Growth Study of a-Si:H Thin Films by Hot Wire Cell PECVD Method

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Abstract : The Hot Wire Cell PECVD method has been newly developed to grow hydrogenated amorphous silicon (a-Si:H) thin films. The optical and electronic properties of the a-Si:H thin films have been investigated. The deposition rate was improved by increasing the rf power. The optical band gap varied from 1.78 eV to 1.66 eV with increasing the rf power from 20 to 60 watts. The FTIR spectra showed lower hydrogen content. The hydrogen content has been successfully reduced without decreasing the films conductivity. The optical band gap varied from 1.69 eV to 1.7 eV with increasing the substrate temperature from 175^{o}C to 275^{o}C. The dark conductivity of the

a-Si:H films deposited with hot wire cell PECVD method is one order of magnitude higher than hot wire PECVD method. The highest dark and photo conductivities ($1.96x10^{-6}$ $S.cm^{-1}$ and $1.76x10^{-3}$ $S.cm^{-1}$, respectively) were obtained at substrate temperature of 275^{o}C.

Keywords: a-Si:H, Conductivity, Hydrogen contents, Hot Wire Cell PECVD.

Introduction

Hydrogenated amorphous silicon (a-Si:H) materials have been applied at optoelectronic devices, such as solar cells. In the solar cell, the a-Si:H material is expected to have a low hydrogen content and high conductivity in order to have stability at high illumination intensity. The hydrogen contents of the a-Si:H thin films can be reduced by using the appropriate growth method. Plasma Enhanced Chemical Vapor Deposition (PECVD) method is commonly used to grow a-Si:H thin films [1]. In this method, the deposition parameter usually affects the distribution of hydrogen in the film [2]. The reaction of gas phase can make high silane bound in rf plasma and increase the defect content in the film. Consequently a new method must be developed to grow a-Si:H material with low hydrogen content. A recent method which has been developed is the Hot Wire Chemical Vapor Deposition (HW-CVD). This method is CVD method added with the hot filament [3-7]. Thin films deposited using this method have low hydrogen content (C_H<4%) [8-9].

However, it has low conductivity and non uniform thickness [10].

Rahman *et.al.* [11], have investigated the effect of argon dilution of silane on the hydrogen contents of a-Si:H films by direct current plasma glow discharge. The use of He dilution lead to higher deposition rate and lower hydrogen content. On the contrary, hydrogen dilution lead to films with high hydrogen content [12]. Recently the Hot Wire Cell method has been developed and successfully applied to grow a-Si:H thin films at a low substrate temperature with relatively high growth rates [13]. In this work, the Hot Wire Cell method has been developed to grow Hot Wire Cell PECVD a-Si:H thin films.

Methods

In our Hot Wire Cell PECVD method, the filament was placed in parallel with inlet gas system and outside of the electrodes. The tungsten wire diameter was 1.2 mm. The filament has coils with a diameter of 5.0 mm and a length of 2.0 cm. The distance between the filament and the electrodes was about 2.0 cm. The filament was heated by supplying the electric power directly and kept constant throughout the experiment. The Hot Wire Cell PECVD schematic diagram is shown in Fig. 1.

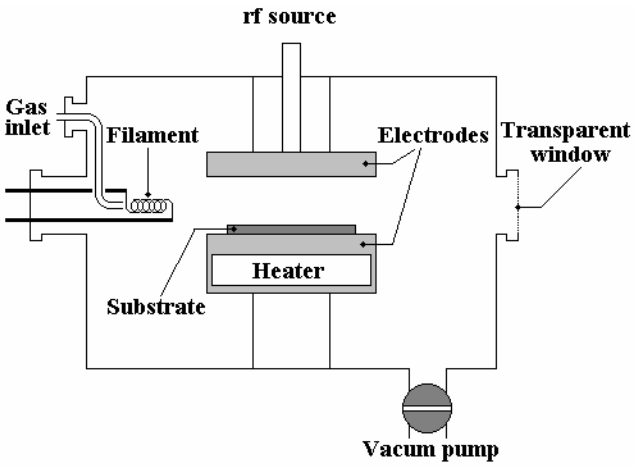

Figure1. Schematic diagram of Hot Wire Cell PECVD system.

