Supporting information

Graphene nanosheets inserted by silver nanoparticles as zero-dimensinal nanospacers for dye sensitized solar cells

Quanhong Chang [a,b], Zhenping Wang [b], Jinzhong Wang *[a], Yuan Yan [a], Zhoujing Ma [b], Jianxiao Zhu [b], Wangzhou Shi [b], Qi Chen [b], Qingjiang Yu[a], Lei Huang*[b]

[a] *Department of Opto-electric Information Materials and Quantum Devices, School of Materials Science and Engineering, Harbin Institute of Technology, 150001 Harbin, China.*

E-mail: jinzhong_wang@hit.edu.cn (J. Wang).

Tel.: +86 451 86418745; fax: +86 451 86418745.

[b] *Joint Lab with Wuhu Token for Graphene Electrical Materials and Application, Department of Physics, Shanghai Normal University, Guilin Road 100, Shanghai 200234, China.*

E-mail: leihuang@shnu.edu.cn; elhuang68@yahoo.com.sg;

Tel.: +86 21 6432 8968; Fax: +86 21 6432 8968.

(*[a]Corresponding Author: jinzhong_wang@hit.edu.cn)

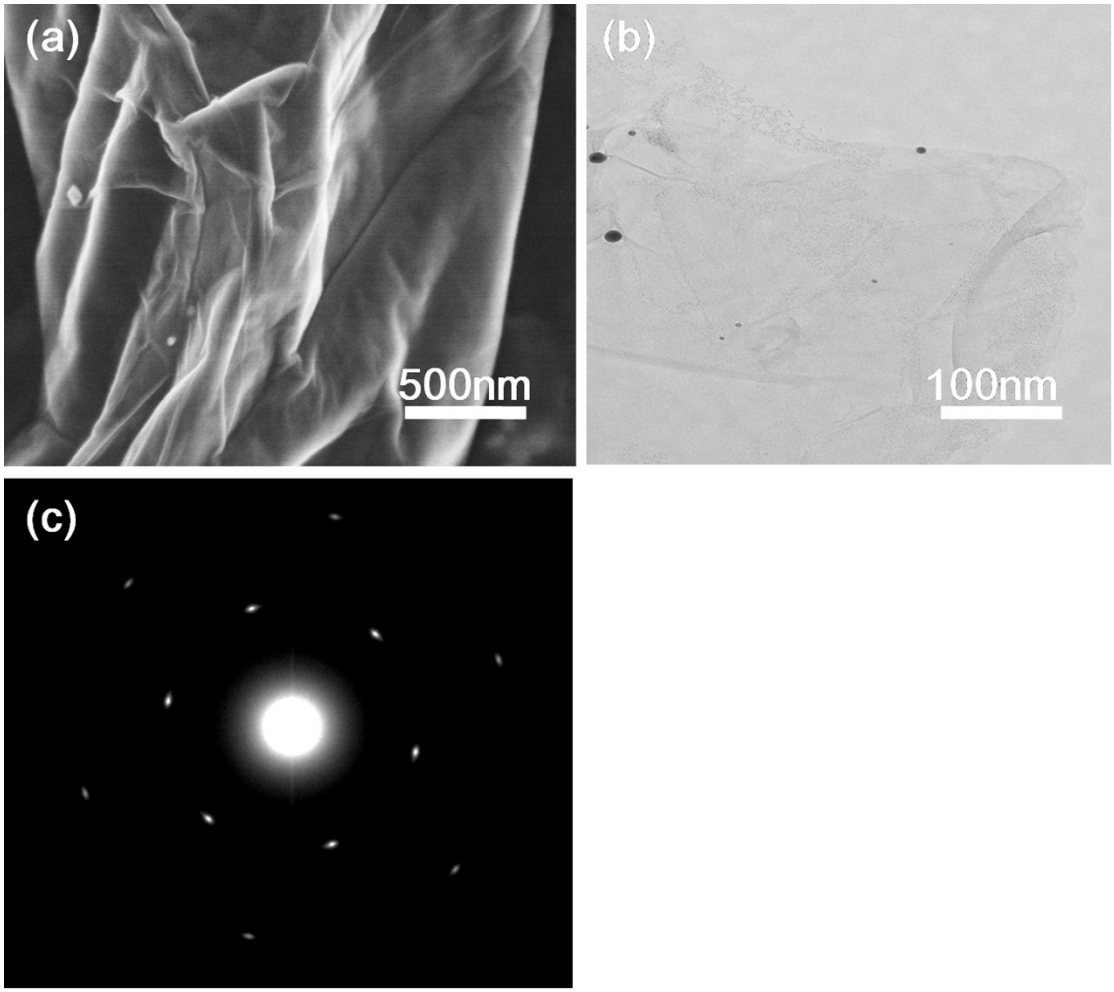

Figure S1. (a) SEM image of the fresh GNs produced by the laser reduction. (b) high-magnification TEM image of the GNs. (c) The SAED pattern of the GNs.

