AVS MN Chapter Annual Symposium

Development and Analysis of Surfaces, Thin Films & Nanomaterials

AVS MINNESOTA CHAPTER

Established 1969

Advancing the Science and Technology of Materials, Interfaces, and Processing in the North Star State and surrounding regions

Wednesday, September 9, 2015

CEC Center, University of Minnesota, St Paul Campus

Sponsored in part by Medtronic, Seagate Technology, and Physical Electronics

Medtronic SEAGATE PHYSICAL ELECTRONICS A DIVISION OF ULVAC-PHI

Agenda

1:00 Welcome & Introduction

1:15 **Morgan Alexander**, University of Nottingham
"Biomaterials discovery using material microarrays: from polymer spots to devices via surface analysis"

1:45 **Alex Shard**, National Physical Laboratory
"Measuring organic shrubbery on surfaces and nanoparticles"

2:15 **Fred LaPlant,** 3M
"The Neglected Vacuum – techniques that need vacuum but don't always get it""

2:45 Poster Session and Vendor Exhibit

4:00 **Peter Ladwig**, Hutchinson Technology, Inc.
"*Miniaturization of electromechanical medical devices using semi-additive photolithographic fabrication technologies"*

4:30 **Bharat Jalan**, University of Minnesota
"*Hybrid molecular beam epitaxy for functional oxide thin films and heterostructures"*

5:00 Reception in poster session area with appetizers and cash bar

5:45 Dinner

6:15 Business Meeting/ Student poster winner announced

6:30 **Michael Kautzky**, Seagagte Technology

"Heat-assisted magnetic recording (HAMR): fundamentals, reliability, and the path to productization"

Oral Presentations

Biomaterials discovery using material microarrays: from polymer spots to devices via surface analysis

Morgan Alexander
Laboratory of Biophysics and Surface Analysis, School of Pharmacy, University of Nottingham, University Park, Nottingham NG7 2RD, UK

Polymer micro arrays have proven to be useful tools for the discovery of new synthetic materials which control cell attachment to surfaces.[1] This high throughput (HT) materials discovery approach is attractive because the paucity of understanding of the cell-material interface hinders the rational design of new materials.[2] The large number of polymer chemistries that can be investigated on a single polymer micro array act as a wide "net" in the search for materials that can achieve a certain cell response. Micro array hits are the starting point from which new materials may be developed.[3] In this talk I will describe this approach with examples from my lab ranging from the identification of a novel class of polymers resistant to bacterial attachment as spots[4] to scale up to catheter coatings which resist biofilm formation in vitro and in vivo through to a medical device for regulatory approval. Surface chemical analysis, in particular ToF SIMS has been an essential component of this process.

[1] Hook, A. L. Biomaterials (2010).
[2] Kohn, J., Nature Materials (2004).
[3] Anderson et al. Nature Biotechnology (2004).
[4] Hook, A. L. et al. Nature Biotechnology (2012).

Measuring organic shrubbery on surfaces and nanoparticles

Alex Shard
National Physical Laboratory, Analytical Science, Hampton Road, Teddington, Middlesex TW11 0LW, UK

Thin films of organic materials are ubiquitously present on surfaces whether we want a shrubbery of such material or not. In some cases, the material is intentional and serves a particular purpose, such as acting as a protective layer or promoting a particular chemical or biological response. In other cases this material is unwanted or unrecognised even though it may have a profound impact upon the performance of the material. It is therefore important to develop methods that can determine what the material is and how much of it there is. In this talk, I will describe progress in the areas of identification and measurement of the organic shrubbery, using gold surfaces as a primary example. The use of XPS and SIMS to measure organic films relevant to biosensors on both flat surfaces[1] and nanoparticles[2] will be described and compared to measurements by other methods at the solid liquid interface. Simple approaches to data analysis will be outlined [3] and some of the current limitations, particularly with regard to the sensitivity of these methods [4] and whether they can approach the detection limits required to understand biological interactions with materials.

