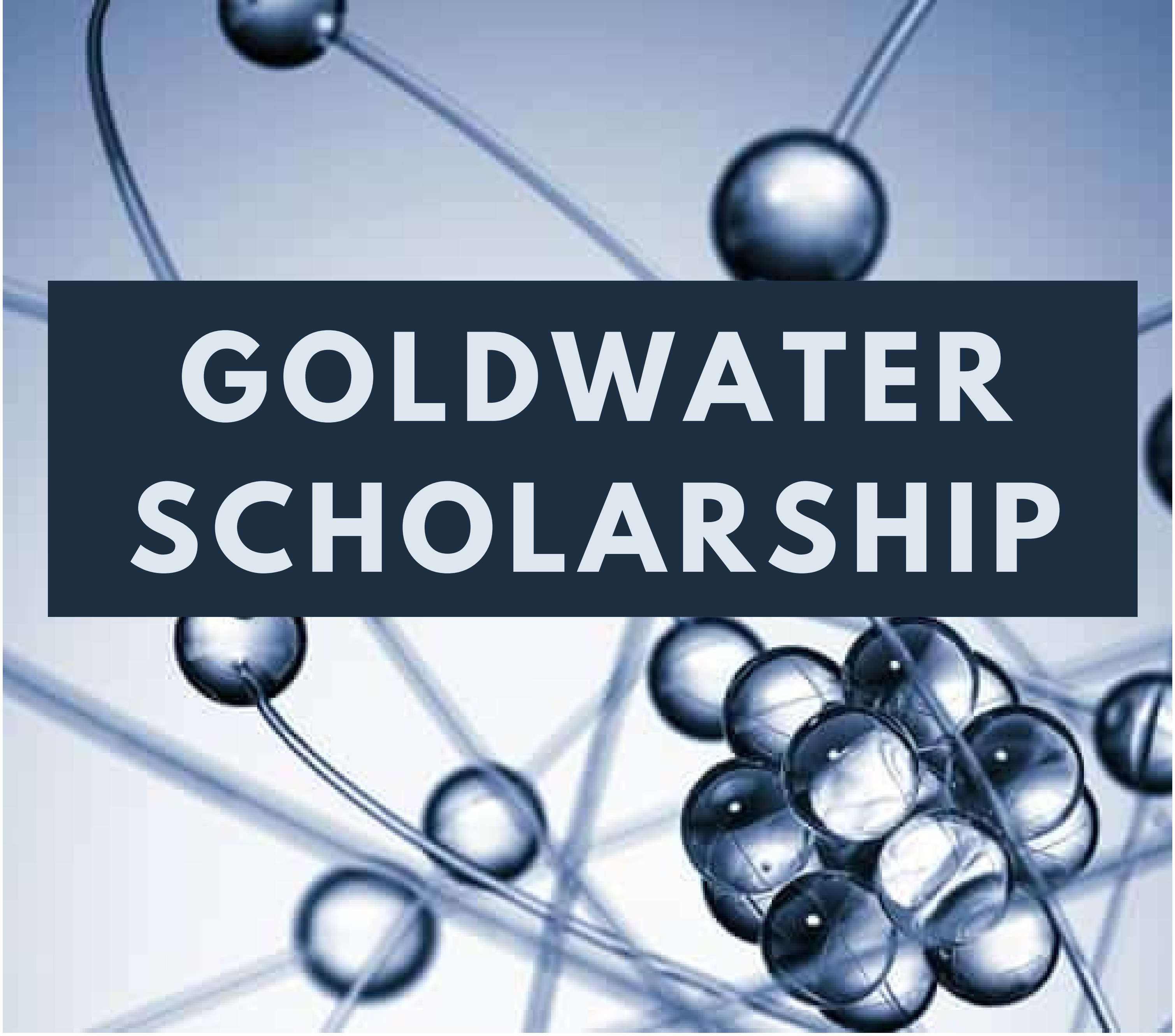


GOLDWATER SCHOLARSHIP

PHYSICS
GOLDWATER RECIPIENT:

2022-2023 APPLICATION

TABLE OF CONTENTS

PROFILE INFORMATION

PERSONAL DETAILS

First Name	Abby
Last Name	Greendale

CAREER/PROFESSIONAL ASPIRATIONS

What is the highest degree you plan to obtain?	Ph.D.
In 1-2 sentences, describe your career goals and professional aspirations. It will be used in publications if you are selected as a scholar	Ph.D. in Physics. Continue researching in condensed matter physics and eventually share my knowledge through teaching at the college level.

