Graphene-based Natural Dye-Sensitized Solar Cells

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Dye-sensitized solar cells (DSSCs) [1] have attracted much attention due to their good light-to-electricity conversion efficiency and simple fabrication. The counter electrode (CE) employed for the regeneration of electrolyte is commonly constituted of a catalytic Platinum (Pt) film deposited on TCOs. TCOs, usually Indium Tin-oxide (ITO) and Fluorine-doped Tin-oxide (FTO), require high temperature processing, hindering the deposition on some substrates (e.g., polymeric substrates). Moreover, they are brittle, limiting their use in applications where flexibility is required. On the other hand, Pt tends to degrade over time when in contact with the (I^-/I_3^-) liquid electrolyte, reducing the overall efficiency of DSSCs.[2] Thus, the replacement of such elements with low-cost and/or more versatile materials is at the centre of an ongoing research effort. In this context carbonaceous materials feature good catalytic properties, electronic conductivity, corrosion resistance towards iodine, high reactivity, abundance, and low cost.[3,4] Another fundamental part of a DSSC is the dye. Generally, transition metal coordination compound complexes [5] and synthetic organic dyes [6] are used as effective sensitizers in DSSCs. However, the preparation routes for these dyes are based on tedious and expensive chromatographic purification procedures. Natural dyes and their organic derivatives are non toxic, biodegradable, low in cost, renewable and abundant, so they are the ideal candidate for environmentally friendly solar cells[7].

Here we show that the combination of graphene and natural sensitizers opens up new scenarios for totally green, natural, environmentally friendly and low cost DSSCs, Figure 1. In particular, its unique electronic [8] and optical properties [9] make graphene an attractive material for CEs in DSSCs. Indeed, graphene matches all the key requirements needed for CE materials such as high specific surface area, high exchange current density and low charge-transfer resistance.

Graphene thin films were produced by liquid phase exfoliation of graphite [10], and spin-casted on stainless steel, FTO and glass. We show that graphene CEs have promising activity, similar to the Pt one. Indeed, DSSCs assembled with CE made of graphene deposited onto FTO (1.42%) outperform the total conversion efficiency of those based on Pt (1.21%). Moreover, we show that graphene, contrary to Pt, can both catalyses the reduction of tri-Iodide and back transfers the electrons arriving from the external circuit to the redox system. DSSCs assembled with graphene deposited onto glass as CE show efficiency ~0.8%. This demonstrates the potential of graphene to simultaneously replace both the Pt catalyst and the conductive glass. We also demonstrate an environmentally friendly DSSC assembled using natural dyes, which show high Internal Photocurrent Efficiency (Figure 2), and graphene as CE with efficiency of ~ 0.40%.