Using 10 % Silane (SiH_4), this was diluted in hydrogen (H_2) gas as gas source. The a-Si:H film were deposited on Corning 7059 glass at rf power of 20 to 60 watts with substrate temperature of 175°C to 275°C and filament temperature of 800°C. The deposition pressure was kept constant at 0.9 Torr. Typical deposition conditions are listed in Table 1.

Table 1. The Deposition Parameters.

Substrate Temperature	175 to 275^{o}C
RF Frequency	13.56 MHz
RF Power	20 to 50 Watts
Deposition Pressure	0.9 Torr
Electrode Spacing	2.0 cm
Filament Temperature	800^{o}C
SiH_4 flow rate	50 sccm

The a-Si:H thin films were characterized using FTIR and UV-Vis spectrometer. The film thickness was measured using Dektak IIA. The conductivity was measured with coplanar method using Keithley 617 electrometer.

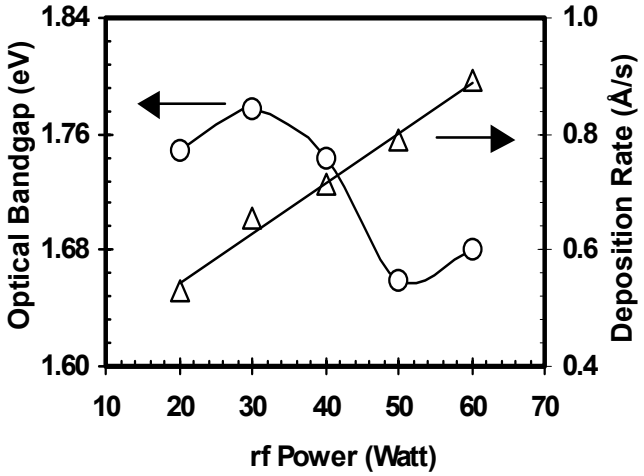

Figure 2. Optical bandgap and deposition rate as a function of rf power.

Results

The deposition rate and optical bandgap as a function of rf power are shown in Fig. 2. The deposition rate monotonously increased from 0.53 Å/s to 0.89 Å/s with an increase in the rf power from 20 to 60 watts. This contribution came from an increase of silane decomposition in plasma. The optical bandgap of a-Si:H thin films increased from 1.75 eV to 1.78 eV with increasing of the rf power from 20 to 30 watts. Further, the optical band gap decreased from 1.78 eV to 1.66 eV with increasing the rf power from 30 to 50 watts. This is attributed to

the decrease of hydrogen content of the a-Si:H films as shown in Fig. 3.

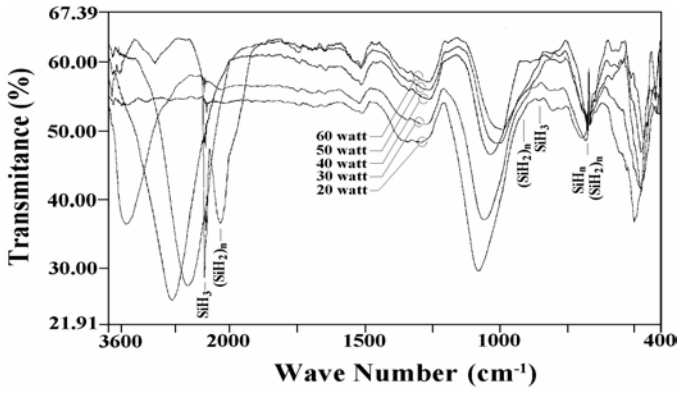

Figure 3. FTIR spectra of the a-Si:H thin films deposited at various rf power.

