Electrical Transport Study of Metal Delafossite $PdCrO_2$ grown by Molecular-Beam-Epitaxy

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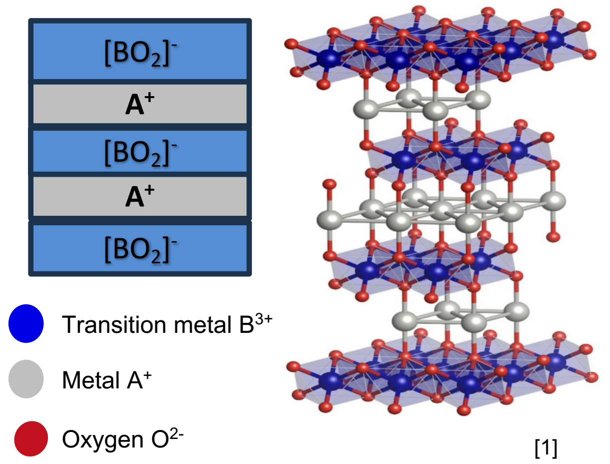
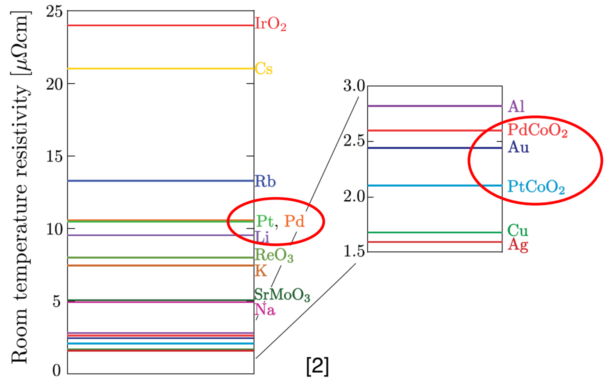
Introduction

Metallic Delafossites ABO_2

- A layered triangular heterostructure
- A^+ is the metallic layer, $[BO_2]^-$ is the transition metal oxide layer
- **Most conductive oxide material**: exhibit high in-plane conductivity and long mean free path.

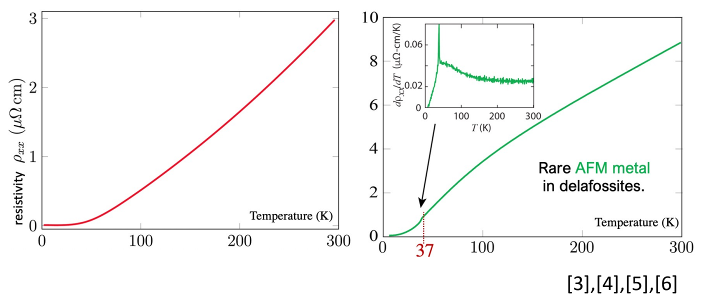


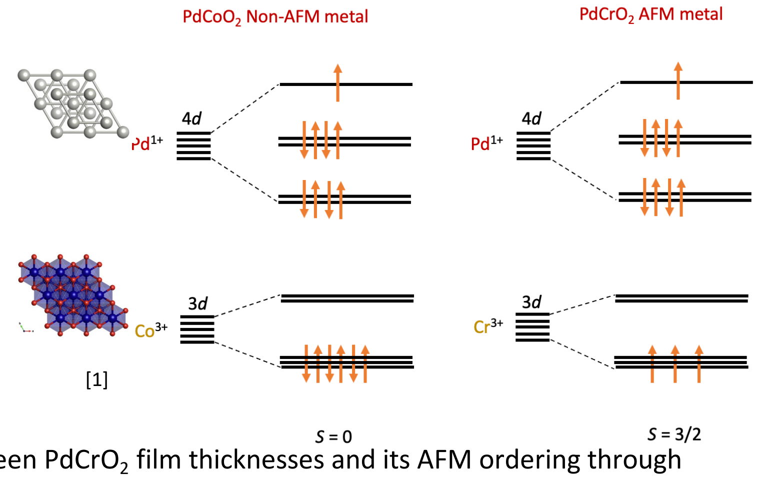


From the chart, metal delafossites $PdCoO_2$ and $PtCoO_2$ have even lower room temperature resistivity than Pt and Pd, comparable to Au.

