



2022 REU Research Symposium

*UC Santa Cruz Research Experiences for Undergraduates
Program on Sustainable Materials*

Thursday, August 11, 2022, 8:50AM

In person: [Interdisciplinary Sciences Building](#) Room 431, UC Santa Cruz

Remote (Zoom): <https://tinyurl.com/3emjt3ad>



UNIVERSITY OF CALIFORNIA
SANTA CRUZ



Symposium Program

8:50AM – 9:00AM **Introductory Remarks**

David Lederman

UC Santa Cruz REU Sustainable Materials Program Director, Department of Physics

9:00AM – 9:15AM **Photolithography for Lab-on-Chip Applications**

Darshika Ravulapalli,¹ **K. B. M. Rakib Hasan**,² and **Ali Yanik**²

¹*Department of Physics, University of California, Santa Cruz,* ²*Department of Electrical & Computer Engineering, University of California, Santa Cruz*

9:15AM – 9:30AM **Electronic Control of H⁺ Current in a Biotic-Abiotic Bioprotonic Device with SLBs**

A Jesse Sanchez,¹ **Le Luo**,² **Yunjeong Park**,² and **Marco Rolandi**²

¹*Department of Chemical Engineering, Oregon State University,* ²*Department of Electrical and Computer Engineering, University of California, Santa Cruz*

9:30AM – 9:45AM **High Performance Electrocatalysts Based on Carbon-Supported Nanocomposites**

Marcus Hawley,¹ **Qiming Liu**,² and **Shaowei Chen**²

¹*Department of Materials Engineering, California Polytechnic State University, San Luis Obispo,* ²*Department of Chemistry and Biochemistry, University of California, Santa Cruz*

9:45AM – 10:00AM **Optimized Mechanical Graphene Exfoliation for Hall effect Device Fabrication**

Olivia Vilaboy,¹ **Anh Nguyen**,² **Ryan Van Haren**,² **Zhehao Ge**,² **David Lederman**,² and **Jairo Velasco Jr.**²

¹*Department of Materials Science and Engineering, Arizona State University,* ²*Department of Physics, University of California, Santa Cruz*

10:00AM – 10:15AM **Optimizing Fabrication Process of Monolayer Graphene Flakes to Investigate Relativistic Electrons at the Nanoscale**

Kevin Perez,¹ **Peter Polizogopoulos**,² **Zhehao Ge**,² and **Jairo Velasco Jr.**²

¹*Department of Physics, Fullerton College,* ²*Department of Physics, University of California, Santa Cruz*

10:15AM – 10:30PM **Doping of Two-Dimensional Transition Metal Dichalcogenides for Tunable Magnetic and Electrical Properties**

Katie Goldstein,¹ **Samuel McNair**,² and **Aiming Yan**²

¹*Department of Mechanical Engineering, Olin College of Engineering,* ²*Department of Physics, University of California, Santa Cruz*

10:30AM – 10:45AM **Synthesizing Metal Halide Perovskite Magic Sized Clusters**

Mia Brawley,¹ **Allison Win**,² and **Jin Zhang**²

¹*California State University Monterey Bay,* ²*Department of Chemistry and Biochemistry, University of California, Santa Cruz*

10:45AM – 11:00AM **Investigating Efficiency of Thin-Film Methylammonium Lead Iodide Perovskite Photovoltaic Devices**

Daniel O'Connor,¹ **Roy Sfadia**,² and **Sue Carter**²

¹*Department of Physics, California State University Stanislaus,* ²*Department of Physics, University of California, Santa Cruz*

11:00AM – 11:15AM Alloying Amorphous Semiconductors for Improved Properties in X-ray Detectors

Corinne Ahern,^{1,2} Kaitlin Hellier,³ and Shiva Abbaszadeh³

¹*Department of Physics and Mathematics, Bowdoin College,* ²*Thayer School of Engineering, Dartmouth College,*

³*Department of Electrical and Computer Engineering, University of California, Santa Cruz*

11:15AM – 11:30AM Investigating Mn Rims of Chondrule Meteorites

Tianna Calderon,¹ Fatima Jorge-Chavez,¹ Nathan McGregor,¹ and Myriam Telus¹

¹*Department of Earth and Marine Sciences, University of California, Santa Cruz*

11:30AM – 11:45AM Competing Magnetic Anisotropies of NiF₂- MnF₂ Epitaxial Alloy Films

Vanessa Hald,¹ Ryan Van Haren,² and David Lederman²

¹*Department of Materials Science and Engineering, Arizona State University,* ²*Department of Physics, University of California, Santa Cruz*

11:45AM – 12:00AM Magnetocrystalline Anisotropy Study in Single Crystalline CMS Thin Film