The FTIR spectra of the a-Si:H thin films deposited at various rf power is shown in Fig. 3. In the figure the absorption peak is at the wave number of 630 cm^{-1} because of the bending vibration of SiH and the rocking vibration of SiH_n and $(SiH_2)_n$. The absorption peak of the wave number of 880 cm^{-1} to 1000 cm^{-1} came from the bend scissors of $(SiH_2)_n$ and symmetric deformation of SiH_3. The stretching vibration of $(SiH_2)_n$ and SiH_3 appeared at the wave number of 2100 cm^{-1} and 2140 cm^{-1}. The lower hydrogen content was obtained at the rf power of 50 watts.

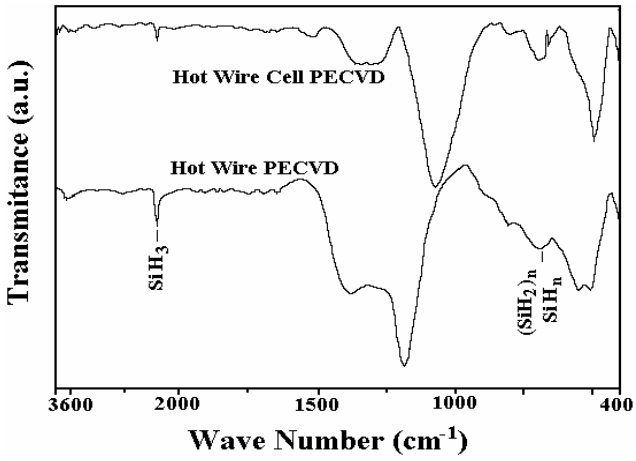

Figure 4. FTIR spectra of the a-Si:H films using Hot Wire Cell PECVD and Hot Wire PECVD.

The FTIR spectra of the a-Si:H films using Hot Wire Cell PECVD and Hot Wire PECVD method are shown in Fig. 4. The hydrogen content of the a-Si:H film deposited with hot wire cell PECVD was lower than Hot Wire PECVD.

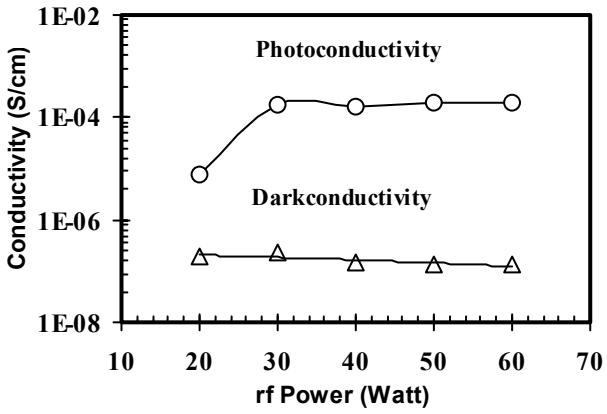

Figure 5. Conductivity as a function of rf Power.

The conductivity as a function of rf power is shown in Fig. 5. The dark conductivity of a-Si:H thin films was relatively constant. The photoconductivity of the a-Si:H films deposited at rf power of 30 watts was two orders of magnitude higher than that of 20 watts (7.55×10^{-6} $S.cm^{-1}$ compared with $1.84 \times 10^{-4} S.cm^{-1}$). The photoconductivity of the a-Si:H films was relatively constant as the rf power increased from 30 to 60 watts. This indicates that the hydrogen contents can be reduced without decreasing the conductivity of the films.

The deposition rate and optical bandgap as a function of substrate temperature are shown in figure 6. The deposition rate increased from 0.62 Å/s to 0.82 Å/s if the substrate temperature veried from 175^{o}C to 200°C. This is attributed to the increasing of the activation energy of the radicals in the deposition process. The increasing of the substrate temperatures from 200°C to 225°C will reduce deposition rate from 0.82 Å/s to 0.57 Å/s. This is attributed to the atoms becoming free of the surface layers in the when deposition process. The higher deposition rate of 0.82Å/s was obtained at substrate temperature of 200°C.

