ArF Excimer Laser Induced Chemical Vapor Deposition of a-Si from Si_2H_6

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Introduction Photo-assisted and/or laser induced chemical vapor deposition (CVD) has attracted special interest recently, and it may become an interesting alternative to a conventional plasma enhanced CVD, whenever much higher quality film or much lower deposition temperature is desirable. Because, in plasma CVD, the substrate is bombarded with energetic neutral and charged particles as well as high-energy radiation, all of which induce chemical and physical damage on a growing film. In the case of photo-assisted CVD of hydrogenated a-Si, both Hg photosensitized reaction process[1] and direct photolytic decomposition process[2] have been examined. In this paper, we report the results of initial experiments on the ArF excimer laser induced CVD of hydrogenated a-Si film from Si_2H_6, and some physical properties of deposited films are shown. Si_2H_6 was used instead of SiH_4 as a source gas in this experiment, since the absorption cross section of Si_2H_6 for the ArF excimer laser beam (193nm) is much larger than that of SiH_4.[3,4]

Experimental Figure 1 is a schematic diagram of the experimental apparatus used. The pulsed excimer laser was operated at 193 nm (ArF) and typically at a repetition frequency of 100 Hz. The laser beam cross section at the substrate was about 10x10 mm^2. The average beam power ranged from 0.5 to 1 W/cm^2. The film growth chamber was constructed of stainless steel (volume =2500 cc) with 3-cm-diam UV-grade fused silica flat window. Si_2H_6 gas (99% purity) flowed through the chamber just 20-mm above the substrate as shown in the figure. The window was continually purged with He to minimize undesired deposition on it. Flow rates were held at 1.25 sccm for Si_2H_6 and 50 sccm for He. The total pressure was maintained at 10 Torr by a vacuum pump. Corning 7059 glass was used as a substrate, and the substrate temperature was varied from 100 to 350 C.

Results Hydrogenated a-Si films are obtained only in the area where the laser beam irradiated, but extremely thin films are deposited at the out side of the area. The film thickness ranged from 150 to 200 nm for 10-min growth-run. The average deposition rate (15-20 nm/min) determined from 10-min growth-run is independent of the substrate temperature. Although the window was continually purged with He, appreciable amount of a-Si was deposited onto the window. Since the a-Si film is opaque to the laser beam, the film deposited on the window affects the maximum film thickness available. The maximum thickness obtained under the experimental conditions stated above is about 250 nm.

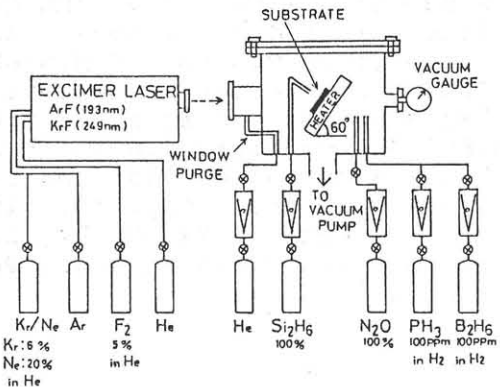

Fig.1 Schematic diagram of

Figure 2 shows the relationship between $(\alpha E)^{\frac{1}{2}}$ and E, where α is the absorption coefficient and E is the photon energy. Figure 3 shows the dependence of the optical energy gap of the laser CVD a-Si films on the substrate temperature. Temperature dependence of the optical gap of plasma CVD and thermal CVD films, which are produced from SiH_4 and Si_2H_6 ($P_{Si_2H_6}$ = 50 Torr), respectively, are also shown for comparison. The optical gap of the laser CVD films tends to decrease with increasing substrate temperature as similar to that of plasma CVD films. But it was found that the gap energy of the laser CVD films is rather large as compared to both films obtained by plasma CVD and Hg photosensitized CVD.[1] The optical gap of the laser CVD film deposited at 350 C is similar to that of thermal CVD film deposited at the same temperature. The optical gap was determined to be in the range of 1.8-2.7 eV, and the reason for this high energy gap is not yet understood.

The dark conductivity of the undoped films ranged from 10^{-11} to 10^{-8} (S/cm), and it tends to decrease with increasing substrate temperature. The photoconductivity upon exposure to 365 nm light from a high-pressure Hg lamp (10^{15} photon/cm^2/sec) ranged from 2×10^{-9} to 2×10^{-6} (S/cm). Figure 4 shows a photoconductive spectrum of the film deposited at 300 C. Since the optical gap is as large as 2.11 eV, the response is observed in relatively shorter wavelengths.

Acknowledgements This work was partly supported by IWATANI & Co., Ltd. and FUJIKIN Co., Ltd. The author would like to thank Mr. K.Harada of TOAGOSEI CHEMICAL INDUSTRY Co., Ltd. for supplying Si_2H_6.

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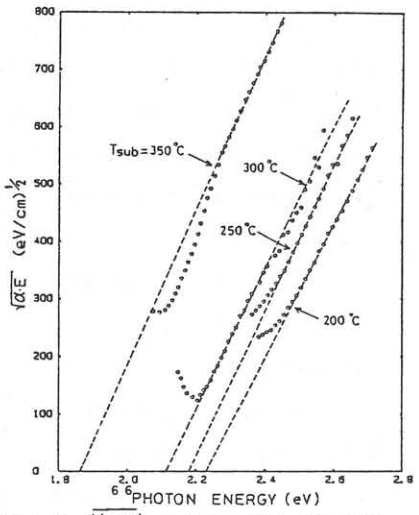

Fig.2 $\sqrt{(\alpha E)}$ vs photon energy for laser CVD a-Si films.

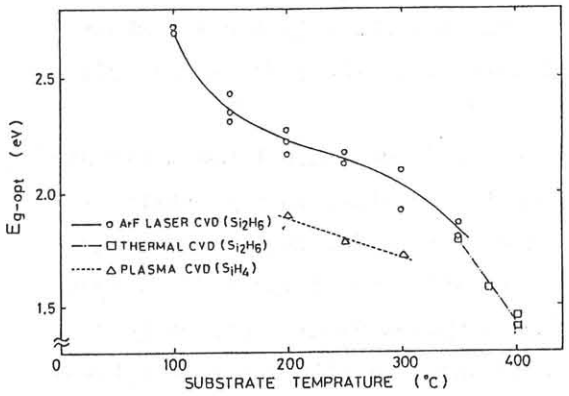

Fig.3 Dependence of the optical gap on the substrate temperature.

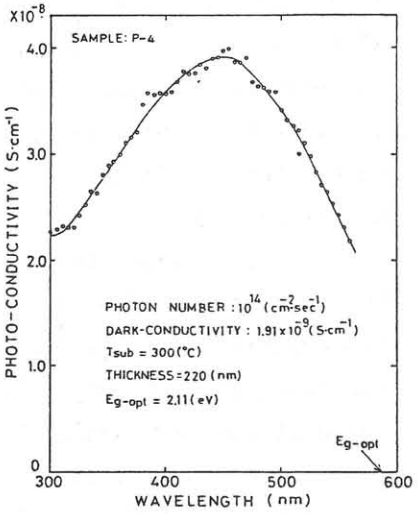

Fig.4 Photoconductive spectrum of laser CVD a-Si films.