[1] S Ray, R T Steven, F M Green, F Höök, B Taskinen, V P Hytönen, A G Shard, Langmuir 31 1921-1930 (2015)
[2] N A Belsey, A G Shard, C Minelli, Biointerphases 10 019012 (2015)
[3] A G Shard, The Journal of Physical Chemistry C 116 16806-16813 (2012)
[4] A G Shard, Surface and Interface Analysis 46 175-185 (2014)

The Neglected Vacuum – techniques that need vacuum but don't always get it

Fred LaPlant
3M Corporate Research Analytical Laboratory, 3M Center, 201-B-S-07, Maplewood, MN 55144 USA

There are a number of surface techniques such as SERS, NSOM, and different flavors of AFM, that can be significantly altered by the presence of surface contaminants, adsorbed water, oxide layers, etc., but for various reasons are rarely done under vacuum. This talk will highlight some of the reasons and challenges, from increased complexity of the instrumentation, challenges of the target application, and scientist sloth.

Miniaturization of electromechanical medical devices using semi-additive photolithographic fabrication technologies

Peter Ladwig
Hutchinson Technology, Inc., 40 W. Highland Park Dr., Hutchinson, MN 55350 USA

Advancements in wearable and minimally invasive medical devices are often enabled by miniaturization. Miniaturization can be achieved not only through reducing the size of components but also by reducing component count. Semi-Additive photolithographic fabrication technologies are processes can that be utilized to both reduce size and reduce component count. Semi-additive manufacturing generally involves the deposition of a thin seed-layer of material (via vacuum deposition), selective patterning (via photolithography), growth of material from that seedlayer (via electro or electroless plating), and removal of undesired seedlayer from the substrate (via chemical or plasma etching). This method can produce features on the single digit micron scale, even on flexible substrates. Component count reduction in enabled by the integration of features typically accomplished with multiple components onto one component. One example of these benefits is the addition of an electrical circuit to connect to a sensor on an existing structural component. In this case, the electrical circuit is "grown" directly onto the structural component instead of attaching individual wires or attaching a separate flex circuit. A limitation of the technology is that it generally requires quasi 2-D substrates; which can, however, be subsequently formed into 3-D shapes after semi-additive processing. Other advantages are: circuits can be built upon just about any solid substrate material with good adhesion, and the cost to add a multitude (sometimes millions) of features to a part is only marginally more costly than adding one feature.

Hybrid molecular beam epitaxy for functional oxide thin films and heterostructures

Bharat Jalan
Department of Chemical Engineering and Materials Science, University of Minnesota, Minneapolis, MN 55455 USA

Complex oxides with ABO3 perovskite structure display a wide-range of phenomena including superconductivity and ferroelectricity. Recent advances in thin film growth approaches have enabled the growth of this material class in thin film and heterostructure form with an excellent structural quality. In fact the structural quality has now become similar to that of the conventional semiconductors such as Si. However the grand challenge in the field is to obtain complex oxides with the high level of stoichiometric and defect control, which are most important for the study of their intrinsic physical phenomena. In this talk, we will present our group's effort to address these challenges using the hybrid molecular beam epitaxy (MBE) approach by combining the advantages of conventional MBE and metal-organic chemical vapor deposition with the focus to understand and control novel electronic and magnetic ground states in defect-managed oxide thin films and heterostructures.

This research is supported through the University of Minnesota MRSEC under award DMR-1420013.

Heat-Assisted Magnetic Recording (HAMR): fundamentals, reliability, and the path to productization

Michael Kautzky
Seagate Technology, Minnesota

With the explosive growth in worldwide data generation and consumption, increasing the storage density of hard disc drives beyond conventional perpendicular recording schemes is essential to maintain cost-effective storage solutions. Heat-assisted magnetic recording (HAMR) is the next-generation technology which promises to deliver areal densities in excess of 1 Terabyte/in2. In this technology, the recording process relies on synchronized heating of the media surface to temporarily lower its coercivity during magnetic writing process. This helps overcome existing limits in media thermal stability and head fields. These changes have required substantial changes to the recording head write element architecture, combining the conventional electromagnet structure with integrated optical light delivery layers, focusing optics, and plasmonic nanostructures for generation of the heating field. In this talk several of the challenges associated with introducing new magnetic, optical, and plasmonic layers in the nanoscale head environment will be reviewed. In particular, new film materials and methods to enable low-loss waveguides and plasmonic near-field transducers will be discussed, along with challenging new failure modes created by the higher head operating temperatures. The talk will

also highlight areal density and HAMR drive demonstrations achieved by Seagate on the path to productization.

