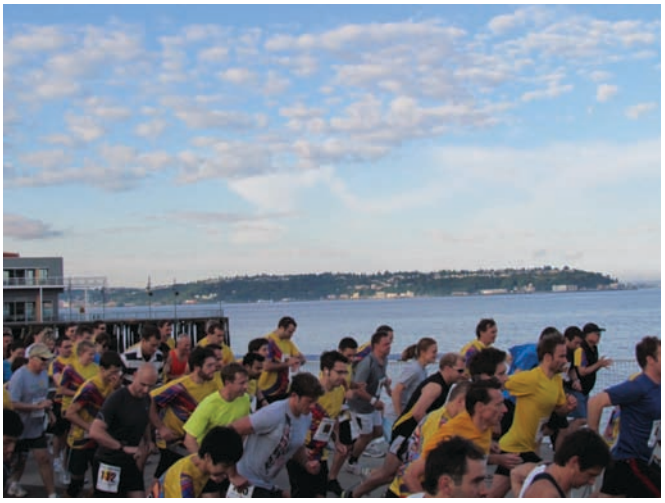
It was a beautiful cool morning in Seattle and a perfect morning for a run. Before the rest of the conference was awake, runners joined Larry Kazmerski for his traditional Sun Run. Reports were that it was perfect running weather. The main work of the conference began later with the usual conference breakfast for presenters and the final three plenary talks in areas 6, 7, and 8.



The Sun Run starts along the harbor.

In his plenary talk Yang Yang mentioned two verified organic photovoltaics results above 8% and a 9.3% efficient result, not yet verified. The results continue the remarkable recent successes in champion device performances in OPV. The rate of increase in efficiency is spectacular. In addition, roll to roll processing has been demonstrated for high throughput. Because the absorption bands are relatively narrow in organics, solution processed tandems are being explored. Still need to impedance match layers -- the interconnecting layer is key. He showed data for current-voltage curves of two separate OPV devices and the tunnel-junction series-connected current voltage behavior of the tandem device. This and other similar recent works show that conventional multijunction methods can applied to OPV to improve performance. The narrow absorption band that typically causes problems in OPV devices does not need to limit the overall performance of OPV. The Yang group's focus is on inverted tandem architecture using P3HT and PSBTBT absorbers. These are all spin coated except for the top electrode. The tandem yields 7%, better than either single device used if measured separately. It works even better in low light. The inverted cell is more stable, using cesium carbonate and vanadium oxide electrodes rather than calcium. The current approach has replaced these with ZnO and MoO_3. Encapsulated cells show 96% of their initial performance after 2100 hours and 85% after 5000 hours in outdoor testing.

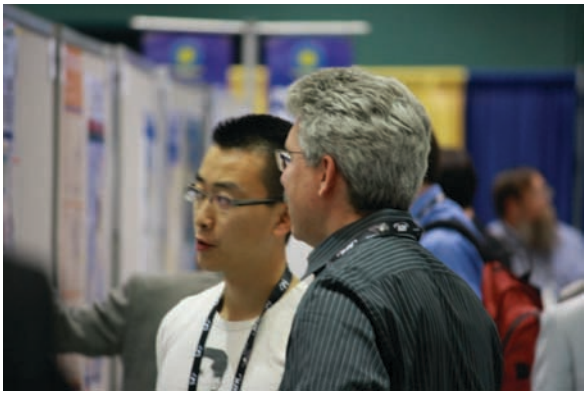
Yang Yang presenting his invited talk.

Pravin Patel of Emcore Corporation presented data showing that the inverted metamorphic based devices are taking the performance lead for both space and terrestrial technologies / applications. They have achieved a material quality enabling V_{oc}'s similar to lattice matched approaches. Four-junction and six-junction inverted metamorphic cells showed efficiencies of 34.2% (135.3mW/cm^2 AM0 spectrum) at 28°C and a >82%

remaining power percentage at end of life following radiation testing. A triple junction cell result of 43.5% under 300x concentration was described. Dr. Patel indicated that substrate removal is key to success in the IMM structures. A relationship was shown between surface roughness and performance in the devices too. Beautiful quantum efficiency data were shown for a four junction device with very high values for most of the junctions. Only the highest energy gap device showed lower peak quantum efficiency. In these cells, the Ge bottom cell is replaced with a wider band gap InGaAs metamorphic subcell to boost voltage without loss of current. They expect over 37% efficiency in six junction devices with high yields. The four junction devices have been made fully flexible. A result showed the devices wrapped around a cylinder of about 2 cm in diameter and operating as LED's in forward bias. The four junction device is designed to provide additional radiation hardness, although results to date have not shown improved radiation resistance over the three-junction devices.

