AlN 박막의 열처리에 따른 표면탄성파의 특성

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Effect of thermal annealing on surface acoustic wave properties of AlN films

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Abstract : In this paper, the effect of thermal annealing on surface acoustic wave (SAW) properties of aluminum nitride (AlN) films were described. The films were fabricated on Si substrates by using Pulsed Reactive Magnetron Sputtering System. The SAW properties of 600°C-annealed AlN films were better than those of both 900°C-annealed AlN films and as-deposited ones. Their SAW velocities (Raleigh mode) and insertion losses were about 5212 m/s and 16.19 dB at 600°C with the wavelength of 40 μm. The dependence of characteristics of AlN films on annealing conditions were also evaluated by using Fourier Transform-Infrared Spectroscopy (FT-IR) Spectrums and Atomic Force Microscopy (AFM)

Key Words : Surface Acoustic Wave, AlN, Annealing, Two Port SAW Resonator

1. Introduction

Aluminum nitride (AlN) is an interesting III-V semiconductor compound and the thin films of AlN have been considered due to the attractive characteristics, such as: good piezoelectric properties, high hardness, large thermal conductivity, and chemical stability. Therefore, this kind of thin films are used widely in a variety of applications, specially, in surface acoustic wave (SAW) devices. Recently, the effects of rapid thermal annealing (RTA) on the crystal quality and piezoelectric response of polycrystalline AlN films were reported, but only an improvement of crystal quality of AlN films with over 900°C of annealing temperature was pointed out. However, the piezoelectric response was not determined clearly. Besides, the previous report had showed that the AlN films got better quality after annealing at 600°C. So, the SAW properties of AlN films were not only influenced by the deposition methods but also by post-deposition heat treatment (as annealing at 600°C ... for instance). In this work, only SAW velocity (V_{SAW}) and insertion loss (IL_{SAW}) of the SAW filters of AlN/Si substrates were compared for the sample annealed at 600°C, 900°C and as-deposited.

2. Experimental

High quality polycrystalline piezoelectric (002) oriented AlN thin films with a thickness of 1 μm deposited on (100) Si wafers by pulsed reactive magnetron sputtering system. Subsequently they were annealed at 600°C and 900°C for 1 hour in N_2 at atmospheric pressure. Then, all the samples were used to fabricate two port SAW resonators by conventional photolithography technique. More detail, a thin Al layer with thickness of 100 nm is deposited onto the (002) AlN/Si sample by thermal evaporator method. After that, inter-digital transducers (IDTs) and reflector (short-circuit) with wavelength (λ) of 40 μm are prepared by UV lithography and Al wet etching. IDTs of 60 finger pairs having a 10-μm finger width and a gap spacing (d) of 10 μm were used. The grating width and a gap of reflector was 10 μm. The number of grating finger was 200 per reflector. Aperture was W=25λ. Center to center length was 2440 μm and spacing between IDT and reflector was 14 μm. The transmission characteristics of the tow port SAW resonator were measured by Agilent 8802A Network Analyzer in room temperature. The qualities and roughness of AlN samples were also evaluated by FT-IR spectrum and AFM.

3. Results and discussion

Fig. 1 shows the transmission characteristic of scattering parameter (S_{21}) of the fabricated SAW resonator with λ = 40 μm. The SAW properties, such as: center frequency (f_0), IL_{SAW} and V_{SAW} were listed in Table 1. In that, the SAW velocities were evaluated by measuring f_0 and λ of the fabricated SAW resonators deduced from $f_0=V_{SAW}/\lambda$. The 600°C-annealed resonator has the smallest insertion loss and higher V_{SAW} than the V_{SAW} of 900°C-annealed samples and as- deposited. From the results above, it can be deduced that the SAW properties of piezoelectric (002) oriented AlN thin films were improved by thermal annealing at 600°C. The insertion losses were affected by many parameters of SAW filter, but the largest influence came from the roughness of surface piezoelectric films. AFM results showed that the roughness of AlN thin films of which the Root Mean Square (RMS) value was 1.776 nm for 600°C-annealed samples was smaller than those of without annealing and 900°C-annealed samples, which were 1.971 nm and 1.828 nm respectively (picture of AFM not show). Their insertion losses decreased significantly due to the surface of AlN films became smoother after annealing at 600°C. The previous report indicated that in thermal treatment, the re-crystallization happened as increasing annealing temperatures and, consequently, the roughness of AlN thin films had been affected. However, with a suitable rate of increasing annealing temperature and optimum annealing temperature point, for example 600° C, it might make the surface of AlN films smoother and quality of crystalline of AlN thin films better.

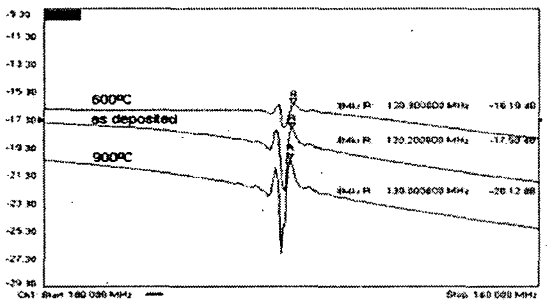

Fig 1. Transmission characteristics (S_{21}) of SAW resonators fabricated on AlN films with annealing conditions

Table 1. The Transmission (S_{21}) values of the two port SAW resonator with annealing conditions

λ=4d [μm]	SAW Properties	without annealing	600°C	900°C
40	f_0 [MHz]	130.2	130.3	130
	V_{SAW}[m/s]	5208	5212	5200
	IL_{SAW}[dB]	17.90	16.19	20.12

Moreover, the FT-IR spectrums of AlN thin films was showed in Fig 2. In that, the intensity of E1 absorption band is related to (002)-oriented crystallites of AlN films. A1 mode of AlN is associated with the existence of random orientations of grains in the films. In this study, the values of wave number of peak E1 were 673.28 cm^{-1}, 675.08 cm^{-1} and 674.48 cm^{-1} for annealed at 600°C, 900°C and without annealing samples, respectively. Obviously, peak E1 shifted toward a higher wave number after annealing at 600°C. The shift of the band strongly relates to the film stress and electromechanical coupling factor K^2 as function of residual stress. From these results, it seems that peak's shift relates to an increase of SAW velocity and the quality of crystals of 600°C-annealed AlN films. Despite of positive results above, it is still difficult to explain the relationship between the spectrums and the SAW properties in detail.

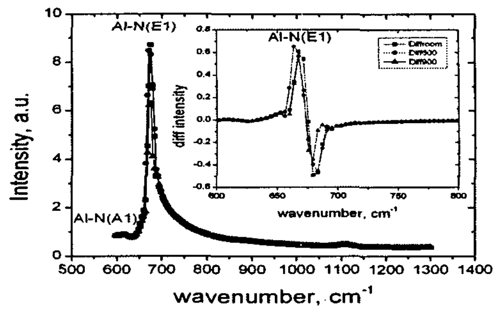

Fig. 2 FT-IR absorbance spectrum of AlN thin films with various annealing temperatures
(■) As-deposited. (●) Annealing at 600°C. (▲) Annealing at 900°C.

4. Conclusion

The SAW properties, such as: SAW velocity, insertion losses, of as deposited and annealed AlN samples have been investigated. The measured results indicated that the roughness, stress or quality of crystals would be changed by thermal treatment and caused the modification of their SAW properties. At the annealing temperature of 600°C, SAW velocity rose slightly and insertion loss reduced considerably. The conclusion is that after annealing the SAW properties of AlN films could be improved and used in SAW applications that require the piezoelectric properties of AlN films.

Acknowledgments

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