Nanoscale-Thick Thin Films of High-Density HfO_2 for Bulk-like Optical Responses

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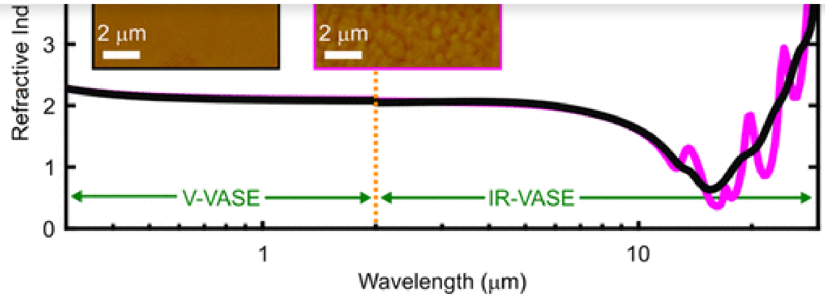
SUBJECTS:
Thin films,



The high refractive index, broadband transparency, and low spectral absorption of HfO_2 (hafnia) make it a suitable choice for thermally stable nanoscale optical filters, UV mirrors, and antireflection coatings. However, achieving dense thin films of HfO_2 with bulk-like optical properties has been a challenge due to differences in film stoichiometric and spatial uniformity at nanoscale thicknesses. Here, we assess HfO_2 thin films (i.e., <200 nm thicknesses) prepared using pulsed laser deposition (PLD) at different substrate temperatures (20–675 °C) and the associated chemical, structural, and optical properties are reported. X-ray diffraction analysis reveals that nanoscale-thick thin films of HfO_2 deposited at an ambient substrate temperature (20 °C) using PLD are amorphous with embedded nanocrystallites, whereas films deposited on heated substrates are polycrystalline monoclinic HfO_2. For the films deposited on heated substrates, further analysis shows that the nanocrystalline phase does not change with increasing substrate temperatures; however, the texture of the crystalline orientation changes to favor $(\bar{1}11)$ at 300–675 °C from the initial (002) orientation at ambient substrate temperature. Such differences in nanoscale-thick thin-film HfO_2 PLD process-dependent amorphousness, crystallinity, and surface textures discussed here exhibit minimal influence on the resulting broadband optical properties (250 nm–30 µm). Furthermore, we show that the complex refractive index of high-density nanoscale-thick thin-film HfO_2 prepared at an ambient substrate temperature using PLD resembles that of bulk HfO_2 responses. The achievement of fully stoichiometric, high-density, thin-film HfO_2 from PLD is expected to further enable thermally robust nanoscale photonic device integration involving low-dimensional high-performance optical and optoelectronic applications.

KEYWORDS: amorphous HfO_2, hafnium oxide, thin-film optical constants, nanoscale-thick thin films

micrographs, XRD results for the $(\bar{1}11)$ and (002) orientations as a function of T_S, XRR patterns at selected T_S, and V- and IR-VASE optical dispersion data with fits (PDF)

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