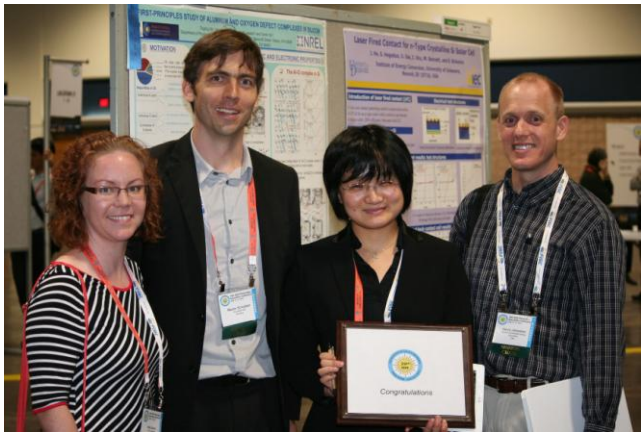
Thursday, June 20th, the fifth day of the PVSC, began with the last three plenary lectures from Area's 6, 7, and 11 that focus on organic PV, space PV, and the PV velocity forum.

In the Area 6 plenary, Karl Leo (photo to left) gave a nice overview of all organic photovoltaic (OPV) technologies, with focus on high efficiency multijunction small molecule cells. He talked about the relationship between molecular structure and electronic properties, and that Oligothiphene's are actually donor materials. He indicated that future improvement in OPV performance may be realized by materials that have a positive temperature coefficient, offer higher performance at lower intensity, and improve diffuse light harvesting.

Pradeep Haldar (photo below right) gave the PV Velocity Forum Area 11 plenary. He spoke of the evolution of the PV industry, and current short term issues, but is optimistic regarding the continued future overall growth of the U.S. commercial and residential sectors. The photovoltaics manufacturing consortium (PVMC) supports supply chain global manufacturing and local distribution channels for the purpose of enabling, accelerating, and growing a sustainable PV industry. Their partnership model allows for both open and proprietary work. They have a particular focus on BIPV and BAPV applications and to achieve lower BOS costs. Pradeep in particular emphasized collaborations, such as those accessible through the PVMC, are necessary to make PV technology successful.

Later in the morning, the last poster session of the conference was in full swing. Special congratulations to Tomasz Drobiazg, the best poster award winner in Area 2 for his poster entitled "Impact of Cu poor to Cu rich transition speed and Mo back contact porosity on the electrical and structural properties of CIGS-based solar cells". Tingting Shi received the Area 4 Best Student Poster award (photo below to the right) for her work on "First Principles Study of Aluminum-Oxygen

Complexes in Silicon" which she completed using density functional theory methods. Many special accolades to the entire group of 2013 best poster award winners!

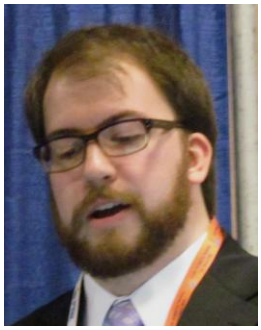


In the early afternoon session Stefan Fischer, of Area 1 and one of the best student presentation award finalists, shared his work demonstrating a world record for up conversion on Si solar cell devices, which was achieved through efficiency utilization of sub-band-gap photons. Itaru Kamiya talked about a fascinating demonstration of up conversion in InAs quantum well islands.

In Area 2, R. W. Collins described the use of spectroscopic ellipsometry for characterizing CIGS. The method is quite versatile in that it can be applied in-line after each deposition step to for example obtain the band-gap profile, and on-line during absorber formation to for example identify a Cu-rich to Cu-poor transition. Variable angle spectroscopic ellipsometry is in particular useful to obtain the band-gap profile. Christian Kaufmann talked about the use of in-situ x-ray analysis during CIGS co-evaporation. Nathaniel Carter described CZTS solar cells fabricated with nano crystal inks. Thomas Weiss shared his work studying the influence of series resistance on CZTS solar cell performance. He observed two capacitance steps and deduced the presence of a defect band at about 350 mV. Myriam Paire described her use of concentrated illumination to characterize CIGS solar cells fabricated by co-evaporation and electrodeposition.

Stefan Braun gave an invited talk in Area 4 on high efficiency multi-busbar solar cells and modules. He showed how the application of multi-busbar technology reduced Ag consumption and reduced cell-to-module losses, ultimately resulting in an optimized solar cell contact design. He presented very encouraging simulation results that were verified at the cell and module levels. Using a standard cell process on p-type Si solar cells with full area back surface field he demonstrated 19.5% efficiency with the multi-busbar design. Jodi Veirman talked about strategies to reduce the cost of HIT solar cells. He presented results replacing Ag by Cu and in addition showed results using monolike material and efficiencies of 21.3%. Yuguo Tao presented his work on fully ion implanted industrial type PERT solar cells with efficiencies up to 20.6%. This was achieved by optimizing the rear phosphorus doping and employing a planar rear surface. Thorsten Dullweber discussed several wafer options for fabrication of PERC solar cells like MCz, or monolike. He showed that minority carrier lifetime can be increased by the regeneration process and that cell efficiency after regeneration is in the range of 19.9-20.2%. In addition, he showed that the efficiency decrease caused by light induced degradation is reduced to below 0.2%. Rubin Sidhu demonstrated an approach for an industrial process flow to manufacture IBC solar cells with screen-printed rear contacts. A chemical etch back of the front surface field enabled conversion efficiencies up to 19.7%.

