Growth of Commensurately Strained $KTaO_3$ by Suboxide Molecular-Beam Epitaxy

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Strain-engineering is a powerful means to tune the polar, structural, and electronic instabilities of incipient ferroelectrics. $KTaO_3$ is an incipient ferroelectric in which highly anisotropic superconductivity emerges near a polar instability in electron doped samples[1]. $KTaO_3$ also has a very large spin-orbit coupling[2]. Growth of high-quality epitaxial films provides an opportunity to use epitaxial strain to finely tune electronic and polar instabilities in $KTaO_3$. The use of molecular-beam epitaxy (MBE) to grow $KTaO_3$ has evaded demonstration—until now. Using a molecular beam of the suboxide TaO_2 emanating from an effusion cell containing Ta_2O_5 in combination with a molecular beam of potassium emanating from an indium-potassium intermetallic in an oxidant (~10% O_3 + 90% O_2) background pressure of $1x10^{-6}$ Torr, $KTaO_3$ films are grown under conditions of excess potassium in an absorption-controlled regime. Biaxial strains ranging from -0.1 % to -2.1 % are imposed on the commensurately strained $KTaO_3$ films by growing them upon $SmScO_3$, $GdScO_3$, $TbScO_3$, $DyScO_3$ and $SrTiO_3$ substrates, all with the perovskite structure. Reciprocal space mapping shows the epitaxial $KTaO_3$ films are coherently strained to the underlying perovskite substrates provided the $KTaO_3$ films are sufficiently thin. Cross-sectional scanning transmission electron microscopy does not show any extended defects and confirms that the films have an atomically abrupt interface with the substrate. X-ray diffraction rocking curves (full width at half maximum < 30 arc sec on all of the above substrates) are the narrowest reported to date for $KTaO_3$ films grown by any technique. Laue fringes confirm that the films are smooth with a well-defined thickness. Atomic force microscopy reveals atomic steps at the surface of the grown films. SIMS measurements confirm that the films are free of indium contamination. By simultaneously using a molecular beam of suboxide NbO_2, mixed $KNb_xTa_{1-x}O_3$ films can be grown and the ferroelectric transition temperature is seen to depend on the niobium concentration in the film.

References

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