Chris Washburn,¹ Sujung Kim,² Yawen Guo,² and Holger Schmidt²

¹*Department of Engineering, Cabrillo College,* ²*Department of Electrical and Computer Engineering, University of California, Santa Cruz*

Photolithography for Lab-on-Chip Applications

Darshika Ravulapalli,¹ K. F. M. Rakib Hasan,² and Ali Yanik²

¹*Department of Physics, University of California, Santa Cruz*

²*Department of Electrical & Computer Engineering, University of California, Santa Cruz*

Abstract: Photolithography is a technique to manufacture patterned wafers using ultraviolet light, specifically ultraviolet. It is a subclass of microlithography and frequently used for batch productions and lower cost in industrial applications. Due to the high throughput of the fabrication process, photolithography is used in fabrication of optomechanical systems, electrochemical sensors for biosensing, and low-cost point-of-care diagnostic lab-on-chip systems. In Polydimethylsiloxane (PDMS) Soft Lithography, we fabricate silicon master wafers serving as a mold for designing microfluidic channels and devices. These are essential for small footprint lab-on-chip systems. The silicon wafer is coated in negative photoresist, a light-sensitive organic material. The wafer is UV exposed in a mask aligner where the photoresist is fortified. It is then submerged in a developer where the regions not exposed to the light dissolve away, leaving behind a coating where the wafer was exposed. For fabricating Interdigital Transducers (IDT), a LiNbO₃ substrate is used. The process follows that of PDMS, however positive photoresist is used on the wafer. For positive photoresist, the material is diminished by the UV exposure and once submerged in the developer, the areas exposed by the light are dissolved. We then observed the device's features shown in Fig. 1. In the UCSC Nano-Engineering Group a complete chip using photolithography will be fabricated with metallic micropatterns on a Si/SiO₂ wafer for designing new biosensor chips.

This work was supported by the UCSC REU program through the National Science Foundation (grant #1950907).

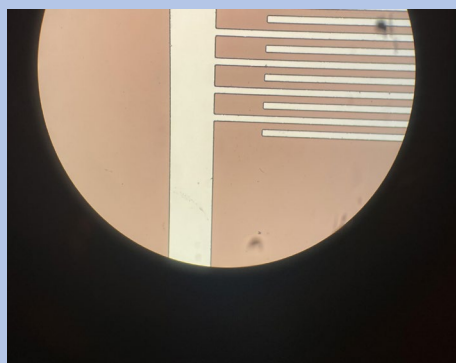


Fig. 1 Chip with interdigitated Ti/Au electrical contacts on Si, 25 μm wide separated by 125 μm .

Electronic Control of H^+ Current in a Biotic-Abiotic Bioprotonic Device with SLBs

Jesse Sanchez,¹ Le Luo,² Yunjeong Park,² and Marco Rolandi²

¹*Department of Chemical Engineering, Oregon State University*

²*Department of Electrical and Computer Engineering, University of California, Santa Cruz*

Abstract: Information processing in living systems requires movements of ions and molecules, therefore an area of interest is investigating high-efficiency information transfer across biotic-abiotic interfaces. Efficient bioelectronic devices have an array of applications, including therapy, drug delivery/discovery, data storage, environmental monitoring, and so on. Based on H^+ control, bioprotonic devices with Pd (palladium) contacts can modulate the H^+ flow, enabling integration between electrical devices and intercellular systems. A fabricated bioprotonic device—combining these Pd contacts and a lipid bilayer—monitors and controls transport of ions to create switches and memories (Fig. 1). Given additional time, inserted DNA nanopores (artificial ion channels) can further display the potential application of bioprotonic devices and their control of ion transport.

This work was supported by the UCSC REU program through the National Science Foundation (grant #1950907).

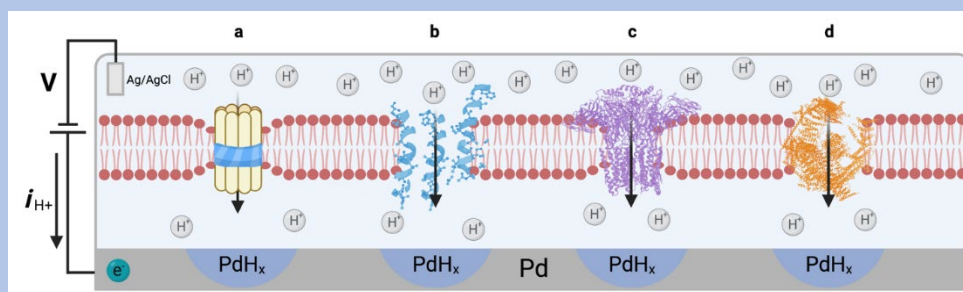


Fig. 1 (a) A DNA nanopore represents passive channels, also called leakage channels, which are always open and allow for a constant flow of ions. (b) Voltage-gated channels are active and conduct ions according to the electrochemical gradient, introduced by an applied voltage. (c) Another active channel is ligand gated, producing a flow of ions by the binding of a neurotransmitter to a site that changes the conformation of the ligand, putting it in a conductive state; some of these proteins have been found to be light activated. (d) Mechanically gated channels are active ion channels that allow ion flow when stimulated by vibrations, specifically touch or sound.

