# Bismuth Pyrochlore Thin Films for Dielectric Energy Storage

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Thin films of cubic pyrochlore bismuth zinc niobate, bismuth zinc tantalate, and bismuth zinc niobate tantalate were fabricated using chemical solution deposition. This family of materials exhibited moderate relative permittivities between $55 \pm 2$ and $145 \pm 5$ for bismuth zinc tantalate and bismuth zinc niobate, respectively, and low loss tangents on the order of $0.0008 \pm 0.0001$. Increases in the concentration of the tantalum end member increased the dielectric breakdown strength. For example, at 10 kHz, the room temperature breakdown strength of bismuth zinc niobate was 5.1 MV/cm, while that of bismuth zinc tantalate was 6.1 MV/cm. This combination of a high breakdown strength and a moderate permittivity led to a high discharged energy storage density for all film compositions. For example, at a measurement frequency of 10 kHz, bismuth zinc niobate exhibited a maximum recoverable energy storage density of $60.8 \pm 2.0$ J/cm$^3$, while bismuth zinc tantalate exhibited a recoverable energy storage density of $60.7 \pm 2.0$ J/cm$^3$. Intermediate compositions of bismuth zinc niobate tantalate offered higher energy storage densities; at 10 mol. % tantalum, the maximum recoverable energy storage density was $\sim 66.9 \pm 2.4$ J/cm$^3$.