16p-B5-10

非極性 air/AlGaN DBR 垂直微小共振器の作製と評価
Fabrication and characterization of nonpolar nitride air-gap DBR vertical microcavities

東大生産研 [1]，東大ナノ量子機構 [2]　○陶 仁春 [1]，有田 宗貴 [2]，加古 敏 [1]，荒川 泰彦 [1,2]
IIS[1], NanoQuine[2], Univ. of Tokyo　○R. Tao[1], M. Arita[2], S. Kako[1], Y. Arakawa[1,2]
E-mail: rctao@iis.u-tokyo.ac.jp

Semiconductor distributed Bragg reflector (DBR) microcavities (MCs) have been widely used for optoelectronics. In III-Nitrides, the difficulty in obtaining a high index contrast means that an air-gap nitride DBR MC turns out to be a promising option [1]. However, due to the chemical inertness and poor selectivity between various nitride materials, no complete air/nitride DBR MCs have been reported to date. In this work, we report the successful fabrication of complete air-gap DBR MCs using a thermal decomposition process [2]. We observe quality factors as high as 1600.

The samples were grown on m-plane free-standing GaN substrates. After the deposition of 4 periods of AlGaN/GaN(117nm/296nm) layers, a AlGaN cavity with single InGaN quantum well (QW) at the center was grown, which was then followed by another 3 GaN/AlGaN(296nm/117nm) layers. Patterns were created in the structure using electron beam lithography and chlorine dry etching. The GaN around the openings was then decomposed by annealing for 20~30mins in the MOCVD reactor at 1070℃, while the AlGaN layers remained unaffected. This process resulted in the formation of air/AlGaN DBR MCs with single InGaN QW at the cavity center (Inset in Fig.2). Four samples have been grown, with cavity thickness ranging from 152 nm to 159nm.

μPL measurements were performed on the samples at room temperature using a CW 266nm laser. A systematic shift of the cavity mode with increasing cavity thickness was observed (Fig. 1). By fitting of a Lorentzian profile, the Q factor of one mode is estimated to be 1600 (Fig. 2). Each spectrum exhibits two modes, which originate from the anisotropic in-plane properties of the nonpolar sample, with $E \parallel a(X)$ and $E \parallel c(Z)$, respectively. The energy difference of the modes is due to a difference in refractive index ($\Delta n = n_e - n_o$ ~0.02). The intensity of the mode with $E \parallel a$ is much higher than that with $E \parallel c$. With a $k \cdot p$ Hamiltonian [3], the matrix elements between the first conduction band and first valence band were calculated for our QW. It is found that near the Γ point, the matrix element $|M_X|^2$ is much larger than $|M_Z|^2$, which is consistent with our experimental observations.

In summary, nitride air-gap DBR MCs have been successfully fabricated using the thermal decomposition of GaN. A Q factor of 1600 reveals the high quality of the cavities, and the mode positions can be fine-tuned by varying the cavity thickness. These results show that air-gap DBR MCs fabricated by thermal decomposition of GaN are very promising for research on light-matter interactions in nitrides.

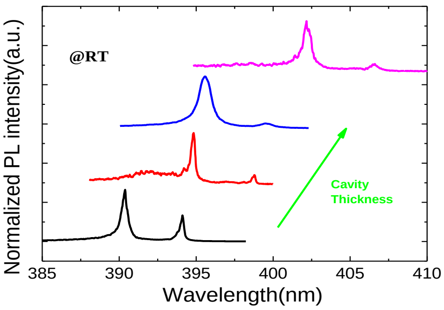

Fig. 1 Systematic shift of cavity mode with increasing cavity thickness (~152nm-~159nm).

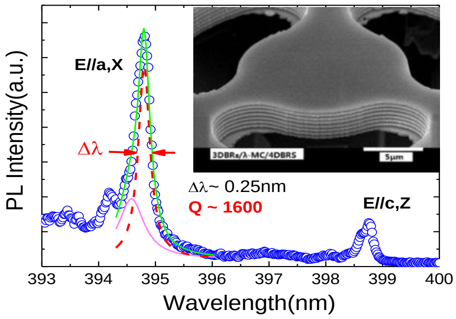

Fig. 2 Lorentzian profile fitting of one measured mode spectrum; the inset is the SEM figure of the fabricated air/AlGaN MC.

Acknowledgement

We would like to thank Dr. Mark Holmes and Dr. Kenji Kamide for discussions on calculation.

This work was supported by Project for Developing Innovation Systems of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan, and by Japan Society for the Promotion of Science (JSPS) through its “Funding Program for world-leading Innovation R&D on Science and Technology (FIRST Program).

Reference

[1] R. Tao et al., the 73th JSAP Fall meeting 12p-H9-14(2012),
[2] M. Arita et al., Applied Physics Express 5, 126502(2012),
[3] S. L. Chuang and C. S. Chang, Phys. Rev. B 54, 2491(1996)