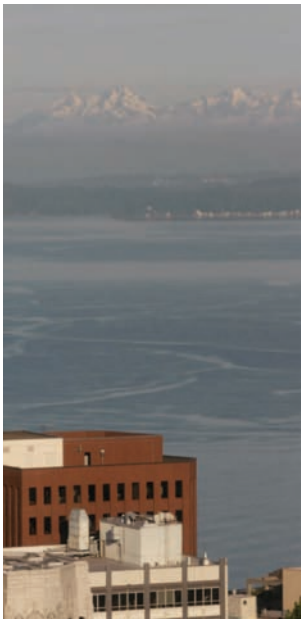
Tuesday was a busy day at the PVSC. The day began with a plenary session including three interesting plenary talks. This was followed by a poster session and an opportunity to visit with exhibitors, lunch, a series of talks in the afternoon, a poster session, and the Cherry Reception. The afternoon posters ran in parallel with a discussion organized on behalf of the Department of Energy Office of Energy Efficiency and Renewable Energy to consider the funding priorities of the SunShot project. Some of the highlights for the meeting on Tuesday were as follows.



Morning over the Seattle harbor.

In the Area 3 plenary on III-V's & Concentrators, Antonio Luque's talk focued on concentrators driven by high efficiency devices. It was argued that concentrators will eventually achieve a practical efficiency of 50% through the application of very high performance devices. A requirement for fully-effective cost competitiveness for CPV is increasing production volume to take advantage of manufacturing scale. Issues with materials were also discussed.

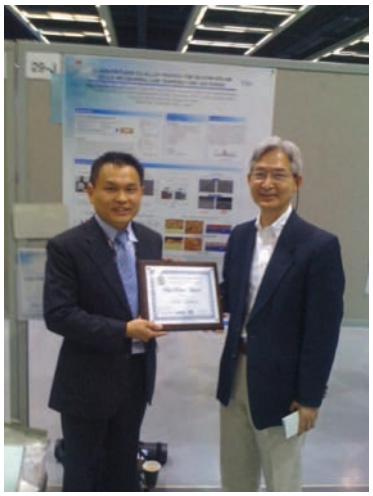
In the plenary of area 5, Ulrich Kroll of Oerlikon Solar presented the history and current status of the company's thin film silicon PV technology, from R&D to large-area production equipment. Record efficiencies on the laboratory level for single junction amorphous cells of 10.09% and for micromorph (amorphous-microcrystalline multi-junction) cells on speciality glasses from Corning of 11.91% have been achieved. These results were obtained using VHF thin film Si and LPCVD ZnO processing technologies. Successfull scale up to 1.4 m^2 modules has been demonstrated, yielding a stable 143 W micromorph module (stable active area efficiency of 10.7%). Impressive production yields of > 97% were demonstrated. The new ThinFab production line with a capacity of 120 MWp/year and record low module cost price of 0.50 €/Wp was described.

In the Area 9 plenary, Dr. David King from DK Solar Work discussed more efficient methods for specifying and monitoring PV system performance. The motivation for this topic is to match the accuracy of technical expectations of PV performance with the demands set by the financial sector. There is considerable concern about PV systems performance variability. Different PV technologies, for instance, might exhibit different performance ratios and final yields. Because power and energy output are applied to define the levelized cost of electricity (LCOE), it would be wise to develop more stable and well-defined indicators. Other product sectors have already experienced similar processes. As an example Dr. King referred to the development of the power rating indicator in the automotive sector. For example, jorse power for different types of cars required a standard definition. For the various PV technologies, including crystalline silicon, thin

David King giving his plenary lecture.

film, low concentration and concentrating photovoltaics (CPV), more uniform metrics should be developed to rate the power and performance in the field. Dr. King suggested that ac-efficiency would be a better metric than performance ratio. He illustrated this by two examples, flat plate PV modules and a CPV system. These showed stable values of ac-efficiency through the year and over several years.

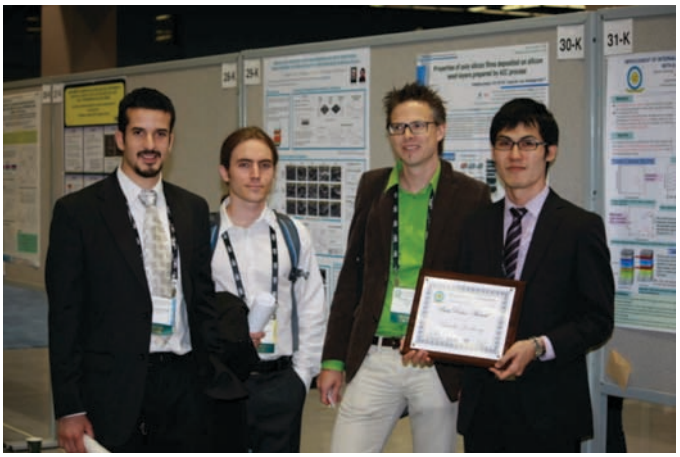
Following the plenary lectures, a poster session was held. Student award winners were selected in areas 1, 2, 3, 5, and 6. A range of excellent posters were presented.



