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# Evolution Optical Coating Thin Films Following Thermal Annealing: IR Spectroscopic Ellipsometry and Raman Investigation

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The development of future gravitational wave observatories such as the Einstein Telescope requires the development of multilayer mirror coatings with low absorption and constant refractive indices **[1]**. These coatings, which are usually amorphous mixed oxides, are deposited by ion beam sputtering. Thermal annealing after deposition is used to enhance the performance of the coatings. However, the specific atomic-scale structural changes that control this tuning are not well understood, especially for promising germania-based systems. This study investigates the effects of thermal annealing at 600° on amorphous oxide coatings based on germanium oxide. We used a complementary approach using infrared spectroscopic ellipsometry (IRSE) to measure the complex dielectric function ($\varepsilon = \varepsilon_1 + i\varepsilon_2$) and Raman spectroscopy to investigate the bond angle distribution and medium-range order in the oxide coatings **[2, 3]**. Our analysis shows a direct correlation between the annealing-induced structural relaxation **[4]** and the evolution of vibrational signatures in both the IR and Raman spectra. This study shows the effects of thermal processing to optimize the atomic structure and optical performance of germanium-based coatings for use in next-generation GWDs.

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*Keywords:* Optical coatings, thermal annealing, Infrared spectroscopic ellipsometry, Raman, GWD mirrors

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