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Introduction

This year marks the introduction of a Thin Film Solar Technology conference to the SPIE Solar Energy + Technology symposium. A record response in terms of the number of submitted abstracts was achieved, and the conference proved to be a stimulating and successful event.

This volume features contributions from scientists and engineers in the general area of Thin Film Solar Technology, with special emphasis on Thin Film Photovoltaics (TF PV). Thin film solar technologies are a compelling alternative to conventional crystalline silicon solar technologies because they are not affected by the crystalline silicon supply fluctuation, they have significantly reduced cost with low material usage, and they have the potential for further cost improvement throughout the value chain. Furthermore, TF PV can use high performing materials that remain efficient under elevated temperature and low light conditions, offering high energy yield in kWh/W_p. In addition, TF PV can be applied to a variety of rigid and flexible substrates for different applications, and offer superior aesthetics.

Presentations in this conference include plenary preseantations in the areas of PV reliability R&D, concentrating solar, and photocatalysts for water splitting. In addition to these topics there were excellent plenary presentations at the conference on organic PV, thin-film silicon PV, and thin film PV (CdTe). To illustrate the breadth of topics covered we mention just a few of the papers in each session. The first session dealt with novel thin film photovoltaic devices. Al Jassim (presenting paper 7409-06 by Liu et al.) described the analysis of Si films, following their solid-phase crystallization, by electron backscatter diffraction and other techniques, and surprisingly concluded that a seed layer did not improve the crystallinity. The second session focused on the growth and patterning of thin films. Here, Gibson et al. (7409-08) explained the use of closed field magnetron sputtering to achieve plasma confinement and increased ionization in both cylindrical and in-line systems. The technique is well suited to reactive processes and results in low ion energies. Its application to materials such as SiO_xN_y, Nb_2O_5, CdS, and ITO was described. Kim et al. (7409-10) reported laser scribing of thin films (CIGS on Mo and a-Si:H on ITO) with pulse widths ranging from nanoseconds to femtoseconds. The advantages of ultra-short pulses to alleviate the problems of burrs, debris, and glass micro-cracks were identified.

The third and fourth sessions dealt with a-Si:H and nc-Si:H. In the third session, Despiesse et al. (7409-11) reviewed the status of European work in thin-film Si photovoltaics. They described the properties of LPCVD ZnO as a candidate TCO for industrial application to modules incorporating nc-Si:H, the deposition by PECVD of intermediate reflectors in p-i-n micromorph cells, and light trapping in n-i-p tandem cells. Notable results included a 13.3% (initial) a-Si:H / nc-Si:H glass-

based tandem cell with an SiO_x intermediate reflector and the improvement of top (a-Si:H) cell J_{sc} for tandem cells on flexible PET through use of a textured ZnO intermediate reflector. Yang and Guha (7409-12) summarized the status of various configurations of multi-junction cells and their component cells consisting of a-Si:H, a-SiGe:H, and nc-Si:H, with a focus on the n-i-p structure. An excellent result for a a-Si:H/nc-Si:H/nc-Si:H triple-junction cell was reported (14.1% initial, 13.3% stable). They concluded with a perspective on future needs for large area machines. Strahm et al. (7409-14) described the use of time-resolved optical emission spectroscopy to study the different regimes of powder formation during PECVD of nc-Si. Particle growth and ejection from the plasma was revealed via its influence on electron density.

In the fourth session, Delahoy et al. (7409-16) described the fabrication of a-Si:H / nc-Si:H tandem junction solar cells by VHF PECVD on a textured TCO produced by linear hollow cathode sputtering. A peak cell efficiency of 9.9% was attained at a crystalline fraction of 50–52% as measured by Raman spectroscopy. Yan et al. (7409-17) determined the principal transport parameter for thin Si:H materials (a-Si:H, a-SiGe:H, and nc-Si:H), namely, the mobility-lifetime product, using devices and bias-dependent collection methods related to Crandall's pioneering work. Strahm et al. (7409-18) examined the width of the amorphous to microcrystalline transition as a function of input silane concentration (using 40.68 MHz power) and conclude that the transition is wider at higher concentrations. Provided RF non-uniformity and/or powder formation are not encountered, this suggests an alternative deposition regime from the conventional one that uses very low silane concentrations. Merz et al. (7409-20) described the use of stretched wire masking for thin film patterning. Their stepping procedures represent an elegant extension of a low-cost method originally used for Al patterning in a-Si module production in the early 1980's before the advent of laser scribing.

The fifth session dealt with CIGS and CdTe devices and modules. Perrenoud et al. (7409-21) described the development of flexible CdTe/CdS cells with ZnO:Al/i-ZnO TCO on commercially available polyimide, and demonstrated efficiency levels exceeding 12%. They indicate that this technology is promising for low-cost roll-to-roll manufacturing, however further optimization of the TCO transmittance and conductivity is needed. Repins et al. (7409-22) presented a comprehensive overview of the material properties required for high-efficiency CIGS modules. They summarized the material properties of each layer in an NREL 20.0%-efficient, small-area, CIGS device, and described the design criteria and thin film characteristics required for achieving 18%-efficient 100-cm^2 devices and 15%-efficient large-area modules. Eldada et al. (7409-23) described a reactive transfer printing method used for volume manufacturing of CIGS thin films with high-quality large columnar grains and preferred crystallographic orientation. Low-cost ink-based atmospheric deposition of CIGS precursors produced cells with performance on par with PVD-deposited precursors. Cell efficiencies of 14% and large-area module efficiencies of 12% were reported. Weiss et al. (7409-24)

described the effect of light soaking on the power measurements of thin film modules. The stabilization of performance characteristics over time were compared under the influence of different illumination conditions for CdTe, CIGS, and a-Si modules. They showed that the different module types behaved very differently, and some types needed very long times to reach a stable state.

The sixth session dealt with thin film and module analysis and characterization. Prof. Jim Sites (7409-26) described the impact of local non-uniformities on thin-film PV performance. He showed that small shunts can affect the efficiency of cm-sized cells without having a significant impact at the module level, whereas low-efficiency areas can reduce module efficiency by a much larger factor than their fractional area. He also showed that in the case of non-uniform illumination, module performance is less degraded if the shadowing is spread relatively uniformly over most of the cells. Wu et al. (7409-28) proposed a non-contact method to measure the refractive index and thickness of dielectric thin films through the use of a polarizing phase shifting interferometer in a setup designed to reduce the effect of environmental vibration. The measurement results were validated by a comparison with ellipsometry measurements.

In addition to the papers just mentioned there are interesting contributions on a range of topics, including numerous other PV materials, magnetron coating, distributed Bragg reflectors, 2D modeling, photonic crystal reflectors, AR coatings, barrier layers, TCOs, sulfurization, and ESR studies.

Although this volume cannot include all the recent important work in the vast field of thin film solar technologies, it does cover a significant cross section of the advances happening globally, and it provides a roadmap for this fast-growing and exciting field by presenting the cutting-edge work and the visions of leading experts who are actively inventing the future.

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