Superconductivity in Ba-doped $KTaO_3$ thin films by Molecular-Beam Epitaxy

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Motivation: The Search for Superconductivity in $KTaO_3$

This work is inspired by the researched performed on superconductivity in $SrTiO_3$ bulk versus interface[1] . 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.

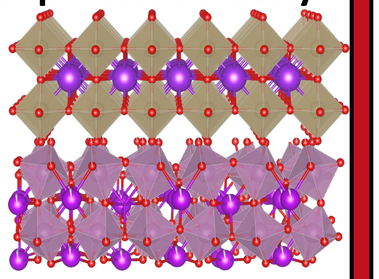
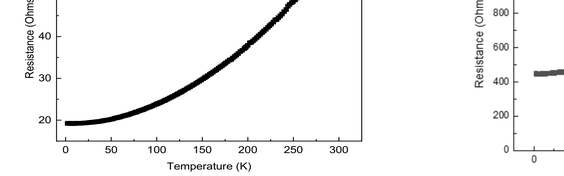


Figure 1: Visualization of $KTaO_3$ (100) growth on $GdScO_3$ (110)

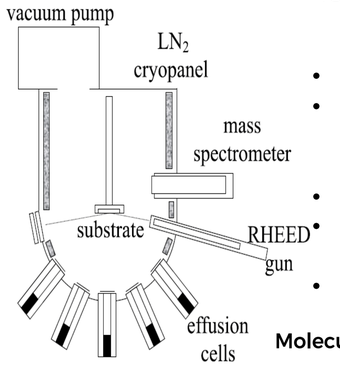
$SrTiO_3$ and $KTaO_3$



	Bulk T_c	Interface T_c
$KTaO_3$	50 mK	2K
$SrTiO_3$	200 mK	200 mK

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[1] $KTaO_3$

Molecular-Beam Epitaxy



(L. Dongmin, 2008)

- **Effusion cells → provide elemental beams**
- RHEED gun (Reflective High-Energy Electron Diffraction) → 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 $KTaO_3$

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Metallic Behavior of Ba-doped $KTaO_3$ films

Figure 6: R vs T (a) $KTaO_3$ films grown on $GdScO_3$ and (b) $KTaO_3$ films grown on $TbScO_3$.

X-Ray Diffraction

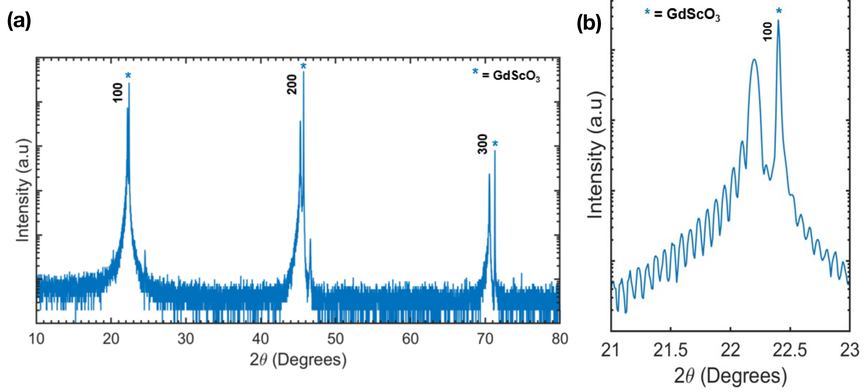


Figure 4: (a) X-Ray Diffraction of $KTaO_3$ growth on $GdScO_3$ and (b) Magnified X-Ray Diffraction of 100 peak of $KTaO_3$ growth on $GdScO_3$ to ensure crystallinity upon barium incorporation into KTO lattice

