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14. ABSTRACT The symposium Chalcogenide Semiconductors Research and Applications (CSRA) and accompanying tutorial was held from August 20-22 as part of the International Materials Research Congress (IMRC) in Cancun, Mexico. The CSRA symposium was designed to bring together researchers in diverse fields that are connected by a shared focus on the processing-properties-performance connections in chalcogenide semiconductors and related electronic materials. The symposium features 15 invited speakers and 14 contributions, and attendees from Israel, the USA, Mexico, Japan, and Singapore.						
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SYMPOSIUM GRANT FINAL TECHNICAL REPORT

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1. Symposium organizers

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Bio: Prof. Jaramillo's research interests sit in the big, fun space between materials science, solid state physics, and renewable energy technologies. His current interests can be characterized as defect engineering of chalcogenide semiconductors. Prof. Jaramillo received a PhD in Physics from The University of Chicago (advisor: T. F. Rosenbaum), and a BS and MEng both in Applied and Engineering Physics from Cornell University

Prof. Yuval Golan
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Bio: Prof. Golan's research interests are in the fields of nanocrystalline materials, thin films, interfacial phenomena, and chemical deposition of semiconductor thin films. Prof. Golan received a PhD and MSc in from the Department of Materials and Interfaces, Weizmann Institute of Science, and a BSc in Chemistry from Tel Aviv University.

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Bio: Dr. Lany is a computational materials scientist with a background in electronic structure calculations for semiconducting materials. He joined NREL in 2003 as a postdoctoral researcher. As a staff scientist, he is currently leading computational research activities in support of the Energy Frontier Research Center and the Solar Energy Technology Program. Dr. Lany received a PhD in Physics from the Universitat des Saarlandes in Germany.

2. Synopsis

Symposium Abstract

Chalcogenides has its origin in chalkos, a Greek word for bronze, assigned to copper-bearing minerals: chalcocite, chalcopyrite, etc. Over time, chalcogenides have come to signify compounds of metals with group-VI elements. Many of these are naturally-occurring crystals that are born as semiconductors: chalcocite (Cu_2S), pyrite (Fe_2S), chalcopyrite (CuFeS_2), chalcostibite (CuSbS_2), herzenbergite (SnS), galena (PbS), etc. They also include materials that are under widespread investigation for devices: transition metal di-chalcogenides (eg. MoS_2) for electronics and photonics, $\text{Cu}(\text{In,Ga})(\text{S,Se})_2$ and $\text{Cu}_2\text{ZnSnS}_4$ for photovoltaics, $(\text{Hg,Cd,Zn})\text{Te}$ for detectors and photovoltaics, Bi_2Se_3 for topological computing, etc. Chalcogenide semiconductors may be key to advancing many of the technical goals of the Office of Naval Research including materials for nanoelectronics combining new functionalities, phase change

materials for microelectronics and RF applications, and materials for infrared imaging. Chalcogenide opto-electronic materials exhibit a wide range of phenomena including layered crystal structures with anisotropic transport, ordering phenomena such as ferroelectricity and density waves, widely tunable band gaps, and strong interactions with light including excitonic effects. Understanding, controlling, and harnessing these phenomena requires a thorough understanding of the science and device implications of chalcogenide electronic materials.

There have been conferences in the past devoted to chalcogenide electronic materials, but over the years the theme has splintered into many subthemes. Researchers in this theme share an awareness of the challenges involved in the material preparation and characterization, and a passion for their wide range of applications. Chalcogenide Semiconductor Research and Application (CSRA) symposia are intended to organize and serve the needs of this growing community.

Meeting Summary

The CSRA symposium and tutorial took place over three days in August 2017 at the XXVI International Materials Research Congress (IMRC 2017). The symposium was well-attended by the international research community, with 15 invited speakers and 14 contributions and with attendees representing Israel, the USA, Mexico, Japan, and Singapore. By design, the topics covered were broad, with presentations ranging from thin film solar cells to single crystal topological materials. The emphasis throughout on the processing-properties-performance connections in chalcogenide materials lead to surprising and interesting connections between research fields that usually do not interact. The full meeting program reproduced below.

3. Location and Meeting Program

Dates of Event: August 20-22, 2017

Event venue: JW Marriott Cancun Resort & Spa, Cancun, Mexico. Tel: (52) (998) 848-9600

Event program:

Sunday, August 20 – Tutorial

- Session 1: Theory (9:00am – 10:15am), Dr. Stephan Lany
 - Introduction to Density Functional Theory and Electronic Structure
- Session 2: Experiment (10:15am – 11am), Dr. Rafael Jaramillo
 - Thin film growth
 - Characterizing phase and composition
- Session 3: Theory (11:15am – 12:30pm), Dr. Prashun Gorai
 - High-throughput computation
 - Application to thermoelectrics
 - Databases
- Session 4: Experiment (12:30pm – 1:30pm), Dr. Rafael Jaramillo
 - Optoelectronic property measurement
 - Advanced characterization

Monday, August 21

- Session 1: Fundamentals of chalcogenide electronic materials – Theory and disorder (8:30am – 11am)

