Effect of column diameter and height on optical properties of regularly arranged GaN nanocolumn grown by rf-MBE

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GaN nanocolumns have a great potential in improving emission efficiency in the longer-wavelength due to dislocation filtering and strain relaxation [1]. The regularly arranged (RA) nanocolumns have been demonstrated on GaN layer, however, the selective area growth of nanocrystals on Si is required in terms of low-cost and large-area substrate. In this study, the effects of diameter and height on optical properties were investigated because it is important to know key points to obtain high crystalline nanocolumns.

The RA-GaN nanocolumns were fabricated on AlN/Si substrate by Ti-mask selective-area growth technique [2]. GaN nanocolumns with different height (350 and 700 nm) were prepared. Figure 1 shows the peak intensity of near-band edge (NBE) emission at RT as a function of diameter. While peak intensity at NBE drastically decreased with increasing the diameter for low height nanocolumns, high PL intensity kept at almost constant value up to 200 nm and dramatically decreased at 230 nm for high height nanocolumns. To understand this reason, CL measurement were performed (Fig. 2). While the ratio of strongly emitting nanocolumns decreased with increasing dimeter for 350 nm-height nanocolumns, it hardly decreased with increasing diameter for 700 nm-height nanocolumns. It would result from that threading dislocation did not propagate to the upper part in the 700 nm-height nanocolumn [1]. Next, the effect of diameter and height on yellow luminescence was investigated. While the ratio of yellow luminescence intensity to total PL intensity monotonically increased with increasing diameter for low height columns, it was constant at small value of less than 0.1 up to thick diameter of 360 nm. Finally, PL spectra at 15 K were evaluated. NBE emission and oxygen-related luminescence (3.41 eV) were observed for high height columns [3]. I_{OX} intensity monotonically decreased with decreasing diameter from 260 to 160 nm. Based on these result, the height and the diameter are important parameters to obtain high crystalline GaN nanocolumns.

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Reference [1] K. Kishino, *et al.*, *Nanotechnology*, **26**, 225602 (2015). [2] H. Sekiguchi, *et al.*, *Appl. Phys. Express*, **1**, 124002 (2010). [3] B. C. Chung *et al.*, *J. Appl. Phys.*, **72**, 651 (1992).

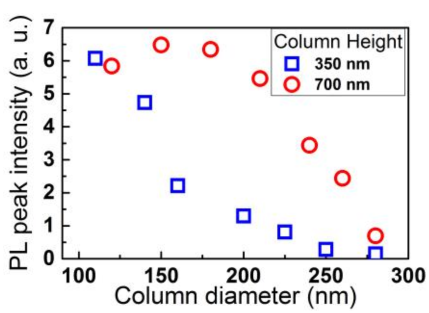

Fig. 1 Peak intensity of NBE emission at RT as a function of diameter.

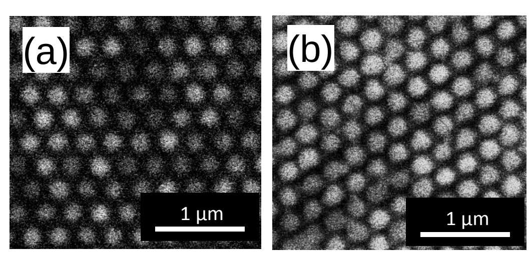

Fig. 2 Panchromatic CL images of 180 nm-height GaN nanocolumns with different height of (a) 350 and (b) 700 nm.

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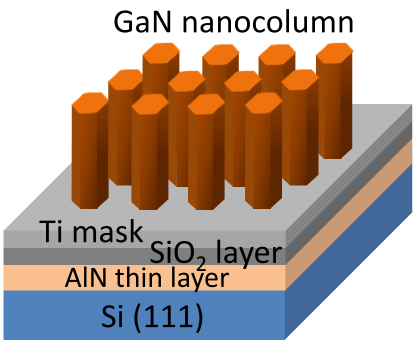

Fig. 1 Schematic diagram of regularly arranged GaN nanocolumns fabricated using Ti-mask selective area growth technique.

