Carbon Ion Characterization in Arc Discharge Plasma

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Abstract - The objective of this study is to determine the energy of carbon ion in different environment and pressures. The purpose of determination the energy of carbon ion is to get better knowledge regarding on the fabrication of different type of carbon nanostructures. Carbon nanostructures become more useful due to their unique carbon elements. They can form ball-shaped, fullerenes and cylindrical nanotubes. The energy of carbon ion can be obtained by measuring the ion track sizes on the CR-39 target. Solid state nuclear track detector (SSNTD) was used to track the charged nuclear particles, such as alpha particles or fission fragments. In this study, arc discharge plasma generated by graphite electrode were chosen to produce carbon nanostructures and the CR-39 were exposed to energetic carbon ion under different environment and pressures. The energetic carbon ion was etched by 6.25 M of NaOH solution for 8 hours. The temperature was maintained at (72±1) °C to ensure the etching process going smoothly. The ion tracks was observed under optical microscope and the diameter of ion track were measured. The energy was determined from the diameter obtained by using the related formula. The energy of carbon ion is influenced by the diameter ion track. High values of carbon ions energy are observed in hydrogen ambient environment as compared to air ambient environment under same ambient pressures and the energy of carbon ions decrease with increase in the ambient pressure

Keywords: *Arc discharge plasma, Solid State Nuclear Track Detector (SSNTD), energy of carbon ion*

INTRODUCTION

Solid state nuclear track detector is used in doing the characterization of carbon ions in arc discharge plasma. Carbon nanostructure are very unique carbon elements. It can form ball-shaped fullerenes and the cylindrical nanotubes. Buckyballs, polyaromatic molecules and graphene is made of C60, the carbon nanostructures include various low-dimension allotropes of carbon including carbon nanotubes. Nanoscale region is the characteristics sizes of carbon structures, the special structures and properties is ‘nanodiamond’ and carbon nanotubes.

Energy and materials segments can be covered by applications of carbon nanomaterials (Zhao et al., 2011). Carbon nanostructures can be produced using many method such as laser ablation method, solar technique, arc discharge process and many more. In this study, arc discharge process was chosen to produce the carbon nanostructures.

Arc discharge is generated between two electrodes under inert atmosphere. Sublimation of carbon will happen between the two rods due the high temperature (Journet and Bernier, 1998). The track etching rate is higher along the latent track, where damage due to the charged particle increase the chemical potential, and etching rate giving rise to holes, the etched tracks (Medeiros and de Carvalho, 1992). CR-39 have very high sensitivity of detection toward the particles. We can gain information on individual particles from the radiation detectors and the persistence of the tracks allowing measurements to be made over long periods of time, and the simple, cheap and robust construction of the detector. Many research have been performed to produce the carbon ions by numerous method. Carbon ions are use in cancer therapy. Optimizing the parameters is the way to observe the properties carbon ions. It is important to study the carbon ions under different ambient environment and pressures in order to produces information such state and energy of the carbon ions by using CR-39 detector. The objectives of this study is to determine the energy of carbon ions in different environments (hydrogen and air) and to estimate the energy of carbon ions in different pressures (0.1 mbar – 100 mbar). This research enable us to understand the fabrication (growth) of different type of carbon nanostructures during arc discharge process. Carbon ions play important role in every various application because of their special properties such as transparent insulating, smoothness, high hardness and high mass density. All the information obtained from this study can help to analyze the optimum state and energy of carbon ions in arc discharge plasma observed under different pressure and different ambient environment that will be used in each of the application.

EXPERIMENTAL SET-UP

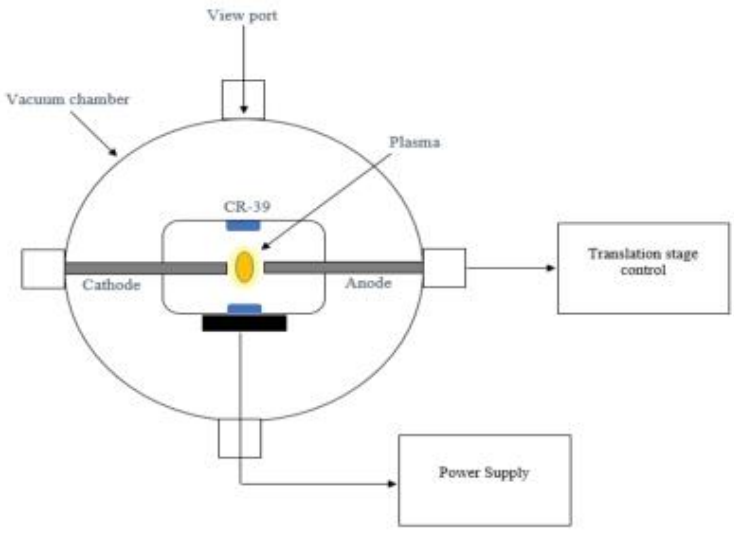

Figure 1: Experimental set-up to produce arc discharge plasma.

Figure 1 shows that the experimental set-up to produce arc discharge plasma. Arc discharge plasma was generated using graphite electrodes in stainless steel vacuum chamber. The experiment will be conducted with different ambient hydrogen and air and under different pressures of 0.1 mbar, 0.10 mbar, 1.0 mbar, 10.0 mbar, 100 mbar respectively.

