Study of Photoconductivity in Carbon Nanodots Synthesized by Laser Induced Fragmentation of Graphite Powder Suspended in Water

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Abstract
Carbon nanodots (CNDs) have been synthesized by laser induced fragmentation of graphite powder in deionized water. The TEM image shows formation of oval like structure of CNDs. Diameter of the CNDs lies in the range of 30 - 100 nm. The Photoconducting properties of synthesized CNDs have been studied under UV- visible illumination. CNDs exhibit anomalous behavior of photocurrent wherein the photocurrent decreases even under steady illumination. Negative photoconductivity is also observed in CNDs. CNDs have potential future applications in optoelectronic devices and as UV-vis photodetectors.

Keywods: Fragmentation, CNDs, TEM, Graphite.
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Introduction

Carbon is one of the most intensively studied materials in the field of physics as it is a diverse element which can form bonds to a huge range of other compounds such as N, S, O, Cl, Br and P in form of single, double or triple bonds to other atoms. In the past few decades, there has been an explosion of interest in area of nano materials due to their unique optical, electronic, and magnetic properties. Carbon nanoparticles have also got attention of research community as carbon nanoparticles are small in size, readily water soluble, low toxic, having low macular weight, eco friendly and favorable to biocompatibility [1–5]. Carbon nanodots (CNDs), quasi spherical carbon nano particles, are found to exhibit size dependent optical and electronic properties. Carbon nano dots have recently attracted wide attention is because of their strong fluorescence, for which they are referred to as fluorescent carbon. CNDs are also good candidates for replacing semiconductor quantum dots because they are superior to them in terms of chemical inertness, stability, toxicity, cost, green synthesis, functionalization and biocompatibility.

CNDs are having applications in field of biological labeling, life sciences, bio-imaging, drug delivery, chemical sensing

and other different optoelectronic device application **[6–21].** Various forms of carbon nano particles such as nano-tubes, fullerenes, graphene, nano fibers, nano diamonds [24–37] etc. are synthesized using different synthesis methods such as laser ablation method, electrochemical oxidation method, chemical oxidation method, thermolysis method, micro assisted method, micro wave hydrothermal method, hydro thermal method **[**38–47] etc. Out of these methods, laser ablation is very efficient physical method for synthesis of nano material [48–50]. This method is green, cheap, easy and versatile for synthesis of various metallic, alloy, semi-conductor, metal oxide and many more nanostructures.

Study of photoconducting properties is considered to be an important tool for providing information regarding the nature of the materials. Photoconducting materials are used in a variety of applications e.g. UV photo-detectors, optical switches, photodiodes, optoelectronic vapor sensors and photovoltaic sensors **[1–10].** Photoconductivity in a materials usually arises as a result of generation of electron - hole pairs in the material after absorption of a photon of suitable energy. Since last few decades, photoconducting properties of inorganic nanoparticles have become subject of intensive study **[17–31]** not only because of fundamental interests in the nature of the electronic excitations but also due to their applications in wide range of optical and electronic devices. Photoconductivity has been extensively studied of a large number of bulk materials. Se, ZnS, ZnO, MgO (in the form of single crystals, thin films, and thick layers) have been studied by several workers (11–18). In addition, a number of studies have also been conducted on the photoconductivity in nanoparticles (NPs), nano rods, and nanowires of SnS, C, SnO2, WO3, FcH, CdS, ZnS, ZnO, CdO and CdSe (19–28).

In the present work, CNDs are synthesized by laser induced fragmentation of graphite powder suspended in water and have been studied for their photoconducting properties.

Experimental

The Graphite powder was mixed in the double deionized water and stirred continuously in a glass tube. An Nd: YAG laser (Spectra Physics, USA) with 1064 nm wavelength, operated at 35 mJ/pulse energy, 10 ns pulse width and 10 Hz repetition rate was focused to a spot size of 200 µm at the centre of the glass tube using 25 cm focal length of quartz lens for 60 minutes. The colloidal suspension of material obtained after ablation has been used for further characterization.