Posters

Analysis of Oxides and Coatings on Titanium Substrates

Mitch Brunkow[1] and Bill Theilacker[2]
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[2]*Corporate Science & Technology, Medtronic, Inc., 710 Medtronic Parkway, Minneapolis MN 55432*

Surface coatings are widely used on medical devices to increase biocompatibility, corrosion resistance, and fatigue strength amongst many other benefits. Several commonly used coatings include hydroxyapatite, parylene, and anodization. The ability to accurately characterize coating thickness and uniformity is essential for quality and optimal device performance. For example, Type II oxide coatings form as a penetrating layer rather than an anodically grown Type I oxide and result in no dimensional change, thus making their characterization very challenging without a field emission scanning electron microscope (FE-SEM). In this study we characterized hydroxyapatite and parylene coatings and titanium oxides (Type I and II) on Ti6Al4V substrates of different geometries by non-destructive and destructive analysis. The samples were analyzed *as is* using X-ray Photoelectron Spectroscopy (XPS), spectroscopic ellipsometry, and/or interferometry. Polished metallurgical cross sections were analyzed by SEM. In addition, three different metallurgical potting media were evaluated and compared (EpoxySet, EpoHeat, and hot press mount). Artifacts and issues arising from the metallurgical cross sectioning process were observed and will be addressed in detail. The coating thickness measurements from each technique will be highlighted with strengths and weaknesses for each coating type.

Unambiguous Molecular Identification with TOF-SIMS Imaging MS/MS

John Newman, Paul Larson, Scott Bryan, Gregory Fisher and John Hammond
Physical Electronics, Chanhassen, MN

A new tandem TOF-TOF imaging mass spectrometer exploiting the unique characteristics of the TRIFT analyzer used in the PHI *nanoTOF* II has been developed [1]. This design allows for conventional TOF-SIMS spectra and product ion spectra of a specific precursor to be acquired in parallel, providing the maximum information from a given analytical volume. It has been recognized for many years that MS/MS is required to unambiguously identify peaks above 200 *m/z* due to the limitations of mass resolution and mass accuracy in commercial TOF-SIMS instrumentation. In the design reported here, a single nominal mass can be picked from the stream of secondary ions after it emerges from the 3rd electrostatic analyzer (ESA) and deflected into a collision cell for collision induced dissociation (CID). The entire TOF-SIMS spectrum, minus the precursor, is acquired in the standard way in the primary mass spectrometer (MS1). The selected precursor ion and fragment ions that emerge from the collision cell are further accelerated into a linear TOF mass spectrometer (MS2). Full mass spectra at both MS1 and MS2 are simultaneously acquired for each pixel in the image. Advantages of this new approach of TOF-SIMS with MS/MS for unambiguous molecular identification with imaging experiments will be demonstrated.

1. P.E. Larson, J.S. Hammond, R.M.A. Heeren and G.L. Fisher, Method and Apparatus to Provide Parallel Acquisition of MS/MS Data, *U.S. Patent 20150090874*, April 2015.

Development of hybrid molecular beam epitaxy for tin based compounds

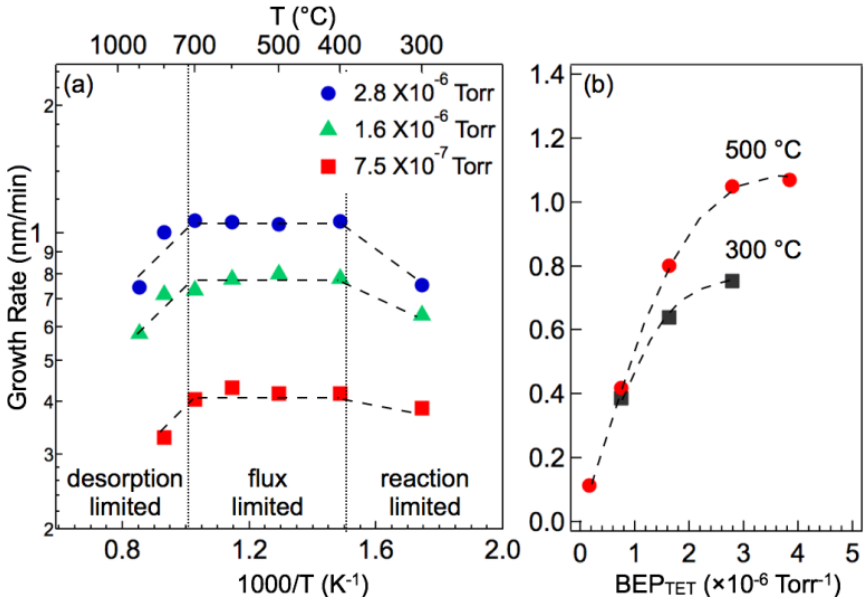
Tiangi Wang[1], Abhinav Prakash[1], John Dewey[1], Christian M. Schleputz[2], and Bharat Jalan[1]

