5 Magnetron Sputtering of ZnO Films

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5.1 Introduction

Glow discharge sputtering is one of the oldest deposition techniques that utilizes an energy input to promote surface diffusion at the substrate and thus, to achieve dense and well-adhering coatings at low substrate temperatures. The term “sputtering” means the ejection of atoms from a usually solid target material due to the impact of highly energetic species. These highly energetic species are usually positive ions, which can either be accelerated in the cathode sheath of a plasma discharge or in an ion source.

The simplest approach for the deposition of ZnO films by sputtering is sketched in Fig. 5.1: A DC glow discharge is ignited between a cathode, which is a planar Zn target, and the anode, which is the chamber of the vacuum system. The system is pumped to a pressure of ∼10 Pa and Ar and O\textsubscript{2} are introduced into the system. The metallic target is oxidized, so that Zn and O atoms are sputtered from the target and condense on the substrate, where the ZnO film is formed. However, this concept has many drawbacks in terms of film properties, deposition rate, and process stability. The development of the so-called “magnetron” sputter sources by Chapin [1] was a breakthrough in the 1970s toward large area high-rate deposition. The key was to increase the sputter current by magnetic confinement of the plasma in front of the target. This feature allows both the deposition rate to be increased and the pressure to be decreased. Both features are crucial for cost effective sputter deposition of high-quality ZnO films.

For transparent and conductive ZnO-based TCO films, however, several further breakthroughs have been necessary: The most crucial point is the control of stoichiometry and phase composition, which are key parameters for efficient doping. Many approaches have been realized: Reactive sputtering from alloy targets allows growth conditions to be varied to a large extent. The metallic targets used are cheap compared to ceramic targets but the drawback is the need for a precise control of the reactive process, which is a delicate but solvable task using advanced process control techniques. Ceramic target sputtering on the other hand permits more robust processes since the metal-to-oxygen ratio is defined by the target stoichiometry up to a certain extent.

The following sections review the work on magnetron sputtering of ZnO films focusing on TCO properties. Section 5.2 outlines the history of ZnO
Fig. 5.1. Setup for glow discharge sputter deposition of ZnO by reactive DC sputtering of a metallic Zn target in an Ar/O\textsubscript{2} atmosphere.

sputtering. Section 5.3 is about the basics of magnetron sputtering and the ZnO film properties, which can be achieved by magnetron sputtering. Section 5.4 treats the manufacturing technology for large area deposition and Sect. 5.5 gives an overview of emerging developments toward more advanced and lower-cost ZnO sputtering technology.

5.2 History of ZnO Sputtering

Sputtering of ZnO films has a history covering more than three decades. The technique is now one of the most versatile deposition processes for industrial production of ZnO films.

First sputtering processes for ZnO deposition were developed in the late 1960s for manufacturing surface acoustic wave devices [2]. The piezoelectric properties of ZnO films are crucial for that application and major efforts were made to develop ZnO sputtering processes which enabled c-axis oriented growth, high resistivity and unique termination of the ZnO crystallites [3,4].

Large-area sputtering of ZnO was established in the field of energy-efficient glazing in the early 1980’s. At that time, ZnO was used as a dielectric film for Ag-based low emissive (low-E) coatings. Coating designs such as float glass/ZnO/Ag/blocker/ZnO were implemented by planar cathode reactive sputtering onto large-area glass panes [5,6]. ZnO was chosen as dielectric material because of its high sputtering rate and its suitability for reactive DC sputtering.

Even today, ZnO films are key components in modern Ag-based coatings for architectural glazing. Nowadays, the most challenging application