Impact of High-Power Impulse Magnetron Sputtering Pulse Width on the Nucleation, Crystallization, Microstructure, and Ferroelectric Properties of Hafnium Oxide Thin Films

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The impact of the high-power impulse magnetron sputtering (HiPIMS) pulse width on the crystallization, microstructure, and ferroelectric properties of undoped HfO_2 films is reported. HfO_2 films were sputtered from a Hf target in an Ar/O_2 atmosphere, varying the instantaneous power density by changing the HiPIMS pulse width with fixed time averaged power and pulse frequency. The pulse width is shown to affect the ion-to-neutral ratio in the depositing species with the shortest pulse durations leading to the highest ion fraction, as shown in Figure 1. *In-situ* X-ray diffraction measurements during crystallization demonstrate that the HiPIMS pulse width impacts nucleation and phase formation, with an intermediate pulse width of 110 µs stabilizing the ferroelectric phase over the widest temperature range. Although the pulse width impacts the grain size with the lowest pulse width resulting in the largest grain size (Figure 2), grain size does not strongly correlate with phase content or ferroelectric behavior in these films. These results suggest that precise control over the energetics of the depositing species may be beneficial for stabilizing the ferroelectric phase in this material.

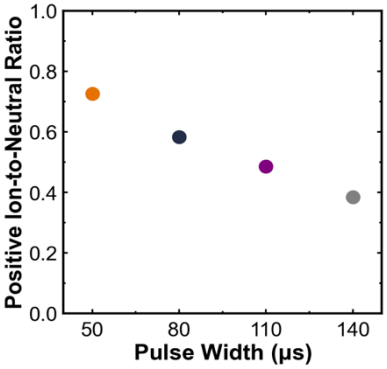

Figure 1: Positive ion-to-neutral ratio calculated from the deposition rates of positive ions + neutrals to neutrals alone.

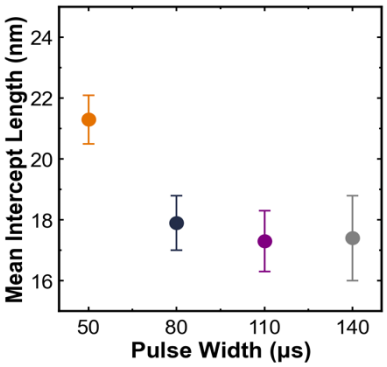

Figure 2: Average lateral grain size calculated using the line-intercept method on the AFM images with error bars representing 95% confidence intervals.

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