

Carbon nanostructures as catalysts in dye sensitised solar cells

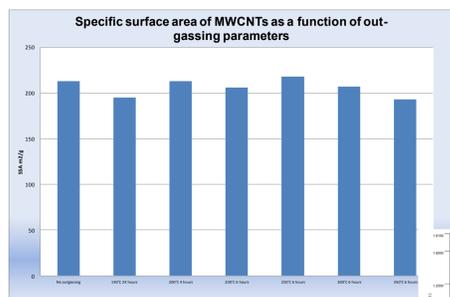
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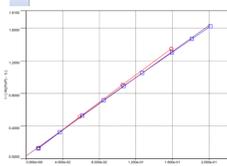
Summary

By using roll to roll production techniques dye sensitised solar cells (DSCs) have the potential to be a low cost alternative to silicon based solar cells. Typically the catalyst of these cells is manufactured from platinum however carbon materials have potential to be more stable than platinum when deposited on flexible substrates using a low temperature deposition method. The catalytic activity and potential for ballistic transport of electrons make carbon nanostructures interesting prospects for use as catalysts. However the industry is in its infancy and theoretical properties have not yet been achieved on material produced in bulk (kilogram) quantities. Specific surface area (SSA) is a useful property to quantify the nanostructures as well as giving an idea of the catalytic activity of the material.

Characterising surface area

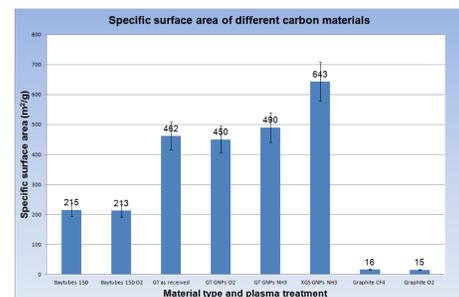


The theoretical surface area of a single sheet of graphene is 2630m²/g. However bulk powders often have many impurities such as amorphous carbon and multilayer flakes. The specific surface area was measured with a NOVA analyser which measures the nitrogen adsorption at 77K. Degassing was shown to be unnecessary due to the hydrophobic nature of carbon nanoparticles, however in the interests of good practice all samples were degassed at 200°C for 4 hours.



$$\text{The governing BET equation is: } \frac{p/p_0}{V(1-p/p_0)} = \frac{1}{V_m c} + \frac{c-1}{V_m c} \frac{p}{p_0}$$

Where V_m is the volume occupied by monolayer coverage of the nitrogen molecule. From this the SSA can be calculated.



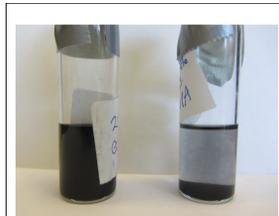
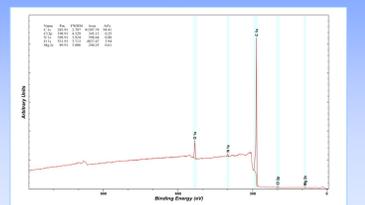
Adding functional groups

Literature has shown that the addition of functional groups (oxygen and fluorine) to graphene can improve its performance as a counter electrode in DSSCs. The mechanism is likely to be due to the functional groups creating extra sites for the catalytic reaction.

Haydale HDPlas low frequency, low pressure cold plasma is used to introduce functional groups. Functional groups added depend upon the plasma gas used but there is some oxygen contamination

Functionalisation improves the dispersion of carbon nanomaterials without the need for surfactants. Functional groups decrease the density of the powder but do not increase the SSA. The presence of oxygen reduces the conductivity of the graphene so this must be balanced with any increase in catalytic activity.

XPS data from graphene technologies material after ammonia plasma treatment



Left jar: functionalised graphene in IPA
Right jar: unfunctionalised graphene in IPA

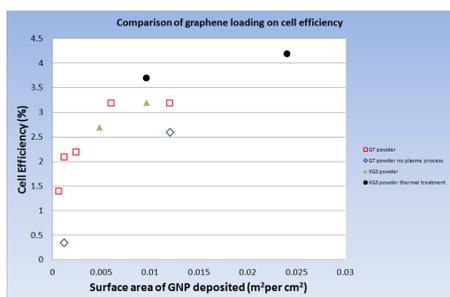


Catalyst printing trials

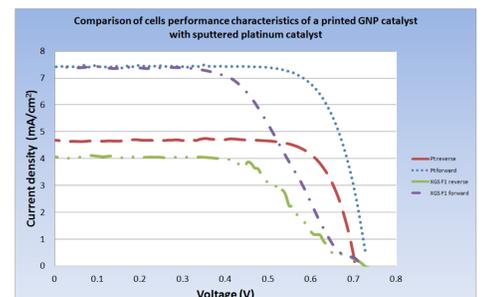
DSCs were manufactured with a TiO₂ nano-particle active electrode, dyed with ruthenium dye. The TiO₂ was coated onto fluorine doped tin oxide (FTO) glass. Graphene counter electrodes made by drop casting suspensions of GT and XGS graphene nanoplatelets (GNPs) onto FTO glass at room temperature. The two substrates were sandwiched together with a Surlyn spacer and then the iodine redox mediator was introduced before final sealing.

The L.H. graph demonstrates a good correlation between surface area loading and cell efficiency. High surface area GNPs (XGS material) have the most potential for transparent applications because they require less loading by mass compared with lower surface area GNPs (GT material) to achieve the same effect. Carboxymethylcellulose was used as the binder in an XGS GNP ink. This ink was printed using an IGT F1 printability tester onto 50Ohm/□ indium tin oxide polyethylene terephthalate (ITO PET) substrate and made into cells, by the same method as above. Comparative cells were made by sputtering a 2nm layer of platinum onto 50Ohm/□ ITO PET substrate.

Tests were performed using a Sol3A solar simulator at 1sun illumination, 1.5 air mass index and 25°C



GNP catalyst printed using an IGT F1 printability tester



Catalyst	Illumination	Voc (V)	Jsc (mA per cm ²)	Fill Factor	Efficiency %
XGS ink	forward	0.73	7.4	54	2.9
Pt sputtered	forward	0.73	7.4	75	4.1
XGS ink	reverse	0.73	4.1	66	2.0
Pt sputtered	reverse	0.71	4.6	78	2.6

Conclusions

- Flexible electrodes with a printed GNP catalyst achieved 77% of the efficiency of sputtered platinum.
- First printed GNP cells suitable for a reverse illumination cell architecture
- 1cm² cells tested—larger than any literature cells with a GNP catalytic layer.

Further work

- Investigate ink rheology and plate design to improve the performance of the printed GNP catalyst.
- Model the charge transfer resistance of printed GNP catalysts.