SUPPLEMENTARY INFORMATION

Interdigitated back-contacted crystalline silicon solar cells with low-temperature dopant-free selective contacts

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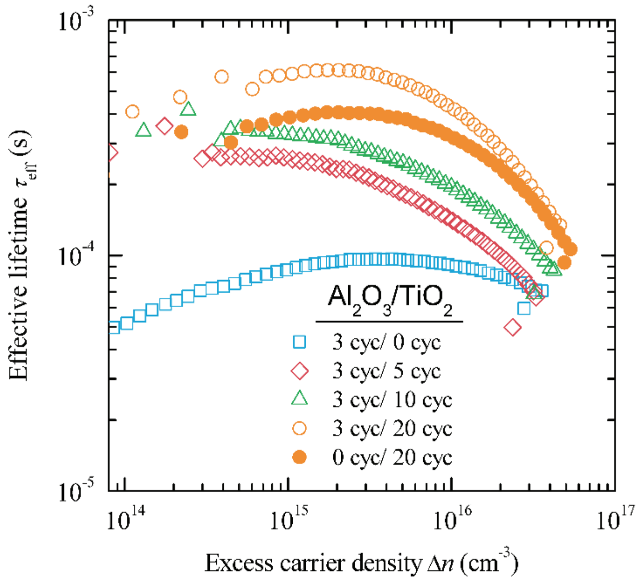

Fig. S 1 Measured effective lifetimes (τ_{eff}) vs. excess carrier density (Δn) of the Al_2O_3/TiO_2 stack passivation samples on n-type c-Si substrates (asymmetric test samples) considering different TiO_2 ALD cycles with a fixed Al_2O_3 layer of 3 ALD cycles (open symbols). Curve with solid symbols corresponds to the sample with only TiO_2 (20 ALD cycles).

The effective surface recombination velocity (S_{eff}) related to silicon/ETL contact interface can be calculated from effective lifetime (τ_{eff}) measurements considering asymmetric test samples (one side ideally passivated) as follows:

$$\frac{1}{\tau_{eff}} - \frac{1}{\tau_{in}} \cong \frac{S_{eff}}{w} \tag{1}$$

where w is the thickness of the wafer (280 µm) and τ_{in} is the intrinsic bulk lifetime (Auger and radiative mechanisms).[1] The bulk trap assisted Shockley-Read-Hall recombination mechanism has not been considered provided the high quality FZ c-Si substrates used in this work. S_{eff} values are extracted at an excess carrier density (Δn) of 10^{15} cm^{-3}.

Alternatively, contact passivation quality can be determine by means of the contact recombination current density (J_{0c}) concept using equation (2) which is evaluated at low injection levels ($\Delta n << N_D$). Where q and n_i are the elementary charge and intrinsic concentration (8.65×10^9 cm^{-3} at 25 °C) respectively.

$$\frac{1}{\tau_{eff}} - \frac{1}{\tau_{in}} \cong \frac{J_{0c}(N_D + \Delta n)}{q n_i^2 w} \cong \frac{J_{0c} N_D}{q n_i^2 w} \tag{2}$$

Comparing eq. (1) and (2) we can establish a relationship between S_{eff} and J_{0c} as[2]

$$J_{0c} \cong \frac{q n_i^2}{N_D} \times S_{eff} \tag{3}$$

Despite assuming low-injection conditions could lead to small inaccuracies in J_{0c} calculations, by applying equation (3) we are able to calculate and compare J_{0c} values from the S_{eff} values and substrate doping densities (or wafer resistivities) reported in references used to build table 1 of the main document.