Materials of Interest

- **PdCoO2** has the highest conductivity per carrier and longest mean free path among all known oxides, reaching 20 m at 4K for the best as-grown crystal [2].
- **$PdCrO_2$** has antiferromagnetic (AFM) order associated with its insulating Cr-O layer with spins from Cr electrons ordered into a non-colinear 120° structure induced by the spin-3/2 state of Cr^{3+} [2]. The combination of AFM-ordering and the metallic conducting behavior of PdCrO2 is interesting, and has potential applications in memory devices and spintronics.





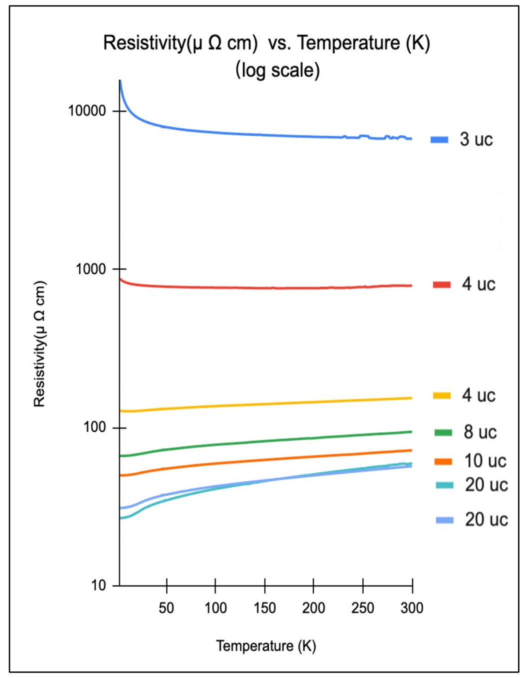
Research Project

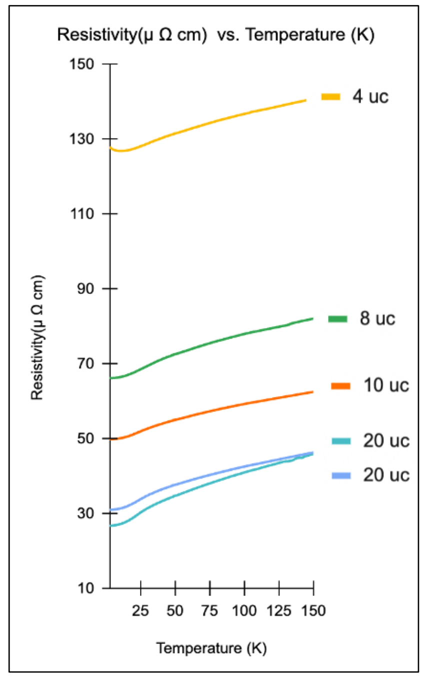
- Understand the correlation between $PdCrO_2$ film thicknesses and its AFM ordering through transport measurements. Since the AFM non-collinear spin directions are not only in-plane but also out-of-plane, the AFM properties are estimated to vary with CrO_2 layer thicknesses.
- Future: study a potential AFM metal Ni-doped $PdNi_xCo_{1-x}O_2$ with varying dopant levels (x = 5%, 10%, 15%, 20%, 33%)

Experimental

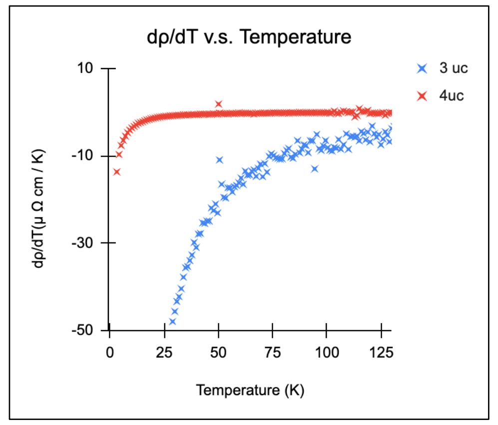
The thickness-dependence of AFM will be studied through transport measurement, comparing the resistivity-temperature measurement results of PdCrO2 samples with a thickness range from 3 unit cells to 20 unit cells. To perform transport measurements, the samples will be wire-bonded following the four-point geometry Van der Pauw method. The resistance-temperature measurements will be carried out using the Quantum Design Physical Property Measurement System (PPMS) over a temperature range from room temperature (300 K) down to 2.5 K.

