

STRUCTURAL AND OPTICAL PROPERTIES OF NANOCRYSTALLINE SILICON ON TEFLON SUBSTRATE BY RF MAGNETRON SPUTTERING

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Abstract

The potential of nanocrystalline silicon (nc-Si) on opto-electronic properties for thin films transistor (TFT) and solar cells applications have been extensively studied. Recently, the application of flexible substrates rapidly rising to form a new electronics large area circuit such as solar cell, flat panel displays (FPDs) and wearable electronic devices. A nc-Si thin film was successfully deposited on flexible substrates by using radiofrequency (RF) magnetron sputtering at room temperature. The effects of structural and optical properties of Argon gas flow rate have been studied. The Field effect scanning electron microscopy (FESEM) was used to analyze the structural properties of thin films. Based on the FESEM images, there is no significant different for all deposited samples, but from FESEM measurement, it showed the average particles size increase from 12.7 to 15.8 nm when the Ar gas flow rate increases from 40 to 100 sccm. The optical properties were measured by using UV-Vis-NIR spectrophotometer (JASCO V-670 EX UV-VIS-NIR Spectrophotometer) with the wavelength ranges between 300 nm and 800 nm. From the results, it shows that the optical transmittance for both on glass and Teflon substrates shown no difference. The optical transmittance result can be associated with the thickness of thin films which the thicker thin film absorbed more lights then led to the transmittance decrease.

Keywords: nc-Si; RF magnetron sputtering; Argon gas flow rate; Teflon substrate;

1.0 INTRODUCTION

The potential of nanocrystalline silicon (nc-Si) on opto-electronic properties for solar cells (Smirnov, 2013) and thin film transistor (TFT) (Park, 2012) applications have been extensively studied over the past decade due to higher mobility and stability of nc-Si over amorphous silicon (a-Si).

Recently, the application of flexible substrates rapidly rising to form a new electronics large area circuit such as solar cell, flat panel displays (FPDs) and flexible electronic devices because of some advantages such as light weight, flexible, unbreakable, remarkable and low-cost (Fortunato, 2012). HW-CVD and PE-CVD also known as hot-wire and plasma enhanced chemical vapor deposition (Sidorov, 2013 and Pawbake, 2015) are the most conducted studies on preparing thin films but there are some disadvantages by using this CVD method. Higher temperature during deposition process is the main disadvantage of CVD to produce thin films on flexible substrate. These CVD methods also have a complex process compare to sputtering method. RF magnetron sputtering method is a simple technique compares to the CVD method which already used to produce thin films such as a-Si and

poly-Si. Therefore, sputtering method can be used for deposition nc-Si on flexible substrate with good quality of thin films (Bouizem, 2012).

In this paper, the field emission scanning electron microscopy (FESEM) and UV-Vis-NIR spectrophotometer were used to characterize the effect of Argon gas flow rate on the structural properties of deposited nc-Si thin film on flexible Teflon substrate by RF magnetron sputtering.

2.0 EXPERIMENTAL

Pure n-type silicon (99.999%) target was used to deposit nc-Si thin film directly on Teflon substrates by using RF magnetron sputtering system. Before starting the sputtering deposition process, the base sputtering pressure was evacuated down approximately to 10^{-7} mTorr, and in order to remove any foreign objects on the target surface, the target was pre-sputtered for about 120 seconds.

The sputtering deposition was carried out for 1 hour in pure argon atmosphere at a room temperature. The effect of amount Ar gas flow rate on the structural and optical properties of deposit nc-Si thin films on Teflon substrate also has been investigated. All other parameters were fixed as shown in Table 1. The heating temperature was set at room temperature due to our objective is to deposit the nc-Si at lower temperatures as low as room temperature. The RF power and sputtering pressure were set at 200 W and 7 mTorr, respectively. The amount of Ar flow rate was varied from 40 sccm to 100 sccm with increasing 20 sccm.

