Materials Science in Semiconductor Processing 17 (2014) 63–66

Contents lists available at ScienceDirect

Materials Science in Semiconductor Processing

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

Short Communication

Synthesis of wurtzite GaN thin film via spin coating method

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ARTICLE INFO

Available online 16 September 2013

Keywords:
Gallium nitride
Wurtzite
Spin coating
Sol–gel preparation
FTIR

ABSTRACT

In this research, hexagonal wurtzite structure gallium nitride (GaN) thin film was grown on silicon (Si) substrate by using spin coating deposition method. Simple ethanol-based precursor with the addition of diethanolamine solution was used. High resolution X-ray diffraction results revealed that wurtzite structure GaN thin film with (002) preferred orientation was deposited on Si substrate. Flied-emission scanning electron microscopy and atomic force microscopy results showed that crack free GaN thin film with uniform and dense grains of GaN was formed. Finally, lattice vibrational characterization by *p*-polarized infrared reflectance technique revealed a strong reststrahlen feature of crystalline wurtzite GaN, and the transverse and longitudinal phonon modes of wurtzite GaN were clearly identified.

1. Introduction

Direct wide band gap gallium nitride (GaN) semiconductor with band gap of about 3.4 eV at room temperature is well-known to be a strong candidate material for applications in photonic [1], high temperature and high-power devices [2]. Traditionally, a variety of deposition techniques were used to synthesise two-dimensional GaN, including metal organic chemical vapor deposition [3], plasma-assisted molecular beam epitaxy [4], hydride vapor phase epitaxy [5], and radio frequency magnetron sputtering [6].

GaN thin films can also be synthesised using a spin coating method which is relatively simpler and cheaper. However, there are two significant challenges encountered when the spin-coating method is applied to synthesize the GaN thin films. These challenges are associated with the difficulty in the preparation of the precursor solution and that associated with the poor wetting of the water-based precursor solution on hydrophobic substrates (such as glass, silicon, and sapphire). For these reasons, only a few studies dealing with spin coating growth of GaN thin films have been reported [7–10].

In recent times, gallium (III) nitrate hydrate ($Ga(NO_3)_3 \cdot xH_2O$) powder which can be used as the gallium source and easily dissolved in water is readily available in the market. It has been used for the synthesis of nanocrystalline GaN powder [11–13]. However, the use of this water-based precursor solution for the synthesis of GaN thin films using spin coating method has not yet been explored. We believe that this is probably due to the poor wetting behavior of this water-based precursor solution onto the substrates.

In this work, we report the synthesis of wurtzite GaN thin film on silicon (Si) substrate via spin coating method and subsequent nitridated in ammonia (NH_3) ambient. To overcome the wetting issue, a simple ethanol-based precursor solution with the aid of diethanolamine (DEA), which has a better wetting property and faster evaporation rate was introduced in this study. The deposited GaN thin film was characterized using high resolution X-ray diffraction (HRXRD) spectroscopy, field-emission scanning electron microscopy (FESEM), atomic force microscopy (AFM) and Fourier transform infrared (FTIR) spectrometry. Note that the DEA solution has been used in synthesis of zinc oxide thin films; however, the use of DEA solution for the synthesis of GaN thin films has not been explored.

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http://dx.doi.org/10.1016/j.mssp.2013.08.013

2. Experimental details

In this experiment, a conventional radio frequency (RF) sputtering system was used for deposition of a very thin layer of aluminum nitride (AlN) buffer layer with thickness ~35 nm on the Si(100) substrate. The AlN buffer layer was used to alleviate the lattice mismatch between the GaN layer and the Si(100) substrate. Gallium nitrate hydrate ($Ga(NO_3)_3 \cdot xH_2O$) powder, ethanol (purity, 99.7%) and DEA were used as gallium source, solvent and surfactant, respectively. First, the $Ga(NO_3)_3 \cdot xH_2O$ powder was dissolved in ethanol (purity: 99.7%) and then DEA was slowly added. The resulting precursor was ultrasonically bathed until the Ga $(NO_3)_3 \cdot xH_2O$ powder fully dissolved. Spin coating was done by dropping the precursor onto AlN/Si(100) substrate and spun in ambient condition for 30 s at 3000 rpm. The spin coating process was done for several times. Prior to the nitridation process, the thin film was annealed in a tube furnace at 950 °C for 2 h. Finally, the coated thin film was nitrided in NH_3 ambient with constant NH_3 flow rate of 300 sccm and at 950 °C for 75 min. After the completion of the reaction, the furnace was allowed to cool down naturally to room temperature. A yellowish deposited layer was found on the surface of the thin film and the thin film was collected and analyzed. The crystalline structure and the crystalline quality of the deposited thin film were examined by HRXRD (PANalytical X'Pert Pro MRD) with a Cu-kα_1 radiation source (λ = 1.5406 Å), whereas the surface morphologies and microstructures of the as-synthesized thin film were examined by FE-SEM (NOVA NANOSEM 450) and AFM (Dimension EDGE, BRUKER). The lattice vibrational properties of the deposited thin film were investigated using an FT-IR spectrometer (Spectrum GX FT-IR, Perkin-Elmer).

