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Fabrication of a counter electrode using glucose as carbon material for dye sensitized solar cells

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ABSTRACT

Carbon material was produced from the graphitization of glucose at high temperature in flowing argon. The produced carbon material was characterized using Scanning electron microscopy, Transmission electron microscopy, Raman spectroscopy and XRD. Carbon slurry of the produced carbon was made in ethanol by using polyvinylpyrrolidone (PVP) as surfactant. Carbon slurry was coated homogeneously on fluorine doped tin oxide (FTO) glass by a doctor blade technique and applied as counter electrode for dye synthesized solar cell. The current density (J) and open circuit voltage (V_{OC}) of fabricated cell was 8.30 mA cm^{-2} and 0.77 V respectively. The efficiency of the cell was 3.63%, which is comparable to 5.82% of cell with platinum counter electrode under the same experimental conditions.

1. Introduction

Dye sensitized solar cells (DSSCs) have attracted much attention due to ease of fabrication, low cost and high conversion efficiency [1–2]. The DSSCs consists of a dye sensitized TiO_2 nanocrystalline electrode, liquid electrolyte acts as a redox couple, counter electrode which collects the electrons arriving from the external circuit and catalyze the I_3^-/I^- redox-coupled regeneration reaction in electrolyte [3]. Platinum is the commonly used material to fabricate the counter electrode for DSSCs due to its high catalytic activity [4] but high cost of this material is the major issue. A lot of research is going on to replace the platinum by other alternatives like carbon materials, conducting polymers, inorganic materials, multiple compounds and composites to fabricate the counter electrodes for DSSCs [5–7]. These materials also have good performances in DSSCs.

Among all the materials carbon materials (carbon black, graphite, carbon nanotubes, graphene etc.) have been studied by many researchers [8–14] as a promising alternatives to substitute the Pt for DSSCs due to their high conductivity, easy fabrication and good catalytic activity. In this work, we report the fabrication of carbon material produced from the graphitization of glucose at high temperature in flowing argon. Carbon slurry was made by using produced carbon material with PVP and carbon film was coated on FTO glass substrate by the doctor blade technique for the fabrication of counter electrode used in DSSCs.

2. Experimental details

2.1. Materials and methods

Carbon material was produced from the graphitization of glucose (Glucon-D, Heinz) (5 g) at high temperature (1400° C) in flowing argon. Carbon slurry from produced carbon was prepared as follows, PVP (K-32, Sigma-Aldrich) (0.12 gm) solution was prepared in ethanol (10 ml), carbon

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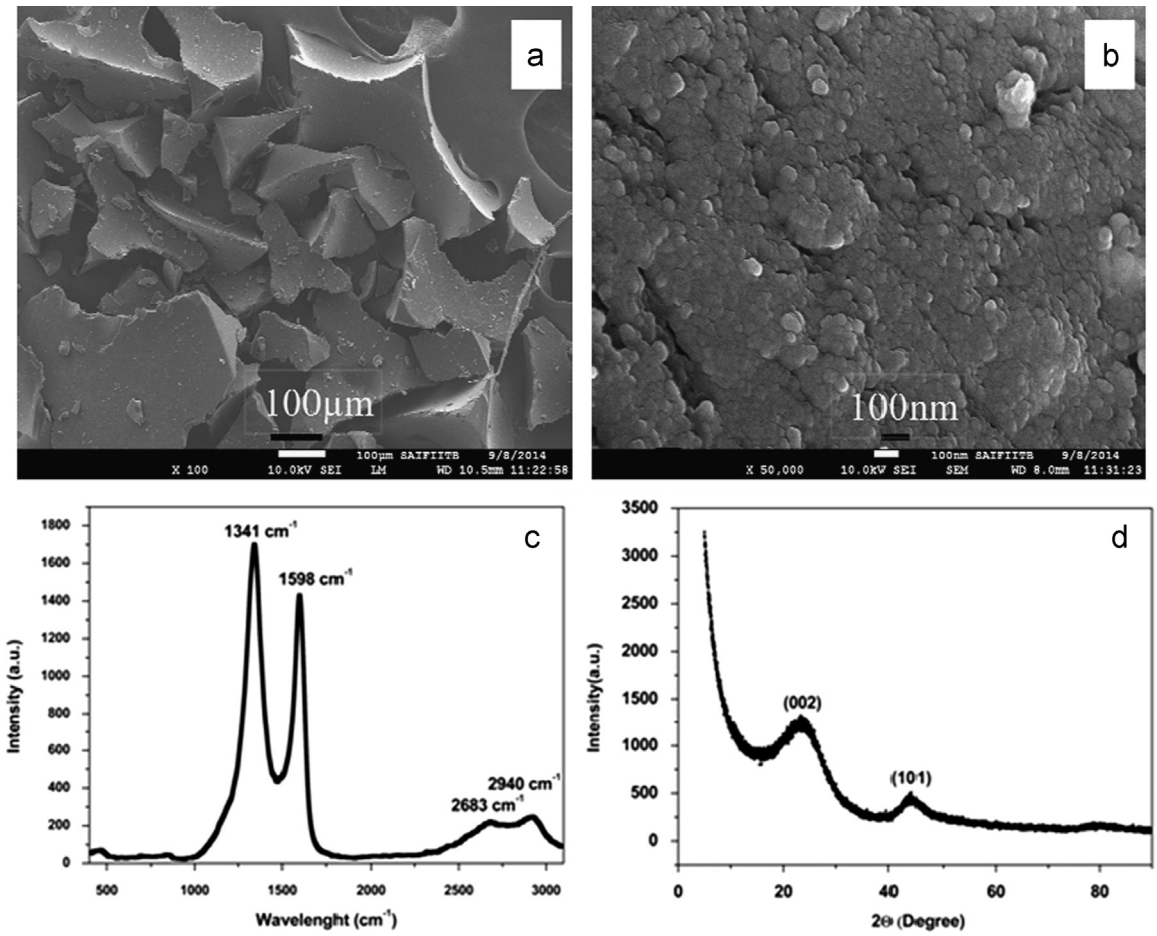