Table 1 Parameters for deposition thin films at different Ar gas flow rate

Heating Temperature (oC)	Room temperature
Ar (sccm)	40, 60, 80, 100
O (sccm)	0
Pressure (mTorr)	7
RF Power (W)	200
Pre-Sputter Time (sec)	300
Process Time (sec)	3600

Conventional organic cleaning is the process where the Teflon substrates were cleaned before going through the deposition process. In this process, the Teflon substrate was soaked in an ultrasonic bath 10 minutes for each solution (acetone, ethanol, and deionized water). To remove organic impurities and oils on the substrates, acetone was used in the first step of cleaning process. Then, methanol was used after acetone because as it can remove the residue left by acetone, another residue left on the substrate. Lastly, DI water was used to dissolve methanol and also to prevent ionic contamination that may affect the proper operation of a device.

The optical properties were measured by UV-Vis-NIR spectrophotometer (JASCO V-670 EX UV-VIS-NIR Spectrophotometer) with the wavelength ranges between 300 nm and 800 nm. The structural properties of thin films were analyzed by using Field effect scanning electron microscopy (FESEM). The FESEM has a large depth of field, which means FESEM can view a greater range of distances while maintaining resolution and produces an image that is good representation of the three-dimensional sample.

3.0 RESULTS AND DISCUSSIONS

3.1 Structural Properties

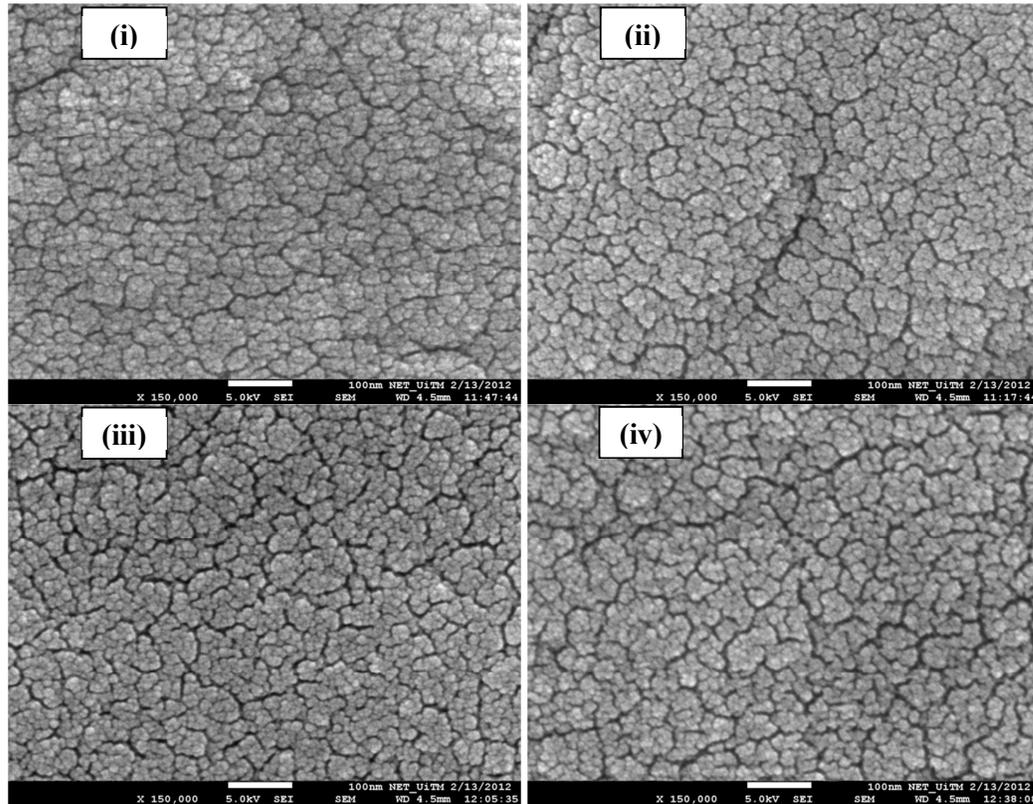


Figure 1 FESEM Images of thin films with different Ar gas flow rate (i) 40 sccm (ii) 60 sccm (iii) 80 sccm and (iv) 100 sccm

Figure 1 shows the FESEM images of deposited nc-Si thin films on Teflon substrate with different Ar gas flow rate. From the figure, it can be observed that there is no significant different for all deposited samples, but from FESEM measurement, it showed the average particles size increase from 12.7 to ~15.8 nm when the Ar gas flow rate increases from 40 to 100 sccm. Kim et al, 2011 reported that the increase of particle size due to the energy particles arriving at the surface decrease with increasing sputtering pressure, leaving less energy for surface diffuse due to collision with more atom.

