

Design Reflective Polarizers for Display Backlight Recycling

Products: DiffractMOD RCWA

Applications: Displays and Imaging

Introduction

Backlight recycling using a reflective polarizer improves the optical efficiency for flat displays. When the unpolarized backlight hits the reflective polarizer, one linear polarization (say, p-wave) will pass through while the other component (s-wave) will be reflected back for recycling. After hitting the rough surface of the diffuser, the s-wave is depolarized. Upon reflection from the diffusive reflector, the p-wave is transmitted, and s-wave reflected again for recycling. In each cycle, about half of the incident light passes through the polarizer. After 3–5 cycles, about 50%–60% of the s-wave is converted to p-wave.

Several types of reflective polarizers have been developed. Among them, multilayer thin film reflective polarizer, also known as DBEF (Dual Brightness Enhancement Film) ^{1, 2}, provides a mechanism to recycle the backlight before it enters the display panel resulting in a big improvement in optical efficiency. DBEF manufacturing technology is mature and is commonly used in commercial products, especially for those battery-powered mobile displays, such as cell phones and notebook computers.

Structure Setups and Simulations

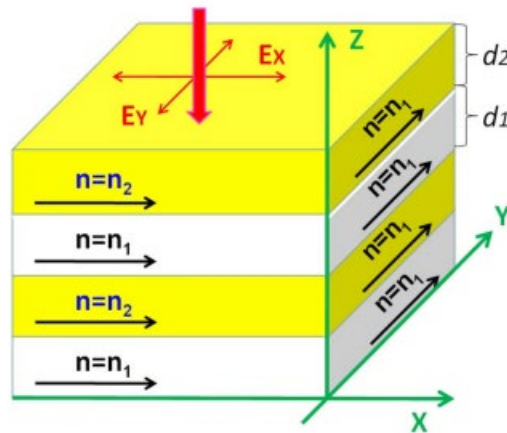


Figure 1. The structure of multilayer birefringent polymereieec reflective polarizer

Figure 1 shows the device structure of a multilayer birefringent reflective polarizer consisting of dozens of alternative layers (materials 1 and 2). Material 1 is an isotropic polymer, while material 2 is a positive birefringence uniaxial polymer. There is a large refractive index difference between the two materials in x axis, while in the other two axes (y and z) their refractive indices are substantially matched. Here z represents the light propagating direction perpendicular to the layers. Meanwhile, the optical thickness of each layer is controlled to be a quarter of a center wavelength. Therefore, Bragg reflection could be established for the polarization component along

¹ M. F. Weber, C. A. Stover, L. R. Gilbert, T. J. Nevitt, and A. J. Ouder Kirk, "Giant birefringent optics in multilayer polymer mirrors," *Science*, vol. 287, pp. 2451–2456, 2000.

² Yan Li, Thomas X. Wu and Shin-Tson Wu "Design Optimization of Reflective Polarizers for LCD Backlight Recycling" *JOURNAL OF DISPLAY TECHNOLOGY*, VOL. 5, NO. 8, AUGUST 2009.

x-axis. For polarization along y axis, it sees a thick slab with uniform refractive index and is transmitted with high efficiency. All the factors for achieving high reflectance reflective polarizer can be modelled and optimized very easily with Keysight RSoft RCWA tool, **DiffractMOD**.

In this application note, NOA81 and BL038 are the two materials used for multilayer polarizer. For convenience, we designate the isotropic material's refractive index as N1 and the uniaxial material's refractive index in x direction as N2. The refractive indices can be expressed with following equations:

$$N_{1,2} = A_{1,2} + B_{1,2} / \lambda^2 + C_{1,2} / \lambda^4$$

Here $A_1=1.5519$, $B_1=0.0036\mu\text{m}^2$, $C_1=0.00049\mu\text{m}^4$

$A_2=1.74775$, $B_2=0.01184\mu\text{m}^2$, $C_1=0.00303\mu\text{m}^4$

are found via fitting for the two materials. Each layer has a quarter-wave optical thickness for the light polarized in x direction.

As shown in Figure 2, the structure can be set up in RSoft CAD with dynamic array features easily. First, we will set up 1 period layer ind file in CAD and define the two materials with above isotropic and anisotropic properties as a unit cell. Then a multilayer array along z direction is set up by using dynamic array. The number of the layers can be changed by the periods in z direction.