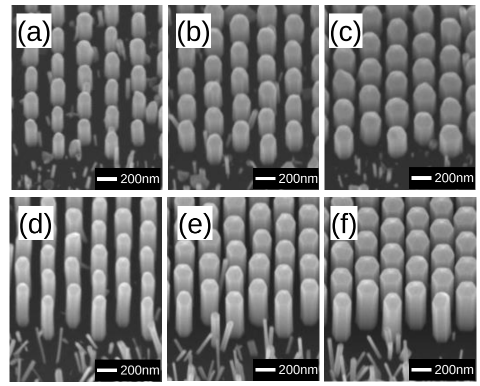

Fig. 2 Bird's eye view SEM images of GaN nanocolumns with different diameters and heights. Samples (a), (b) and (c) are height of 350 nm. Samples (d), (e) and (f) are height of 700 nm. Diameter: (a) 140 nm, (b) 160 nm, (c) 200 nm, (d) 140 nm, (e) 180 nm, (f) 210 nm.

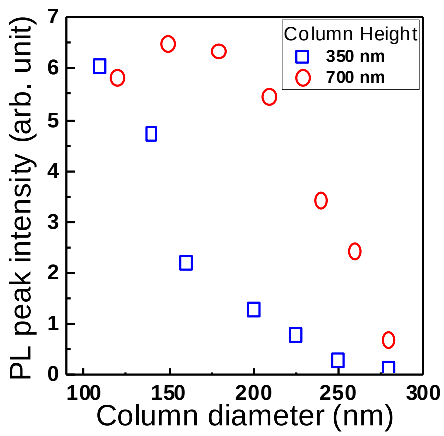

Fig. 3 Peak intensity of near-band edge (NBE) emission at RT as a function of column diameter of GaN nanocolumns with different height nanocolumns.

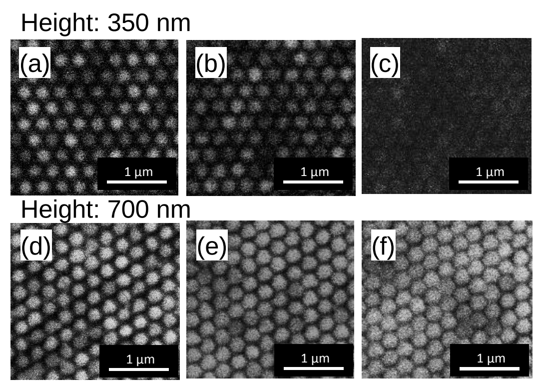

Fig. 4 Panchromatic CL images of GaN nanocolumns with different diameter and height. Samples (a), (b) and (c) are height of 350 nm. Samples (d), (e) and (f) are height of 700 nm. Diameter: (a) 180 nm, (b) 200 nm, (c) 225 nm, (d) 180 nm, (e) 210 nm, (f) 240 nm.

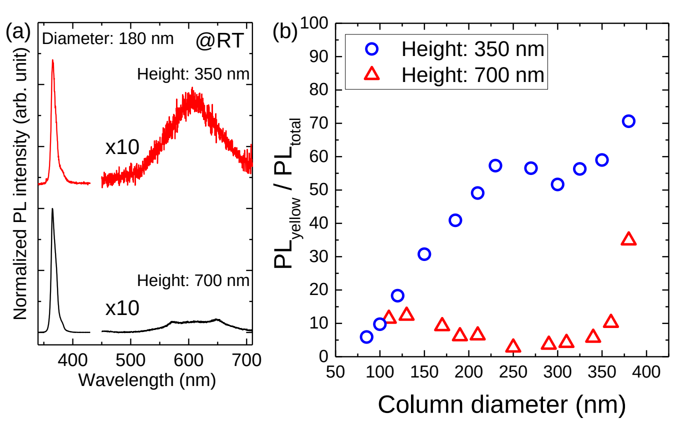

Fig. 5 (a) PL spectra at RT for 180 nm-diameter nanocolumns with height of 350 and 700 nm. (b) Ratio of yellow luminescence intensity to total PL intensity at RT as a function of diameter for nanocolumns with different height of 350 and 700 nm.

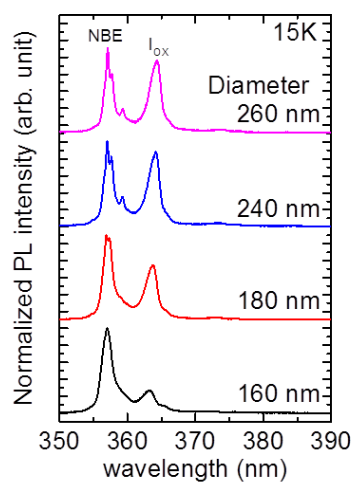

Fig. 6 PL spectra at 15 K of 700 nm-height GaN nanocolumns with different diameters of 160, 180, 240, 260 nm.