[1]*Department of Chemical Engineering and Materials Science, UMN, Minneapolis, USA*
[2]*Advanced Photon Source (APS), Argonne National Laboratory, Chicago, USA*

We report on the development of hybrid molecular beam epitaxy approach for the growth of tin based compounds. First, we will present a detailed growth study of SnO_2 films on r-plane sapphire as a function of tin precursor flux, oxygen pressure and substrate temperature. High-resolution x-ray diffraction (HRXRD) and atomic force microscopy (AFM) revealed phase-pure, epitaxial (101) SnO_2 films and atomically smooth surfaces respectively. Three growth regimes were identified as a function of substrate temperature where films grew in reaction-, flux- and desorption-limited regimes with increasing temperature. Further growth exploration at constant substrate temperature revealed that the growth rate first increases and then becomes constant with increasing tin precursor flux. Building upon these results, we will present our preliminary study of the growth of $BaSnO_3$ films on $SrTiO_3$ using co-deposition of chemical precursor for tin, solid elemental source for barium and rf plasma source for oxygen. HRXRD using synchrotron sources of 5 nm $BaSnO_3$ on $SrTiO_3$ suggests mostly coherent films with out-of-plane lattice parameters of 4.20-4.25Å for different cation flux ratio, which are remarkably similar to the calculated value of the out-of-plane lattice parameter (4.26Å) using elastic tensors and assuming $BaSnO_3$ grows coherent on $SrTiO_3$. The effect of various growth parameters on the stoichiometry of $BaSnO_3$ films will be discussed.

Supporting figure(s)

Figure 1: (a) Growth rate of SnO_2 films as a function of substrate temperature with TET beam equivalent pressure of 7.5×10^{-7} Torr, 1.6×10^{-6} Torr, and 2.8×10^{-6} Torr. (b) Growth rate as a function of TET beam equivalent pressure (BEP) for films grown at 300 °C and 500 °C. All films were grown using oxygen BEP of 5×10^{-6} Torr. Dashed lines are shown as a guide to the eye.



Electronic Transport in BaSnO3-δ Deposited via High Pressure Oxygen Sputtering

Koustav Ganguly, Abhinav Prakash, Jong Seok Jeong, K. Andre Mkhoyan, C. Leighton, and Bharat Jalan
Chemical Engineering and Materials Science, University of Minnesota

$BaSnO_3$, owing to its high electron mobility (320 $cm^2V^{-1}s^{-1}$) at 300 K, is an attractive material for high mobility oxide two dimensional electron systems [1]. Theoretically, it has been argued that the dominance of Sn 5*s* states in the conduction band minimum is key for the high room temperature electron mobility. However, from the experimental point of view certain questions like choice of dopants, substrate for thin film growth, and scattering mechanisms still remain to be answered.
In this work, we establish vacuum annealing as a facile route to create oxygen vacancies in $BaSnO_3$ films grown *via* high pressure oxygen sputtering technique [2]. High-resolution x-ray diffraction confirms phase-pure, epitaxial $BaSnO_3$ with (001) orientation on $SrTiO_3$(001), MgO(001), and $LaAlO_3$(001). The out-of-plane lattice parameter of films is obtained from wide angle x-ray diffraction (WAXRD), and used as a sensitive probe for stoichiometry and strain relaxation. Thermal annealing under vacuum better than 10^{-7} Torr is seen to dope the material *n*-type, with carrier concentration in excess of 10^{19} cm^{-3} and room temperature mobility of 50 $cm^2V^{-1}s^{-1}$. Temperature dependence of resistivity shows metallic behavior with a weak upturn at low temperature. Detailed temperature dependent magnetotransport will also be presented, and mobility limiting factors in $BaSnO_{3-\delta}$ films will be discussed.

