Lattice-matching epitaxy of rutile-type $Ge_xSn_{1-x}O_2$ alloy film on TiO_2 substrate for device applications

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Rutile-type (r-) oxides, such as r-SnO_2, r-GeO_2, and their alloys, have recently emerged as a novel class of wide-band-gap semiconductors. In a previous study, the potential of the rutile-type oxide framework as a wide-band-gap semiconductor alloy system was demonstrated by tuning the bandgap of r-$Ge_xSn_{1-x}O_2$ films from 3.8 to 4.4 eV by changing the alloy composition on r-TiO_2 substrates. However, the films in question exhibited a significant presence of threading dislocations at lower and higher alloy compositions, adversely affecting their electrical properties. This study reports the characterization and application of mist-CVD-grown r-$Ge_xSn_{1-x}O_2$ films (x=~0.53) lattice matching to r-TiO_2 (001) substrates.

The growth led to a consistently flat surface of r-$Ge_xSn_{1-x}O_2$ films (x = 0.49–0.56), which is attributable to the lattice-matching between r-$Ge_xSn_{1-x}O_2$ films and r-TiO_2 (001) substrates. XRD measurements confirmed that the r-$Ge_{0.55}Sn_{0.45}O_2$ film was single-crystalline without misoriented domains. Furthermore, TEM and STEM observations revealed a high-quality interface between the film and substrate with a coherent structure and an absence of detectable threading dislocations (Fig. 1). Finally, lateral Schottky barrier diodes were fabricated using an r-$Ge_{0.49}Sn_{0.51}O_2$ film that was lattice-matched to the r-TiO_2 (001) substrate. The diodes exhibited rectifying properties with a rectification ratio of approximately 105 at ±5 V (Fig. 2). These results highlight the potential of r-$Ge_xSn_{1-x}O_2$ as a practical semiconductor for power-electronic applications.