magnitude lower compared to the losses of SiO₂ and Ti:Ta₂O₅ at the same temperatures. Nonetheless, the optical absorption of this material is still 2 to 3 orders of magnitude higher than the specifications required for the ET at different working wavelengths. This work still proves to be useful, as it shows the potential of crystalline materials in cryogenic optical applications. Furthermore, a wide range of compounds (Ga₂O₃, Fe₂O₃, Ti₂O₃⋯) is epitaxially compatible with sapphire, i.e. presents the same corundum structure, so there is a wide margin for optimization and choice for the most suitable pair of materials to employ in the multilayer.

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