Best poster award winner in the Area 4 poster session from AIST, entitled Glass Fritless Cu Alloy Pastes for Silicon Solar Cells Requiring Low Temperature Sintering.

In a joint session organized by Areas 8 & 10 on measurements and standards a panel discussion presented an overview of a workshop sponsored by NIST in May 2010. The goal of the workshop was to identify the Grand Challenges in four different technology areas: crystal Si, III-V, thin films, and excitonic PV. Common themes include (i) in-line measurements in manufacturing and (ii) long term reliability and models to understand accelerated life testing.

The afternoon began with a series of oral presentations. In Area 2 in a session with the topic Materials for Substrates and Transparent Conductors**,** Karl Boer suggested that the necessity of the CdS layer in CdTe and CIGS devices is related to the modified junction due to high field domains. This would explain why the activation energy of the saturation current density only equals the absorber bandgap when in the presence of CdS. Patrick Bloesch presented a discussion of low temperature deposition of CIGS with Na post-treatment as a valuable method to obtain highly-efficient CIGSe cells on stainless steel.



Best poster award for Area 5 presented to the Tuesday Morning poster K31 by Bancha Janthong of the Tokyo Institute of Technology.

Iron diffusion was proposed to degrade CIGS device performance. It was suggested that it would act as a deep defect in the CIGSe layer and that this was why the device was degraded. Other impurities including Cr and Ni were also suggested to be concerns. A requisite to avoid contamination from the stainless steel is to obtain a dense Mo layer. This can be obtained by a bilayer deposition process.

The Area 6 oral session kicked off with an invited talk by

Yuping Liu on new polymers for organic photovoltaics. An integrated approach to OPV devices was described including the use of new low gap polymers and more stable interfacial layers for contacts, improving V_{oc} and stability. Inverted devices employing Cu electrodes were presented as were new transparent conductors using metal grids. Brian Worfolk reported on air-stable inverted cell with ALD like PEDOT:PSS/organic multilayers and a vanadium oxide/aluminum counter electrode. Xin Xiao talked about novel squarine C60 absorbers. They form a nanocrystalline ordered film resulting in a solar cell with 4.4% efficiency. These squarines cover the solar spectrum exceptionally well. V_{oc} values near 1.0 V were obtained. Annealing the cells gave near 6%. A. belay talked on UV Ozone modification of PCBM. They explored polymerization with C-O-C bonds. This significantly alters the material. They have not made OPV devices yet with these materials. Robert Street reported on density of states measurements in OPV materials and full solar cells. They also measured the mobility in PCDTBT which was concluded to exhibit dispersive transport, as would be expected in very low mobility trap-dominated materials. Optical measurements confirmed the electrical measurements. The data can be used to probe environmental effects.

Yuping Liu presents a discussion of design of materials for organic photovoltaics.

The PV Velocity forum (Area 10) session focused on workforce development and in particular on how to encourage more women to participate in PV science and technology. Questions discussed included how environmental challenges can be addressed. The PV community is with less than 10% female, indicating a major issue with the climate for women in the field. Diversity is broadly seen as increasing the chances of success in all fields so changing this situation is key to optimized progress. Young women should be mentored to join the community as early as possible.

In the III-V concentrator area, P.Chiu described a 42.3%-efficient triple junction solar cell measured under 400 suns concentration. This was achieved by bifacial growth with a doping gradient in the base at the bottom of the cell and a doping gradient in the emitter of the top cell. Average efficiencies of 41% were retained at 165C for 2000 hrs. I. Garcia described research on the impact of III-V growth by OMVPE on a diffused silicon junction. Both high temperatures and precursors commonly used in OMVPE certainly impact the interface between silicon and GaP, but they have shown by TEM, reasonable passivation of this interface. Carbon-doped AlGaAs/Te-doped GaInP tunnel junctions were also described. Peak photocurrents of 700 mA/cm^2 were obtained.

