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Amorphous semi conducting carbon thin films from Castor oil

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ABSTRACT

Carbon thin films of n-type semi conducting nature were prepared by spray pyrolysis technique using castor oil as a natural α-carbon precursor.The obtained films were uniform,pinhole free and strongly adherent to the quartz substrates. Studies dealing with the temperature dependence of conductivity revealed the semi conducting nature of the films and Hall measurements indicated the n-type conduction.The low band gap (1.03eV) and semi-conducting nature of these amorphous carbon thin films indicated the future scope of low-cost and high efficiency carbon PV solar cells.

Key words: Carbon; Semiconductors; Thin films; Photovoltaic solar cells.

INTRODUCTION

Besides the crystalline forms, amorphous form of carbon has been found to be having a lot of technological applications**.** The properties of these amorphous carbons sensitively depend on the relative concentration of sp3 and sp2 hybridized carbons. The resulting amorphous materials are variously referred to as tetrahedral amorphous carbon (tα-C), amorphous conducting carbon (α-C), hydrogenated amorphous carbon (α-C: H), amorphous conducting carbon (α-CC), etc.

Research efforts toward the fabrication of carbon based devices are growing rapidly.[1-3] Carbon has attracted much attention as an environmentally benign and cheap optoelectric device material over amorphous Si due to several reasons viz- cheap, chemically inert and optically stable. There is growing interest in amorphous carbon (α-C) and hydrogenated amorphous carbon (α-C: H) thin films because of their well known outstanding properties and especially due to the feasibility of band gap engineering over a wide range, from insulated diamond (5.5 eV) to that of metallic graphite (0.00eV). Application of carbon, in the form of α-C,α-C:H and C_{60} as a semi conduction PV solar cells is attempted, though rather limited till date.[4-7] The α-C and α-C:H thin films are prepared by various methods. The properties of these thin films strongly depend on the precursor material and methods of deposition. H in α-C thin films modifies their properties and introduces many sp^3 sites causing an increase in the optical band gap.[8]

Recently M.Sheron [9-12] et al. have reported organic materials possessing C-atoms with sp^2 and sp^3 both configurations can be most suitable precursors for producing carbonaceous thin films for their application in solar cells. They synthesized various forms of carbon by the simple pyrolysis of camphor [13] and kerosene [6] in a completely hydrogen free atmosphere without using any catalyst. Along the same line we thought that turpentine oil[14] and castor oil might be useful precursor for preparing thin films of carbon. This research article reports the results of our efforts

made in this direction and describes the structural, optical and electrical properties of conducting carbon thin films prepared from the pyrolysis of oil of turpentine, a natural α-carbon precursor. Amorphous quartz substrates were used, as they are convenient for the mentioned studies. The pyrolysis technique has been used in the present investigations due to simplicity, low cost and feasibility for a mass production process.

EXPERIMENTAL

Carbon precursor

Castor oil has been used as a source of amorphous carbon thin films. It is supplied by CAS CHEM. Castor oil, also known as ricinus oil, is a triglyceride of fatty acids, which occurs in the seeds of castor plants. It is the only source of an 18 C – hydroxylated fatty acid with one C=C bond. Ricinoleic acid (12-hydroxy 9-octadecinoic acid) comprises approximately 90% of the fatty acid composition. The structure of ricinoleic acid ($C_{18}H_{34}O_3$) is as follows:

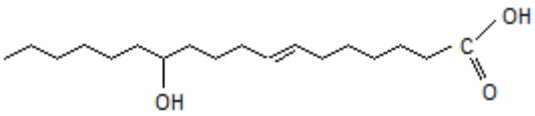

Fig. -1

The structure shows that it consists of both sp^2 and sp^3 hybridized carbons along with H and thus facilitating the band gap engineering of carbon.

Thin film deposition

The experimental parameters used for sample preparation of conducting carbon thin films using castor oil as natural precursor by pyrolysis technique were:

Temperature range- 700-850°C.
Carrier gas- Nitrogen gas.
Distance between spray nozzles to substrate- 10-12 cm.
Deposition period- 4-5 hours.

