

Supporting Information:

Determination of the Defect Density in Thin (i) a-Si:H Used as Passivation Layer in a-Si:H/c-Si Heterojunction Solar Cells from Static Planar Conductance Measurements

Alexandra Levtschenko, Sylvain Le Gall, Rudolf Brüggemann, Jean-Paul Kleider

GePs, UMR 8507, CNRS, CentraleSupélec, Université Paris-Sud, Université Paris-Saclay, Sorbonne Université, 11 rue Joliot-Curie, Plateau de Moulon, F-91192 Gif-sur-Yvette Cedex, France

Modeling of the c-Si and a-Si:H layers

The solar cell is modeled with regions which are delimited by the different materials. Electrical parameters of these materials are gathered in **table I**. Amorphous silicon layers were modeled with a density of states (DOS) in the bandgap consisting in two exponential tail state distributions (acceptor-like for the conduction band tail and donor-like for the valence band tail) and two Gaussian deep defect distributions representative of dangling bonds (one donor-like and one acceptor-like). The DOS parameters are gathered in **table II** where the different parameters are explained in the caption. The input parameters displayed in the (i) a-Si:H “bulk” column are those commonly used for bulk material (see references. [1-5]) whereas those of the (i)a-Si:H “proposed” layer column are those used in this study to fit the experimental results. All the parameters are set with respect to the valence band edge. In (p) a-Si:H layer, a donor concentration of $5.9 \times 10^{19} \text{ cm}^{-3}$ was added to the previously described defect distributions, leading to a position of the Fermi level at 0.39 eV above the valence band, while the Fermi level of (i) a-Si:H is located at midgap (0.85 eV above the valence band).

TABLE I. Input electrical parameters of materials at 300 K

	(p) c-Si	(i) a-Si:H	(p) a-Si:H
E_g (eV)	1.12	1.7	1.7
χ (eV)	4.05	3.87	3.87
ϵ_r	11.9	11.9	11.9
μ_n (cm ² /(V.s))	1300	20	20
μ_p (cm ² /(V.s))	500	4	4
N_c (cm ⁻³)	2.8×10^{19}	5×10^{20}	5×10^{20}
N_v (cm ⁻³)	1.04×10^{19}	5×10^{20}	5×10^{20}

TABLE II. Input electrical parameters of density of states in (i) and (p) type a-Si:H. The parameters N_G , ω_G , and E_G correspond, respectively, to the density at the maximum, characteristic energy width, and energy position referred to the valence band edge of the Gaussian deep defect distributions. The parameters $\sigma_{G,e}$, $\sigma_{G,h}$ are the corresponding capture cross-sections for electrons and holes, respectively. Similarly, all the parameters with a T-index correspond to the same physical quantities but in the exponential tail distributions, N_0 and E_0 being the value at the band edge and the characteristic width of the exponential tail, respectively.

		(p) a-Si:H		(i) a-Si:H "Bulk" layer		(i) a-Si:H "Proposed" layer	
		Valence band (donor)	Conduction band (acceptor)	Valence band (donor)	Conduction band (acceptor)	Valence band (donor)	Conduction band (acceptor)
Exponential tail states distribution	N_0 ($\text{cm}^{-3} \text{eV}^{-1}$)	2×10^{22}	2×10^{22}	10^{21}	10^{21}	10^{21}	10^{21}
	E_0 (meV)	60	34	43	26	60	34
	$\sigma_{T,e}$ (cm^2)	10^{-16}	10^{-17}	10^{-16}	10^{-17}	10^{-16}	10^{-17}
	$\sigma_{T,h}$ (cm^2)	10^{-17}	10^{-16}	10^{-17}	10^{-16}	10^{-17}	10^{-16}
Gaussian deep defect distribution	N_G ($\text{cm}^{-3} \text{eV}^{-1}$)	1.2×10^{20}	1.2×10^{20}	3×10^{15}	3×10^{15}	varying	varying
	ω_G (meV)	190	190	190	190	190	190
	E_G (meV)	1250	1450	600	1100	1250	1450
	$\sigma_{G,e}$ (cm^2)	10^{-16}	10^{-17}	10^{-16}	10^{-17}	10^{-16}	10^{-17}
	$\sigma_{G,h}$ (cm^2)	10^{-17}	10^{-16}	10^{-17}	10^{-16}	10^{-17}	10^{-16}
Doping	N_a, N_d (cm^{-3})	-	5.9×10^{19}	-	-	-	-
Fermi level position	$E_F - E_V$ (eV)	0.39		0.85		varying	

Experimental Current-voltage (I-V) measurements

Current-voltage (I-V) measurements have been done between coplanar electrodes at room temperature (RT) for various structures. The I-V curves are shown in the **Figure 1** according to different (i) a-Si:H thicknesses for an inter-electrode distance of 1.8 mm. We observe an expected linear behavior in the range of ± 1 V where the current decreases when the thickness

of the (i) a-Si:H layer increases. This is due to a reduction of the hole inversion channel at the interface. The normalized conductances G_{norm} discussed in the text are extracted from these I-V curves.

