Anti-Reflection Coating and Periodic Multilayer Color Filter Made of Indium-Tin-Oxide (ITO) Electrode for Liquid Crystal Display Panel

by

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ABSTRACT

Tunable-refractive-index materials have expanded the anti-reflection capabilities of optical thin films in many applications. In this Master Thesis, we apply the technology of tuning the refractive indices of materials to the Indium Tin Oxide (ITO) electrodes in Liquid Crystal Displays (LCDs). The tuning of the refractive index of a material is accomplished by controlling the porosity of the material. One application of this tunable-refractive-index ITO electrode is an anti-reflection ITO electrode. Another application is color filtering by a multilayer ITO electrode. For both applications, employment of tunable-refractive-index materials is shown to enhance the light output of LCDs.

As an introduction, we discuss the theoretical foundation of optical coating optimization. A popular Transfer-Matrix Method for calculating reflectance and transmittance of a multilayer structure is introduced. With the Transfer-Matrix Method, the calculation of the transmittance through multilayer structures is very practical and efficient.

As a first part of this Master Thesis, we employ ITO with tunable refractive index as electrode for LCD panels. Conventional LCDs use dense ITO as electrode. The refractive index mismatch at the ITO / glass interface and ITO / Liquid Crystal interface causes Fresnel reflection losses. By matching the refractive index of ITO to its ambient, using tunable refractive index ITO, reflection losses are significantly reduced. Using the Transfer-Matrix Method, we demonstrate a theoretical transmittance enhancement of 13 % for an LCD using a refractive-index-matched ITO electrode. The ITO with tunable refractive index is realized by Oblique Angle Deposition. We compare a dense ITO electrode with a refractive-index-matched porous ITO electrode. We find the transmittance through the porous ITO electrode is much larger than the transmittance through dense ITO electrode. We also investigate the influence of ITO thickness on transmittance. We find for four different thicknesses, porous ITO electrodes enhance the transmittance compared with dense ITO electrodes. Subsequently, we experimentally demonstrate an ITO electrode that is refractive-index-matched to the glass substrate and

a silicone (with similar refractive index as liquid crystal) ambient. We find a 5% transmittance enhancement.

As a second part of this Master Thesis, we explore a multilayer ITO electrode using ITO with tunable refractive index for light recycling in LCD panels. This kind of electrode functions as reflective color filter. Conventional pigment-based color filters *absorb* light in the stop-band region of the color filters. However, our ITO color filters *reflect* light in the stop-band region. This property enables light recycling by backside mirrors in the LCD. By modifying the period of high / low refractive index multilayer structure, and using a Genetic Algorithm as the optimization tool, a periodic multilayer structure is designed for blue, green, and red color filters. Increasing the number of pairs in a color filter structure has the effect of enlarging the maximum-to-minimum transmittance ratio for all three kinds of color filters. Following simulation, a group of color filters with up to four pairs (8 layers) is experimentally demonstrated. A maximum transmittance of 95.2% and a minimum transmittance of 26.2% are realized for the red color filter structure.