High Performance Electrocatalysts Based on Carbon-Supported Nanocomposites

Marcus Hawley,¹ Qiming Liu,² and Shaowei Chen²

¹*Department of Materials Engineering, California Polytechnic State University, San Luis Obispo*

²*Department of Chemistry and Biochemistry, University of California, Santa Cruz*

Abstract: The hydrogen evolution reaction (HER) is a significant rate limiting step for water electrolysis and engineering alternative catalysts with competitive performance remains a challenge. However, Platinum and Ruthenium dichalcogenides (PtX_2 and RuX_2) hold promise as cheaper and more abundant electrocatalysts than platinum – carbon catalysts for water electrolysis. Platinum – carbon catalyst has near ideal properties since their reaction kinetics are fast, and the material is stable have demonstrated impressive catalytic behavior in both acidic and alkaline media due to their near ideal hydrogen binding energies and low overpotential. Yet they either lack sufficient reaction kinetics or chemical stability to be currently considered for commercial use. As such, the performance of these dichalcogenides supported on carbon nanocomposites are of particular interest since this structure better mimics the construction of full-scale electrolysis devices, aids the electron-transfer kinetics and improves overall performance. The main characteristic examined in the dichalcogenide samples are reaction kinetics for HER. By using cyclic voltammetry in acidic and alkaline media, we can determine the reaction kinetics of each sample and select the best performing composition to conduct long term testing. The first step of this project is to synthesize the various dichalcogenides with solution chemistry. The samples are then washed, dried, and suspended in a new solvent and combined with powdered carbon black. The samples are then pyrolyzed in a programmable tube furnace under an inert atmosphere. The samples are added to inert electrodes in a three-electrode cell to conduct electrochemical characterization. Preliminary findings of non-pyrolyzed samples suggest minimal HER activity above background which does not bode well for solution synthesis of electrocatalysts.

This work was supported by the UCSC REU program through the National Science Foundation (grant # 1950907), and NSF grants #1950907, CHE-1900235, and CHE-2003685.

Optimized Mechanical Graphene Exfoliation for Hall effect Device Fabrication

Olivia Vilaboy,¹ Anh Nguyen,² Ryan Van Haren,² Zhehao Ge,² David Lederman,² and Jairo Velasco Jr.²

¹*Department of Materials Science and Engineering, Arizona State University*

²*Department of Physics, University of California, Santa Cruz*

Abstract: Graphene is an attractive honeycomb structure material. It is unique among two-dimensional electron systems in its ability to maintain electrical isolation at high carrier densities. However, graphene is not magnetic in its pristine form and has extremely weak intrinsic spin-orbit coupling, and the gapless band structure in graphene limits its applications in electronic devices. The introduction and control of magnetism in graphene can lead to significant advances in electronics, and the magnetic proximity effect (MPE) is a more robust and less invasive way to induce magnetism in graphene via a magnetic substrate [1]. For decades, the mechanical graphene exfoliation technique has been widely used to obtain a few layers of graphene (FLG) for device fabrication. Here, a modified mechanical exfoliation has been developed to acquire a larger area of FLG and a higher yield of flakes. The adhesion force between the graphite sheet and the substrate surface is enhanced by the heat treatment with the temperature ranging from 91 °C to 108 °C in the time ranging from 3 minutes to 5 minutes. Atomic Force Microscopy (AFM) characterization shows a smooth surface of graphene before it is used to fabricate the graphene Hall device using electron beam lithography. The result of gate response and the current-voltage curve will be discussed.

This work was supported by the UCSC REU program through the National Science Foundation (grant # 1950907), the U.S. Air Force Office of Scientific Research (grant #FA9550-19-1-0307), and Army Research Office under contract W911NF-17-1-0473.

