A new generation of PECVD reactor system will be presented, specifically dedicated but not restricted to the production of high-efficiency silicon heterojunction (SHJ) solar cells. Its innovative design is based on the novel Mirror reactor concept, property of INDEOtec. This new concept allows for ultra-homogeneous coatings of wafers without breaking the vacuum and without the need of substrate flipping. In the Mirror reactor, substrates are held on an opened carrier plate (“bi-facial” carrier-plate), making depositions from both sides of the substrates possible thanks to two different reactor designs: one for depositions from above the substrates (called “top” configuration), and one for depositions from below the substrates (called “bottom” configuration). Due to the use of bi-facial carrier-plates, additional challenges with regard to film uniformity apply in the Mirror reactors. Indeed, the gap space below or above the substrate affects the global RF electrical field distribution and, finally, leads to film inhomogeneity on the substrate. The approach INDEOtec has patented to overcome this problem is the use of a secondary RF electrode on the carrier-plate side. A properly adjusted RF power level fed to the secondary electrode can compensate the undesirable voltage drop in the gap space and hence, any loss in local plasma power above or below the substrate. Experimental results at CSEM have demonstrated highly uniform amorphous silicon (a-Si:H) layers in the PECVD Mirror top and bottom reactors with < 5% thickness relative deviation in such bi-facial carrier-plates for multiple-wafer co-processing (typically 4 wafers of 6-inch per plate). High-quality and homogeneous a-Si:H passivation layers have been developed in these reactors (refer to Figure 1(a)), with minority carrier lifetimes up to 5 ms measured on solar cell precursors (CZ n-type 3 Ohm·cm c-Si wafers). This PECVD Mirror reactor concept has been integrated in an Octopus II cluster system (see Figure 1(b)) featuring as well two load-lock modules for sample loading/unloading, a PVD reactor allowing for top and bottom PVD depositions of TCOs and metals, a carrier exchange module for the transfer of wafers from PECVD to PVD carrier plates without breaking vacuum, and a central transfer module connecting all the modules listed above. Large-area SHJ solar cells (>100 cm² size, both-sides contacted, CZ n-type 160 µm thick 6” wafer) with efficiencies up to 21.8% and fill factors above 79% have been fabricated with PECVD a-Si:H layers deposited in the Mirror reactors, on par with the best cells obtained in standard PECVD chambers using similar materials (c-Si, TCOs, metallization). All these experimental results fully validate the concept of these innovative and unique reactors. With such a complete cluster system integrating the PECVD Mirror concept, it is possible to produce complete SHJ cells (the wafer preparation by wet-chemistry and the front metallization step being excluded) without any vacuum break nor substrate flipping, and with very limited contamination of the wafer surfaces. Latest developments made on a-Si:H layers deposited in standard PECVD reactors as well as improvements in subsequent SHJ fabrication process steps have enabled CSEM to demonstrate up to 23.6% efficiency on 4 cm² solar cells with screen-printed contacts. All these developments will be transferred to the Mirror reactor concept, which will open the way for a further SHJ efficiency increase that will be presented at the conference.

Figure 1: (a) Photo-luminescence imaging of SHJ solar cell precursor produced in the Mirror reactors with proper power compensation. A perfectly homogeneous and highly passivated substrate is obtained. (b) INDEOtec Octopus II cluster system installed at CSEM, dedicated to R&D of SHJ solar cells. Up to four 6” wafers can be co-processed per carrier-plate.