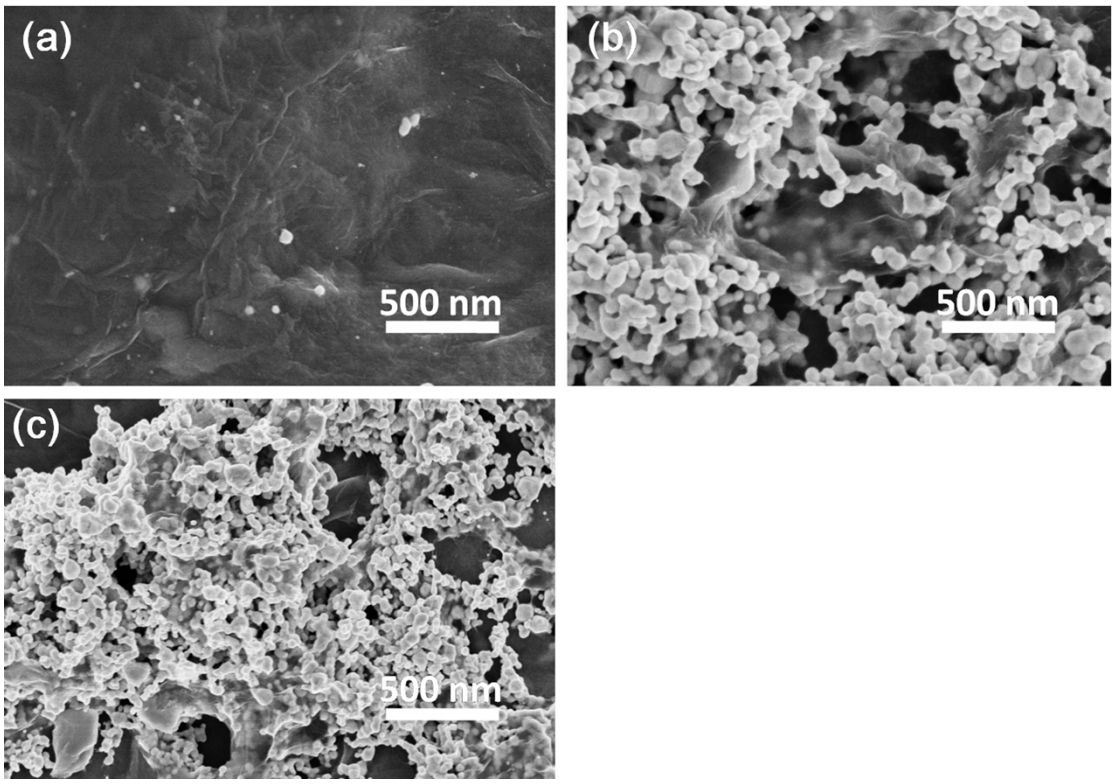

Figure S2. The SEM images of Ag/GNs hybrids with the different concentration of Ag nanoparticles.

