CHAPTER I

PREFACE

1.1 Introduction

The science and technology of thin films have made revolutionary changes in microelectronic industries and even today they continue to be recognised globally as frontier areas of research. The properties of thin film materials have triggered the surface physicists whose contributions have also given due recognition in industrial sectors. The large number of successful applications for a variety of scientific, engineering and industrial purposes is mainly because of the rapidly increasing scientific understanding of the nature of processes used to deposit the films. Micro and optoelectronics, space physics and communication network are some of the major fields of development, highly benefitted from the influence of thin film technology. Apart from the technological field, basic physics and chemistry have also profited much from the study of thin films. In fact one cannot identify a field where the impact of this technology has not been felt, directly or indirectly.

The availability of ultra high vacuum techniques has brought forth significant developments in thin film deposition techniques from the thermal evaporation to the more sophisticated and expensive molecular beam epitaxy. The last few decades have witnessed the evolvement of various chemical techniques as well,
like solution growth, chemical vapour deposition, anodization, spray pyrolysis etc. which have contributed significantly to the growth of thin film technology.

Extensive theoretical and experimental investigations on conduction in thin insulating films have led to an understanding of the nature of the film, the various transport mechanisms involved and also to the determination of the barrier parameters and barrier profiles for an insulator and the insulator-electrode interfaces. The optical studies on such films help us to classify materials suited for the manufacture of interference filters, antireflectors etc. Among the various insulating films developed in the last few decades, SiO, SiO₂ and Ta₂O₅[1-5] films have been widely used in semiconductor devices and integrated circuits.

1.2 Past work and the aim of the present investigation

The wide survey of literature clearly revealed that the rare earth elements have important physical and chemical characteristics and that these ones are often sharply increased in the case of compounds and/or alloys. Also, various works on these compounds show that they have chemical and thermal stability, a relatively high permittivity, and good radiation resistance[6,7]. Because of these important characteristics rare earth compounds[8,9] have drawn special attention for various device applications. Many researchers have reported works carried out on various properties of rare earth oxides[6,10-28]. Fromhold and Foster[8] have given an experimental survey of the dielectric
properties of thermally evaporated rare earth oxides for use in thin film capacitors. The optical properties of various thermally evaporated rare earth oxide and fluoride thin films have been studied by Hass et al.[9]. The dielectric properties of electron beam evaporated $Y_2O_3$ films have been studied extensively[29-31]. Also studies on dielectric properties of $Yb_2O_3$[32], $Dy_2O_3$[33] and $La_2O_3$[34] films, have been carried out by various researchers.

Maddocks and Thun[35], Lancaster[36] and Kalra et al.[37] have extensively studied the electrical properties of $CeF_3$ thin films. Tiller et al.[38] and Lilly et al.[39] have reported the conductivity and transport properties of polycrystalline $LaF_3$ thin films. The dielectric properties of various rare earth fluoride films have also been studied by Bertulis and Tolutis[40] and Mahalingam et al.[41-43].

A thorough knowledge of these literature reveals that rare earth oxide and fluoride thin films, though they have excellent chemical and thermal stability, require further investigation in order to make them viable for industrial applications. Their characteristics are generally studied according to sandwich (MIM, MIS or MOS) structures. The study of dielectric properties of thin films of these compounds is of considerable practical importance because of their potential use in a number of device applications[44-47]. The electrical conduction study gives a better insight into the insulator system. Particularly from the a.c. conduction study one can gain additional and/or independent
information about the localized states.

Thin film optical coatings play a vital role in the design and operation of optical systems. The coatings are normally required to alter, to a desired extent, the optical characteristics such as reflection, transmission or absorption of single optical component or system of components and consists of a single layer or a multilayer of metals and dielectrics. The increasing demand for high power laser systems in research, industrial and defence applications, calls for the need of design and fabrication of optical coatings with high damage threshold and consistency in optical parameters such as refractive indices etc. Various rare earth fluoride films such as CeF$_3$ and NdF$_3$ films have been used as optical wave guides[48] for the measurement of their optical attenuation and refractive indices. Hopkins et al.[49] have used LaF$_3$ films as moisture-resistance protective coatings. Electroluminescence study has also been carried out on many of the rare earth fluoride films[50-52].

