Structural and Electrical Properties of Dysprosium Barium Copper Oxide (DBCO) Thin Films

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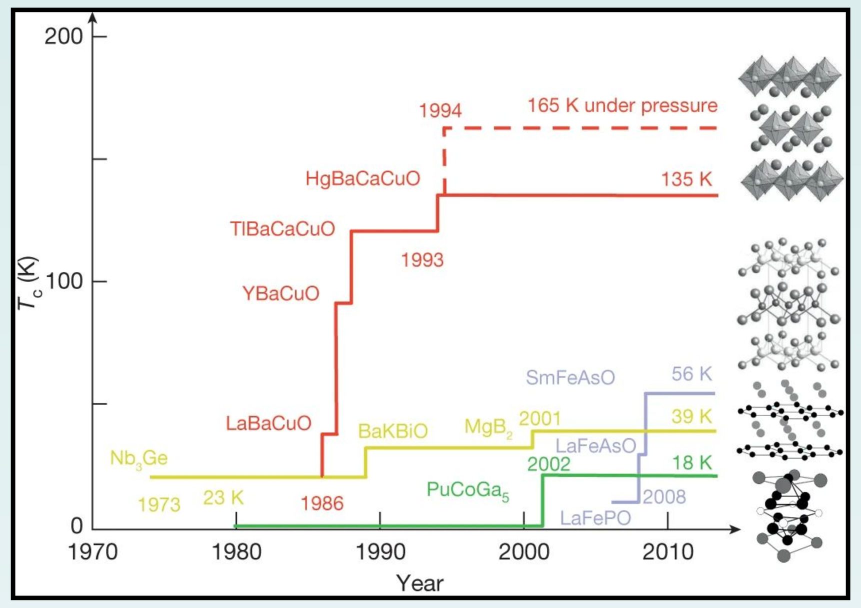
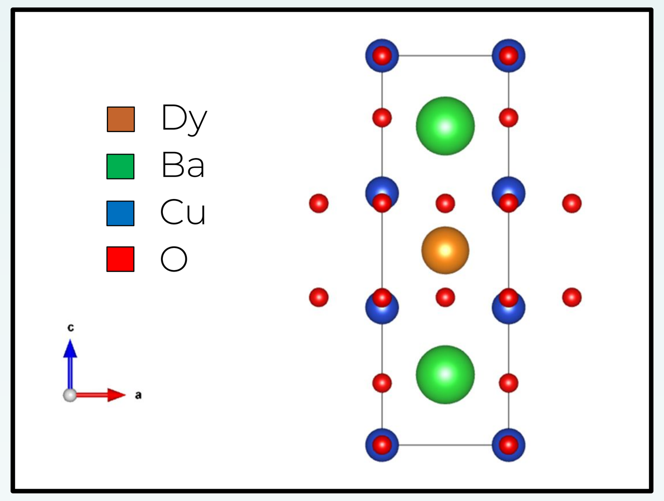
Introduction

Since the discovery of high-temperature superconductivity in La-Ba-Cu-O[1] scientists have continued to discover superconducting materials with even higher critical temperatures (T_c). The discovery of $YBa_2Cu_3O_{7-x}$ (YBCO), a compound with higher T_c[2] soon followed making it the first to have a critical temperature higher than the boiling point of liquid nitrogen. One way to make superconducting materials with precise structural control is fabricating them in the form of thin films[3] and the recent improvements in vacuum technologies and thin film growth systems incentivizes revisiting these high-T_c cuprates. In this work, we revisit $DyBa_2Cu_3O_{7-x}$ (DBCO) thin films[4], which displays structural similarities with YBCO. We focus on improving their structural and electrical properties utilizing thin films grown by the oxide molecular beam epitaxy (MBE) system.



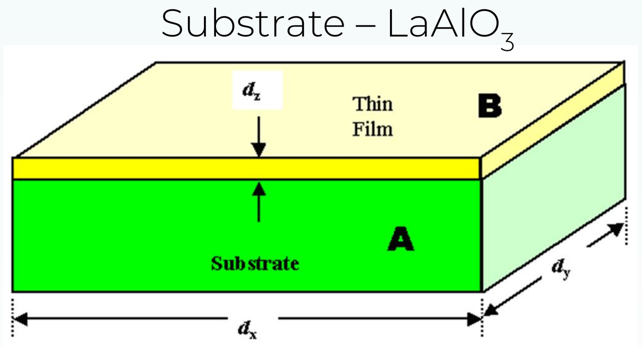
Higher critical temperature materials discovered as time progresses.[5]

