Poster Session 3

Commons East, Easel 61

2:30 PM to 4:00 PM

Scalable Synthesis Method for Monodisperse Silica Nanoparticles

Brandon Chen, Senior, Mat Sci & Engr: Nanosci & Moleculr Engr
Mentor: Devin MacKenzie, MSE and ME
Mentor: Holly Brunner, Materials Science and Engineering

Composite materials utilizing nanoparticles can exhibit improved properties and qualities. Silica (SiO_2) nanoparticles exhibit unique optical, electrical, and mechanical properties and are an ideal candidate for the dispersed phase in many applications, such as precursors for optical films with controlled optical properties and rheology. Atomic forces dominate when particles shrink to sizes below the visible wavelength spectrum, generating unique phenomena. One problematic phenomena, however, is the agglomeration of primary particles into a polydisperse collection of dimer, trimer, or larger secondary particles when calcined or mixed into the continuous phase of the composite. Monodisperse colloids and nanopowders are critical for consistent and optimized performance of composites and nano features. Silica particle synthesis has been well researched, but the practicality of producing pure, monodisperse, and non-agglomerated particles at scalable operations is still in question. This research investigates the factors leading to the agglomeration of spherical silica nanoparticles when synthesized with variations of the Stöber method, and evaluates changes in synthesis parameters that can reduce agglomeration in order to determine the most viable process for scalable production. Parameters that are manipulated include the ratio of ammonia catalyst with tetraethyl orthosilicate (TEOS) in ethanol or methanol solvents and the addition of anionic electrolytes. SEM imaging is then used to evaluate the distribution of the particles. Surface treatments for anti-agglomeration as incorporated into the synthesis process or as post processing are also evaluated, with minimal remnant impurities in the product as a priority. The end goal of this research is to successfully synthesize monodisperse sub-10 nanometer silica particles for pseudoplastic shear-thinning precursors used in fast throughput nanoimprinting of an antireflective layer for solar cells.

Poster Session 3

Commons East, Easel 59

2:30 PM to 4:00 PM

Xenon Flash Lamp Annealing of $CH_3NH_3PbI_3$ Films

Brandon Kern, Senior, Materials Science & Engineering
Mary Gates Scholar
Mentor: Devin MacKenzie, MSE and ME

As the world looks for sources of clean energy, the recent advances in lead halide solar cells have shown great promise, increasing from 3% efficiency to 20% in the last few years. Many lead halide or perovskite devices provide the opportunity for low carbon solar cell manufacturing, yet they are still scaled to laboratory settings. By using additive solution based treatments, large-area high-efficiency solar films can be scalably processed through the rapid deposition of perovskite solvents onto roll to roll printers similar to the printing presses used in the newspaper industry. In order to allow for the scaling of the perovskite solar cells, areas of improvement are needed on the small scale with perovskite films on glass substrates, including the need for rapid thermal processing to reduce processing time from 30+ minutes to a matter of seconds. In our work, various methods of rapid thermal treatment on perovskite films were performed by using a xenon flash lamp under different experimental intensities and time series. The flash lamp uses high pulses of energy that interact with the film to rapidly heat it while avoiding degradation due to quick thermal dissipation. These samples will be characterized using X-ray Diffraction, UV-Vis Spectrometry, and Scanning Electron Microscope in order to examine the degradation and grain growth effects. Then, the results will be compared to samples thermally treated from 10 minutes to an hour. Future work of this heat treatment process will be used to optimize the rapid thermal processing needed to roll coat scalable perovskite solar cells films onto a flexible plastic substrate, polyethylene terephthalate (PET). The xenon flash lamp will be attached to the roll to roll printer which will print large area flexible perovskite solar cells to reduce wasted processing energy, and meet increasing energy production needs.