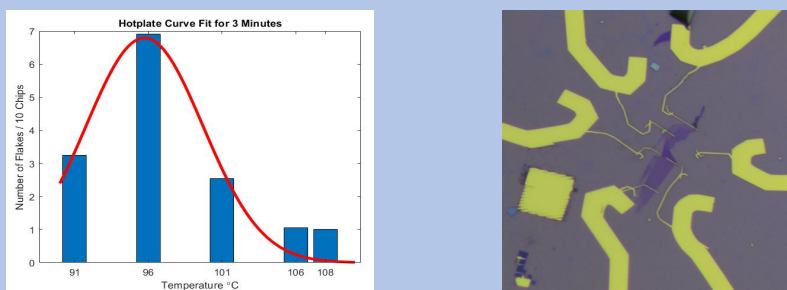


Fig. 1 (a) Normalized few layers of graphene (FLG) that are exfoliated and treated at different temperatures and at different times (left). (b) Graphene Hall devices fabricated using electron beam lithography.

[1] A. H. Castro Neto, F. Guinea, N. M. R. Peres, K. S. Novoselov, and A. K. Geim., *Rev. Mod. Phys.* **81**, 109–162 (2009).

Optimizing Fabrication Process of Monolayer Graphene Flakes to Investigate Relativistic Electrons at the Nanoscale

Kevin Perez,¹ Peter Polizogopoulos,² Zhehao Ge,² and Jairo Velasco Jr.²

¹*Department of Physics, Fullerton College*

²*Department of Physics, University of California, Santa Cruz*

Abstract: Graphene is a two-dimensional (2D) material composed of carbon atoms that has shown promising conductive properties. Specifically, Twisted Bilayer Graphene (TBG) has generated interest due to its ability to host tunable electronic behavior by stacking one layer on top of another and rotating the two layers at small angles. TBG has exhibited unconventional superconductivity and the potential to host chaotic phenomena, which remains to be fully understood. Already having explored states of relativistic electrons (also known as Dirac fermions) in electrostatically defined circular confinement potentials, the task is now to investigate such states in non-circular structures, which may further open the door to highly controlled studies on the nature of confined Dirac fermions, or as we call it, *Dirac billiards*. The Scanning Tunneling Microscope (STM) is a powerful tool that will be used to create non-circular confinement structures for Dirac electrons hosted in graphene and collect electronic information at the atomic scale (Fig. 1). To perform these experiments, attention has been placed onto the synthesis of graphene flakes that are required for STM studies. Difficulties lie with attaining flakes that have a large surface area, are thin, and exhibit uniformity, which are all essential for collecting electronic information via the STM. To produce such flakes, the scotch tape exfoliation method was used, and investigation was conducted into optimizing the fabrication of large and uniform monolayer graphene flakes by determining a standard heating time, temperature, and scotch tape condition that resulted in higher quality and yield.

This work was supported by the UCSC REU program through the National Science Foundation (grant # 1950907) and NSF CAREER award 1753367.

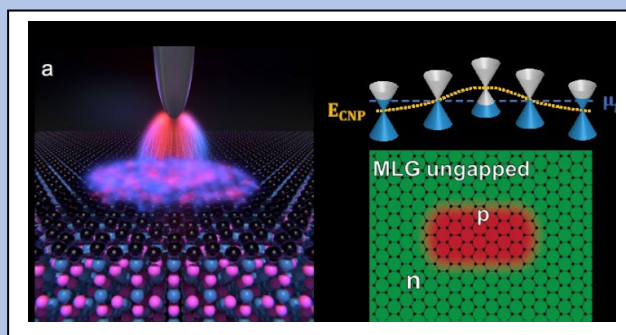


Fig. 1 (a) An illustration of the potential structure fabrication method using STM and (b) noncircular confinement structure that can host quantum chaos.

Doping of Two-Dimensional Transition Metal Dichalcogenides for Tunable Magnetic and Electrical Properties

Katie Goldstein,¹ Samuel McNair,² and Aiming Yan²

¹*Department of Mechanical Engineering, Olin College of Engineering*

²*Department of Physics, University of Santa Cruz, Santa Cruz*

Abstract: Two-dimensional (2D) transition-metal dichalcogenides (TMDs) are promising semiconductor materials for next generation ultra-thin, flexible electronics. By adding dopants into their crystal structure, we can tune their electrical properties to reduce metal-semiconductor contact resistance in field effect transistors, which takes us one step closer to being able to integrate these materials into electronic components [1]. Additionally, certain dopants can introduce magnetism to the non-magnetic 2D TMDs, leading to air robust two-dimensional diluted magnetic semiconductors for use in magneto-electric devices [2]. In this project, we first synthesize pure TMDs and then explore different methods to introduce dopants into the pure TMDs. We use chemical vapor deposition (CVD) method to synthesize TMDs- pure and doped. Some of the resulting growths can be seen in Fig. 1. The CVD method is used due to its desired scalability. We were able to synthesize pure WS₂ and WSe₂ via CVD method. We also explored using a solution-based precursor containing the tungsten and vanadium sources to synthesize vanadium doped WS₂. This method allows us to combine the two precursors with any known ratio, thus any doping level in the resulting 2D TMD. We prepared the solution precursor by dissolving different solid chemicals for the CVD growth. More work is needed to achieve vanadium-doped TMDs using this method.

