Jurnal Teknologi

Full Paper

FABRICATION OF CARBON THIN FILMS BY PULSED LASER DEPOSITION IN DIFFERENT AMBIENT ENVIRONMENTS

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Article history
Received
15 August 2015
Received in revised form
15 November 2015
Accepted
30 December 2015

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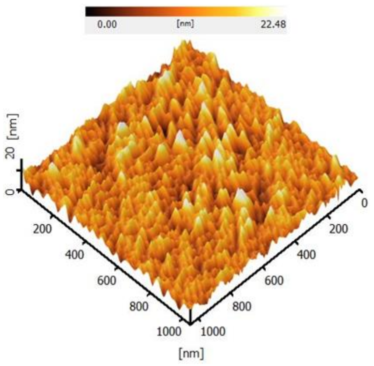
Graphical abstract



Abstract

In this work, carbon thin films are grown in different background environments (Air, Helium and Argon) at different pressures (60, 160, 500 and 1000 mbar) by ablating the graphite target with Nd:YAG laser of wavelength of 1064 nm, pulse energy of 740 mJ and pulse rate of 6 ns. 10,000 laser shots are used to ablate graphite target under different ambient conditions. Grown thin films are analyzed by Atomic Force Microscopy (AFM) to measure thickness, roughness average, maximum profile peak height, average maximum height of profile and spacing ratio of the surface. The obtained results show that the roughness average, thickness of film, maximum profile peak height, average maximum height of profile and spacing ratio of thin films decreases with increase in ambient pressures-and shows highest value at low pressure (160 mbar) in helium environment as compared with air and argon.

Keywords: Pulsed Laser Deposition, Nd:YAG Laser, carbon thin film

Abstrak

Karbon filem nipis yang disimpan di persekitaran latar belakang yang berbeza (Udara, Helium dan Argon) pada tekanan yang berbeza (60, 160, 500 dan 1000 mbar) oleh peruapan sasaran grafit dengan Nd: YAG laser (panjang gelombang 1064 nm, tenaga nadi 740 mJ dan kadar nadi 6 ns). 10,000 tembakan laser digunakan untuk peruapan sasaran grafit di bawah keadaan ambien yang berbeza. Parameter seperti laser, bahan sasaran, substrat, dinamik plasma tekanan persekitaran dan alam sekitar dan lain-lain juga mempunyai kesan langsung kepada sifat-sifat filem nipis berkembang. Morfologi permukaan filem nipis yang disimpan telah dianalisis oleh Tentera Atom Mikroskopi (AFM)untuk mengkaji ketebalan, purata kekasaran, ketinggian maksimum profil puncak, ketinggian maksimum purata profil dan nisbah jarak permukaan. Di samping itu, nilai yang diperolehi daripada keputusan yang diperolehi menunjukkan trend purata kekasaran, ketebalan, ketinggian maksimum profil puncak, ketinggian maksimum purata profil dan nisbah jarak filem nipis di gas ambien yang berbeza (Udara, He dan Ar) berkurangan dengan peningkatan dalam tekanan ambien dan menunjukkan nilai tertinggi pada tekanan rendah (160 mbar) dalam persekitaran helium berbanding dengan udara dan argon.

Kata kunci: Pemendapan Denyut Laser, Laser Nd:YAG, filem tipis carbon

1.0 INTRODUCTION

Carbon thin films have received much attention due to their potential applications in the field of technology. It has interesting properties like electrical, optical and mechanical which can be functioning in long term performance [1] and useful in large number of applications. Other than that, properties of carbon thin films such as transparent insulating [2], high hardness, smoothness, high mass density and low friction coefficient also contribute towards technological applications in different fields of studies. The structure-processing relationship during the deposition of carbon thin films by pulse laser deposition (PLD) is of great importance in order to optimize the structure and chemistry of these films [3].

Several types of deposition methods are used to grow thin films such as pulse laser deposition [4], chemical vapour deposition [5], sputtering [6], ion beam deposition [7] etc. Each fabrication technique influences the properties of the thin film. PLD is one of the useful technique to grow thin films [8] with optimized characteristics which can be applied for various types of the materials such as metals, semiconductor or polymers. Deposition of the carbon by PLD gives an advantage in biomedical applications [9]. PLD shows the ability of the production of high quality films as compared to other deposition techniques [10]. However, PLD is lacking because the thickness of the deposited film is not consistent [3].

The important parameters used for growing thin films using laser induced plasma technique on the substrates are laser source, target materials, substrates, plasma dynamics, ambient pressure and environment etc. Surface properties of the thin films also play crucial aspect such as surface binding energy, surface energy, microstructure and morphology, electrochemical potential, absorption and reflection coefficient for industrial and medical applications [3].