The solid state nuclear track detector (CR-39) will exposed to energetic carbon ions under different conditions then etched with 6.25 M of NaOH solution for 8 hours at temperature (72 ± 1)℃ to remove the material form the tracks. The etched detectors will be analysed with the help of optical microscope (Amscope model B100B-MS). By measuring the diameter of the ions track the energy of carbon ions are estimated by using the empirical formula which has the track diameter of ions in μm and the energy of ions in keV.

Etching process of CR-39 samples will be conducted in NaOH solution for seven hours. The temperature of the solution will be set at (72±1) °C. This is important to ensure the all the material formed on the track are fully removed. The etched detector will be analyzed using optical microscope. From the tracks, the properties of incident ions such as energy is determined. Pressures of the environment will influence the energy of carbon ions in CR-39. The energy of carbon ions can be measured from the diameter of the tracks. Tracks which has different diameter which produced from ions will have different energy.

RESULTS AND DISCUSSION

The energy of carbon ions under different environment and pressure was determined using CR-39 detectors. The energy of carbon ions produced by arc discharge plasma has been identified under the air and hydrogen environment at 10-2 mbar, 10-1 mbar, 100 mbar, 101 mbar and 102 mbar respectively. By measuring the diameter of the track on the SSNTDs surface, the energy of carbon ions is determined.

Table 1: The average of diameter of the ion track in air.

No. of sample	Pressure (mbar)				
	10^{-2}	10^{-1}	100	10^{1}	10^{2}
Diameter 1	0.754	0.535	0.425	0.502	0.276
Diameter 2	0.717	0.363	0.373	0.468	0.343
Diameter 3	0.589	0.427	0.417	0.504	0.378
Diameter 4	0.635	0.606	0.344	0.326	0.307
Diameter 5	0.667	0.862	0.373	0.198	0.263
Diameter 6	0.589	0.641	0.417	0.251	0.253
Diameter 7	0.833	0.767	0.353	0.355	0.261
Average (μm)	**0.6622**	**0.5911**	**0.4065**	**0.372**	**0.3022**

Table 2: The average of diameter of the ion track in hydrogen.

Num. of sample	Pressure (mbar)				
	10^{-2}	10^{-1}	100	10^{1}	10^{2}
Diameter 1	0.511	0.653	0.425	0.4	0.294
Diameter 2	0.448	0.751	0.417	0.368	0.353
Diameter 3	0.708	0.708	0.449	0.4	0.353
Diameter 4	0.85	0.462	0.486	0.481	0.353
Diameter 5	0.601	0.462	0.417	0.4	0.391
Diameter 6	0.633	0.56	0.527	0.447	0.415
Diameter 7	0.861	0.633	0.425	0.379	0.404
Diameter 8	0.511	0.56	0.417	0.368	0.353
Diameter 9	0.722	0.571	0.449	0.368	0.277
Average (µm)	**0.6608**	**0.6013**	**0.4437**	**0.3933**	**0.35478**

Table 3: Energy of carbon ion due to different pressure and environment.

Pressure (mbar)	Carbon Ion Energy (keV)	
	Air	Hydrogen
10^{-2}	0.072647851	0.071720227
10^{-1}	0.036098322	0.04010625
100	0.00359821	0.006167102
10^{1}	0.002082355	0.002934335
10^{2}	0.000578927	0.001555101

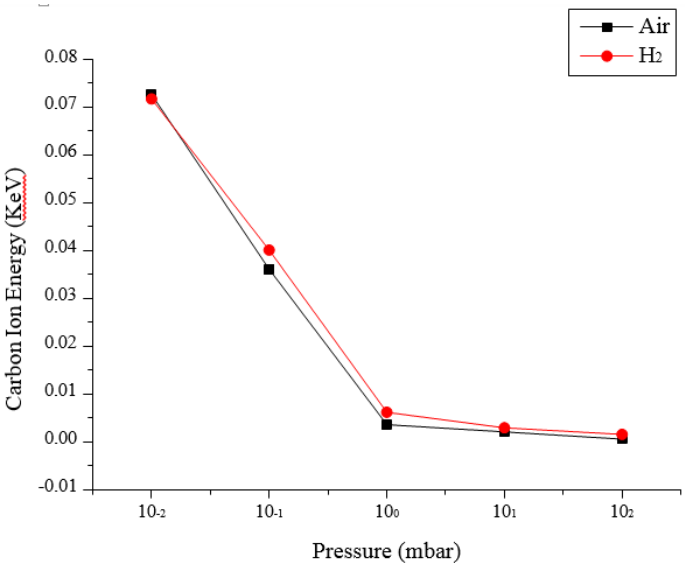

Figure 2: Graph energy against pressure in air and hydrogen.

As a general trend, a decrease in the ions energy is observed with increase in the ambient pressure in both ambient environments air as well as hydrogen. The maximum ion energy is observed at 10-2 mbar ≈70 eV and minimum energy estimated energy is 0.5 eV at high ambient pressure 102 mbar.

CONCLUSIONS

In this research, what we have obtained is the energy of carbon ion in different environment and under different pressures using arc discharge plasma. From the results obtained, it is clear that the energy of carbon ions in air background has lower values as compared with hydrogen. The higher the ambient pressure, the lower the energy values of carbon ions.

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