$DyBa_2Cu_3O_{7-x}$ Structure



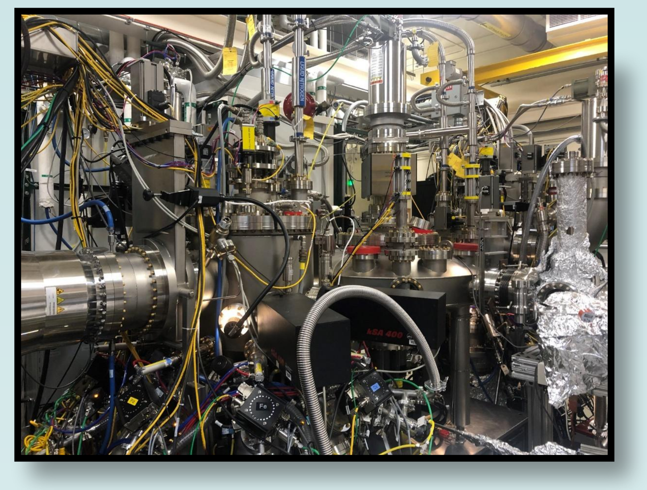
Structure of $DyBa_2Cu_3O_{7-x}$ illustrated using on VESTA.[6]

Substrate – $LaAlO_3$



https://www.tf.uni-kiel.de/matwis/amat/semitech_en/kap_3/backbone/r3_2_2.html

Experimental Methods



PARADIM's oxide molecular beam epitaxy (MBE) system.

PANalytical Empyrean x-ray diffractometer.

Four-point Van der Pauw geometry system dipped into a dewar of liquid helium.

X-Ray Diffraction (XRD)

Temperature Dependent Resistivity

Figure 1. Growth temperature 630°C – *a*-axis DBCO with mild *c*-axis contribution