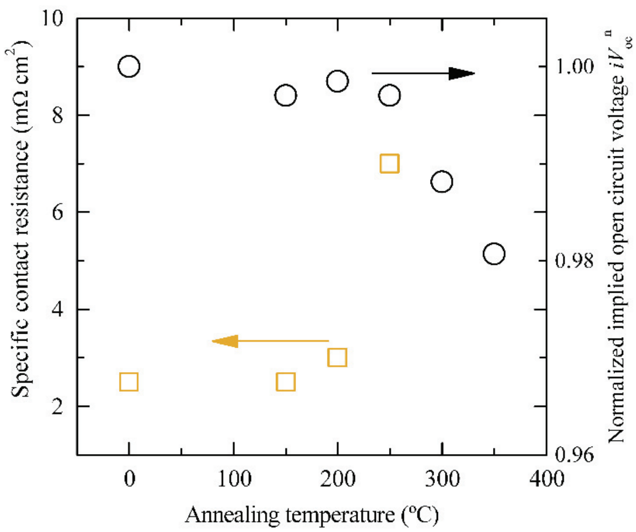

Fig. S 2 Annealing temperature study of Al_2O_3/TiO_2 stacks (6/20 ALD cycles) for both passivated and contacted (Mg-coated) test samples on n-type c-Si substrates. Notice that only one sample underwent the annealing study, i.e. cumulative annealing. All annealing stages were carried out during 5 min in forming gas (N_2/H_2) atmosphere. Implied open circuit voltage values are normalized to their initial values (iV_{oc}^n).

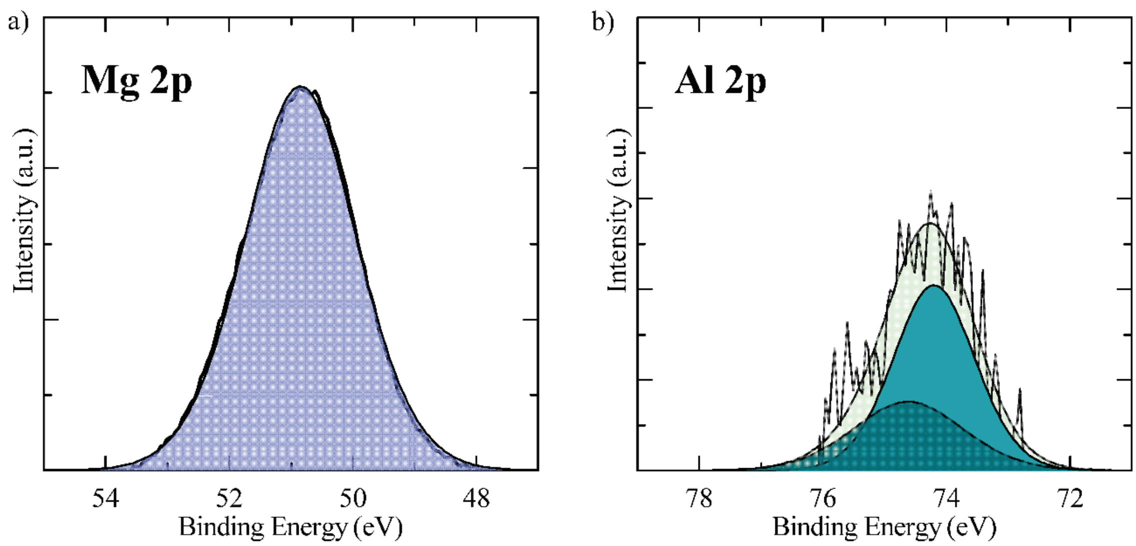

Fig. S 3 High-resolution XPS spectra of Mg-coated Al_2O_3/TiO_2 stacks (6/20 ALD cycles) on n-type c-Si substrates. a) Mg 2p and b) Al 2p core levels spectra.