Pravin Patel of Emcore.

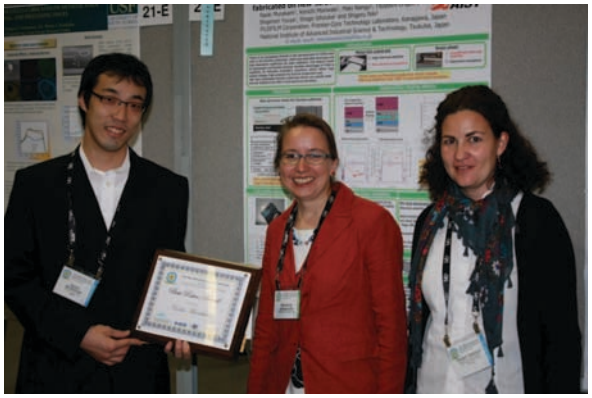
Yanfa Yan described characterization using electron microscopy and modeling of extended defects in semiconductors used in solar cells. They showed that the general trend of defect formation mainly depends on the covalent/ionic character of the compound (Si, GaAs, CdTe, CIGS, CZTS). Covalent materials produce deep levels, while ionic materials produce shallow levels (a useful design rule for PV absorbers). Similar tendencies apply to grain boundaries. As a result, in contrast to thin film Si and III-V's, II-VI-based polycrystalline materials have relatively good PV performance. Yan explained why cation-rich growth is favorable for lower recombination. However, anion-rich growth is desirable for better devices in which electrons are the minority carriers. He suggested that one should grow the material anion-rich, and then passivate the anion-rich defects. Reduction of defect DOS was shown with a Cu-Cl co-passivation.



Conversation at the poster session.

After a break the conference resumed with a morning poster session. A wide variety of excellent posters were presented and awards were given to the top posters in select areas. In Area 2 the winner was Naoki Murakami and collaborators for their poster “monolithically integrated CIGS submodules fabricated on new-structured flexible substrates.” The

winner in Area 9 was Jamie Keller for his poster "fault current contribution from PV grid-tied single-phase inverters." Shubham Dutta Gupta won in Area 4 for "high quality surface passivation for low resistivity p-type c-Si by hydrogenated amorphous silicon nitride deposited by industrial scale microwave PECVD." Finally Tim Hülsheger and collaborators won for their poster "angle and temperature behavior of InGaP/GaAs/Ge triple junction solar cells for high temperature solar generators."



Area 2 poster winner Naoki Murakami receives his award from the Area 2 judges.

Over the lunch break there was the awards ceremony for the morning's run. A large crowd gathered near the registration booths to hear their results and to be congratulated in a style only Kaz can provide. During the lunch break the Cherry Committee also met to discuss the upcoming year's conference planning and the operation of the organization in general.

Presentation of the SunRun awards.

Following lunch the sessions resumed with orals in a variety of areas. In Area 1, Alex Zunger described an inverse design method, whereby specific properties of materials dictate the material chosen. Typically, device designers are limited by a relatively small database of available, workable materials. Through inverse design, Zunger is hoping to develop the framework for experimentalists to tune a desired property through control of atomic structure and doping, among other methods. To illustrate, Zunger has reported on 106 new compounds, out of 406 that have not been discussed in the literature. His perspective is that this inverse design principle will lead to a shift of paradigm for device designers.

Dave Wilt described his group's work on a flexible coverglass alternative for devices, known as pseudomorphic glass (PMG). PMG is composed of 20-40μm-diameter glass spheres of both borosilicate glass and fused silica, mixed with common adhesives and cast into thin sheets. After bonding this material on a triple-junction cell, a negligible

change in J_{sc} was seen with fused silica beads. Results from UV and radiation testing were presented indicating the viability of this material as an alternative coverglass.

