Controllable Bandgap Design in (2+1) D Colloidal Photonic Crystals

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Photonic crystals (PCs) are artificial periodic dielectric materials with the characteristic of photonic bandgap (PBG), which can control the behavior of photons in a similar manner as what semiconductors do for electrons. (2+1) D photonic crystals, as a novel photonic crystal structure, possess unique advantages in both structural tenability (control in single layer level) and optical property (PBG broadening and deepening) compared with traditional 1D, 2D and 3D photonic crystals. However, the fabrication of high quality (2+1) D photonic crystals is still a big challenge, which greatly limit the systematic study on its optical property. Here we present a simple strategy to achieve (2+1) D photonic crystal with enhanced crystalline integrity by layer-by-layer deposition of annealed colloidal crystal monolayers. By simply manipulating the diameter of PS spheres, arrangement type and repetition period of the colloidal monolayers, flexible control in structure and stopband position of the (2+1) D photonic crystals (including superlattice and heterostructure) have been realized. The optical properties of the resulting (2+1) D PCs with different lattice constants were systematically studied and a universal photonic stopband variation rule was proposed, which makes it possible to program any kind of stopband structure as required. The superlattice structure exhibits fine control in PBG position and obvious PBG resonance enhancement. While dual- or multi-stopbands and ultra-wide stopband can be achieved by fabricating heterostructures. This work may afford new opportunities for delicate engineering photonic bandgap materials. Furthermore, we explored their fluorescence (FL) enhancement ability based on their special bandgap effect and demonstrate their application in heavy metal ion detection. A multiple heterostructure photonic crystal (MHPC) with super-wide stopband improved the limit of detection of Cr(VI) to 0.2ppb. and may find significant applications for augmenting FL intensity in chemical and biochemical sensing, imaging, disease diagnosis, and environmental monitoring.

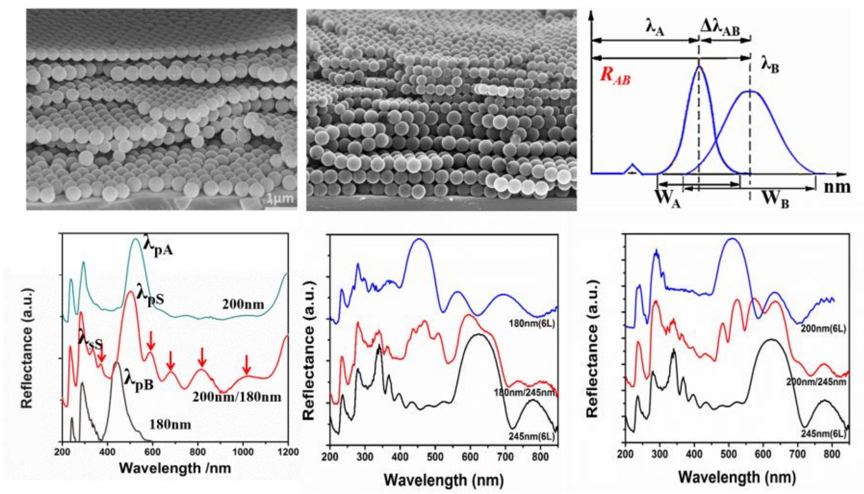

Fig.1 (2+1) D photonic crystal structure (superlattice and heterostructure) and their corresponding band gap properties.