In recent years, surface ablation by femto-second laser achieved high intensity value compared with the nano-second laser due to the increasing in kinetic energy of the ejected particles [10]. The kinetic energy (KE) of the deposited carbon species effects the films behaviour. Alternative methods are implemented in order to control the (KE) of the carbon species [11]).

Diamond-like carbon films (DLC) has unique properties such as high hardness, optical transparency, low friction and chemical inertness which can be grown by different method like pulse laser deposition, filtered cathodic vacuum arc (FCVA) and mass-separated ion beam deposition (MSIBD) [11]. DLC can also be used in infrared optical, mechanical, electronic and biomedical applications [12]. Besides, another thin films likes silicon carbide (SiC) films makes an appearance in the field of technology which are widely used materials in optoelectronics, photo-voltaic and thin films transistor due to the adjustment regarding its refractive index and band gaps. SiC have interesting properties that have potential in large application as wide band gap, high saturated electron velocities, good radiation resistance, high thermal conductivity, optical transparency, high electrical breakdown field, high hardness and good electrical and chemical stabilities [13].

2.0 EXPERIMENTAL

2.1 Substrate Preparation

Materials to be used for metal oxide semiconductor substrate must be strong enough to accommodate the high temperature and pressure force because the substrate serves as a mechanical support for the thin film. In addition, it also must not be reactive to any element that is in terms of its physical and chemical force reaction. So, the corning glass has chosen as a medium due to its high melting point at about 800°C, long term stability and free of chemical reaction to occur that might change its properties. The substrate must be cleaned to ensure that it free from dirt, dust or fingerprints and any element that effects the film deposition by putting in the (Branson 3210) Ultrasonic Bath Cleaner using deionized water and alcohol.

2.2 Deposition and Characterization

Solid graphite with high purity of 99.997% is used as source of carbon. The graphite is ablated by the laser pulse which is deposited as carbon thin film on substrate. The experiments are performed in a stainless steel vacuum chamber. The Nd:YAG laser with wavelength 1064 nm is used as a source of energy with frequency 10 Hz, pulse energy 740 mJ and pulse duration of 6 ns to ablate the graphite target. 10,000 of shots are used to ablate graphite target. The growth of thin films on the substrates is performed under different ambient environments as helium, argon and air with different ambient pressure which are 60 mbar, 160 mbar, 500 mbar, and 1000 mbar. The grown thin films are analysed by using Atomic Force Microscopy (AFM) model SPA 300HV SEIKO. Figure 1 shows the schematic diagram of the experimental setup.