With the push to reach 50% efficiency, 4-6 junction devices are being explored, but one limiter is a viable wide band gap top cell with a band gap from 2-2.2eV. Stephanie Tomasulo from Yale University shared her recent results on metamorphic InGaP solar cells on GaAsP buffer layers. Their optimization of buffer layers have reduced threading

dislocation densities comparable to other groups. For 1.90 to 2.07 eV band gap, InGaP devices have achieved open circuit voltages about 0.6 V lower than Eg/q. While not fully optimized to get down to the typical 0.4 V offset, this is very good progress.

It is well known that a lattice mismatched 1.0eV InGaAs cell is better optimized for the bottom cell in a triple junction device than other alternatives, but questions remain open as to what is the optimal way to integrate such a mismatched cell with the GaInP and GaAs upper cells. Philip Chiu spoke to the benefits of the bifacial epitaxial growth process he is developing at Spire. Benefits over the alternative, inverted metamorphic (IMM), are primarily focused around the elimination of the wafer bonding (handle) and epitaxial lift-off processes. They have been able to achieve 42.3% efficiency under 406 suns after significant optimization on isotype cells, including adding a pseudomorphic InGaAs layer between the GaAs cell and substrate in order to reduce loss of carriers being absorbed in the substrate via defect levels. They have also done high temperature burn-in testing at 165C and have seen no degradation.

Students from Tufts enjoy the Cherry Award reception.

In the module reliability session the discussion concerned performance and reliability of modules. Peter Hacke discussed how degradation by system voltage has been reported by numerous sources, and for that reason concise methods for testing seem necessary. In his presentation, methods involving measurements of the leakage current as an indicator for potential-induced degradation (PID) were reported. Na-lime glass/EVA exhibits significant PID. PID environmental stress factors were also discussed. Humidity strongly controls leakage current. Voltage (both polarities) and temperature stresses were considered. Results suggested a single thermally activated degradation mechanism. The ionic motion and PID degradation was illustrated by a PV module scheme. Max Koentopp noted that PID is common cause of degradation in PV systems. PID can be managed in all elements of a PV system. Interestingly, degradation mechanics depend on cell characteristics as well as historical environment. It was observed that shunting is an expanding area effect, not a point effect. PID can be influenced by glass type, encapsulant and AR coatings, which may offer design control to module companies for managing PID. The effect is independent of emitter sheet resistance. Dirk Jordan noted that PV module degradation is about 0.5 percent per year according to literature. Pre and post 2000 degradation for crystalline silicon is similar; but for thin films, large differences exist from 1.5 up to 2 percent. The

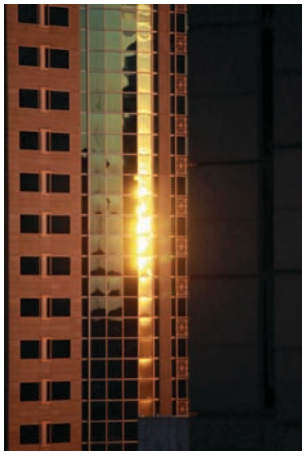
The band performing at the Cherry Award Ceremony.

warranty default risk has substantially decreased in the last decade. For a CIGS Shell Solar system, outdoor measurements have been performed at NREL. No significant degradation was detected, with antiregressive integrated moving average ARIMA trends investigated.

The U.S. Department of Energy (DoE) Office of Energy Efficency and Renewable Energy (EERE) has embarked on a series of programs to expand research at U.S. universities in support of competitive and near competitive PV technologies and to promote both industrial research and coordinated university/industry research. The objective is named SunShot in honor of the mission to the moon announced by the Kennedy administration in the 1960's. Dr. Mihn Le described the SunShot program and its goals to advance PV technologies and bring costs down. He also talked about SunPath, an incubator program that bridges between early stage research and discovery that the National Science Foundation or DoE Basic Energy Sciences might fund, and large scale manufacturing that a venture capital organization might support. Following the introduction, the participants broke up into moderated groups that discussed the key research goals and their potential for impact on cost of PV. These provide feedback to DoE EERE as it makes choices about what to fund under SunShot and SunPath.

Dr. Mihn Le, Chief Engineer, Solar Energy Technologies Program at the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy.

Students from Sealth International High School with their award for their design project.



Sunset on the skyscrapers of downtown Seattle

The day wound down with the Cherry Award reception. It was a party for the rest of the evening with a band and a lot of attendees enjoying their evening. Students from Sealth International High School and Ballard High School received certificates for winning the student design competition. There was a lot of networking and visiting with colleagues. In short, it was a great way to bring an exciting day of science to a close.

-- Angus Rockett