Characterization of three-dimensional GaAs/Al_xO_y near-infrared photonic crystals fabricated by using an auto-cloning technique

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ABSTRACT

A series of three-dimensional photonic crystals are fabricated. The existence of photonic bandgap is demonstrated in the near-infrared wavelength range and bandgap position shows red-shift with increasing feature size of photonic crystals.

EXPERIMENTAL RESULTS AND DISSCUSSION

Photonic crystals (PhCs), first proposed by Yablonovitch [1] and by John [2], are crystal structures with periodic variation of material refractive indices or dielectric constants where light cannot propagate in any direction. Three-dimensional photonic crystals with the face-centered cubic structure are fabricated in this study. We apply the auto-cloning technique [1,3,4], which is by means of alternating deposition of $Al_{0.98}Ga_{0.02}As/Al_{0.3}Ga_{0.7}As$ layers on a GaAs template with submicron feature sizes [5]. Fig. 1 shows the cross-section SEM picture of an fcc $Al_{0.98}Ga_{0.02}As/Al_{0.3}Ga_{0.7}As$ periodic structure with feature size 0.6 μm and layer thickness 0.2 μm. After wet oxidation from the lateral direction, three-dimensional $Al_{0.3}Ga_{0.7}As/Al_xO_y$ photonic crystals are formed.

The fabricated photonic crystals are investigated through the optical transmission measurement. From the photonic crystal with feature size 0.55 μm, a transmission dip around 1430 nm, more than 9 dB lower than the transmission signal through a non-patterned reference sample, is observed. The photonic crystal with feature size 0.6 mm shows a dip around 1500 nm, as depicted in Fig. 2. From the red-shift of the transmission dip position with increasing feature size, a photonic bandgap at near-infrared wavelength range is demonstrated. Furthermore, we also fabricate photonic crystals with line defects. Transmission spectrum of the photonic crystal with a defect formed by removing a 7-feature-size-large structure is shown in Fig. 3. A transmission peak at 1286 nm within the bandgap is observed, which might be attributed to the line-defect mode. Systematic investigations will be carried out in the future to explore the properties of defect structures.

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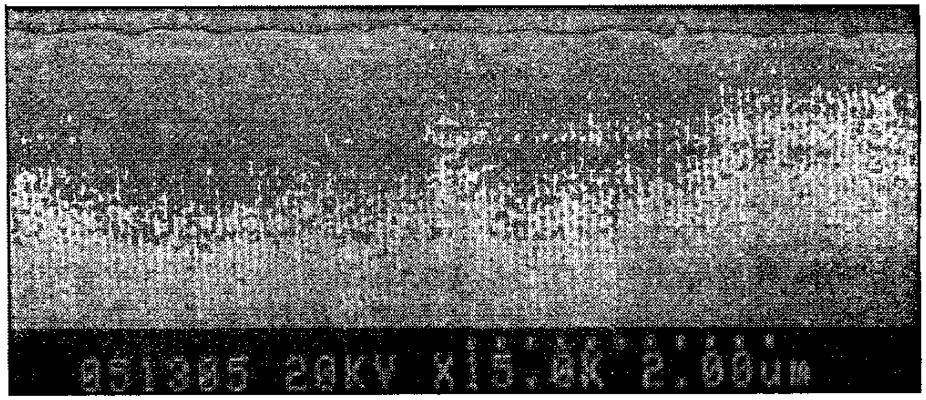

Fig. 1. Cross-section SEM picture of an fcc $Al_{0.98}Ga_{0.02}As/Al_{0.3}Ga_{0.7}As$ periodic structure with feature size 0.6 μm and layer thickness 0.2 μm.

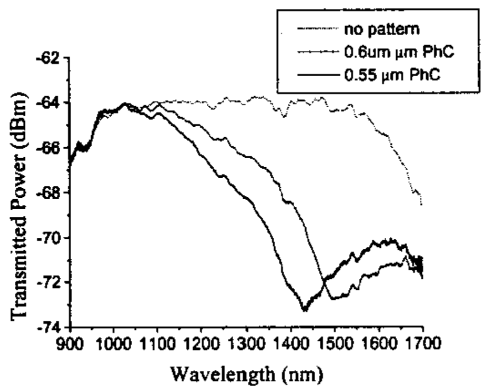

Fig. 2 Transmission spectra of photonic crystals with feature sizes 0.55 μm and 0.6 μm respectively, together with the transmission spectrum through a non-patterned reference sample.

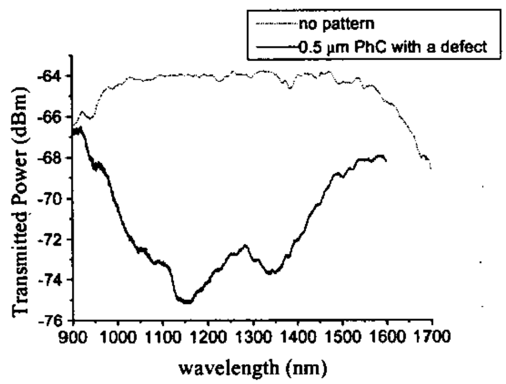

Fig. 3 Transmission spectrum of a photonic crystal with a defect formed by removing a 7-feature-size-large structure, together with the transmission spectrum through a non-patterned reference sample.

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