CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

In this thesis it is established that vacuum evaporation of high purity silicon granules using tungsten baskets followed by hydrogen plasma annealing is a reliable and economical method for the production of hydrogenated amorphous silicon thin films. In the second chapter the experimental set-up for the production of hydrogenated and unhydrogenated amorphous silicon films are presented in detail.

The investigations presented in this thesis are mainly centred around the electrical properties of amorphous silicon and cadmium sulphide thin films. In chapter 3 a detailed analysis of the results of the investigations on d.c. and a.c. electrical conduction on a-Si and a-Si:H is presented. It has been proved that a-Si:H films prepared by the present method are very similar to the glow discharge produced films as far as the electrical properties are concerned. It is observed that generally d.c. electrical activation energies of a-Si films are very high compared to that of a-Si:H films. Intrinsic films with an activation energy $E_a = 0.75 \text{ eV}$ are obtained for hydrogen annealing temperature of 573K at a hydrogen partial pressure of 0.05 torr. The a.c. conductivity of a-Si:H films is measured as a function
of frequency, temperature and film thickness. It is found that $\sigma_{a.c}$ is proportional to $\omega^n$ where $n$ varies from 0.7 to 1.5.

The investigations on the adsorbate induced d.c. conductivity changes in the a-Si and a-Si:H thin films have established the effect of donor type and acceptor type gases. The investigations have shown that by simply exposing a silicon film to hydrogen does not change its conductivity much. Similarly, the effects of $N_2$, $O_2$ and $H_2S$ are also negligible. An exposure of the films to $CO_2$ causes the conductivity to decrease by 60% of its original value. However, exposures to $NH_3$ gas and $H_2O$ vapour cause the conductivities to increase dramatically, especially in the latter case in which $\sigma$ increases to about 3000 times. The change is more pronounced in the first few hours and then $\sigma$ remains almost a constant. This study establishes unambiguously how the presence of a very small amount of certain gases can change the electrical properties of a-Si and a-Si:H thin films. This also explains the diverse results obtained by various research groups in different laboratories and sometimes at the same laboratory at different preparation runs. Important differences are observed in the general shapes of the curves between the a-Si and a-Si:H films studied here.
Dielectric properties of the a-Si and a-Si:H films are measured as a function of frequency, temperature and film thickness. In the case of a-Si the dielectric constant \( \varepsilon \) increases with frequency. \( \varepsilon \) is also found to be independent of temperature in the measurement range studied. This rules out the presence of interfacial polarization. The most possible mechanism is suggested as due to the polarization resulting from imperfections, defects and microvoids in the films. Dangling bonds in the material are the most important defects in amorphous silicon films and they play an important role in the dielectric properties of these films. In a-Si:H films interfacial polarization is dominant. This is due to the passivation of dangling bonds by hydrogen which reduces their contribution to the polarization mechanism. The thickness dependence of \( \varepsilon \) is explained as the direct manifestation of the porosity of the films. The increase in the loss factor with frequency in the manner observed in these experiments indicates the role of electrode and lead resistance in the measurements. In brief it can be said that the dielectric properties of a-Si and a-Si:H are very much dependent upon the frequency, temperature and film thickness.

In chapter 5, the details of the successful fabrication and characterization of a-Si and a-Si:H field effect transistors are presented. It was possible to draw an
appreciable drain current by using an interdigitated finger structure for the source and drain electrodes. Instead of the usual SiO₂ films, vacuum evaporated europium oxide films are used as the gate insulator. This made the fabrication much easier. The maximum amplification ratio of 194 is observed for a gate insulator thickness of 715 Å. It is also found that since the semiconductor is almost intrinsic in nature, both electrons and holes contribute to the conduction through the channel. The main limitation of the device is the low value of the gain-bandwidth product. This can be improved by a careful modification of the preparation conditions.

Finally in chapter 6, a detailed account of the preparation of CdS thin film by chemical bath technique and its characterization are presented. By this method it was possible to prepare nearly intrinsic CdS films. A.C. conduction through the films was measured and was analysed using Elliott's theory for a.c. conduction in chalcogenide glasses. The density of states at the Fermi level was calculated from this data and was found to be nearly seven orders less than the reported values. This is explained as due to the fact that most of the reported values represent n-type materials with very high sulphur deficiency. The films prepared by the present method are almost intrinsic
in nature. Also the difference may not be as high as it appears since most of the reported values are found out by the field effect method and it is a common fact that this method has a tendency to over estimate the density of states. From the dielectric studies $\varepsilon$ is found to be independent of temperature upto 423K. From the frequency dependence of $\varepsilon$, the existence of monovalent impurities, vacancies and microvoids in the films is suggested.

SUGGESTIONS FOR FUTURE WORK

A careful examination of the various reviews on the properties of a-Si:H would reveal that it exhibits a variety of electrical properties making it one of the most important materials for device applications. Eventhough the material has been subjected to thorough investigations regarding its structural and electrical properties, so many questions still remain unanswered. Further studies on the precise relationships between defects, hydrogen content and dopants are required for a better understanding and control of the compositional and structural homogeneity of a-Si:H films. Conflicting evidences have been presented over the existence of steep gradients in hydrogen concentration. Also there are questions relating to the interfaces between a-Si:H and both metals and insulators. Of course
the most important application for which a-Si:H films are used is the production of low cost solar cells. In this field also there are still problems to be resolved, like the Staebler-Wronski instability, dependence of solar cell fill factor on film thickness etc. Similarly in the case of a-Si:H field effect transistors, the low value of the gain-bandwidth product is still a problem to be tackled.

The limitation to the efficiency of a-Si:H devices is mainly due to the high localized state density. A further decrease in the density of localized states will have to be obtained by improved deposition techniques and heat treatments. A significant increase in the mobility of the charge carriers has also to be achieved. If these targets can be attained, a-Si:H films can be used to produce thin film FETs, diodes and charge coupled devices successfully and economically.