Applied Surface Science 347 (2015) 109–115

Contents lists available at ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

Thermal stability of AlN films prepared by ion beam assisted deposition

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ARTICLE INFO

Article history:
Received 23 September 2014
Received in revised form 28 February 2015
Accepted 20 March 2015
Available online 25 March 2015

Keywords:
Aluminum nitride
Thermal stability
Optical properties

ABSTRACT

The thermal stability of AlN films deposited by ion beam assisted deposition was performed at 600 °C for 192 h under air ambient. The composition, morphology and optical properties were studied by X-ray photoelectron spectrometer, transmission electron microscopy, scanning electron microscopy, spectroscopic ellipsometry and UV–vis spectroscopy. The results show that the deposited film is polycrystalline, smooth, dense and homogenous. The oxidation of grain boundary takes place due to the element diffusion in the polycrystalline material. Oxidation produces amorphous oxide layers on the surface of film. As annealing time increases, surface roughness and diffuse reflection increase. Annealing has little influence on refractive index and extinction coefficient.

1. Introduction

Aluminum nitride, which is a wide band-gap (6.2 eV) III–V semiconductor, has the structure of hexagonal wurtzite. Owing to its excellent physical and chemical properties, such as high thermal conductivity, low thermal expansion coefficient, good corrosion resistance, and high transmission in the visible and near-infrared ranges [1–4]. It has been widely used as the buried insulator materials [5], protective coatings [6], surface acoustic wave devices [7] and anti-reflection layer on the solar coatings [8,9].

As an anti-reflection layer of the solar selective absorbing coatings, it may be operated at high temperature. For example, when the coatings were used in the parabolic trough collector, the operation temperature often keeps at 390 °C or 550 °C for the oil and molten salt heat exchange system, respectively. Aluminum nitride will transform to Al_2O_3 at high temperature under oxidizing atmosphere. Most of investigations have focused on the oxidation behavior of the bulk or powder form material [10–13], and a few for the thin film material [14–18]. However, there is little report on the effect of both the temperature and oxidizing atmosphere on the optical property of AlN film. The aim of this work is to study the effect of thermal stability properties on the AlN film's microstructure, composition and optical properties.

2. Experimental

AlN films were deposited on single crystal Si (1 0 0) wafers by ion beam assisted deposition (ISB700). The Al target with the purity of 99.999% was used for sputtering. Al atoms were sputtered by argon ion generated by Kauffman ion source with the energy of 2700 eV and ion beam current of 100 mA. The assisted nitrogen atoms with the energy of 200 eV were used to reactively deposit the AlN film. The base pressure was 2.0×10^{-4} Pa and the substrate temperature was 200 °C. After sputtering, the AlN films were annealed at 600 °C for different times under air atmosphere.

Chemical state was analyzed by the X-ray photoelectron spectrometer (XPS, PHI Quantera SXM). In order to eliminate the effect of contamination, the film was firstly etched about 10 nm by the argon ion before measurement. A Tecnai G^2 F20 transmission electron microscope, equipped with a high-angle angular-dark-field (HAADF) detector, X-ray energy-dispersive spectrometer (EDS) systems, was used for micro-structure and composition analysis. The surface morphology was observed by scanning electron microscopy (SEM, Hitachi-S4800). The 3D topographies and surface roughness (Ra) were measured by 3D profiler (Nano Map-D) using contact mode. The optical properties were measured by spectroscopic ellipsometry (M-2000) with the incidence angle fixed at 70°. The diffuse reflectance was measured by using UV–vis spectrophotometer (UV-3600) equipped with a diffuse reflectance attachment. The incident beam was collimated, and reflected light was captured by an integrating sphere. A barium sulfate ($BaSO_4$) reference was used to provide a nominal 100% reflectance measurement.

