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THICKNESS AND CRYSTALLINE PROPERTIES OF SPUTTERED POLYCRYSTALLINE SILICON THIN FILM DEPOSITED ON TEFLON SUBSTRATES

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Abstract

A Polycrystalline silicon (poly-Si) thin film was successfully deposited on Teflon substrates at a room temperature using radiofrequency (RF) magnetron sputtering. The effects of sputtering pressure on the thickness and crystallinity properties of the thin films have been studied. Raman scattering spectrometer which manufactured by Horiba Jobin Yvon was used to measure the crystallinity. Based on the Raman spectroscopy results, it shows that the peak is around 512 cm^{-1} with 7 mTorr on the Teflon substrates. The crystalline's quality of the films on the Teflon substrates can be increased by increasing sputtering pressure to indicate the improvement of crystalline quality. Thickness for Teflon substrates was measured by using a surface profiler KLA-Tencor P-6. The results show that the thickness decreases by the increment of sputtering pressure. It can be concluded that, the kinetic energy during the sputtering process strongly influences the properties of deposit film such as crystalline quality and film density.

Keywords: *Poly-S; RF magnetron sputtering; sputtering pressure; teflon substrate*

1.0 INTRODUCTION

Poly-Si thin films have attracted much attention in application for advanced electronic devices such as thin film transistors (Kimura, 2011) and solar cells (Juang et al., 2010). Various techniques have been explored for fabricating poly-Si thin films and have been divided into two large groups; one is direct deposition of poly-Si thin films, and the other one is converting amorphous silicon (a-Si) to crystallized poly-Si. For a direct deposition method, plasma-enhanced chemical vapor deposition (PECVD) (Gall, 2010) and hot-wire CVD (Matsumoto et al., 2008) can be given as examples. However, the use of extremely gases such as silane, diborane and phosphine used in CVD is their drawbacks.

On the other hand, Solid Phase Crystallization (SPC) (Schmich et al., 2007), Excimer Laser Annealing (ELA) (Kuo, 2011), and Metal Induced Crystallization (MIC) (Gall et al., 2009) methods convert the deposited a-Si films into crystallized poly-Si films. ELA method can be done at low temperature, which is suitable for glass substrates, but there are some problems such as non-uniformity of grain growth on large area glass substrates and expensive processing costs (Gall et al., 2009). Although the SPC produces uniform thin films, longer processing time (4-64 hours) and high process temperature (~650°C) are their disadvantages (Gall et al., 2009). Other than the mentioned method, magnetron sputtering is also a promising method for the preparation of poly-Si thin films because the crystallinity can be controlled easily (Kim et al., 2004). Thin film growth can be substantially modified by ion bombardment during sputtering (Smith, 1995). In magnetron sputtering, there are a few parameters can be controlled during this sputtering process to get good crystalline quality such as sputtering power, substrate bias power, temperature, pressure, and mixing gas (Illiberi et al., 2009).

In this work, considering future applications of Si thin films for state-of-the-art electronic devices, in which light weight and flexibility are highly needed thus, deposition on low-heat resistance flexible substrate will be considered. We attempt deposition at room-temperature using RF magnetron sputtering.

This paper focuses on the effect of the sputtering pressure on the thickness and crystallinity properties of the poly-Si thin films on the Teflon substrates. The structural properties of deposited thin films on glass substrate were characterized using Raman spectroscopy for crystallinity and surface profiler for thickness measurements.

2.0 EXPERIMENTAL

Poly-Si thin films were deposited directly on Teflon substrates by using RF magnetron sputtering system using pure (99.999%) n-type silicon target (4 inches diameter and 0.25 inches thickness). Prior to each deposition, the base sputtering pressure was evacuated down to (~ 10^{-7} mTorr), and for about 120 seconds, the target was pre-sputtered to remove any impurity on the surface of the target.

