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Introduction of Tensile-Strained Dilute Nitride Quantum Wells For Its Application to Dielectric-Rod Type Photonic Crystals

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Abstract

We investigate the application of tensile-strained dilute nitride gain medium onto the dielectric-rod type photonic crystals. Introducing the GaInNAs quantum wells with the cavity structure on which rod-type photonic crystal is patterned, we observe the enhancement of extracted luminescence efficiency from the surface depending on the correlated variation of TM-polarized photonic bandgap.

1. Introduction

Photonic crystal (PC) has been a material of great interest because of the possible control of light which shows many prospects for the new generation optical devices. We here investigate the application of tensile strained compound semiconductor quantum wells into the framework of potonic crystal. A quantum being tensile strain condition provides a emission of light polarized to transverse-magnetic (TM) mode, and expectations of high efficiency photoelectric conversion and suitable high-frequency operation of optical devices such as lasers.[1] Dilute nitride materials, a few % of nitrogen is introduced for the standard compound semiconductors such as GaAs and InP, can be a material of possible TM-polarized light source because of the introduction of nitrogen reduces band gap of host matrix as well as lattice constant. Onto a sample of optical waveguide structure containing this dilute nitride gain medium, we introduce dielectric rod type photonic crystal and investigate its impact on the system.

2. Experimental Details

Figure 1 shows the sample structure, calculated TM-mode photonic bands for the rod-type PC structure, and the dependence of band gap as a function of PC lattice constant when the rod-radius r is proportionally varied for the lattice constant a as r=0.36a. The rod type PC is fabricated on the sample surface. 5-periods (13 nm $Ga_{0.972}In_{0.028}N_{0.016}As_{0.984}$/ 13 nm GaAs) quantum wells were used as the active medium. As seen in the figure, we can control the photonic band gap by varying a and r as described the above. To experimentally examine the effect of the photonic band gap, we fabricate the structure on the sample surface as shown in Fig. 2. The series of the structures are clearly fabricated. The height of the rods are about 200 nm, which will effect on the behavior of light confined between the bottom side AlGaAs and the upper side air having its thickness 300 nm ~ 1 λ/n..

3. Results and Discussions

Figure 3 shows the results of photoluminescence obtained from the series of the samples with micro-photoluminescence setup. The excitation and detection of the luminescence was carried out from the sample surface at an normal incidence. The luminescence intensity varies with respect to r and a. As seen in the compiled figures, we obtain clear enhancement of detected luminescence efficiency by close to the order of magnitude at the second photonic band gap region. That is probably related to the effect of photonic bandgap, providing the higher extraction efficiency of the luminescence. A similar result

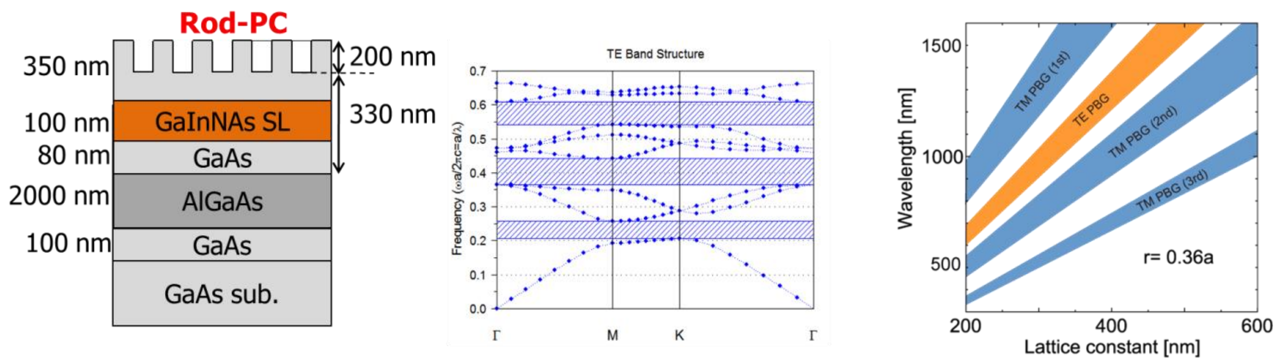

Fig. 1 Sample structure, photonic band structure, dependence of photonic band gap as a function of lattice constant

