Spotlight on Lucas Berla and Sam Rosenthal: Materials for the Future

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One of the most innovative areas of research at Stanford occurs in the Materials Science and Engineering Department, with students studying computing power, alternative energy resources, magnetic properties, and tissue engineering. Special Features is pleased to highlight two students who are doing cutting-edge research. Senior Lucas Berla has been working with Materials Science and Engineering Professor William Nix to model hillock growth in integrated circuits, a complex phenomenon that can lead to circuit failure. Senior Sam Rosenthal, as part of Materials Science and Engineering Professor Michael McGehee’s team, has been researching organic photovoltaics, solar cells made out of organic materials that could enable the production of renewable energy at a price lower than coal. I first spoke with Lucas about his research.

Q: What is your research topic?

Lucas: Integrated circuits, such as those in computer microprocessors, are fabricated at high temperatures. Normally, integrated circuits operate at room temperature, so these circuits must be cooled dramatically following fabrication. This cooling process may give rise to invasive processes that can damage the metal films in the circuits. I studied one of these processes: hillock growth. Hillocks are protrusions that grow out of the surface of a metal. After the circuitry is cooled, hillock growth proceeds as a means of stress relaxation. Hillock growth is problematic, as it often leads to dielectric cracking and thus creates shorts in integrated circuits. This is a really big problem in the microelectronics industry and any company that manufactures integrated circuits, such as IBM, Intel, and AMD, has to worry about hillock growth.

Q: How did you become interested in this topic and what kind of work have you been doing?

Lucas: I started working with Professor Nix the summer after sophomore year in 2006. I was really interested in his research on solid state nanomechanics. I applied for a VPUE grant for summer research in the Department of Materials Science and Engineering. One member of our team, a visiting professor from Korea, obtained experimental hillock growth data that spurred my specific project. Professor Nix and I began working to theoretically model hillock growth. Initially, I spent a lot of time working to understand an earlier paper on hillock growth written by Dr. Praveen Chaudhari. After we finished formulating our model, I compared both Chaudhari’s model and our model to experimental data in order to determine the successes and shortcomings of the two models. Last fall I began writing up our results for a journal, and it was recently accepted into Material Science & Engineering: A. I worked many hours a day for several weeks to write the first draft of the paper. It was a great experience through which I learned to write clearly about complicated topics that I’d studied for months.

Q: What applications are there for this research in the future?

Lucas: Through our research, we have provided a mechanistic understanding of the hillock growth process. We hope that industry workers and researchers will utilize our model and our findings to work toward the suppression of hillock growth.

Q: How would you characterize your overall research experience and its affect on your future goals?

Lucas: This research project was very challenging and also highly educational. The project has reinforced my desire to do graduate work in Material Science, as I have realized that a PhD will be necessary for me to continue to perform fruitful research. Also, through this research I’ve realized that I don’t want to be a pure experimentalist; I’d like to find a balance between theory and experimental work. During my graduate studies, I will continue to study nanomechanics, but I hope to develop into a well-rounded scientist and not a specialist. Working with Professor Nix has been an incredible opportunity. One cannot ask for a better mentor. Although he helped me out a lot, he also wanted me to learn on my own. The most important thing I have learned is to never give up. I don’t know how many times we ran into an apparent roadblock during our research endeavor. You have to put in creative thought to overcome obstacles, and such creativity will yield unexpected yet insightful results.

Q: What is your research topic?

Sam: I work on organic photovoltaics. Due to the unique nature of the organic materials used in these devices, they could potentially be manufactured at far lower costs than conventional solar cells. However, they also pose significant new challenges that must be overcome before they can be commercialized. In order to produce

Figure 1: Scanning electron micrograph of anodic titania nanotubes on a transparent conducting oxide.
electrical power, two different materials are used: for solar cells like the ones I make, these are a semiconducting polymer, which absorbs light, and titania, which harvests electrons from the polymer. A polymer layer at least 300 nm thick is needed to absorb most of the light from the sun, but all of the polymer must be within 10 nm of the titania for charge transfer to occur, design constraints that may seem to be mutually exclusive. I am working to overcome this challenge by creating a titania nanostructure, consisting of an ordered array of tubes 300–500 nm long and 10–20 nm in diameter, which could be filled with a semiconducting polymer to create an efficient solar cell.

Q: How did you become interested in this topic and what kind of work have you been doing?

Sam: Solar energy research is the most promising pathway to a renewable energy solution that I know of, so I was very excited to have an opportunity to contribute to the field. I started working with Professor Mike McGehee the summer after Junior year, and he’s had the idea of using ordered titania nanostructures for organic photovoltaics since he first came to Stanford. It was an attractive project because there were so many interesting physics and engineering problems to investigate. The approach I’m using now is based on literature that was found by Brian Hardin, a graduate student in the group. I’ve been anodizing thin films of titanium to create the titania nanostructures that I need. My work goes through cycles of about a week. I start with a transparent conducting oxide and deposit various materials on top of it, finishing with 500 nm of Ti metal. This then goes into an acidic bath with a strong electric field, which anodizes the metal, creating densely-packed titania nanotubes. I crystallize these tubes by heating them overnight, and then look at the resulting structure using a scanning electron microscope.

Q: How has your project evolved and what challenges have you faced?

Sam: Now that I can make these titania nanostructures, my most significant problem is large particles that form sporadically on the surface of the film. I’ve been able to analyze their composition and determine when they appear, but I don’t know what causes them. Currently, I’m working on various options to prevent them from forming or to remove them once they appear.

Q: What applications are there for this research in the future?

Sam: The hope is that one day organic photovoltaics could be used to provide inexpensive renewable energy. Today, they suffer from low efficiencies and short lifetimes. If these problems can be overcome, organic solar cells may replace coal as the least expensive energy source, completely changing the way that the world gets its power.

Q: How would you characterize your overall research experience and its effect on your future goals?

Sam: I think it’s been a great research experience. I’ve gotten to work independently, designing experiments and thinking about how to approach this problem. It’s been a really good first step towards a research career, and I plan on going back to school for a doctorate after a year or two off. Next year I’ll be working for a solar cell startup founded by my advisor’s first graduate student. Until then, I’ll keep working on this project so that I can publish the results or hand it off to a graduate student in the group. The field of organic photovoltaics is relatively new and there are many questions that haven’t been answered yet. I’ve been able to work on one of them.

SAM ROSENTHAL is a senior in Materials Science and Engineering, with a focus on the electrical and optical properties of materials. Over the past two years, he has conducted research to develop several solar cell technologies, working with Professors Alberto Salleo and Michael McGehee. After a year working with a local photovoltaics startup, Sam plans to enter a doctoral program in Materials Science.

LUCAS BERLA is a senior from Walnut Creek, California. As an undergraduate student at Stanford, he has performed research in the Department of Materials Science and Engineering under the supervision of Professor Nix. While working with Professor Nix, Lucas has developed an interest in studying the mechanical properties of nanoscaled materials. In one project, they formulated a theoretical model to explain the growth of hillocks from thin metal films. Lucas recently received an NSF Graduate Research Fellowship, which he will use to fund his Ph.D. studies in Materials Science and Engineering at Stanford.