

Analysis of thin layer optical properties of A-Si:H P-Type doping CH₄ and P-Type without CH₄ is deposited PECVD systems

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Abstract. The study of a thin layer growth of hydrogenated amorphous silicon (a-Si: H) using the technique of plasma enhancing chemical vapor deposition (PECVD) has been conducted. Material a-Si: H is one type of materials that is applied as solar cells. In this study, a thin layer of a-Si: H grown on glass substrates by using CH₄ and without CH₄. Most sources Si gas were used in silane gas (SiH₄) 20% dissolved in hydrogen gas (H₂). The addition of CH₄ gas greatly affects the structure of layer morphology and energy gap in thin layers. Based on the results of characterization using AFM, it was obtained a layer thickness which was added by CH₄ 100 nm and layer thickness of 45 nm without CH₄. While the optical energy band gap were conducted, based on the data from characterization using UV-Vis in the wavelength range of 400-800 nm, it was obtained layer optical energy band gap added by CH₄ that was 1.95 eV and layer without CH₄ that was 1.89 eV.

1. Introduction

Since the early 1970, the study of the development of crystalline to amorphous semiconductors has been carried out by the researchers. The study is characterized by hydrogenated amorphous silicon, a-Si: H, which is semiconductive [1],[2]. As the example of application of the device a-Si: H is solar cells, photovoltaic, color sensors, thin film transistor (TFT) and others [3]. This development is followed by the development of electronic device technology itself, as a result of various studies of the basic constituent materials.

Material a-Si:H can be grown by using the methods of Plasma Enhanced Chemical Vapor Deposition (PECVD), with plasma as growth media. This method uses Silane gas (SiH₄) as a source gas containing 10% in hydrogen gas (H₂) and amorphous silicon material obtained by the hydrogen content of about 10-20% [4]. The effect of hydrogen content in the process of growing resulting in defect rate moved into the conduction band and valence, so that the density of states (state density) is reduced sharply, as shown in Figure 1. For the band gap energy is strongly influenced by the hydrogen content and the existence of a defect in a thin layer of a-Si: H.



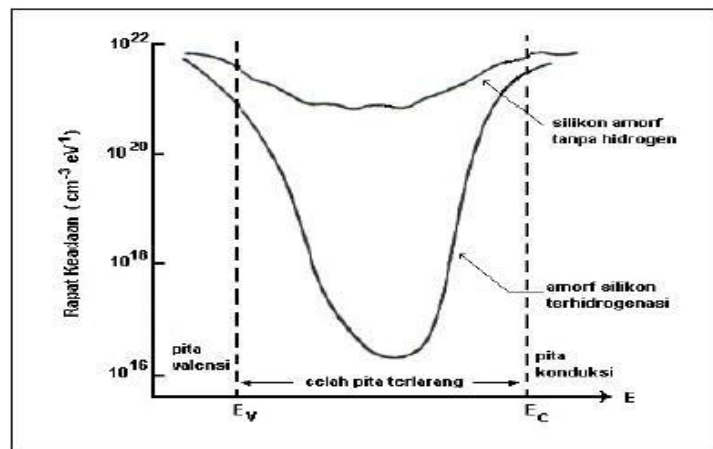


Fig.1 The effect of hydrogen content in the amorphous silicon to a state density [5].

The growth of material a-Si: H has some optimization parameters that determine the physical properties generated with the aims to improve the conversion efficiency of solar cells [6]. The optimization parameters are: The flow rate of hydrogen gas (H_2), chamber pressure, substrate temperature, RF frequency, RF power, time of deposition, dopant concentration [7], [8].

This research will be conducted on the comparison of the optical properties of a thin layer of a-Si: H p-type doping CH_4 with p-type without CH_4 is deposited by PECVD system with RF 13.56 MHz.

2. Experimental Methods

Thin layer of a-Si: H p-type was grown on the ITO substrate with PECVD system with gas flow SiH_4 , B_2H_6 and added CH_4 . During the process, it was given the deposition chamber pressure of 4800 mTorr, a temperature of 210 degree. RF power of 5 watts and time 15 minutes. The rate of gas fixed at 20 sccm SiH_4 and B_2H_6 gas rate fixed at 2 SCCM, while the rate on the layer used CH_4 gas at 30 SCCM.

