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EFFECTS OF SILANE FLOW-RATE ON THE STRUCTURAL PROPERTIES OF a-Si:H THIN FILMS DEPOSITED BY D.C. AND PULSED PECVD

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ABSTRACT

A pulsed PECVD system was developed from a modification of the existing d.c. PECVD system with a modulation frequency of 10KHz. In this work, the effects of silane flow-rate on the structural properties of films prepared by both techniques were investigated. These films were analysed using X-ray diffraction (XRD), Fourier Transform infrared (FTIR) absorption and Raman spectroscopy. The results presented here are only initial results from the pulsed PEVCD system since the deposition conditions are fixed to the optimized deposition conditions for the d.c. PECVD system which are 200^{o}C, 0.45 mbar and 1.4 W for the deposition temperature, pressure and power respectively. The ON-time and OFF-time was set at 30 seconds for the pulsed PECVD system. The FTIR absorption spectroscopy results showed that films produced by pulsed PECVD technique were comparatively more homogeneous and had lower H content at most flow-rates than the d.c. PECVD films. Evidence of nanocrystallites presence in the film structure was observed at high silane flow-rate in the pulsed PECVD films. The Raman spectroscopy results were used to confirm this effect.

INTRODUCTION

Hydrogenated amorphous silicon (a-Si:H) films produced by pulsed PECVD technique has been proved to be a respectable material for applications in thin film device technology like in solar cells [1, 2] and thin film transistors (TFTs) [3]. This deposition technique suppresses the dust formation in-a-Si:H films deposited at high deposition rates [4]. This is accomplished by modulating the plasma frequency and varying the ON-time to OFF-time. In such plasma conditions, nanocrystallites are formed in the a-Si:H films structure, improving the stability of the film properties [5]. Besides, by modulating the glow-discharge, the size of the particles generated in the plasma phase and incorporated into the growing film can be monitored [6].

In this work, the structural properties of a-Si:H films obtained by d.c. and pulsed PECVD techniques are investigated using FT-IR spectroscopy, X-ray diffraction (XRD) and Micro-Raman spectroscopy techniques. A comparison between the effects of silane flow-rate on the structural properties of the d.c. and pulsed PECVD a-Si:H films are made and studied.

EXPERIMENTAL DETAILS

The a-Si:H films studied in the work were prepared using a home-built pulsed PECVD system and was deposited on polished c-Si substrates. The pulsed power supply was applied to the PECVD system with the discharge time of 30 seconds and post-discharge time 30 seconds. The 30 seconds discharge time was accomplished using a pulsed voltage with a modulation frequency of 10 kHz. The deposition pressure and the substrate temperature were maintained at 0.45mbar and 200^{o}C respectively throughout the deposition process. Table 1 presents the deposition parameters used in the deposition of the a-Si:H films studied in this work.

Table : a-Si:H films preparation condition using d.c. and pulsed PECVD techniques.

	PULSED	DC
Flow-Rate of Silane	5, 10, 20, 30, 40SCCM	5, 10, 20, 30, 40SCCM
Deposition Voltage	640-700V	900-950V
Deposition Power	12.8-14W	12.6-13.3W
Deposition Time	3hours	1hour

The Fourier Transform infrared (FTIR) spectra were performed in transmission mode within the scanning range of 400 to 4000cm^{-1} using a Perkin-Elmer System 2000 FTIR spectrometer. The hydrogen content; C_H was determined using the relation [7]:

$$C_H = \frac{A}{N_S}\int \frac{\alpha(\omega)}{\omega} d\omega \quad \ldots\ldots\ldots\ldots \qquad (1)$$

