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Minimizing Mechanical Losses through Partial Crystallization in Ion-Beam Sputtered Tantalum Oxide Thin Films

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The standard post-deposition treatment on amorphous tantala (Ta2O5) mirror coatings consists in a 10 hours thermal annealing at 500℃ temperature. This procedure reduces internal strains, thus lowering the coating loss angle. The coating remains amorphous during this procedure, which makes it optically homogeneous.
Treating the samples at higher temperatures and/or for longer annealing times may lead to the formation of crystalline regions inside the coating, which are generally considered detrimental from the optical point of view. It is however not clear to what point the annealing procedure can be pushed in order to achieve the best performances, eventually allowing for the presence of small amount of crystallized material.
In this work we performed controlled thermal annealing treatments on amorphous tantalum oxide (tantala, Ta2O5) thin films produced by Ion-Beam Sputtering in order to to achieve varying degrees of crystallized fraction. We characterized the microscopic structure of the annealed samples by combining different analytical techniques. Our investigation revealed that the amorphous films comprise randomly distributed crystalline grains, whose density and average size depends on the duration of thermal treatment.
Furthermore, we assessed the mechanical losses of the treated coatings via a Gentle Nodal Suspension (GeNS) system. Remarkably, we detected a substantial reduction in the coating's mechanical loss angle with respect to annealed amorphous coatings. The reduction in mechanical losses comes at the expense of an increase in optical scattering.
This observed improvement in mechanical loss angle may lead to the definition of alternative thermal treatments to improve the mechanical performances of coatings for gravitational wave detectors or other highly sensitive optical experiments.

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