Characterization of Cubic Perovskite $BaRuO_3$ Under Varying Degrees of Epitaxial Strain

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Abstract

Perovskite barium ruthenate ($BaRuO_3$) presents an opportunity for material science research, as its cubic phase offers both a better understanding of the electronic structures of ruthenate perovskites and, through its barophilic nature, an insight into epitaxial stabilization. Here, the material's reaction to epitaxial strain was investigated by measuring the effect that varying levels of strain had on the temperature of ferromagnetic transition, with preliminary measurements indicating a loss of the transition recorded in prior literature when placed one percent strain.

Introduction

Ruthenate perovskites are, as a family, deserving of investigation, as they demonstrate non-trivial variation in their electromagnetic properties depending on the cation present in their crystal lattice, with some even being superconductors [1][2].

Compound	Cation	Ground state
$CaRuO_3$	Ca^{2+}	Paramagnetic non-fermi liquid metal
Ca_2RuO_4	Ca^{2+}	Antiferromagnetic Mott insulator
$SrRuO_3$	Sr^{2+}	Ferromagnetic metal
Sr_2RuO_4	Sr^{2+}	Odd-parity superconductor
$BaRuO_3$	Ba^{2+}	Ferromagnetic metal
Ba_2RuO_4	Ba^{2+}	Paramagnetic metal + potential

Table 1. A summary of the diversity of electromagnetic properties assumed by Ruthenate perovskites.

$BaRuO_3$ is of particular interest, as it can assume a cubic crystal structure, allowing its electronic structure to be characterized more easily.

This cubic phase is also of interest for being, to our knowledge, the most barophilic material ever to be stabilized through the use of epitaxial growth. This stabilization is necessary, as, at standard conditions, the crystal prefers to take on a hexagonal structure.

This tendency can be overcome through the aforementioned method, where the constituents of the crystal are vaporized and deposited on a substrate, adopting that substrate's crystal structure. This induces an epitaxial strain on the film. as it is forced to adopt a lattice parameter smaller than that which it would when grown in bulk.

Methods

Initial growth of barium Ruthenate on a $TbScO_3$ substrate demonstrated no ferromagnetic transition, evinced on the resistance vs temperature graph by the lack of a notable kink.

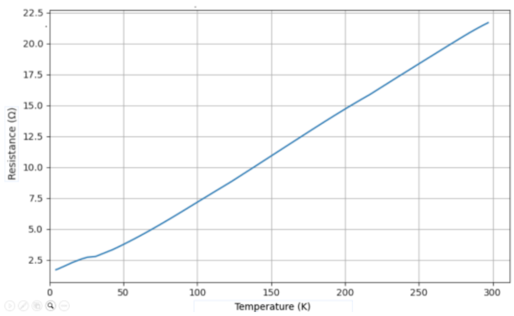

Figure 1. Graph of measured temperature vs resistance of barium ruthenate at 1% strain on terbium scandate ($TbScO_3$).

This was anomalous, as prior literature regarding bulk and thin film samples indicated a transition in the vicinity of 50 K [3][4]. Further investigation of material grown on $SmScO_3$ revealed a return of the transition.

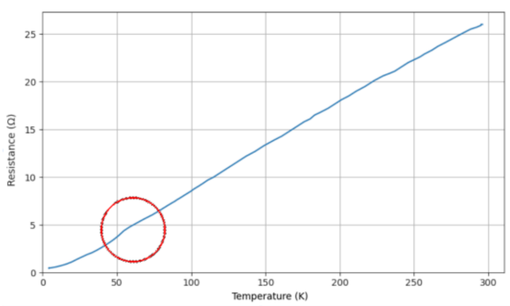

Figure 2. Graph of measured temperature vs resistance of barium ruthenate at 0.25% strain on samarium scandate ($SmScO_3$).

Since X-ray diffraction scans revealed the films to be of excellent quality, the only explanation for the variation in ferromagnetism was the difference in strain experienced by films growing on either substrate.