References

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Figures

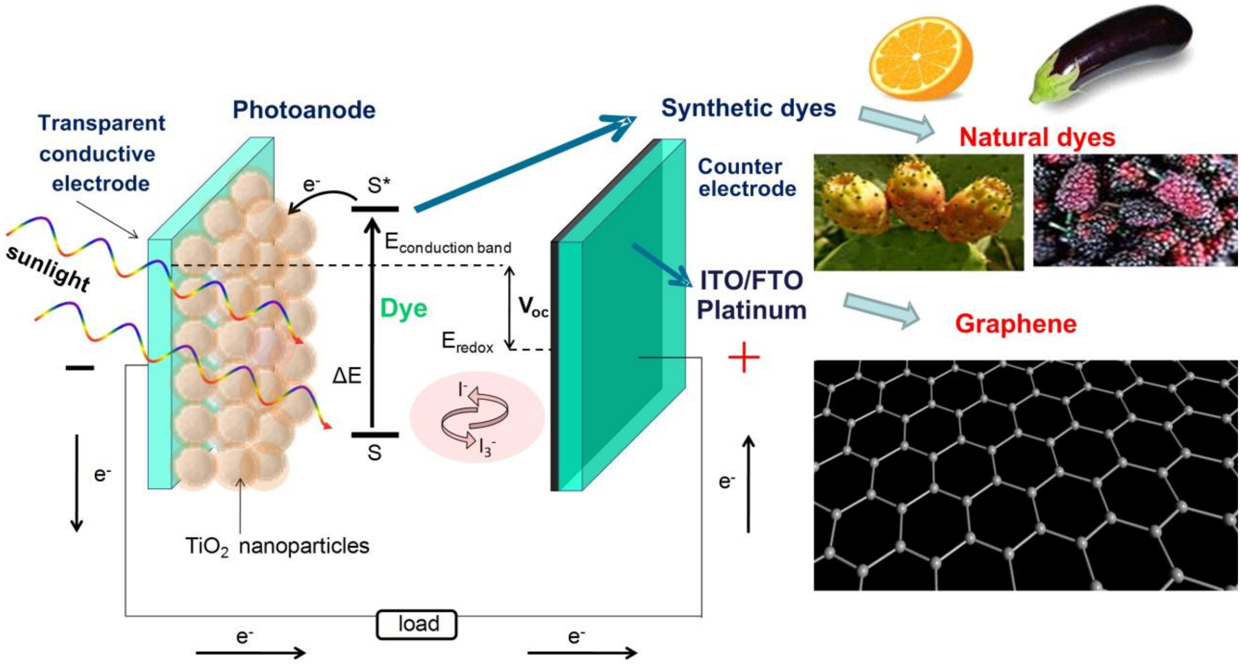

Figure 1: Schematic representation of the where the synthetic dyes are replaced by the natural dyes and graphene is used at the CE to simultaneously replace TCO films and Pt.

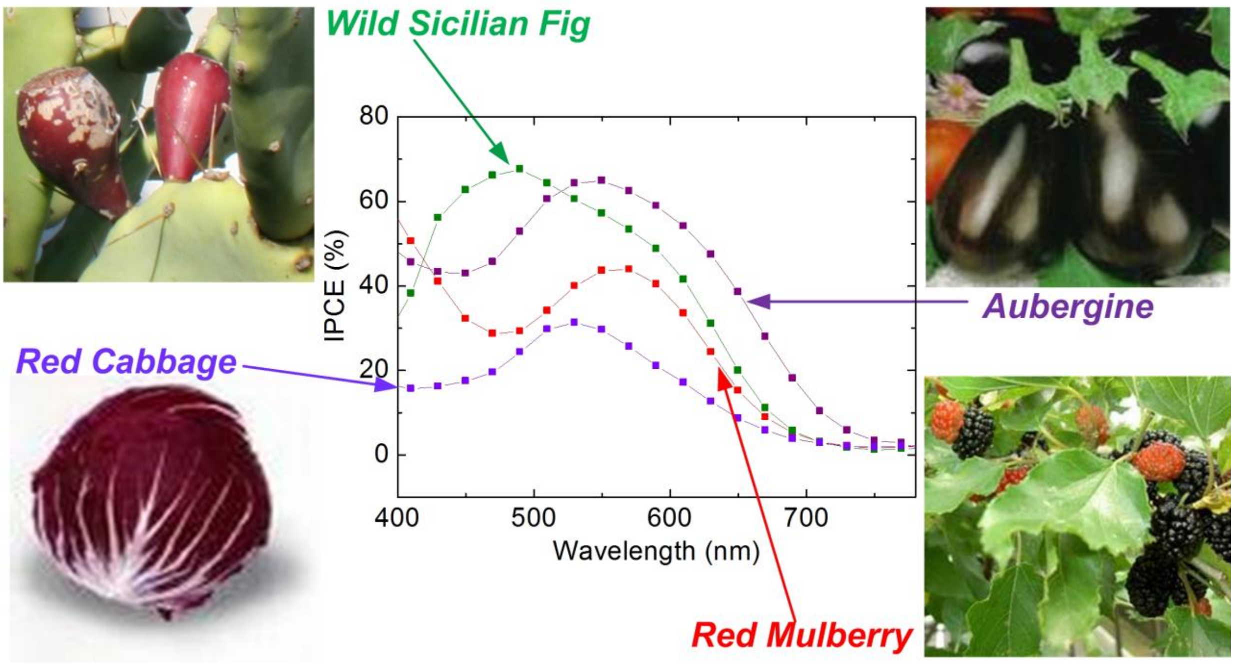

Figure 2: Internal Photocurrent Efficiency spectra of: Wild Sicilian Fig (green line), Aubergine (purple line), Red Mulberry (red line) and Red Cabbage (violet line).