What are your career goals and aspirtations? Indicate which area(s) of mathematics, science, or engineering, you are considering pursuing and specify how your current academic program and your overall educational plans will assist you in achieving your career goals and professional aspirations

I want to continue learning my entire life. I want to continue seeking the thrill of discovery that I've already gotten a taste of in my current lab. I want to continue researching in physics and I'm certain in my desire to continue my studies through graduate school and beyond. I would love to eventually work towards becoming a lecturer and professor because one of my favorite things I've been able to experience in college has been the ability to teach others about the things that have sparked such an interest in me. Ever since I gained a surer footing for myself early in high school, I've been tutoring in science and math along with my own studies. Being the person who can explain a concept and see the gears finally click into sync has been so incredibly rewarding because I want others to understand and appreciate the intricate workings of everything in front of them as much as I have been able to. Becoming a professor also comes with the wonderful benefit of being able to continue to research. I don't think I could feel fulfilled unless I remained a lifelong learner. I've enjoyed the lab I am currently working in as strenuous and stressful and above-my-paygrade that it once was because it has given me the rare opportunity to explore specific materials and phenomena that I (and no one else) had ever observed or predicted before. There's a certain elation that attends a surprising day in the lab – like running an experiment and seeing its resistivity drop to zero the first time I ever induced a superconductive transition. It felt so rewarding to have spent so many hours constructing the system to measure something so exotic. I want to continue pursuing that high and hopefully bring a good portion of insight and renovation with me along the way. Research has truly become both a passion and reward in itself. I think my experience has been a lot like Andrew Wiles' description of developing his proof for Fermat's last theorem. Sometimes research feels like you're standing in the middle of a street as dark as the darkest thing you've ever seen. And when you finally fumble your way to a wall and then a door, when you open it, you're often in a room that was darker than that street ever was. However, the reward of being able to feel your hands along the wall and find a light switch is so illuminating and gratifying. Even when it often just reveals more doors to more dark rooms, the sense of that lonely frustration of being in the dark when you're truly working on a project no one has even thought to approach yet is somehow still comforting. I think I've become somewhat addicted to those moments when you flick on the light switch and I truly do want to spend my life seeking methods to flip every light on that I possibly can - especially if I can share those dawning realizations with the people around me.

Describe an activity or experience that has been important in helping shape or reinforce your desire to pursue a research career in STEM.

I think failing for the first time and feeling the absolute crushing sensation of that failure is what solidifying my need to continue in research. One day in the stressful week before our trip to Argonne lab, I made a mistake where I forgot for just one second to double check the spacing between the two diamonds in the cell I was working with. In a fatal gentle closure of the two cell halves, I shattered the two most expensive and precise diamonds we had intended to experiment on at Argonne just two days before our plane left. There was no time to order replacements (let alone set aside the thousands it would cost to replace them) and I felt genuinely horrible. I no longer felt motivated to go to lab because I felt like everything I was trying to do at the time was going wrong and I had no clue how to get out of that rut. Eventually, my PI (who had been extremely kind and patient about my mistakes) pulled me aside and told me that the work I was doing was bigger than the mistakes I was making. She reminded me that one of the most important reasons for me to be in lab wasn't to do her work for her, but rather to learn and grow as a researcher who will continue to contribute for years into the future. I forced myself to come back. I asked to be transferred to a different project for the time being. Now, I'm much more confident in my need to continually come back. To experiment and try. I think failure was what I needed to realize that I could build my own positive inertia.

