GaN Thin Film SAW Filter with High Velocity and Low Insertion Loss grown by MOCVD

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ABSTRACT

III-nitride wide band gap materials, grown either in the [0001] direction of a wurtzite structure or in the [111] direction of a Zinc-blende structure, exhibit strong lattice polarization effects, as both directions are parallel with the polar axes[1]. This suggests that III-nitride materials are uniquely suited for application in high temperature piezoelectronics, pyroelectric sensors[2], and SAW devices[3]. AlN is a promising material for SAW devices because it has a high SAW velocity, which qualifies it for GHz-band application. Devices working at over 2 GHz have already been built[4]. However, until now, there have been no other reports on a SAW device fabricated on an epitaxially grown GaN thin film. This is because an undoped GaN epitaxial layer, even grown by very sophisticated MOCVD(metalorganic chemical vapor deposition) or MBE(molecular beam epitaxy), usually exhibits a high electrical conductivity, due to residual donors unintentionally introduced during the growth, which increases the insertion loss of the device that is fatal in realizing a good SAW device. Accordingly, to be used as a piezoelectric material for a SAW filter, the GaN thin film that is grown must include a high resistivity as well as a high bulk and surface crystallinity. This study proposes GaN thin film as a piezoelectric material for SAW(surface acoustic wave) filters. All the GaN samples in this work were grown in a vertical type MOCVD system with a resistively heated rotating disk reactor. The total gas pressure during the growth was set at 200 torr and the spinning rate of the substrate was about 1000 rpm. Mg-doped GaN films with different thicknesses of 1.3, and 2.0 μm, and the thickness of undoped GaN sample was fixed at 2.0 μm.

The GaN SAW filters were composed of a normal inter-digital transducer (IDT) with 18 pairs of single $\lambda/4$ electrodes with a λ of 10 and 20 μm, where λ was the wavelength of the SAW of the synchronism frequency. Al electrodes with a thickness of 200 nm were evaporated. The patterning of the electrodes for the SAW IDT was performed by a conventional lift-off process. A schematic diagram of the cross-section and top picture of the IDT/GaN/sapphire SAW filter are shown in Figs. 1(a) and (b). The width and spacing of the IDT fingers were both 10 and 20 μm.

The frequency responses at the center frequency of GaN SAW filters with an IDT with 18 pairs of single electrodes(λ=60 μm) are shown in Figs. 2(a) and (b), and the two Mg-doped samples with different thicknesses of 2.0 μm and 1.3 μm. In both samples, the attenuation of the center frequency near 96.725 MHz was 22 dB smaller than those at the tops of the first sidelobes. In spite of the absence of a suitable impedence matching, the insertion losses were as low as –9.87 dB and –7.74 dB for the 1.3 and 2.0 μm

thicknesses, respectively, which would appear to be related to the inherently high sheet resistivity of Mg-doped GaN film. A propagation velocity of 5802 ㎧ was obtained from the center frequency and wavelength (λ =60 ㎛), which is the highest value ever reported for a GaN-based SAW filter. Therefore, these superior characteristics would seemingly facilitate a ~GHz operation when the IDT geometry is designed using a 1 μm scale.

REFERENCES

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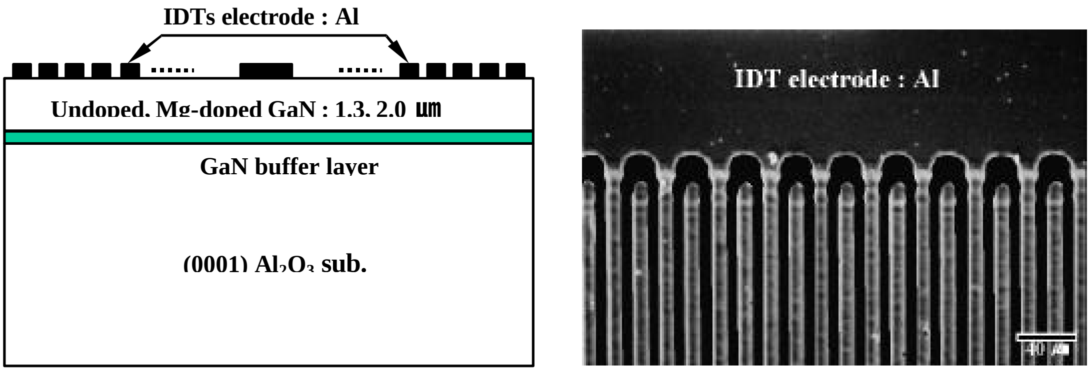
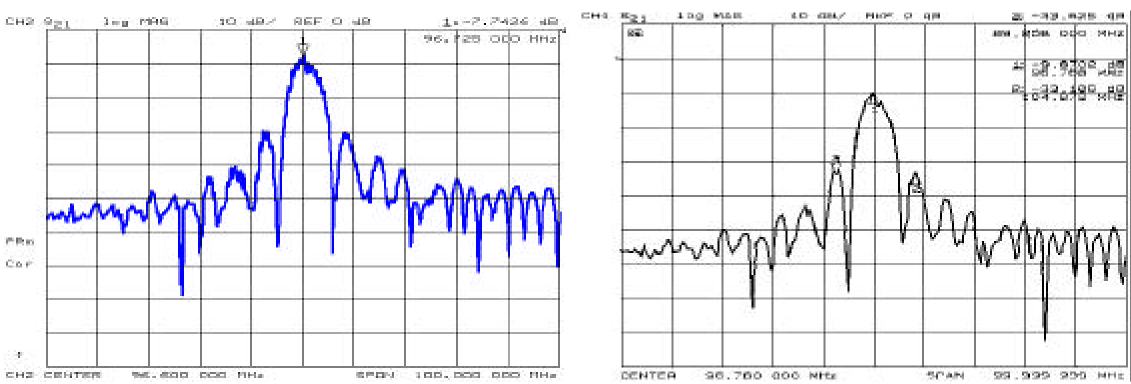


(a) (b)

Fig. 1 Schamatic diagram of cross-section (a) and top picture (b) of fabricated GaN SAW filter.



(a) (b)

Fig. 2 Frequency response characteristics of fabricated GaN SAW filter with wavelength 60 ㎛ for two different thicknesses of Mg-doped GaN film. (a) 2.0 ㎛ and (b) 1.3 ㎛