Basically, in RF magnetron sputtering, the effect of Argon gas flow rate is similar with the effect of sputtering pressure.

3.2 Optical Transmittance

Figure 2 shows the optical transmittance of nc-Si thin films deposited on Teflon substrate at different Ar gas flow rate. From figure 2, it can be seen that the optical transmittance of the sample deposited at 100 sccm, shows the highest transmittance of nc-Si thin films at around at 91%. At the Ar flow rate 40 sccm, the optical transmittance is around 82% can be observed. At this point, the percentage of transmittance shows the lowest transmittance. For 60 and 80 sccm, the transmittance is around 85% and 88% was observed.

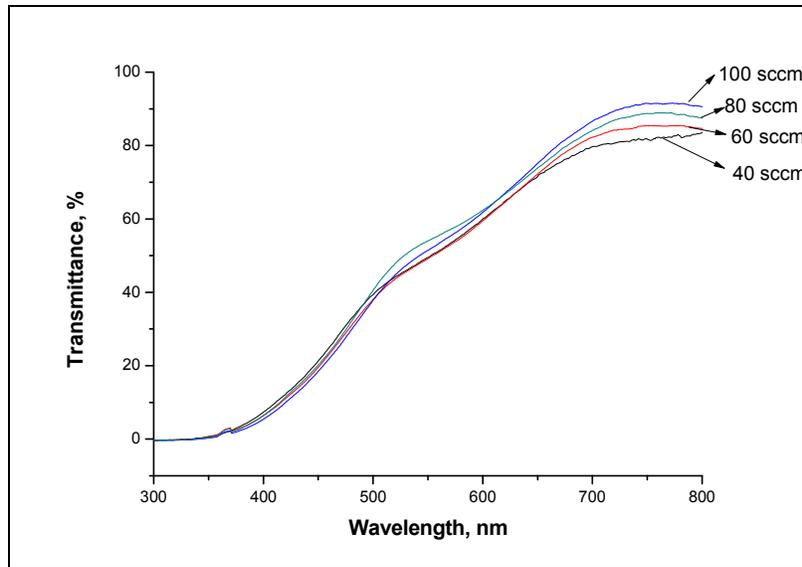


Figure 2 Optical transmittance deposited on Teflon substrate at different Ar gas flow rate

While, Figure 3 shows the optical transmittance of nc-Si thin films deposited on glass substrate at different Ar gas flow rate. From figure 2, it shows that the optical transmittance of the sample deposited at 100 sccm shows the highest transmittance of the nc-Si thin films at around at 91%. At the Ar flow rate 40 sccm, the optical transmittance around 76% can be observed. The percentage of the transmittance at 40 sccm shows the lowest transmittance. At Ar gas flow rate 60 and 80 sccm, the transmittance at around 83% and 85% was observed.

Wu et al. (2013) was reported the influence of transmission spectra of AZO thin films deposited at various Ar gas flows. The results indicate that the transmittance spectrum of the AZO films was about 80~92.8% in visible range. This means that the Ar gas flow rate does not have significant effect on the transparency. These results are similar with our result from figure 2 and 3.

By referring to the optical transmittance results, it can be related with the of thickness of thin film. Figure 4 shows the thickness and deposition rate of deposited nc-Si thin films on teflon substrate as a function of Ar gas flow rate. As can be seen from figure 4, the thickness and deposition rate increase from 40 sccm to 80 sccm, then slightly decrease when reach 100 sccm. The thickness of 100 sccm, 80 sccm, 60 sccm and 40 sccm was 273.6 nm, 354.6 nm, 364.8 nm and 347.4 nm, respectively.

From the result, it shows that at 100 sccm has the lowest thickness and the optical transmittance at 100 sccm for both on Teflon and glass substrate were around 90% which is the highest transparency. The optical transmittance result can be related to the thickness of thin films where by using thicker thin film, it absorbed more lights and then led to transmittance decrease.