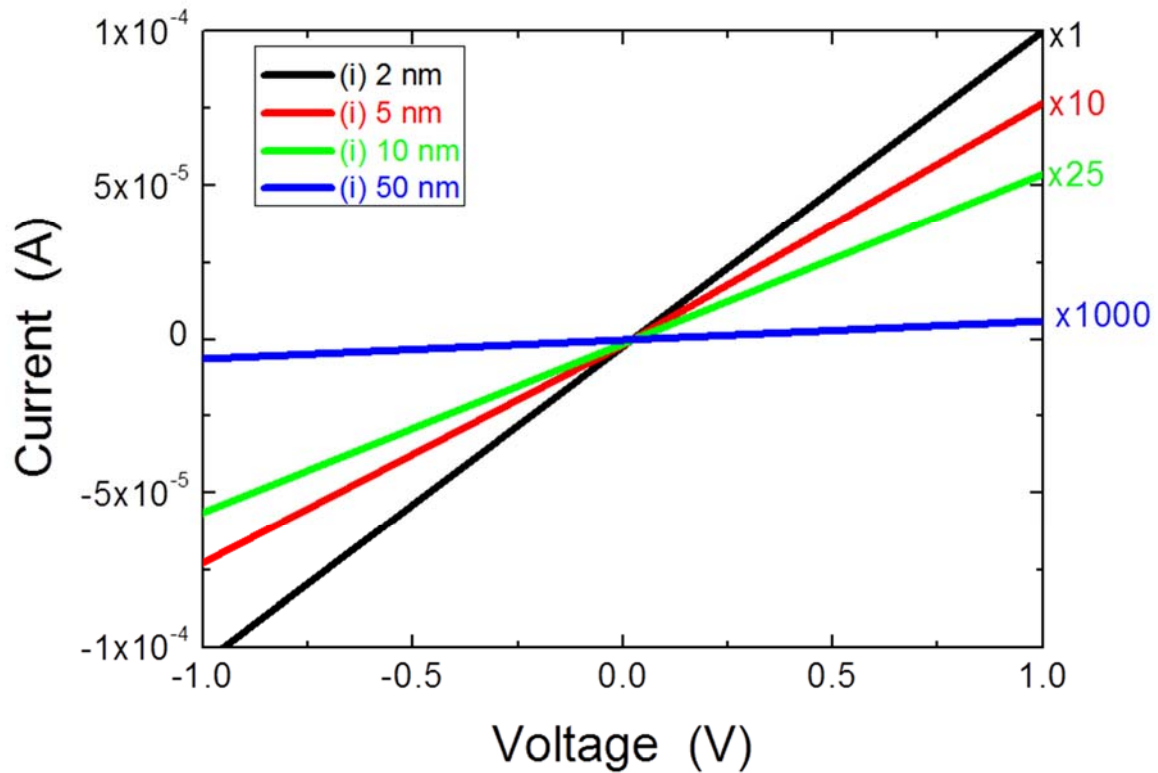


Figure 1. Experimental I(V) characteristics for various (i) a-Si:H thickness (black: 2 nm; red: 5 nm; green: 10 nm and blue: 50 nm) done at RT. For clarity reason, the I-V curves have been scaled with a multiplicative factor. The inter-electrode distance is 1.8 mm.

References

- [1] A. Levchenko, S. Le Gall, R. Lachaume, J. Michalon, S. Collin, J. Alvarez, Z. Djebbour, J.-P. Kleider, *Nanotech.* **2018**, 29, 255401.
- [2] A. Levchenko, S. Le Gall, R. Lachaume, J. Michalon, S. Collin, J. Alvarez, Z. Djebbour, J.-P. Kleider, *Phys. Status Solidi C* **2017**, 1700181.
- [3] Y. Hayashi, D. Li, A. Ogura, and Y. Ohshita, *IEEE J. Photov.* **2013**, 3, 1149
- [4] M. Rahmouni, A. Datta, P. Chatterjee, J. Damon-Lacoste, C. Ballif, P. Roca i Cabarrocas, *J. Appl. Phys.* **2010**, 107, 054521.
- [5] A. Fantoni, M. Viera, R. Martins, *Sol. Energ. Mat. Sol. Cells* **2002**, 73, 151-162.

