Structural, Optical and Electronic Properties of Oxidized AlN Thin Films at Different Temperatures

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We report on the properties of a novel insulator, AlO:N for application in semiconductors produced by thermally oxidizing AlN thin films. The process steps were similar to those used for SiO_2, creating the possibility of a new technology for metal-insulator-semiconductor field effect devices and integrated circuits. Thin films of AlN were deposited by radio-frequency magnetron reactive sputtering on p-type silicon or fused quartz substrates. As-deposited AlN film thickness ranged from 0.05 to 0.7 μm, with polycrystalline structure revealed by x-ray diffraction. Oxidation was performed under O_2 flow at 800 to 1100°C for 1–4 h. AlN films were oxidized partially or fully into Al_2O_3, depending on initial thickness, oxidation temperature and time. X-ray diffraction indicates the presence of several phases of Al_2O_3 at 1000°C, whereas at 1100°C, only the α-Al_2O_3 phase was found. Considering the importance of surface field effect device applications, the surfaces of oxidized films were examined with atomic force microscopy in air, and a clear change was observed in the surface structure of the oxidized film from that of as-deposited AlN films. Capacitance-voltage measurements of metal-oxide-semiconductor structures yielded a dielectric constant of AlO:N between 8–12 and a net oxide-trapped-charge density of ~10^{11} cm^{-2}. Using Fourier transform infrared spectrometry transmittance and reflectance, some α-Al_2O_3 modes were observed. In this paper, we describe the general properties of the oxide thin films, bulk and interface, at different temperatures.

Key words: AlN, aluminum oxide, gate insulators, thermal oxidation, thin films

INTRODUCTION

Insulators, especially stable thermal oxides, have immense importance for semiconductor optoelectronic devices and their integration into integrated circuits (ICs). So far, SiO_2, the native oxide of Si, has been used almost exclusively in microelectronic device integration. However, new materials like III-nitrides have emerged in this field with a vast promise, for which stable native oxides would be of major importance.[1] Oxidation of some III-V compounds (e.g. AlAs, AlGaAs) has successfully yielded oxide mirrors for vertical cavity surface emitting lasers (VCSEL).[2,3] Also, the current SiO_2/Si field effect technology is approaching its limits. As gate oxide thickness shrinks to the nanometer range, tunneling effects dominate metal-oxide-semiconductor (MOS) characteristics. As more devices and circuits are being operated in extreme environments (high temperature, high field, high altitude, space), the lifetime of devices decreases rapidly, especially due to radiation related damages.[4] In this paper, we report structural, electronic, and optical properties of a novel insulator, AlO:N, obtained from oxidizing thin films of AlN, which may be very promising in the applications mentioned above.

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EXPERIMENT

AlN thin films were deposited on p-type Si (100) and fused quartz substrates by magnetron sputtering with an Al metal target and a mixture of N_2/Ar gases, where the Ar flow varied from 0 to 25%. The structure of the as-deposited films ranged from amorphous to