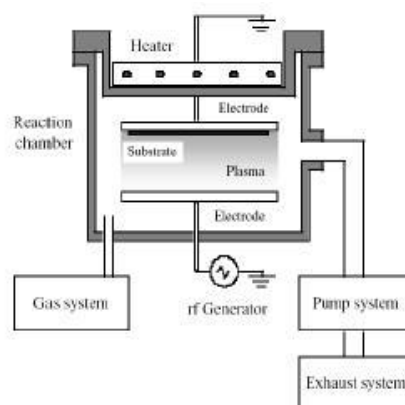


Fig. 2 Schematic RF-PECVD system [9]

Table 1.Parameters layer deposition of a-Si: H p-type

l a y e r	Substrate	ITO glass
o f a-Si:H	Substrates Temperature	210 degree
p-type	RF Frequency	13,56 MHz
a d d e d	FR Power	5 watt
C H 4	Pressure Deposition	4800 mTorr
	Source gas	SiH ₄ 20 sccm, B ₂ H ₆ 2 sccm and CH ₄ 30sccm
	Time	15 Minute
l a y e r	Substrate	ITO glass
o f a-Si:H	Substrates Temperature	210 degree
p-type	RF Frequency	13,56 MHz
w i t h o u t	FR Power	5 watt
C H 4	Pressure Deposition	4800 mTorr
	Source gas	SiH ₄ 20 sccm, B ₂ H ₆ 2 sccm
	Time	15 Minute

After the manufacture sample was completed, each sample sought optical properties that were the band gap by using a UV-VIS spectrometer. A thick of the sample layer was characterized by using testing tools Atomic Force Microscopy (AFM).

Microstructures, particle size and topography layer of a-Si:H were studied using AFM. For the measurement of tapping mode, AFM has been used for the purpose of investigation of surface topography of the A-Si:H. AFM Nanoscope III-A (Digital Instruments, Veeco, Metrology Group) utilized the optical beam deflection to monitor the placement of silicon cantilever having a spring constant 42 N/m and the resonance frequency of 300 kHz. It has been done with silicon probes that were above the cantilever in tapping mode. This method significantly showed improvement in the lateral resolution and resolution surface observations thin layer. Roughness of the surface was carried out by measuring the roughness parameters (RMS), which was defined as the average of the high RMS (Z) obtained from the mean data plane [10].

$$RMS = \sqrt{\frac{\sum_{i=1}^N (Z_i - Z_{ave})^2}{N}} \quad (1)$$

Z is a Z value at the time of measurement and N is the number of points between cursors. The method used for particle analysis can be performed with a height. This type of analysis works well on material by determining particle size that is connected to high.

3. Result and Discussion

The nature of a-Si: H p-type that has grown with PECVD system relies heavily on the particles (atoms or molecules) that is charged in the plasma and its interactions on the surface of the substrate. The particles (atoms or molecules) charged were called radical. Radicals were formed in the plasma include SiH molecules, SiH₂, SiH and atom H and atom B.

The results of the thickness measurement by Atomic Force Microscopy (AFM) are mentioned in the form of graph. Figure. 3 shows the morphology structure and thickness of thin layer a-Si: H to the rate of 2 SCCM B₂H₆, 20 SCCM SiH₄ and 30 SCCM CH₄ obtaining thickness of the layer of a-Si: H p-

type by adding CH₄ at 100 nm. Figure 4 shows the morphology structure and thickness of thin layer a-Si: H to the rate of 2 SCCM B₂H₆ and 20 SCCM SiH₄ obtaining thickness of the layer of a-Si: H p-type without adding CH₄ is 45 nm.

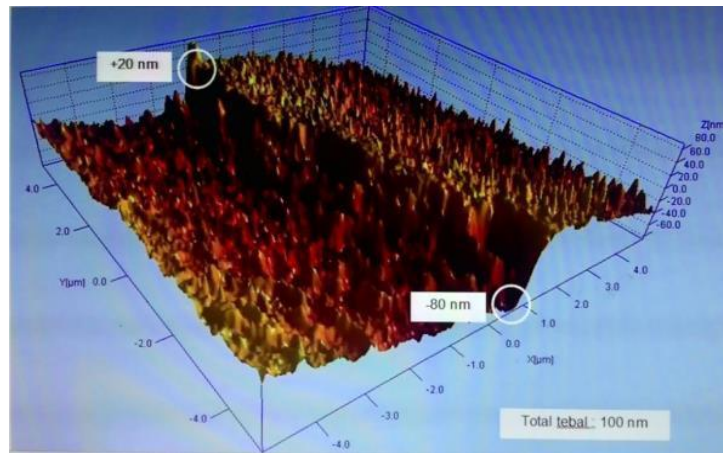


Fig. 3 The Morphology Structure and Thickness of Thin Layer a-Si: H p-type with the Addition of CH₄.

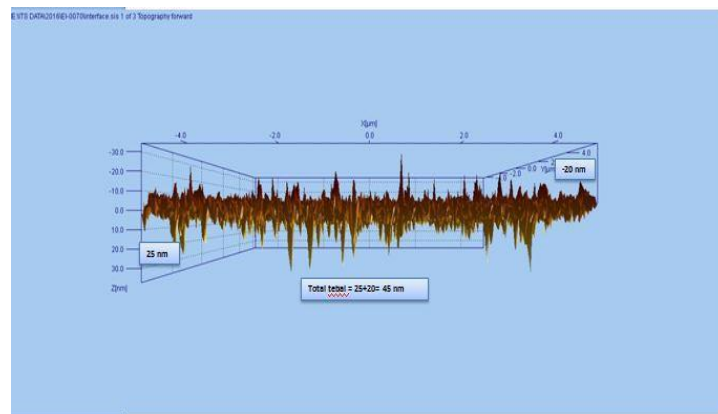


Fig. 4 The morphology Structure and thickness of thin layer a-Si: H p-type without addition of CH₄.

