CHAPTER I
INTRODUCTION

1.1 Background

Multilayer optical thin films have been coated on substrate in order to obtain desired reflectance and transmittance of specific wavelength of light and have wide range of applications such as anti-reflection coatings, high reflection coating, highly reflecting laser mirrors, dichroic mirrors, various kinds of optical filters, beam splitters, heat reflectors, solar cell covers and thin-film polarizers. Multilayer optical coatings are used to modify the interaction of light with a surface by utilizing the interference of reflections from multiple interfaces. The performance of an optical coating is highly sensitive to any variations of layer refractive indices and thickness. Accurate control of film parameters, thickness, composition uniformity and roughness, is necessary to accomplish the designed particular function of the coating stack (Hilfiker *et al.,* 2019). It is important to know the thickness, optical and absorption properties of individual layer as a function of wavelength to predict the behavior of modern optoelectronic and optical devices (Sultan *et al.,* 2015).

Metal oxide is an important role of the optical coating materials because of its tunable properties, excellent optical transparency, and chemical and environmental stability (Park *et al.,* 2017). Common metal oxide coating materials are SiO_2, TiO_2, Al_2O_3, ZnO, Nb_2O_5, HfO_2 and Ta_2O_5. Silicon dioxide (SiO_2) and titanium dioxide (TiO_2) are famous coating materials due to their excellent properties and producibility. Titanium dioxide films are widely used in various fields of applications, for example, gas sensors, photocatalysis, solar cells, optical devices, etc. They have high optical transmittance with high refractive index in the visible range, outstanding chemical stability, high photocatalytic activity, satisfied mechanical hardness and non-toxicity (Pjević *et al.,* 2015)

Silicon dioxide is an inexpensive optical coating material with low refractive index, high transmittance from the ultraviolet (UV) to near infrared (NIR) region, good insulation and chemical and mechanical properties. It is widely used in optical multilayer films when coupling with a high refractive index material (Wang *et al.,* 2018). In addition, SiO_2 films are a key part of gate dielectrics in semiconductor industry because of their high resistivity, superb dielectric strength, large band gap, high melting point, and native, low defect density interface with Si (Šimurka *et al.,* 2018). Hence, these are the reason that TiO_2 and SiO_2 films are suitable candidates for many optical applications.

Up to now, many methods such as electron beam evaporation, ion assisted deposition, ion beam sputtering, magnetron sputtering, sol-gel, evaporation, chemical vapour deposition, and so on are used to prepare TiO_2 and SiO_2 thin films on various types of substrates. Among these methods radio frequency (RF) magnetron sputter deposition has many benefits, for instance, excellent control of film quality and thickness over large deposition areas, good adhesion, density and uniformity (Braeuer *et al.,* 2010). Therefore, rf magnetron sputtering has become an interesting technique for the preparation of controllable metal oxide films at low substrate temperatures (Jeong *et al.,* 2004). Basically, the film thickness is adjusted by controlling the deposition rate and time. In order to control the refractive index of the optical films a method that has been proposed is varying the porosity of thin films. However, film porosity is not easy to reproduce, especially when using different experimental or industrial setups. Thus, control of composition is a more reliable possibility to tailor the film refractive index (Gracia *et al.,* 2006).

In this work, the preparation of metal oxide single layer thin films with desired optical and structural properties for optical applications by using RF magnetron sputtering is studied and the various analytical techniques including synchrotron-based characterization methods are extensively used to characterize the prepared films. SiO_2 and TiO_2 are two main focused metal oxide materials in this study and thin film multilayer of these two materials is designed and fabricated.

1.2 Objectives and structure of this thesis

In this work, the preparation of metal oxide single layer thin films with desired optical and structural properties by using RF magnetron sputter deposition is studied. The various analytical techniques including synchrotron-based characterization methods are extensively used to characterize the prepared films. Thin film multilayer of two kinds of material is designed and fabricated. The research objectives are described below.

- To prepare the metal oxide single layer thin films by RF magnetron sputtering on glass substrate with controllable refractive index and film thickness.
- To investigate the optical and structural properties of prepared films.
- To study the relationship between the preparation conditions and film properties especially refractive index and film thickness.
- To design and fabricate thin film multilayer with two kinds of material.

1.3 Scope and limitations

- RF magnetron sputtering is the deposition technique of metal oxide thin films for this work.
- SiO_2 and TiO_2 are two main focus materials for metal oxide single layer thin film.
- Optical properties of metal oxide thin films will be investigated by UV-Vis-NIR spectrophotometer and spectroscopic ellipsometer.
- The film properties will be characterized by X-ray diffraction (XRD), scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM), X-ray Photoelectron Spectroscopy (XPS), X-ray absorption spectroscopy (XAS).
- The effects of deposition parameters on the optical and properties of thin films will be focused.