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Thin Film Silicon Solar Cells and Modules Deposited by PECVD: From R&D Lab Developments to Large-Area Production Tools

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Up-scaling of thin film silicon solar cells to industrial commercial products of over 1 m^2 module area is a highly challenging task. Hereby, the transfer of high efficiency device results obtained in small area research-type equipments to large area high performance R&D and high productivity mass fabrication equipment are important issues needed to be solved. Especially the PECVD equipment in the thin film production line is one of the most important key elements to bring the module efficiency up and to reduce manufacturing costs. Oerlikon Solar uses a plasma excitation frequency of 40.68 MHz instead of the industrial standard frequency of 13.56 MHz for the amorphous and microcrystalline thin film silicon deposition due to the increased deposition rate and obtain "softer" plasma processes. In the first step, silicon deposition processes are developed and optimized in smaller R&D KAI M systems. A stabilized record cell efficiency of 10.09% has been obtained for a single-junction amorphous silicon solar cell device and independently confirmed by NREL (Golden, USA). Furthermore, a "Micromorph" (amorphous/microcrystalline silicon) tandem cell having a stabilized efficiency of 11.3% has been manufactured. Both latter devices have been deposited in small R&D KAI M systems using our LPCVD ZnO as front and back contact TCO. In the second step these process parameters are then transferred to industrial size PECVD reactors of 1.4 m^2 (KAI-1200). Following this strategy we achieved recently for amorphous silicon p-i-n single-junction and "Micromorph" tandems 1.4 m^2 R&D modules having initial aperture efficiencies of 10.0% respectively 11.0 %. These remarkable efficiencies clearly demonstrate the high potential of the PECVD KAI systems. Based on these results, Oerlikon Solar as an equipment manufacturer is installing production facilities for amorphous silicon and "Micromorph" PV modules above 450 MW capacities for all its clients worldwide.