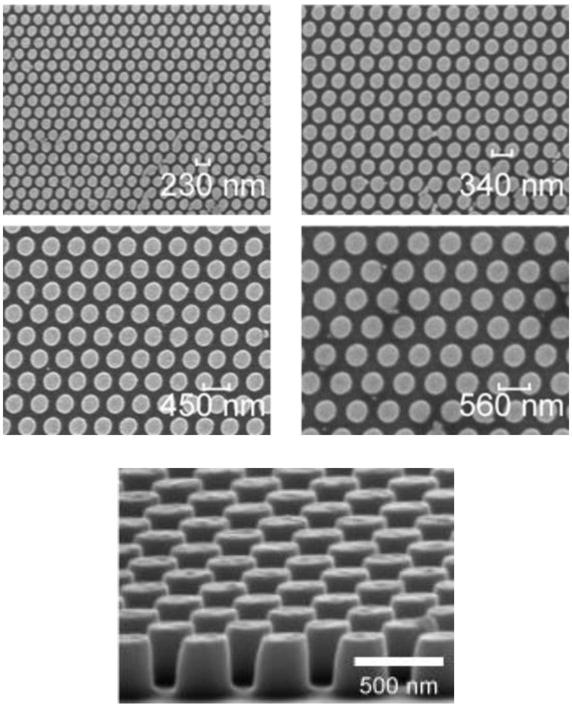

Fig. 2 Photonic crystal structures

was reported until now for the standard photonic crystals having air-hole arrays. [2] There, the extracted luminescence efficiency is reported as a result of reduced spontaneous emission rate and the resulting re-distribution of light energy toward the direction of out-of-plane. We believe, we have observed the phenomena in our sample investigated, which shows the prospect of the realization of functional rod-type photonic crystal devices with tensile strained dilute nitride medium. Considering the structure required, that would be applicable to a concept of recently-emerging nanowire-arrays.

4. Conclusions

We investigate the application of tensile-strained dilute nitride gain medium onto the dielectric-rod type photonic crystals. Introducing the GaInNAs quantum wells with the cavity structure on which rod-type pho-tonic crystal is patterned, we observe the enhancement of extracted luminescence efficiency from the surface depending on the correlated variation of TM-polarized photonic bandgap.

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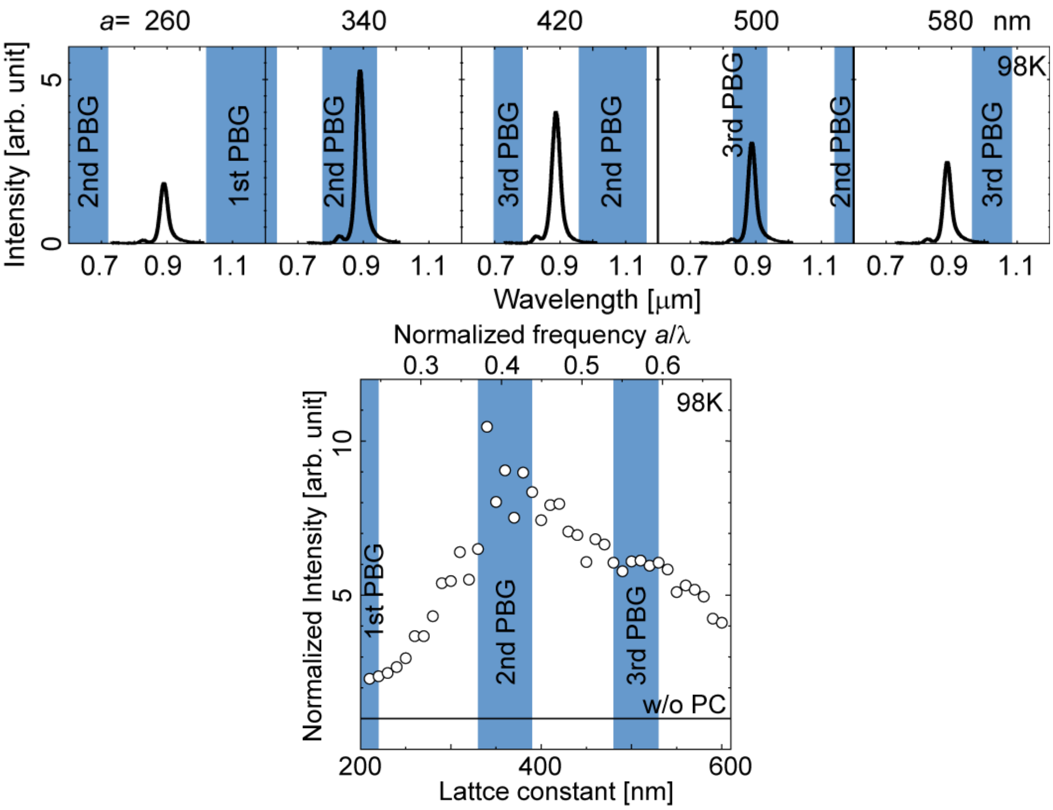

Fig. 3 Dependence of PL intensity obtained from the surface as a function of lattice constant