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No Effect of Ar Eximer Lamp on Diamond-Like Carbon Deposition by Photo Chemical Vapor Deposition

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Abstract

Diamond-like carbon was deposited on glass substrates by a photo chemical vapor deposition method using methane and hydrogen gases as a starting material. Light from an Ar excimer lamp was tentatively applied to the deposition together with a mercury lamp. The experimental results show the effect of an Ar excimer lamp was not obtained, indicating that other condition is necessary to make use of the Ar excimer lamp.

Keywords

Diamond-Like Carbon, Photo Chemical Vapor Deposition (CVD), Ar Excimer Lamp

1. Introduction

Diamond has excellent physical properties such as hardness, thermal conductivity, and also electrical properties such as a large bandgap and high electrical resistivity. However, precise diamond is quite difficult to grow. An imperfect stuff composed of both sp^3 and sp^2 bonds can be formed relatively easily and shows similar properties to diamond, then widely called diamond-like carbon. In other words, diamond-like carbon can be said an intermediate material between diamond and graphite. Since diamond-like carbon has similar properties to diamond [1], it has a high potential of practical use in terms of chemical stability, high electrical resistivity, high light transmittance and high hardness. These properties have been studied so far [2]-[5].

Chemical vapor deposition (CVD) methods are nowadays popular methods for semiconductor thin films. Starting materials are supplied in the form of gas and decomposed on the surface of substrates. The decomposition needs some energy

that is usually introduced as thermal energy or photo energy, or plasma was utilized as an energy source. In this paper, photo CVD was employed for the diamond-like carbon deposition. In addition to the mercury lamp, an Ar excimer lamp was superimposed. An Ar excimer lamp provides light at 126 nm, which is in the vacuum ultraviolet region and then has the ability to break chemical bond. For example, Ar excimer laser showed the bond breaking in silicon dioxide [6] or silicon nitride [7]. An Ar excimer lamp has the ability of surface cleaning of silicon wafers [8].

2. Experiment

The schematic diagram of photo CVD apparatus is shown in Figure 1. On the right hand, there is a substrate chamber that was evacuated to 20 or 200 Pa by a turbo pump. Slide glass (that was ultrasonicated for 3 min. in advance) was put on a plate as a substrate and a low-pressure mercury lamp (the wavelength is 185 and 254 nm) was installed 40 mm above the substrate. The plate was heated and controlled to be 100˚C. The gases of methane and hydrogen are introduced from the left side of the chamber, under the condition that the partial pressures of methane and hydrogen were controlled to be 1:1 at any time.

The two options were provided: Hg vapor and an Ar excimer lamp. Hg vapor was introduced from the bottom of the deposition chamber by heating Hg up to 70˚C. An Ar excimer lamp was installed in the left end, and emitted light to the gas mixing chamber. The output fluence and the wavelength were 5 mW/cm^2 and 126 nm, respectively. Ar gas was flowed at the rate of 10 l/min. A MgF_2 window separated the gas mixing chamber and an Ar excimer lamp.

In all experiments, deposition was performed for 2 hours. The obtained sample was taken out after cooled down to 40˚C. IR spectra were taken with a Fourier-transformed spectrometer of Spectrum 2000 by Perkin Elmer. Since the obtained film was too thin to detect by the transmitting configuration, a reflection method was adopted.

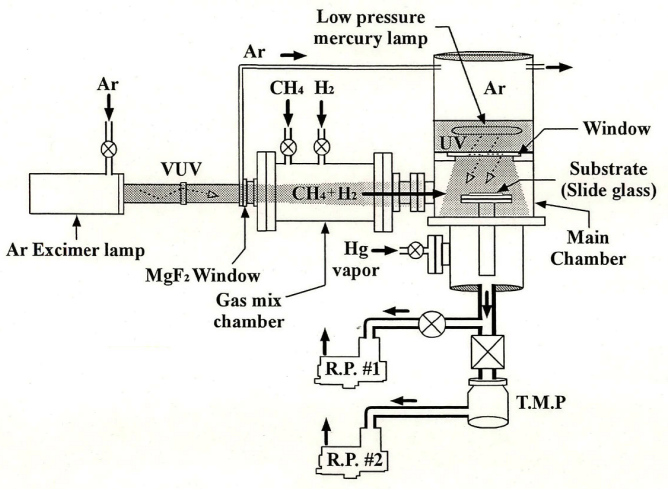

Figure 1. The apparatus for photo chemical vapor deposition.

3. Results and Discussion

The obtained samples show no trail of film deposition by a naked eye. A surface roughness analyzer did not obtain a film thickness more than several ten nanometers at the film edge. As a result, obtained films are supposed to be quite thin. Figure 2 shows IR spectra from six samples. Sample (a) is a non-deposited substrate for comparison. Sample (b) was formed under 20 Pa without Hg vapor, only with mercury lamp and Ar excimer lamp. In the region between 2855 and 2958 cm^{-1}, eight kinds of sp^3-bonding related absorption bands are situated [5] [9]-[13]. Sample (b) shows a weak and broad absorption band is observed.