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http://dx.doi.org/10.1016/j.apsusc.2015.03.120
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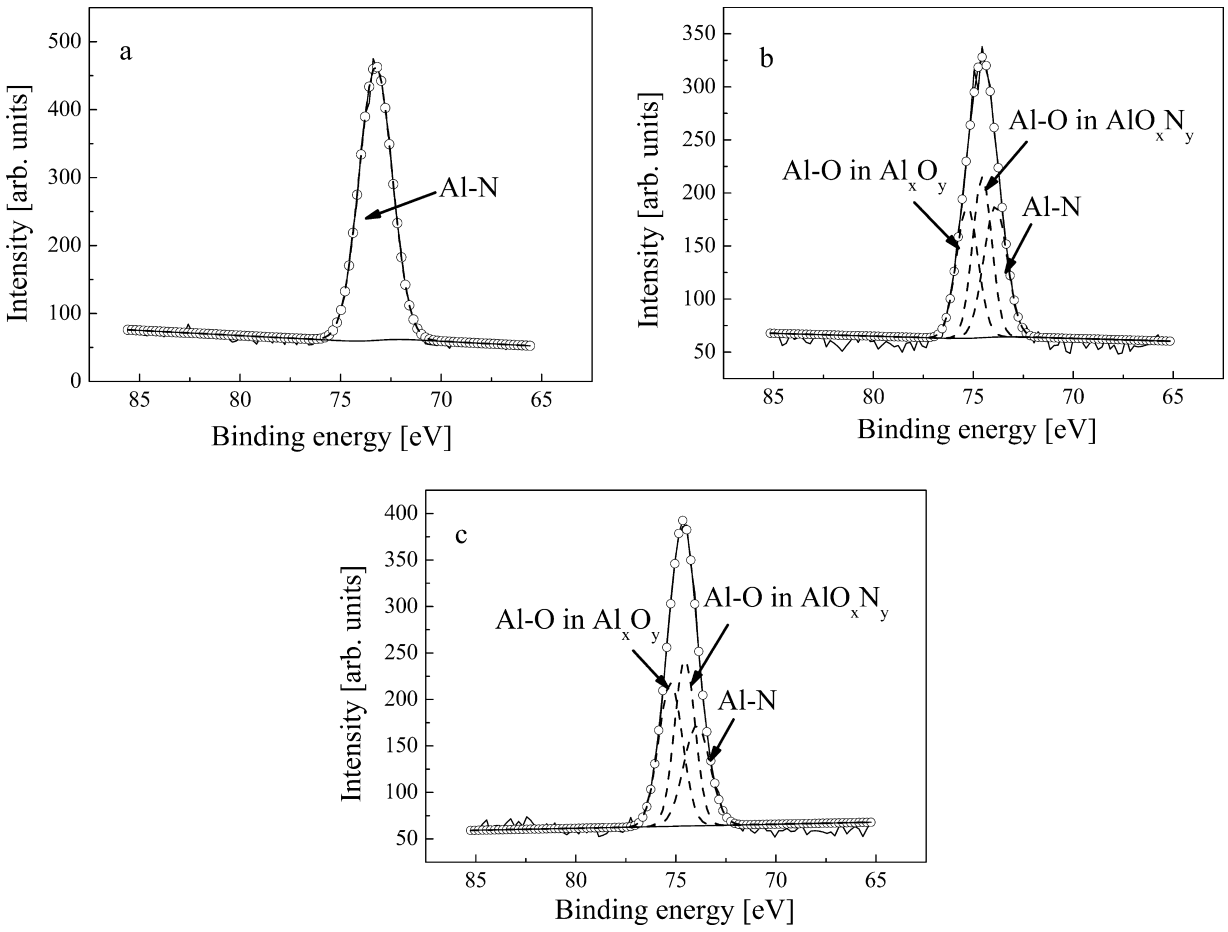

Fig. 1. Al2$p_{3/2}$ core level spectra of the AlN film (a) is the as-deposited state, (b) and (c) are the films annealed at 600 °C for 96 h and 192 h, respectively.

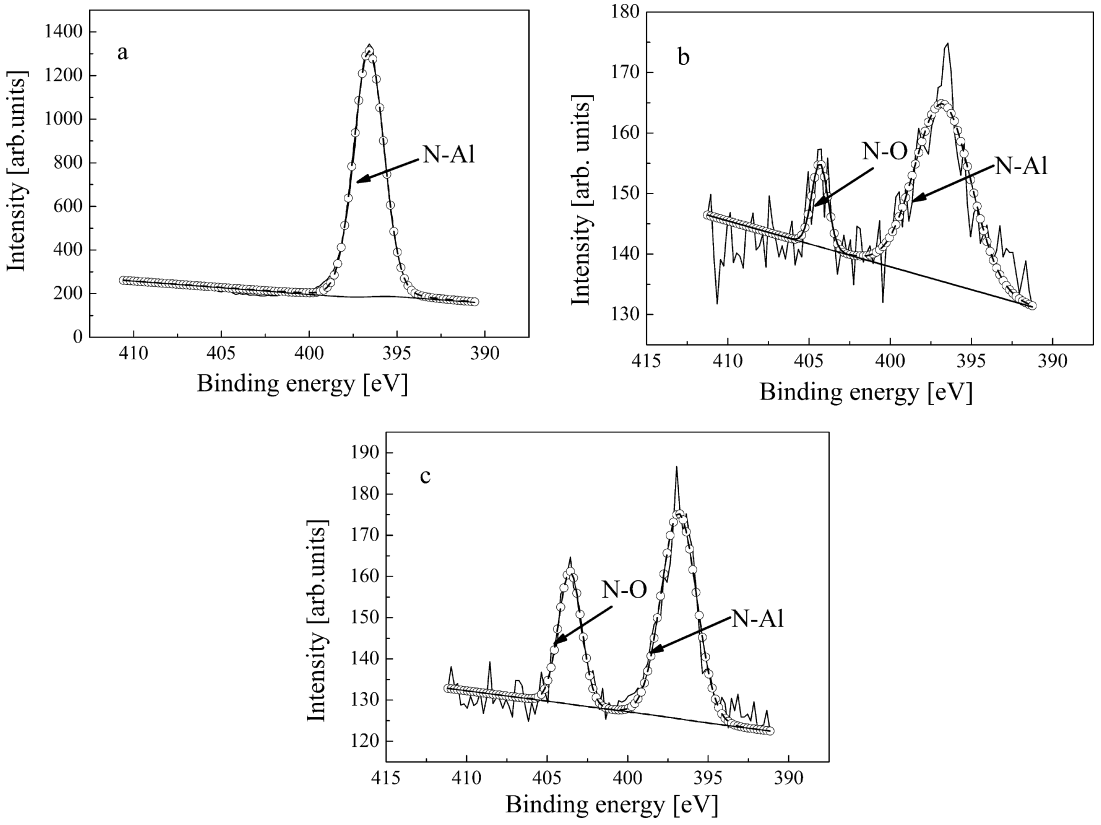

Fig. 2. N1s core level spectra of AlN film (a) is the as-deposited state, (b) and (c) are the films annealed at 600 °C for 96 h and 192 h, respectively.