National Conference on 'Advanced Analytical Tools for Materials Characterization' (AATMC-2018)
© 2018 IJSRSET | Volume 5 | Issue 4 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Science and Technology

Study of Glassy Carbon Films Synthesized Using Natural Precursor

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ABSTRACT

Thick films of glassy carbon were synthesized at 800^0 C using natural oil vapour deposition of Pongamia glabra oil. Scanning electron microscopy, X-ray diffraction, and micro-Raman spectroscopic study of the sample showed the disordered graphitic nature of films. Study of magnetic behaviour with hysteresis loop has shown a ferromagnetic nature.

Keywords: Glassy Carbon, Natural Oil Vapour Deposition, Magnetic Behaviour

I. INTRODUCTION

Films of glassy carbon (GC) are an interesting form of disordered carbon, having physical and chemical properties similar to those of diamond like carbon (DLC) [1]. It is a mixture of amorphous and nano crystalline carbon, commonly having sp3 and sp2 chemical bonds. These carbon materials have a variety of potential applications due to their characteristics similar to those of DLC films and additional properties of higher conductivity and thermal resistance than DLC. The physical properties of GC including low density, chemical inertness, closed porosity, thermal stability, electrical conductivity and glass-like isotropic properties allow its application in the aerospace, medical, mechanical, chemical, semiconductor industries [2-10]. As an interesting material, we have performed some magnetic measurement on GC films and reporting the experimental evidences of its ferromagnetic behaviour.

II. METHODS AND MATERIAL

Natural oil of Pongamia glabra seeds was used for synthesis of thick films of glassy carbon with natural oil vapour deposition method. Here, the crude oil of pongamia glabra seed was pyrolised and deposited on quartz substrate at reaction temperature of 800^0 C. Hydrogen was used as carrier gas to carry the oil vapours in the reaction zone of the furnace and deposited as a film. Samples were annealed for 45 minutes in hydrogen atmosphere.

III. RESULTS AND DISCUSSION

Micro-Raman Spectrum of GC film shows three broad peaks at 1356 cm^{-1}, 1600 cm^{-1} and 1930 cm^{-1}. Here, Raman shift Peak located at 1356 cm^{-1} corresponds to sp^3 carbon bond of multi-crystalline graphite[11] and is designated as the D-peak that means disordered[12, 13] allowed zone edge, A_{1g} mode of graphite. Such peak is due to the breathing modes of A_{1g} symmetry involving phonons near the K-zone boundary [13-16]

and has contributions from both highly defective sp^3 carbon and disordered sp^3 carbon. This mode is forbidden in perfect graphite and only becomes active in the presence of disorder r[17] .The second peak at 1600 cm^{-1} is more intense and related to the sp^2 carbon bond, designated as G-peak , zone centre E_{2g} phonon mode at around 1580 cm^{-1} to 1600 cm^{-1}. The peak located at 1930 cm^{-1} of Raman spectra (figure 1), indicates that GC film can have a significant fraction of carbon-carbon *sp* chains and peak assigned to a stretching vibration of the *sp* carbon chain, normally located at about 1900-2000cm^{-1} [18]. The decrease in intensity of this peak may be a result of destruction of sp phase due to its exposure to air [19].

Ratio of intensity of D- peak (I_D) and G-peak (I_G) for film was calculated to be ~ 0.95. This ratio correlates with the in-plane graphite crystallite size La, according to the relationship, $La=4.4I_G/I_D$ (in nm) [13].The calculated value of La is 4.6 nm, implying the microcrystalline graphite planar crystal size is about 4.6 nm in the formed GC film. By using the polynomial equation [20] developed on the basis of data presented in the references [17, 21],

$$sp^3\text{content} = 0.24 - 48.9(\omega G - 0.1580) \qquad (1)$$

Here, unit of ωG has taken as inverse of micrometre unit [22]. Using the shift in G-peak position in the above equation, the changes in sp^3 content in the films can be calculated. In our GC film ~ 15 % of sp^3 type of carbon was found for 1600 cm^{-1}. SEM image of GC film (figure2) shows that the film is made of a continuous amorphous carbon layer.

