Band Structure of Low-Refractive-Index Photonic Crystal Slabs

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Photonic crystal slabs made of polymer have many potential applications since they can be fabricated easily, and can be doped with fluorescent centers such as organic dyes. The disadvantage of the use of polymers, on the other hand, is that their refractive indices are low compared with those of semiconductors, and that the confinement of light to the core layer is relatively weak. In general, in low-refractive-index systems, the characteristics of the light modes in them are much more affected by the cladding layers, and tend to be leaky more easily than in high-refractive-index systems. To fully utilize low-refractive-index systems for waveguides, the characters of the guided modes, such as the lifetime and the mode pattern, should be known. In this report, we studied the lifetime and the intensity distribution of photonic modes in a low-refractive-index photonic slab, which has been used in the previous experiments, and clarified that some of the modes have a lifetime sufficiently long for device applications.

We used three-dimensional finite difference time domain (FDTD) method for the calculation of the band structure and the field distribution of each mode in a four-layer slab which consists of air, a polymer photonic crystal layer, an Al_2O_3 layer, and a SiO_2 substrate. The calculated band structure and the intensity distribution in the vertical direction are shown in fig. 1. The modes shown can be classified using the intensity distribution into polymer modes which have a peak in the polymer layer and alumina modes which have a peak in the alumina layer. The photonics band structure of polymer modes are found to be strongly affected by the photonic crystal structure. The lifetime of each mode was calculated from the spectral width. It was found that the lifetimes of the polymer modes are around 40 fs, and that of the alumina mode are longer than 100 fs, which are sufficiently long for applications in photonic devices.

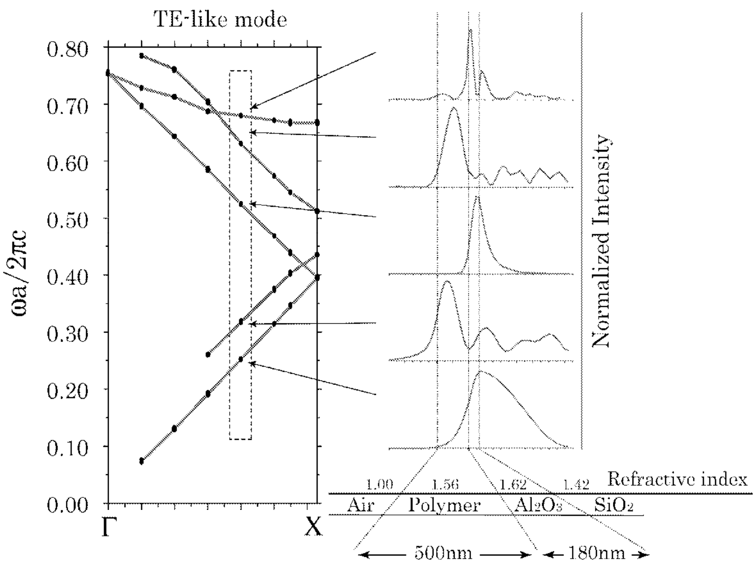

Fig. 1: The band structure and intensity distribution of several modes for TE-like polarization and Γ-X propagation direction.