- Invite 1: Lany, Stephan - "Disorder and defects in chalcogenide photovoltaic materials"
- Invite 2: Makov, Guy - "PROPERTIES OF A NOVEL NANOMETRIC CUBIC PHASE IN MONOCHALCOGENIDE SEMICONDUCTORS"
- Contrib 1: P Karuna Nair, simF.1-abs016, OPTICAL AND ELECTRICAL PROPERTIES OF COMPONENT THIN FILMS OF ANTIMONY CHALCOGENIDE SOLAR CELLS
- Contrib 2: Rafael Jaramillo, simF.1-abs012, Mechanism of Persistent Photoconductivity in Chemical Bath Deposited CdS thin films
- Invite 3: Gorai, Prashun - "Computationally Guided Discovery of Chalcogenide Thermoelectric"
- Invite 4: Agarwal, Ritesh - "THE ROLE OF DISORDER ON ELECTRONIC, STRUCTURAL AND POLAR DOMAINS IN PHASE CHANGE CHALCOGENIDES"
- Session 2: Chemical strategies for electronic materials design (12:30pm – 2pm)
 - Invite 5: Mitzi, David - "SEARCH FOR HIGH-PERFORM. EARTH-ABUNDANT MULTINARY CHALC. ABSORBERS FOR SOLAR ENERGY CONVERSION"
 - Contrib 3: Yuval Golan, simF.1-abs001, Chemical Epitaxy of Chalcogenide Semiconductors
 - Invite 6: Simpson, Robert - "PHASE CHANGE CHALCOGENIDES BY DESIGN"
- Session 3: Beyond semiconductors (4:00pm – 6:30pm)
 - Invite 7 Moodera, Jagadeesh - "CREATING A FERROMAGNETIC TOPOLOGICAL INSULATOR: INTERFACE EXCHANGE AND QUANTUM TRANSPORT"
 - Contrib 4: Nidia G. García Peña, simF.1-abs058, ROD-SHAPED BISMUTH SULFIDE-GRAPHENE OXIDE COMPOSITES AS POSSIBLE PHOTOCATALYST FOR CO₂ REDUCTION
 - Contrib 5: Sadasivan Shaji, simF.1-abs026, Tin sulfide nanoparticles and thin films synthesized by pulsed laser ablation in liquid
 - Invite 8: Mao, Zhiqiang - "NOVEL LOW DIMENSIONAL TERNARY TRANSITIONAL METAL CHALCOGENIDES WITH SEMICONDUCTING AND TOPOLOGICAL SEMIMETALLIC PROPERTIES"
 - Contrib 6: Amanda Carrillo, simF.1-abs010, CuS thin films as a proposal of active material in SC devices: A complete study of CBD parameters
 - Contrib 7: Aizuddin Suppe, simF.1-abs005, CHARACTERIZATION OF FeS_xO_y THIN FILMS PREPARED BY THREE-STEP PULSE ELECTROCHEMICAL DEPOSITION
 - Invite 9: Clarke, Simon - "SOFT CHEMICAL CONTROL OF IRON-BASED SUPERCONDUCTORS AND RELATED COMPOUNDS"
- Poster session (6:30pm – 8:30pm)

Tuesday, August 22

- Session 4: Advances in thin films (9:00am – 11:00am)
 - Invite 10: Redwing, Joan - "MOCVD GROWTH OF MONOLAYER AND FEW LAYER TRANSITION METAL DICHALCOGENIDE FILMS"
 - Contrib 8: Vineetha Vinayakumar, simF.1-abs003, Effects of rapid thermal treatments on the photovoltaic properties of CuSbS₂ thin films
 - Invite 11: Bent, Stacey - "NOVEL MOLYBDENUM SULFIDE HYBRID FILMS"
 - Contrib 9: Bindu Krishnan, simF.1-abs028, AgSb(S_xSe_{1-x})₂ thin films for photovoltaics
 - Contrib 10: David Avellaneda, simF.1-abs039, Thin films of Cu-Sn-S system, obtained by chemical bath deposition and thermal evaporation methods
 - Contrib 11: P Karuna Nair, simF.1-abs015, Sb₂S_xSe_{3-x} THIN FILMS OF VARYING COMPOSITIONS IN SOLAR CELLS PRODUCED BY THERMAL EVAPORATION
- Session 5: Advances in microelectronics (12:30pm – 2:00pm)
 - Invite 12: Park, Jiwoong - "Paper and Circuits, only Atoms Thick"
 - Contrib 12: Christopher Muratore, simF.1-abs029, 2D CRYSTAL CALIGRAPHY: NOVEL TECHNIQUES FOR PATTERNING 2D MATERIALS AND DEVICES ON FLEXIBLE SUBSTRATES
 - Invite 13: Hongtao Lin (JJ Hu postdoc) - "Chalcogenide glass for integrated graphene photonics"
 - Contrib 13: Diogenes Placencia, simF.1-abs013, INVESTIGATION OF CONTACT INTERFACES IN PbS NANOCRYSTAL DEVICES FOR OPTOELECTRONIC APPLICATIONS
- Session 6: Materials design for optoelectronics (4:00pm -5:15pm)
 - Invite 14: Zakutayev, Andriy - "EMERGING CHALCOGENIDE SEMICONDUCTORS FOR PHOTOVOLTAIC ABSORBER APPLICATIONS"
 - Invite 15: Ravichandran, Jay - "Optical Properties of Perovskite Chalcogenides: Materials for Visible to Infrared Applications"
 - Contrib 14: P Karuna Nair, simF.1-abs017, Chemically deposited lead-, tin-, and antimony chalcogenide thin films and applications