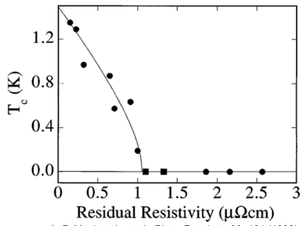
Optimizing Superconductivity in Sr_2RuO_4 Thin Films with Varying Cation Flux Ratio Grown by Molecular-Beam Epitaxy

Casey K. Kim[1], Jinkwon Kim[1], Darrell G. Schlom[1]

[1]Department of Materials Science and Engineering, Cornell University, Ithaca, NY 14853

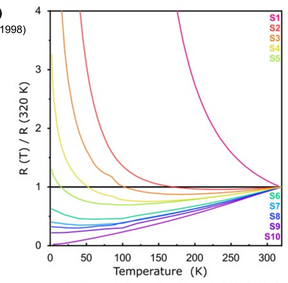
Introduction

- Sr_2RuO_4 is extremely sensitive to disorder such as impurities and ruthenium vacancies



A. P. Mackenzie et al., Phys. Rev. Lett. **80**, 161 (1998)

- Purity of Sr_2RuO_4 affects superconductivity
- Intergrowth of Ruddlesden-Popper pervoskites should be avoided

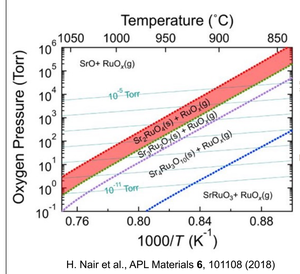


G. Kim et al., Phys. Rev. Mater. **3**, 94802 (2019)

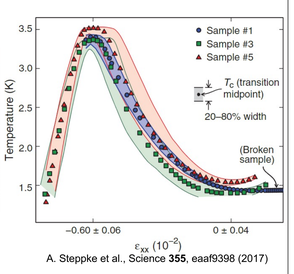
- Ruthenium vacancies can also suppress superconductivity
- Vary the cation flux ratio to optimize the superconductivity in Sr_2RuO_4 thin films

Experimental

- Growth conditions were set by the thermodynamics of MBE (TOMBE) diagram at a substrate temperature of 940˚C and ozone pressure of 6×10^{-7} Torr
- $NdGaO_3$ (110) substrate induces compressive strain for enhanced superconductivity

