

CHAPTER 6

CONCLUSION

In this work, the hydrogenated amorphous silicon films studied were prepared using d.c. plasma glow discharge at substrate temperature of 200°C. Helium dilution play an important role in the plasma deposition of a-Si:H. Thus the main objective of this work is to study the effects of helium dilution on the optical, electrical and structural properties of the films.

Diluting silane with helium resulted in a significant increase in growth rate of the a-Si:H films. At helium to silane flow-rate ratios of three or less, population of helium atoms in the metastable state was increased. These metastable helium atoms supply energy and momentum for gas decomposition generating high-energy deposition precursors thus increasing the deposition rate. The deposition of a-Si:H on c-Si substrates were also significantly higher than on glass substrates. Glass is a poorer conductor of heat than c-Si thus reduces electron impact dissociation of silane at the substrate surface thus decreasing the deposition rate of the film.

The non-silicon atom concentration of the film, I% represents the concentration of non-silicon atoms bonded to the Si atom such as H, O, N, and C. From IR spectra, only small amounts of oxygen impurities was found in the sample which was indicated by the weak absorption peaks at approximately 1000 cm^{-1} . Consistently, these results showed that O contaminant is smallest when He to SiH_4 flow-rate ratio is 2 and 3. The actual H content in the film, H% can be determined accurately from IR spectrum. Helium dilution showed a significant effect on the incorporation of H atom into the a-Si:H film structure at He to SiH_4 flow-rate ratio of three or less. The atomic percentage of hydrogen, H% in the film increases to a maximum value (~13%) when the helium to silane flow-rate ratio is one, but decreases when helium to silane flow-rate ratio is

increased further. The H(%) in fact have strong correlation with the deposition rate of the a-Si:H film. The high deposition rates of a-Si:H films prepared at helium to silane flow-rate ratios of 1, 2 and 3 is due to the increase in flux ratio of deposition precursors which is believed to be SiH₃ radicals to hydrogen or impurity ions or radicals at the growing surface of the film [1].

Helium diluted film appears to have effect on absorption edge of the transmission spectrum where the edge shift towards longer wavelength. Consistently, the helium dilution resulted in a decrease in the optical energy gap in the films. The optical energy gap decreased to a minimum with helium dilution and maintained this optical energy gap value when the helium to silane flow-rate ratio was increased further. The higher refractive index for the optimized helium to silane flow-rate ratio is due to the presence of higher concentration of Si-Si bonds as compared to Si-H, Si-O or Si-N in the film. The films deposited at He to SiH₄ flow-rate ratios of 3 or less had high concentration of Si-Si bonds as compared to the films prepared from pure SiH₄ and higher gas rate ratios. The Urbach energy, E_e value decreases sharply from 88 to 39 meV with helium dilution. This proved that the film formed using helium dilution silane prepared by d.c. PECVD are of high structural order equivalent to device quality a-Si:H.

The results from X-ray Diffractogram (XRD) showed an interesting phenomenon where evidence of microcrystallinity is observed for films deposited on c-Si substrates at helium to silane flow-rate ratio of 2, 3 and 4 but no XRD peaks were observed for the films deposited on glass substrates indicating that the films are purely amorphous. The absence of microcrystallinity in films deposited on glass substrates could be due to the lower deposition rate of the films [2].

From the AFM micrographs of a-Si:H films, it can be concluded that the surface roughness is significantly reduced for helium diluted films on c-Si substrate but no

significant change in the surface roughness is observed for the films deposited on glass substrate.

Dark conductivity of the a-Si:H film was significantly reduced at He to SiH₄ flow-rate ratio of two and less. As a conclusion, film prepared at He to SiH₄ flow-rate ratio of 2 produced the most homogeneous a-Si:H film with high Si-Si atom concentration and low oxygen contaminations. H atoms incorporated in the form of monohydride Si bonds are more dominant in this film and actively passivate dangling bonds reducing defects in the film structure. This contributes to the low film concentration as defect concentration in the film is significantly reduced. Thus He to SiH₄ flow-rate ratio of two can be deduced to be the optimum helium dilution of silane for the preparation of a-Si:H using d.c. PECVD technique in this work.

Hydrogenated amorphous silicon thin films produced by the homebuilt horizontal d.c. plasma glow discharge system can be used to encourage more work on it in the future. Beside using d.c. power, a-Si:H can also be produced by using pulsed or r.f. power. The effect of other deposition parameters such as the deposition temperature, pressure and ionization current on the film properties can also be studied.

There are other characterization techniques which can be used to study the film properties. The Electronic Scanning Resonance (ESR) technique which was widely described in the literature can also be used to provide valuable information on the microscopic structure of the a-Si:H film. The structural inhomogeneities of the film and the possibility of the presence of microcrystallinity can be determined from Raman Spectroscopy. The d.c. conductivity measurement also can be expanded by measuring the film at different temperatures ranging from liquid nitrogen to temperatures as high as 100°C.

All the information on the properties of a-Si:H in this thesis hopefully can be used as a necessary framework for a further improvement of this material and for future application especially in optoelectronic devices.

6.1 References

1. J. Perrin, *J. Non-Cryst. Solids*, **137 & 138** (1991) 639.
2. J. Cárabe, J.J. Gandía, N. González, A. Rodríguez, M.T. Gutiérrez, *Appl. Surf. Sci.*, **143** (1999) 13.