A drop from colloidal solution of nanoparticles was placed on a carbon coated copper grid and was dried for Transmission Electron Microscopy (TEM) analysis. The UV-visible absorption spectrum of synthesized colloidal solution of nanoparticles was obtained by using Perkin Elmer Lambda 35 double beam spectrophotometer. Photoconductivity was

measured with help of a cell type device. The direction of illumination is normal to field across the electrodes. The cell was mounted in a dark chamber with a slit where from the light is allowed to fall over the cell. An Hg-bulb of 300W was used as a photo-excitation source. A stabilized dc field was applied across the cell to which a digital dc nano-ammeter, NM-121 (Scientific Equipment, Roorkee) for the measurement of current and RISH Multi 15S with adapter RISH Multi SI 232 were connected in series. All the measurements were performed at room temperature.

Results and Discussion

Fig. 1 shows the UV-visible absorption spectrum of CNDs synthesized by laser induced fragmentation of graphite powder suspended in water. It is observed from the UV-visible absorption spectrum that absorption peak is at 272 nm lying in the absorption band 250-300 nm. A similar result has been reported earlier by several authors [56-59]. Hu et al. has also reported the absorption spectrum band at 300 nm [60].

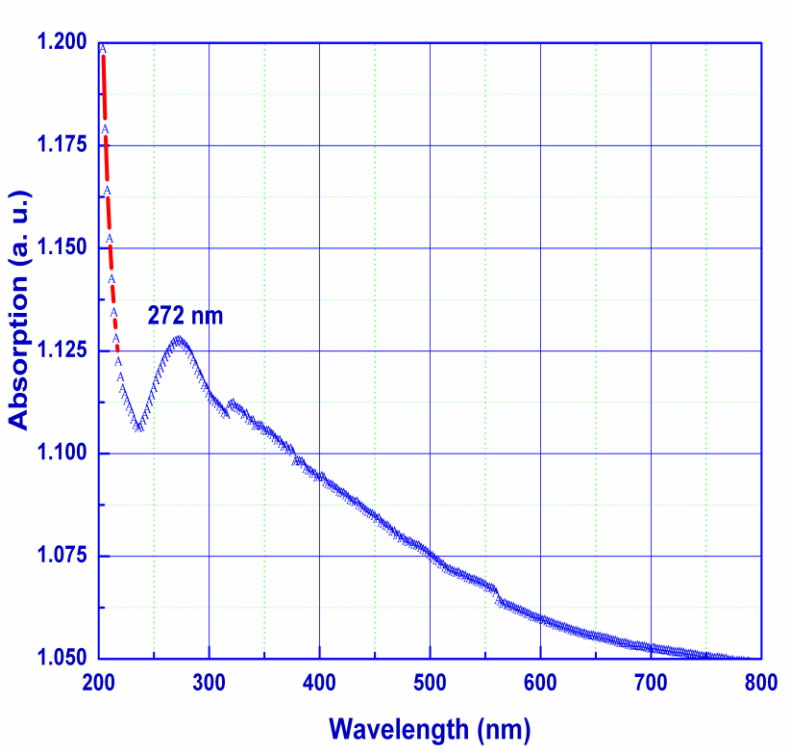

Figure 1: UV–visible absorption spectrum of CNDs synthesized by laser induced fragmentation method.