This work was supported by the UCSC REU program through the National Science Foundation (grant # 1950907).

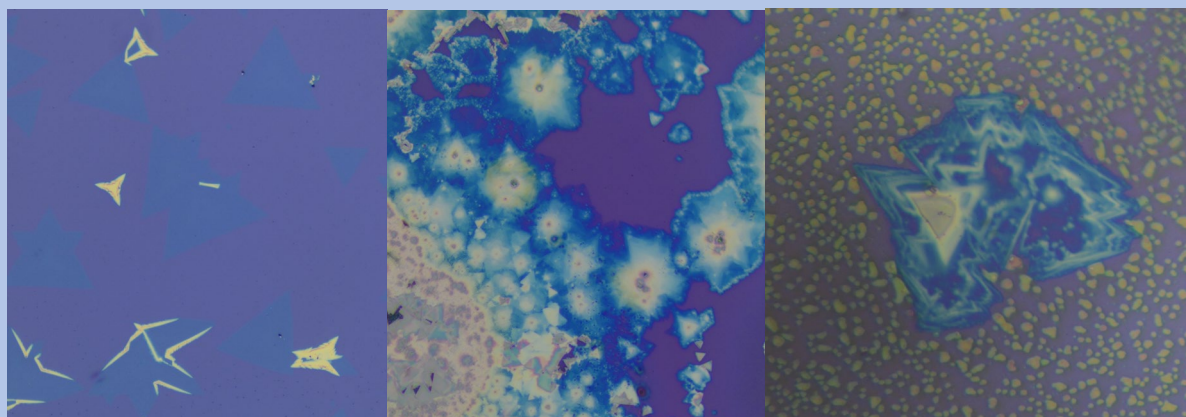


Fig. 1 Optical microscope images of CVD growth of (a) undoped WS₂, (b) vanadium-doped WS₂, (c) WSe₂

[1] Shisheng Li. et al., Adv. Sci **8**, 2004438 (2021).

[2] Fu Zhang et al., Adv. Sci **7**, 2001174 (2020).

Synthesizing Metal Halide Perovskite Magic Sized Clusters

Mia Brawley,¹ Allison Win,² and Jin Zhang²

¹California State University Monterey Bay

²Department of Chemistry and Biochemistry, University of California, Santa Cruz

Abstract: Magic-sized clusters (MSCs) are a particular type of nanoparticle with semi-conducting applications. Examples of these fields being photovoltaic cells and LED imaging. Perovskite magic-sized clusters (PMSCs) are defined by their general chemical formula ABX_3 . The “A” component is composed of either inorganic or organic cations. The “B” component is defined by a particular metal cation, and the “X” is a halide anion. The main goal of this project is to improve upon the stability of these particles, which are prone to degradation over time. PMSCs also tend to be quite unstable in the presence of water. During this summer, the main perovskite metal halide synthesized was methylammonium lead bromide ($MAPbBr_3$). Initially, the goal was to dope this particular perovskite metal halide, however the characteristic 600 nm emission of Mn^{2+} was not present in any of the produced samples. The method utilized in order to produce this perovskite is referred to as the ligand assisted reprecipitation method (LARP). Essentially, a sonicated precursor solution of starting materials is injected into a nonpolar solvent, and MSCs are immediately produced. Certain variables were changed in the procedure in order to compare and contrast how properties, behavior and quantity of methylammonium lead bromide nanoparticles would be affected. Data was collected via the UV-Visible spectrophotometer; this instrument is useful in order to determine the absorbance of particular samples. The PL, or photoluminescence spectrophotometer was used in order to characterize the sample's light emission and its intensity. Three different acids and amines were used in the attempted doped series: Oleylamine and Oleic Acid, Butylamine and Valeric Acid, Octanoic Acid and Octylamine. The other thing changed was then the actual dopant source from $MnBr_2$ to $MnCl_2 \cdot 4H_2O$. The Oleylamine and Oleic Acid tuned the size of PMSCs at particular concentrations of $MnBr_2$. The Valeric Acid and Butylamine created larger populations of molecular clusters (MCs), even smaller nanoparticles, at increasing $MnBr_2$ concentrations which do not include the “A” component of the PMSCs. Interestingly, the PMSCs synthesized at each concentration remained relatively stable and did not vary significantly. The Octylamine and Octanoic Acid doped series did form small populations of quantum dots, however besides this both populations of PMSCs and QDs were identical despite increasing concentrations of the dopant $MnBr_2$. Absorbance and fluorescence spectroscopy revealed that the integrity of the $MAPbBr_3$ magic-sized clusters is affected by the ligands and dopants used.

