Cathodic arc system grown Carbon Nanocluster characteristics

Niranjana S*, B S Satyanaryana**, U C Niranjan *** and Shounak De****

*Assistant Professor, MIT, Manipal University, Manipal, India.

** Principal, R .V. College of Engineering, Bangalore, India.

***Adjunct Professor, Department of E&C, MIT, Manipal, India.

**** Assistant Professor, MIT, Manipal University, Manipal, India.

ABSTRACT

Dimension reduction is critical and challenging for new nano-electronic applications. Cathodic arc is a low temperature process used for the growth of carbon based nanocluster. Carbon nanoclusters with varying sp2/ sp3 are grown at low temperature under different process parameters includes: arc voltage, arc current, gases helium, nitrogen and hydrogen, temperature, deposition rate, deposition time and distance of substrate from source. Studied Morphological and Raman based study of carbon nanoclusters grown under varying conditions, using continuous and pulsed arc systems. Reported morphological details of nanoclusters using SEM. The G peak and D peak of Raman responses along with other signatures proves Raman as probe for nanomaterial study. The nanocluster thin films morphology and quality are highly influenced by the type of arc and other process parameters.

Keywords - **Cathodic arc, Carbon Nanocluster, Raman response, and SEM**

I. INTRODUCTION

Indian scientists Raman C.V and Krishnan K S in 1928, published a new type of secondary radiation effect [1]. The Raman effect is undoubtedly one of the greatest scientific achievements in the last century and Raman was awarded Nobel prize. Raman spectroscopy made revolution developments in life science and material science research. The use of the Raman spectroscopic signature of life will lead to a non-invasive, instantaneous and in vivo diagnostics of the viability of a living cell [2]. Raman spectroscopy is a nondestructive and instantaneous tool for nano material evalution and its characterization [3].

Dimension reduction is reached to a challenging stage, where new material and process technologies are expected to come for further developments in the field of nanoelectronics. Among many nanostructures nanocarbons have already shown its importance in different domains. Initially nanocarbon found applications as tribological coating in hard disk, automobile, aircrafts. The surface property either hydrophilic and hydrophilic nature of the thin films finds its applications separately in different industries. In the field of electronics nanostructures are seen as interconnects, dielectric layer, and also they are part of cold cathode vacuum devices [4-8]. Nanocarbon on the other side developed for sensor industry based on conductive or vaccum based principle. Nanocarbon like DLC coatings are used on artificial joints proves its tribological fitness. However bio-compatibility of those nanocarbon thin films having varying sp2/sp3 content cytotoxicity is a major concern [9].

Nanocarbons grown from near room temperature to high temperature of the order (1000^{o}C). includes: Nanocluster, CNT, Fullerene, Nanodiamond, Graphene, diamond like carbon [DLC], Tetrahedral amorphous carbon (*ta*-C). Each nanocarbon has varying sp2 and sp3 bonding. The Tetrahedral amorphous carbon (*ta*-C) is characterized by high percentage (~85%) of ‘‘diamond-like’’ *sp*3 bonding and a small percentage of sp2 bonding. Whereas nanocluster is chracterised by high percentage of sp2 bonding. The sp3 fraction controls the mechanical properties of ta-C, while sp2 sites primarily control the optical and electrical properties. The Raman characteristic derived parameters such as the $I(D)/I(G)$, G peak position and FWHM were found to change gradually with the deposition temperature, consistent with the optical and electrical properties of the films. The $I(D)/I(G)$ has a relationship with band gap and these results shows how Raman derived parameters can be correlated. The Raman spectra of carbon films can be band fit to separate the contributions of the "graphitic carbon" (G band) from the "disordered carbon" (D band)[10-14].

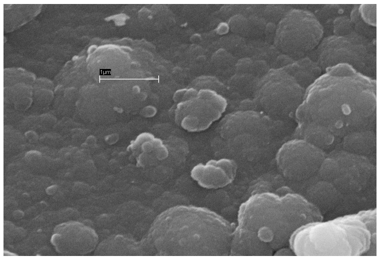
The materials including nano-diamond, carbon nanotubes, nanostructured graphite, carbon nanocluster, have been shown to emit electrons at reasonably low fields, and they have varying conductivity based on its growth conditions. The materials have been grown using different process like Hot Filament Chemival Vapor Deposition (HF-CVD), Microwave Plasma Chemical Vapor Deposition(MP-CVD), Continuous Cathodic Arc and Pulsed Cathodic Arc. The need is for a low temperature or near room temperature, low cost process, compatible with silicon process technology. The Cathodic arc system is one that offers unique opportunity of growing any form of carbon. Based on continuous or pulsed cathodic arc system nanocarbons from highly sp^3 bonded material like diamond to highly sp^2 bonded graphite like material such as carbon nanotube and all the intermediate stages including DLC, ta-C and nanoclusters at near room temperature can be grown. The specially designed (scaled up) Cathodic arc system may be used, for large area film growth [15-18]. Presented here low temperature grown carbon nanocluster grown at various process conditions, discussed their morphological and Raman features.