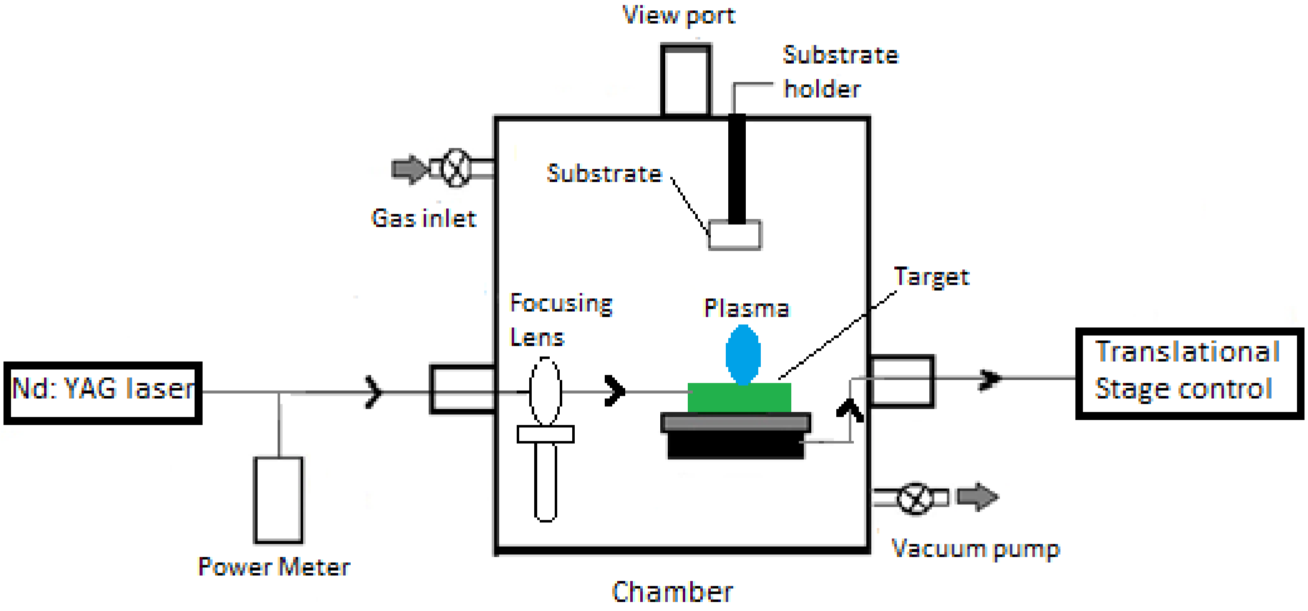


Figure 1 Schematic diagram of experimental setup

3.0 RESULTS AND DISCUSSION

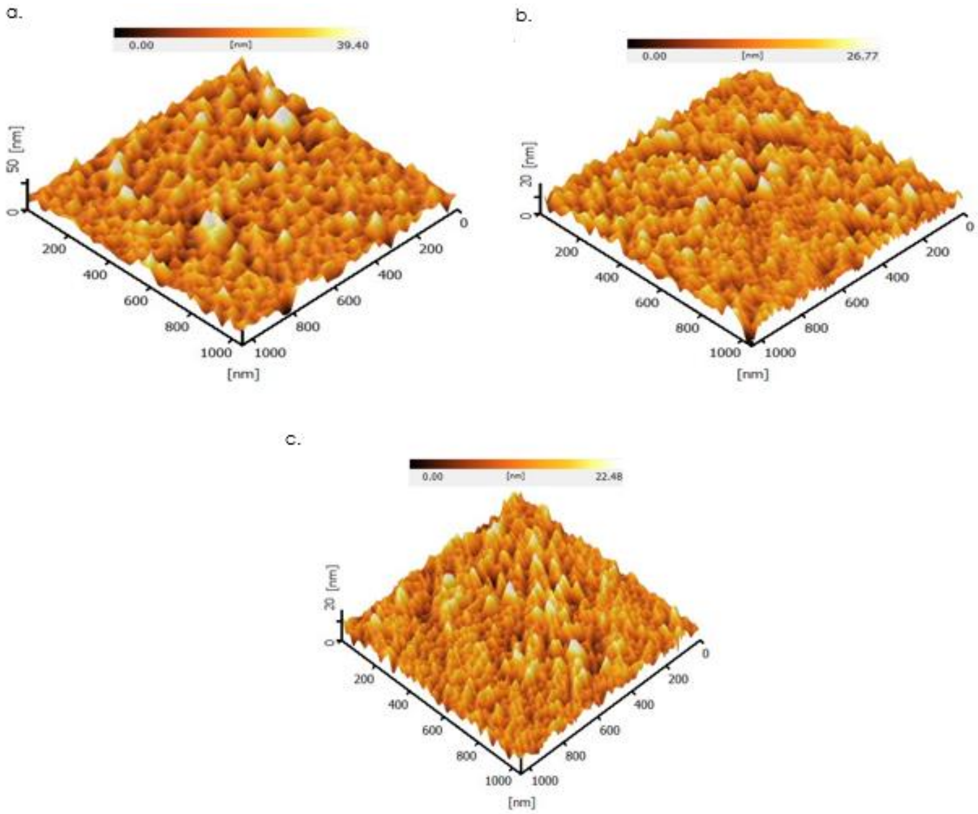


Figure 2 AFM image of deposited carbon thin film in air with pressure a.) 60mbar, b.) 500mbar and c.) 1000mbar

Figure 2a shows the AFM images of deposited carbon thin film at ambient pressure of 60 mbar. Figure 2b refers to the AFM image of deposited carbon thin films with pressure of 500 mbar and Figure 2c indicates AFM images of deposited carbon thin film with pressure of 1000 mbar. From Figure 2, the surface morphology of carbon thin film deposited on Corning glass substrate at ambient pressure of 1000 mbar shows smoother surface rather than at pressure of 60 mbar and 500 mbar. This is due to the small size of carbon particle from the ablated graphite [13]. Another reason for high roughness in low pressure because of the incident ablated graphite is less mobile and reside inside the interstitial space as compare to high pressure environment where the incident graphite particle do not reside inside interstitial space. Hence, the energy of laser also play an important role to determine the roughness of the carbon thin film.