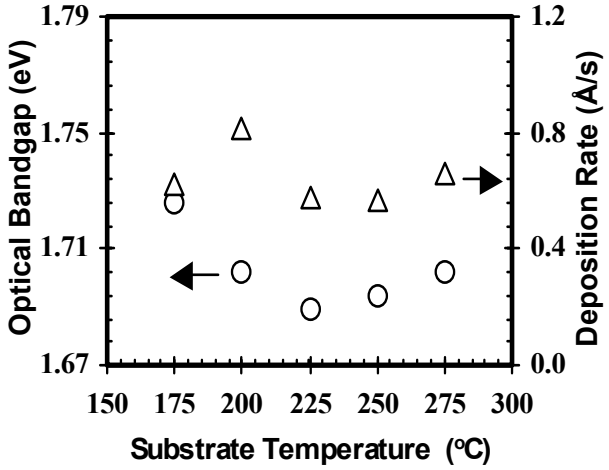

Figure 6. Optical bandgap and deposition rate as a function of substrate temperature.

The optical bandgap decreased from 1.726 eV to 1.690 eV due to increasing substrate temperature of 175°C – 225°C. This is attributed to the decrease of hydrogen content and an increase in bending of Si-Si in films. The optical bandgaps varied from 1.69 eV to 1.70 eV if substrate temperature increased from 225°C to 275°C. This is due to the reduced defect in the films.

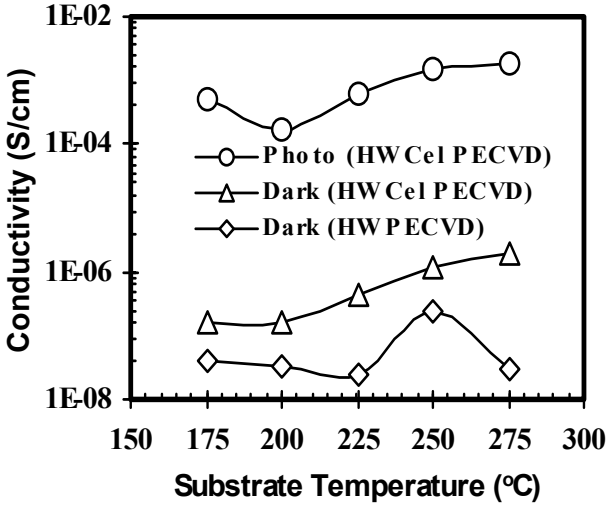

Figure 7. Conductivity as a function of substrate temperature.

The conductivity as a function of substrate temperature is shown in Fig. 7. The dark and photo conductivity of the a-Si:H thin film increased from 1.59 x 10^{-7} S cm^{-1} to 1.96 x 10^{-6} S cm^{-1} and 1.72 x 10^{-4} S cm^{-1} to 1.76 x 10^{-3} S cm^{-1}, respectively, with increasing substrate temperature from 175°C to 275°C. The highest dark and photo conductivities (1.96 x 10^{-6} S.cm^{-1} and 1.76 x 10^{-3} S.cm^{-1}, respectively) were obtained at substrate temperature of 275°C. The dark conductivity of the a-Si:H films deposited with hot wire cell PECVD method was one order of magnitude higher than hot wire PECVD method.

Conclusions

The deposition rate of the a-Si:H films monotonously increases with increasing rf power. The hydrogen contents of the

a-Si:H film deposited with hot wire cell PECVD is lower than Hot Wire PECVD. The hydrogen content has been reduced without decreasing the conductivity of the films. The dark conductivities of the a-Si:H films deposited with Hot Wire Cell PECVD method is one order of magnitude higher than Hot Wire PECVD method. The highest dark and photo conductivities were obtained at substrate temperature of 275^{o}C.

Acknowledgments

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