In what way did COVID-19 or other hardships over the past couple years affect your research career plans and did those events alter your ability to pursue those plans? If you have had to make changes, in what way(s) did you adapt to the situation? If COVID-19 did not influence your plans, simply state there was no impact.

No impact

RESEARCH PROJECTS AND SKILLS

RESEARCH PROJECT #1

Understanding Magnetism Using Transport Measurements at Extreme Conditions

Dates	11/2021-05/2022
Average Hrs/Wk	15 (academic year)
Name of Project Mentor	Shanti Deemyad
Position and Affliation of Project Mentor	Associate Professor of Physics and Astronomy, University of Utah
Where the research was performed	University of Utah
Do you have paper/publications/presentations related to this project?	**Campus Poster Presenter** Audrey Glende, Shanti Deemyad, Mason Burden, Tushar Bhowmick, Tessa McNamee, Fatemah Safari. Understanding Magnetism Using Transport Measurements at Extreme Conditions. Poster

Description of research, including your involvement in AND contribution to the project

This research project acted as my first foray into condensed matter physics research. I learned how to construct and align a Diamond Anvil Cell (DAC) and was tasked with refining our methods for doing so. I developed an independent system for safely and efficiently cleaning the diamonds used in the DACs and established a usable literature review and manual for understanding the relationship that the electrical properties of a sample holds with its exposure to magnetic fields. Through this project, I established a greater understanding of electrical resistivity and magnetism and used that background along with proof of the work I had completed constructing multiple DACs to experiment upon in order to apply for and gain funding for a new project that would build upon this foundation. I constructed and presented a symposium poster that provided an elementary understanding for any individual interested in the work done within our lab.

Research Skills: Briefly describe any research skill(s) you developed while working on this project that will be important going forward in your research

This project taught me how to construct and align DACs. The field of condensed matter physics is notorious for constant and persistent failure. This intro project eased me into that sense of frustration and taught me patience. It also taught me to creatively compensate for my poor motor control.

RESEARCH PROJECT #2

Refining and Redesigning Methods and Machinery

Dates	02/2022-05/2022
Average Hrs/Wk	20 (academic year)
Name of Project Mentor	Shanti Deemyd
Position and Affliation of Project Mentor	Associate Professor of Physics and Astronomy, University of Utah
Where the research was performed	University of Utah
Do you have paper/publications/presentations related to this project?	No

Description of research, including your involvement in AND contribution to the project

I redesigned and refined circuitry and systems that were outdated and/or malfunctioning/inaccurate. I soldered and insulated new wired connections, co-redesigned a new interface for a data collection system, and built a new switcher box system to collect a more accurate average resistivity. This work dealt with limiting our circuitry's ability to circuit and the resistivity of our wired connections. I redesigned a module that had loose ports and built a breadboard that limited the number of needed moving parts. I also worked with another lab member in LabVIEW to create a system that would correctly allow our newly instated switcher box system to accurately communicate with the cryostat temperature control system and our hand-written data collection software by completely rewriting these communications to be more efficient and less bugged.

Research Skills: Briefly describe any research skill(s) you developed while working on this project that will be important going forward in your research

I developed good hands-on skills with various types of machinery of various ages. I am now proficient in soldering and creating effective and non-confounded circuitry. I am a proficient LabVIEW user and can also troubleshoot systems that have failed or developed bugs.

RESEARCH PROJECT #3

Beamtime at Argonne National Lab

Dates	06/2022-07/2022
Average Hrs/Wk	60 (summer)
Name of Project Mentor	Shanti Deemyd
Position and Affliation of Project Mentor	Associate Professor of Physics and Astronomy, University of Utah
Where the research was performed	University of Utah
Do you have paper/publications/presentations related to this project?	No

Description of research, including your involvement in AND contribution to the project