Zachary Bittner from RIT talked about his work on GaP solar cells for high temperature applications. Due to the wide band gap of GaP, InGaP quantum wells were added which led to an 8% increase in J_{sc} beyond the cutoff of GaP. The temperature performance of several devices was shown with GaP outperforming standard GaAs cells at expected temperatures for satellites operating near the sun.

In addition to these talks, Honsberg described hybrid design concepts such as combining intermediate band with multiple exciton generation, which could lead to improved efficiency over non hybrid designs. Antolin discussed PbTe quantum dots in CdTe which were identified as possible intermediate band device materials. LeBris showed data presenting the signature of hot carrier effects and indicated the importance of light concentration for potential hot carrier applications. Finally, Slocum presented a very interesting discussion of nipi doped superlattice effects

In Area 4, among other interesting talks, Peter Engelhardt of Q-Cells reported on a 19.5 %-efficient multicrystalline Si solar cell. He emphasized that some mc-Si has an advantage over Cz-Si in high-efficiency PERC structures due to the lower oxygen content.

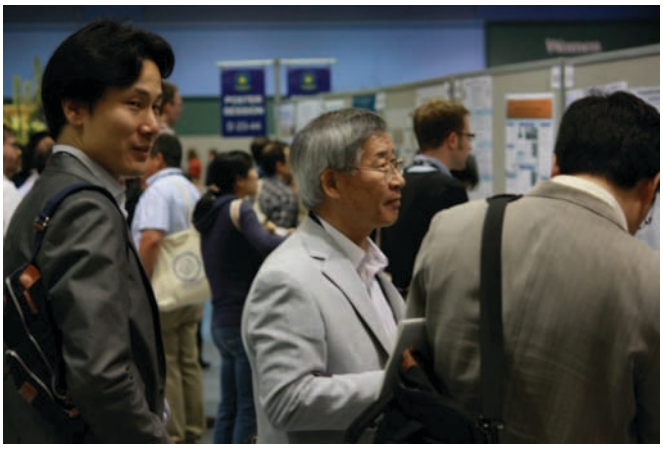
Meeting of the Cherry Committee discusses the organization of future PVSCs.

In what has become normal for the PVSC, the space technology session (Area 7) has demonstrated the highest performing solar cells. For example, Spectrolab showed data for four and five junction devices exhibiting 33.5% efficiency under AM0 illumination and a second showing epitaxial lateral overgrowth-based cells at 29% efficiency. In Area 8, the most impressive were talks numbers 570 and 571 dealing with atom probe tomography investigations of grain boundaries in CIGS.

In Area 9, Klaus Kiefer from the Fraunhofer Institute presented a talk entitled "Quality Assurance of Large scale Commercial PV Power Plants." The talk compared variability and lower performance ratio data in Systems from the 1990's (70%) contrasted to current ratios of 80-90%. The major reasons for the improvement were shown to be better module rating and labeling, better inverter performance, and over all quality of major systems components. He went on to describe validation testing and monitoring of PV arrays at Fraunhofer to ensure that systems will produce power as rated and meet the business plan used to generate funding for the system. Differences in the performance ratios were analyzed between system design companies. Long term field analysis showed

crystalline silicon modules retaining >90% of the original power as guaranteed by the manufacturer. 100 systems were analyzed and all performed similarly. The conclusion was that PV systems are highly reliable and predictable. The tariff is now close to parity for residential and commercial customers with ~100% uptime.

Alex Panchula from First Solar presented "First Year Performance of a 20 MWac PV Power Plant." One year of data gives a good platform to confirm assumptions and to refresh the model to include any findings. Key drivers cited in long term prediction included - weather data accuracy, snow loss, and system availability. Sources of error when forming predictions were categorized as: module temperature uniformity assumptions, inverter input from the module performance files including non-STC values, and measurement error from array monitoring tools. There was an interesting discussion of the use of the Hay vs Perez sky model.



