Chapter VI

Conclusion:

The aim of this work is to characterize the electrical and optical properties of crystalline and amorphous semiconductors. In the case of the crystalline semiconductors the electrical and optical properties of single crystal silicon and germanium were studied exclusively. Four-Point probe technique was used to determine the conductivity of crystal germanium. The band gap obtained from the conductivity measurement at different measurement temperatures agreed accurately with the theoretical results. The X-ray diffraction spectrograph indicated a slightly strained lattice structure. The infrared spectroscopic results revealed the presence of oxygen and carbon impurities in the sample. It is believed that the impurities are trapped in the voids during the growth of the crystal. However the crystal silicon surface has strong affinity for oxygen atoms in the atmosphere. This is confirmed by the FTIR spectrum, which revealed the contamination of the sample with oxygen and hydrogen. Even after surface etching, the oxide layer could not be removed completely, hence the conductivity of the crystal was beyond the measurement range of the Four-Probe equipment. Finally, the conductivity was measured using the Keithley Source measurement unit. The oxide layer formed on the surface of the crystal greatly reduced the conductivity and hence the activation energy too. The optical gap of the sample was determined by optical transmission spectroscopic studies. The optical gap was slightly lower but within the experimental error. The lattice spacing calculated from the X-ray diffractogram of crystal silicon agreed well with the theoretical results showing that the crystal is perfect without defects. Thus

the crystalline semiconductors were extensively studied to understand the further work carried out on hydrogenated amorphous silicon.

The two most important effects studied on hydrogenated amorphous silicon are the effects of annealing on the structure and the role of hydrogen atoms on the optical and electrical properties of the film. It is evident from the work of other workers [D.K. Biegelsen et al] that when the film was annealed at temperatures less than 400°C hydrogen was evolved mainly from weakly bonded Si-H (eg. (SiH_3) & $(SiH_2)_n$) bonds and annealing at higher temperatures above 400°C removed hydrogen from the bulk Si-H bonds. It was emphasized that the removal of hydrogen from these strongly bonded Si-H bonding configurations changed the structure of the film significantly. The sample studied in this work was prepared by home built horizontal plasma glow discharge system at room temperature with a deposition flow of silane of 10sccm. The FTIR spectrum revealed the presence of polyhydride groupings characteristic of film prepared at room temperature. When the sample was annealed at low temperatures, a competition between healing of shallow defects and formation of dangling bonds resulted in an almost constant optical gap with slight fluctuations when the sample was annealed at temperatures below 400°C. When the sample was annealed at 400°C the removal of hydrogen from bulk (SiH_2)n sites transformed deep states formed in the midgap to shallow defect states which reduced the optical gap of the film. The sudden increase in photoconductivity observed in this film is also due to the significant drop in optical gap and the states formed at the mid gap served as recombination centers in between the valence and conduction band. The removal of hydrogen atoms from the surface and bulk at

different annealing temperatures also made the film thinner and denser. This also showed that the removal of hydrogen atoms especially from the bulk reduced the optical gap, increased the dangling bonds and transformed the midgap states to shallow Si matrix defects. The hydrogen content of the as prepared film was ~32% and annealing of the film to 500°C reduced the hydrogen content in the film to ~19%. The excessive hydrogen present in the as prepared film formed hydrogen related defects, which formed localized states at the tail regime and these sites served as recombination centers. Hence the as prepared film exhibited significant photoconductivity. When the sample was annealed at 200°C hydrogen was evolved mainly from the polyhydride sites that contributed to states at the Fermi level. This explains the sudden decrease in the density of states at the Fermi level when annealed at 200°C. These results concluded that the preparation parameters and the way the hydrogen is incorporated are very important in understanding the properties of hydrogenated amorphous silicon film and annealing could be used as an excellent tool to modify the property of the film to one's convenience.

As it is already established that the properties of no two films prepared under different preparation conditions are same. Further works could be done by studying more of hydrogenated amorphous silicon samples prepared using different flow rates and also samples prepared at different deposition temperature. Other characterization tools like the AFM, TEM and XPS/AES could be used to do further works in this area of research. The Atomic Force Microscope (AFM) for instance can be used to study the effects of annealing on the surface structure of the film. Critical information on surface features obtained can provide valuable informations on the

presence of contaminants in films and also gives a clear picture of columnar structures and voids formed in the film. The Transmission Electron Microscopy (TEM) is another characterization tool employed to study the morphology and chemical composition of nm particles, analysis of defect structures and characterization of microstructures in thin films. Examination of hydrogenated amorphous silicon film after each annealing process under a TEM would guide us to understand the exact and type of structural transformation brought about by annealing and it's effect on the optical and electrical properties of the film. With the aid of X-Ray Photoelectron Spectroscopy (XPS)/Auger Electron Spectroscopy (AES) the surface of the film could be thoroughly analyzed for elemental compositions, bond structures. Thus this area of research is certainly very wide and need to be explored to further enhance the applications of a-Si:H in electronic devices.