Study the mechanical loss of amorphous mirror coatings for gravitational wave detection by two level system model

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For future generations of laser interferometer gravitational-wave observatory (LIGO), thermal noise from amorphous mirror coatings will form a limiting noise source in its most-sensitive frequency band, which is current around 150 Hz.[1] In previous study, two level system (TLS) model have been used to study the mechanical loss of the amorphous SiO_2, Ta_2O_5, doped SiO_2 and Ta_2O_5 amorphous mirror coatings successfully.[2-4] With the help of reverse Monte Carlo method (RMC), we generate amorphous models for both as-deposited and heat treated samples base on the experimental grazing-incidence pair distribution function (GIPDF) measurements.[5] In this work, we further refine the RMC models of 50% ZrO2doped Ta_2O_5 with first-principle atomic structure relaxation and improve the previous TLS model by correctly taking into account two relaxation times associated with one asymmetrical TLS transition. The mechanical loss of each TLS is considered individually. From the mechanical loss calculation based on these models, we find annealing will partially eliminate voids (or pores) larger than 200 A_3 and smaller than 100 A_3 and make atomic structures more uniform resulting higher mechanical loss at low temperature. The void distribution is one of the possible structure features to understand the annealing effect to the mechanical loss of the amorphous materials.

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