This work is supported by NSF through the UMN MRSEC under award nos. DMR-0819885 and DMR-1420013.

[1] H. J. Kim *et al.*, Applied Physics Express **5**, 061102 (2012)

[2] K. Ganguly *et al*., APL Materials **3**, 062509 (2015)

Super-resolution chemical imaging

Isabel Rich and Nathan Lindquist

Bethel University, Department of Chemistry, 3900 Bethel Dr, St Paul, MN 55112

Super-resolution chemical imaging: Optical microscopes are typically thought to have a resolution limit of half the wavelength of the light used. Recent advances (leading to the 2014 Nobel Prize) have brought optical microscopy into the nano-world. In this research, we use the large concentration of electrons in metallic nano-structures to confine optical fields into very small volumes. These confined and extremely intense optical fields are called “plasmons” and exhibit unique characteristics for a wide variety of applications. Here, we use these plasmons for super-resolution chemical imaging. Since the plasmons are confined to very small volumes, they will interact with a single molecule on the surface at a time. Then, since the plasmons are so intense, they will excite a unique "surface enhanced Raman spectrum" (SERS) to be emitted from these single molecules. This “fingerprint” spectrum is collected by our microscope and localized to within ~10 nm, producing a super-resolved chemical map of the surface, one molecule at a time. (Isabel Rich)

Direct Spectral Imaging of Plasmonic Nanoholes on Analyte-Sensitive Substrates for Vapor Sensing

Spencer Seiler and Nathan Lindquist

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Direct Spectral Imaging of Plasmonic Nanoholes on Analyte-Sensitive Substrates for Vapor Sensing: Plasmon-enhanced optical transmission through an array of nano-structured holes has led to the development of an entirely new generation of optical biosensors. While nanoholes have been typically used in a liquid environment, plasmonic sensing of gas-phase analytes is also an important area of research and development. In this paper, we employ a template stripping method to produce plasmonic nanohole arrays on analyte-sensitive substrates for real-time vapor sensing. By properly positioning the nanoholes, an illumination source, and a suitable spacer layer, transmitted light will diffract from the nanohole array, spread into a spectrum over the space of a few millimeters, and land on an imager chip as a full spectrum. This spectrum is monitored in real-time and the plasmon-enhanced transmission peaks shift upon exposure to different concentrations of ethanol vapor in nitrogen. This on-chip solution circumvents the bulky components (e.g. microscopes, coupling optics, and spectrometers) needed for traditional plasmonic biosensing setups while maintaining good sensitivity and multiplexing capability.

MBE growth, and the study of structure and electronic properties of NdTiO3/SrTiO3 interfaces

Peng Xu, Christopher Cheng and Bharat Jalan
Department of Chemical Engineering and Materials Science, University of Minnesota

In this presentation, we will present a novel approach for creating high-density two-dimensional electron density at perovskite heterojunction using internal charge transfer for novel electronic devices such as high charge-gain power electronics. 2D carrier density much higher than 0.5 e^-/u.c./interface expected based on resolution of the polar discontinuity at perovskite oxide heterojunctions can be achieved via internal charge transfer using band-engineering approaches. Combining the state-of-the-art molecular beam epitaxy growth study with DFT modeling and experiments using x-ray photoelectron spectroscopy, scanning transmission electron microscopy, electron energy loss spectroscopy, energy dispersive x-ray spectroscopy and electronic transport measurements, we will discuss the origin of these carriers, dimensionality and transport mechanisms. We will discuss how electron and hole doping via band-engineered approaches may provide an exceptional route to revisit the phase diagrams of transition metal oxides in the “clean” doping limit. Finally, we will present how cationic intrinsic defects can be used to modify and tailor electronic properties of these materials.