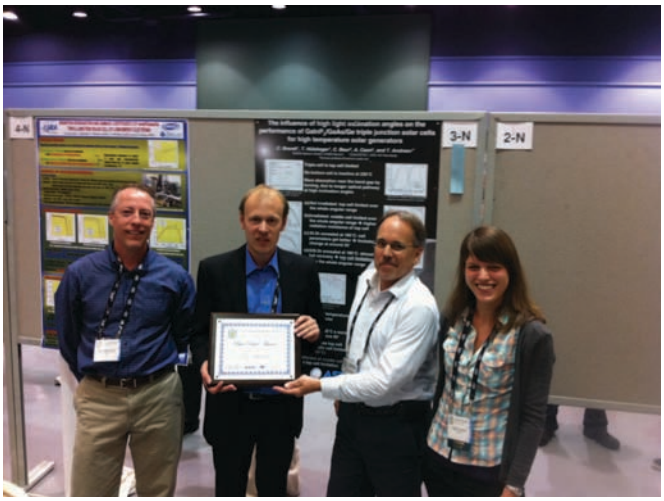
Discussion at the poster session.

Steve Best from Auburn University presented a "Comparison of Solar Modeling Data to Actual PV Installations: Power Predictions and Optimal Tilt Angles". The presentation summarized the performance of three research arrays in Alabama at the Lee County Justice Center, one tracking and two fixed tilt. Performance prediction algorithms were compared through working with a test array consisting of five modules tilted at varying angles from 20 to 50 degrees. PVSYST, PVWatts, and Design Pro G showed predictions that were lower than the actual performance for the arrays.

Ye Zhao from Northeastern University presented "Fault Analysis in Solar PV Arrays Under Low Irradiance Conditions and Reverse Connections." The analysis considered two types of faults in array performance which create problems. These include low irradience fault conditions, which may not be picked up from the over current protection devices. For example these could clear the fault and reverse connections in the array, which can also cause large problems, usually in array commissioning.

In the PV velocity forum there was a lot going on. The discussion ranged widely with arguments presented on the value of PV energy in a range of applications. In the morning there was discussion of the value of PV (15-41 c/kWhr) that often times exceeds costs 15-30 c/kWhr). This is because there are expensive aspects of conventional power that can be specifically addressed by PV. For example, generation and capacity, distribution, fuel mitigation, grid security, environmental & health, long-term societal, economic growth, and other benefits can make PV power attractive. Rates, incentives, system price, solar resource, and financing are the factors incorporated into software tools to estimate financial benefits of PV systems.

M Hill presented their interactive analysis of the 25 Solar Cities and how PV energy costs compare to conventional grid energy. There was also discussion of pluggable electric vehicles. For example, these vehicles can currently achieve seven to eight km (four to five miles) per kWh on an electric vehicle. Thus, a 2 kW PV array would typically supply enough energy to cover average short-range driving needs. Adding the cost of batteries it was estimated that an electric car could provide local transportation for the equivalent fuel cost of $0.90 per liter ($3.40 per gallon), with an expected reduction by 33% over the next decade. Therefore the value proposition for PV exceeds that of delivered electricity from fossil fuels. It was noted that the Japanese government is planning a new feed in tariff to start in April 2012 that will support development of the PV market. Current goals are to reduce PV electricity levelized cost of electricity by 67% by 2020 and 83% by 2030 to help get to 20% renewable generation by 2020.



Winners of the poster award, Tim Hülsheger receives the award from the judges.

The afternoon session in Area 10 was a panel discussion focusing on supply chain support of high-growth PV. The comments soon focused on supply and consumption of the most critical resource, capital. Organizer and Session Chair, Kirk Thompson, framed the discussion by using the specific description of the "Valley of Death" as an image of cumulative free cash flow. The depth of the valley is the cash consumed in establishing the validity of the technology and capital expenditure ("capex") required to purchase the first tool set. CEOs Stanbery of HelioVolt and Pearce of NuvoSun explained the challenge of developing innovative tools designed for high throughput and low capex, without losing the advantages due to the engineering and production cost of the custom unit, when priced by external vendors. Putting these factors into a formula where, in the U.S., capital is expensive and low-cost electricity leaves low margins for PV systems the valley can be deep and wide. Tom Baruch of CMEA Ventures added a note of reality from the investor perspective, stating that returns are measured by compound interest rate, a factor that explains the exponential loss of investor support as time required to achieve positive returns increases. This time is driven by the wait for permits and reliability validation. Government support, incentives and loan guarantees help to overcome these barriers. It is critical to maintain these incentives in the short term.

