

## ABSTRACT

Diamond-like-carbon (DLC) thin films were prepared on silicon and glass substrates using direct current – plasma enhanced chemical vapour deposition (DC-PECVD) from a mixture of methane, hydrogen, and argon. Two sets of samples are successfully deposited with different substrate temperatures varied from 200°C to 550°C for the first set and deposition time from 60 minutes to 180 minutes for the second set of sample, while maintaining other important deposition

parameters. The films thickness is determined by using a conventional ellipsometer, the morphology of the films has been analyzed by using Atomic Force Microscope (AFM) and the structure of the films is studied by using FT-IR spectroscopy. The thickness analysis shows that the thickness of DLC thin films is decrease as the substrate temperature increase but increasing as the deposition time increase for both glass and silicon substrate. The AFM results show high rms roughness at 550°C for glass substrate and 300°C for silicon substrate; meanwhile both of substrate materials show a high rms roughness at 120 minutes deposition time. The transition temperature is suggested to be 400°C for glass substrate and 550°C for silicon substrate. The growth mechanism is explained base on subplantation model. The IR spectra show that both set of sample contain a lot of  $sp^3$  clusters but hydrogen is still present in each sample. The degree of absorption is also enhanced by the reduction of substrate temperature and deposition time.

## ABSTRAK

Filem tipis karbon serupa intan telah disediakan di atas substrat kaca dan silikon dengan menggunakan sistem pemendapan wap kimia diperkuat plasma arus terus (DC-PECVD) daripada campuran gas metana, hidrogen, dan argon. Dua set sampel telah berjaya disediakan dengan suhu substrat yang berbeza dari 200°C hingga 550°C untuk set pertama dan masa pemendapan antara 60 minit hingga 180 minit untuk set kedua, sementara parameter pemendapan yang lain ditetapkan sepanjang tempoh pertumbuhan. Ketebalan sampel ditentukan dengan menggunakan alat ellipsometer, kajian morfologi bahan pula dianalisis dengan menggunakan Atomic Force Microscope (AFM) dan struktur sampel pula dianalisa dengan menggunakan spektroskopi fourier transform-inframerah. Analisis ketebalan sampel menunjukkan bahawa ketebalan filem tipis karbon serupa intan menurun dengan peningkatan suhu substrat tetapi meningkat dengan peningkatan tempoh pemendapan. Analisis AFM pula menunjukkan darjah kekasaran permukaan karbon serupa intan maksimum pada suhu 550°C untuk substrat kaca dan 300°C untuk substrat silikon, manakala darjah kekasaran permukaan yang tinggi juga diperolehi pada tempoh pemendapan 120 minit untuk kedua-dua jenis substrat. Suhu peralihan disarankan sebagai 400°C untuk substrat kaca dan 550°C untuk substrat silicon. Mekanisme pertumbuhan dijelaskan bersandarkan kepada model subplantation. Spektrum inframerah menunjukkan bahawa kedua-dua set sampel mengandungi banyak ikatan  $sp^3$  tetapi hidrogen masih lagi hadir di dalam setiap sampel. Keamatan penyerapan spektrum inframerah juga meningkat dengan penurunan suhu substrat dan penurunan tempoh pemendapan.

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# CHAPTER I

## INTRODUCTION

### 1.1 Introduction

Diamond has inspired both legends and industries. Its special properties have also spawned what can legitimately be called a wealth of niche applications. Today, there are just two ways in which diamond is both unique and dominant: the status diamond, and the working diamond. Status diamonds are symbols of power. Their beauty, rarity and cost limit ownership (Koizumi et al., 2008).

Diamond in the English, and Diamant in the French, are both synonymous with Adamant, which comes directly from the Greek word, *ἀδάμας*, meaning literally invincible, the unconquerable, and from the Latin word, *adamare*, to love, and also the Latin word *adamas*, meaning hard (Hershey, 1940).

Apart from their appeal as gemstones, diamonds possess a remarkable range of physical properties. Indeed, a glance at any compendium of material data properties will prove that diamond is almost always 'the biggest and best'. Among other properties, diamond is the hardest known material, has the highest thermal conductivity at room temperature, is transparent over a very wide wavelength range, is the stiffest material, the least compressible, and is inert to most chemical reagents.

With such a wide range of exceptional properties, it is not surprising that diamond has sometimes been referred to as ‘the ultimate engineering material’ (May, 2000).

## 1.2 Background Study

In 1797 Smithson Tennant demonstrated that diamond was a form of carbon; this is readily shown by burning a diamond in oxygen (Davis, 1993). For centuries, diamond had been found only in the gravel of rivers, so nothing had been known about its origin. Only in the late 1860s, diamond was found in South Africa, in Kimberlite – a volcanic rock formed under high pressure. In fact, appropriate conditions for diamond synthesis could be found inside the earth at a depth of a few hundred kilometers. It is therefore believed that diamonds were formed in this way. It is estimated that it happened up to  $2 \times 10^9$  years ago (Marinkovic, 2004).

Due to the high cost and scarcity of large natural diamonds, the researchers began to produce synthetic diamonds. The first successful synthesis of diamond was reported by Bundy and co-workers (1962). They used the high pressure and high temperature (HPHT) technique in which diamond was prepared at 8 GPa pressure and 1500 K, and graphite was the source of carbon and Fe, Ni and Co were used as catalyzes. After that the HPHT technique was developed by many researchers. Until now diamond for industrial consumption has been mainly from the HPHT synthesis method (Byrappa and Ohachi, 2003).

