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The properties of nanocomposite aluminium–silicon based thin films deposited by filtered arc deposition

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Abstract

Thin films of aluminium silicon oxynitride have been deposited on conducting (100) silicon wafers by filtered arc deposition (FAD) under nitrogen and/or oxygen gas flow. The influence of the N_2/O_2 flow ratio on the crystal structure, optical and mechanical properties has been investigated. The results of X-ray diffraction showed that the film structure comprised of an AlN crystallite with amorphous Si_3N_4 and SiO_x. The optical properties over the range of 350–800 nm were measured using spectroscopic ellipsometry and found to be strongly dependent on N_2/O_2 flow ratio. The refractive index values of the films were measured to be in the range of 2.2–1.64 at a wavelength of 670 nm for oxygen flow range of 0–100%. The hardness of the films was found to be strongly dependent on the oxygen content in the film. The hardness range of the films was between 10 and 22 GPa and for the stress between 0.3 and 1.2 GPa.

Keywords: Filtered arc deposition; Oxides; Nitride; Optical properties; Nanocomposite; Aluminium; Silicon; Structure and mechanical properties

1. Introduction

Many practical applications, such as optical and opto-electronics, require properties of thin films which allow the possibility to change many properties such as refractive index, microstructure, stress and surface roughness. For example, in optical lasers, thin film optical waveguides and lenses, it is desirable that the films have wide band gap and a tuneable index of refraction [1]. Currently, mixing two or more materials allows the alteration of these properties [2]. However, the drawback is the complexity of the deposition systems, through the need to employ separate deposition sources for each material [3,4]. Nanocomposite thin films offer potentially a homogenous mixture and consequently, refractive indices that do not exist in other materials. However, most research in the field of nanocomposite thin films currently focuses on the mechanical properties such as hardness [5,6]. There is only scant information available on the optical properties of nanocomposite thin films.

Aluminium oxynitride films (AlO_xN_x) are applied for protective coatings against wear, diffusion and corrosion [7], optical coatings [8], and other fields of technology [9]. The film properties can be tailored between those of pure aluminium oxide (Al_2O_3) and Aluminium Nitride (AlN), depending on the demands. The refractive indices are 1.67 for Al_2O_3 and 2.1 for AlN at 550 nm. The addition of silicon into the matrix is expected to make a more useful optical thin film with variable optical constants over a wider range than Al_2O_3 and AlN.

The cathodic arc is a low-voltage, high current plasma discharge that takes place between two metallic electrodes in vacuum. It is an ideal method for ion-assisted film deposition since the cathode spot is an intense source of ionised material with energies sufficient for self-densification when condensed onto a substrate surface. The main disadvantage of the arc process as a technique for thin film deposition has been the presence of microparticles in the emitted flux, which are ultimately incorporated into the coating. Various schemes and devices have been employed to reduce macroparticles, but the most successful of those are based on the use of a curved plasma duct filter. Filtered arc deposition (FAD) is a novel deposition method [10,11], where the degree of ionisation and energy of the depositing species is higher than that of thermal evaporation and magnetron

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