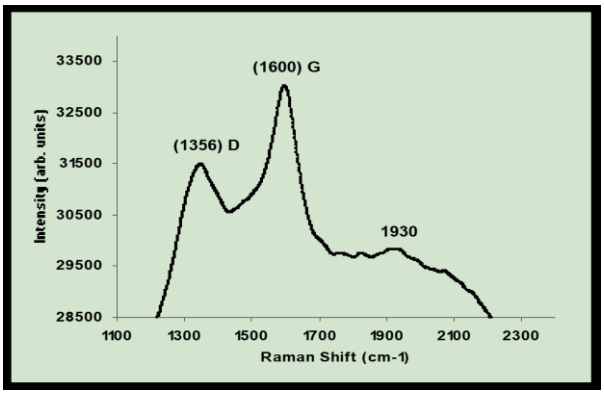

Figure 1 .Raman spectra of GC film

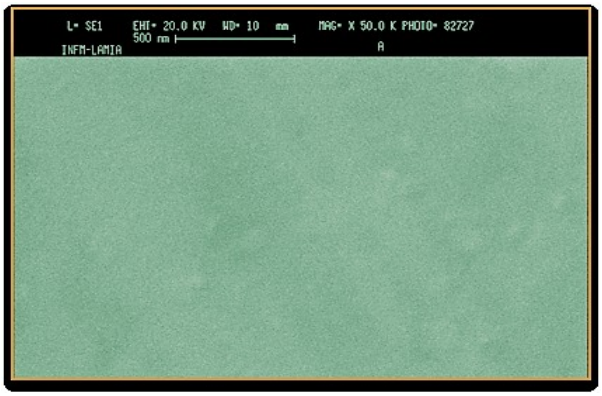

Figure 2. SEM image of GC film

In the XRD data spectrum, which is analogous to the spectrum [3] given by Z. Zeng *etal* for glassy carbon [23], two broad peaks at (002) and (101) was observed. These broad peaks were the indication of a disordered material, where the crystallinity of the sample was far from the crystal material [24].

A hysteresis for the GC film (figure 3) at comparatively low field H=1kOe, clearly gives the evidence of ferromagnetic behaviour. Moreover, the curve asymptotically tends to a quite large positive value possibly due to the presence of ferromagnetic impurities [24].To confirm such ferromagnetic behaviour magnetization hysteresis loops were measured in the field range between -50kOe to +50kOe . A typical ferromagnetic like hysteresis loop was observed for GC films (figure 4) which provides a relation between the magnetization (M) and applied field (H). The saturation magnetization (Ms) was observed ~ 4.4 kOe at 0.000618emu/g. It is a main characteristic of the hysteresis loop, which is normally observed, when all the magnetic moments are aligned along a common direction that results in the largest value of the magnetization.

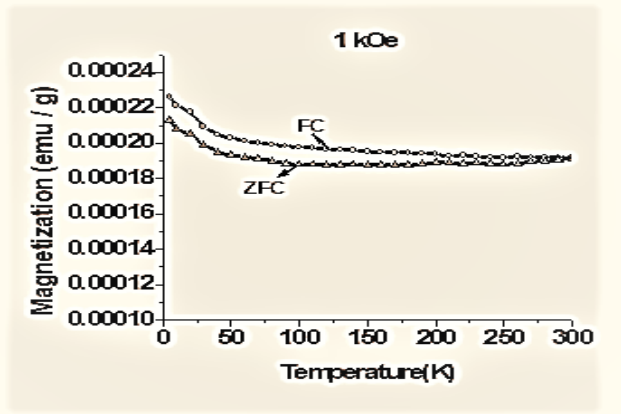

Figure 3. M–T curves for GC film under zero-field-cooling (ZFC) and field cooling (FC)

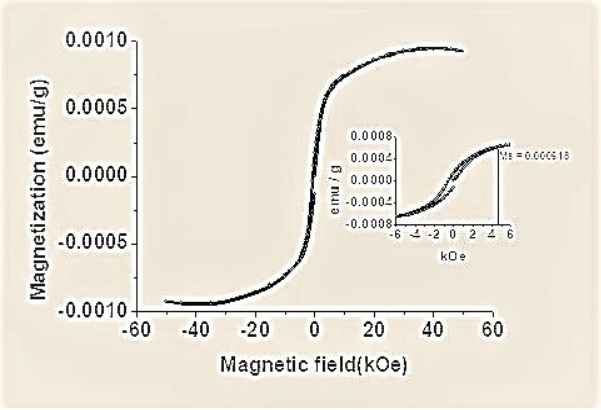

Figure 4. Hysteresis loop for GC films

Remnant magnetization, which is the leftover magnetization, has value 0.000121 emu/g. From the above data of SQUID measurement, it is clear that, the GC films synthesized from Pongamia glabra oil have ferromagnetic property. Here, the ferromagnetism may couple the paramagnetism of common amorphous carbon with some ferromagnetic clusters formed by defects during the formation of film. This possibility is supported by the micro-Raman spectrum of GC film (figure 1), as the film is made of disordered sp^2 and sp^3 network along with some carbon-carbon *sp* state. It means, such ferromagnetic behaviour of material can be ascribed to the structural instability that can coexist during the process of graphitization.

IV. CONCLUSION

Carbon films with glassy surface can synthesized from pongamia glabra oil by vapour deposition method. Study of its morphology as well as reasonable magnetic response reveals occurrence of ferromagnetic response in accordance with applied field, if we take into account that the structural changes have a great impact on this magnetic behaviour evolution. However, further study is necessary to explain the magnetic behaviour of such films.

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