Fig. 1. FEG-SEM micrographs (a) at low magnification and (b) at high magnification, Raman Spectroscopy (c), XRD pattern (d) of the carbon produced from the graphitization of glucose at 1400 °C.

(1 g) was crushed in a mortar pestle to make it finer was added to the PVP solution and this mixture was kept on pot mill for 48 h in order to make a homogeneous slurry by deagglomeration of powder. To measure the particle size of the produced carbon, carbon slurry was diluted by ethanol to make the diluted carbon solution and put in a sonicator for 15 min to reduce the agglomerates. Diluted carbon solution was also used for FEG-TEM characterization. This solution was put on carbon grid and dried under a UV lamp for characterization. Counter electrode was made by coating the slurry on FTO-glass substrate (TEC8, sheet resistance 8–9 $\Omega\,\square^{-1}$ Pilkington) by the doctor blade technique. Scotch tape (3 M) was used to coat on the desired area. The counter electrode was kept in furnace at 450 °C for 1 h in flowing argon in order to burn out the binder. Sputter deposited platinum on FTO glass was also used as counter electrode to fabricate the cell. Titania slurry used for fabricating photoanodes was prepared by roller milling TiO_2 nanopowder (P25, Degussa), PEG 600 (Thomas Baker) and ethanol for 24 h. The slurry was then coated onto the cleaned FTO-glass substrates and sintering was carried out at 450 °C for 1 h. Then the electrodes were cooled to 80 °C and dipped into a 0.3 mM solution of N3 (Dyesol) dye in ethanol. After 24 h, the electrodes were taken out of the dye solution, rinsed with ethanol and dried. An electrolyte used in the DSSCs was prepared by mixing 1-Methyl-3-propylimidazolium iodide [PMII] ($\geq$98% Aldrich) (0.60 M), iodine (LR, Thomas Baker) [I2] (0.03 M), guanidinium thiocyanate (0. 10 M) and 4-tert-butylpyridine (0.50 M) [TBP] (96% Aldrich) in the mixture of acetonitrile and valeronitrile (volume ratio: 85:15). The solution was stirred by magnetic stirring for 30 min [15]. Cell was fabricated using electrolyte, electrodes and spacer. To seal both the electrodes together, a 25 µm spacer (SX1170-25PF, Solaronix) was used and the assembly was heated at 115 °C for 15 min. The active area of each cell was 0.25 cm^2.

2.2. Characterization

The produced carbon from the graphitization of glucose at 1400 °C was independently characterized by FEG-SEM (JEOL,JSM-7600F), FEG-TEM (JEOL,JEM-2100F), BET (Smart Sorb 92/93, Smart Instruments Co.), DLS(Beckman Coulter, Delsa Nano-C particle analyzer), XRD measurement was performed with the scan rate of 20°/min with Cu-Kα source (Expert Pro, 40 kV,30 mA, Panalytical) and Raman spectroscopy measurement was performed with the scan