This work was supported by the UCSC REU program through the National Science Foundation (grant #1950907), NSF grant CHE-1904547, and NASA (MACES grant NNX15AQ01A).

Investigating Efficiency of Thin-Film Methylammonium Lead Iodide Perovskite Photovoltaic Devices

Daniel O'Connor,¹ Roy Sfadia,² and Sue Carter²

¹*Department of Physics, California State University Stanislaus*

²*Department of Physics, University of California, Santa Cruz*

Abstract: With increasing green initiatives and a shifting focus toward renewable energy, solar energy has become a promising option for commercial, industrial, and residential energy consumers. Thin-film perovskite solar cells (PSCs) offer an appealing alternative to first generation solar cells (crystalline silicon) due to their potential lower costs, ease of manufacturing, and rivaling efficiency. In this work, we optimized the electrodes, charge extraction layers, and absorption layer to improve power conversion efficiency (PCE). The quality of these layers was evaluated through photoluminescence, atomic force microscopy, absorption spectroscopy, and device performance. Different fabrication processes were experimented with to generate the best-performing perovskite device, optimizing the thickness of each layer while minimizing surface roughness, with a 30x increase in PCE from the first devices fabricated.

This work was supported by the UCSC REU program through the National Science Foundation grant #1950907.

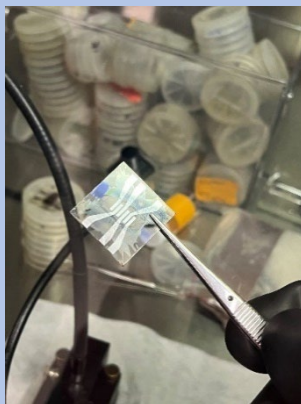


Fig. 1 A thin-film perovskite solar cell comprised of the following five layers: indium tin oxide (ITO), poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS), Methylammonium Lead Iodide (MAPI), [6,6]-phenyl C61 butyric acid methyl ester (PCBM), and aluminum.

Alloying Amorphous Semiconductors for Improved Properties in X-ray Detectors

Corinne Ahern,^{1,2} Kaitlin Hellier,³ and Shiva Abbaszadeh³

¹*Department of Physics and Mathematics, Bowdoin College*

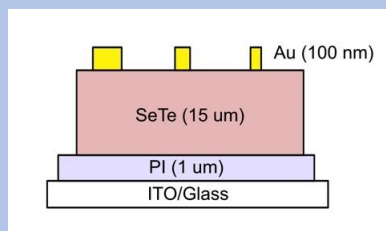
²*Thayer School of Engineering, Dartmouth College*

³*Department of Electrical and Computer Engineering, University of California, Santa Cruz*

Abstract: Amorphous selenium (a-Se) is a heavily researched photoconductive material that has a long history in xerography and indirect flat panel x-ray imagers. Advantages of using a-Se in x-ray imaging include that it can be easily deposited over a large area (up to 1 mm thick), it can keep a low dark current with minimal noise, it has high conversion efficiency at high applied electric fields (>10 V/ μm), and it is low cost. However, a-Se has low charge carrier mobility and crystallizes at low temperatures. In addition, a-Se's band gap of 2 eV prevents use with longer wavelength scintillators that emit in the green through IR wavelengths. Doping a-Se with Te is known to lower the band gap of a-Se, which will in turn improve absorption at longer wavelengths and help performance when paired with longer wavelength scintillators. Unfortunately, Te is known to increase energy states within the forbidden region which can negatively affect the conversion efficiency of the detector. In this research, we investigate doping a-Se with Te at 0-15 at.%. Devices were fabricated using ITO/glass substrate, 1-micron thick polyimide as a hole blocking layer, and a 15-micron thick a-Se_{1-x}Te_x layer, and a gold (Au) top contact [Fig. 1(a)]. These samples were characterized by taking dark and photocurrent measurements for conversion efficiency, responsivity, and linearity. The data collected indicates that the Se-Te devices have similar conversion efficiencies to pure a-Se at high applied fields and increasing the Te concentration in Se-Te improves conversion efficiency at longer wavelengths [Fig. 1(b)]. In addition, the Se-Te samples show a linear photo response similar to pure a-Se.

