Topological Insulator BSTS as a Broadband Switchable Metamaterial

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The development of metamaterials into a viable platform for nanophotonic applications, data processing circuits, sensors, etc. requires identification of new plasmonic materials to overcome the limitations of noble metals, in particular their high losses. Here we describe a class of topological insulator materials which support broadband plasmonic response and possess extremely appealing photonic properties ranging from mid-IR to UV. $Bi_{1.5}Sb_{0.5}Te_{1.8}Se_{1.2}$ (BSTS) is a bulk insulator with robust conducting surface states protected by time-reversal symmetry, due to the strong spin-orbit coupling. BSTS single crystals were synthesized by melting high-purity Bi, Sb, Te and Se powders at 950°C in an evacuated quartz tube. The temperature was then gradually decreased to room temperature over a span of three weeks. The resulting crystals were then cleaved along the (100) family of planes to a thickness of ~0.5 mm. BSTS dielectric constants were derived by ellipsometric measurements and appear to be in excellent agreement with first principle DFT calculations. Unlike common direct or indirect bandgap semiconductors, the anomalous dispersion region falls in the visible part of the spectrum, leading to negative values of the permittivity. This behavior of the optical response is attributed to a combination of bulk interband transitions and surface contribution of the topologically protected states. To prove metallic behavior of BSTS, we fabricated metamaterials and gratings on crystal flakes and registered strong plasmonic response from UV to NIR. The coexistence of plasmonic response of the topological surface with dielectric properties of the semiconducting bulk enables ultrafast (t>100 fs) and broadband (to mid-IR) photo-modulation of the optical response. These findings show the potential of topological insulators as a platform for high-frequency switchable plasmonic metamaterials.