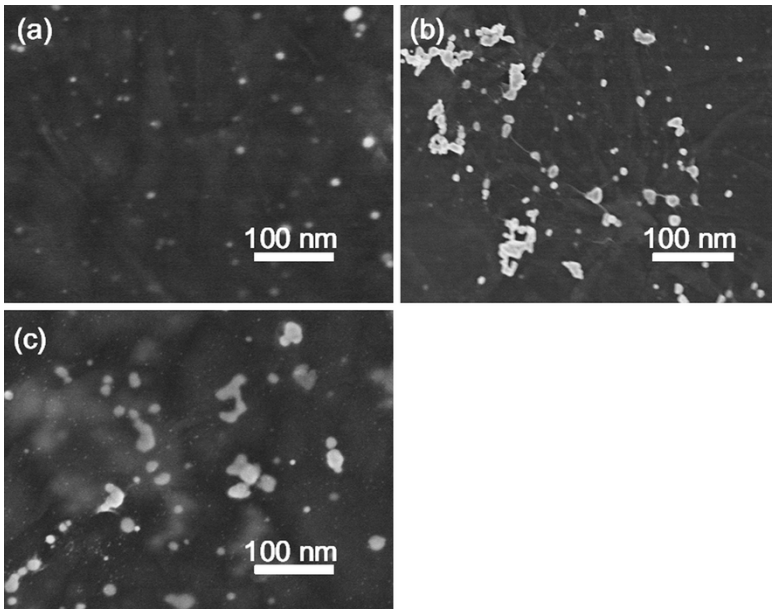

Figure S3. The SEM images of the Ag nanoparticles with different size.

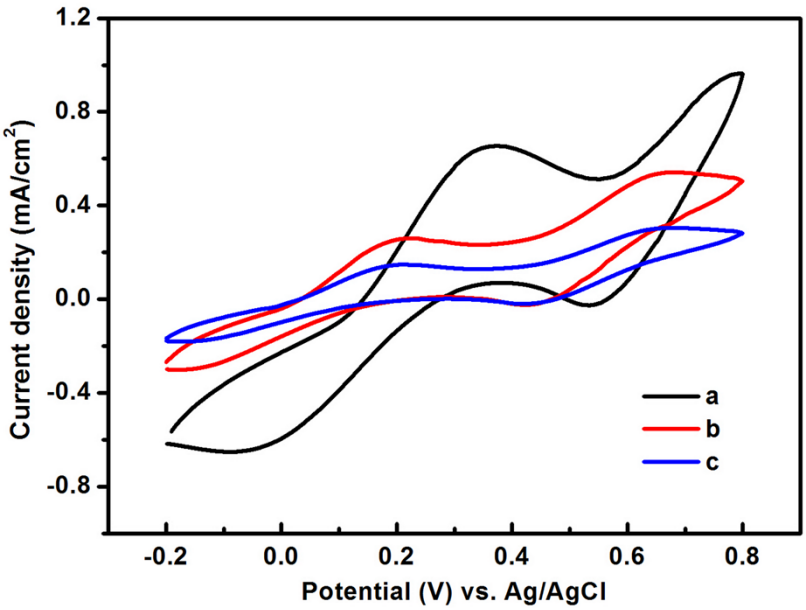

Figure S4. The CV curves of the Ag/GNs with different size of Ag nanoparticles in Figure S3,(a) ~8 nm, (b) ~20 nm and (c) ~30 nm.

It was clearly observed from the Figure S3 that the morphology of Ag nanoparticles due to their different size was relatively obvious. As exhibited in Figure S3a, the Ag nanoparticles with small size can be

easily dispersed and inserted into both sides of the GNs. However, when the size of Ag nanoparticles increases into 20-30 nm (Figure S3b and S3c), they would mainly aggregate on the outer surface of the GNs. Meanwhile, the effect on the performance of Ag/GNs hybrids due to the size of Ag nanoparticles could be reflected in the electrocatalytic activity, as shown in Figure S3. In comparison to the Ag/GNs hybrids with large size of Ag nanoparticles, the Ag/GNs hybrids with small size Ag nanoparticles shows higher electrocatalytic current density, indicating that small size Ag nanoparticles serve as zero-dimensional nanospacers inserting into GNs to lift the interspacing layer between individual GNs.

