Numerical analysis of dielectric guided-mode resonance reflective filter

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***Abstract*— Structural color filter is researched actively since it can complement dye-based color filter. We solved the problem of monolithic dielectric guided-mode resonance (GMR) filters with narrow bandwidth by using refractive index of 1.8. Since the depth of binary grating and the thickness of substrate of RGB color filters are same respectively, process at one go is practicable. Also, the structural color structure having wide viewing angle is suggested and demonstrated.**

Keywords-Diffraction and gratings, Color filter

I. INTRODUCTION

Color filter is the key sector in the various electronic equipment for image display. Dye-based color filter has many physical limitations such as low effectiveness, imperfect color selectivity [1]. Therefore, structural color filter based on diverse optical properties is researched actively since it can complement dye-based color filter. Dielectric GMR reflective filters are generally known that it can have high efficiency with narrow bandwidth [2, 3].

In this paper, we propose RGB binary structural color filters using refractive index material of 1.8 for broadband viewing angle. Manufacturing process of RGB color filters in one pixel at a stroke is almost impossible in the previous studies because each structure has different depth. Since the proposed structure has same thickness, process at one go is possible. However, these colors are not observable in every direction due to the short period. We also propose the structure that compensates wide viewing angle even at short period.

II. CHARACTERISTIC OF DIELECTRIC BINARY GMR REFLECTION-TYPE FILTER

Figure 1(a) shows monolithic dielectric binary structure. Since we found that a high refractive index is the key point for broadband color filter in the previous research, we use refractive index of 1.8 in this structure. In Fig. 1(b)-(d), transmission and reflection spectrum of RGB color filters what we found through the parametric study are shown. We used Fourier modal method (FMM) which is a kind of rigorous coupled-wave analysis (RCWA) in this simulation [4]. What is important here is that the thickness of substrate and the height of RGB color filters are same. Thus, manufacturing process of RGB color filters is possible at a single stroke. Pitches of RGB color filters are 510nm, 400nm, and 360nm, and widths of those are 306nm, 280nm, and 144nm, respectively.

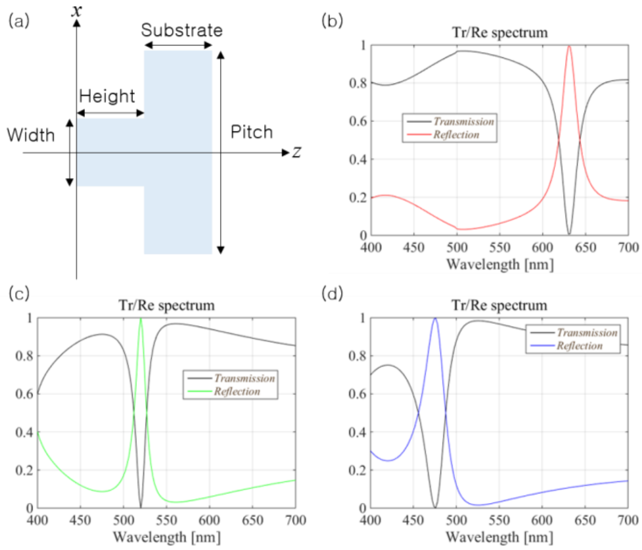

Figure 1. (a) Monolithic binary structure. (b) Transmission and reflection spectrum of RGB color filters.

As is well-documented in many previous studies, color filter using GMR has no tolerance for incidence angle as shown in Fig. 2(a)-(c). If an angle of incidence varies, the observed color is also changed. To prove this, white diffraction simulation passed off. In the conventional white diffraction simulation, plane wave was used. Because the structure is repeated infinitely in this simulation, interference is observed in the field visualization. Thus, Gaussian light source and geometric optical wave (GOW) are applied to our simulator for making clear field visualization without interference. In Fig. 2(d)-(f), the result of white diffraction is shown when incidence angle is 22.5 degree. Left region and right region are divided reflection field omitted input and transmission respectively on z=0 basis.

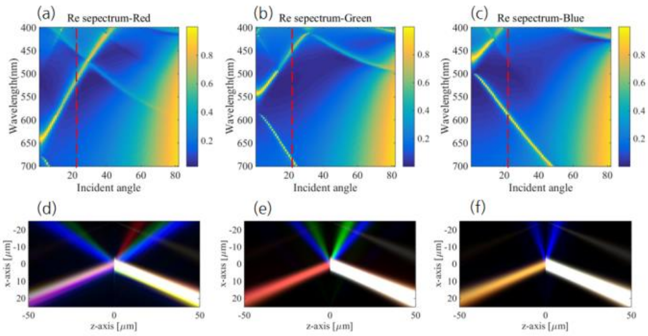

Figure 2. Spectrogram in accordance with the incident angle of (a) red, (b) green, and (c) blue. Field visualization of (a) red, (b) green, and (c) blue.

III. PROPOSED STRUCTURE TO COMPENSATE VIEWING ANGLE

Since pitches of RGB color filters are shorter than wavelengths, observable points are limited. To be exact, we can observe color at only -1st, 0th, and 1st positions. The ultimate goal of our research is to find a reflection-type color filter which has wide viewing angle. In this paper, we propose the structure that compensates wide observation angle even at short period.

Proposed structure is described in Fig. 3(a) and its field visualization is shown in Fig. 3(b). Compared to Fig. 2(d)-(f), structural colors are visible in every direction. However, the intensity of reflection light is low. We put aluminum (Al) in the last layer to improve intensity. According to our expectation, the brightness of reflective light is enhanced, as shown in Fig. 4.

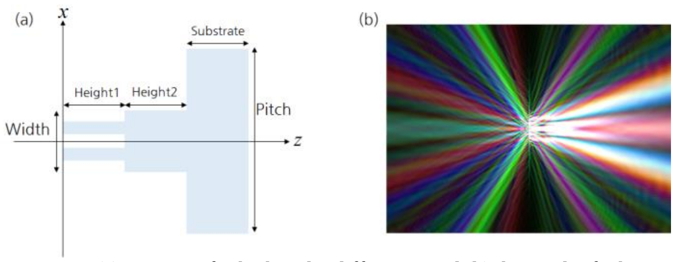

Figure 3. (a) Structure for high-order diffraction and (b) the result of white light diffraction.

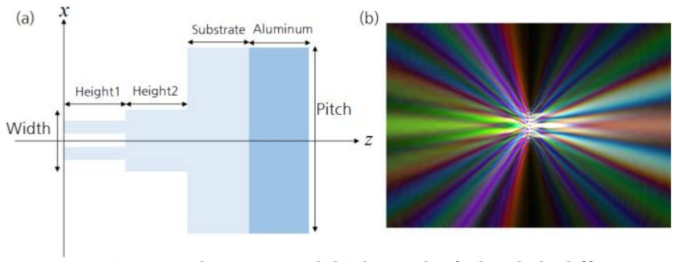

Figure 4. (a) Proposed structure and (b) the result of white light diffraction.

IV. CONCLUSION

We proposed monolithic dielectric refection-type RGB color filters using high refractive index material. It is notable that manufacturing process of RGB color filters is possible at a stroke. But observable points are limited because pitches of RGB color filters are shorter than wavelengths. To compensate viewing angle, the structure having wide observation angle even at short period is proposed. Hereafter, we have a desire to find structure that compensate the light more equally.

ACKNOWLEDGMENT

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