CHAPTER 7

SUMMARY, CONCLUSION AND FUTURE WORK

7.1 SUMMARY

This chapter summarizes the important results and conclusions obtained in the present work, on the deposition and characterization of Ti and TiN thin films with supported discharge method. The discharge characteristics of the supported discharge/ triode system have been studied to improve the ionization during deposition process. The process parameters have been optimized for film thickness and composition uniformity over the given area. The deposited films have been characterized for their structure/microstructure, optical and electrical properties, under various processing conditions.

7.2 DISCHARGE CHARACTERISTICS OF D.C. SPUTTERING WITH SUPPORTED DISCHARGE

Discharge characteristics of D.C. sputtering with supported discharge have been studied with respect to working pressure, target voltage and target current.

1. The drawback of mutual dependence of pressure, voltage and current in diode mode can be overcome by supported discharge, by controlling the voltage applied to the filament.
2. The supported discharge system enables independent control target current irrespective of operating pressure and target voltage.

3. By introducing a thermionic filament and negatively biasing the same, it is possible to maintain the discharge at relatively lower pressures compared to conventional sputtering.

4. In order to improve the ionization rate (deposition rate) in the discharge chamber, the supported discharge (triode) is added in the sputtering system.

5. It is possible to achieve the required physical properties of thin films at room temperature by the supported discharge dc magnetron technique compared to other sputtering techniques.

6. No magnetic field is used to focus the electrons.

7. Films deposited by sputter deposition on slanted or vertical surfaces do not exhibit uniform thickness, and the density of films deposited on these surfaces is usually not as high as the films deposited on horizontal surfaces.

8. But with supported discharge we can able to get uniform thickness over the substrate (both vertical and horizontal).

7.3 **Ti THIN FILMS**

The influence of process parameters on film structure and microstructure on the Ti thin films deposited by a D.C magnetron sputtering with supported discharge/triode and diode system have been studied by different analytical techniques like XRD, SEM and AFM. The electrical properties have been measured using standard four probe method.
In diode mode, XRD studies of Ti films deposited at a pressure of $3 \times 10^{-2}$ mbar did not show any crystalline up to target power of 100 W. Only at a target power of 120 W the films showed crystalline with a preferred orientation of (100) and (002). SEM studies have shown that the films deposited at higher target power results smaller grains over the surface. The electrical resistivity found to be high due to smaller grains.

In triode mode, Ti thin films deposited at a pressure of $7 \times 10^{-3}$ mbar with a target power of 60 W found to be amorphous in nature. The onset of crystalline started at 80 W of power having preferred orientation of (002). Further an increase in power to 100 W showed another preferred orientation of (100) along with (002) preferred orientation. At a power of 120 W the intensity of the peaks increased with the appearance of (101) peak with diffraction peaks $2\theta = 35.18^\circ$, $37.92^\circ$ and $39.73^\circ$ which exhibits hexagonal cubic structure (HCP). SEM studies have shown that the films deposited at higher target power results uniform surface pattern without any pin holes over the surface. AFM studies have shown increase in the average crystallite size and film roughness with increase in target power. The electrical resistivity found to be low due to the crystalline nature of Ti thin films.

The working pressure of $7 \times 10^{-3}$ mbar, TSD of 4 mm, deposition time 20 min, target power of 120 W, filament voltage 14 V x 13 A, filament bias voltage 25 V and the discharge current of 1.0 A have been found to produce coatings with better morphology and micro-structure of the films compared to conventional diode magnetron deposition. Under these optimized process parameters, the repeatability has also been established. It can be conclude that, the dc magnetron sputtering system with supported discharge can results in better morphology and micro-structure of the films compared to conventional diode magnetron deposition.
7.4 TiN THIN FILMS

The influence of process parameters such as target power, N₂ partial pressure, TSD and deposition time on film structure and micro-structure on the TiN thin films deposited by Titanium target and Nitrogen gas (reactive gas) has been studied. The TiN thin film deposited with total (Ar+N₂) working pressure of 7 x 10⁻³ mbar, target power of 70 W, N₂ partial pressure of 7 x 10⁻³ mbar TSD of 4 cm and deposition time of 30 min found to produce stoichiometric TiN. The crystal structure of the as-deposited film was found to be amorphous in nature. The optical reflectance found to be increase for the films deposited at the working pressure of 7 x 10⁻³ mbar, target power - 70 W, TSD - 4 cm and deposition time - 30 min. The PL spectrum of deposited TiN thin films with above set condition shows that emission appearing in single band (360 nm) is only in the visible region. This shows that the TiN films prepared with different nitrogen partial pressure have good optical property. The electrical resistivity of the as-deposited TiN thin films was found to be 1800 μΩ-cm.

The working pressure - 7 x 10⁻³ mbar, target power - 70 W, TSD - 4 cm, deposition time - 30 min, filament voltage 14 V x 13 A, filament bias voltage of 25 V and the resulting discharge current of 1.0 A have been found to produce stoichiometry coatings with better morphology and micro-structure.

7.5 THE EFFECT OF THERMAL ANNEALING ON THE TITANIUM NITRIDE THIN FILMS ON THE STRUCTURAL PROPERTIES, OPTICAL AND ELECTRICAL PROPERTIES

The effect of thermal annealing on the Titanium Nitride thin films on the structural properties, optical and electrical properties has been studied.
TiN thin film has been prepared in unheated substrates with target power of 70 W, N\textsubscript{2} partial pressure 6 x 10\textsuperscript{-3} mbar, TSD of 4 cm and deposition time of 30 min. The as-deposited samples were annealed in 1 x 10\textsuperscript{-5} mbar vacuum pressure at 373 K, 473K and 573 K each for one hour. After annealing the TiN thin films, the structure changes from amorphous to crystalline structure. The structural/micro-structural, optical and electrical properties were studied with respect to annealing temperature. In summary, TiN thin films deposited by D.C magnetron sputtering with a supported discharge and annealed at much lower temperatures show better physical properties than the TiN thin films deposited by other techniques and annealed at higher annealing temperatures.

7.6 **SCOPE OF FUTURE WORK**

1. Annealing of Ti in oxygen atmosphere to form TiO\textsubscript{2} thin films for solar cell applications.

2. The co-sputtering technique can be used to deposit TiZrN, TiCrN, TiAlN thin films with supported discharge system. And to study the physical properties of above mentioned thin films for opto electronic device applications.