This work was supported in part by UCSC REU program National Science Foundation Grant #1950907, DOE grant number DE-SC0022343, DOE grant number DE-SC0021975, and Western Digital Corporation.

a)



b)

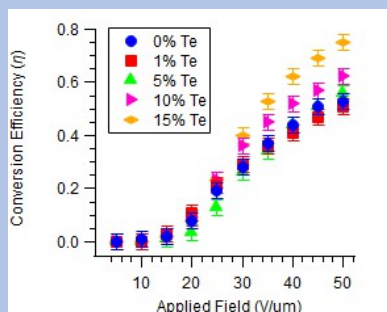


Fig. 1 (a) Schematic of fabricated SeTe devices used in dark and photo current measurements. (b) Conversion efficiency of the tested devices as a function of field.

Investigating Mn Rims of Chondrule Meteorites

Tianna Calderon,¹ Fatima Jorge-Chavez,¹ Nathan McGregor,¹ and Myriam Telus¹

¹*Department of Earth and Marine Sciences, University of California, Santa Cruz*

Abstract: Meteorites are rocks that come from cosmic objects known as planetesimals. They are usually pieces of rocks that have been ripped apart from its parent object (a larger, usually older object) and now have landed on Earth (Fig. 1). There are two types of meteorites: undifferentiated and differentiated. Chondrites are undifferentiated meteorites. These meteorites are considered undifferentiated because they did not experience melting and are the most unaltered type of meteorite. These chondrites have circular formations called chondrules. There are two types of chondrules: MgO-rich and FeO-rich. Chondrules form in the nebula from nebular dust, they experience heating and a rapid cooling, solidifying to create a chondritic planetesimal (Fig. 2). These chondrules can be altered through the means of aqueous alteration or thermal metamorphism. We observe these chondrites and their chondrules in an effort to understand solar system evolution. Here, we are looking at the manganese-rich rims around the chondrules on a chondrite. Through these observations we are trying to determine whether these Mn-rich rims were created during formation, from aqueous alteration, or by thermal metamorphism. To look more closely and figure this out, we're going to be using the chemical makeup using the scanning electron microscopy.

This work was supported by the UCSC REU program through the National Science Foundation (grant # 1950907).

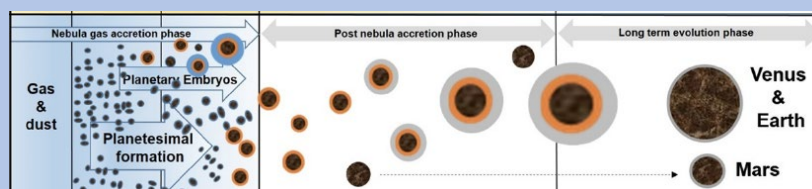


Fig. 1 Schematic of planet formation from gas and dust and planetesimals from Lammer.

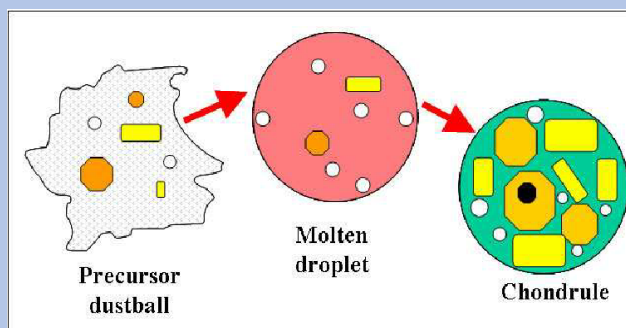


Fig. 2 Schematic of chondrule formation in the nebula from Jones et al. 2005.

Competing Magnetic Anisotropies of NiF₂- MnF₂ Epitaxial Alloy Films

Vanessa Hald,¹ Ryan Van Haren,² and David Lederman²

¹*Department of Materials Science and Engineering, Arizona State University*

²*Department of Physics, University of California, Santa Cruz*

Abstract: Fluoride antiferromagnetic insulators such as NiF₂ and MnF₂ have significant potential for magnon generation in electronics and spintronic devices. These materials are of particular interest due to their perpendicular magnetic anisotropies with respect to each other. Previous experiments using graded layers of NiF₂ and MnF₂ have shown unusual magnetic behavior, leading to an interest in studying the magnetic behavior of the alloys at various MnF₂ concentrations. In order to study this behavior, epitaxial thin films of varying concentrations of MnF₂ were grown on a MgF₂ (110) substrate with a 1 nm deposition of pure NiF₂ via molecular beam epitaxy. Reflection high-energy electron diffraction (RHEED) imaging was taken in situ after growth to ensure the thin films were of a single crystal orientation and low surface roughness. A superconducting quantum interference device (SQUID) magnetometer was then used to measure the magnetic properties of these epitaxial alloy films to discover the MnF₂ concentration at which the magnetic moments reorder from the easy a-b plane anisotropy to the c-axis anisotropy. Measurements of the magnetization as a function of temperature show that the alloys behave like NiF₂ even after the MnF₂ concentration has exceeded 50%, suggesting that the exchange energy between the Ni and Mn atoms is greater than the exchange energy between the Mn atoms (Fig. 1). This project has demonstrated that NiF₂ and MnF₂ can successfully be grown into novel thin film alloys with good crystal quality while maintaining antiferromagnetic ordering, and has also provided valuable insight into the exchange energies of these two systems.