Our lab was awarded beamtime at Argonne National Lab. In preparation we built 9 DACs on short time (a usually very frustrating and time consuming task). Of those 9 I did the brunt of the work for 6 and helped on the remaining 3. I trained a new REU student on how to handle and construct DACs. I visited the Argonne Facility and learned to run high pressure experimentation using their x-ray to take diffraction measurements. Here I learned a new cryostat and laser system. I used ruby fluorescence to measure pressure and also performed structural analysis on x-ray spectra to isolate sample characteristics and construct crystallography models. I also collected data integral to a paper that my PI published and was acknowledged on that paper. (Citation: Cai, W., Yan, L., Chong, S. K., Xu, J., Zhang, D., Deshpande, V. V., Zhou, L., & Deemyad, S. (2022). Pressure-induced metallization in the absence of a structural transition in the layered ferromagnetic insulator)

Research Skills: Briefly describe any research skill(s) you developed while working on this project that will be important going forward in your research

This taught me to learn and use new systems on the go and also was a good practice in long grueling hours (graveyard shifts back-to-back with day shifts). I learned teamwork and data analysis. I learned how to use crystallography software and how to safely work with a particle accelerator.

RESEARCH PROJECT #4

High Pressure Studies on Colossal Magnetoresistant Material EuCd2P2

Dates	06/2022- ongoing
Average Hrs/Wk	15 (academic year); 50 (summer)
Name of Project Mentor	Shanti Deemyd
Position and Affliation of Project Mentor	Associate Professor of Physics and Astronomy, University of Utah
Where the research was performed	University of Utah
Do you have paper/publications/presentations related to this project?	**Campus Poster Presenter & Author** Audrey Glende, Mason Burden, Tushar Bhowmick, Tessa McNamee, Fatemah Safari, Shanti Deemyad. High Pressure Studies on Colossal Magnetoresistant Material EuCd2P2. Poster session presented at: University of Utah Summer Symposium; 2022 August 4; Salt Lake City, UT. Mason Burden, Audrey Glende, Tessa McNamee, Fatemah Safari, Tushar Bhowmick, Shanti Deemyad. Electronic Properties and Crystal Structures of Materials at Extreme Conditions. Poster session presented at: University of Utah Summer Symposium; 2022 August 4; Salt Lake City, UT.

Description of research, including your involvement in AND contribution to the project

I am currently working with a Colossal Magnetoresistant (CMR) material from the Tafti Lab. The crystal is very atypical so in identifying it as a potential superconductive candidate, at the advice of my mentor I have decided to run resistivity measurements as a function of pressure and temperature in order to get a sketch of its equation of state. I construct and load four-probe DACs with crystals of the sample and pressurize it to multiple GPa and then use the switcher-box system I designed to measure its resistivity as a function of temperature. I have already performed multiple of these hours-long experimentations and am currently confirming my results with multiple prepared cells. Some issues arose when two cells that should have held similarly static conditions were displaying different data, however, examining the crystal through separate planar orientations could theoretically explain these behavioral discrepancies. I am conducting further experimentation to confirm this theory.

Research Skills: Briefly describe any research skill(s) you developed while working on this project that will be important going forward in your research

I have learned a lot about CMR and have also really become fluent in the systems of our lab as I am actively redesigning and refining the systems as I go. I can proficiently run a low temperature resistivity measurement and can load and employ a liquid-helium cryocon system.

RESEARCH PROJECT #5

Creating an Optical System for Electronic Raman Spectroscopy

Dates	09/2022- ongoing
Average Hrs/Wk	10 (academic year)
Name of Project Mentor	Shanti Deemyd
Position and Affliation of Project Mentor	Associate Professor of Physics and Astronomy, University of Utah
Where the research was performed	University of Utah
Do you have paper/publications/presentations related to this project?	No

Description of research, including your involvement in AND contribution to the project

Raman spectroscopy has been a viable method for studying samples in our DACs because it allows for data collection while under extreme conditions of pressure and temperature. Since we hold samples in our cryostat and the sample chamber's size in these experiments is very small, about 10-100 microns. t is necessary to create a Raman spectroscopy setup that can work at a long distance from the sample and still produce high-quality images from outside the cryostat window. To achieve this, I've been using a dual-parabolic mirror setup to create a perfect image of the sample on a camera lens some couple inches removed from the actual cryostat window. I can flip two 45 deg mirrors into the path to then perfectly direct a laser into the area of the DAC that the camera is focused on. I use several optical standards, a few alignment lasers, and a black box enclosure to create a light path that is accurate, level and has minimal light loss.