3. Results and discussion

Fig. 1 illustrates the XRD diffraction pattern of a GaN thin film grown on an AlN/Si(100) substrate measured in the 2theta–omega ($2\theta-\omega$) scan mode. Three intense diffraction peaks indexed to the hexagonal wurtzite structure GaN(002) and GaN(004) (JCPDS File No. 05-0792) as well as Si(100) can be clearly observed. The prominent GaN(002) diffraction peak indicates the preferential orientation with the *c*-axis perpendicular to the substrate surface [14]. No other crystalline phases associated with gallium oxide and other phases of GaN were detected in the spectrum. Note that the AlN buffer layer did not produce any peaks in the XRD spectrum, which is probably due to its amorphous nature. Alternatively, the AlN buffer layer might have been too thin to give any diffraction information.

To estimate the quality of the GaN thin film, the XRD rocking curve (XRD-RC) of the GaN(002) plane measured in the ω scan mode was obtained as shown in the inset of Fig. 1. From the analysis, the full width at half maximum (FWHM) value of the XRD-RC pattern is approximately 2.13°. The obtained FWHM value is much higher than that obtained by Sardar et al. [7]. Nevertheless, this result revealed that the precursor solutions used here were very promising candidates for high quality GaN thin films. Besides that the preparation of this precursor was also easier and faster as compared to that of Sardar et al.

Fig. 2(a) shows the plan-view FESEM image of the deposited GaN thin film on Si(100) substrate captured at low-magnification (× 10k) while the inset shows the higher-magnification (× 100k). No cracks were observed on the surface of the thin film. At higher-magnification, some hexagonal grains of GaN can be clearly seen. The cross-sectional view of the FESEM image of the deposited thin film is shown in Fig. 2(b). It can be observed that GaN thin film with an average thickness of approximately 0.256 μm was formed on the Si(100) substrate.

Fig. 2(c) shows the AFM image of the deposited GaN thin film on Si(100) substrate. The image reveals that uniform and dense grains of GaN were formed. Measurement of the surface roughness shows that the root mean square (RMS) surface roughness of the GaN thin film is about 39 nm.

Fig. 3 shows the *p*-polarized IR reflectance spectrum of GaN thin film grown on AlN/Si(100) substrate over the entire range from 400 to 7500 cm^{-1}. The inset figure shows the same spectrum but in the range of 500–1000 cm^{-1},

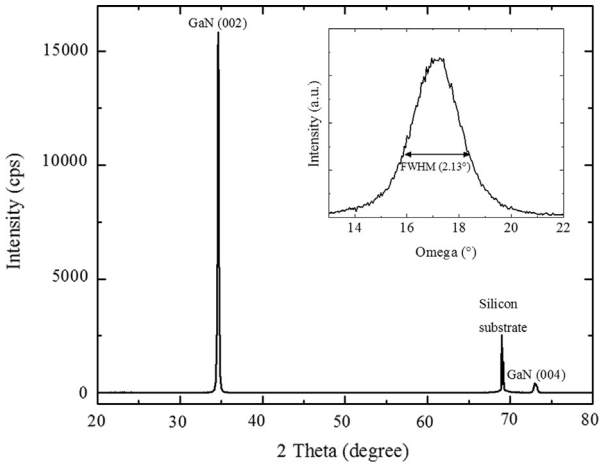

Fig. 1. XRD diffraction pattern of the deposited GaN thin film on AlN/Si(100) substrate with the AlN buffer layer measured under the 2θ–ω scan mode. Inset is the XRD-RC of the GaN(002) plane measured in the ω scan mode.