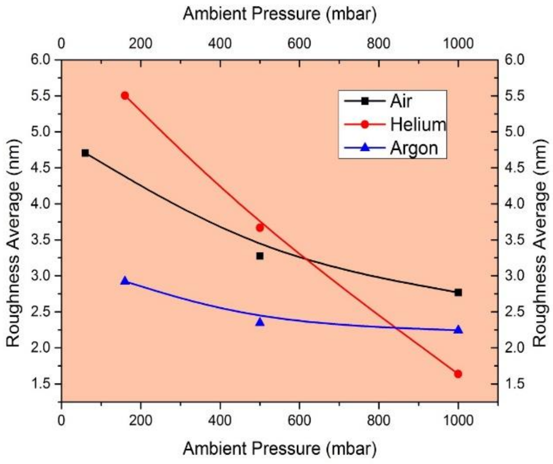


Figure 3 Graph of roughness average, R_a against ambient Pressure

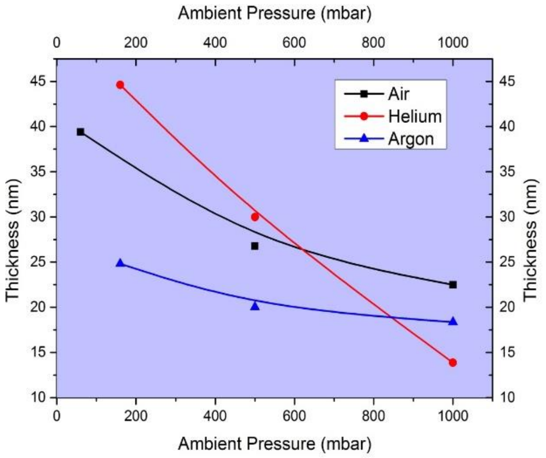


Figure 4 Graph of thickness against ambient Pressure

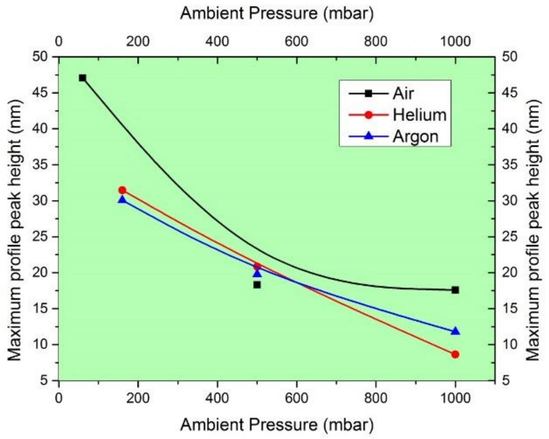


Figure 5 Graph of maximum profile peak height against ambient Pressure

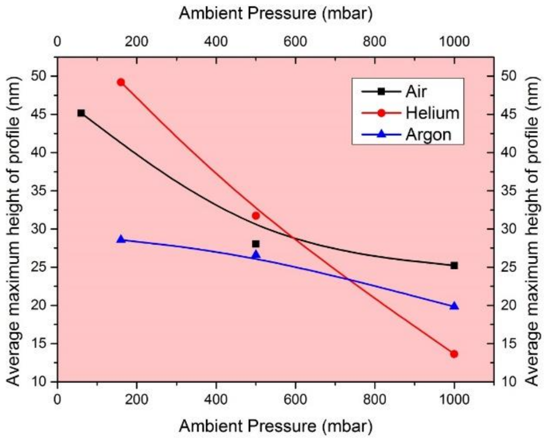


Figure 6 Graph of average maximum height of profile against ambient Pressure

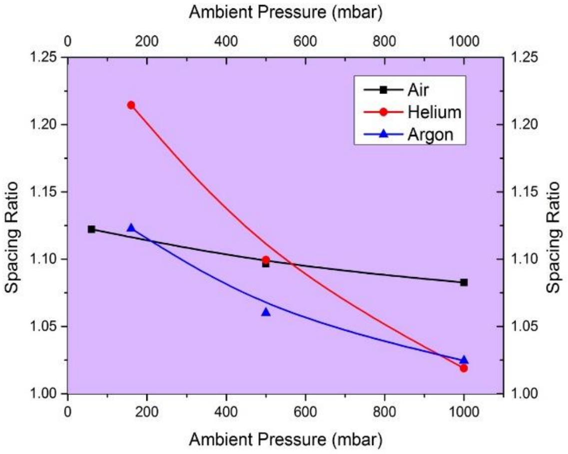


Figure 7 Graph of spacing ration against ambient Pressure

Figure 3 represents the surface roughness average of each ambient pressure which is 60, 160, 500 and 1000 mbar for different ambient gases (Air, He and Ar). The graph shows that increasing in pressure leads to decrease in the roughness average, R_a of the surface. The roughness average value for air environment is 4.706 nm at 60 mbar as compared to the 3.275 nm at 500 mbar and 2.768 nm at 1000 mbar. The highest roughness average value for argon gases is 2.923 nm at 160 mbar as compared to the 2.348 nm at 500 mbar and 2.246 nm at 1000 mbar. The roughness average is highest for helium environment as compared to other gases which are 5.504 nm at 160 mbar and 3.668 nm at 500 mbar but helium gas also shows the lowest value of roughness average which is 1.637 nm at 1000 mbar. In general, the increasing in ambient pressure decreases the cluster size [13].