However, the drawback of the HPHT method is that it still produces diamond in the form of single crystals ranging in size from nanometers to millimeters, and this limits the range of applications for which it can be used. What is required is a method to produce diamond in a form that can allow many more of its superlative properties to be exploited, in other words, as a diamond thin film (May, 2000).

However, diamond films require high temperature (more than 700°C) to grow, hence limiting the choice of the suitable substrate. Diamond films also difficult to achieve smooth surface morphology for polycrystalline diamond and are not easy to deposit them on a large surface and at reasonable growth rates (Halbleitertechnik and Tibrewala, 2006).

The historical overview describes how Diamond-Like-Carbon (DLC) has a much shorter history than diamond itself. The discovery of DLC can be summarized as follow (Donnet and Erdemir, 2008, Liu and Dandy, 1995). In 1949, W. G Eversole from Union Carbide Corporation in US discovered that diamond could be deposited on a substrate from a hydrocarbon gas or a CO/CO<sub>2</sub> mixture by chemical vapour deposition (CVD) at low pressure and temperatures.

In 1953, Heinz Schmellenmeier reported a black carbon film derived from C<sub>2</sub>H<sub>2</sub> gas in glow-discharge plasma. His films exhibited great hardness and, hence, were very resistant to scratching by other hard objects. Meanwhile, in early 1970s, Eisenberg and Chabot produced such films on negatively biased metallic substrates by using ion beam deposition system. Their films were very hard and hence resistant to scratching and also possessed a high dielectric constant, high index of refraction, excellent optical transparency, and high resistance to corrosion in strongly acidic solutions.

However, in mid 1970s, Derjaguin, Angus and their co-workers led the first successful growth of diamond crystals on non-diamond substrates at a commercially practical deposition rate. Holland et al. and a few other researchers were also able to synthesize DLC films from other hydrocarbon sources by simply applying a radio frequency (RF) bias to the substrate materials and thus creating glow discharge plasma. This was followed by the development of various methods, such as dielectric discharge and hot filament, to increase the concentration of atomic hydrogen during CVD.

In late 1970s, Weissmantel et al. proposed that these films composed of crystalline diamond by systematic microscopic studies, confirming that the DLC films had an amorphous structure. In early 1980's, Japanese research group at

National Institute for Research in Inorganic Materials (NIRIM) synthesized individual faceted diamond crystal by microwave plasma and hot-filament assisted CVD. These result with convincing characterization evidence by electron microscopy, x-ray diffraction and Raman spectroscopy confirmed the earlier experiments and refocused worldwide attention on the synthesis of diamond by CVD.

### **1.3 Problem Statement**

Previous studies have shown various method of deposition of diamond-like carbon thin films, but most of them involve the high cost of construction and maintenance. To compete in global market of diamond-like carbon, providing the low-cost system is the most important task but at the same time, the high quality of diamond-like carbon is still maintain. In this study, a low cost and home-made DC-PECVD system is used but only amorphous carbon has ever been deposited previously. Continuation of the previous study, the diamond-like carbon will be tempted to produce from the same system. Slight modifications were made to enable a higher substrate temperature is achieved during the deposition process.

Influence of substrate temperature during deposition on the properties of the evolving diamond-like carbon is very often ignored (Lifshitz, 1996). Hence, this study will give more emphasis to the influence of substrate temperature on the formation of diamond-like carbon, thickness and IR spectrum of each sample. In the meantime, not many studies focusing on the transition substrate temperature where this value is important for continuity in future studies because researchers no longer need to find the minimum substrate temperature each time they want to deposit diamond-like carbon. But, this value is different for each technique, substrate material and precursor gas used in system, providing a wide room for study this value. This study will try to find the transition substrate temperature on silicon and corning glass substrate using DC-PECVD technique.

## 1.4 Objectives of Study

- i. To grow diamond-like carbon (DLC) thin films by using a conventional DC-PECVD technique from a mixture of methane, CH<sub>4</sub>, hydrogen, H<sub>2</sub> and Argon, Ar gasses at different substrate temperature and different deposition time.
- ii. To characterize the surface roughness and IR spectrum of diamond-like carbon (DLC) thin films by using Infrared Spectroscopy, Atomic Force Microscopy (AFM) and Ellipsometer.
- iii. To find the transition substrate temperature for diamond-like carbon deposited onto silicon and corning glass substrate.

## 1.5 Scope of Study

A conventional direct current – plasma enhanced chemical vapour deposition (DC-PECVD) is used to grow diamond-like carbon (DLC) thin films with different substrate temperature and substrate material. A mixture of methane (CH<sub>4</sub>), Argon (Ar) and Hydrogen (H<sub>2</sub>) gasses is used to deposit all samples. This technique is commonly used to grow diamond-like carbon thin films because of their low cost and easy to operate system. This study focused on determining the best substrate temperature to produce diamond-like carbon and also to compare the quality of diamond-like carbon deposited onto silicon and glass substrate.

In order to determine surface roughness of diamond-like carbon, Atomic Force Microscopy (AFM) is used to characterize the surface roughness of each sample. Meanwhile, the Infrared (IR) spectra can help us to show the contents of hybrid bonding in each sample, thus it can be used to determine the type of the samples that have been deposited. This IR spectrum is obtained from Infra-Red Spectroscopy analysis.