Sodium Incorporation and MoS2 Reduction during Annealing of Colloidal Copper Zinc Tin Sulfide Nanocrystal Coatings to Improve Grain Growth

Nancy D. Trejo, Boris D. Chernomordik, and Eray S. Aydil

Department of Chemical Engineering and Materials Science, University of Minnesota

Copper zinc tin sulfide (Cu_2ZnSnS_4, CZTS), made from earth-abundant elements, has emerged as a potential sustainable photovoltaic material because its direct band gap (1.5 eV) and high absorption coefficient (>10^4 cm^{-1}) are ideally suited for absorbing the solar spectrum. At present, there is no clear superior method for depositing CZTS films. This study focuses on forming thin polycrystalline films from coatings cast from colloidal dispersions (inks) of CZTS nanocrystals (NCs) and then annealing the coating in a sulfur atmosphere to grow micron size crystals. This approach has the potential to be less expensive than vacuum deposition methods. The CZTS NCs are synthesized by first dissolving copper, zinc, and tin diethyldithiocarbamate precursors in oleic acid and then injecting these precursors into hot (340 °C) oleylamine to initiate rapid nucleation and growth of the CZTS NCs. After synthesis, the NCs are cleaned and dispersed in toluene. NC coatings are formed through drop-casting onto Mo-coated soda lime glass (SLG) substrates. SLG is chosen because Na impurities in the glass have been shown to improve CZTS grain growth. NC films are then sealed with sulfur in an evacuated (10^{-6} Torr) quartz ampoule, and placed in a preheated (600 °C) furnace for up to one hour. Raman spectroscopy, X-ray diffraction (XRD), and energy dispersive X-ray spectroscopy (EDS) are used to confirm the formation of CZTS while scanning electron microscopy (SEM) is used to analyze the microstructure. We completed a solar cell with 1.66% efficiency by depositing, on the CZTS films, CdS, i-ZnO, and indium tin oxide through chemical bath deposition, RF sputtering, and DC sputtering, respectively. DC sputtering was used to deposit the Ni/Al top contacts. One of the significant barriers in improving efficiency is a thick interfacial MoS_2 layer that forms between CZTS and Mo layers during annealing. This is particularly problematic in annealing NC coatings because sulfur can easily diffuse to Mo through the NC film. MoS_2 increases the series resistance through the device and inhibits grain growth by restricting the diffusion of Na into the CZTS film. Annealing temperature, annealing time, and sulfur pressure influence MoS_2 thickness. A longer annealing time leads to larger CZTS grains but also encourages MoS_2 growth. We solve this problem by incorporating Na into the film from the vapor phase during annealing. Specifically, we coat the quartz tubes used for annealing with aqueous NaOH solution. Drying leaves behind trace but controlled amounts of Na on the quartz surface. This Na is then incorporated into the CZTS films and help grains grow even though MoS_2 may block Na diffusion from the SLG.

Computational Modeling of Wafer Cooling to Reduce Stress Induced Delamination

Timothy Bontrager, Sehyun Hwang, Sreejith Karthikeyan, Stephen Campbell

Department of Electrical and Computer Engineering, University of Minnesota

When a material containing Se is deposited on a layer of Mo, a reaction can lead to the formation of horizontal sheets of $MoSe_2$, a 2D transition metal dichalcogenide[1]. It is well understood that the weak out-of-plane interactions between the adjacent sheets of $MoSe_2$ creates poor adhesion between the sheets, allowing for them to be easily exfoliated by the scotch tape method. The ease of exfoliation leads to difficulties when the $MoSe_2$ is formed as a byproduct, as in the fabrication of $CuInSe_2$ solar cells. Small amounts of non-uniform stress can lead to localized delamination[2]. **Error! Reference source not found.** shows a low gallium content $CuIn_xGa_{1-x}Se_2$ sample delaminated from the wafer.

In an effort to curb the delamination problem, we turned to computational heat transfer models to describe the temperature profile of the wafer as it cools. The wafer is cooled by two different mechanisms, acting independently of each other. Initially the wafer is held in high vacuum where it cools radiatively. Due to the non-directional nature of radiative cooling, the temperature gradient across the wafer is minimized and the wafer cools at a uniform rate. However, radiative loss is proportional to T^4, and so cooling to room temperature takes a very long time. Therefore, the wafer is removed from the vacuum at some point and allowed to finish cooling in ambient air. As the wafer heats the surrounding air, natural convection causes a plume of heated air over the center of the wafer, while drawing cooler air from the edges of the wafer towards the center, creating a substantial temperature gradient. The magnitude of this temperature gradient is heavily dependent on the temperature of the wafer when it is placed in the air, which depends on the length of time that the wafer is radiativly cooled.

