The Growth and Characterization of Lanthanide-Phosphate-Based Scintillators for Radiation Detection Applications

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Abstract: Lanthanide phosphate single crystals activated with rare-earth dopants exhibit a combination of physical and optical properties that make them of interest for use in a variety of radiation-detection applications. In addition to the established chemical durability, radiation resistance, and physical properties of this class of compounds, when properly doped, they are efficient and fast scintillators for the detection of gamma rays. Scintillators formed by doping lutetium orthophosphate (LOP) with either Ce or Nd are particularly promising. LOP:Ce scintillators have a decay time of 24 ns and a light output that is 217% that of bismuth germanium oxide. When doped with Nd, lutetium orthophosphate scintillators have a luminescence spectrum that is centered at 190 nm. This short-wavelength output has led to recent interest in the possibility of using LOP:Nd as a scintillator that could be coupled to a proportional counter. Alternatively, recent results have shown that LOP doped with Eu and scandium orthophosphate doped with Sm have high light outputs (123,200 photons/MeV for LOP:Eu) in the long-wavelength region that matches the response of Si solid state detectors and the low-loss transmission characteristics of optical fibers. Most recently, promising cerium-doped alkali/lanthanide double phosphate scintillators have been discovered that are also characterized by relatively long wavelength emission. In the case of Ce-doped potassium/lutetium double phosphate decay times of 37 ns and outputs of 52,500 photons/Mev have been observed. Flux-grown single crystals of the double phosphates have recently been used in carrying out the first x-ray and neutron single crystal structural refinements for these substances. The practical application of lanthanide-phosphate-based scintillators is presently constrained by crystal-growth problems. The phosphates are grown by flux methods which need to be extended to top-seeded solution growth in order to produce phosphate scintillator crystals on a practical/economically viable scale.

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