where $\int \frac{\alpha(\omega)}{\omega} d\omega$ is the integrated intensity of the Si-H absorption band at 650cm^{-1}. A is the proportionality constant for this Si-H mode and the value used for the films studied in this work is 1.60x 10^{19}cm^{-2} [8] and and N_{Si} is the atomic density of silicon atoms in c-Si which is taken to be 5x10^{22}cm^{-3} [9]. The Si-H/Si-H$_2$ stretching band at around 2000cm^{-1} was deconvoluted into two Gaussian functions centred at around 2000cm^{-1} and 2090cm^{-1}. The microstructure parameter, R was determined using the relation [10]:

$$R = \frac{I_{2090}}{I_{2000} + I_{2090}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \qquad (2)$$

where I_{2000} and I_{2090} were the integrated intensities at the Si-H stretching band at 2000cm^{-1} and at the Si-H$_2$ stretching band at 2090cm^{-1} respectively.

The Raman measurement was used to obtain the Raman transverse optic (TO) mode peak at 480 cm^{-1} wave number [11]. In this work, the Renishaw System 2000 micro-Raman spectrometer was used to obtain the Raman spectra of the samples. The light source used was Ar+ laser, 514.5 nm (25mW) wavelength with laser spot size of 1mm. The scanning range used for this measurement was from 200 cm^{-1} to 1000 cm^{-1}.

Crystallinity in the a-Si:H films were investigated using a glaze-angle X-ray system, model SIEMENS D5000. The particle size, *D*, for a-Si:H films can be calculated from Scherrer's equation [12]:

$$D = \frac{k\lambda}{\beta_{\frac{1}{2}} \cos\theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where λ, $\beta_{1/2}$ and θ are the wavelength of the X-ray beam (Cu-Kα=1.5402Å), the full width half maximum (FWHM) value and Bragg angle of the diffraction peak respectively.

RESULTS AND DISCUSSIONS

Fig. 1 shows the variation of the hydrogen content with silane flow-rate of a-Si:H films as determined from the FTIR spectrum of the films. C_H decreases gradually with increase in silane flow-rate for the d.c. PECVD films. As for the pulsed PECVD films C_H increases to a maximum at silane flow-rate of 20sccm and decreases again with further increase in silane flow-rate. Generally, C_H in pulsed PECVD films is lower than C_H in d.c. PECVD films except at silane flow-rates of 20sccm and 40sccm.

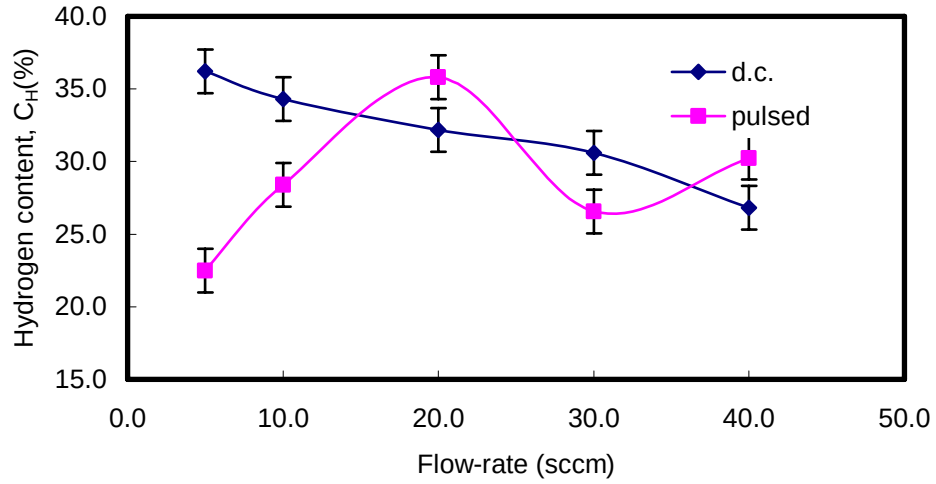

FIGURE 1: Variation of the hydrogen content of a-Si:H films with silane flow-rate by using d.c. and pulsed PECVD techniques. d.c. and pulsed represents the d.c. and pulsed PECVD techniques.

