Surface Characterization of C_{60} Thin Film Induced By DC Glow Discharge Plasma

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Abstract: ***The work presented in this paper concerns surface modification of C_{60} thin film induced by DC glow discharge, low-pressure air plasma. To identify the chemical bond and structure of surface modified C_{60} thin film have been studied by FTIR spectroscopy. The carried out IR spectroscopy has been given information about the C_{60} thin film surface state and chemical bonds created in the atom groups formed on their surface . The modified films have been characterized by X-ray diffraction spectroscopy. Additionally, the surface morphology is derived using scanning electron microscope.***

Keywords: C60 Fullerene, FTIR, XRD, SEM, DC glow discharge low-pressure air Plasma

1. Introduction

Fullerenes, hollow and stable molecular structures formed by carbon atoms, have given rise to a whole family of bulk materials consisting entirely of carbon. In order to explain the stability of this molecule Krtoto et al [1] proposed the highly symmetric soccer-ball- like molecular shape coined Buckminsterfullerene. Since the discovery of buckminsterfullerene, fullerene research has experienced tremendous developments. Due to their limited solubility and organic nature, fullerenes have posed a challenge for analysis by spectrometric techniques. In order to fully exploit the potential application of the large fullerenes the surface properties of this new carbon species must be better understood.

Most surface properties, such as adsorption, wettability, hydrorepellence, and adhesion, of materials are strongly related to their microscopic properties, such as micro-porosity, roughness, and elemental and molecular composition. Knowledge of the surface dynamics of materials has recently allowed significant progress in many academic and scientific fields [2]. In recent years, electron spectroscopy techniques have been developed as potential methods for surface analysis. Among these techniques, X-ray diffraction spectroscopy (XRD), electron- and Scanning electron microscope and infrared spectroscopy have greatly improved our understanding of interfacial phenomena and surface characteristics of materials [3]. Recently, various structural morphologies have been reported for fullerene and fullerene derivatives in the solid state as well as in solution [4, 5].

In this study we will investigate the surface modification of C_{60} fullerene. Air plasma is used to increase the polar functional group which can successfully increase the surface changes of C_{60} thin film. Here thin films were treated with DC glow discharge air plasma which gives the intrinsic low surface properties. Confirm the change in structure of C_{60} thin film after plasma treatment, based on the XRD spectroscopy and surface morphology of the modified C_{60} thin film was characterized by scanning electron microscopy.

2. Experimental Setup and Methodology

Plasma Processing operating Parameters as follows:

Discharge potential -400V
Discharge power -10W
Pressure -0.3mbar
Exposure time -10min Electrodes separation -6cm
Plasma gas -Air
Samples -C_{60}thin film

C_{60} with 99.9% were used without further purification. Reactions were carried out in freshly distilled toluene. Thin film samples have been prepared starting from the solutions of fullerenes in toluene. Thin films were deposited on glass substrate by laser ablation pure C_{60} powder under high vacuum (10^{-8} Torr).

DC glow discharge plasma of low pressure was generated in a glass chamber of 29cm length and 10cm internal diameter size. Vacuum of 10^{-3} mbar was maintained inside the chamber using a vacuum pump. Required vacuum was maintained using fine control gas needle valve. Pirani gauge was used for pressure measurement. Circular-shaped electrodes made of aluminum with a diameter of 5cm were inside the chamber. The electrodes were separated by a distance of 6cm. Air was used as the reactive gas. High-tension DC power supply of 1.5kV was used. The C_{60} thin films were placed perpendicular to the discharge axis between the parallel electrodes using a holder. The discharge potential and base pressure were 400V and 0.3mbar, respectively.

The surface of the treated and untreated C_{60} thin films has been investigated by a Fourier Transform spectrometer in the mid region that is 4000-400 cm^{-1} and a standard technique with KBr pellets. The crystalline properties of the samples were examined by conducting X-ray diffraction measurements with Siemens D-500 powder diffractometer.

3. Result and Discussion

3.1 FTIR Analysis

For modified surface measurements the FTIR spectrum were recorded for untreated C_{60} thin film, treated thin films with plasma exposing time of 5minutes and 10 minutes which is as shown in Figure 1. The characteristic absorption bonds as observed from the untreated sample were identified [6] as the spectrum is simple i.e only a few absorption band is present. So that it is low molecular weight. It indicates the Physical property that, the material is crystalline solid. The broad band indicates the hydrogen bonding should be exist and are often related to crystalline structure of the material.

a) The in-plane C-H bending vibrations of aromatic compound is presented at the region of 1132.26-1095.61cm^{-1}

b) More than one band is obtained in the region of 850-670cm^{-1}. It indicates the C-H bending vibration is present. This C-H stretching can also be used to support the presence of an aromatic structure.

c) The bond around 740cm^{-1} may support simple ortho substitution.