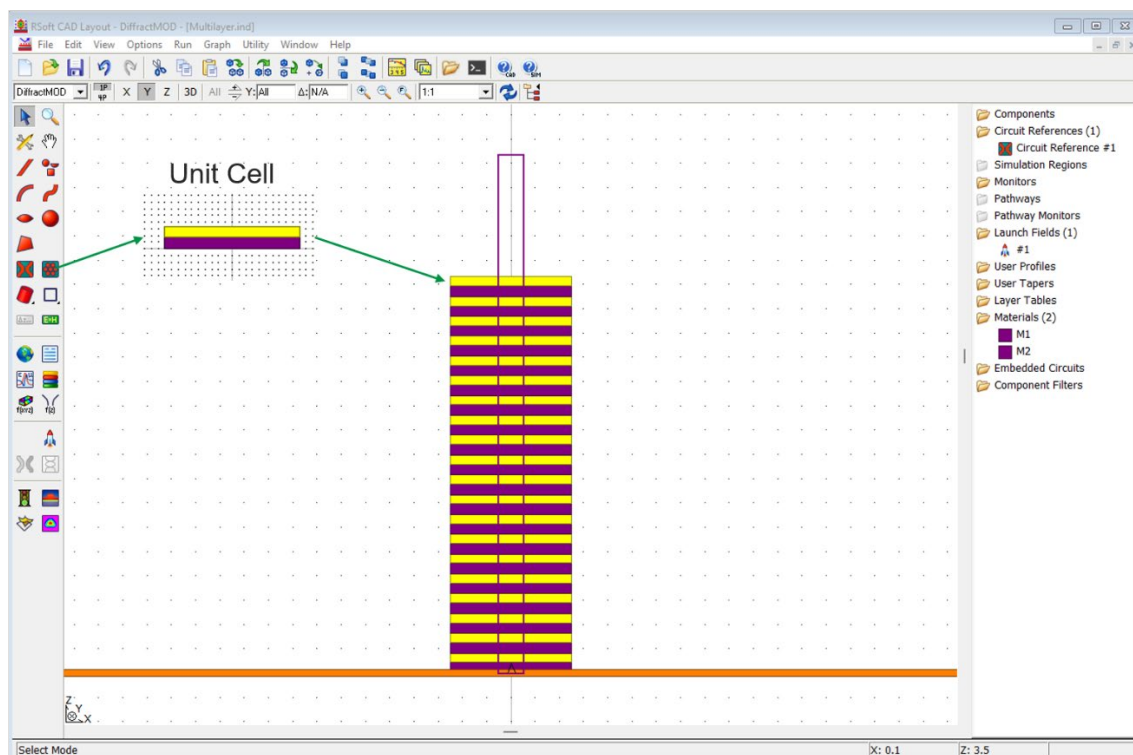


Figure 2. Multilayer structure setups in RSoft CAD

The simulation for multilayer film with DiffractMOD is very simple and fast. Only 0th harmonic is needed for the calculation. The reflection diffraction efficiency vs wavelength corresponding to 20, 50 and 100 periods are plotted in Figure 3. Strong reflection spectrum around 0.55 μm wavelength shows the Bragg reflection is established. The more layers shows higher reflection efficiency and wider bandwidth. For s-polarization, the multilayer won't show Bragg reflection effects.

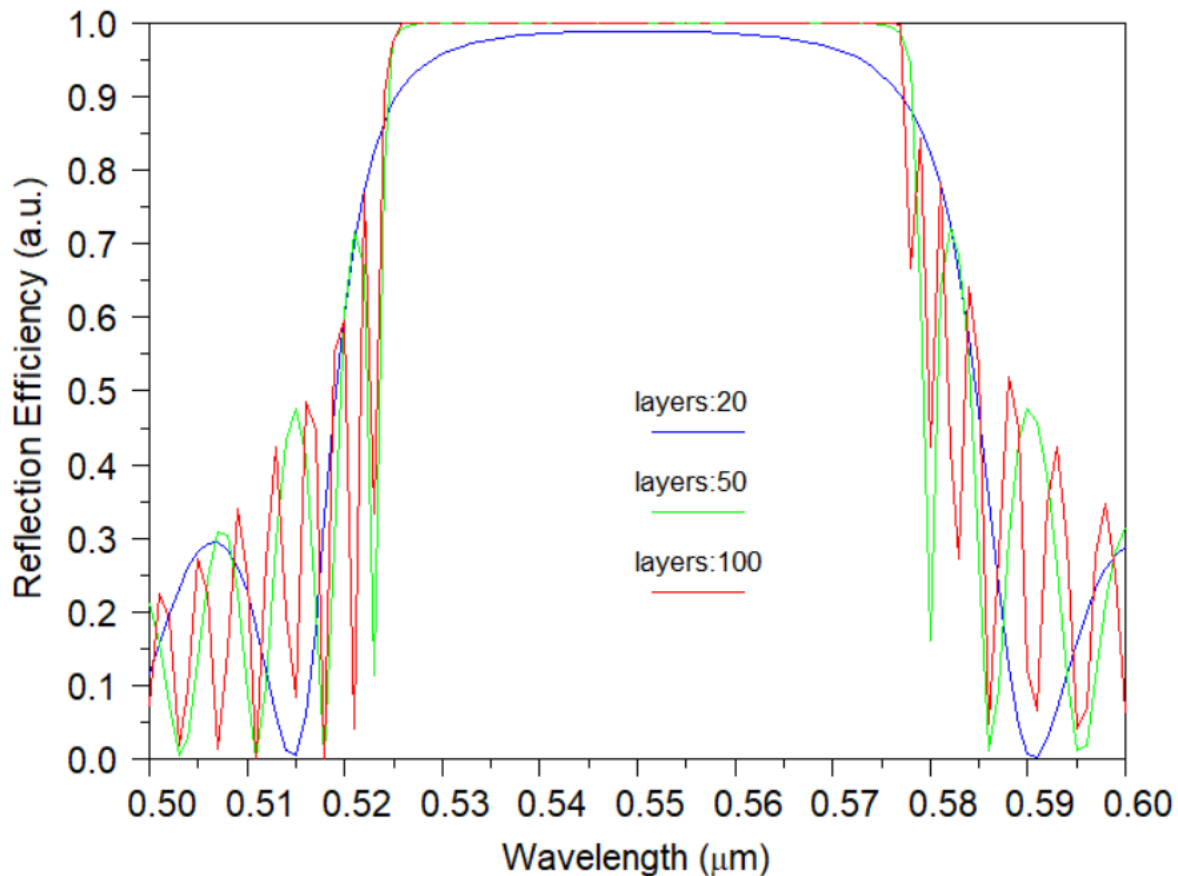


Figure 3. Simulated Reflection Efficiencies of x-polarization (p-polarization)

Example Files

Supporting Files for RSoft Application Note "Design Reflective Polarizers for Display Backlight Recycling"