In Area 6 Brian Lassiter, a best student presentation award finalist, talked about the optimization of small molecule tandem solar cells achieved with the interdiffusion of C60 and small molecule absorber materials. In an exceptional result, tandem efficiencies exceeding 8% were achieved from squarine-based absorbers. Biswajit Ray provoked the audient to think about the question – “Is it possible to make an efficient organic solar cell from a single material?”. His calculations show that heterojunction-free solar cells could deliver 10% efficiency and that excitonic dissociation may not be bottleneck in the process.



Invited speaker Steve Polly (photo to right) showed some very enlightening data regarding the potential negative effects of delta doping diffusion in quantum dot (QD) solar cells. In addition, he showed that temperature dependent band edge shifting may introduce a source of error in certain two photon experiments. Jamie Phillips presented some interesting GaSb QD results. He reported that the GaSb QD’s have an extremely complex morphology requiring further study. Stanko Tomic gave an entertaining talk on a theoretical study of the impact of shifting to a type two band alignment by increasing the Sb content of the barrier. Giacomo Mariani showed some impressive images of GaAs nanopillars including a focus on fabrication and as well as an impressive 9.1% power conversion efficiency for InGaP-passivated GaAsP nanowire p-n diode device. David Forbes showed some interesting results for capping of InAs dots using an In flush approach.

In Area 6, Eszter Voroshazi gave an excellent presentation on the stability of OPV devices and showed that an inverted device architecture increased the device lifetime. John Mudrick talked about the use of interfacial modifiers as a means to structure the growth of active layer materials.

Marina Leite of Area 8 talked about a new approach for mapping thin-film conductivity by scanning a tip with a NSM light source. The presentation showed very interesting results: most grain boundaries in polycrystalline thin films exhibited higher current than the grain interiors. The authors studied both the back CdTe surface and cross-sectional surfaces and similar results were obtained. Helio Moutinho gave a very nice presentation on grain boundary recombination properties in CdTe thin films using cathode luminescence (CL) imaging and electron back-scatter diffraction (EBSD). For CdTe films grown in a superstrate configuration, the CL and EBSD images showed good correlation. However, for CdTe films grown in a substrate configuration, the CL and EBSD images showed poor correlation, which he postulated was due to significant Cu diffusion from the Cu_xTe layer used in the substrate configuration. D. Kuciauska gave an impressive talk about the measurement and analysis of minority carrier lifetime in solar cells. A two photon excitation approach was demonstrated and significantly improved the PL measurement.

John Wohlgemuth of Area 10 talked about the fact that EVA is still in use today, despite a known discoloration issue caused by the use of a Naugard P antioxidant additive. He recommended that module manufacturers and EVA manufacturers test for this failure and where possible use non-discoloring EVAs. Sarah Kurtz described her findings related to forecasting real world performance from accelerated test data. She found that the data filtering approach has a huge impact on the calculated degradation rate and that proper attention should be given to variables such as seasonal effects. Yuzuru Ueda presented his team's results that demonstrate an effective array peak power shows only slight degradation over time for crystalline silicon. He found that multi-silicon is much more variable among makes/models than crystalline silicon. The median degradation rate was -0.71%/yr, which is lower than previous reports. Jaspreet Singh shared his work characterizing the performance of 1900 PV modules after 12 to 18 years exposure to a hot-climate. For these modules the measured degradation rates ranged from 0.6 to 2.5%/yr depending on the make and model. Assuming a linear degradation and 20 year power performance warranty at 80%, almost 80% of the modules in this study would fail to meet the criteria. In one case, the warranty replacement modules degraded faster than originals. A PID failure mechanism was considered, although the data suggests PID cannot explain the observed degradation. Liza Boyle shared a good correlation with previous studies. Yaohua Mai presented on the importance of using a proper installation process to avoid early life failure due to breakage.

In the evening, the PVSC community enjoyed dinner, a live band, live animals and rides at the world famous Busch Gardens. Bill Shafarman and Jennifer Granata reported having gotten soaked on the river raft ride while many people tried the roller-coasters. There was plenty of food and the band played right up to 10 pm. Many of the attendees got up and danced and everyone had a good time.

That wraps up the fifth day of the 39th IEEE PVSC conference.