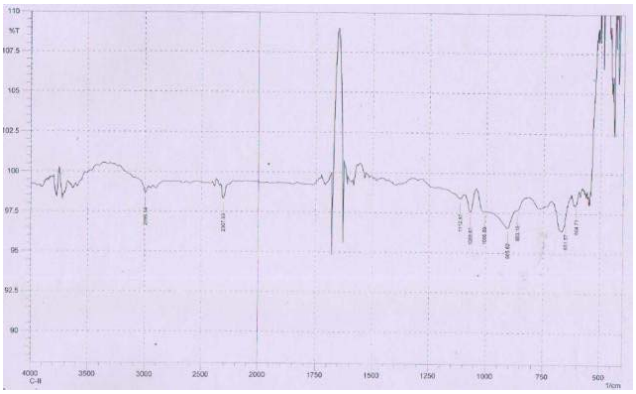

Figure 1.a. FTIR Spectrum of untreated C_{60} thin film.

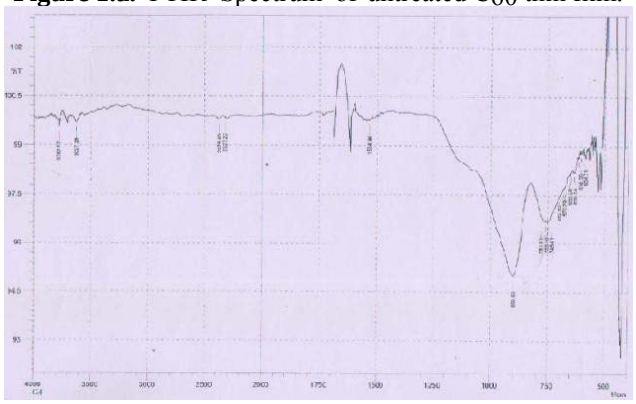

Figure 1.b. FTIR Spectrum of C_{60} thin film with 5minutes plasma treated

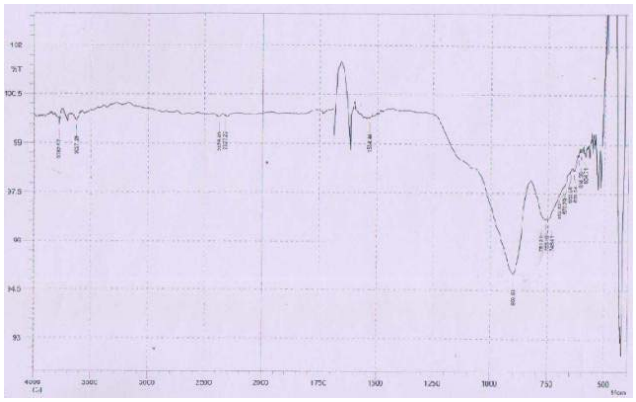

Figure 1.c. FTIR Spectrum of C60 thin film with 10minutes plasma treated.

3.2 Structure Analysis

The XRD data for the treated and plasma treated C_{60} thin films are shown in Fig. 2. Figure shows the major peaks rise due to X- ray diffraction from the (8 6 2), (3 3 3), and (2 2 1) planes. These peaks are relatively narrow; FWHMs ranging from about 0.21– 0.41. The treated C_{60} thin film shows a broad peak with FWHM 0.21-0.36. In the case of the treated C_{60} thin film, we observe diffraction peaks from (3 3 3), (2 2 2), (3 1 1). The major peaks in this two thin films clearly show the fcc structure. Also the peak was more intense for the treated film due to the increase in crystallinity. Therefore, no major changes in the shape or position of the diffraction peaks after plasma treatment as shown in Table.1. However, the crystallographic quality of the treated C_{60} film is much better than that of the C_{60} thin film.

