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Integrating Freestanding Membranes for Band Gap Modulation in Gd-Doped CeO2

The development of advanced optoelectronic devices critically depends on the precise control of electronic and optical properties in functional materials. Among wide band gap oxides, ceria (3.0 ~ 3.2 eV) is a promising candidate due to its potential due to its tunable band gap, high chemical and thermal stability, and favorable ionic and electronic conductivity enabled by oxygen vacancies. However, conventional band gap engineering methods, such as chemical substitution, often introduce undesirable defects and degrade carrier mobility, ultimately limiting device performance. In this study, we demonstrate a novel strategy to engineer the band gap of Gd-doped CeO2 (GDC) using a freestanding membrane approach. Epitaxial GDC thin films with (001) and (111) orientations were fabricated via pulsed laser deposition on single-crystal $SrTiO_3$ substrates, utilizing a Ca-containing $Sr_3Al_2O_6$ (SCAO) water-soluble sacrificial layer and a polypropylene carbonate protective coating to ensure membrane integrity during release. Following complete detachment, the GDC membranes were transferred onto Al_2O_3 substrates. Interestingly, the (001) and (111) orientations resulted in flat and wrinkled surface morphologies, respectively, due to orientation-dependent lattice mismatch with SCAO. Despite these differences, electrical transport properties remained robust, suggesting the material's resilience to morphological variation. Importantly, surface wrinkling induced during fabrication led to a notable increase in the GDC membrane's band gap, offering a controllable optical effect relevant for device applications. This freestanding membrane approach enables precise band gap tuning while preserving conductivity and minimizing defect formation. Furthermore, the freestanding platform is compatible with a range of substrates and device architectures, facilitating scalable integration into advanced optoelectronic systems. Our results establish freestanding membrane-based band gap engineering as a promising alternative to traditional doping methods, setting a new paradigm for functional oxide material design.

Topical Area

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