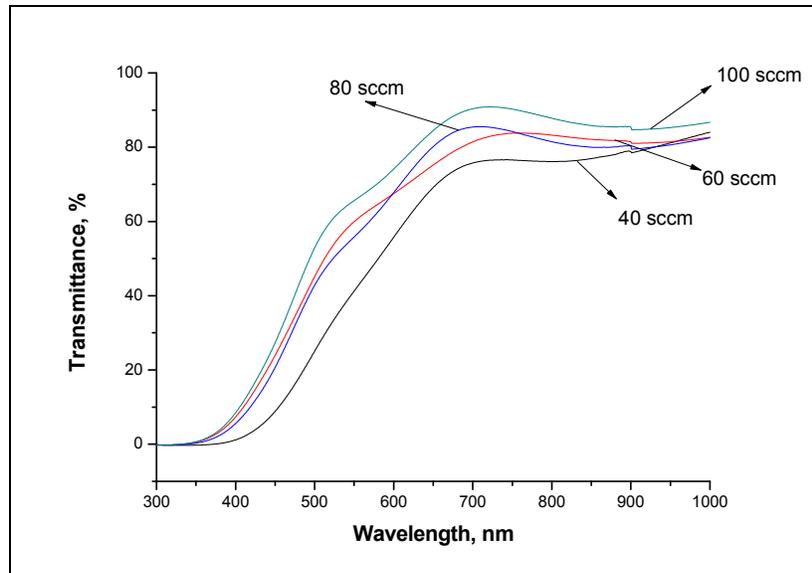


Figure 3 Optical transmittance deposited on glass substrate at different Ar gas flow rate

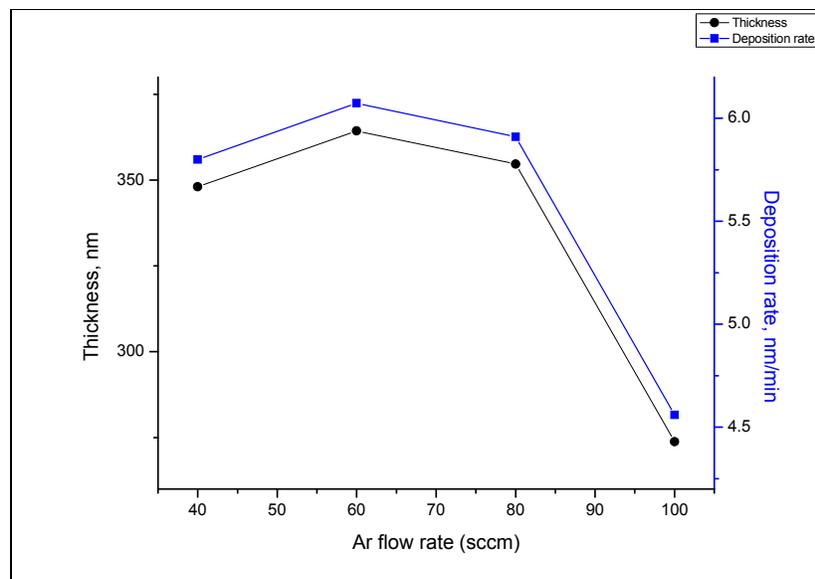


Figure 4 Thickness and deposition rate as a function of Ar gas flow rate

4.0 CONCLUSION

In conclusion, nc-Si thin films were successfully deposited directly on Teflon substrate by using RF magnetron sputtering at room temperature. The effects of optical and structural properties of thin films were investigated. There is no significant different on FESEM images for all deposited samples, but from FESEM measurement, it showed the average particles size increase from 12.7 to ~15.8 nm when the Ar gas flow rate increases from 40 to 100 sccm due to the energy particles arriving at the surface decrease with increasing sputtering pressure, leaving less energy for surface diffuse due to collision with more atom. Optical transmittance for both on glass and Teflon substrate shows no

difference. The optical transmittance result can be associated to the thickness of thin films which the thicker thin film absorbed more lights and then led to the transmittance decrease.

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