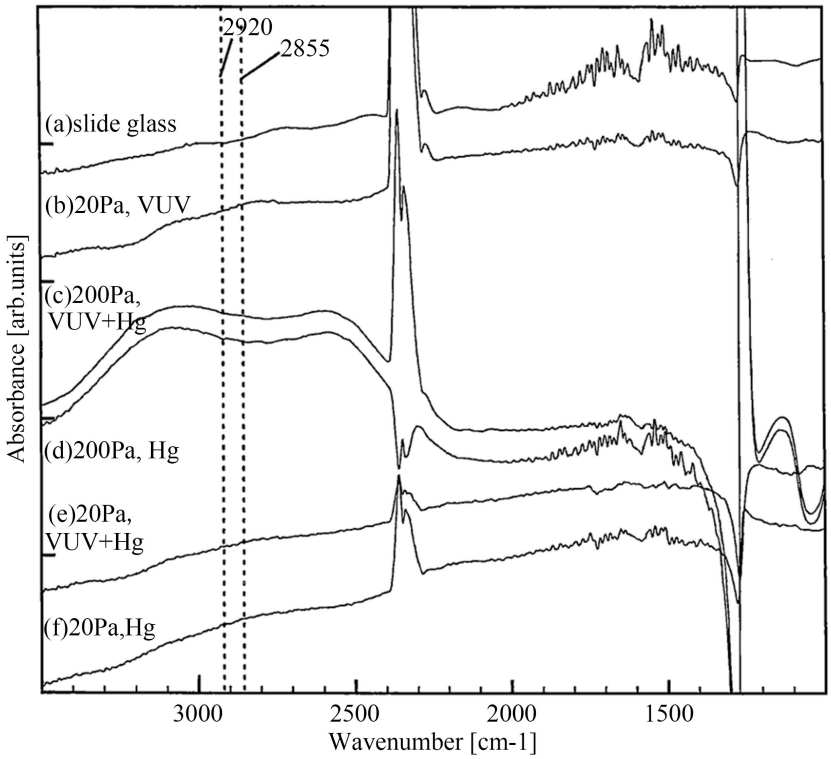

Figure 2. FTIR spectra taken from the 6 kinds of samples.

Ray *et al.* reported the formation of diamond-like carbon by photo CVD with the help of Hg vapor [9]. Samples (c)-(f) were deposited when Hg vapor was introduced. Samples (c) and (d) were obtained at a total pressure of 200 Pa, while samples (e) and (f) at 20 Pa. Samples (e) and (f) shows similar weak absorption in the same region as sample (b). On the other hand, samples (c) and (d) shows significantly strong absorption was observed. The broadness of the absorption peak suggests the disorder of atom arrangement in the film. The total pressure of 200 Pa seems to be critical for the deposition anyway.

The samples (c) and (e) were helped with Ar excimer lamp where the samples (d) and (f) without Ar excimer lamp. From these two sets of spectra, Ar excimer lamp appears to have given no effect on the IR absorption properties. Tode *et al.* reported that carbon contamination on Si wafers can be removed only with an

excimer lamp [8]. Al-Gharabli *et al.* reported the utility for water purification [14]. While the potential of an excimer lamp was reported, the mechanism has not yet been clarified so far in both cases. They did not show any evidence to show molecular decomposition. On the other hand, irradiation of Ar excimer laser light on silicon nitride induces decomposition and forms silicon on the surface [7]. In this case high temperature is an important factor at the same time as discussed in the literature. Samples c and d show little difference in our experiment; this implies other condition is necessary to make the use of an excimer lamp effectively.

4. Conclusion

The diamond-like carbon was challenged to deposit on glass substrate by means of photo CVD method. The main issue of this article is the effect of an Ar excimer lamp to the deposition in addition to an Hg lamp. Unfortunately, the enhancement of the deposition by the Ar excimer lamp was not clearly observed in our experiments. On the other hand, it was clarified that when the inner pressure of the deposition chamber was 200 Pa instead of 20 Pa, broad absorption was observed around 2900 cm^{-1}, which are attributed to the stretching vibration of sp^3 bonds between carbon and hydrogen. However, the absorption band is prominently broad. The reason for the broadness is assumed to the fact that the deposited film is not a crystal but an amorphous. It is found other condition is necessary to make the use of an excimer lamp effectively to form diamonds. It is speculated that the substrates are needed to be at high temperature, as is of the case for the chemical transformation from SiO_2 or Si_3N_4 to elemental silicon only by means of Ar excimer laser irradiation [6] [7].

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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