$Pb_2Ir_2O_7$ Thin Film Growth for Spin Transport

Luke Omodt[1], Maya Ramesh[2], Anna Park[2], Xiaoxi Huang[2], Yorick A. Birkholzer[2], Dan Ralph[2], Darrell G. Schlom[2]

[1]Augsburg University, [2]Cornell University

ABSTRACT

$Pb_2Ir_2O_7$ is a promising material for spin transport. $Pb_2Ir_2O_7$, having cubic structure, is interesting because it contrasts the many low symmetry spin transport studies. This paper shows the successful growth of $Pb_2Ir_2O_7$ {111}, {110}, and {100} in order to explore the possibility of different crystal orientations yielding distinctive spin transport results. In addition, we did extensive x-ray diffraction (XRD) and x-ray photoelectric spectroscopy (XPS) studies proving the successful growth. Lastly, this paper includes preliminary spin transport data on $Pb_2Ir_2O_7$ {111}.

INTRODUCTION

Thin film spintronics has become an incredibly popular field of study for its interesting and powerful properties. Certain thin films have shown Strong Spin-Orbit-Coupling (SOC) and long spin diffusion times. With our limited knowledge of spintronics we are already able to utilize these properties to create non-volatile, passive memory.

Because spintronics is a new area of study, mainly low symmetry crystals have been studied. Crystals containing iridium have the potential for large amounts of spin torque because iridium has large amounts of unpaired electrons. With increasing knowledge of spin transport, new techniques allow measurements of high symmetry crystals. For this reason, $Pb_2Ir_2O_7$, a defect Fluorite with high symmetry, could expand our understanding of spintronics. Additionally, we hypothesize that differently oriented crystals could have distinct spin torque. Because spin torque is largely a surface measurement, we have grown 5nm thick samples. We are specifically interested in finding unconventional spin torque.

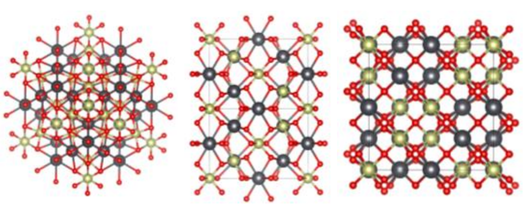


Figure 1: From left to right are the $Pb_2Ir_2O_7$ {111}, {110}, and {110} crystal structures.

This paper details the growth and characterization of $Pb_2Ir_2O_7$ films to better understand spin transport. Methods of $Pb_2Ir_2O_7$ {111}, {110}, and {100} growth will be given. We will prove our growth regime is not adsorption controlled through XPS, and we will show XRD to show correct crystal structure. Conclusions will include preliminary spin transport measurements as well as future plans to grow $Bi_2Ir_2O_7$.

METHODS

$Pb_2Ir_2O_7$ was grown via molecular-beam epitaxy with sources of lead oxide and elemental iridium. $Pb_2Ir_2O_7$ was grown on Yttria Stabilized Zirconia (YSZ) because of its near lattice match and because it is relatively inexpensive. Because of its high oxidation potential, 80% ozone and 20% oxygen was used at a pressure of 2e-6 torr for all three orientations of $Pb_2Ir_2O_7$.

While we initially believed that this regime is adsorption controlled by the iridium concentration, further studies using XPS revealed there is no adsorption control in our growth regime. We found that rather than applying an overpressure of lead, it is necessary to maintain a Pb:Ir flux near 0.7:1 for $Pb_2Ir_2O_7$ {110}, and a 1:1 flux is necessary for both $Pb_2Ir_2O_7$ {111} and {100}. Under these conditions, 400°C is the ideal substrate temperature. To keep the samples less than 10nm thick the samples were grown for 25min, 40min, and 70min for $Pb_2Ir_2O_7$ {111}, {110}, {100} respectively. Thicknesses were calculated by x-ray reflection and were found to be ~5nm.

In order to measure spin torque, we apply a magnetic field of resonance frequency to cause electron precession and create a spin current, which we measure to determine voltage.

