Electro-optic polymers and their nano-composites

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Recent developments of high-speed electro-optic (EO) modulators and switches attract silicon photonics related researchers. Among candidates of EO modulators, polymers are promising because of their high EO-coefficients and processability that match to silicon photonics technologies.

Large optical nonlinearities, low optical loss, and long-term nonlinear optical stability are important requirements for EO polymers to be applied for these devices. However, optical loss of EO polymers are generally high due to their intrinsic absorptional and scattering characteristics. Therefore, it is both fundamentally and practically important to make clear the way for realizing highly transparent EO polymers.

To realize excellent transparency, quantitative analysis of individual loss factors is important. To date, very limited detailed optical loss analyses of EO polymers has been examined. Thus, in this presentation, EO polymer optical losses were precisely examined.

Rayleigh scattering loss and absorption loss were evaluated using dust-free EO-polymer rods. Methyl methacrylate (MMA) or deuterated methyl methacrylate (MMA-d_8) as a monomer were used for the evaluation. Donor substituted Disperse Red-1 (DR-1) like chromophores as a NLO dye was synthesized by diazo coupling reaction. Each NLO chromophore was doped into PMMA or PMMA-d_8 matrices.

We found that scattering loss could be suppressed by modifying the chromophore structure. Di-ethylamino-DR-1, which had similar structure to that of commercially available DR-1, was high in scattering loss. On the other hand, scattering loss of di-hexylamino-DR-1 was the smallest among DR-1 like chromophores. It indicates that NLO chromophore aggregation will be suppressed by the substitution of donor alkyl chain with longer alkyl structure. In addition, scattering loss reduction could be corresponded to the NLO chromophore solubility into monomers. So improvement of affinity between the NLO chromophore and the host polymer is critical for optimizing NLO chromophore structure to suppress its optical loss.

For further improvement of optical loss of EO polymers, PMMA-d_8 with excellent transparency from visible to near-IR wavelengths was chosen as a matrix. Between PMMA matrix and PMMA-d_8 matrix, scattering loss difference was basically negligibly small. In this case, NLO chromophore can be dispersed homogeneously in both polymer matrices. Optical loss at 850 nm wavelength was not so different each other, though, optical loss at 1,300 nm was improved dramatically by using PMMA-d_8. So PMMA-d_8 matrix is useful for improving optical loss at 1,300 nm wavelength.

Thus, at telecommunication wavelengths, Rayleigh scattering and $\tilde{\pi}\ \pi^{*}$ absorption from EO-chromophores did not influence the total loss, though, molecular vibrational loss was a critical factor. On the other hand, at datacom wavelengths, depending on $\pi \bullet \pi^{*}$ absorption of EO-chromophores, total loss was dramatically changed.

Hybrid structure of EO polymers with inorganic nano-particles will be an important strategy to obtain EO polymers with high nonlinearity and thermal stability.