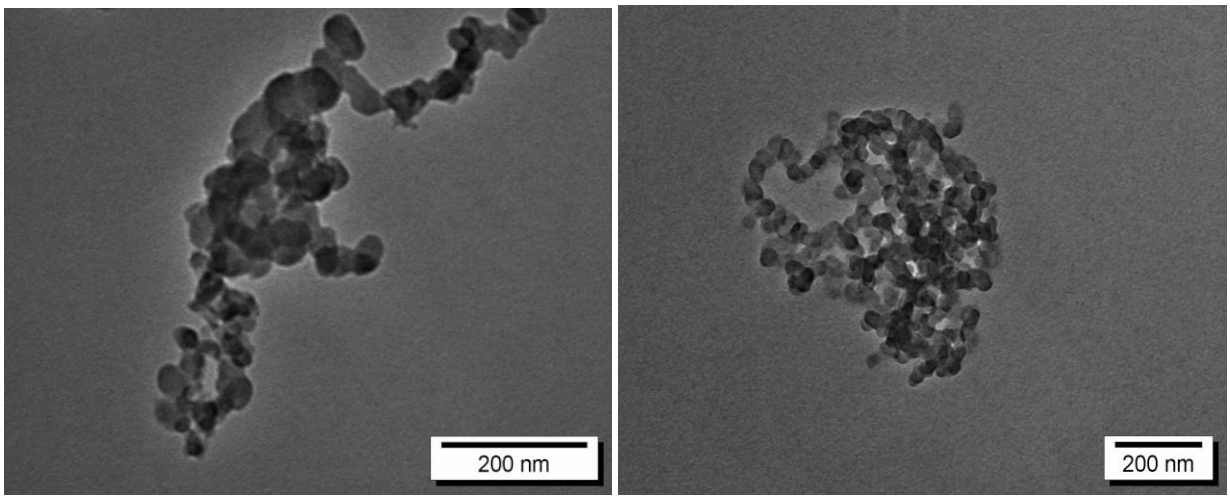

Figure 2: TEM image of CNDs at 200 scale

Fig. 2 shows TEM images of CNDs synthesized by laser induced **f**ragmentation of graphite powder suspended in water. TEM image shows the oval like structure of CNDs. The particle size calculated from TEM image lies in the range of 30 to 100 nm.

Rise and Decay

Variation of current in CNDs as a function of time under UV-visible illumination in air is shown in Fig. 3 In dark, when voltage is applied across the cell, the current starts increasing and settles to a saturated value of 60 nA. When the light is switched on, the photocurrent sharply increases to a peak value of 71 nA. Later, the photocurrent decreases continuously even during steady illumination and settled to a value 2 nA lower than the saturated value of dark current. Such kind of negative photoconductivity has been reported by Lians Peng et al. in cobalt doped zinc oxide nanobelts (61). When the light is switched off, a reverse process is observed where in the current first falls sharply and then, similar to dark current, it increases slowly to attain a saturated value of 34 nA. However, saturated value cannot recover to the original dark current level of 60 nA. The increase in dark current may be attributed to the field induced desorption of O_2 molecules on the surface of CNDs (62-63). Sharp increase in the photocurrent, when the light is switched on is due to fast process of generation of electron-hole pairs as a result of absorption of UV-visible photons. The anomalous behavior of photocurrent in CNDs wherein the photocurrent decreases even during steady illumination may be attributed to light-induced adsorption of O_2 molecules on the surface of CNDs (64-65). The sharp fall in current when is switched off is due to fast process of recombination of electron - hole pairs. Later, the slow process of adsorption of O_2 molecules is supposed to dominate, as a result, the current starts increasing slowly.

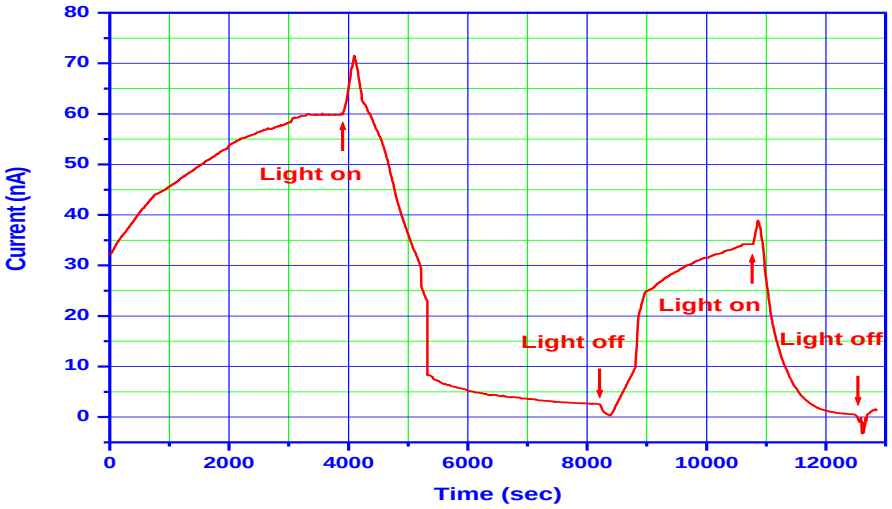

Figure 3: Rise and decay of CNDs synthesized by laser induced fragmentation method

Conclusions

CNDs have been synthesized by laser induced fragmentation of graphite powder suspended in water. The UV-visible absorption spectrum of synthesized CNDs exhibits absorption peak at 272 nm within broad absorption band of 250 to 300 nm. TEM image shows oval like structure of CNDs and particle size calculated from TEM lies in the range of 30 to 100 nm. CNDs exhibit negative photoconductivity under UV-visible illumination in air.

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