Chapter 6
Conclusion

Hydrogenated amorphous silicon (a-Si:H) films is a well known material and have been intensively studied by many researchers since the discovery of solar cells application. Many valuables information and reports of the a-Si:H properties have been archived by researchers many years ago. It have been proposed that the structure of a-Si:H is a random network with short range bonding amorphous structure [1]. Studies on the surface morphology of a-Si:H showed that surface clusters and microstructure is related to the Si-H_2 component which can be identified from the infrared spectrum of the films. The structural and optical properties are greatly influenced by the preparation techniques and preparation conditions such as temperature, ionization current and inert gases dilution on silane. Through the studies on effects of the inert gasses dilution of silane on the a-Si:H films, *J.C. Knigths* [2] and collaborators reported that gasses of argon, neon, helium and krypton greatly affect the microstructural properties of a-Si:H. Argon are also found to have the effects of enhancing the growth rates of a-Si:H [3]. Result from many researchers also indicated that argon dilution produced higher defect densities associated with microstructures in the a-Si:H film [2]. Argon which has always been observed as a passive diluent gas, play an important role in the growth mechanism of a-Si:H microstructure network [4]. Since argon is a metastable atom, it is never involved in the chemical reaction of a-Si:H deposition process at least up to 400°C [5]. During deposition process, argon absorbs energy from electrons in the plasma and exchanged energy with the growth zone of the materials, as proposed by a model to explain the effect of argon dilution [4]. Besides, the two important effects of argon dilution during plasma deposition are argon ion bombardment [6] and argon incorporation [5,7] that can not be ignored. It is important to note that ion bombardment of argon on a-Si:H film during growth mechanism will cause both the beneficial and detriment effects on the growth materials [8].

In this work, the a-Si:H films were prepared using the d.c plasma glow discharge of pure silane and silane diluted with different flow-rates of argon. The a-Si:H films were categorized into high argon dilution samples and low argon dilution samples as described in previous chapters. The results from the optical spectroscopic studies and morphological studies of the films significantly show that argon dilution strongly affected the optical and morphological properties of a-Si:H films. The flow-rates of silane directly has strong influence on the deposition rates of a-Si:H film. The effects of using glass and c-Si substrates were observed to have some effect on the surface morphology however with high argon dilution, these effects become insignificant.

From the optical properties derived from the optical transmission spectrum, both of the high and low argon dilution samples showed a significant shift of the absorption edge with increase in argon dilution of silane. These observations showed that argon dilution does have an effect on the optical properties of a-Si:H films. The deposition rate of a-Si:H films in this work were influenced by argon dilution and also silane flow-rates. As expected, the higher flow-rate of silane increased the deposition rate of a-Si:H within similar environment and condition. The effects of argon dilution are different for high and low argon dilution samples. As expected, argon dilution has the effect of increasing the deposition rates in high argon dilution samples as argon plays the role of energy exchange in growth mechanism. However, the deposition rate decreased in low argon dilution films because of the strong ion bombardment of argon which results in the etching on the film surface [8]. Argon dilution reduced the refractive index of a-Si:H films which can be observed from the variation of refractive index with argon flow-rates. This indicated that argon dilution have effect of reducing the bulk densities of a-Si:H film and also argon ion incorporation resulted in the a-Si:H being less compact. Further studies on the variation of refractive index with deposition rates also showed that the increase in refractive index corresponded to the decrease in deposition rates. Low deposition rates result in a more compact structure of a-Si:H film.

Generally, argon dilution show the effects of increasing the optical energy gap (E_g) of a-Si:H but the effect depends on the deposition condition. At low argon dilution, the E_g showed a significant increase in E_g at 15sccm flow-rate of argon gas. While in high argon dilution films, the Eg increased to a maximum at argon flow-rate of 10sccm and is increased where 5sccm silane was diluted in 15sccm of argon. Argon dilution has the effect of reducing the H content in a-Si:H film. Argon dilution of silane decreased the Urbach Tail bandwidth, Ee for both the high and low argon dilution. This suggests that the argon dilution provided better growth mechanism to build a more ordered microstructure.

From the studies of the surface morphology utilizing the AFM, argon diluted a-Si:H generally exhibited a uniformly distributed granular clusters on the film surface as observed by many researchers. The appearance of these cluster are due to the formation of $Si\text{-}H_2$ component or $(Si\text{-}H_2)_n$ polymerization [6]. Besides the granular clusters, microstructure like isolated island clusters [9] and wavier columnar clusters also have been observed in some of samples in this work. From the AFM images of argon diluted a-Si:H, it can be inferred that argon dilution strongly affected the a-Si:H surface morphology. An exceptional morphological property was observed for a-Si:H prepared from 5sccm and 20sccm silane diluted in 5sccm argon, a wavier columnar cluster is formed on the a-Si:H films for both the high and low argon dilution a-Si:H films. This type of microstructure did not appear in the a-Si:H films as the flow-rate of argon was increased further than 5sccm. However, the size of granular cluster is observed to become smaller when the argon flow-rate used is higher. This suggested higher flow-rate of argon dilution contributed to a smoother a-Si:H surface and smaller sizes of granular cluster. The comparison of the high and low argon dilution a-Si:H films also showed that a-Si:H film prepared from higher flow-rate of silane gas have larger granular clusters compared to lower flow-rate of silane gas. The mean grain diameter of the a-Si:H films in this work lei between 45nm to 494nm while the roughness are in the range of 1nm to 34nm. The roughness and mean grain diameter have the similar behavior in the variation with argon to silane flow-rate ratio where they show two maximum points at 0.25 and 0.75 of argon to silane flow-rate ratio. These maximum points are believed to be due to the wavier columnar cluster affected by 5sccm flow-rate of argon dilution. The values mean grain diameter and roughness increased towards saturation values as the argon to silane flow-rate ratio increased furthers than 1due to the effect of argon dilution.

The Urbach Tail bandwidth, E_e and refractive index, n show an exponentially decreasing trend in the variation of these parameters with the argon to silane flow-rate ratio. The variation of E_e with n also show that the E_e varied linearly with n, thus suggesting that higher argon dilution resulted more ordered microstructure and consequently contributed to higher bulk density or more compact structure.

In the studies on effects of c-Si and glass substrate on the film surface morphology, the substrates has minor effects on the a-Si:H morphology. Due to the natural crystalline structure of c-Si, the c-Si substrate have the effect of producing smooth a-Si:H film morphology as compare to glass substrates. Glass does not have any effects on the deposited a-Si:H film morphology as the glass is a stable materials which is amorphous compounds of silicon oxide.

Since the studies on a-Si:H films in this work involved a-Si:H prepared from the d.c plasma glow discharge of silane diluted in argon at room temperature, it is suggested that future works should involve the studies on the effect of other inert gases such as helium and neon on the a-Si:H film properties. The effects of the preparation temperature also is an important factor to be studied because temperature greatly affected the growth mechanism of a-Si:H film. Since many researchers reported that annealing effects [5] improve the microstructure properties of a-Si:H, the studies on the annealing effects can be done for further information. In order to obtain a complete information of the studied a-Si:H properties, the characterization experiment is encouraged to utilizing others advance instrument such as Fourier Transform Infrared spectroscopy (FTIR), Tunneling electron microscopy (TEM), electron spin resonance (ESR) and Raman Scattering spectrometer.

References

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