Application of graphene to transparent contacts for silicon-heterojunction solar cells

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Silicon-heterojunction cells represent one of the most promising approaches in photovoltaics, with record efficiencies above 26% [1]. These cells have very thin and relatively resistive front emitters, so they need transparent front electrodes to extract current. State-of-the-art contacts for this application are transparent conductive oxides (TCOs) having a rather limited sheet resistance, of the order of 120 Ω/□. A significant reduction of this parameter would help reduce cell series resistance and hence improve performance. The present work is aimed at developing graphene-based transparent electrodes having sheet resistances about one half of that of TCOs or less.

Graphene samples respectively having one, two and three atomic layers have been optically and electrically characterised. White-light transmission maps have been used to correlate transparency and number of layers. Transmission-line measurements (TLM) using different metal contacts have allowed to assess sheet resistances and contact resistances, leading to the choice of Ti+Ag as a good reference metal contact.

The results obtained so far have yielded graphene sheet resistances which, connected in parallel with present TCOs could well allow to attain 50 to 60 Ω/□ with an excellent optical transmission. The full compatibility between graphene transfer methods and cell materials and surfaces is being tested. Low [2]- and high-temperature transfer procedures are being compared.

The work undergone so far clearly suggests the possibility to noticeably improve transparent electrodes with this approach and therefore to further enhance silicon-heterojunction cell performance.

References

[1] M. Green, et al. Prog. Photovolt: Res. Appl. 24 (2016) *in press*.
[2] A. Boscá *et al.*, Scientific Reports (2016) 6, 21676

Figures

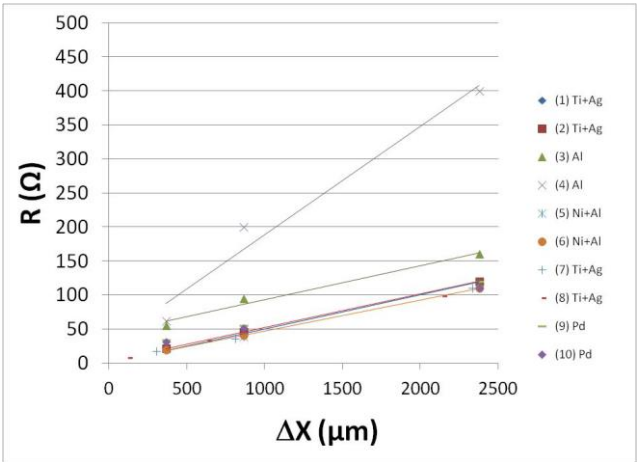

Figure 1: TLM measurement results. Contacts made by depositing different metals onto monoatomic-layer graphene. Al is not suitable. Ti+Ag is a good choice with contact resistances below 1 Ohm·cm²

No of at. layers	White-light Transm.	$R_□$ (Ω/□) Transf. high T	$R_□$ (Ω/□) Transf. low T
1	97.6%	375 ± 25	295 ± 25
2	95.0%	175 ± 10	155 ± 10
3	92.6%	120 ± 15	125 ± 15

Table 1: White-light transmission and sheet resistance for graphene samples of different thicknesses transferred at respectively high- and low temperatures.

Acknowledgement: Work supported by MINECO project GRAFAGEN (ENE2013-47904-C3).