Si diffusion into self-organized GaN nanocolumns grown on Si(111) by RF-MBE

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The small-size micro-LED displays requests micrometer-scale pixels. The monolithic fabrication of GaN-based LEDs (monolithic integration) is also interesting for high-dense integration. In a view of the optical isolation of integrated LEDs, GaN nanocolumns grown on Si is interesting for the monolithic integration, because threading dislocations in them can be reduced (filtering effect) [1]. However, Si atoms will be diffused into the GaN nanocolumns. In this study, these carrier concentrations as a function of the amount of a Mg dope (compensation of electron carrier) are estimated using Raman spectra.

GaN nanocolumns (NCs) was grown on the substrate using plasma-assisted molecular beam epitaxy (RF-MBE). The growth time was 60 min., the growth temperature was 1020 °C, the Ga flux was 9.0×10^{-7} Torr, the N_2 flow rate was 2.0 ccm, and the RF power was 400 W. In a case of a Mg dope, its beam equivalent flux of 5.7×10^{-9} Torr was adopted. Raman spectra of GaN nanocolumns were observed using a 532-nm-line of YAG: Nd. The modes of E2 and LO-phonon-plasmon coupled (LOPC) modes [2] are shown in Figs. 1 and 2. The peak shift of E2 modes means the amount of strain in the layers. The strain in GaN NCs grown on Si is free compared with that in GaN layers grown on sapphire by MOVPE. It means that the NCs have the low dislocation densities due to "filtering effect" [1]. On the other hand, a very weak peak of the LOPC mode was observed form the GaN NCs. This means to the high electron carrier concentration in GaN NCs. The LOPC mode in carrier compensated GaN NCs using a Mg dope (Mg concentration was estimated using a local vibration mode) is also observed. A clear LOPC peak was observed. These peak positions indicate that the Si concentration in GaN NCs is approximately 100 ppm.

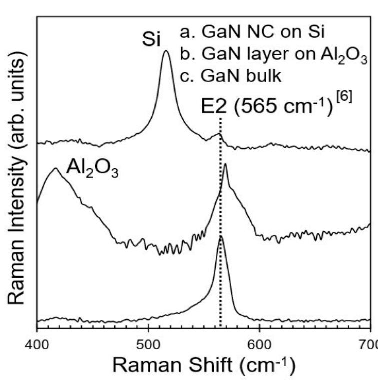

Fig. 1. E2 modes of GaN NC and GaN layers.

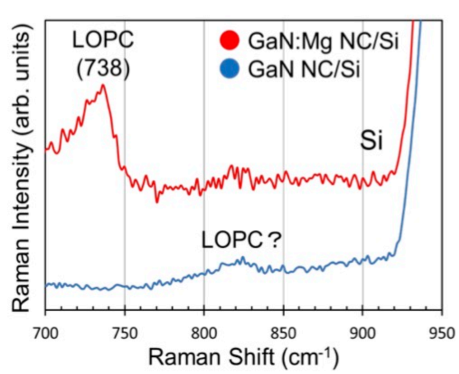

Fig. 2. LOPC modes of GaN NC and its Mg-doped case.

[1] H. Sekiguchi et al., APEX, **1**, 124002 (2008). [2] H. Harima et al., J. Cryst. Growth, **189/190**, 672 (1998).

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GaN nanocolumns grown on Si. The cross-sectional images observed using SEM are shown in Fig. 3. The Mg doping technique was used for the reduction of electron carrier concentration. The amount of Mg concentration was confirmed using LVM modes in Raman spectra, which is shown in Fig. 4.

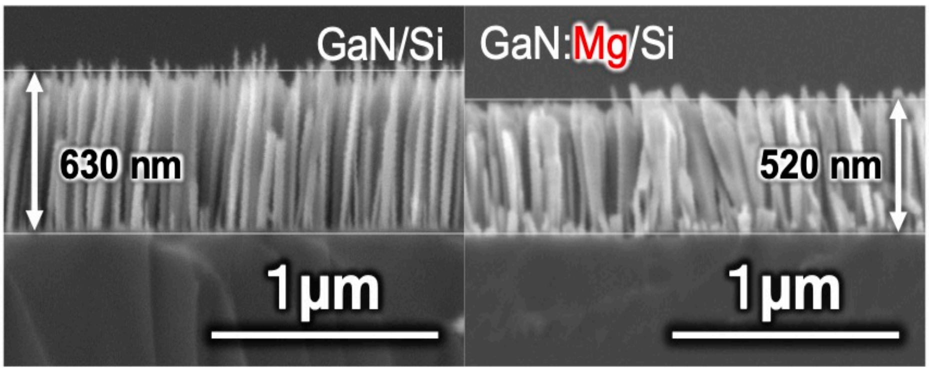

Fig. 3. SEM images of GaN NCs on Si and Mg-doped GaN NCs on Si.

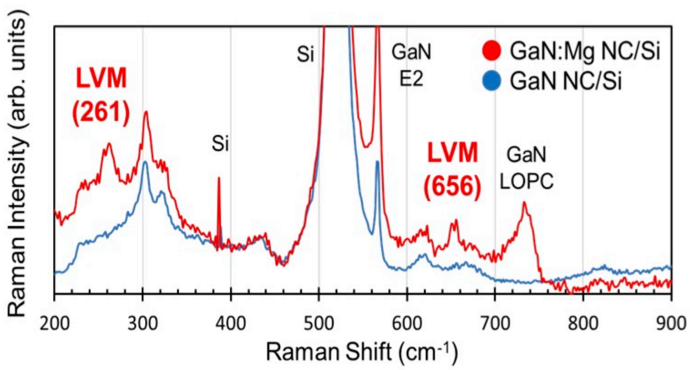

Fig. 4. Raman spectra of local vibration modes (LVMs) in GaN NCs w/o Mg dope.