Superconductivity in Ba-doped KTaO$_3$ thin films by Molecular-Beam Epitaxy

Motivation: The Search for Superconductivity in KTaO$_3$

This work is inspired by the researched performed on superconductivity in SrTiO$_3$ bulk versus interface$^{[2]}$. Interestingly, KTaO$_3$ does not share this phenomena and instead demonstrates different superconducting transition temperatures at the interface versus bulk$^{[2]}$. A newfound ability to synthesize KTaO$_3$ by MBE$^{[3]}$ gives opportunity to investigate similar doping on bulk KTaO$_3$ superconductivity.

SrTiO$_3$ and KTaO$_3$

Figure 1: Visualization of KTaO$_3$ (100) growth on GdScO$_3$ (110)

Figure 2: (a) SrTiO$_3$ structure compared to KTaO$_3$ structure and (b) Comparison of superconducting transition temperatures of SrTiO$_3$ bulk$^{[2]}$ and interface$^{[2]}$ KTaO$_3$

Molecular-Beam Epitaxy

- Effusion cells $\rightarrow$ provide elemental beams
- RHEED gun (Reflective High-Energy Electron Diffraction) $\rightarrow$ in-situ monitoring of crystalline/film quality
- High Vacuum Environment
- Quartz Crystal Microbalance (QCM) to approximate source fluxes
- One-of-a-kind laser substrate heater

Molecular beam epitaxy of KTaO$_3$

Figure 3: Rocking curves of (a) KTaO$_3$ on GdScO$_3$ and (b) KTaO$_3$ on TbScO$_3$

Metallic Behavior of Ba-doped KTaO$_3$ films

Figure 4: (a) X-Ray Diffraction of KTaO$_3$ growth on GdScO$_3$, and (b) Magnified X-Ray Diffraction of 100 peak of KTaO$_3$ growth on GdScO$_3$ to ensure crystallinity upon barium incorporation into KTO lattice

Figure 5: (a) X-Ray Diffraction of KTaO$_3$ growth on TbScO$_3$ and (b) Magnified X-Ray Diffraction of 100 peak of KTaO$_3$ growth on TbScO$_3$ to ensure crystallinity upon barium incorporation into KTO lattice

X-Ray Diffraction

Figure 6: R vs T (a) KTaO$_3$ films grown on GdScO$_3$ and (b) KTaO$_3$ films grown on TbScO$_3$.

The Effect of Strain

Enhanced superconductivity was observed in strained SrTiO$_3$ films and similar principles were applied to KTaO$_3$ to study if similar effects occur.

Figure 7: Reciprocal Space Mapping for (a) KTaO$_3$ on GdScO$_3$ and (b) KTaO$_3$ on TbScO$_3$ to ensure films are commensurately strained.

Conclusions and future plans

- Minimum barium source temperature that provides sufficient carriers to enable metallic behavior down to 4K in KTO films
- Secondary Ion Mass Spectroscopy to determine precise barium concentration as well as shallow and deep level donors
- Dilution Fridge measurements to observe if 50mK transition occurs.

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References


[1] Hayley Ruddick$^{[1]}$


