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Luminescent Properties of Plastic Scintillator with Large Area Photonic Crystal Prepared by a Combination of Nanoimprint Lithography and Atomic Layer Deposition

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Abstract : Plastic scintillators play an important role in the measurement of a mixed neutron/gamma pulsed radiation, neutron radiography and pulse shape discrimination technology. In some research, these luminescent properties are necessary that photons produced by the interactions between a plastic scintillator and radiations can be detected as much as possible by the photoelectric detectors and more photons can be emitted from the scintillators along a specific direction where detectors are located. Unfortunately, a majority of these photons produced are trapped in the plastic scintillators due to the total internal reflection (TIR), because there is a significant light-trapping effect when the incident angle of internal scintillation light is larger than the critical angle. Some of these photons trapped in the scintillator may be absorbed by the scintillator itself and the others are emitted from the edges of the scintillator. This makes the light extraction of plastic scintillators very low. Moreover, only a small portion of the photons emitted from the scintillator easily can be detected by detectors effectively, because the distribution of the emission directions of this portion of photons exhibits approximate Lambertian angular profile following a cosine emission law. Therefore, enhancing the light extraction efficiency and adjusting the emission angular profile become the keys for improving the number of photons detected by the detectors. In recent years, photonic crystal structures have been covered on inorganic scintillators to enhance the light extraction efficiency and adjust the angular profile of scintillation light successfully. However, that, preparation methods of photonic crystals will deteriorate performance of plastic scintillators and even destroy the plastic scintillators, makes the investigation on preparation methods of photonic crystals for plastic scintillators and luminescent properties of plastic scintillators with photonic crystal structures inadequate. Although we have successfully made photonic crystal structures covered on the surface of plastic scintillators by a modified self-assembly technique and achieved a great enhance of light extraction efficiency without evident angular-dependence for the angular profile of scintillation light, the preparation of photonic crystal structures with large area (the diameter is larger than 6cm) and perfect periodic structure is still difficult. In this paper, large area photonic crystals on the surface of scintillators were prepared by nanoimprint lithography firstly, and then a conformal layer with material of high refractive index on the surface of photonic crystal by atomic layer deposition technique in order to enhance the stability of photonic crystal structures and increase the number of leaky modes for improving the light extraction efficiency. The luminescent properties of the plastic scintillator with photonic crystals prepared by the mentioned method are compared with those of the plastic scintillator without photonic crystal. The results indicate that the number of photons detected by detectors is increased by the enhanced light extraction efficiency and the angular profile of scintillation light exhibits evident angular-dependence for the scintillator with photonic crystals. The mentioned preparation of photonic crystals is beneficial to scintillation detection applications and lays an important technique foundation for the plastic scintillators to meet special requirements under different application backgrounds.

Keywords : angular profile, atomic layer deposition, light extraction efficiency, plastic scintillator, photonic crystal
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