Sputter deposition was carried out at a room temperature for 1 hour in pure argon atmosphere. RF power was 200 W. Total gas pressure was varied between 5 to 8 mTorr. Prior to the sputtering deposition, the glass substrates were cleaned by the conventional organic cleaning using acetone, ethanol, and deionized water (DI water) in an ultrasonic bath for 10 minutes respectively for each solution. Acetone was used in the first step of cleaning process as it helps to remove oils and organic impurities on the glass substrates. Methanol was then used as it can clean the residue left by acetone on the substrates and also remove any other residue left. DI water was then lastly used to dissolve methanol and also to prevent ionic contamination that may affect the proper operation of a device.

Film thickness was measured by surface profiler. Crystalline properties were measured with a laser Raman scattering spectrometer using a semiconductor laser of 532 nm wavelength, over a range of Raman shifts from 300–600 cm^{-1}.

3.0 RESULTS AND DISCUSSION

3.1 Thickness and Deposition rate

Figure 1 shows the thickness and deposition rate of thin film as deposited under various sputtering pressures (5 mTorr, 6 mTorr, 7 mTorr and 8 mTorr) on the Teflon substrates. In this figure, the film thickness and deposition rate decreased when the sputtering pressure increased from 5 to 8 mTorr.

It can be observed that the thickness and deposition rate at 5 mTorr was around 366 nm and 6.10 nm/min respectively. As the sputtering pressure increases to 6 mTorr, the thickness and deposition rate around 5.20 nm and 320 nm/min. Further increment of the sputtering pressure to 8 mTorr, the thickness and deposition rate decrease to 4.5 nm and 270 nm/min.

From this result, it shows that the thickness of film decreases while increasing the sputtering pressure. This indicates that higher sputtering pressure will result in a lower deposition rate. When in the sputtering process, there are some beneficial elements used to the film in order to become more crystallized, it is by increasing the number of the sputtered particles and the kinetic energy because with that will improve the migration of the particles on the growth of the film surface. By increasing the sputtering pressure, the density in the gas molecules in the deposition chamber will increase and by doing that process it also increases the number of sputtered particles. Meanwhile, the decrease of the mean free path of the sputtered particles will increase the collision probability and by that the decrease of the kinetic energy of the sputtered particles will happen.

So, from the above factors, it can be said that the crystallinity of the thin film is affected by the changes of sputtering pressure. This is also similar to the results of (Tseng et al., 2010) which explain that at a lower pressure, the sputtered materials have higher surface mobility and hence, a higher growth rate takes place. The kinetic energy of sputtered particles decreases by increasing sputtering pressure because collisions with sputtering gas are promoted. Particularly, at higher sputtering pressure, the mean free path is shorter than the distance between the substrate and the target, the kinetic energy is exponentially reduced with the pressure, so it decreases the thickness and deposition rate of the thin films.

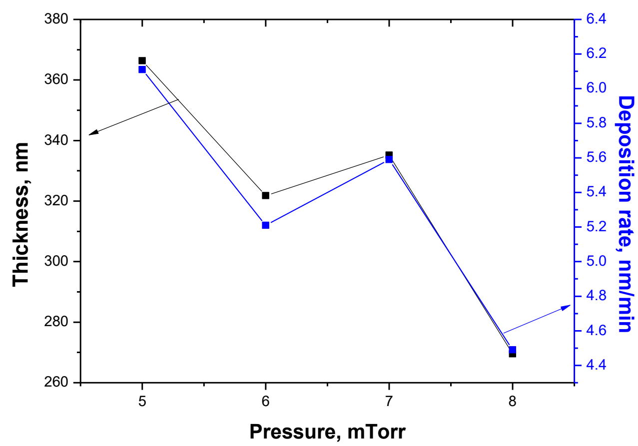

Figure 1 Thickness and Deposition Rate of Poly-Si Thin Film on Teflon Substrate

3.2 Crystallinity

Figure 2 shows the Raman spectra of poly-Si thin films on the Teflon substrates with different sputtering pressure. From this figure, it clearly shows that for thin film deposited at 5 mTorr, the transverse optical (TO) peak is located below 500 cm^{-1} which means that the thin film is not crystallized under this condition. However, when the deposition pressure increased from 6 mTorr to 8 mTorr, the Si-Si TO peaks ranging from 502 to 512 cm^{-1} are observed, it indicates that the thin film partially crystallized.