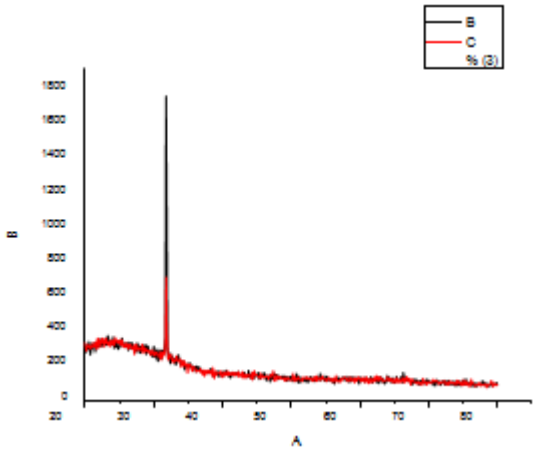

Figure 2. XRD of untreated and plasma treated C60 thin film
(C=Untreated, B=Plasma treated)

Table 1

Pos. (2the)	Height (cts)	FWHM (2the)	d-Spacing (A)	Rel Int (%)
Before Plasma Treatment				
31.8051	601	0.2183	2.8129	100
After Plasma Treatment				
31.7846	173	0.2308	2.81306	100

3.3 Surface Analysis

Particle morphology and crystalinity were determined with the scanning electron microscopy (SEM). The SEM image at different magnitude of untreated and plasma treated C60 thin film is shown in Figure 2, which is prepared at 400C. The highly smooth and uniform nature of the C60 surface is apparently visible from the image. The calculated diameter of the untreated C_{60} thin film varies between 10µm to 200µm and 3µm to 200µm for treated C_{60} thin film. The length of C_{60} thin film is a few tens in micrometers. Result shows that the most of fullerene particles processed at 400C are nearly spherically in shape and rough on the surface. Some elongated C_{60} particles are observed. Different shapes of fullerene particles were observed by SEM. For example, hexagonal plate-like, decahedral and icosahedral particles. The hexagonal plate-like (Platelet) particles are the most common among the faceted particles.

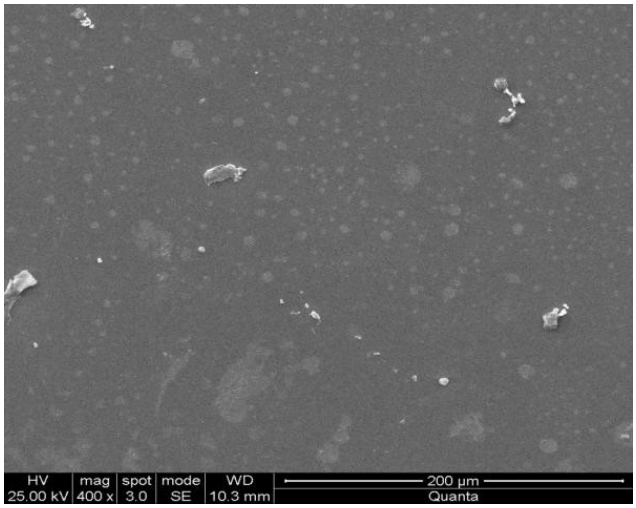

Figure 3.a. SEM image of untreated C_{60} thin film varies 200µm.

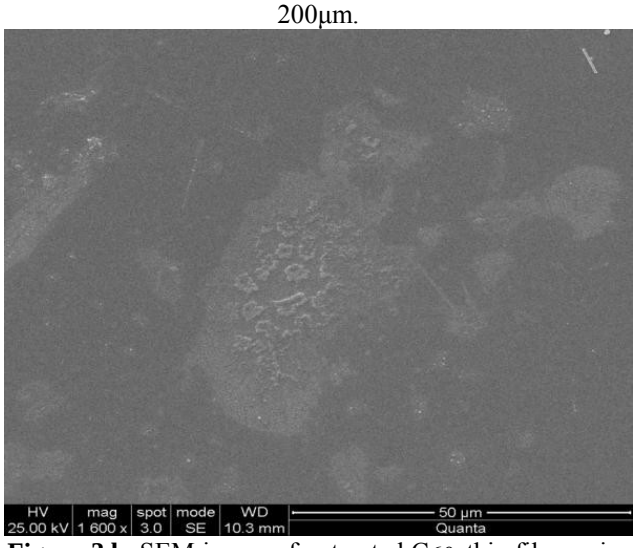

Figure 3.b. SEM image of untreated C_{60} thin film varies 50µm.