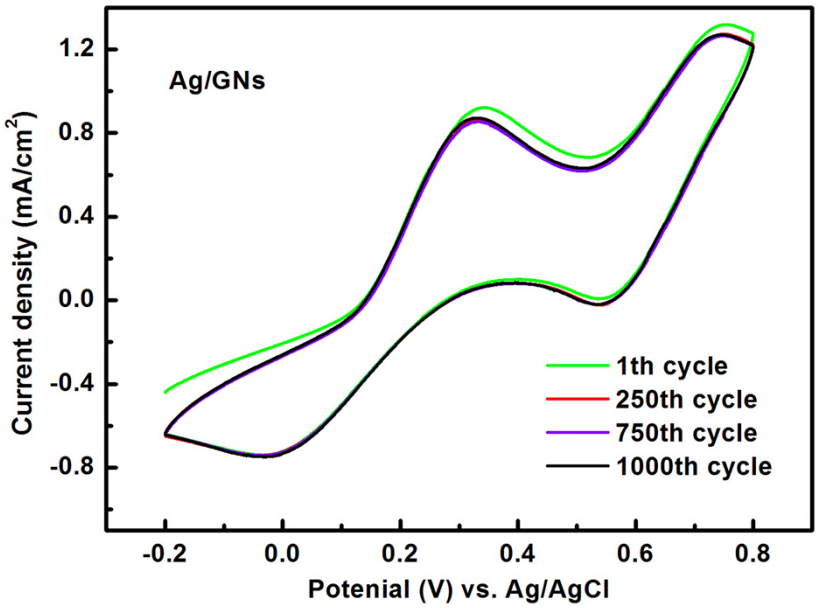

Figure S5. Continuous CV of Ag/GNs in I_3^-/I^- electrolytes at a scanning rate of 50 mV/s from -0.2 V to 0.8 V.

Furthermore, Ag/GNs CE show an excellent stability of electrocatalytic activity, as proved by the continuous cyclic voltammetry experiment. No

decrease in the current density of the redox processes at the Ag/GNs nanohybrid films CE was observed after the 1000th cycle.

Table 1 Long term stability of DSSC cells with a CE of Ag/GNs.

Ag/GNs for DSSC	J_{SC}/mA cm^{-2}	V_{OC}/V	FF/%	η/%
0h	14.67	0.732	72	7.72
200h	14.66	0.731	71	7.60
400h	14.66	0.730	71	7.60
800h	14.63	0.730	70	7.47
1000h	14.60	0.731	71	7.58

To study the durability of the newly prepared Ag/GNs CE for DSSCs, the photovoltaic cell was subjected to light soaking with full solar intensity (100 mW/cm^2) under a solar light simulator (Sun 2000). As shown in Fig. 3b, after 1000 h of light soaking, the DSSC using the Ag/GNs as CE shows an excellent stability with less than 2% drop in efficiency during 1000 h aging, which is consistent with the reported results of a similar Graphene/Pt nanohybrid device structure.[2]

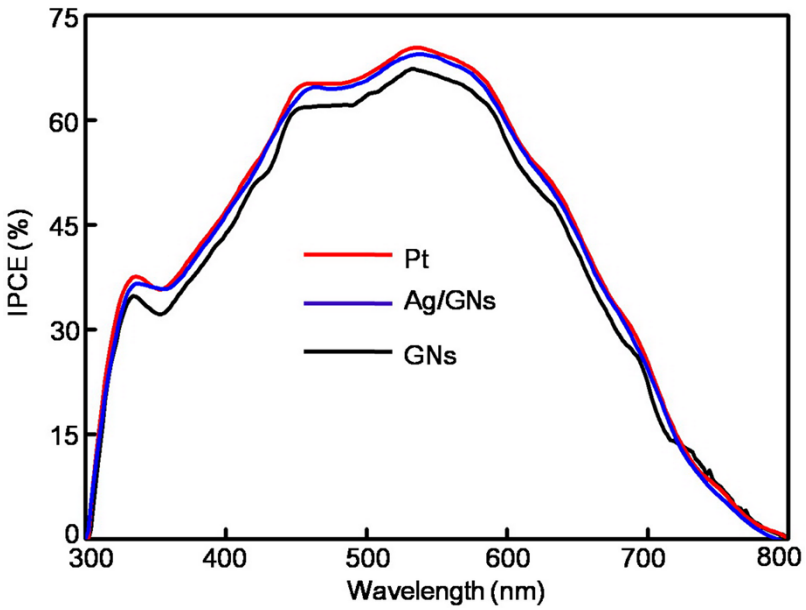

Figure S6. Incident photon to charge carrier efficiency (IPCE) of DSSCs with GNs, Ag/GNs and Pt CEs.

The incident photo-to-current conversion efficiencies (IPCE) were plotted as a function of wavelength from 300 to 800 nm using a QE/IPCE test system (Solar Cell Scan100, Zolix). As shown in Fig. 3d, the Ag/GNs CE and Pt CE exhibit maximum IPCE values of 70.64% and 71.13% at 540 nm, respectively, thus indicating improved performance of the Ag/GNs CE that is comparable to that of Pt CE. Besides, the values in the IPCE curves of the Ag/GNs CE were higher than that of pure GNs CE and show good agreement with the cell performance data.