This work was supported by the UCSC REU program through the National Science Foundation (grant # 1950907) and the Air Force Office of Scientific Research (grant # FA9550-19-454963).

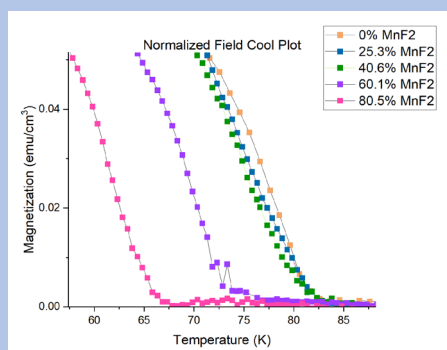


Fig. 1 Normalized magnetization vs. temperature while cooling in a 1 kOe field depicting the transition temperatures of NiF₂-MnF₂ alloy films of various molecular ratios.

Magnetocrystalline Anisotropy Study in Single Crystalline CMS Thin Film

Chris Washburn,¹ Sujung Kim,² Yawen Guo,² and Holger Schmidt²

¹Department of Engineering, Cabrillo College

²Department of Electrical and Computer Engineering, University of California, Santa Cruz

Abstract: By controlling the magnetic properties of materials, it is possible to produce a higher energy efficiency in spintronic devices. The Co₂MnSi (CMS) alloy exhibits half-metal behavior, high Curie temperature, and a low damping coefficient (α), which make it a strong candidate for future applications in spintronics. Additionally, epitaxially grown CMS films possess magnetocrystalline anisotropy. As a result of this, the frequency response of the magnetization precession in CMS films can be controlled along different crystallographic orientations under an applied magnetic field. The all-optical study of anisotropic frequency response arose from magnetocrystalline anisotropy in single crystalline CMS thin film (grown on an MgO substrate with a 1 nm cobalt iron (CoFe) buffer layer).

To detect the time-dependent magnetic response, we used pump-probe time-resolved magneto-optics Kerr effect (TR-MOKE) technique. A 400 nm femtosecond laser pulse (pump beam) was used to initiate the magnetization dynamics. A secondary laser beam of 800 nm was then used to detect changes in polarization as the information was sent to two lock-in amplifiers. External magnetic fields of strengths between 1000 and 5000 Oe were applied at various azimuthal angles (with respect to the surface normal. $\theta = 30^\circ, 45^\circ, 55^\circ$) and polar angles (in-plane angle. $0^\circ \leq \varphi \leq 90^\circ$). Interestingly, the frequency shows a notable drop at $\varphi = 45^\circ$, being most intense when coinciding with $\theta = 45^\circ$ (Fig. 1). Analysis of the lattice structure suggests this direction to have the lowest atomic density (Fig. 2), based on the assumption that the CMS used shows L21 symmetry, and the [110] crystallographic orientation aligns with $\varphi = 45^\circ$. With further investigations into which crystallographic direction this CMS film takes with respect to the substrate orientation, this study can provide better insight on how the magnetocrystalline anisotropy affects the frequency response of CMS thin film.

This work was supported by the UCSC REU program through the National Science Foundation (grant # 1950907).

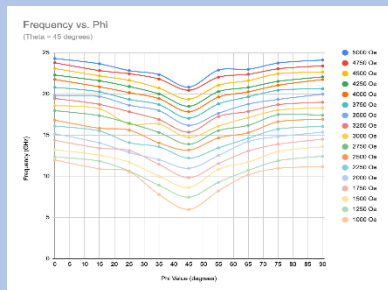


Fig. 1 Frequency response for various applied magnetic fields and φ values when $\theta = 45^\circ$.

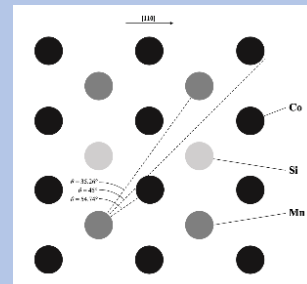


Fig. 2 Lattice plane along the [110] direction showing three θ angles.

