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Analysis of H_2 and SiH_4 in the Deposition of pm-Si:H Thin Films by PECVD Process for Solar Cell Applications

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In the last decade, the amorphous materials have attracted the attention because their industry potential application as an appropriate material for the fabrication of semiconductor devices [1]. The hydrogenated amorphous silicon (a-Si:H) is one of them. This material is characterized because it has a spatially random lattice with Si-Si and Si-H covalent bond. That means, the function of the hydrogen atoms is saturate empty bonds, improving the quality of the material [2]. The a-Si:H is frequently fabricated as thin film employing techniques as: evaporation, sputtering, chemical vapor deposition, etc. In microelectronic and photovoltaic industry, Plasma Enhanced Chemical Vapor Deposition (PECVD) is the technique more employed to obtain a-Si:Hi films. Here, the plasma dissociates the molecules of inert gas and by sputtering the reactive species is deposited in substrate and this process occurs to temperatures below 300°C [3-4]. Polymorphous silicon films (pm-Si:H) are characterized by being hydrogenated amorphous silicon films with silicon crystals of nanometer size, embedded in the amorphous material. The presence of nanocrystals in the amorphous matrix results on films with lower density of defects on the band gap, and consequently better transport properties and larger stability than the amorphous materials. These optical and electrical properties of the pm-Si:H films make it an excellent material for the fabrication of optoelectronic devices, infrared sensors and solar cells. Therefore, in this work we deposited, studied and characterized pm-Si:H thin films obtained by PECVD at low frequency process with substrate temperature at 200°C at different values of pressure [5] and gas flows rates. Principally, we focused the study in the analysis of H_2 and SiH_4 in the deposition of the pm-Si:H thin films for solar cell applications. The films surface morphology was characterized by Atomic Force Microscope (AFM) while the analysis of the films cross section was performed by Transmission Electron Microscopy (TEM), as well UV-Visible Ellipsometry was used to obtain the optical band gap, films thickness and deposition rate. In the deposition conditions, one has influence in the nanocrystal density in the pm-Si:H thin films.

In this work, ten samples of pm-SI:H films were deposited by PECVD system “Applied Materials” AMP 3300 model with H_2 and SiH_4 gas mixed flows to low frequency (110 kHz). The chamber pressure and flow of H_2 and SiH_4 were adjusted in each sample. The values are shown in the table 1. In the Figure 1 are shown images obtained by AFM, corresponding to morphology of the pm-Si:H surface of the ten samples. One can see, at low pressures was not found evidence of nanoclusters and when it increases above 1000 mTorr, the silicon nanocrystals into the amorphous silicon films in surface can been seen. This study reports the analysis of Si nanoparticles of approximately 1.5 nm in size. Also, FTIR measurements were carried out in the spectral range from 400 to 2400 cm^{-1} in absorption mode. FTIR spectra of pm−Si:N:H films are presented in Figure 2. The spectrum of pm−Si:N:H consisted of typical absorption bands for different hydrogen bondings to nitrogen and silicon and silicon−nitrogen related bands. One can observe the peak around 640 cm^{-1} corresponds to Si–H rocking/waging modes, the band

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around 800–950 cm^{-1} is related to SiH_2 or SiH_3 bonding with low intensity. Main trend that intensity of bands assigned to SiHn decreases with the increase in ammonia content in PECVD. With this research is confirmed that by PECVD technique are obtained films of polymorphous silicon with controlled chamber pressure and gas flows. The influence of H_2 and SiH_4 in the deposition of pm-Si:H thin films by PECVD Process for Solar Cell Applications

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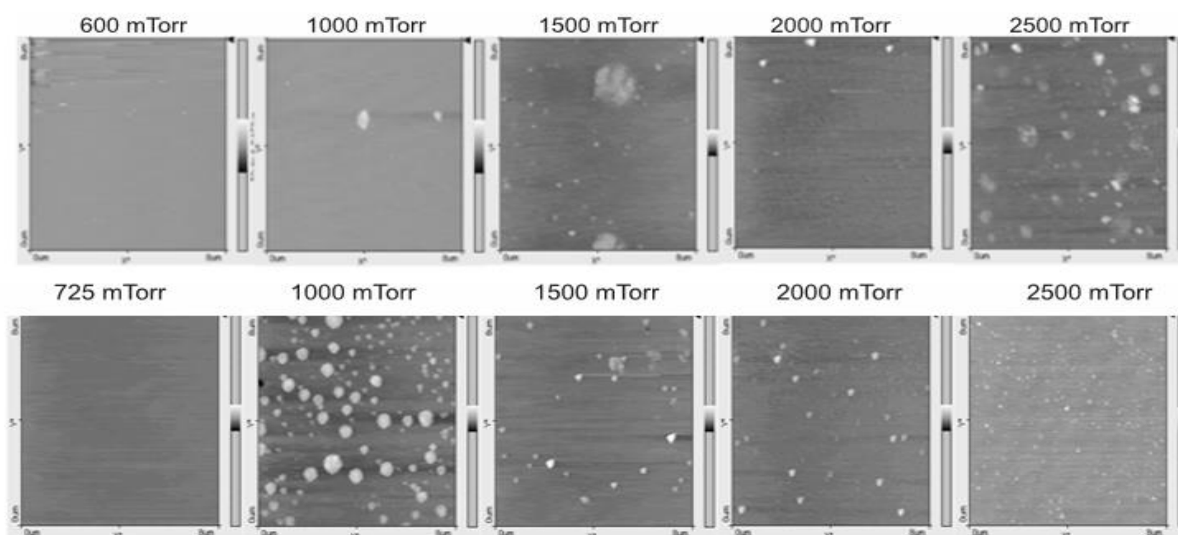

Figure 1. AFM photos of pm-Si:H films.

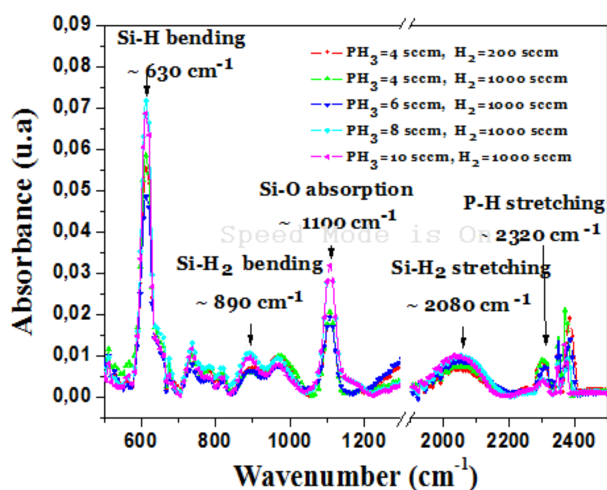

Table 1. Deposition conditions for pm-Si:H films and some characteristics.

Process	Pressure (mTorr)	H_2 flow (sccm)	SiH_4 flow (sccm)	Thickness (Å)	Band gap (eV)
1	600	1 000	50	583.6	1,97
2	1 000	1 000	50	414.0	1,98
3	1 500	1 000	50	995.1	1,96
4	2 000	1 000	50	680.5	1,90
5	2 500	1 000	50	105.1	2,03
6	725	4 000	200	1037.7	1,83
7	1 000	4 000	200	1118.6	1,90
8	1 500	4 000	200	1408.0	1,91
9	2 000	4 000	200	1073.6	1,90
10	2 500	4 000	200	132.1	1,95

Figure 2. FTIR spectra for pm-Si:H films. The main peak is located in the range of 630–670 cm^{-1}, that is characteristic of nanostructured silicon thin films.

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