Abstract

The next generation 3D display like the glass-free flat display and hologram calls for advanced spatial light modulation of devices with high density of optical processing efficiency, for which the lossless optical modulation with high processing speed and submicron pixilation would be appreciated. Traditional spatial light modulators (SLM) for 2D display like the LCD and DMD are insufficient for such advanced 3D display. Magneto-optical based SLM can be expected for sensitive detection of the output optical polarization rotation faster than ~10^{-7} s with only a thin film structure. Mie scattering based all dielectric metasurface show novelty in lossless subwavelength light tailoring with the typical periodicity of the nano structures as small as hundreds of nano-meters. Either of them can be expected a good candidate for the development of SLM for the future 3D display application. Here we proposed two approaches for solution of the idea: the MnBi based magneto-optical SLM (MO-SLM) and liquid crystal (LC) based TiO_2 active metasurface. Study of fabrication and optics analysis was carried out to verify the performance and feasibility of the MO-SLM and active metasurface device for application.

In this paper, the background and motivation of the research work is given in Chapter 1; the literature review about the MO effect and Mie scattering is given in Chapter 2; the fabrication and optical response of LC infiltrated TiO_2 metasurface is introduced and discussed in Chapter 3 to 7.

In this paper, the thin layer 60 nm low temperature phase MnBi thin films was successfully obtained with a large perpendicular magnetization anisotropy (PMA) of 480 emu/cm^3 and a MO Kerr rotation (MOKE) as much as 0.5^o which is much larger than other material candidates. Sample was fabricated by deposition of the interlaced Mn and Bi thin layers as $[Mn/Bi]_{10}$ with a total thickness ratio of Mn/Bi=20/40 nm before a 350 ^{o}C thermal annealing for 2 hrs. An interlaced structure of $[Mn/Bi]_x$ can improve the inter-diffusion of Mn and Bi atoms during the thermal annealing thus results in a better MnBi phase formation. However, the sample is apt to be oxidized presented by magnetic measurements comparison between the 14-day interval exposure in ambient environment. Ta capping layer is more effective than Ru for protection of the MnBi surface structure and further the magnetic properties. MO was detected and varies in consistent with the PMA depending on the Mn/Bi contents. A TiO_2 dielectric layer can be introduced in contact with the MnBi to induce a dramatic enhancement (0.86^o to 9.5^o at 633 nm) based on the numerical simulation. However, the large PMA and MOKE can be only received in cost of large coercivity, which would hinder the possible application of the MO-SLM for display application.

In the meantime, an electrically drivable active metasurface was realized by LC infiltration with the TiO_2 nano cylinder metasurface. A wide range shift in spectra (close to 20 nm) can be obtained in a 1.5 um thin layer LC based metasurface driven by a small voltage below 8V and thus receiving a dynamic phase control about 1.2 π. Strong surface anchoring effect is observed inducing a more

than 30^{o} deviation of the LC alignment with respect to the preset LC photoalignment and thus the optical response. Based on the measurement of optical observation and Raman spectrum, the LC alignment is co-affected by the rubbing/photoalignment strength, liquid thickness and the surface anchoring energy. Based on the Frank-Oseen model analysis, the stronger surface anchoring effect of the nano structure can be confirmed to suppress the rubbing influence and induces an almost parallel LC alignment along with the anchoring direction of the nano structure for the gentle rubbing strength. The LC alignment can be controllable by either a more accurate define of the nano structure arrays' periodic direction or a harder rubbing strength performed during the fabrication. The dynamically tunable metasuface can be expected a candidate for the development of the tunable Huygens' surface device in future.

Publication list

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