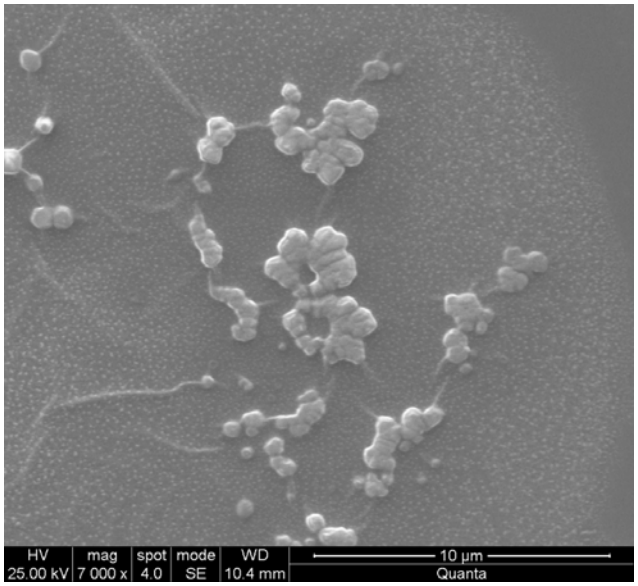

Figure 3.c. SEM image of untreated C_{60} thin film varies 10µm

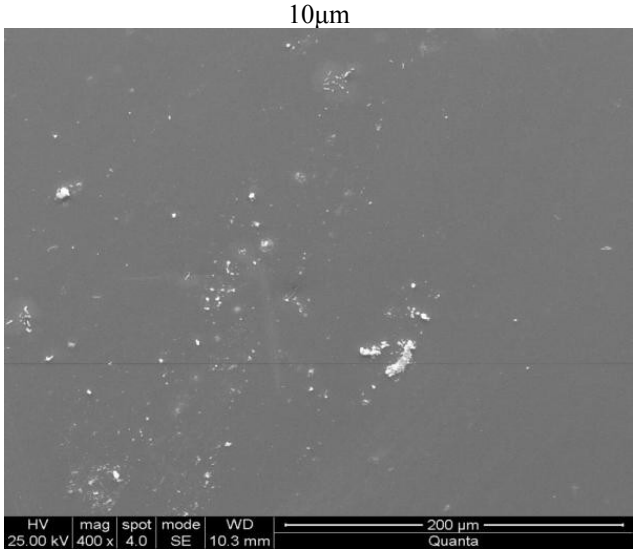

Figure 4.a. SEM image of C60 thin film with 10minutes treated varies 200µm.

