

Ultrafast control of the dielectric constant in ferroelectric $\text{Hf}_{0.5}\text{Zr}_{0.5}\text{O}_2$ embedded in titanium nitride-based terahertz nanocavities

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The Landau-Ginzburg-Devonshire theory predicts dipoles in ferroelectric hafnium dioxide (HfO_2) can switch between two distinct local energy minima. Based on the energy landscape, many prior studies have debated the nature of the ferroelectric switching pathway in HfO_2 , particularly whether it proceeds through a crossing or non-crossing pathway between polarization states. However, the structural pathway connecting these minima during polarization switching under an external electric field remains experimentally unexplored. The absence of direct observation of the switching pathway has limited a detailed understanding of switching dynamics, as previous studies have primarily focused on the final switched state.

Here, we report the ultrafast change in the effective dielectric constant during ferroelectric polarization switching of the $\text{Hf}_{0.5}\text{Zr}_{0.5}\text{O}_2$ embedded in vertically oriented TiN-based nanocavities using time-resolved terahertz (THz) pump-THz probe spectroscopy. We observed a signature of a transient structural change from the orthorhombic to the monoclinic phase during polarization switching, confirmed by a reduction in the effective dielectric constant from approximately 7.7 to 6.4. Following polarization reversal, the effective dielectric constant subsequently increases to 7.7, consistent with a transition to the orthorhombic phase in the opposite polarization state, which indicates reversible structural switching behavior. These results provide experimental evidence for the dynamical pathway of ferroelectric polarization switching in HfO_2 .