Transparent conducting graphene electrodes for photovoltaic applications

Rita Rizzoli[1], Luca Ortolani[1], Caterina Summonte[1], Giulio Paolo Veronese[1], Marco Allegrezza[1], Marica Canino[1], Gurpreet Singh Selopal[2,3], Riccardo Milan[2,3], Isabella Concina[2,3], Alberto Vomiero[2,3], Vittorio Morandi[1]

1. CNR-IMM Bologna,via Gobetti 101,40129 Bologna, Italy.
2.CNR-INO SENSOR Laboratory, via Valotti 9, 25133 Brescia, Italy.
3. Dept. of Information Engineering, University of Brescia, Via Branze, 38, 25123 Brescia, Italy
rizzoli@bo.imm.cnr.it

Abstract

The use of few-layer graphene (FLG) sheets as front transparent conductive electrode (TCE) is proposed, both for thin film solar cells requiring high temperature processing and for dye sensitized solar cells obtained on glass and flexible substrates.
This kind of solar cells imply the use of a TCE front contact, which is normally made of metal oxides such as Indium Tin Oxide (ITO), Al-doped ZnO, MgO, F-doped Tin Oxide (FTO). The use of such materials for high processing temperatures or for the fabrication of flexible devices is an open issue. ITO contact is brittle and rapidly degrade after bending, so that it is unsuitable for flexible electronics applications [1]. Moreover, the TCE represents one of the most costly parts of the solar cell, and many strategies are under investigation to replace these precious films with low cost and still effective layers.
In the case of silicon nanodot based 3rd generation solar cells, the fabrication requires processing temperatures up to 1100°C [2]. While ITO contacts degrade above 900°C, the FLG sheets are expected to meet the requirements in terms of transparency, conductivity [3-5] and resistance to high thermal budget processes.
Our results on C-CVD grown FLG large sheets (see Figure 1), both transferred on quartz and on different kind of flexible transparent substrates, show a sheet resistance of about 500 ohm/sq for transmittances around 94 %. Annealing treatments in the 400-1100°C range, performed both in vacuum and inert atmospheres on FLG sheets on quartz, evidence that their optoelectronic properties are stable after annealing up to 1100 °C.
Moreover, the careful control of the growth parameters as well as a tailored approach to the transfer process on functional substrates is capable to provide the suitable control of physical and chemical properties of the front contact over large area, which is mandatory in photovoltaic devices.
The results on a-Si:H pin (see Figure 2), Si nanodot-based solar cells and dye-sensitized solar cells (see Figure 3), fabricated on graphene TCE front contacts, will be reported. The major limitation in solar cells application derives from the high sheet resistance of the state-of-the-art wet transferred graphene with respect to standard ITO coating. In order to address this issue, doped FLG sheets [6] will be studied as TCE.

References

[1] L.G. De Arco et al., ACS Nano **4** (2010) 2865.
[2] P. Löper et al., Appl. Phys. Lett. **102** (2013) 033507.
[3] F. Bonaccorso et al., Nature Photonics **4** (2010) 611.
[4] G. Jo et al., Nanotechnology **23** (2012) 112001.
[5] M. Bawendi et al., Nano Lett **13** (2013) 233.
[6] S.Bae et al., Nature Nanotechnology **5** (2010) 574.

Figures

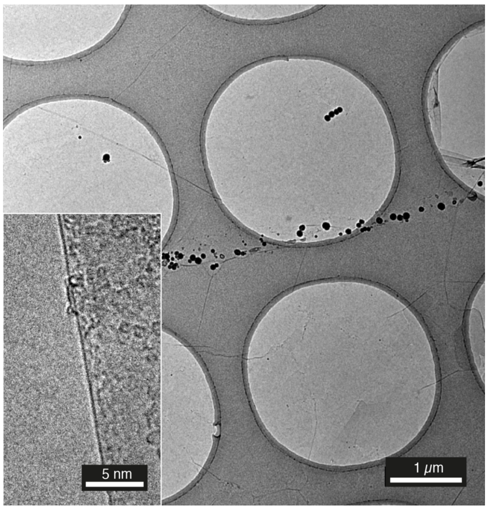

Figure 1 - TEM image of a graphene membrane. The graphene spans over the whole 3 mm grid, covering the holes of the grid carbon film. (inset) Detail of a folded edge in a monolayer region.

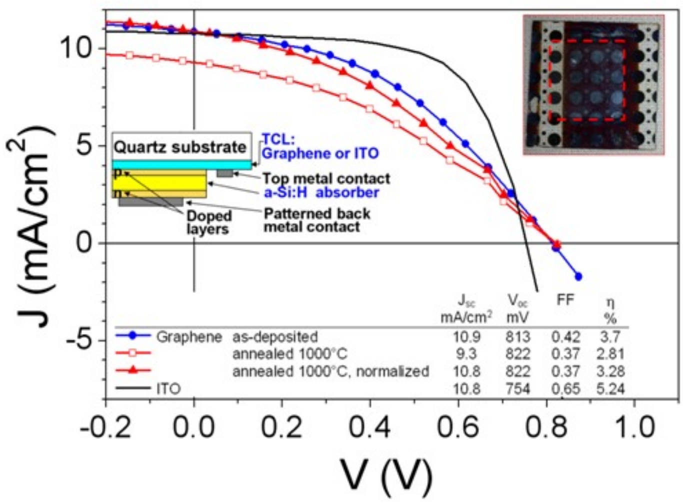

Figure 2 - JV characteristics under AM1.5 illumination of a-Si:H pin solar cells integrating graphene as TCE. The data of the reference device are also included. Insets: sketch of the structure and picture taken on as deposited and annealed samples. The colored dashed square indicates the region covered by graphene

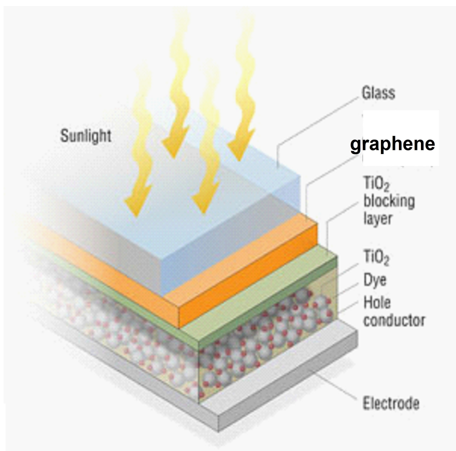

Figure 3 – Sketch of a Dye Sensitized Solar Cell with graphene TCE