The calculation result of the energy gap by using a UV-VIS spectrometer was analyzed in graphic form with the relationship between the wavelength and absorption. Figure 5 shows the magnitude of the energy gap of a thin layer of a-Si: H to the rate of 2 SCCM B₂H₆, 20 SCCM SiH₄ and 30 SCCM CH₄ obtaining energy gap layer of a-Si: H p-type by adding CH₄ ~1.95 eV. Figure 6 shows the magnitude of the energy gap of a thin layer of a-Si: H to the rate of 2 SCCM B₂H₆ and 20 SCCM SiH₄ obtain energy gap layer of a-Si: H p-type without adding CH₄ ~1.89 eV.

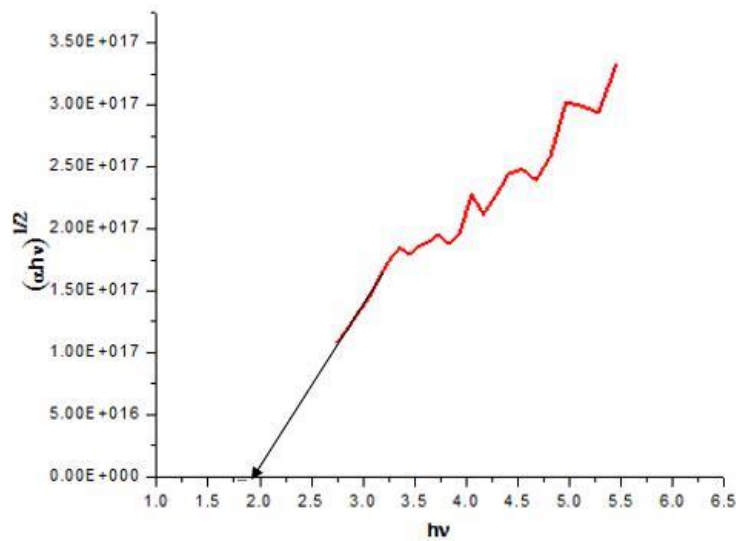


Fig. 5 Graph of the relationship between the wavelength with the absorption of a thin layer of a-Si: H p-type with the addition of CH4

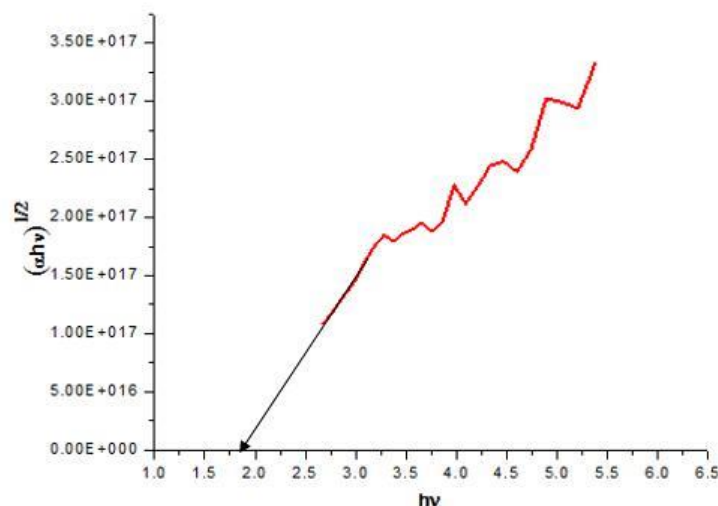


Fig. 6 Graph of the relationship between the wavelength with the absorption of a thin layer of a-Si: H p-type without the addition of CH4.

The parameter of optimization is a key indicator of the physical properties that will be generated. However, the development to get the material a-Si: H is still based on technology that is easy, inexpensive, efficient and of good quality.

The phase of characterization became the last stage that shows the physical properties produced by optimization of growth parameters that were performed [11],[12]. Physical properties that were obtained became a benchmark for subsequent optimization stages in order to get the quality of a thin layer of a-Si: H better. The increase in the rate of hydrogen causes more irregular layer a-Si: H p-type are formed but the rising rate of Boron causes irregularity of layer formed.

4. Summary

Based on this research, it can be concluded that the layer properties of a-Si: H p-type are influenced by the rate of source gas (SiH_4 , B_2H_6 and CH_4). The rate of source gas affects the number of radicals formed in the plasma. Thus, it also influences the effectiveness of interactions (bonding) between atoms on the layers of a-Si: H p-type with CH_4 , its thickness 100 nm and its energy gap ~ 1.95 eV, whereas a layer a-Si: H p-type without CH_4 , with its 45 nm thickness and its energy gap ~ 1.89 eV.

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