Fig. 2 shows the variation of microstructure parameter, R of a-Si:H films produced by using d.c. and pulsed PECVD techniques with silane flow-rate. The value of R gives a good indication of the film quality. Higher R value suggests that film is less homogeneous and contains higher concentration of microstructures. The results indicates that pulsed PECVD amorphous silicon films have lower R values than d.c. PECVD films at all silane flow-rates thus indicating that pulsed PECVD films are more homogeneous and have lower concentration of microstructures.

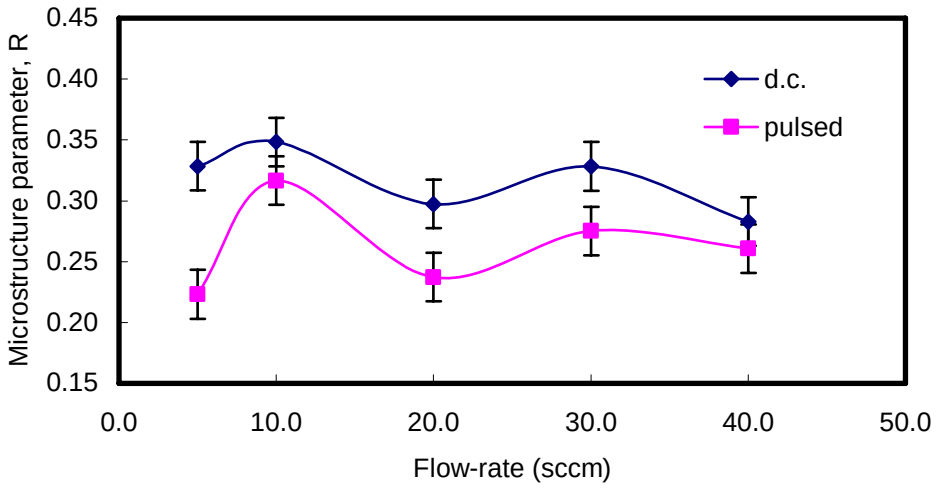

FIGURE 2: Variation of the microstructure parameter of a-Si:H films with silane flow-rate by using d.c. and pulsed PECVD techniques.

Fig. 3 represents the X-ray diffraction (XRD) spectra of a-Si-H films prepared by pulsed PECVD technique. No XRD peak is observed for any d.c. PECVD films indicating a purely amorphous structure. Evidence of nano-crystallinity is observed for pulsed PECVD films prepared at silane flow-rate of 40sccm. A single XRD peak is observed at 2θ angle of 56^{o} corresponding to (311) plane of crystal Si. The average crystallite size corresponding to this peak is about 50nm. This peak arises from the amorphous silicon baseline, indicating that most probably, that the material has isolated microcrystalline phases within the amorphous phase of the film structure.

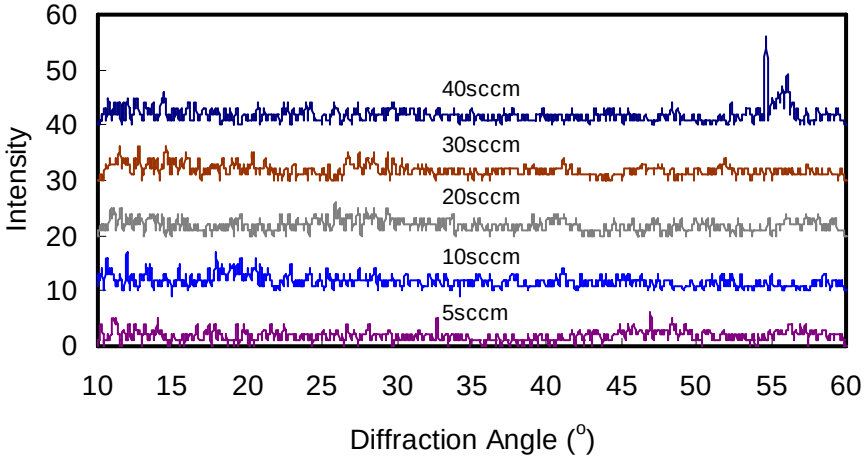

FIGURE 3: X-ray diffraction spectra of a-Si:H films deposited at different silane flow-rates using pulsed PECVD technique.

