1차원 광자결정의 피코초 비선형 투과 특성 연구

Picosecond Nonlinear Transmission measurement in SiO_2/TiO_2 One-dimensional Photonic Crystals

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One of the most important phenomena of photonic crystals (PCs) is the presence of photonic bandgaps (PBGs) where the propagation of light is prohibited(1). Various optical applications in PCs such as ultrafast optical switching in a 1-D silicon-based PC, defect mode shift in 1-D PC with a gold nanoparticles have been studied further, since the first proposal of optical limiting and switching(2). Distributed Bragg reflector (DBR) mirror is a simple and important example of 1-D PCs, which consists of a stack of layers with periodic high and low refractive indices.

In this study, we have fabricated SiO_2/TiO_2 1-D PCs with different periods of refractive indices by a sol-gel method and performed a picosecond pump-probe time-resolved nonlinear optical (NLO) measurement in 1-D PCs. A Nd:YAG picosecond mode-locked laser with 40-ps pulse width and 10-Hz pulse repetition rate (Continuum) was employed for the pump-probe measurement. The 2nd and 3rd harmonics (532 nm and 355 nm) were used as the pump and probe lights, respectively. The probe light was normally incident upon the sample, and the incident angle of pump light was 21°

Before investigating the NLO behavior of the SiO_2/TiO_2 1-D PC, we measured the NLO transmission of single TiO_2 and SiO_2 film with the same thickness of 500nm by a picosecond pump-probe time-resolved measurement. Figure 1 shows the NLO transmission changes of TiO_2 film. On the other hand, we didn't observe any NLO response in the single SiO_2 film. The TiO_2 film has three different structures, i.e., brookite, anatase, and rutile(3). We find that our TiO_2 film which was annealed at 500℃ has the anatase crystalline phase through the XRD measurement in Figure 2. The expanded bond-orbital theory describes two competing mechanisms for the electronic excitation of the transition-metal (TM) oxides involving virtual electronic excitation to "*d*-orbitals" and the conduction band "*sp*-orbitals." The *d*-orbital contribution increases in the TM oxides with relatively short bond length such as TiO_2, invoking a large NLO response. Therefore the observed NLO transmission results from a *d*-orbital contribution of TiO_2.

We fabricated two SiO_2/TiO_2 1-D PC structures with the different position of PBG to investigate the NLO transmission properties at the low-energy band edge (sample 1) and high-energy band edge (sample 2) through the pump-probe NLO measurement. The triangles and circles in Figure 3(a) and (b) are the linear transmissions for the 532 nm-probe light and the normalized NLO transmission changes by varying the incident angles from zero to 60° for the sample 1 and 2. We find that the maximum NLO transmission change is as large as 4.5% with the sign reversal in the sample 1 (the low-energy band edge) and the maximum NLO transmission change is 8% at the incident angle 30° ith the negative sign regardless of the incident angle in the sample 2 (the high-energy band edge). The observed NLO transmission changes in the band edges gives the possibility of a new optical device performing an ultrafast optical switching in 1-D PCs.

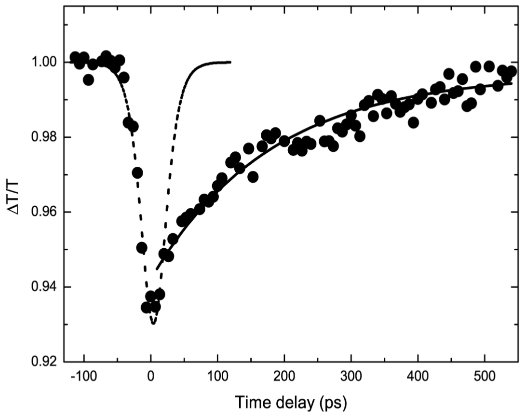

Fig. 1. The NLO transmission for the probe light in TiO_2 film as a function time delay.

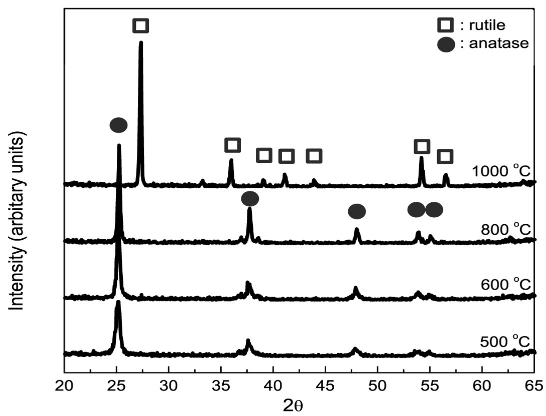

Fig. 2. The XRD patterns of TiO_2 films as the calcination temperature changes.

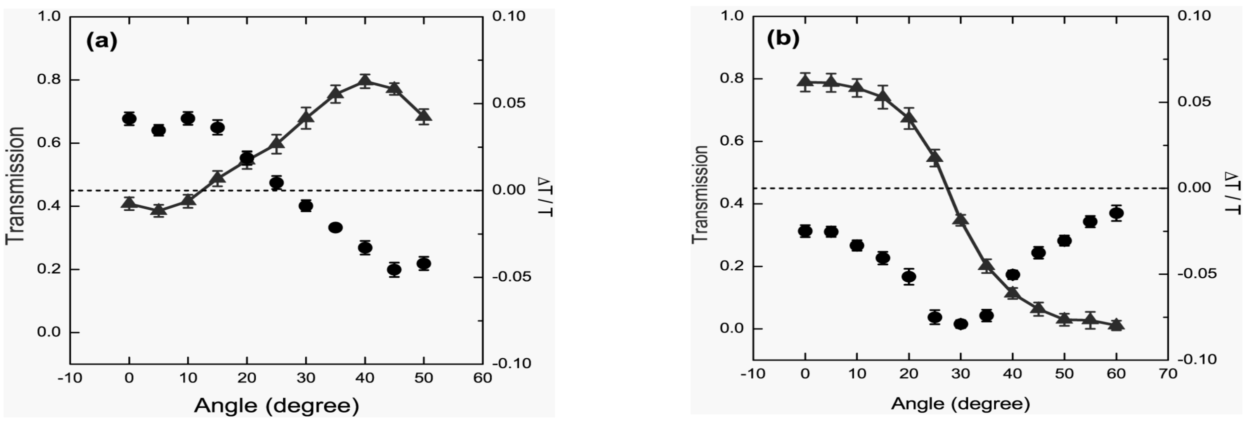

Fig. 3. The linear transmissions (triangle) and NLO transmissions (circle) of sample 1 (a) and 2 (b) as a function of the incident angles.

References

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