Demonstrating Advanced PECVD Reactor for Uniform Coating on both Sides of a Substrate

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The Mirror reactor is a new PECVD system invented and patented by the Swiss company INDEOtec, specifically dedicated but not restricted to the production of high-efficiency silicon heterojunction (SHJ) solar cells. Thanks to its innovative design allowing ultra-homogeneous coatings of wafers on both sides without breaking the vacuum, the handling of the substrates is significantly simplified, leading to higher production throughput and yield, reduced costs, and potentially to improved device performance. The experimental results obtained confirm the validity of this reactor concept, demonstrated by full-area 6-inch SHJ solar cells with efficiencies up to 21.5%.

The potential of the silicon heterojunction (SHJ) technology to reach high conversion efficiencies is well known, with a recent record efficiency for silicon solar cells above 25%. While the overall fabrication process for both-side-contacted SHJ solar cells is relatively simple, further cost reductions are still possible to render this technology even more competitive at the mass production level.

The Mirror reactor is a new concept of PECVD reactor, invented and patented by the Swiss company INDEOtec, and demonstrated by CSEM and INDEOtec in the frame of the CTI project "Mirror". The new reactor allows for uniform depositions on both sides of a substrate without the need of flipping it and of any vacuum break. By using a multi-chamber cluster tool equipped with such novel reactors and PVD chambers attached, the typical production process of SHJ cells would be significantly simplified. Fabrication costs would be decreased thanks to a reduction of process time (pumping and venting time), process steps (wafer flipping, loading and unloading), and equipment footprint. Furthermore, the removal of handling steps (flipping, loading) is also potentially beneficial for the device performance and production yield, as eventual surface contamination issues and risks of wafer breakage are significantly reduced.

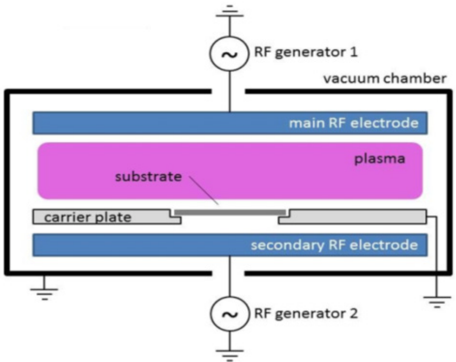

Figure 1: Schematic design of the Mirror PECVD reactor. A sister chamber with inversed position for the main and the secondary electrodes is used for deposition on the other side of the substrate.

In a classical PECVD reactor, the substrates are simply lying on an electrically-grounded metallic carrier-plate. Deposition is therefore only possible on one side of the substrates. In order to deposit on the second side, typically the substrates have to be taken out of the vacuum process chamber and mechanically flipped. In the Mirror reactor, the substrates are hanging in a carrier-plate with openings ("bi-facial" carrier-plate), making depositions from both sides of the substrates possible. However, the use of such bi-facial carrier-plates induces additional challenges with regard to film uniformity. Indeed, the gap space below the substrate acts as an additional capacitor in the equivalent electrical circuit, which affects the global RF electrical field distribution and, finally, leads to film inhomogeneity on the substrate. This reduction of the deposition rate in the center of the substrate compared to its edges leads to considerable losses in performance and is therefore unacceptable for the production of high-performance SHJ solar cells.

The approach to overcome this problem is the use of a secondary RF electrode on the carrier-plate side (see Figure 1). A properly adjusted RF power level fed to the secondary electrode can compensate the undesirable voltage drop in the gap space and, hence, loss in local plasma power above the substrate. This compensation permits a film deposition as uniform as in the standard configuration.

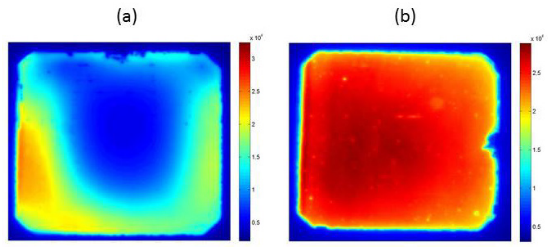

Figure 2: Photo-luminescence imaging of SHJ solar cell precursors produced in the Mirror reactor (a) without power compensation; (b) with power compensation.

Figure 2 shows lifetime mappings of 6-inch SHJ solar cell precursors, produced at CSEM in a Mirror reactor with and without the power compensation of the secondary electrode. Clearly, this compensation is mandatory to obtain homogeneous layer depositions in such bi-facial carrier-plates (corresponding layer thickness non-uniformity on the substrate surface: >40% without compensation, <4% with compensation). Complete full-area 6-inch SHJ solar cells with efficiencies up to 21.5% were produced in the Mirror reactor (busbar-less front grid design), on par with the best cells obtained in standard PECVD chambers using similar materials. These experimental results fully validate the concept of this reactor. Combined with PVD chambers directly attached to the same system, such multi-chamber cluster tools appear as extremely competitive for the production of high-efficiency SHJ solar cells. More details are available here [1].

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[1] O. Shojaei, *et al*., Proceedings of IEEE Photovoltaic Specialists Conference 2015, New Orleans, USA