Abstract

As the field of photonics constantly strives for ever smaller devices, the diffraction limit of light emerges as a fundamental limitation in this pursuit. A growing number of applications for optical "systems on a chip" have inspired new ways of circumventing this issue. One such solution to this problem is active plasmonics. Active plasmonics is an emerging field that enables light compression into nano-structures based on plasmon resonances at a metal-dielectric interface and active modulation of these plasmons with an applied external field. One area of active plasmonics has focused on replacing the dielectric layer in these waveguides with an electro-optic material and designing the resulting structures in such a way that the transmitted light can be modulated. These structures can be utilized to design a wide range of devices including optical logic gates, modulators, and filters.

This thesis focuses on replacing the dielectric layer within a metal-insulator-metal plasmonic waveguide with a range of electrically active materials. By applying an electric field between the metal layers, we take advantage of the electro-optic effect in lithium niobate, and modulating the carrier density distribution across the structure in n-type silicon and indium tin oxide.

The first part of this thesis looks at fabricating metal-insulator-metal waveguides with ion-implantation induced layer transferred lithium niobate. The process is analyzed from a thermodynamic standpoint and the ion-implantation conditions required for layer transfer are determined. The possible failure mechanisms that can occur during this process are analyzed from a thin-film mechanics standpoint, and a metal-bonding method to improve successful layer transfer is proposed and analyzed. Finally, these devices are shown to naturally filter white light into individual colors based on the interference of the different optical modes within the dielectric layer. Full-field electromagnetic simulations show that these devices can preferentially couple to any of the primary colors and can tune the output color of the device with an applied field.

The second part of this thesis looks at fabricating metal-insulator-metal waveguides with n-type silicon and indium tin oxide. With the silicon device, by tuning the thicknesses of the layers used in a metal-oxide semiconductor geometry, the device we call the "plasMOStor" can support plasmonic modes as well as exactly one photonic mode. With an applied field, this photonic mode is pushed into cutoff and modulation depths of 11.2 dB are achieved. With the indium tin oxide device, the doping density within the material is changed and as a result, the plasma frequency is shifted into the near-infrared and visible wavelengths. Using spectroscopic ellipsometry, the

structure is characterized with and without an applied electric field, and measurements show that when an accumulation layer is formed within the structure, the index of refraction within that layer is significantly changed and as a result, will change the optical modes supported in such a structure.