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Commons East, Easel 58

2:30 PM to 4:00 PM

Study of Diffusion Lengths in MAPI Perovskites through Photoluminescence Spectroscopy

Doc Daugherty, Senior, Mat Sci & Engr: Nanosci & Moleculr Engr
Mentor: Devin MacKenzie, MSE and ME

Single-junction solar cells that employ metal-halide perovskites have generated intense interest due to their rapid increase in demonstrated power conversion efficiency. In contrast with previously explored solar cell active materials, perovskites are solution-processable, tunable band-gap materials with small energetic losses. Because of this they are ideal candidates for use in tandem solar cells, which integrate a large-bandgap and a small-bandgap solar cell into one structure, significantly increasing maximum efficiency. Current tandem solar cells can have marked efficiency loss due to excess window layers and poor layer design leading to absorptive losses. Additionally, the comparatively poor understanding of perovskite processing methodology can result in suboptimal perovskite active layers. Our goal was to explore the feasibility of using a metal grid-type electrode collection layer in place of a standard transparent window layer, in order to minimize absorptive losses for successful integration into a tandem structure. Principally important to characterizing this structure was exploration of device fabrication and perovskite processing methods that resulted in effective carrier extraction. The mean diffusion length of charge carriers in a material is one of the primary factors that affect carrier extraction. Current literature gives a diffusion length ranging from 0.3 – 10 um for methylammonium lead iodide (MAPI) perovskite layers. We fabricated test cells with electrode grid pitches ranging from 0.4 – 10 um using photolithography techniques. We then explored the effect of variable deposition method, heat treatment and solution composition as well as observed layer morphology on diffusion length and charge extraction using photoluminescence spectroscopy.

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Commons East, Easel 60

2:30 PM to 4:00 PM

Impact of Zinc Oxide on Quantum Efficiency of Perovskite Solar Cells

Neema Rostami, Senior, Mat Sci & Engr: Nanosci & Moleculr Engr
Gavin Wayne (Gavin) Ames, Senior, Mat Sci & Engr: Nanosci & Moleculr Engr
Mentor: Devin MacKenzie, MSE and ME

In the last 10 years, perovskite solar cell efficiencies have increased from four to over twenty percent. Perovskite materials possess great application in thin-film photovoltaics and roll to roll processing. Unlike in traditional silicon solar cells with layer thicknesses on the order of 100 microns, the perovskite layer in a thin-film photovoltaic can be fewer than 100 nanometers. This study looks at the suitability of zinc oxide nanoparticles for use as an electron transport layer in a lead halide perovskite thin-film. Of particular interest is the ability to adjoin the zinc oxide and perovskite layers without any degradation of the perovskite. The effects of solvents, additives (i.e. surfactants), and particle size are analyzed using a variety of methods such as x-ray diffraction, transmission electron microscopy, and photoluminescence spectroscopy to determine optimal interfacial properties and exciton separation in the electron transportation layer. The success of the ZnO layer is further analyzed by comparing the quantum efficiencies and current-voltage characteristic curves of the assembled solar device to an identical solar cell that uses PCBM as the electron transport layer. PCBM is one of the most effective electron transport layers, but due to high cost, the need for alternatives such as ZnO was made necessary. The overall goal of this project is to attain efficient solar cells, using cost-effective materials and processing methods. By doing so, it will open up the field of solar energy for a wider market and broader applications.

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Interactive Electric Vehicle Queueing Simulation

Hyun (Haley) Cho, Senior, Physics: Applied Physics
Mentor: Don MacKenzie, Civil & Environmental Engineering

As the usage of electric vehicles (EV) expands around the world, there are numerous challenges to overcome. One of the biggest challenges encountered is the efficiency of EV charging systems. This research explores the trade-offs between maintaining availability of DC fast chargers and other variables including waiting times, station utilization, and cost per vehicle served. To determine the utilization rate of chargers, we created a queueing model by using characteristics of EV models and chargers such as charging rates, battery size, and range. A queueing system is a generic model that is comprised of three elements: a user source, a queue, and a user facility. For this research, the three elements of the queueing model are linked to a cost model to evaluate the attractiveness of private sector investments in charging infrastructure. Since there are many uncertainties and results are sensitive to assumptions, we developed an interactive R Shiny app that allows users to specify assumptions and visualize the relation between the number of vehicles served and key performance metrics. This visualization can help decision makers determine the optimal number of chargers required to balance the tradeoffs between availability of chargers and utilization rate in order to provide satisfying services for users and beneficial business for operators. Ultimately, our model shows that it is difficult to maintain high reliability of utilization and low cost per vehicle served, and that improving this trade-off demands significant growth in the total number of EVs on the road.