Neodymium oxide and neodymium fluoride, two of the promising representatives from the wide group of rare earth compounds, have been chosen for the present investigation with a view to characterize them systematically and to study their application as thin film capacitors and thin film field effect transistors. Various researchers have reported work carried out on different forms(bulk and film) of these materials[8,40,53-65]. Kadzhoyan and Egiyan[53] have studied the dielectric properties of Nd$_2$O$_3$ films
prepared by sputtering as well as by the oxidation of Nd metal films. Fromhold[54] studied the I-V characteristics of 64 nm thick Nd$_2$O$_3$ films. Illins and Ushchakovskii[59] have investigated the dielectric constant, dielectric losses and electrical characteristics of some of the rare earth oxide (Nd$_2$O$_3$, Gd$_2$O$_3$, Tb$_2$O$_3$ and Dy$_2$O$_3$) films with f.c.c. structure.

Likewise, Bertulis and Tolutis[40] have studied the dielectric properties of NdF$_3$, PrF$_3$ and CeF$_3$ thin films. Recently Dharmadhikari and Goswami[61,65] have studied dielectric properties of vacuum deposited Nd$_2$O$_3$ and NdF$_3$ thin films. In the light of the above survey and discussion, although much work has been carried out on the dielectric properties of bulk and thin films of various rare earth compounds, reports on the important physical properties of thermally deposited neodymium oxide and neodymium fluoride thin films are very less. Also no systematic study has been made in order to characterize the thin films of these materials and to use them for device applications. Keeping these in mind, in the present investigation a detailed study on the important physical properties such as structural, dielectric, electrical breakdown, optical and laser induced damage, has been carried out systematically on thermally evaporated neodymium oxide and neodymium fluoride thin films. Also using these materials as gate insulators, thin film field effect transistors have been fabricated.
1.3 Details of the present work

The investigations presented in this thesis comprise of studies on vacuum deposited neodymium oxide and neodymium fluoride films. The first chapter is of introductory nature and has been devoted to explain the importance of the present investigations briefly. The details of the experimental techniques employed in the present work such as the fabrication of neodymium oxide and neodymium fluoride film capacitors, thin film field effect transistors and thickness measurement by multiple beam interferometry have been dealt with in chapter II.

The third chapter deals with the structural analysis of the as-deposited neodymium oxide and neodymium fluoride films. The X-ray diffraction method adopted in the present study has also been briefly explained in this chapter. The dielectric properties of these films along with the general theory of dielectrics have been given in chapter IV. The effect of aging and annealing on the dielectric parameters and the thickness dependence of dielectric constant have been discussed in detail. Dependence of capacitance and loss factor on frequency and temperature ranges specified therein has been examined. The evaluation of temperature coefficients of capacitance and permittivity and the linear expansion coefficient has also been dealt with in detail in this chapter.

The fifth chapter deals with the electrical, both a.c. and d.c., conduction properties of these films. The dependence of the a.c. conductivity on frequency and temperature and the dependence
of d.c. conductivity on temperature and field have been discussed in detail. The nature of the conduction mechanisms has also been evolved.

The dielectric breakdown studies on these films have been dealt with in chapter VI. The thickness dependence of the breakdown field has been interpreted on the basis of Forlani-Minnaja theory and the variation of the onset breakdown field with the temperature has been explained. The different types of dielectric breakdown patterns observed in these films have also been explained.

Chapter VII deals with the optical properties of these vacuum deposited films. The optical constants have been calculated and the energy band gap has been estimated. Effect of thickness on refractive index has also been discussed.

Laser induced damage study has been made on the aforesaid films. The threshold damage energy and the possible damage mechanism and their dependence on film thickness have been examined and they are discussed in detail in chapter VIII.

Chapter IX deals with the design and fabrication of thin film field effect transistors using the vacuum deposited neodymium oxide and neodymium fluoride films as gate insulators and cadmium selenide as semiconductor layer. The drain current characteristics of the fabricated transistors have been analysed in this chapter.

Finally the important conclusions drawn from the studies on vacuum deposited neodymium oxide and neodymium fluoride films have
been summarised and presented in chapter X.

Part of the results presented in this thesis has been published in the form of the following papers.

1. Dielectric behaviour of neodymium oxide thin films,

2. Electrical conduction studies on neodymium oxide thin films,

3. Aging, annealing and dielectric properties of neodymium oxide thin films,

4. Laser induced damage study of neodymium oxide thin films,

5. Dielectric and a.c.conduction properties of neodymium oxide thin film capacitors,

6. Optical properties of neodymium oxide thin films,

7. Structure and electrical properties of thermally evaporated neodymium oxide thin films,

8. Effect of thickness on the damage threshold of vacuum deposited neodymium fluoride thin films,
9. D.C. conduction studies on thermally evaporated neodymium oxide thin films,
References
42. T.Mahalingam, M.Radakrishan and C.Balasubramanian, ibid, 59 (1979) 221.
44. C.Weaver, Vacuum 15 (1975) 171.
46. A.Arconada and F.Papini, ibid, 30 (1975) 161.