실리콘/폴리머 물질 기반의 광 결정 광변조기

Photonic Crystal Electro-Optic Modulator Incorporating Hybrid Silicon/Polymer Material

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The design and analysis of a novel photonic crystal (PhC) electro−optic (EO) modulator are presented in this paper. The device incorporates an EO polymer slot waveguide into the center of a silicon PhC waveguide. In this device, strong optical confinement in EO polymer core and small group velocity by PhC structure provide a surprise enhancement of EO effect.

Many research groups have demonstrated the use of silicon or electro−optic (EO) polymers in Mach−Zehnder (MZ) modulator devicesusing electro−optic (EO) effect. Silicon EO modulators are mostly based on the plasma charge carrier effect(1) or thermo−optic effect(2) because of its poor EO effect(3). To the other hand, EO polymers specially provide an interesting alternative to bulk materials such as Lithium Niobate for a range of applications to several active devices because of their low cost and good process ability(4). However, most of MZ modulatorsare generally quite long, and it is challenging to achieve high−speed operation in silicon−based modulators. These are caused by their slight changes of refractive index. This problem can be overcome by small group velocity effect induced by photonic crystal (PhC) structures. In PhC waveguide modes, high local field factor, which is due to its extremely small group velocity, enhances nonlinear susceptibilities. Therefore, it can reduce the effective length for π−phase shift(5). In this paper, we propose a novel PhC−based EO modulator incorporating an EO polymer slot waveguide into the center of a silicon PhC waveguide. In this device, guided light has not only a strong optical confinement in EO polymer core slot waveguide but also a small group velocity effect by surrounding silicon PhC structures.These two main effects provide the enhancement of both EO effect and change of refractive index.

We design a novel photonic crystal EO modulator and analyze its enhancement characteristics. Our device consists of two−dimensional silicon PhC line−defect slab waveguide incorporating EO polymer slot waveguide and EO polymer holes[the inset of Fig. 1]. Effective refractive indices of silicon and EO polymer are 2.93 and 1.6 at 1550−nm wavelength. Lattice constant, "a", of silicon PhC structure is 370−nm and radius of holes is 0.3a. And we assume that EO coefficient, r33, of polymer is 100−pm/V at 1550−nm. As shown in the right−side of Fig. 1, guided modes require both a single mode operation and an optical confinement in polymer region. These provide an effective interaction between light and nonlinear polymer material. These guided modes have small group velocity, from 0.187c to 0.016c in the wave number, "k", range from 0.35 to 0.39 [Fig. 2]. This small group velocity induces high local field factor, "f", which is defined by the group velocity inside the bulk polymer and the group velocity in the PhC[6]. This high local field factor enhances nonlinear susceptibility and effective EO coefficient of guiding core material. We obtain a change of refractive index, Δn, is from 0.009 to 0.4 at applied electric field, Ez, of 8.6-V/um. These changes of index are 5~220 times larger than the bulk EO polymer at the same condition. More detailed characteristics will be discussed, such as comparison with other types of modulator and experimental characteristics.

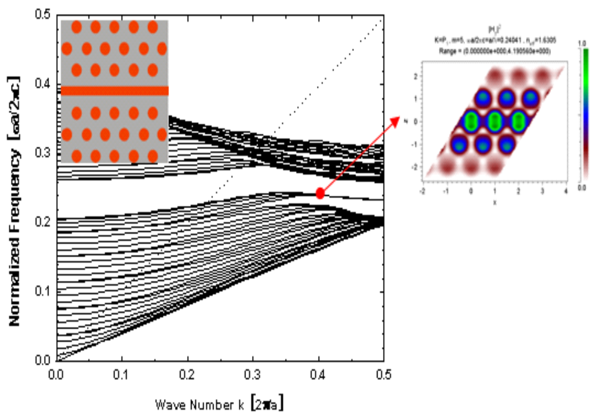

Fig. 1 Band diagram and mode profile of guided mode

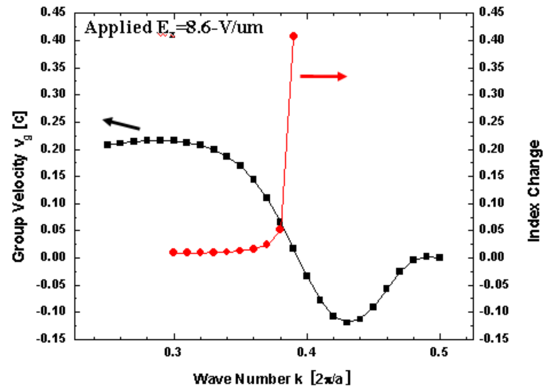

Fig. 2 Calculated group velocity and induced refractive index change as function of wave number

Acknowledgements
This work has been supported by the Korea Science and Engineering Foundation (KOSEF) through OPERA (R11-2003-022) and the 21C Frontier Microbial Genomics/Applications Program.

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