The conducting thin films were deposited on chemically cleaned quartz substrate. The horizontal experimental setups were made for spraying the precursor. The complete deposition process was carried out in nitrogen gas atmosphere. After the deposition of thin films the samples were left freely inside the quartz tube for different period for sintering. The samples were then taken out and were subjected to different types of characterization and measurement.

The optical and electrical properties of thin films were characterized by band gap measurement, resistivity measurement, Hall measurement and mobility measurement.

RESULTS AND DISCUSSION

The weight difference method was employed for measuring the thickness of the thin films that was found to be 0.12 to 0.0218 ìm for the substrate temperatures 600~850°C respectively. Obviously the film thickness decreases with increase of temperature of substrate, which seems to be due to increase in evaporation rate of initial product before reaching to the substrate.

The electrical resistivity of thin films was studied in the temperature range 25 ~ 500°C in order to exactly locate the donor level and Fermi level of thin film material. It was observed that the electrical resistivity of thin films depends on the time of deposition and temperature range. A number of samples of thin films were studied and observed that increase of temperature decreases the resistivity of the films and vice-versa. The variation of sheet resistivity with temperature for sample V_1 and V_2 are presented in Fig. 2 and 3.

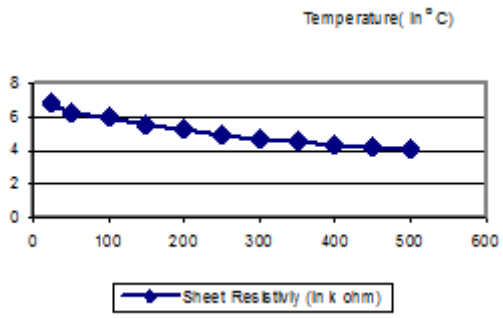

Fig. -2

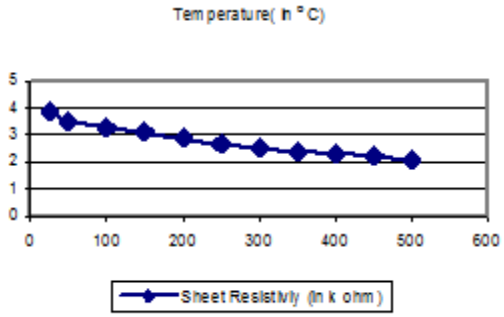

Fig. -3

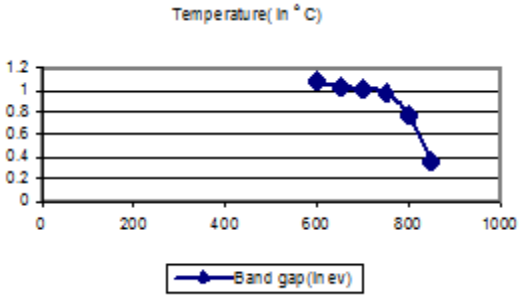

Fig. -4

Raman scattering analyses of the deposited films revealed amorphous nature of the carbon. As-grown conducting carbon films were found to be semi-conducting nature. UV-visible absorbance spectra of the turpentine pyrolysed carbon thin film revealed a direct band gap of 1.03eV. It was also found that band gap is inversely proportional to temperature which also indicates the semi-conducting nature of the thin films (Fig.-4).

Hall coefficient values measured for these films were all negative, suggesting the films to be n-type. The carrier concentration was found in the order of 6.90 x 10^{11} cm^{-3}. Hall mobility of a typical film was calculated to be 1.83 X 10^5 cm^2V^{-1} s^{-1}. Further, the inverse variation of band gap with temperature (Fig. -4) showed the semi conducting and amorphous nature of carbon thin films similar to amorphous Si thin films.

The electrochemical behavior of as-grown conducting carbon films was investigated in various electrolytes at different p^H. The electrochemical window of castor oil carbon electrode in 100 mM H_2SO_4 was found to be 2.83V. Cyclic Volta metric studies revealed that turpentine carbon electrode has tendency towards oxygen evolution, which suggests that it can be used as oxygen electrode more efficiently. Regarding application the studies still under progress.

Conclusion

In conclusion, castor oil may be considered as one of the cheapest precursors for producing high-quality carbon thin films by the pyrolysis technique. The
Carbon thin films obtained from this process may also become one of the best inert electrodes for electrochemical studies.

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