Figure 4 refers the thickness of the deposited carbon films regarding its different ambient conditions. The graph shows that thickness of the carbon decreases with increase in ambient pressure. The thickness of the film in air is 39.40 nm at 60 mbar as compared to the 26.77 nm at 500 mbar and 22.48 nm at 1000 mbar. The surface in helium gas is thicker at 160 mbar which 44.61 nm and 29.98 nm at 500 mbar compared to other gases but at higher pressure of 1000 mbar, it shows the thinner surface with 13.86 nm compared to other gases. For argon, the thickness of the surface at 160 mbar is 24.82 nm while 20.03 nm at 500 mbar and 18.35 nm at 1000 mbar.

Figure 5 shows the maximum profile peak height at the substrate surface for ambient pressures of 60, 160, 500 and 1000 mbar and different gases (Air, He and Ar). The graph shows that maximum profile peak height decreases with the increase in ambient pressure. The maximum profile peak height of the particles is highest for air which is 47.06 nm at 60 mbar, 18.33 nm at 500 mbar and 17.59 nm at 1000 mbar as compared to helium and Argon. The maximum profile peak height for helium is 31.47 nm at 160 mbar compared to the 20.84 nm at 500 mbar and 8.636 nm at 1000 mbar. For argon, the maximum profile peak height of the particles is 30.09 nm at 160 mbar, 19.78 nm at 500 mbar and 11.78 nm at 1000 mbar.

Figure 6 represents the average maximum height of profile for ambient pressures of 60, 160, 500 and 1000 mbar and ambient environments air, helium and argon. The graph shows that the increase in pressure decreases the average maximum profile height of the particles. The average maximum profile height of the particles at 60 mbar is 45.15 nm which is higher as compared to the 28.04 nm at 500 mbar and 25.21 nm at 1000 mbar for air. For helium, the average maximum profile height is highest rather than air and argon which 49.20 nm at 160 mbar and 31.74 nm at 500 mbar while the value is lowest at 1000 mbar which 13.64 nm. For argon, the average maximum profile height of the particles at 160 mbar is 28.58 nm compared to the 26.60 nm at 500 mbar and 19.85 nm at 1000 mbar.

Figure 7 shows the spacing ratio of thin films at different ambient conditions. The graph shows that the spacing ratio of the particles decreases with increase in ambient pressure. The value of spacing ratio for air is 1.12215 at 60 mbar while 1.09664 at 500 mbar and 1.08257 at 1000 mbar. The highest value of spacing ratio is in helium gas which is 1.21453 at 160 mbar and 1.09938 at 500 mbar while it is the lowest spacing ratio, 1.01885 at 1000 mbar. For argon, the value of spacing ratio is 1.12285 at 160 mbar while 1.06014 at 500 mbar and 1.02449 at 1000 mbar. From the obtained data, the results show the relation between the spacing and the roughness. Larger spacing area, rough the surface of the substrate.

4.0 CONCLUSION

The carbon thin films are successfully grown under different ambient environment (Air, He and Ar) and different ambient pressures (60, 160 500 and 1000mbar) by pulsed laser deposition technique. The fabricated thin films are characterized for the surface morphology by AFM. Carbon thin films are analysed by measuring roughness average, thickness, maximum profile peak height, average maximum height of profile and spacing ratio of the surface thin film. The observations show that the carbon thin films deposited at high pressure of 1000 mbar are smoother rather than at low pressure. From the results obtained, it can be seen that the roughness average, thickness, maximum profile peak height, average maximum height of profile and spacing ratio of thin films decreases with increasing in ambient pressure and shows highest value at low pressure in helium environment as compared with air and argon. Thus, helium gas shows better results in growth of carbon thin film under different ambient conditions.

Acknowledgement

We would like to thank Laser Center, ISI-SIR, Universiti Teknologi Malaysia and MyBrain15 under Ministry of Education (MoE) and for financial support. This study is supported by GUP grant K65.

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