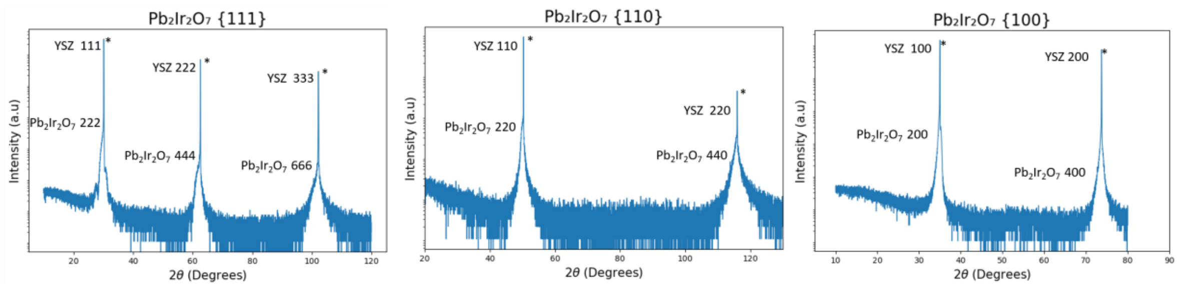
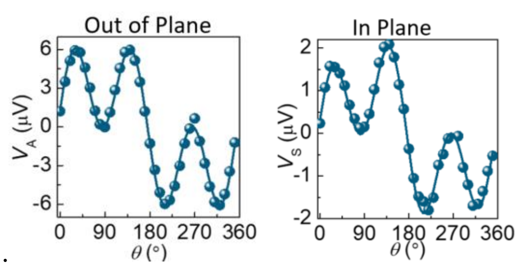


Figure 2: These x-ray diffration graphs show we have grown the correct crystaline structure of $Pb_2Ir_2O_7$ {111}, {110}, and {110} from left to right. It is of note that $Pb_2Ir_2O_7$ {111} has growth fringes while the {110} and {100} are faint beneath the substrate peaks. This is because the {110} and {100} are less energetically favorable and more difficult to grow. While these samples could be more crystalline, they are still of good enough quality for spin transport.

Results

We were able to grow $Pb_2Ir_2O_7$ {111} with growth fringes shown in figure 2. While discovering ideal growth parameters, we found $Pb_2Ir_2O_7$ {111} is less sensitive to the flux ratio than both $Pb_2Ir_2O_7$ {110} and $Pb_2Ir_2O_7$ {100}. All samples have been proven by XPS to be stoichiometric, so the faint film peaks shown in figure 2 are from $Pb_2Ir_2O_7$ {110} and $Pb_2Ir_2O_7$ {100}. However, for a more crystalline sample more experimentation is required.

As of 8/8/2023 we only have preliminary spin measurements. While we are yet to have data on $Pb_2Ir_2O_7$ {110} and $Pb_2Ir_2O_7$ {100}, measurements (figure 3) on $Pb_2Ir_2O_7$ {111} yield no unconventional spin torque out-of-plane and unconventional spin torque in-plane.



.

Figure 3: Pictured above are the in-plane and out-of-plane spin transport measurements for $Pb_2Ir_2O_7$ {111}. From these graphs we can determine that while there is no out-of-plane unconventional spin torque, there is in-plane unconventional spin torque.

Conclusion

With a substrate temperature of 400°C we grew $Pb_2Ir_2O_7$ {111}, {110}, and {100}. Because this regime is not adsorption controlled, a Pb:Ir flux of 1:1 is needed for both $Pb_2Ir_2O_7$ {111} and $Pb_2Ir_2O_7$ {110}, and a Pb:Ir flux of 0.7:1 is needed for $Pb_2Ir_2O_7$ {110}. Notably, $Pb_2Ir_2O_7$ {111} has unconventional in-plane spin torque. Our collaborators continue to study the spin transport of the grown samples to determine if there is indeed a difference in the spin transport measurements due to crystal orientation. We have begun to grow $Bi_2Ir_2O_7$ to expand the breadth of our spin torque study.

Acknowledgments

I would like to thank my mentor Maya Ramesh for her excellent guidance throughout this project. Her expertise and mentorship made this project great to work on. I would also like to thank Kathy Azizie for her help mentoring me. Lastly, I would like to thank Darrel G. Schlom for allowing me to work in his lab and Jim Overhiser for organizing the REU.