Research Skills: Briefly describe any research skill(s) you developed while working on this project that will be important going forward in your research

I have received hands-on work with designing and executing optical set ups. This has been a measure in patience and step-by-step work as each stage of the optical array must be aligned singularly in order using a number of alignment lasers and standards.

MENTOR RECOGNITION

LETTER WRITER INFORMATION

OTHER ACTIVITIES/ ACCOMPLISHMENTS

Activity/ Accomplishment	Association of Women in Mathematics
Organization/Scope of Activity	University of Utah/College/University
Role/ Involvement	I am the treasurer of the Association of Women in Mathematics for the University of Utah chapter. I have been a member for over a year and was elected treasurer this last may. I handle all finances and merch for the program.
Position/Length of Involvement	Treasurer/More than 1 academic year

Activity/ Accomplishment	PASSAGE
Organization/Scope of Activity	University of Utah/College/University
Role/ Involvement	PASSAGE (Physics and Astronomy Society for Support and Advocacy of Gender Equity) is a program dedicated to female and marginalized gender group involvement in physics. I attended meetings and activities frequently.
Position/Length of Involvement	Member/Academic Year

Activity/ Accomplishment	ACCESS Scholar Mentor
Organization/Scope of Activity	University of Utah/College/University
Role/ Involvement	I was a member of the 2021 ACCESS Scholars cohort and am currently a mentor for the 2022 cohort. I advise and mentor students as they enter research for the first time. I help prepare symposium poster and assist in lab placement selections.
Position/Length of Involvement	Mentor/More than one academic year

RECOGNITIONS

Recognition/Type	SURP REU Research Grant/College/University
Year	2022
Description	SURP (Summer Undergraduate Research Program in Physics and Astronomy) is a physics summer research program married to the REU program at the University of Utah. It provides a stipend that covers a summer of full-time work for a proposed project.

Recognition/Type	ACCESS Scholars/College/University
Year	2021
Description	ACCESS Scholars is a program intended to enable first-year marginalized students to enter research early in their respective degrees. I was awarded this along with a grant to cover my first semester of research.

Recognition/Type	Mathematics Department Scholarship/College/University
Year	2022
Description	The award is for outstanding undergraduate students in the department of mathematics who display involvement in the department and a high Mathematics GPA.

Recognition/Type	National Merit/International
Year	2021
Description	The National Merit Scholarship is awarded to students who perform well on the PSAT in high school and set themselves apart through the application process after qualifying to apply.

Recognition/Type	Flagship Scholarship/College/University
Year	2021
Description	The Flagship Scholarship is a Merit-based Scholarship provided by the University of Utah for distinguished academic performance while in high school.

RESEARCH CAREER INTEREST/DIRECTION

Major Field of Study	Physics & Astronomy
Physics & Astronomy Areas of Specialization	Condensed Matter Physics
Is the research you intend to do in a multidisciplinary area?	No

CURRENT COLLEGE/UNIVERSITY

GPA	3.87
Graduation Year	Spring 2025

COURSEWORK

RESEARCH ESSAY

Uncovering Transitive Properties of $EuCd_2P_2$ at Extreme Conditions

Background

Technological innovation is constrained by the physical phenomena present in the materials we utilize globally. The goal of condensed matter physics research is to solidify our understanding of material properties at an atomic scale through the variation of variables such as pressure and temperature to discover and further tune these properties to the best usable conditions. Using this, we can rearrange interatomic structures and reveal new material properties that are not feasibly discovered in ambient conditions.

For example, a Diamond Anvil Cell (DAC) can exert millions of atmospheres of pressure upon a sample inserted between the tips of two diamonds.

