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Electrical and Structural characteristics of sputtered c-oriented AlN thin films on Si (100) and Si (110) substrates

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Abstract:

This paper discussed about the morphological and electrical properties of c-axis oriented aluminium nitride (AlN) thin films grown on Si (100) and Si (110) substrates by direct current (DC) reactive sputtering technique. Both the films showed intense (002) peak with the texture coefficient (γ) of 3.1 and 2.8 corresponding to Si (100) and (110) substrates. The AlN/ Si (110) have grain sizes (20-30 nm) compared to the relatively denser grains (30-40 nm) of the film on Si (100) substrate. Both the films exhibited slanted columnar structures with slanting angle of 15° (Si (100) substrate) and 20° (Si (110) substrate). The dielectric constant values of the films at low frequency are found to be 7.4 and 8.8 corresponding to the Si (100) and Si (110) substrates respectively. The variation in dielectric constant values over the low frequency regime seems to be due to the presence of trapped charges present in the AlN layer and AlN-silicon interface (interface trap density~10^{12} cm^{-2} eV^{-1}). The flat band voltages are found to be 0.85 V and -0.35 V corresponding to the Si (100) and (110) substrates respectively. The AlN/ Si (100) film showed poor leakage current density ~ 10^{-4} A/ cm^{-2} as compared to AlN / Si (110) (~ 10^{-5} A/ cm^{-2}). The AlN films exhibited dielectric breakdown field of 4.4 MV/ cm and 6.6 MV/ cm corresponding to the Si (100) and Si (110) substrates respectively.

Keyword: Aluminum Nitride, Dielectric constant, Morphology, Metal-insulator-semiconductor structure, Trapped charges

1. Introduction

Since last few decades, aluminum nitride (AlN) thin films are being widely investigated for various electronic as well as sensors applications. Superior insulating properties ($\rho = 10^9–10^{11}$ Ω-m) combined with high thermal conductivity (180 Wm^{-1}K^{-1}) of AlN films make it an excellent choice for fabrication of III–V based electronic devices [1-3]. Moreover, wide band gap (direct; 6.2 eV) of AlN enable it as a favorable candidate for integrated optics in the ultraviolet (UV) region [1, 4] as well as solar concentrator in solar cells [5]. It can be used as an active layer in the various Micro electro mechanical systems (MEMS) based sensors and actuators due to its piezoelectric properties and sustainability in harsh environments [6, 7]. AlN is also often used as passivation layer for electronic devices due to its high thermal and chemical resistance [8]. In addition, AlN layers are also being employed developing bulk and surface acoustic wave (SAW) based sensors and devices due to the high acoustic velocity (6000-8000 m/ sec) [9, 10].

Over the years, many researchers have deposited thin films of AlN on different substrates like sapphire, SiC, Quartz, silicon, Glass etc. [11-15]. Among them, silicon offers the edge of integration of optical devices with very well established CMOS technology.