# Materials and interface characterization within recombination junctions for two terminal perovskite / silicon heterojunction solar cells

*Pia J. Vasquez [a, b], Apolline Puaud[a], Delfina Muñoz [a], Muriel Matheron[a], Anne-Sophie Ozanne[a], Gema López [c], Isidro Martin[c], David Muñoz-Rojas[b]*

(a) *Univ. Grenoble Alpes, CEA, Liten, Campus INES, 73375 Le bourget du Lac, France*
(b) *Univ. Grenoble Alpes, CNRS, Grenoble INP, LMGP, 38000 Grenoble, France*
(c) *Univ. Politécnica de Catalunya (UPC), MNT 08034 Barcelona, Spain*

Perovskite (PK) / Silicon heterojunction (SHJ) tandem solar cells have shown great developments during the last few years, with efficiencies reaching 29.5% in 2020 with a 2 terminal architecture[1]. A key component of this type of structure, the interconnection layer (IL), allows efficient recombination of charge carriers (electrons, holes) coming from each subcell, thus avoiding the formation of a counterdiode within the tandem. Several possibilities of IL, including transparent conducting oxides (TCOs)[2], tunnel junctions[3] or direct interconnection between subcells[4] have been proposed. Whatever the solution, it is imperative to fulfil the optical, electrical and chemical requirements in order to ensure a high performance as well as a good stability and durability[5] of the tandem. The basic layer requirements include thinness, good vertical / poor lateral conductivity, and transparency within the optical range of the bottom cell. These parameters can be easily tuned with deposition tools, and measured with standard techniques. However, the detailed characterization of IL and interface phenomena within tandem configurations is not straigthforward, because of the correlation of multiple effects within a complex stack.

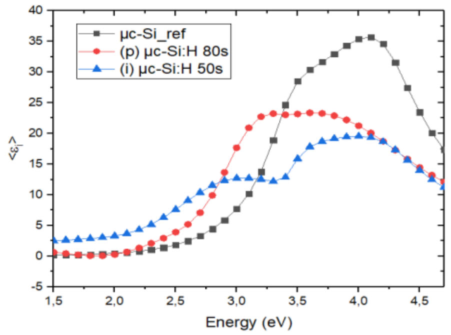


*Figure 1: Imaginary part of the pseudodielectric function of µc-Si:H films. (Black): reference µc-Si peak around 4.2 eV, (blue): formation of a 15 nm µc phase film, and (red) amorphization of layers induced by Boron deposition.*

In this work, we explore strategies to better understand charge transport phenomena at the p+/HTL interface by developing symmetric p-type bottom cell precursors using standard, industry compatible deposition tools. We discuss the difficulties of growing (p+) µc-Si :H layers by Boron effects which tend to amorphize the µc phase, as shown in Figure 1. We propose and test different deposition techniques to overcome this issue. Our next goal is to develop and characterize thin films for the interconnection layer of 2T PK/SHJ tandems. We have considered the configurations shown in Figure 2, including direct junction, and heavily doped (n+/p+) microcrystalline (µc) silicon thin films as recombination layer. On the top cell side, we consider several inorganic transition metal-oxides (TMO) as hole transporting layers, which have generated interest by their suitable properties[6]. We have found on these materials promising features such as good chemical compatibility with adjacent layers, transparency within the VIS/NIR and low contact resistivities. We also envisage the integration between p –type precursors and TMOs to characterize charge transport phenomena.

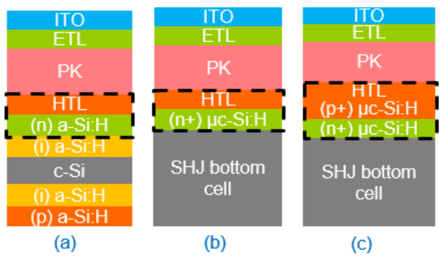


*Figure 2: Investigated tandem structures (a) direct junction, (b) (n+) µc-Si :H/HTL, (c) (n+)/(p+) tunnel junction/HTL.*

[1] https://www.pv-magazine.com/2020/12/21/oxford-pv-retakes-tandem-cell-efficiency-record/
[2] Shen, Heping, et al. *Science advances* 4.12 (2018): eaau9711.
[3] Sahli, Florent, et al. *Advanced Energy Materials* 8.6 (2018): 1701609.
[4] Zheng, Jianghui, et al. *ACS Energy Letters* 3.9 (2018): 2299-2300.
[5] Li, C., Wang, Y., & Choy, W. C. (2020). *Small Methods*, *4*(7), 2000093.
[6] Gerling, Luis G., et al. *Solar Energy Materials and Solar Cells* 145 (2016): 109-115.