High-Efficiency Silicon Heterojunction Solar cells: Status and Perspectives

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Silicon heterojunction technology (HJT) uses silicon thin-film deposition techniques to fabricate photovoltaic devices from mono-crystalline silicon wafers (*c*-Si). This enables energy-conversion efficiencies above 21 %, also at industrial-production level. In this presentation we review the present status of this technology and point out recent trends. We first discuss how the properties of thin hydrogenated amorphous silicon (*a*-Si:H) films can be exploited to fabricate passivating contacts, which is the key to high-efficiency HJT solar cells. Such contacts enable very high operating voltages, approaching the theoretical limits, and yield small temperature coefficients. With this approach, an increasing number of groups are reporting devices with conversion efficiencies well over 20 % on *n*-type wafers, Panasonic leading the field with 24.7 %. Exciting results have also been obtained on *p*-type wafers. Despite these high voltages, important efficiency gains can still be made in fill factor and optical design. This requires improved understanding of carrier transport across device interfaces and reduced parasitic absorption in HJT solar cells. For the latter, several strategies can be followed: Short-wavelength losses can be reduced by replacing the front *a*-Si:H films with wider-bandgap window layers, such as silicon alloys or even metal oxides. Long-wavelength losses are mitigated by introducing new high-mobility TCO's such as hydrogenated indium oxide, and also by designing new rear reflectors. Optical shadow losses caused by the front metalisation grid are significantly reduced by replacing printed silver electrodes with fine-line plated copper contacts, leading also to possible cost advantages. The ultimate approach to minimize optical losses is the implementation of back-contacted architectures, which are completely devoid of grid shadow losses and parasitic absorption in the front layers can be minimized irrespective of electrical transport requirements. The validity of this approach was convincingly demonstrated by Panasonic, Japan in 2014, reporting on an interdigitated back-contacted HJT cell with an efficiency of 25.6%, setting the new single-junction *c*-Si record. Finally, given the virtually perfect surface passivation and excellent red response of HJT solar cells, we anticipate these devices will also become the preferred bottom cell in ultra-high efficiency *c*-Si-based tandem devices, exploiting better the solar spectrum. Such tandem cells have the potential to overcome the fundamental single-junction limit of silicon solar cells (29.4%). Combining HJT cells with perovskite solar cells as top cell appears to be particularly appealing.