II. EXPERIMENT

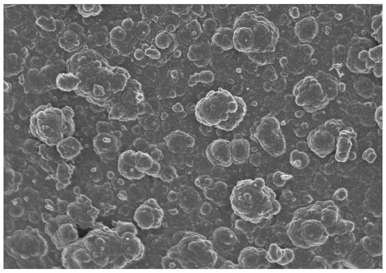
The cathodic arc with 90^o bend duct with magnetic filter is choosen for the growth of nanocluster. The nanocarbon thin films of about 80-100 nm thickness were deposited on n++ silicon substrates, at room temperature conditions using a filtered continuous and pulsed cathodic arc process. The circular graphite target is the cathode. Substrate fixed on substrate holder acts as anode and is held in the duct area 20-32cm away from the cathode. Manual Arc triggering enables the plasma in magnetic filtered Continuous cathodic arc system. The system was initially evacuated to a base vacuum in the 10^{-7} torr range. The samples were deposited under varying Helium partial pressure [10^{-4} Torr to 10 Torr] conditions, for a fixed nitrogen partial [10^{-3} Torr] as reported earlier in the case of nanocluster carbon films grow using a continuous cathodic arc process. With a similar growth conditions carbon nanoclusters are grown using Pulsed arc system. Which uses DC Pulsed power supply system (10-12KV & 500 A).The cathodic arc system has magnetic filter which reduces the macro particle deposition on the substrate. Macro particles are trapped there by a controlled growth from smooth to clusters / fibers are grown. The samples deposited on silicon and glass substrates are used for Raman measurements. The Raman measurements were taken using a Reinshaw Raman spectroscopy equipment with a 514.5nm excitation source.

III. RESULT AND DISCUSSIONS

Resulted smooth graphitic film from Cathodic arc system without using helium during the process. Typically 1-3 torr of helium partial pressure at nitrogen partial pressure (10^{-3}torr) resulted distributed nanoclusters on the Si/ glass substrate. Shown in figure 1 (a & b), are the SEM images of the samples grown using continuous and pulsed cathodic arc system. Both the modes of deposition resulted in carbon based nanoclusters with varying size of clusters along the film with minor protrusions and rough surfaces. Both the images are having the clusters with slight overlap. The nanoclusters in the carbon films produced by the pulsed arc are more uniform and has smaller size, where as continuous arc grown clusters are having some macro clusters distributed. The nanoclusters size varies between 20nm to 1µm. The nanocluster form is lost at higher helium partial pressure of the order 50torr, resulting nanostructures are named nanofibers.

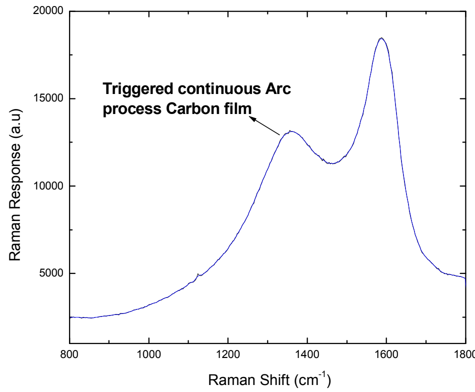


(a)



(b)

Figure 1, a) SEM of carbon Nanocluster thin film grown using continuous cathodic arc system, b) SEM of carbon Nanocluster grown using pulsed cathic arc system.



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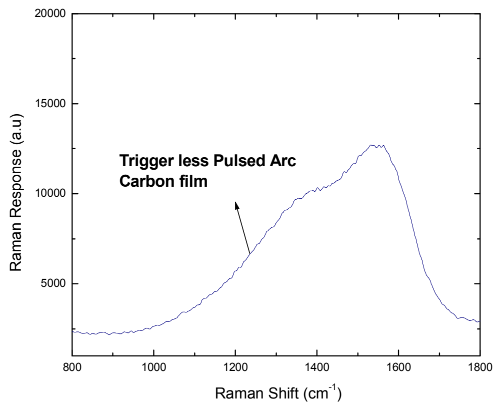


(b)

Figure 2(a-b), Raman Response of carbon nanocluster grown using Continuous cathodic arc and pulsed arc system.