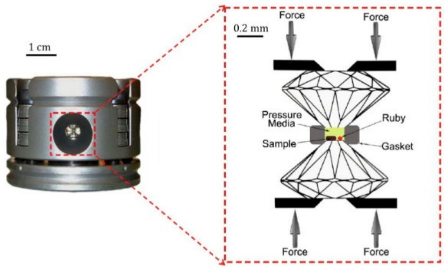


Diagram of a Diamond Anvil Cell [1]

Applying pressure condenses the interatomic distances of the material to change its physical properties. Resultantly, producing high pressures becomes an integral tool to methodically profile sample properties and allow for data collection to theorize patterns in behavior and predict desirable qualities like superconductivity and colossal magnetoresistance (CMR).

Room temperature superconductivity is the 'holy grail' of high-pressure research. Its discovery would stimulate a global technological revolution as high-temperature quantum computing would become feasible and everyday markets could introduce machinery that would never overheat or throttle. Interesting phenomena like the Meissner effect would even induce infrastructure redesigns with the introduction of near-zero energy magnetically levitated trains.

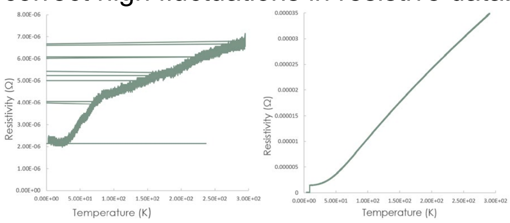
CMR is characterized by a severe change in the electrical resistance of a material when in the presence of the magnetic field. Although most materials displaying CMR require too low of temperatures and bulky machinery to maintain their CMR properties, there are theorized applications in acute magnetic sensing and disk read-and-write heads which would allow for increases in hard disk drive data density. Most materials that display colossal magnetoresistance hold one or more of a few certain properties: it contains the elements manganese or oxygen, a Double-Exchange interaction, a mixed valence, a perovskite structure, and/or a Jahn-Teller distortion [2].

$EuCd_2P_2$, a newly synthesized material, displays very high levels of CMR despite lacking any of the above properties. Due to this curious behavior, I've taken a special interest in finding correlational properties of this material that would attend its spike in CMR within a particular range of pressure and temperature.

By the interesting performance and conditional dependence of $EuCd_2P_2$, we have identified the material as a candidate for superconductivity and have conducted electrical resistance measurements at varied conditions to further map its equation of state. In the case that superconductivity is discovered, I will then lead a project to see if such behavior can be tuned to feasibly employ at ambient conditions.

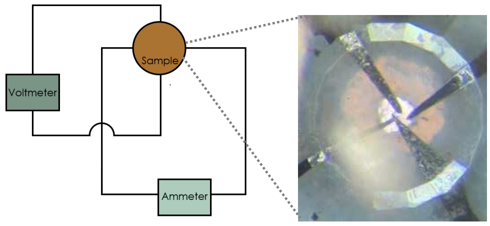
Methods and Refinements

In order to accurately take these transport measurements, many systems in the lab had to be refined and updated. The AC system that had previously enabled us to perform resistivity measurements was relatively inaccurate and would record data points that appeared to be artifacts of shorting connections and other circuitry failings. To address this, I fully rewired the connections within and between our cryostat (where the sample is kept and cooled) and the modules that would record data from internal samples. With another researcher in the lab, I introduced a switcher box system and programmed data-collection software that could provide a more reliable method that would take the average result of multiple measurements to correct high fluctuations in resistive data.



before after

To take electrical resistivity data of a sample within a DAC, a four-probe method is used to isolate the sample's electrical resistivity from the resistivity of the circuitry. The need for these procedures stems from the incredibly small size of the sample – if a sample is only microns across and measurements are taken a distance from the isolated system, data can become convoluted by the wires' own resistance. With four equally spaced electrical probes, current is applied to the sample and the voltage drop is measured along its surface.



