Photonic crystal transmission-type color filters

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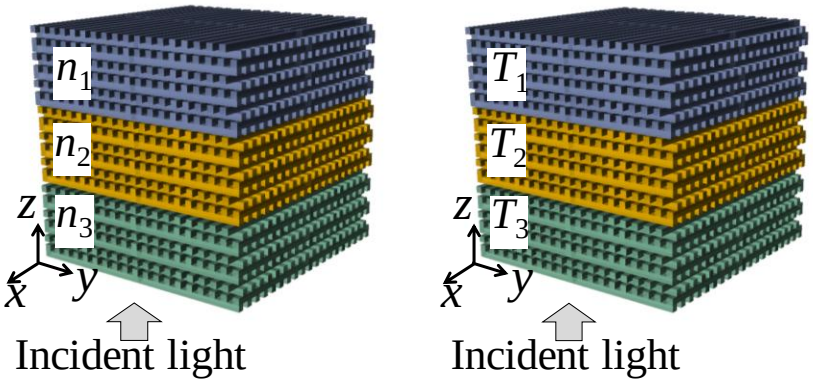
Three-dimensional (3D) periodic optical subwavelength structures attract world-wide research interest. Metamaterial is 3D subwavelength structure of the elements that show unnatural magnetic resonances. In the category of 3D optical subwavelength structure, 3D photonic crystal structure is included. In general, the concept of metamaterial is focused on elementary resonance structure, i.e. meta-atom or meta-molecule, while photonic crystal is basically assuming internal periodicity of specific dielectric structure. In this sense, photonic crystal is said to be meta-solid. When the distance between meta-atoms becomes closer and closer, and hence the interaction between the meta-atoms will be considerable, then the coupled meta-material should also be understood as optical meta-solid [1]. In this sense, 3D woodpile photonic crystals can be considered as optical meta-solid.

In this presentation, optical characteristics of 3D woodpile photonic crystal are reviewed and the transmission-type color-filter structures based on 3D woodpile structures are investigated [2]. It is shown that the wide-viewing angle transmission-type red, green, and blue color-filters can be constructed by the heterojunction layer structure of 3D woodpile photonic crystals, woodpile photonic crystal multilayer (WPCML). The schematic of the WPCML is illustrated in Fig. 1. The WPCML is classified into three types (i) index modulation type WPCML with same periodicity (See Fig. 1(a)), (ii) period modulation type WPCML with same refractive index (See Fig. 1(b)), and (iii) WPCML with degree of freedom in both periodicity and refractive index. These heterojunction multilayer structures of woodpile photonic crystal can be used as wide-viewing angle color filters.

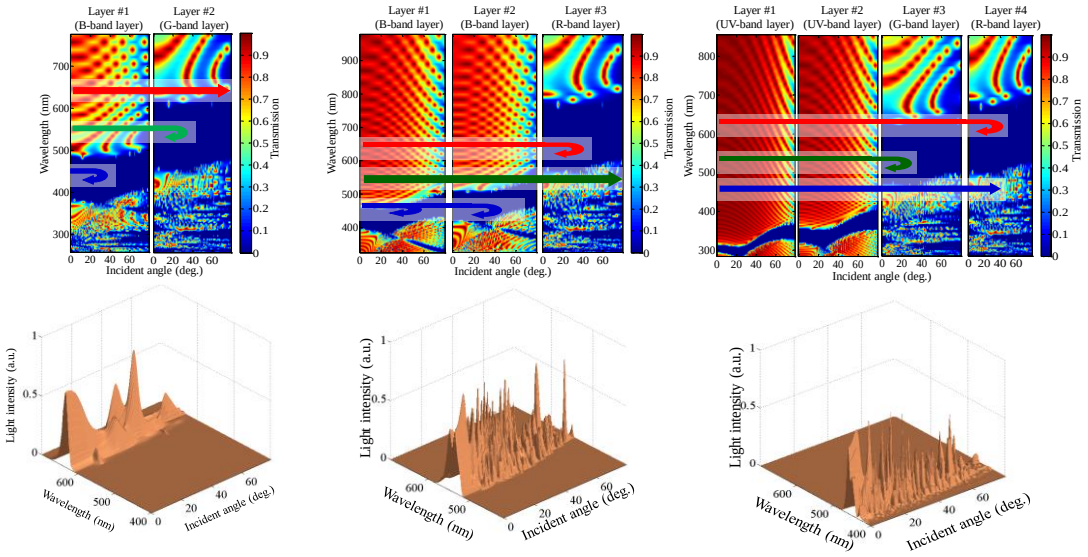


(a) (b)

Fig. 1. (a) Index modulation type woodpile photonic crystal multilayer (WPCML), and (b) period modulation type WPCML

In Fig. 2, the operational principle and optical characteristics of the designed index modulation type WPCML red, green, and blue color filters are presented. For red color filter in Fig. 2(a), the first layer has a photonic bandgap reflecting the blue band and transmitting the red and green bands. The illumination source is assumed to be conventional LED light. The transmission efficiency of WPCML structure for various wavelengths and incidence angles is analyzed with the rigorous coupled wave analysis (RCWA). The color filter characteristics of WPCML red, green, and blue filters are presented in Figs. 2(a), 2(b), and 2(c), respectively. As seen in the photonic bandgap

structure of the designed color filters, the ultra high refractive index material (UHRIM) with refractive index greater than 3 in the visible band to form wide-bandwidth photonic bandgap of the final layer is necessary in the case of index modulation WPCML. The ultra high refractive index material (UHRIM) is considered as an important category of metamaterial research [3,4]. The development of low-loss UHRIM at visible and infrared wavelength bands is required.



(a) (b) (c)

Fig. 2. WPCML color filter characteristics (a) two layer red color filter, (b) three layer green color filter and (c) four layer blue color filter. The photonic bandgap of single woodpile photonic crystal layer is designed to block single color band and transmit the other color bands. The WPCML structure produces transmission-type structural coloring effect for wide-viewing angle.

In the case of period modulation WPCML, the design target is to optimize the bandgap of cascaded woodpile photonic crystals made of the same material by adjusting the spatial period. In the presentation, numerical results are presented in the presentation and discussed. Also, recently proposed plasmonic transmission-type color-filter structure is also simulated [5] and compared with WPCML.

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