Growth of *a*-plane $BaTiO_3$ on *a*-plane β-Ga_2O_3 by Molecular-Beam Epitaxy

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Introduction

We demonstrate the epitaxial growth of single-phase (100) $BaTiO_3$ films on (100) β-Ga_2O_3 substrates using molecular-beam epitaxy. β-Ga_2O_3 shows immense promise as a semiconductor for power electronics due to its ultra-wide band gap (4.4–4.9 eV), large predicted breakdown field (~8 MV cm^{-1}), and mobilities that can be controlled with doping over device-relevant ranges (10^{15}–10^{19} cm^{-3}) [1–5]. One major issue hindering the performance of vertical β-Ga_2O_3-based devices is the difficulty in terminating junctions to achieve low peak electric fields. The maximum voltage that can be applied to the devices is ideally limited only by the breakdown electric field of the β-Ga_2O_3 itself but in practice breakdown is limited to lower average fields due to stronger electric fields at junction edges. It has been demonstrated that vertical Schottky-barrier diodes made utilizing conventional metal anodes in direct contact with β-Ga_2O_3 are limited to about 3.5 MV cm^{-1} [6]. Xia *et al* demonstrated that by incorporating a polycrystalline high-dielectric constant material between the anode and β-Ga_2O_3 they could achieve a higher average breakdown field of 5.7 MV cm^{-1}, which is the highest reported to date [6]. In this work we tackle the challenge of integrating epitaxial $BaTiO_3$ with β-Ga_2O_3 in a way that provides the direction of highest *K* in the out-of-plane direction, i.e., (100)-oriented $BaTiO_3$, on vicinal (100) β-Ga_2O_3 substrates that appear promising for vertical high-voltage β-Ga_2O_3 devices [7].

Results and Discussion

We find that (100) $BaTiO_3$ grows epitaxially on (100) β-Ga_2O_3 by molecular-beam epitaxy (MBE) over a broad range of substrate temperatures with various *in-situ* and *ex-situ* analysis techniques including RHEED, XRD, XRR, AFM, and STEM. By growing $BaTiO_3$ and Si-doped β-Ga_2O_3 on appropriately vicinal (100) β-Ga_2O_3 substrates by MBE and suboxide molecular beam epitaxy (S-MBE), respectively, we fabricate a metal oxide semiconductor (MOS) capacitor and measure the epitaxial $BaTiO_3$ to have a dielectric constant in the out-of-plane direction of $K_{11} \approx 670$, which is more than twice as high as all prior dielectrics that have been integrated with β-Ga_2O_3 [6,8]. We show that by being able to epitaxially integrate a high *K* $BaTiO_3$ layer, we can achieve up to a 20% decrease in the peak electric field.

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