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Nanoscale-Thick Thin Films of High-Density HfO₂ for Bulk-like Optical Responses

Lirong Sun, John G. Jones, John T. Grant, Neil R. Murphy, C. V. Ramana, Kurt G. Eyink, Jonathan P. Vernon, and Peter R. Stevenson*

✓ **Cite this:** *ACS Appl. Nano Mater.* 2021, 4, 10, 10836–10844

Publication Date: September 30, 2021 ▾

<https://doi.org/10.1021/acsanm.1c02267>

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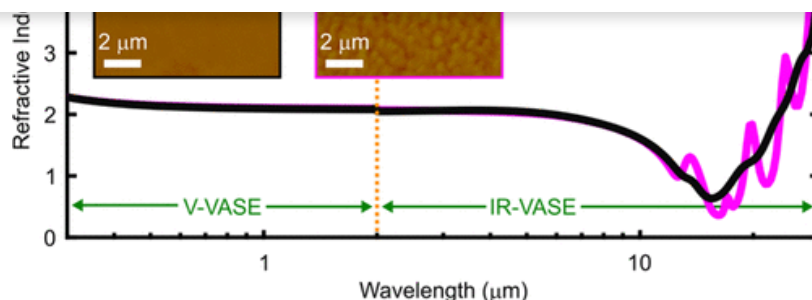
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SUBJECTS:

Thin films, ▾

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The high refractive index, broadband transparency, and low spectral absorption of HfO₂ (hafnia) make it a suitable choice for thermally stable nanoscale optical filters, UV mirrors, and antireflection coatings. However, achieving dense thin films of HfO₂ with bulk-like optical properties has been a challenge due to differences in film stoichiometric and spatial uniformity at nanoscale thicknesses. Here, we assess HfO₂ 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 HfO₂ deposited at an ambient substrate temperature (20 °C) using PLD are amorphous with embedded nanocrystallites, whereas films deposited on heated substrates are polycrystalline monoclinic HfO₂. 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 (111) at 300–675 °C from the initial (002) orientation at ambient substrate temperature. Such differences in nanoscale-thick thin-film HfO₂ 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 HfO₂ prepared at an ambient substrate temperature using PLD resembles that of bulk HfO₂ responses. The achievement of fully stoichiometric, high-density, thin-film HfO₂ from PLD is expected to further enable thermally robust nanoscale photonic device integration involving low-dimensional high-performance optical and optoelectronic applications.

KEYWORDS: amorphous HfO₂, hafnium oxide, thin-film optical constants, nanoscale-thick thin films ▾

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micrographs, XRD results for the (111) 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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Supporting I



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