Chapter 8

Conclusion and Proposal for Future Work

The aim of this work is to investigate the role of hydrogen in the dc plasma glow discharge system produced by our in-house system. Hydrogen plays an important role in the plasma deposition of a-Si:H and its has been found that hydrogen content in a-Si:H film may vary from 5 to 50 %. Incorporation of hydrogen in the a-Si matrix is sensitively dependent upon the preparation condition and the main bonding configurations include Si-H, Si-H_2, Si-H_3 and $(Si-H_2)_n$. In this work, helium is used as a diluent for the reactant gas SiH_4 during the deposition process, and the effect on the resultant materials is investigated. It is found that diluting the silane in helium results in the reduction of Si-H_2 species in the film. The valence electron model (VEM) and a more comprehensive chemical bonding infra-red model (IRM) are used to determine the hydrogen percentage in the film. The VEM utilizes the optical transmission spectrum in the visible region while the IRM utilizes the Fourier Transform Infra-red transmission spectrum in the calculation of hydrogen content in the film. The effects of annealing on the hydrogen content calculated from these two techniques along with the effects of annealing on the optical energy gap, the room temperature conductivity and the density of states at the Fermi level N(E_f), are used to analyse the bonding sites of the bonded hydrogen calculated by these techniques. The hydrogen content calculated by the VEM is found to be associated to the H content on the Si-H sites while the IRM deduced hydrogen content represents the total hydrogen content in the film both in the monohydride and polyhydride bonding configurations. The VEM also includes Si-H bonding modes which are bonded or coupled to impurity atoms which are bonded to Si atom, as in the case of sample SAR10C where the Si-H bonds are bonded to Si-O-Si bonds to form O-(Si=)-H bonds.

The variation of the VEM hydrogen percentage with the optical energy gap for samples that are prepared by helium diluted silane and pure silane behaves in a similar fashion, with the variation of hydrogen content at the Si-H bonding sites. A similar observation has been made on the variation of the optical energy gap with hydrogen content due to Si-H bonding site for a-Si:H films prepared by rf sputtering in hydrogen atmosphere. This further strengthens the suggestion that the VEM hydrogen percentage is the H content at the Si-H bonding site.

Since the way hydrogen is incorporated into the film and not the hydrogen content in the film itself which will result in defect reduction and improvement in the electronic properties of the a-Si:H film, the effect of the VEM hydrogen percentage and IRM hydrogen percentage on the conductivity and density of states at the Fermi level, N(E_f) are studied. It is found that the VEM hydrogen percentage and the IRM hydrogen percentage on their own fail to provide a good answer to the conductivity and N(E_f) behaviour in our a-Si:H films. Results suggest that there must be a balance between the hydrogen content at the monohydride and polyhydride bonding sites in a-Si:H particularly in films deposited by dc plasma glow discharge in order to produce low defect density material with device quality optoelectronic properties.

When the hydrogen in the film is bonded mostly in the Si-H_2 or (Si-H_2)$_n$ configurations, i.e. when the ratio of VEM H% to the IRM H% is small, formation of columnar structures result in the film. This increases hydrogen related defects in the film which increases $N(E_f)$. When this ratio is large, the material will consist of mostly hydrogen bonded in the Si-H bonding configuration, but more of it in the clustered phase instead of the dilute phase thus resulting in the degradation of the electronic quality of the film and also increases defect density in the film.

This work was carried out successfully even when sophisticated equipment were not made available in the laboratory. With the present availability of more R&D grants, more sophisticated equipment are purchased thus further works can be done in this area of research. The home-built dc glow discharge system can be upgraded with precise measuring equipment and efficient pumping system attached and hence a better control on deposition parameters. The preparation and conditions of the a-Si:H films can thus be optimized and the H% by VEM and the IRM can then be tested on optimized as-prepared films to further confirm the above results. The Si-H bonded sites in the film can actually be varied by changing the helium to silane ratio in the discharged gas during deposition while keeping other parameters constant. The concentration of the Si-H bonding sites in the film can also be determined from the IRM technique by deconvoluting the FTIR absorption spectrum at the $Si\text{-}H_x$ stretching peak into two peaks representing the hydrogen content bonded at the monohydride and polyhydride bonding sites. The hydrogen content at the Si-H bonding sites calculated by this technique can then be compared to the H% VEM . The difference in the hydrogen percentage should represent hydrogen at Si-H bonding sites which are bonded or coupled to impurity atoms. Thus, the effect of the hydrogen content at these Si-H sites on the optoelectronic properties of the film can then be studied.

This work can in fact be extended further by studying a-Si:H film alloyed with other materials like Ge, C or N. The VEM and IRM techniques are indeed very useful not only to determine the hydrogen content in the film but also to identify the bonding configurations of the hydrogen content more effectively. Thus, the contribution of these techniques and the home-built dc plasma glow discharge system in promoting further research in a-Si:H in our laboratory specifically are indeed very significant.