A MATLAB model for a radiativly cooling wafer was created by generating a mesh of points describing the temperature of the wafer at set intervals in three dimensions. The simulation began with the entire wafer at an initial temperature, and it was then allowed to radiativly cool. The temperature of each point was calculated using Fourier's heat transfer equation, and the heat flux from the surface of the wafer was calculated using well-known equations for radiative heat transfer to a black body.

Numerically modeling natural convection air flows over a horizontal flat-plate is not well understood as the system tends to produce turbulent air flow even at relatively low temperatures[3], substantially complicating the modelling process. For this reason, Solidworks Flow Systems κ-ε turbulance model was used to model the temperature of the wafer as it cooled in air. As expected, the maximum temperature gradient across the wafer was heavily dependent on the time that the wafer was radiativly cooled before removal to the ambient. A wafer that is radiativly cooled for 1 hour experiences a temperature gradient of 19.3 K across the surface of the wafer, as seen in **Error! Reference source not found.**a, and nearly 900kPa of stress, while a wafer that is radiativly cooled for 3 hours experiences a temperature gradient of only 7K, as seen in Figure 2b, with a vastly reduced stress. By increasing the amount of time that we

[1] $MoSe_2$ layer formation at Cu(In,Ga)Se_2/Mo Interfaces in High Efficiency Cu($In_{1-x}Ga_x$)Se_2 Solar Cells. Shiro Nishiwaki *et al* 1998 *Jpn. J. Appl. Phys.* **37** L71

[2] Effects of selenization conditions on densification of Cu(In,Ga)Se thin films prepared by spray deposition of CIGS nanoparticles. SeJin Ahn *et al* 2009 *J. Appl. Phys.* 105

[3] Fluid Flow and Heat Transfer of Natural Convection over Upward-Facing, Horizontal Heated Circular Disks. Kenzo Kitamura and Fumiyoshi Kimura. 2008 *Heat Transfer-Asian Research 37*

allowed the wafer to radiativly cool, we noticed a substantial decrease in the amount of delaminations that our films experienced, and substantially increased the number of viable devices that we could produce (Figure 3).

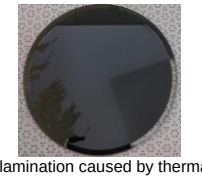

Figure 1. Film delamination caused by thermal non-uniformity

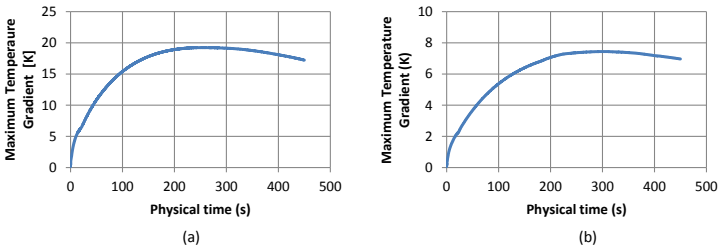

Figure 2. Maximum Temperature Gradient for Wafer Radiativly Cooled for (a) 1 Hour, and (b) 3 Hours.

Figure 3. Wafer after long radiative cool showing substantial reduction in delamination.

Exhibitors

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The Characterization Facility (CharFac) houses over $20M of equipment (replacement value) with a staff of 12.5 including several PhD experts. The annual user/client base includes not only hundreds of internal researchers but also ~100 individuals from dozens of companies and other academic institutions. Occasional workshops/demos are held for community education (suggestions welcome).

Instrumentation includes ten electron microscopes (6 TEM, 4 SEM) with numerous ancillaries (EELS, EDS, EBSD, CL, cryo); eleven X-ray scattering systems (SAXS, WAXS, area detectors, micro, temperature control); nine proximal probes (nano/micro indentors, profilometer, 4 AFMs including environmental); ion beam analysis (RBS, etc.); 3 XPS/Auger spectrometers, microcontact angle; spectroscopic ellipsometer; FTIR (/ATR) & confocal Raman microscopes.

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