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Improving the stoichiometry of RF-sputtered amorphous alumina thin films by thermal annealing

High quality alumina thin films were deposited on glass substrate by reactive radio-frequency sputtering. The deposition process and rate were controlled by radio-frequency power and reactive gas (oxygen) flow rate. The relationships between O/Al ratio contents and the structural, electrical resistivity and optical parameters of the films were investigated. The O/Al of the films varied with change in oxygen flow ratio, power density and post deposition annealing. The structure and phase of the films were unaltered as the deposition parameters and post deposition annealing up to 573 K were varied. O/Al of 1.5 was obtained at oxygen flow ratio of 11 %, radio-frequency power of 250 W and post deposition annealing of 573 K. The sheet resistance of the films were all very high but the same within experimental uncertainties. The optical parameters (transmittance, refractive index and extinction coefficient) of the films varied considerably and depended on the films' stoichiometry.

Keywords: Alumina; Thin films; Amorphous; Stoichiometry; Optical constants

1. Introduction

Alumina thin films can be obtained in amorphous and different crystalline phases [1–3]. The high temperature requirement for the formation of the crystalline phases [4–8] has limited their deposition on temperature-sensitive surfaces. Subsequently, due to their low temperature requirement, amorphous alumina has become the most common form [1] and can be deposited on a variety of substrates for different applications depending on which of its properties is being explored.

Many properties of amorphous aluminium oxide including high optical transparency [9], chemical and thermal stability [10, 11] have led to the successful applications of alumina films in optical, electronics and protective coatings [12–15]. How successful the films are in these applications depends on their homogeneity and chemical inertness. The two factors which depend on films' deposition method and parameters are serious challenges in film deposition.

Aluminium oxide films in recent times have been successfully deposited using different methods [9, 16–32] with interest in their diverse properties and applications. Few of these works however have investigated the optical properties of amorphous alumina films, and fewer have paid attention to how stoichiometry affects the optical behaviour. Alumina is the only stable oxide of aluminium (Al) [33], and thus in the absence of an atom of any other element, a chemical combination of Al and oxygen (O) would always give alumina (which may be amorphous or any of the known crystal phases depending on temperature of formation [1–9]). Although, non-stoichiometry of alumina film could be deliberate and desirable in some applications [34–38], it should however be noted that excess of either Al or O (non-stoichiometry) in Al_2O_3 constitutes an impurity and can impact on the films' properties. Therefore, the use of optical characterization of alumina films, as it used to be the case, for validation of deposition method may not be adequate. This is because optical behaviour may not necessarily indicate good stoichiometry [16, 17]. Thus a comparison of optical properties of alumina films deposited by different methods will require that the stoichiometry of the films from the methods is the same. Therefore, there is the need to understand the relationship between stoichiometry and optical behaviour of aluminium oxide.

Reactive radio-frequency (RF) sputtering is a commonly used deposition procedure for compound films where good controls of thickness are required. RF sputtering has been used [17, 39–43] for the deposition of aluminium oxide films in many studies without much emphasis on stoichiometry and its relation to optical properties. This may be due to the fact that an appreciable number of parameters are available for permutation to achieve stoichiometry. These parameters, which affect the deposition rate and film composition in different ways, include RF power density, sputtering and reactive gas flow ratios with partial pressures, base and total pressures. Many efforts at depositing stoichiometry alumina film by RF sputtering [17, 39–43] with minimal parametric variation have rarely succeeded.

In this research, stoichiometric amorphous alumina films were deposited by a sequential variation of just three parameters – oxygen flow ratio, RF power and post deposition annealing temperature. The effects of these parameters on deposition process, film composition and film optical parameters were also investigated.