Effect of Growth Condition on Well-Arranged InGaN/GaN Nanocolumns Grown by Selective Area Growth (SAG) of rf-Plasma-Assisted Molecular-Beam Epitaxy

Hiroto Sekiguchi*1,2, Katsumi Kishino*1,2, and Akihiko Kikuchi*1,2
*1 Department of Electrical and Electronics Engineering, Sophia University, 7-1 Kioi-cho, Chiyoda-ku, Tokyo 102-8554, Japan, Tel: +81-3-3238-3323, Fax: +81-3-3238-3321
*2 CREST, Japan Science and Technology Agency
Tel: +81-3-3238-3323, Fax: +81-3-3238-3321, e-mail: kishino@katsumi.ee.sophia.ac.jp

1. Introduction
GaN nanocolumns are self-organized one-dimensional columnar nano-crystals of 20-200 nm diameter, 1 µm height, and ~10^{10} cm^{-2} column density [1]. The nanocolumns, which are expected to possess excellent optical characteristics due to almost bringing about variation in thickness and In composition of InGaN quantum wells. For the development of high performance nano-devices, the size and position control of nanocolumn were essential issues. To meet the situation, recently we have developed the selective area growth (SAG) of GaN nanocolumn by the use of Ti nano-pattern [5].

2. Experiments and Results
In this talk, the effect of the growth parameter on well-arranged InGaN/GaN nanocolumns grown on GaN template by the Ti mask SAG technique of rf-MBE is described. Figure 1 shows schematically the SAG procedure of InGaN/GaN nanocolumns. A Ti film of 5 nm in thickness was evaporated on the GaN surface. Various nano-hole arrays with the nano-hole size of 100 to 550 nm, arranged in triangular or square lattice, were prepared on the same substrate by focus ion beam (FIB). On the patterns, the GaN nanocolumns and 3-period InGaN/GaN multi quantum wells (MQWs) were grown. In the growth, firstly the surface nitridation of the Ti film was performed at 400 °C for 10 min, followed by the growth of GaN nanocolumns on them for 3 hours. In this study, the growth temperature (T_g) and supplied nitrogen flow rate (Q_{N2}) were changed as growth parameters from 880 to 926 °C and from 3.5 to 1.0 sccm, respectively. Figure 2 shows SEM top surface images of the GaN nanocolumns grown at the T_g values of 880 to 926 °C. Note that 900 °C was the critical temperature for the SAG. Below that, no SAG of GaN was observed. At the T_g above 900 °C, the regular arrangement of GaN nanocolumns was obtained, but an excess increase in T_g introduced fluctuation and decrease in column size.

Acknowledgements
This study was partly supported by a Grant-in-Aid for Scientific Research on Priority Areas #18069010 and (B) #18310079 from the Ministry of Education, Culture, Sports and Technology.

References
Fig. 1 Schematic diagram of regular arranged nanocolumns

InGaN/GaN MQW
3 periods or nothing
GaN nanocolumns
Ti thin layer (5 nm)
GaN template (3.5 µm)
Sapphire substrate

Fig. 2 Growth temperature dependency of the selective area growth of nanocolumns ((a)880°C, (b)900°C, (c)917°C, (d)926°C)

Fig. 4 SEM images of nano-hole and GaN nanocolumn with the supplied nitrogen flow rate of 1.0 sccm ((a) top view of nanohole, (b) top view of nanocolumn, (c) bird’s eye view of nanocolumn)

Fig. 5 Size distribution of nano-hole size and nanocolumn size

Fig. 6 PL spectra of GaN nanocolumn and HVPE-GaN

(TDD: 6-8x10⁶ cm⁻²)