Optical and electrical properties of GaN films with Ga-polarity grown by radio-frequency plasma-assisted molecular beam epitaxy

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Wide band-gap GaN and related III-nitride materials have attracted a great deal of attention due to their potential usefulness in optical and electronic devices. Recently, lattice-polarity in III-nitride films becomes a hot topic due to its great influence on the optical and electrical properties of the films. It is well known that lattice-polarity of MOCVD-grown GaN films usually shows Ga-polarity, however, the lattice orientation of conventional MBE-grown sample is assumed to be mainly N-polarity [1]. Recently, we succeeded in realizing GaN growth with Ga-polarity on sapphire substrates grown by rf-MBE and pointed out that the qualities of GaN films could be essentially improved by applying growth under the Ga-polarity mode [2,3]. However, the optical and electrical properties of Ga-polarity GaN films grown by rf-MBE have not been investigated in details. In this study, we characterized optical and electrical properties of Ga-polarity GaN films grown by rf-MBE. XRD rocking curve, PL and Hall-effect measurements were carried out to characterize the qualities of GaN films. The GaN films were grown on sapphire (0001) substrates by rf-MBE. The details of the realization of Ga-polarity growth and growth conditions were described elsewhere [2,3].

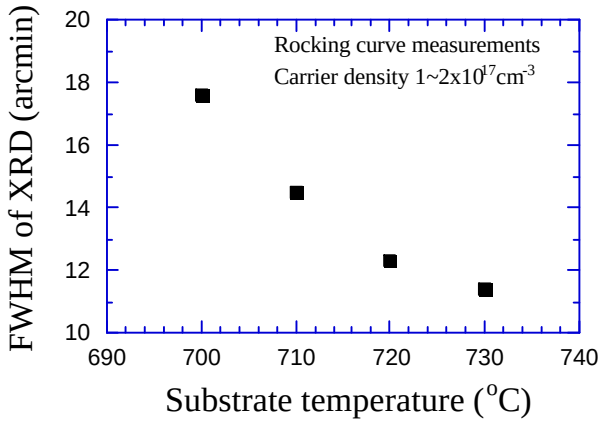

Fig.1. The growth temperature dependence of FWHM values of XRD rocking curve measurements

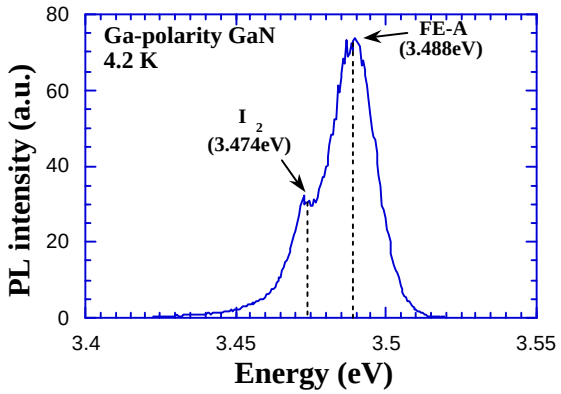

Fig. 2. PL spectrum of a Ga-polarity GaN film at 4.2K

XRD (rocking curve scan) measurements were applied to characterize the structural property of Ga-polarity GaN films. It is clear that the FWHM of GaN (0002) peak decreased when the growth temperature was increased as shown in Fig.1. This means that the structural property was improved by increasing the growth temperature. PL measurements (He-Cd laser as an exciting source) at 4.2K were carried out to characterize the

optical properties of GaN films. Figure 2 shows the typical PL spectrum of one GaN sample. Good optical property with sharp band-edge-related peaks and almost no yellow-band emissions was obtained. Furthermore, the band-edge-related emission was separated into two peaks at about 3.474 eV and 3.488 eV, which is related to I_2 and free-exciton (A exciton) recombination, respectively [4]. However, in case of N-polarity GaN films, only I_2 peak was observed. This indicated that the optical property of Ga-polarity film was greatly improved

Electrical property of GaN films is an important reference to the film quality. In case of N-polarity GaN films, we got the electron mobility typically to be a few 10 cm^2/Vs at room temperature (RT). However, GaN films with Ga-polarity always show much higher mobility. GaN films were doped by Si, because Ga-polarity films were always high resistive. Figure 3 illustrates the dependence of mobility on carrier concentration at different growth temperatures. It is clear that the dependence at a fixed growth temperature is very similar to the results reported by H.M. Ng et al.[5]. However, the increase of mobility at different growth temperatures is thought to be due to the improvements of structural property of GaN films as shown in Fig.1. The highest mobility we got is 568 cm^2/Vs at RT with carrier concentration being $1.1x10^{17}$ cm^{-3}.

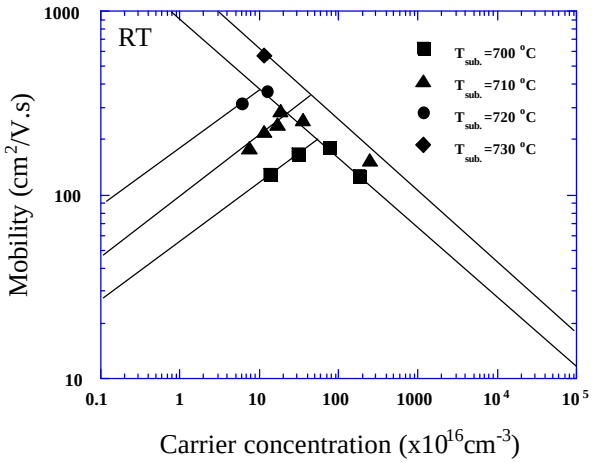

Fig.3. The dependence of electron mobility on carrier concentration at different growth temperatures

As a summary, GaN films with Ga-face lattice polarity grown by rf-MBE were characterized by XRD, PL and Hall-effect measurements. Both optical and electrical properties of Ga-polarity GaN films were dramatically improved. PL results showed that free-exciton recombination process was dominant. The highest electron mobility obtained in this study was 568 cm^2/Vs at RT with carrier concentration being $1.1x10^{17}$ cm^{-3}, which is comparable with those grown by MOCVD. The results indicated that high quality GaN films could be obtained by applying growth under the Ga-polarity mode in rf-MBE.

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