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Fabrication and Characterization of Solar Supercapcitors Integrated with a Laser Scribed Graphene Oxide film

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Abstract: An on-chip concept of supercapacitor electrical energy storage integrated with solar cells using thin-film graphene oxide was demonstrated. The solar supercapacitor showed a 62% columbic efficiency with non-degradation in the solar cell performance.

OCIS codes: (220.4000) Microstructure fabrication; (350.6050) Solar energy; (130.3120) Integrated optics devices

1. Introduction

Currently stand-alone secondary energy storage systems as lithium-ion and lead-acid batteries are used to store the electricity generated by solar cells. However, the high cost, large footprint and short life span of those conventional energy storage systems limit the cost reduction of the solar electricity and hinder the large-scale deployment of solar cells as a primary energy source. Therefore, it is highly desirable to develop low-cost, high performance, scalable and highly integrable energy storage devices to lift the competitiveness of solar energy. Recently solar cell integrated energy devices have been developed on the main stream silicon solar cells using supercapacitors based on the etching of the silicon layer in a solar cell [1]. However the performance of the solar cell became degraded due to the low charge collection efficiency of the etched crystalline-silicon (c-Si).

In order to overcome these challenges, we demonstrate, for the first time, an on-chip electrical energy storage, integrated silicon solar cells using the reduced graphene oxide (R-GO) thin-film supercapacitor, which are predicted to have a long life span, millions of life cycles and eco-friendly using the direct laser writing method [2]. Most important of all, the integrated system does not require extra footprint compared to the normal solar panels and the fabrication process is simple, low-cost and highly scalable.

2. Sample preparation and experiment method

The GO sheets are synthesized by the chemical reduction of graphite via a modified Hummers method [3]. The synthesized GO sheets are dispersed by a deionized water/methanol mixture with an optimal ratio of 1:5 to form the homogenous GO solutions. The GO films were prepared by the drop casting method directly on the reverse side of the c-Si solar cells, which have an efficiency of around 17%-18% [4].

Direct patterning of the micro-electrodes in the drop-casted GO film was conducted using the CO_2 continuous wave laser beam at 10.6 µm which results in the photo-thermal reduction of the GO film [5, 6]. The reduced GO regions form micro-electrodes for the supercapacitor. The electrolyte used in this study was an ionogel containing fused silica and ionic liquid [BMIM] [NTF_2]. The schematic of the obtained solar supercapacitor is shown in Fig. 1. (a).

3. Results and Discussions

The performance of the obtained solar supercapacitor depends on the charging efficiency of the solar cell as well as the R-GO film properties like conductivity and the mean ion free path of the electrolyte ions. In our case the patterning of the GO film was done by using a CO_2 commercial laser which is diffraction limited. So we are restricted to obtain micro-electrodes which increase the mean free ion path of electrolyte and result in lower capacitances.

Even with these limitations, we were able to obtain an electrical conductivity of 10^4 S/m for the R-GO film and an areal capacitance in micro-farads calculated from the cyclic voltammetry curve as shown in Fig. 1. (c) with energy and power densities for the supercapacitor around 5µWh cm^{-3} and power density of 4.6 W cm^{-2}. The charge-discharge studies conducted on obtained integrated solar supercapacitors using the solar simulator under the standard illumination of 1000 W/m^2 showed a 62% Columbic efficiency without the degradation in the performance of solar cells (Fig. 1. (b)).

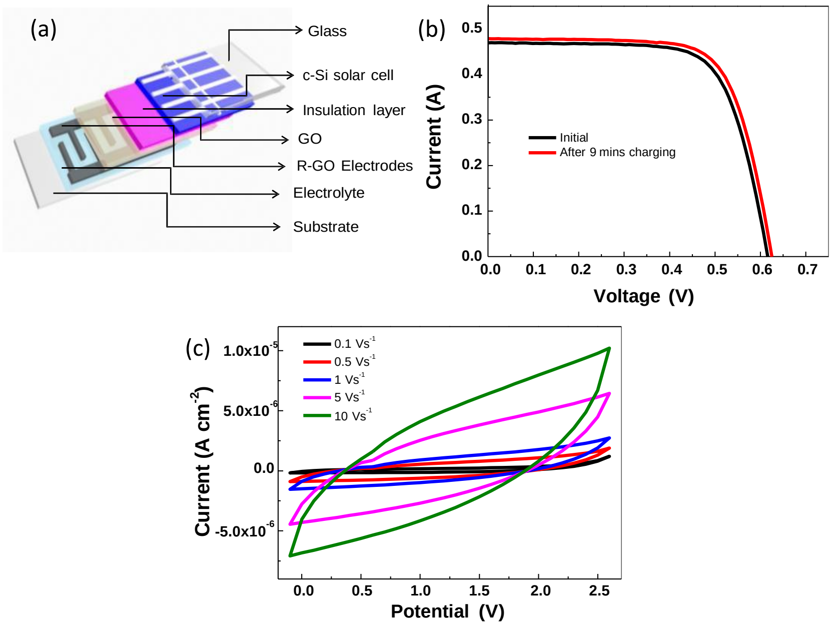

Fig. 1. (a) Schematic of the solar supercapacitors. (b) Performance of the c-Si solar cell before and after the integration of the supercapacitor. (c) Cyclic voltammetry curve of the integrated supercapacitor.

4. Conclusions

In conclusion, solar supercapacitors have been fabricated on the reverse side of silicon solar cells without any degradation in the performance of solar cells and supercapacitors. This concept can lead to the standalone photovoltaic systems.

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