Results

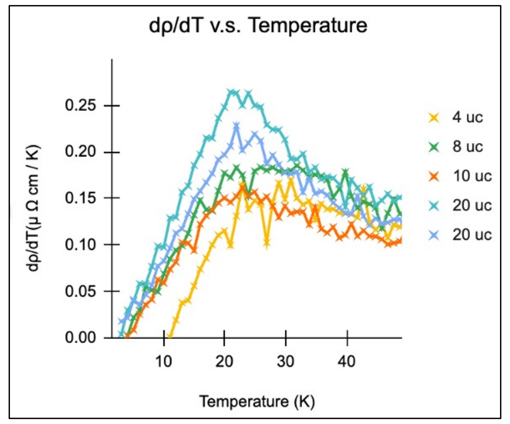




- As $PdCrO_2$ film thickness increases the resistivity decreases.
- Thinner films have an insulating behaviour
- Thick films have a metallic behaviour and the phase transition associated with AFM-ordering.

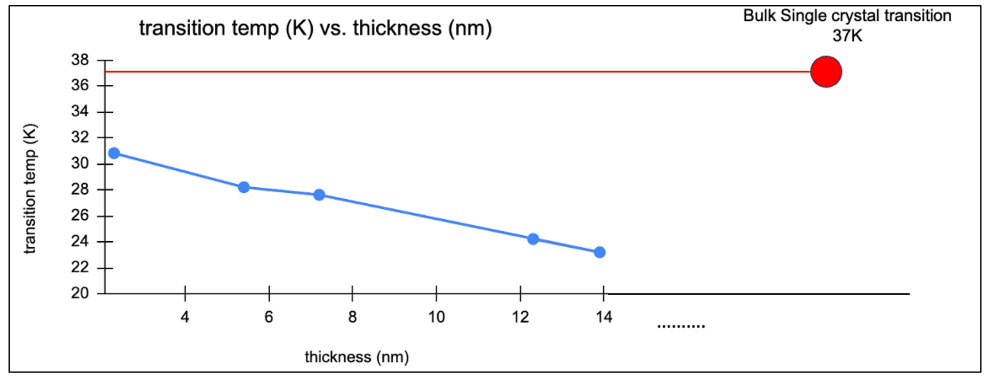


The insulating thin films without the magnetic ordering do not have any magnetic transition and a corresponding peak.



Magnetic transition due to AFM ordering is indicated by each peak for the thicker films.

Results



The transition temperature is determined by Gaussian fitting to each peak in dρ/dT versus T plots.

This decreasing trend is against the expectation that as the thickness of $PdCrO_2$ samples increases, the transition temperature would increase and approach the bulk single crystal transition temperature at 37K.

Conclusions

- Electrical transport measurement of PdCrO2 shows the decrease in conductivity as film thickness increases
- A inverse relationship between transition temperature and thickness is found, against the expectation of a proportional relationship. This is possibly due to the lack of sample data for a reliable conclusion.
- The trend comes from only 5 data sets, which suggests the limitation in our scope of sampling. Thus, more PPMS data collection is needed in order to clearly make a conclusion on the behaviour of AFM-order transition temperature versus the thickness of PdCrO2 samples.

Acknowledgments

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References

1 Billington, *et al. Sci Rep* **5**, 12428 (2015).
2 A P Mackenzie 2017 *Rep. Prog. Phys.* **80** 032501
3 *V. Sunko, Springer Theses. Springer, Cham. (2019)*
4 *Nandi, N., et al. npj Quant. Mater. 3, 66 (2018)*
5 *C. W. Hicks, et al. Phys. Rev. B 92, 014425 (2015)*
6 *H. Takatsu, et al. J. of Crys. Growth 312, 3461 (2010)*