Materials Research Bulletin 94 (2017) 399–407

Contents lists available at ScienceDirect

Materials Research Bulletin

journal homepage: www.elsevier.com/locate/matresbu

Nitrogen doped carbon quantum dots as a green luminescent sensitizer to functionalize ZnO nanoparticles for enhanced photovoltaic conversion devices

Rama Krishna Chava*, Younghwan Im, Misook Kang*

Department of Chemistry, College of Natural Science, Yeungnam University, 280 Daehak-Ro, Gyeongsan, Gyeongbuk 38541, Republic of Korea

ARTICLE INFO

Article history:
Received 4 May 2017
Received in revised form 27 June 2017
Accepted 27 June 2017
Available online 1 July 2017

Keywords:
A. Nanostructures
A. Semiconductors
B. Chemical synthesis
B. Luminescence
C. Photoelectron spectroscopy
C. Transmission electron microscopy(TEM)

ABSTRACT

A simple and facile hydrothermal approach for the synthesis of highly green luminescent nitrogen doped carbon quantum dots (NCQDs) is reported. The prepared NCQDs show narrow size distribution of 2–3 nm, abundant surface functional groups and good water solubility. To showcase the potential of these NCQDs as a solar light harvesting material, we designed NCQDs sensitized ZnO nanoparticles based photoanodes for photovoltaic solar cells. As a result, NCQDs sensitized ZnO photoanodes exhibited 75% higher photoconversion efficiency when compared to that of bare ZnO photoanodes. The characterization and optical properties of NCQDs sensitized ZnO photoanodes is also discussed.

1. Introduction

To meet the increasing demand of clean energy, the harvesting of electricity from solar energy at economically feasible cost with high efficiency is needed [1–3]. Quantum dot sensitized solar cells (QDSCs) are expected to play an important role in this revolution due to their potential in exceeding the Shockley–Queissar limit, their size-tuned optical response, and their efficient multiple carrier generation [4,5]. The important issues in the semiconductor QDSCs are their toxicity, durability and also the poor effective charge separation [6]. So an alternative to these toxic semiconductor-based QDs, currently an extensive work has been in progress to obtain non-toxic QDs for their use in QDSCs. The accidental discovery of carbon quantum dots (CQDs) [7] through the purification of single walled carbon nanotubes, have become a prominent new member in the nanocarbon family [8–10]. Due to the structural and quantum confinement effects, CQDs are attracting great interest towards many applications in the fields of bio-imaging [11], drug delivery [12,13], sensors [14], and photocatalysis [15–17] due to their exceptional properties such as high intense photoluminescence (PL), high photo stability and biocompatibility. Usually CQDs are discrete and quasi-spherical shaped NPs with sizes below 10 nm [18]. In comparison to traditional organic dyes and QDs, CQDs have number of benefits such as low cost, low toxicity, biocompatibility, tunable fluorescence emissions, photoresistance, and chemical inertness [19–21]. After the first report on CQDs based photocatalysts by Li's group [22], the importance of CQDs in photocatalysis has been increased exponentially as catalysts and co-catalysts. Commonly the CQDs show a good photocatalytic performance which is directly connected to their optical/PL properties. The PL emission is produced by sp^2 clusters isolated by sp^3 networks in the CQDs [23,24]. Therefore, CQDs have a great potential to replace semiconductor QDs. Doping is an effective strategy to adjust the intrinsic and optical properties of CQDs, leading to improve the performance of solar energy conversion devices. Nitrogen doping has been reported to improve the optical properties and it can lower the work function of CQDs which in turn increased the photocatalytic performance [25–27].

Because of good stability and low cost materials, nanostructured oxides have been extensively studied as photoanodes in solar energy conversion devices. As a representative nanostructured metal oxide, ZnO has been widely studied because of its high electron mobility, photosensitivity and biocompatibility which can be used in many applications [28–32]. The metal oxides alone have high bandgap energies, which limit the visible light absorption resulting a low performance in the solar energy conversion

* Corresponding authors.
E-mail addresses: drcrkphysics@hotmail.com (R.K. Chava), mskang@ynu.ac.kr (M. Kang).

http://dx.doi.org/10.1016/j.materresbull.2017.06.040
0025-5408/