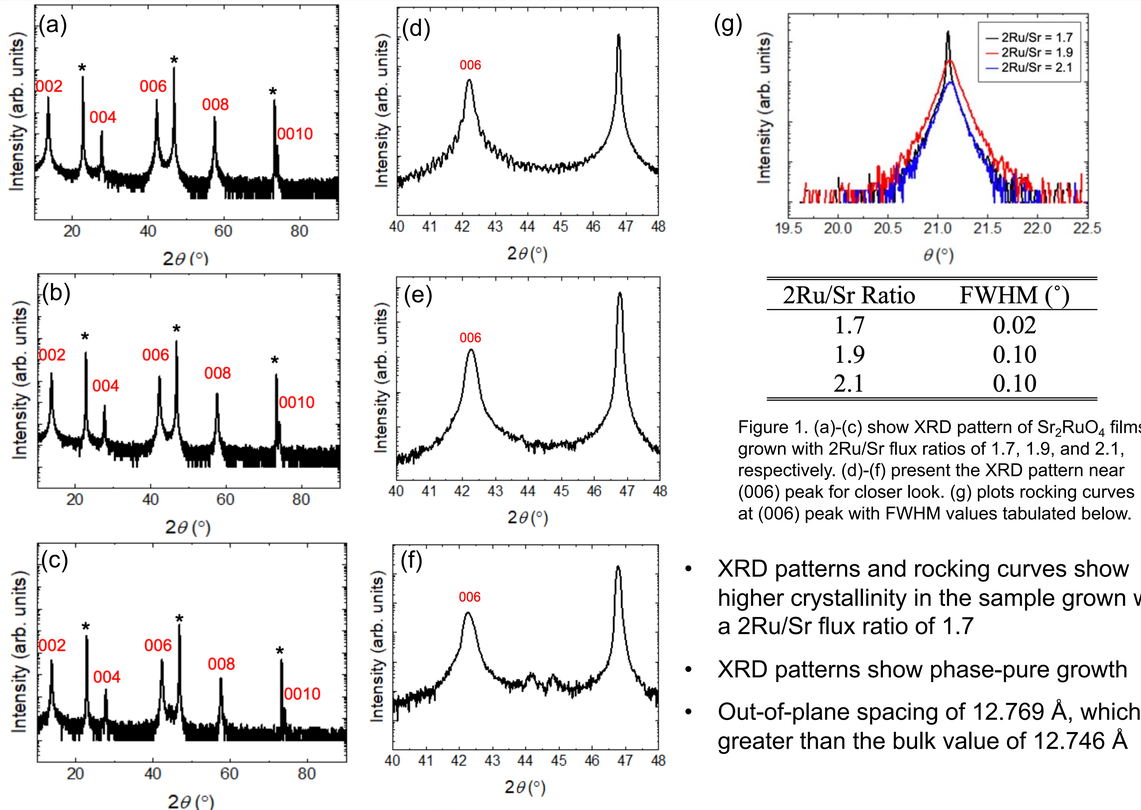


H. Nair et al., APL Materials **6**, 101108 (2018)



A. Steppke et al., Science **355**, eaaf9398 (2017)

Results



2Ru/Sr Ratio	FWHM (˚)
1.7	0.02
1.9	0.10
2.1	0.10

Figure 1. (a)-(c) show XRD pattern of Sr_2RuO_4 films grown with 2Ru/Sr flux ratios of 1.7, 1.9, and 2.1, respectively. (d)-(f) present the XRD pattern near (006) peak for closer look. (g) plots rocking curves at (006) peak with FWHM values tabulated below.

- XRD patterns and rocking curves show higher crystallinity in the sample grown with a 2Ru/Sr flux ratio of 1.7
- XRD patterns show phase-pure growth
- Out-of-plane spacing of 12.769 Å, which is greater than the bulk value of 12.746 Å

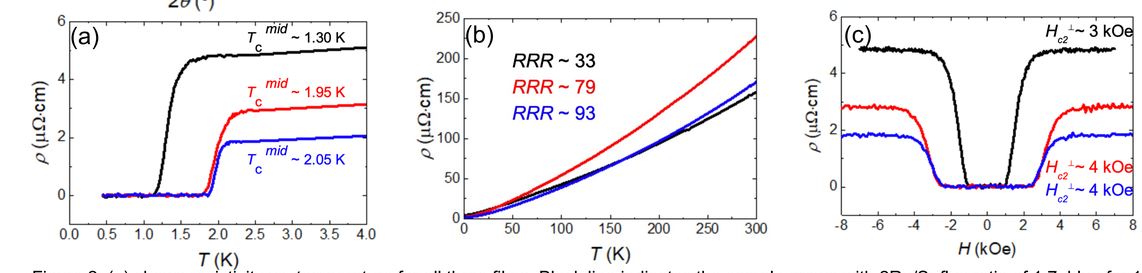


Figure 2. (a) shows resistivity vs. temperature for all three films. Black line indicates the sample grown with 2Ru/Sr flux ratio of 1.7, blue for 1.9, and red for 2.1. (b) presents residual resistivity ratio (RRR), and (c) exhibits magnetoresistance of the samples with critical magnetic field value. Same color coding as (a) applies on (b) and (c).

- Transport phenomena show enhancement with increased ruthenium flux
- T_c^{mid} as high as 2.05 K and RRR of 93 obtained from the sample grown with a 2Ru/Sr flux ratio of 2.1

Conclusions

- Phase-pure Sr_2RuO_4 thin films were successfully grown epitaxially on $NdGaO_3$ (110) substrates by Molecular-Beam Epitaxy
- The sample grown with a 2Ru/Sr ratio of 2.1 showed enhanced transport properties with the highest T_c ever reported in this material
- We plan to study the magnetic structure of Sr_2RuO_4 by Mu ion scattering experiments
  - We aim to minimize the thickness of the Sr_2RuO_4 film with the optimized flux ratio 2Ru/Sr of 2.1

Acknowledgements

I thank my mentor Dr. Jinkwon Kim and PI Professor Darrell G. Schlom for their support and guidance in this project. This research was funded by the National Science Foundation (NSF) Platform for the Accelerated Realization, Analysis, and Discovery of Interface Materials (PARADIM) under Cooperative Agreement No. DMR-2039380 as well as the NSF REU Site: Summer Research Program at PARADIM under Cooperative Assignment No. DMR-2150446.

References

[1] Y. Maeno et al., Nature **372**, 532-534 (1994)
[2] K. D. Nelson et al., Science **306**, 1141-1154 (2004)
[3] Y. Maeno et al., Physics Today. **54**, 42-47 (2001)
[4] A. P. Mackenzie et al., Phys. Rev. Lett. **80**, 161 (1998)
[5] G. Kim et al., Phys. Rev. Mater. **3**, 94802 (2019)
[6] H. Nair et al., APL Materials **6**, 101108 (2018)
[7] A. Steppke et al., Science **355**, eaaf9398 (2017)
[8] M. Schmidbauer et al., Acta Cryst. **B68**, 8 (2012)
[9] L. Walz and F. Lichtenberg, Acta Cryst. **C49**, 1268-1270 (1993)
[10] C.M.P. Garcia et al., Commun. Mater. **1**, 23 (2020)