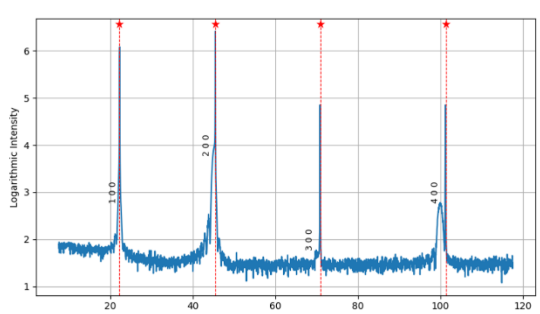

Figure 3. X-ray diffractometry scan with Laue fringes indicating high sample quality in barium Ruthenate grown on $TbScO_3$.

As the above experiments demonstrated a change in ferromagnetic transition temperature dependent on the strain, further experiments were proposed to investigate the nature of this change by growing $BaRuO_3$ on a collection of $BaTiO_3$ pseudosubstrates grown on $SrTiO_3$ and doped with strontium to produce a range of differing strains.

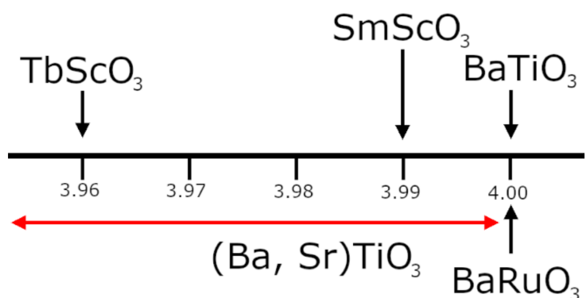

Figure 4. Number line indicating lattice parameters antecedent to the strains of varying samples and the proposed range of doped lattice parameters.

Results and Conclusions

When, as a preliminary step, a sample was grown on a pseudosubstrate of pure barium titanate, it demonstrated no obvious kink, despite the near complete lack of strain.

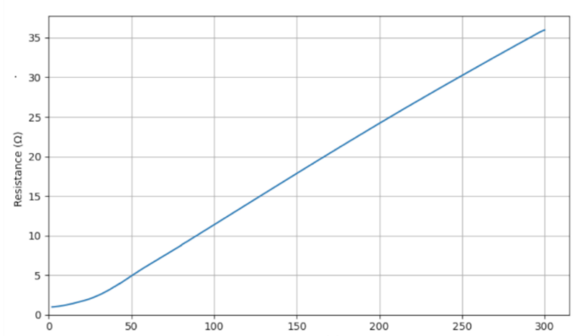

Figure 5. Graph of measured temperature vs resistance of barium ruthenate at ~0% strain on barium titanate ($BaTiO_3$).

However, when the derivative was taken of the region where a transition was expected to occur, evidence of a faint kink was detected.

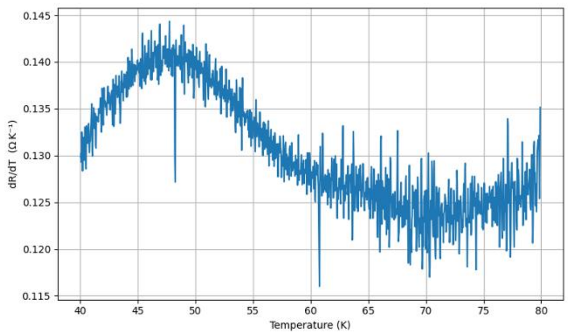

Figure 6. Graph of temperature derivative of temperature vs resistance of barium ruthenate at ~0% strain on barium titanate ($BaTiO_3$).

Due to the faintness of this kink, Hall measurements searching for the anomalous Hall effect will be required to confirm the existence of a transition.

Future work will consist of taking these measurements of the sample on barium titanate to confirm or disprove the existence of a ferromagnetic transition.

Following that, more samples will be grown on scandate substrates in order to avoid the sample quality issues faced here.

References

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