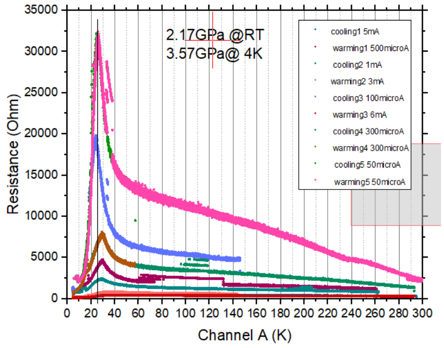
Basic Diagram and Image of $EuCd_2P_2$ Four-Probe

These four-probe systems must be hand constructed within the DAC and are in most cases built with micron-precision. The process can be tedious and unfruitful, so I've begun researching methods of platinum lithography and plasma sputtering stencils to enable our lab to more efficiently produce four-probe DACs.

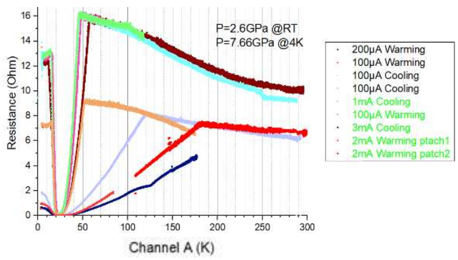
In preparing the DAC I used to experiment on $EuCd_2P_2$, I laser-cut and epoxy-coated multiple insulated gaskets (sheets of metal that sits between the tips of diamond anvils to produce an evenly pressurized sample chamber) and hand-aligned and loaded the DAC with a ~50 μm crystal of $EuCd_2P_2$. I placed four platinum probes that were micro-soldered to copper wires that I could connect to the current source and voltmeter from inside the cryostat.

Experimentation and Results

After properly constructing and loading multiple DACs with $EuCd_2P_2$ crystals, I attached the devices to our four-probe and cryocon measurement system. I measured pressure with ruby fluorescence and took continuous measurements of the electrical resistivity as temperature steadily dropped. After each cooling, I would either adjust current levels or the pressure of the cell and repeat the process to gather more data. In order to accurately gauge the equation of state for my sample, this process had to be repeated multiple times at various pressures with distinctly prepared cells. Variance in current allows us to better account for resistive heating (the sample holds an electrical resistance of thousands of Ohms) and also note any possible amperage-dependent behavior. The data collected for each distinct cell separately tested within in the cryostat is then graphed as below:



[fig. 1 – DAC1]



[fig. 2 – DAC2]

As can be seen above, the individually prepared cells provided highly distinct planar modulations of the equation of state for $EuCd_2P_2$. Our preliminary analysis has led us to believe that the electrical properties of the sample are directionally dependent upon the orientation of the crystal. This would explain that although (upon first glance) our separate cells appeared to have vastly distinct electrical mappings, they were displaying drastic electrical changes at similar temperatures and pressures – behavior that is consistent with electrically directional crystals.

I have proposed further study to map the directional dependance of $EuCd_2P_2$ through a comparative analysis of the crystal's structural orientation as seen through Raman spectroscopy and each sample's resistivity. As I move forward in this research, I have begun writing a paper detailing our findings on this exotic material's electrical properties.

Looking to the future, there is a large potential for a break-through in our understanding of how exotic CMR materials function. The large change in resistivity found around 18-28 K could indicate varied changes in phase of matter – whether that phase change be a superconductive transition, or a previously undocumented behavior. Either way, future analysis must be performed to further validate our current findings.

References

[1] Yang, S. and Zhaohui, D. (2011) Novel pressure-induced structural transformations of inorganic nanowires, in Nanowires – Fundamental Research, ed. Abbass Hashim, InTech, Rijeka, Croatia.

[2] Wang, Z. C., Rogers, J. D., Yao, X., Nichols, R., Atay, K., Xu, B., Franklin, J., Sochnikov, I., Ryan, P. J., Haskel, D., & Tafti, F. (2021). Colossal magnetoresistance without mixed valence in a layered phosphide crystal. Advanced Materials, 33(10), 2005755