Evaluation of low temperature curing pastes to scale-up the metallization of perovskite/silicon tandem devices by screen-printing

Emmanuel Tetsi, Johann Jourdan, Olivier Dupré, Delfina Muñoz, Wilfried Favre
CEA – INES, 50 Avenue du Lac Léman, Savoie Technolac, 73370 Le Bourget-du-Lac (France)

Multijunction photovoltaic devices hold a great promise to go beyond the 29% theoretical limit of silicon solar cell, by using materials with different band gap, harvesting therefore a large window of the solar spectrum. In this context, intensive developments of tandem solar cells based on perovskite and crystalline silicon absorbers are currently ongoing, leading to a recent record of 29.15 % cell efficiency[1]. However, these tandems face challenges at different levels. As an example, the main metallization process so far used – evaporation - is not compatible with large-scale integration and industrial throughput; in addition, several works highlighted the dramatic decrease in the cell performances due to processes conditions[2]. To address this issue, we focus on the evaluation of low temperature silver pastes applied by screen-printing, an industrial technique demonstrated for silicon heterojunction (SHJ). To this purpose, the effect of curing conditions (temperature and time) have been investigated for three different pastes and later compared to the paste used for the SHJ devices, already know as a low temperature paste. Once printed on chemically polished silicon substrate covered with a layer of 100 nm ITO, the metallization pattern was assessed in terms of geometrical and physical properties using profilometer/optical microscope and four-point probes respectively. Furthermore, Transfer length method (TLM) and shear tests measurements were conducted to extract the contact resistance (ρ_c) and the adhesion force of the silver/ITO interface. The results are summarized in Table 1.

Curing (°C/min)	T = 140/15	T = 130/45			205/17 (Ref*)
Pastes	**A**	**B**	**C**	**D**	**A**
Height (µm)	11 ± 2 µm	16 ± 4 µm	7 ± 2 µm	12 ± 5	11 ± 2 µm
Width (µm)	48 ± 3 µm	45 ± 5 µm	60 ± 5 µm	56 ± 5	48 ± 3 µm
Rline (ohm/cm)	3	3	4,30	**2,50**	1
$\rho_{c\ Ag/ITO}$ **(mΩ.cm^2)**	500	**160**	**220**	**126**	0,1-22
Adhesion force (mN/mm^2)	0,074	0,096	**0,18**	**0,19**	0,20-0,23

Table 1. Comparison of the properties of the different pastes. Ref* is standard conditions for SHJ and is used as reference for contact resistance and adhesion force

Results underline the similar behaviour of the pastes in terms of finger geometry (thickness ~ 10 µm and width ~ 50 µm) and the better line resistance (in the range of ~ 2.5-4 Ω/cm) of the really low temperature pastes compared to the SHJ reference paste. Moreover, paste D exhibits promising contact resistance and adhesion properties even for curing temperature below 130°C, as shown in Figure 1, opening the way to tandem device integration.

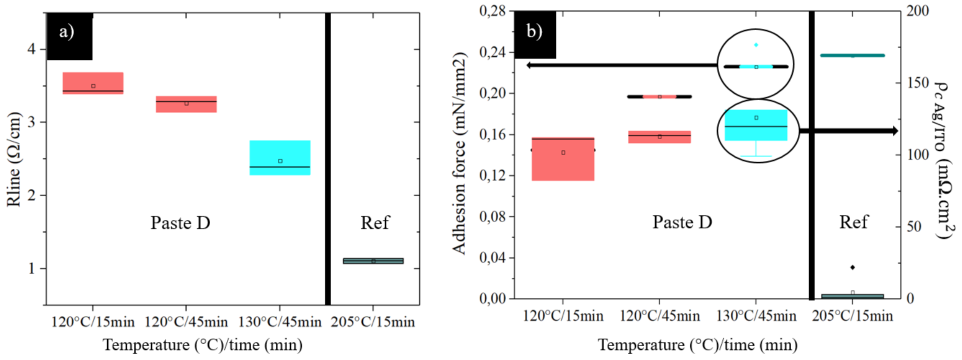

Figure 1. Impact of curing temperature on line resistance (figure 1.a) and adhesion force/contact resistance (figure 1.b) of pastes D and A

1. Al-Ashouri, Amran, et al. *Science* 370.6522 (2020): 1300-1309.
2. Boyd, Caleb C., et al. *ACS Energy Letters* 3.7 (2018): 1772-1778.