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Ferroelectrics Everywhere: New Material Discovery by Engineered Instabilities

Ferroelectricity in wurtzite-based crystals was observed in 2019 and immediately introduced exciting opportunities to explore and discover new structure-property relationships in novel formulation spaces, and to investigate new integration and device implementations given new process compatibilities. The seminal discovery of ferroelectric Al1-xScxN initiated this excitement and was followed by comparable observations of polarization reversal in the structurally similar Al1-xBxN and the Zn1-xMgxO systems. These observations lead one to speculate that ferroelectricity might be found much more broadly, even "everywhere", by introducing the appropriate disorder in a variety of hosts. The presentation will begin with a brief history of ferroelectricity with specific attention to the last 10 years where this important property was discovered in new oxide and nitride crystals, and how these lead the community's thinking about finding more. The remaining content will focus on the structure-process-property relationships in the B-substituted AlN and Mgsubstituted ZnO wurtzite systems. The B-substituted materials exhibit square hysteresis loops with polarization values between 150 μC/cm2 and 120 μC/cm2 when boron concentrations range between 2% and 15% respectively. Coercive field values fall with additional boron, from 5.5MV/cm to about 5 MV/cm at B saturation. Bandgap values are approximately 5 eV or above in all cases. Material can be prepared between 100 ℃ and 350 ℃ with very little difference in electrical properties. Case studies will be shown using metallic, metal nitride, and doped Si bottom electrodes. In the best cases, capacitors can be prepared down to 10 nm thickness while still exhibiting ferroelectric switching. Below 25 nm, however, leakage current becomes problematic during low frequency hysteresis measurements. First principles calculations that rationalize the unit cell volume, bond angle distribution, and remanent polarization will be presented. Comparable results will be presented for the Zn1-xMgxO system. Between ~7% and 45% Mg substitution, square hysteresis loops with remanent polarization values near 100 μC/cm2 are readily achieved. In comparison to AlBN, coercive field values for ZMO can be less than 2.0 MV/cm. The presentation will also include examples where proximity effects in layered ZnO/Zn1-xMgxO, AlN/Al1-xBxN, and Zn1-xMgxO/AlN heterostructures can induce switching in pure ZnO and AlN layers. The presentation will finish with a summary of accomplishments and challenges that the community is observing for these novel ferroelectric compositions and an outlook regarding opportunities to shepherd their integration into device applications.

Topical Area

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