가변 T-선 광결정

Tunable T-ray Photonic Crystals

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It is well known that periodic dielectric structures can exhibit a certain frequency range where the propagation of electromagnetic wave is forbidden, i.e., photonic band gaps (PBGs).[1,2] Such structures showing PBGs are called photonic crystals (PCs) or PBG structures. PBGs result from the multiple reflections with fixed phase correlations due to a periodic variation of the wave impedance $(\mu/\varepsilon)^{1/2}$.[3] Here μ is the magnetic permeability and ε is the dielectric constant. Thus the periodic variation of μ and ε can be employed separately to control the properties of PBGs. Since PCs enable us to control the spontaneous emission and the propagation of EM waves, many applications of PCs have been proposed in improving the performance of optoelectronic and microwave devices such as high-efficiency semiconductor lasers, light emitting diodes, waveguides, and optical filters, high-Q resonators, antennas, frequency-selective surfaces, and amplifiers.[4,5]

Tunable PCs are believed to have interesting applications in optoelectronic and microwave devices such as optical modulators, switches, tunable filters, and tunable resonators. The photonic band structure (PBS) of a given PC structure can be tuned by changing μ or ε values of the constituent materials by controlling the temperature, electric field, or magnetic field. Thus various materials such as liquid crystals[6] ferroelectric materials, and ferrimagnetic materials.[7] can be employed to make the tunable PCs. Especially, Halevi has theoretically demonstrated that the two-dimensional (2D) PCs composed of circular intrinsic InSb rods can exhibit PBGs with wide temperature-tunable ranges for the *s*-polarized wave,[8] the wave whose electric field is parallel to the rods. For the practical applications, the 2D PC that exhibits a complete PBG, the common band gap for the *s*- and *p*-polarized (magnetic field parallel to the rods) waves, would be more useful. However, any feasibility study has not been reported for the PCs constructed with the semiconductor constituent that exhibit temperature-tunable complete PBGs. Very recently, we have predicted that the metallo-dielectric PCs with the liquid-crystal constituent exhibit wide enough temperature-tunable complete PBGs.[9]

In this talk, we demonstrate that the 2D PCs constructed with the square rods of intrinsic semiconductors can exhibit a temperature-tunable complete PBG in the THz frequency range. The idea is based on the following two facts; i) the dielectric constant of a semiconductor is strongly temperature-dependent and behaves like that of the real dielectric material in certain frequency range, ii) some kinds of 2D dielectric PCs exhibit complete PBGs. Specifically, we have investigated the dependence on temperature of the complete PBG of 2D square lattice of intrinsic square InSb rods in the air.

Figure 1 shows the PBSs for *s*-(solid line) and *p*-polarized waves (circle) of square lattice of square InSb rods at T=200 K (a) and the dependence of their edge frequencies on the temperature between 200 and 300 K (b), respectively. The lattice constant and the volume fraction was taken as 50 μm and and 0.34, respectively. One can see that a complete PBG exists between the seventh band for *p*-polarized wave and the eighth band for *s*-polarized wave. As the temperature increases, the position (magnitude) of PBGs for each polarization moves up (decreases). Recently, we have analytically shown that the center frequency (magnitude) of PBG increases (decreases) as the mean refractive index (the contrast of impedance) of the periodic structure decreases.[10] The dielectric constant of InSb rods at a given frequency decreases as the temperature is increased, due to the increase of plasma frequency. Thus the mean refractive index and the impedance contrast between the InSb rods and the air background should decrease as the temperature is increased. Thus the moving-up (decrease) of PBG position (magnitude) is evidently due to decrease of the dielectric constant with the increase of temperature. The width of complete PBG also decreases with the increase of temperature and becomes narrow at room temperature. Since the complete PBG is sufficiently below the phonon resonance frequency (35 THz for InSb), damping effects should be moderate in the tuning range. Thus 2D square lattice of square InSb rods is a good candidate for 2D tunable complete PBG structure in THz range

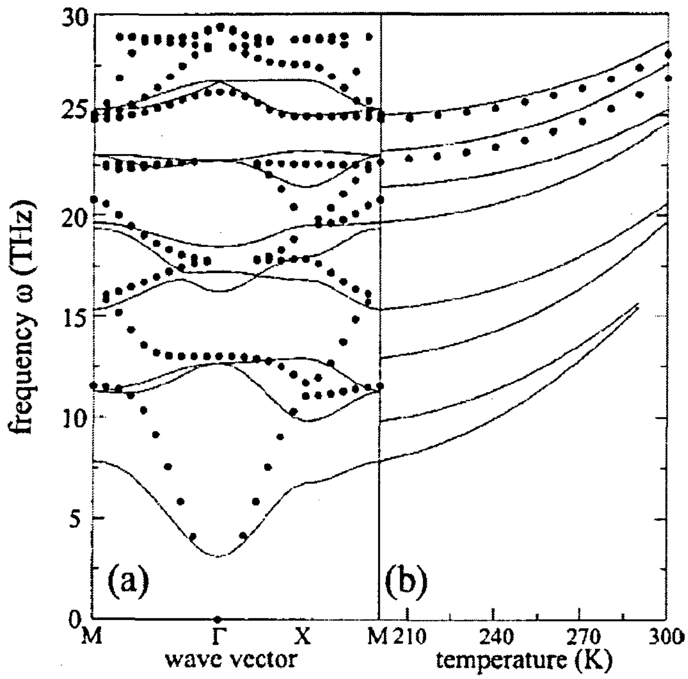

Fig. 1. (a) PBSs for *s*-(solid line) and *p*-polarized waves (circle) of the square lattice of square InSb rods at T=200 K.(b) The temperature dependence of the edge frequencies of PBGs for *s*- and *p*-polarized waves between 200 and 300 K.

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