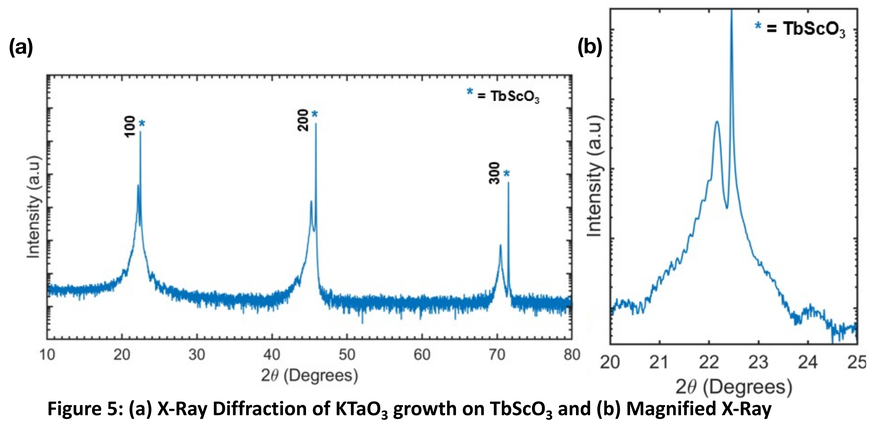
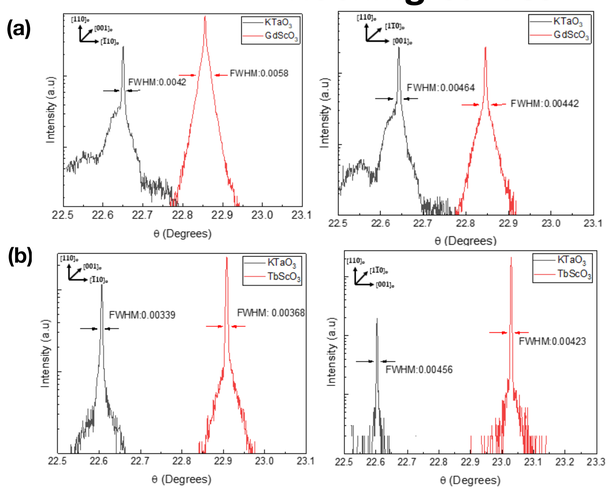


Figure 5: (a) X-Ray Diffraction of $KTaO_3$ growth on $TbScO_3$ and (b) Magnified X-Ray Diffraction of 100 peak of $KTaO_3$ growth on $TbScO_3$ to ensure crystallinity upon barium incorporation into KTO lattice

Rocking Curves



Maintaining high crystalline quality while introducing charge carrier through chemical doping. Crystalline quality limited by the epitaxial template.

Figure 3: Rocking curves of (a) $KTaO_3$ on $GdScO_3$ and (b) $KTaO_3$ 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.

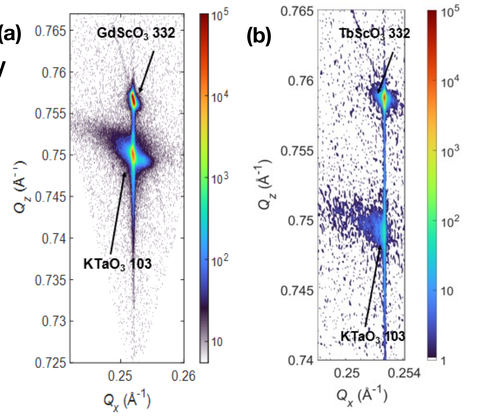
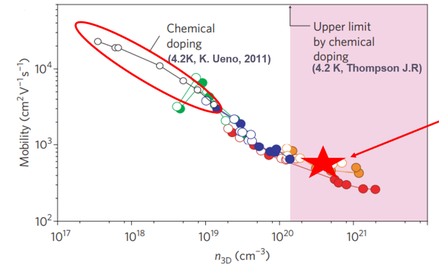


Figure 7: Reciprocal Space Mapping for (a) $KTaO_3$ on $GdScO_3$ and (b) $KTaO_3$ on $TbScO_3$ to ensure films are commensurately strained.

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**



We push the previously established chemical doping carrier limit!

Carriers in KTO on GSO ~ 4.36 x 10^{20} carriers

Acknowledgements

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