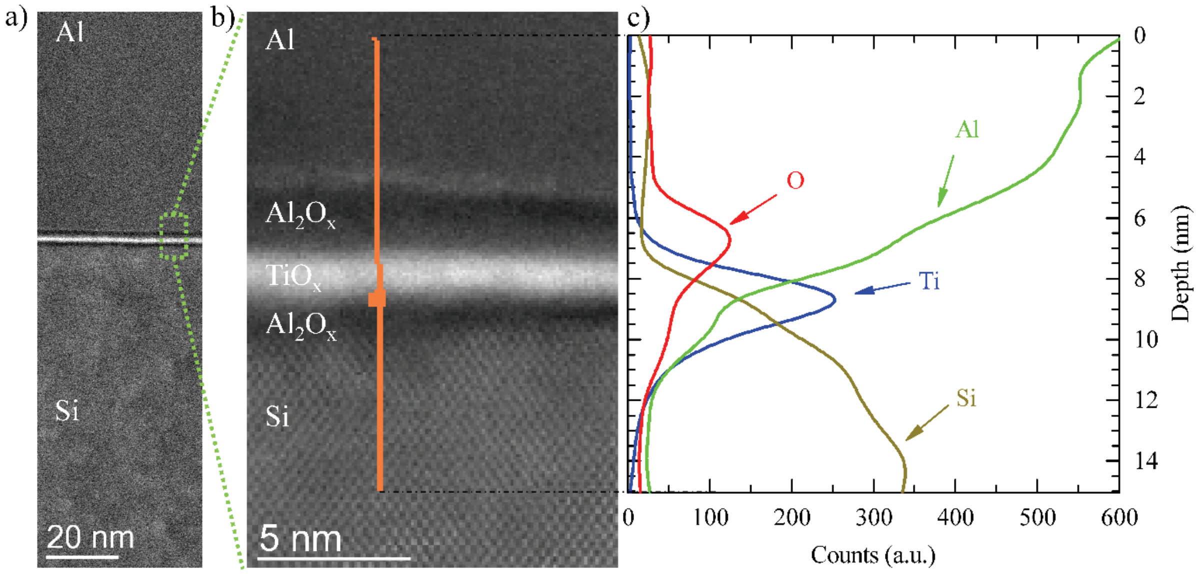

Fig. S 4 a) High-resolution STEM image of contact resistance test samples with Al-coated Al_2O_3/TiO_2 stack (6/20 ALD cycles). b) A close view of the Al_2O_3/TiO_2 stack; c) EDX line scan confirming a AlO_x interlayer grown in between TiO_2 and Al films.

Figure S5 shows the dark *J-V* curves of two V_2O_x-based IBC cells with either laser-doped or TMO-based ETL formation strategies, exhibiting a similar exponential *J-V* trend with an ideality factor (n) close to 2 at intermediate and high voltage levels. Then, the origin of such a relatively high n value should be related to HTL regions. In order to optimize the V_2O_x properties, test diodes whose c-Si surface was fully covered by the HTL layer were fabricated resulting in n values of about 1.2.[3] This much lower value suggests that the patterning of V_2O_x needed to create the IBC structure introduces the distortion in the dark *J-V* negatively impacting *pFF* and *FF*. The interdigitated structure of HTL is defined by thermal evaporation of the corresponding V_2O_x/Ni layer on windows previously patterned by standard photolithography. This technique could lead to poor material coverage at the edge of the HTL interdigitated regions. As a result, an increase of surface recombination could occur explaining the foregoing exponential trend in the *J-V* curve[4] and the difference between V_{oc} and iV_{oc} values reached in our finished IBC solar cells and test samples. Notice that for an interdigitated back-contacted approach the perimeter vs. area related to HTL regions is typically much higher than for the both-side contacted solar cells counterparts intensifying any edge-related effect. In future developments, HTL layers also deposited by ALD technique will be investigated in order to guarantee a conformal layer coverage.

