A BaTiO$_3$-based Electro-optic Thin-film Waveguide Modulator

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The drive towards integrated photonics requires the integration of various optical devices on a chip including an optical modulator. Currently, optical modulation with active waveguiding structures is implemented using LiNbO$_3$ single crystals. These devices require complex and expensive fabrication processes. In addition, their relatively low electro-optic coefficient leads to large component sizes, limiting miniaturization. The current demands for an increased degree of integration with cost-efficient device fabrication can, in principle, be met using thin films of barium titanate [1-3]. In bulk form, this material possesses a superior electro-optic coefficient. Applications using thin-film structures necessitate careful study of processing parameters and their impact on material properties. Our efforts are geared towards gaining a fundamental knowledge of the behavior of thin film barium titanate (BaTiO$_3$) and developing processes to fabricate devices for applications in optical data transmission and processing.

The focus is on optimizing the electro-optic response of BaTiO$_3$ and related thin-film materials deposited by pulsed laser deposition (PLD) and sputtering onto single-crystal substrates directly or with buffer layers. Figure 1 shows a cross section of a waveguide Mach-Zehnder interferometer structure, using a SiN strip-loaded waveguide. The optical waveguide structure is formed by growing a Si$_x$N$_y$ layer with plasma-enhanced-chemical-vapor-deposition (PECVD) on BaTiO$_3$ and patterning it lithographically. This is followed by the sputtering and patterning of Al electrodes next to one arm of the Mach-Zehnder structure. The operation of the interferometer is characterized by launching polarized light into the waveguide and measuring the modulation of the output intensity as a function of applied voltage. A typical DC response of a sample electro-optic modulator based on barium titanate is shown in Figure 2. We have demonstrated an effective electro-optic coefficient as high as 85pm/V with BaTiO$_3$/SrTiO$_3$ superlattices, which is considerably greater than that available with bulk LiNbO$_3$ crystals.

Figure 1: Cross section of the Mach-Zehnder waveguide modulator.

Figure 2: Measured optical intensity at the Mach-Zehnder waveguide modulator output as a function of electric field between adjacent electrodes.

REFERENCES