In the PV Velocity Forum discussion of life cycle analysis and the environment the discussion went on. The following are some of the points made. V. Fhentkis of the Brookhaven National Lab discussed the environmental impact of large projects. The U.S. Southwest has a consistent solar resource. To make an impact solar energy must take

advantage of this. There are environmental concerns with respect to PV systems but it was noted that more land is used by the coal lifecycle than is used by PV. 75% of the land used for coal mining is surface land, disruptive for wildlife. The speakers advocated a three pronged strategy: avoidance, restoration or compensatory migration. In San Louis Obispo, First Solar has a planned 550 MW plant and SunPower has a planned 250 MW plant. The companies have engaged in a collaborative approach to supporting the local wildlife. The natural contour of the ground requires only shallow grading to prepare the site. There is little soil impact, which will allow grass and other vegetation to regrow in a few years around the installed modules. SunPower acquired land away from the Kangaroo Rat and enacted other project innovations to minimize the impact on the wildlife and land. Some of the environmental benefits cited for the use of solar energy in this region include the following: 70 billion pounds of carbon dioxide will be displaced, 235 million pounds of nitrogen oxide and 517 million pounds of sulphur dioxide will be displaced. Permitting can be a long process but the Bureau of Land Management and the Department of Energy are working to speed this up. Investigators at the Brookhaven National Lab are studying the affect of a PV array on wildlife at it's Long Island Solar Farm.

Clara Davis discussed her study of the current patent activity for PV. PVSC areas 1-6 were studied and search strings developed for each of these topics. The search string results were studied from 1976 through 2010. There was no patent activity before 1990. There has been a significant increases in patent applications in the past few years. Since 2007, applications for III V and concentrator PV have significantly increased. The U.S. Patent and Trade Mark Office Green Tech Pilot Program is a new project to fast track patent activity. Patent reform will change from first to invent to first to file. This is fundamentally changing the way patents are filed in the US. New legislation will give inventors a monopoly with a lower standard of proof. The real problem with first to invent is that most ideas will not be commercialized. Most ideas may not have patents filed. If we change to first to invent, companies may file on all ideas creating a barrier to new ideas. This may be good for patent attorneys but bad for innovation, particularly for smaller companies.

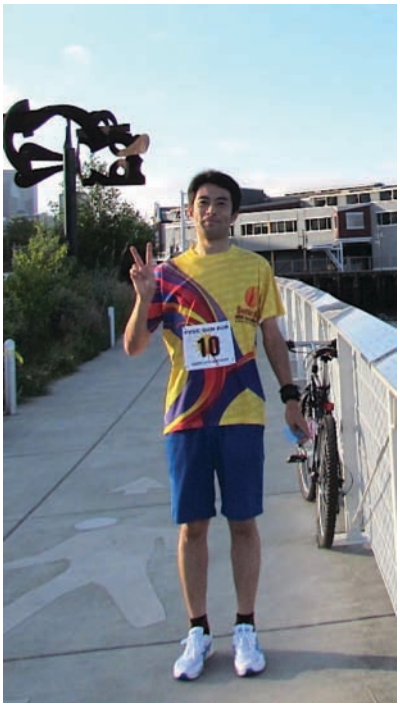
Wolfram Palitzsch discussed recycling methods for all PV materials. A method was developed that applied to all metal types. A film of the actual process was shown. The resulting product (glass) can be reused. After water recycling the rare metals can be recovered.

The evening session where Ryne Raffaelle ran a spirited quiz between ex conference chairs and the rabble (attendees).

Fundamentals and new concepts session: Ryne Raffaelle led another hilarious evening event of quiz competition between a panel of previous conference

general chairs and the audience of rabble (conference attendees). There was pizza aplenty along with an ample supply of beer, wine, and soft drinks to lubricate the audience and panel. If Ryne wants to quit as a Professor or NCPV Director he can look for work on Comedy Central. It was a very amusing and informative evening. Did you know that a half foot high gopher mound growing at the same rate as the PV industry since 1970 would be as high as 3.5 14,000 foot high (that's 4267 m in SI units by the way) mountains? Now we do.

-- Angus Rockett



First place in the SunRun.