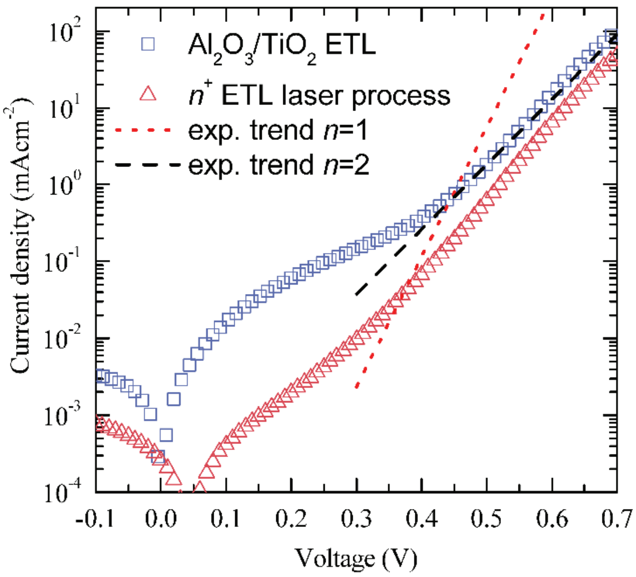

Fig. S 5 Comparison of dark current density-voltage curves for the best IBC solar cell and its counterpart (same HTL coverage) using laser-doped contacts to form n^+ ETL regions.[3]

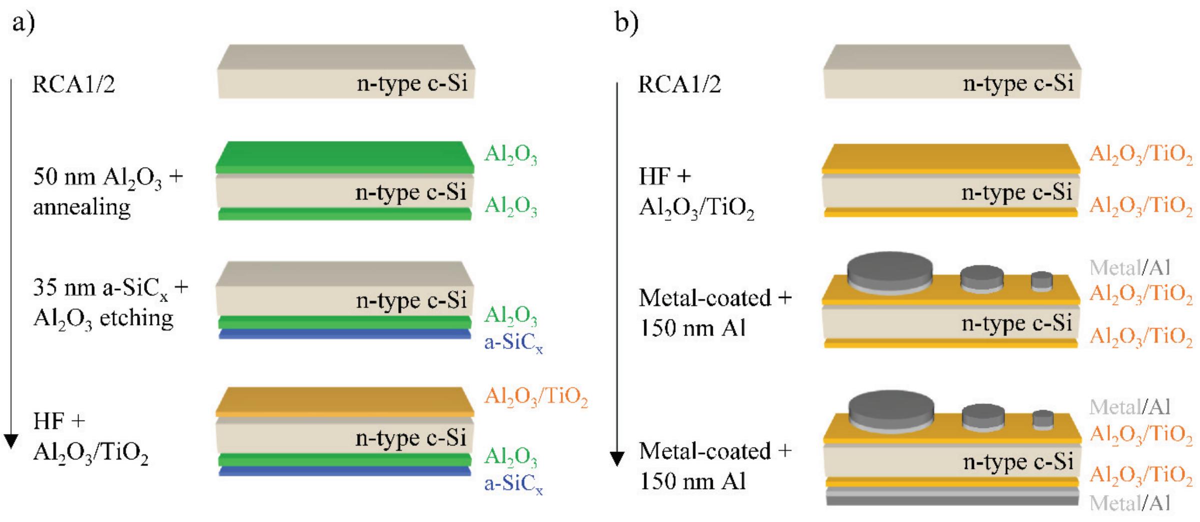

Fig. S 6 Process flow showing the main technological steps involved in the fabrication of a) passivation and b) contact resistance test samples.

[1] A. Richter, S. W. Glunz, F. Werner, J. Schmidt and A. Cuevas, *Phys. Rev. B*, 2012, **86**, 165202.
[2] A. G. Aberle, *Prog. Photovolt: Res. Appl.,* 2000, **8**, 473.
[3] G. Masmitjà, L. G. Gerling, P. Ortega, J. Puigdollers, I. Martín, C. Voz and R. Alcubilla, *J. Mater. Chem. A*, 2017, **5**, 9182.
[4] C. H. Henry, R. A. Logan and F. R. Merritt, *J. Appl. Phys.*, 1978, **49**, 3530.