Typical Raman response of nanocarbon with varying sp^2/sp^3 has embedded signatures. Shown in figure 2(a) & 2(b) are the typical Raman spectrum for nanocluster films grown using continuous and pulsed arc approach respectively. The response has a peak around 1582cm^{-1} and a shoulder with another peak around 1350cm^{-1}. Those two prominent peaks are denoted as G peak and D peak. These peaks are seen shifting left or right for change in sp^2/sp^3 ratio. Each of the Raman response is analyzed with lorenzian curve fitting technique. The curve fitted Raman response is shown in figure 3 has G curve and D curve. Estimated different features includes: Id (Peak intensity of D-peak), Ig (Peak intensity of G-peak), Id/Ig Ratio, Areas under G and D-peaks. The features extracted from Raman response has been correlated with its dimension, and field emission derived parameters response derived parameters. The nanocluster grown at various conditions of Helium, Nitrogen are studied. The better clusters and lesser amorphous phase leads to relatively more distinct G & D peaks in the case of nanolcuster carbon film grown using the continuous arc as compared to a broader G peak and a shoulder indicating the D peak in the case of the nanolcuster carbon films grown using a trigger less pulsed arc.

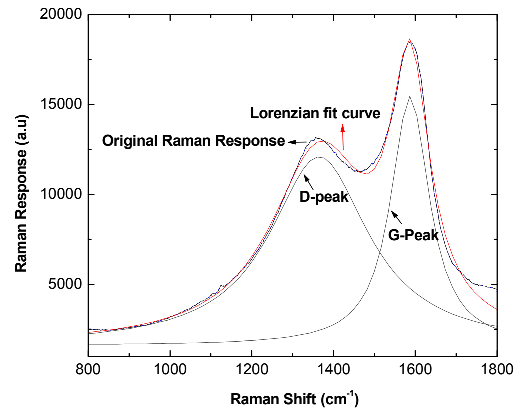
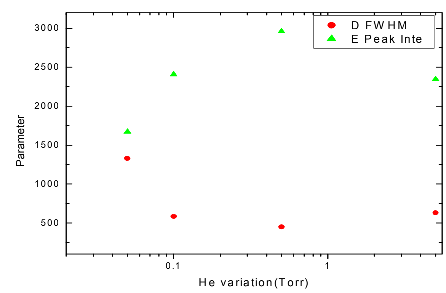
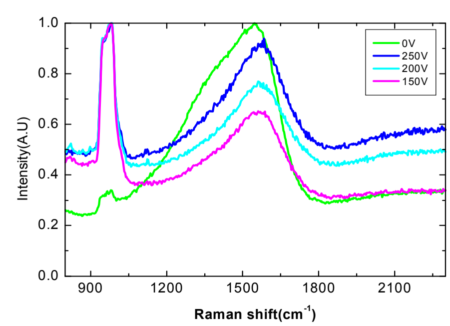


Figure 3, Curve fitted Raman response with Lorenzian peak fit.



(a)



(b)

Figure 4(a) Influence of Helium variation on Raman response Parameters, 4(b) Raman Response of nanocluster thin films with bias varying.

Shown in figure 4(a) is a plot drawn for with various values of Helium partial pressure (PP) and Raman response derived parameters: Full Width Half Maximum (FWHM) and peak position. The FWHM of G peak decreases with Helium pressure variation, where as the peak intensity gets incremented. Grown carbon nanocluster under varying bias across cathode anode during process and its Raman measurements are shown in figure 4(b). Increased in the bias changed the position of G-peak between 1550-1580cm^{-1}.

The shift in G peak changes the quality or sp2/ sp3 of the thin film. The resulting shift indicates more graphitic nature of the film with increased bias within the specified experimental conditions. With the decrease in the energy, decrease in FWHM or sharper G peak resulted more uniform films.

IV. CONCLUSION

The growth of nanocarbon clusters at low temperature with continuous and pulsed cathodic systems, are interesting. Studied the SEM for its morphological characteristic and Raman Response of theses nanostructures with different parameters (FWHM, peak position). The Raman spectroscopy is an interesting tool for nanoelectronics, where it is expected to evaluate the nanomaterial in-situ applications. It was observed that the pulsed cathodic arc process generates relatively lower macro particles even when no filtering process was used. The results indicate that with further optimization of the process conditions it should be possible to grow more controlled size of nanoclusters with uniform distribution using pulsed cathodic arc process. The low temperature growth process can result electronics on plastic or fabrics in the future.

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