Fig. 4 presents the Raman spectra of a-Si:H films deposited at different silane flow-rates using dc and pulsed PECVD techniques. The Raman spectra for all films showed broad peaks with maximum at 480cm^{-1} indicating purely amorphous structure. The Raman spectra for the pulsed PECVD film prepared at silane flow-rate of 40sccm showed a sharp protruding peak at 495cm^{-1} emerging from the broad amorphous peak. This confirms the presence of nanocrystalline phase in this film as observed from the XRD spectrum of this film. This crystalline peak shifted to lower wave number due to the dominance of the amorphous phase of this film.

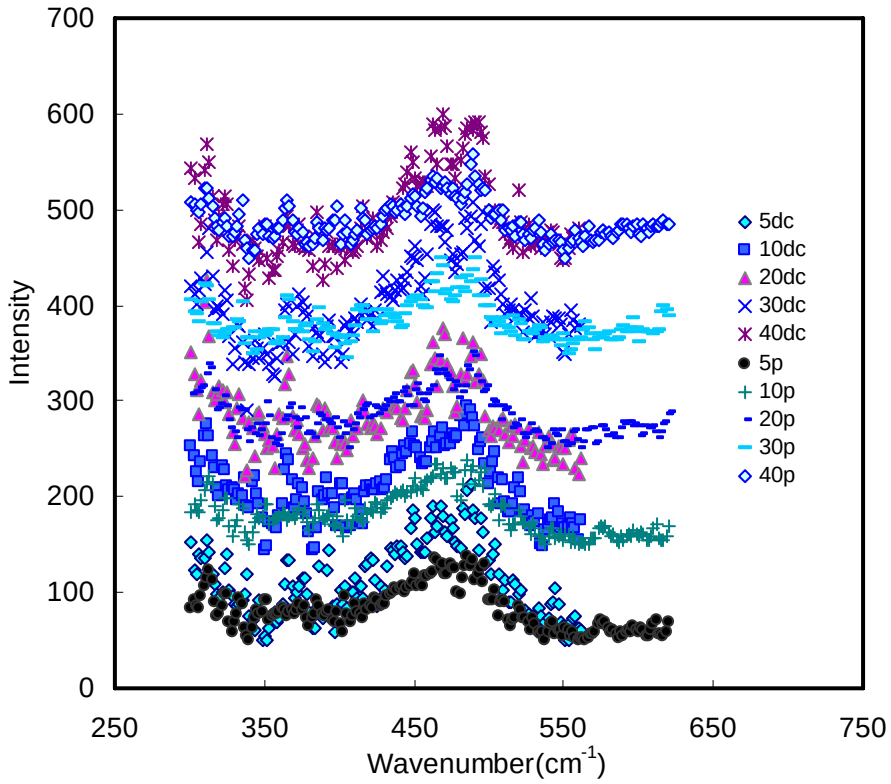

FIGURE 4: The Raman spectra of a-Si:H films deposited at different silane flow-rates using d.c. and pulsed PECVD technique. The number on the legend of these plots indicates the silane flow-rate used, dc indicates d.c. PECVD film and p indicates pulsed PECVD film.

CONCLUSIONS

The structural properties of the a-Si:H films deposited using our newly developed pulsed PECVD system and our existing d.c. PECVD system has been studied. The pulsed PECVD a-Si:H films generally have lower hydrogen content and are more homogeneous than the films produced by our d.c. PECVD system. High silane flow-rate used in pulsed PECVD system results in films with isolated nano-crytallite phase.

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