Considering that the single crystalline Si peak is at 520 cm^{-1}, from the figure it also indicates that the thin film deposited at 7 mTorr gives the highest crystallinity among the other with the Raman peak shift at around 512 cm^{-1}. It also indicates the existence of poly-Si phase for the sample deposited at 7 mTorr on the Teflon substrates.

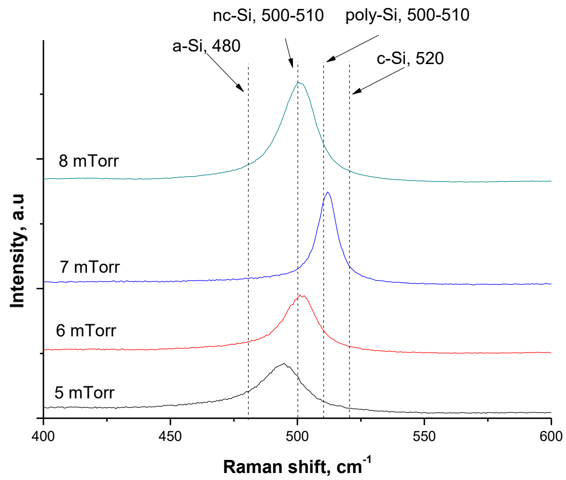

Figure 2 Raman Spectroscopy Result for Films Deposited Under Different Sputtering Pressure on Teflon Substrate

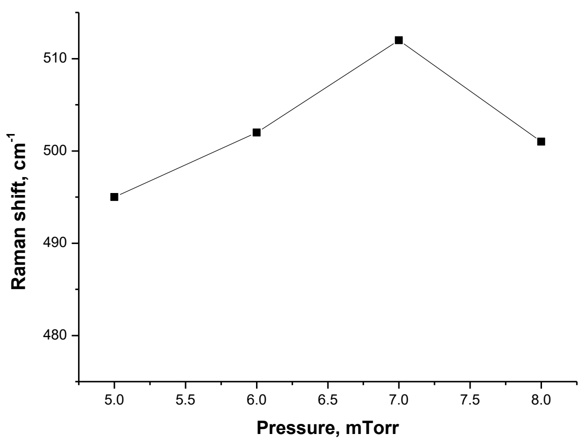

Figure 3 Relationship Between Raman Shift and Sputtering Pressure

Figure 3 shows the summarization of the relationship between Raman shifts and sputtering pressure. The number of Raman shift increases by increasing the deposition pressure indicating the improvement in crystalline quality. Considering crystallinity dependences on the sputtering pressure, theoretically, at a lower deposition pressure, higher bombardment occurs and there are two effects on the deposited thin films, one is to damage the crystallized particles and the other is to enhance the surface migration of the deposited particles and to promote the crystallization of the films. Crystallization becomes more effective when the film quality is poorer (Chawla et al., 2010). On the other hand, the damage becomes more serious when particles with higher kinetic energy bombard a film with higher quality. This can be seen in the films on the Teflon substrate in which the crystallinity is improved by the increasing pressure however it degrades at higher pressure.

As reported by Hashim et al., (2012) which poly-Si deposited on a glass substrate, the crystallinity decreased as sputtering pressure has increased. But, as shown in figure 3, the crystallinity increased from 5 to 7 mTorr and then decreased when sputtering pressure reached at 8 mTorr. It shows that the sputtering pressure parameter is more suitable to the Teflon substrate compared to the glass substrate.

4.0 CONCLUSION

In conclusion, poly-Si thin films were successfully deposited directly at room temperature by using RF magnetron sputtering. The effects of sputtering pressure on thickness and crystallinity were investigated. The increasing of sputtering pressure, results in thinner thin films and lower deposition rate. The kinetic energy during the sputtering process strongly influences the properties of deposit film such as crystalline quality, film density, and surface roughness. Based on the Raman spectroscopy results, it shows that the peak was around 512 cm^{-1} for this condition showing that the thin film is nanocrystalline instead of polycrystalline silicon. So, it needs the right combination of RF magnetron sputtering parameters in order to achieve a pure poly-Si thin film on the substrates.

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