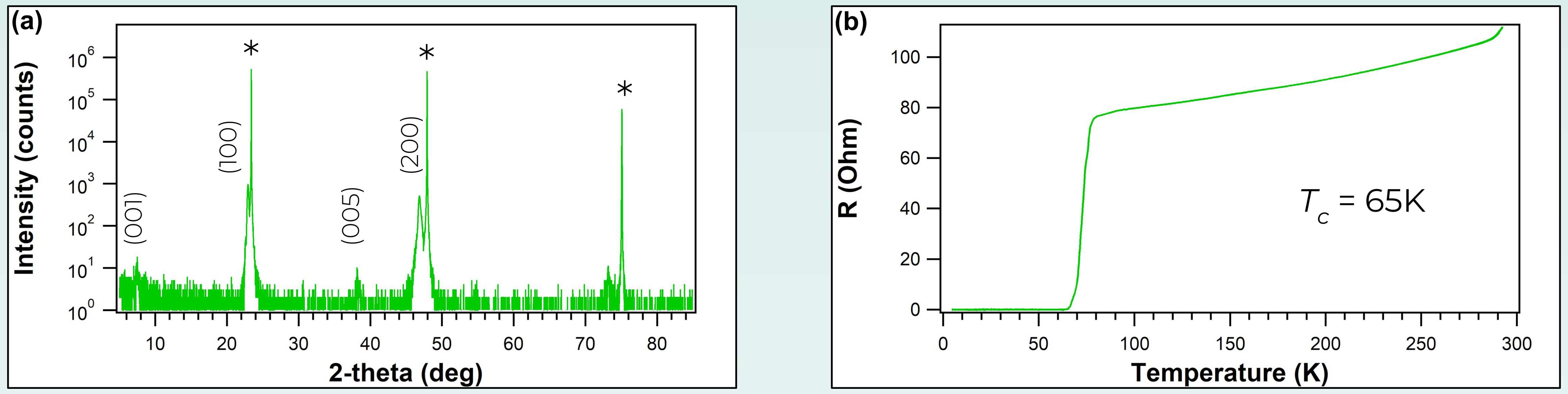


Figure 2. Growth temperature 680°C – *c*-axis DBCO

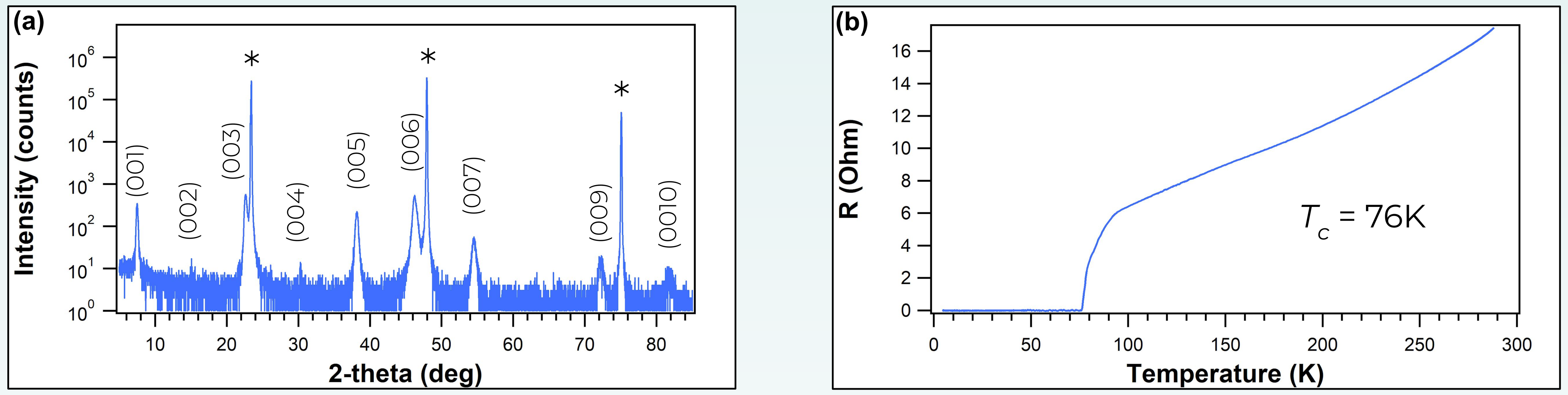
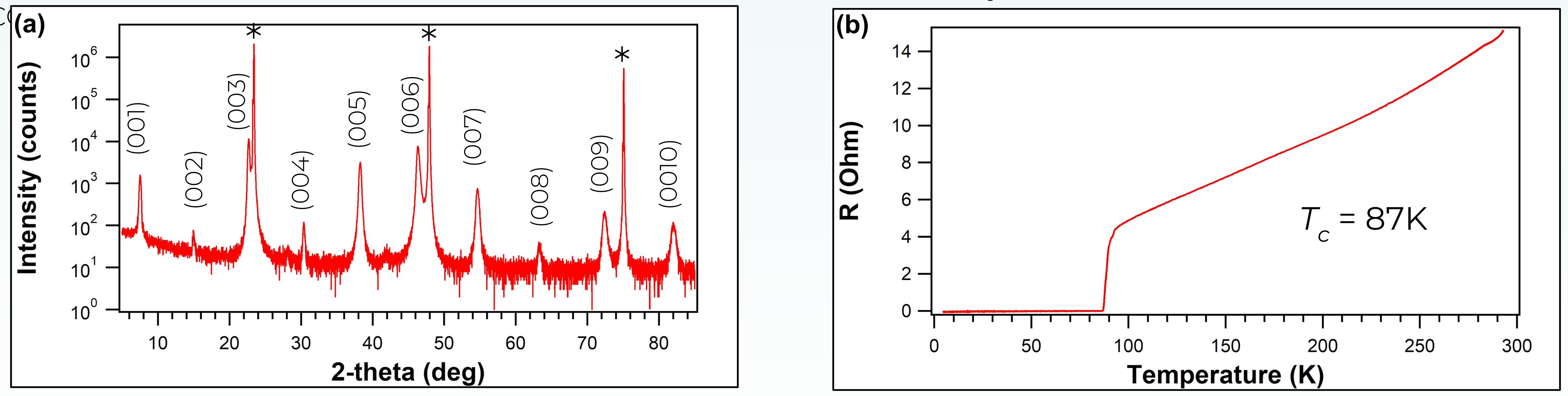


Figure 3. Growth temperature 750°C – high-quality structure and highest T_c c-axis DBCO



Results & Discussion

We can gather the following results from our data:

- ✔ Sample A was grown at 630°C and depicts an *a*-axis DBCO film with mild *c*-axis contribution (Figure 1a) and a sharp superconducting transition (Figure 1b).
- ✔ Figure 2a demonstrates the structural quality of the *c*-axis DBCO film grown at 680°C (Sample B), where a superconducting transition temperature of 76K is obtained with temperature dependent resistivity measurements that displays a wide transition (i.e., T_c onset to T_c R=0) (Figure 2b).
- ✔ Sample C was grown at 750°C and exhibits a high-quality *c*-axis DBCO film (Figure 3a) that also has the highest critical temperature and the sharpest superconducting transition temperature among our samples (Figure 3b).
- ✔ The *a*-axis DBCO film (Figure 1) shows higher room-temperature resistance when compared with the other samples in our data set (c.f. Figures 2,3).

Conclusion & Future Work

In summary, we scanned a wide range of growth temperatures and found the optimal temperature for growing DBCO thin films using 2theta-ω scans. This optimal growth temperature for high-quality DBCO films for our MBE system is found to be ~750°C.

Since we have optimized the growth conditions of high quality DBCO films, in the next stage we will have laid a good foundation to grow other kinds of thin films and multilayers. This data will also pave the way for designing new heterostructures.

References

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Acknowledgements

Schlom Lab Group
Jim Overhiser
Dr. Y Eren Suyolcu

Sean Chang acknowledges the support from Arthur R. Adams Fellowship. The research leading to these results is funded by the National Science Foundation under cooperative agreement No. DMR-2039380.