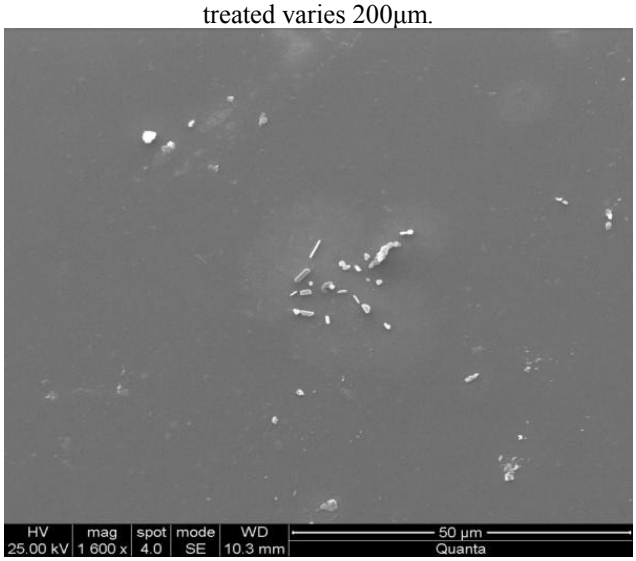

Figure 4.b. SEM image of C60 thin film with 10minutes treated varies 50µm

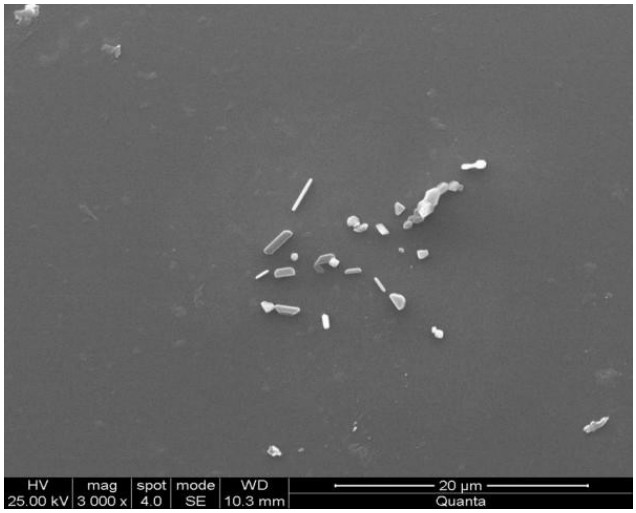

Figure 4.c. SEM image of C60 thin film with 10minutes treated varies 20µm

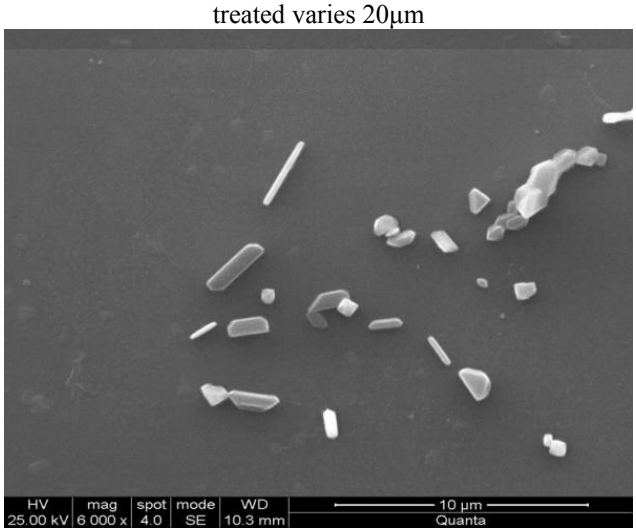

Figure 4.d. SEM image of C60 thin film with 10minutes treated varies 10µm.

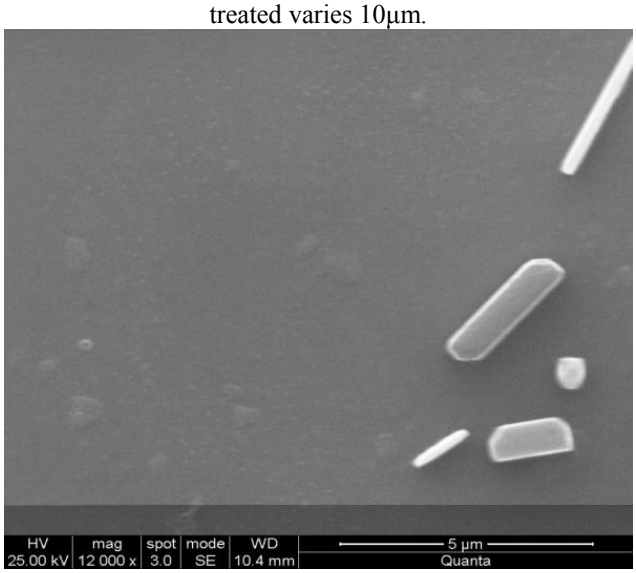

Figure 4.e. SEM image of C60 thin film with 10minutes treated varies 5µm.

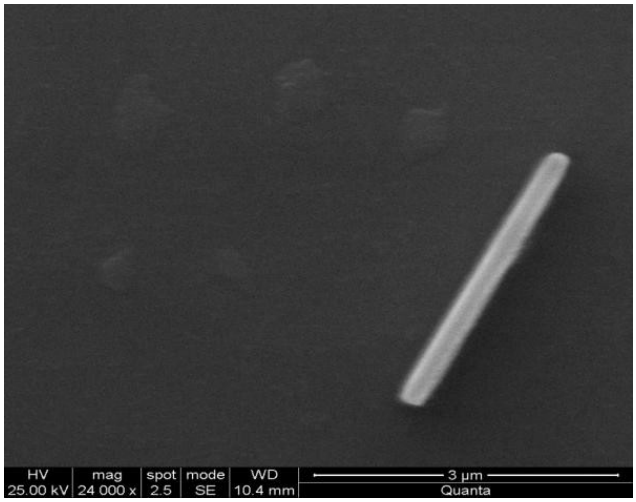

Figure 4.f. SEM image of C60 thin film with 10minutes treated varies 3µm.

4. Conclusion

We have demonstrated the surface modification of C_{60} thin film due to plasma treatment on C_{60} thin film and the Spectrometric analysis of the surface characteristics of plasma treated C_{60} thin film. In contrast to purified sample, a remarkable change of C_{60} thin film structure is observed after the plasma treatment. Due to this plasma treatment could provide the utilization, such as roughness of the surface properties when compared to untreated C_{60} thin film. In addition, FTIR, XRD and SEM spectrometric data showed excellent qualitative results on the surface characteristic and chemical composition of the surface treated plasma treatment.

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