Development and material design of structured scintillators for high resolution radiation imaging and thermal neutron detection

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In this talk, our research on functional composites with considering refractive indexes for radiation imaging and thermal neutron detection applications will be presented.

1. Light guiding scintillator using large refractive index difference: The eutectic crystals have a structure in which scintillator crystal fibers of several μm diameter are arranged in a matrix and have excellent position-resolving performance against x-rays and charged particles [1]. However, it was extremely difficult to grow the eutectic enough large or long size, and it was impossible to grow them as a single fiber. Most recently, we proposed a novel optical-guiding crystal scintillator (OCS) [2]. It consists of halide single crystal scintillator core and glass clad. The refractive index of the halide single crystals is higher than the glass in this system. Generated scintillation light above the critical angle is totally reflected at the interface with the glass and optically waveguided like optical fibers and the scintillating fivers (fig.1-right). In OCS, the molding of the cladding and the crystal growth of the scintillator core are performed in the same process. OCS was not limited to single fiber but could also be formed into bundles for high resolution radiation imaging.

2. Transparent eutectic scintillator using a small refractive index difference: For the decommissioning of Fukushima Daiichi Nuclear Power Plant, fuel debris is scheduled to be removed from the primary containment vessel. Sorting is important because a large amount of fuel debris and radioactive waste are mixed and It is necessary to distinguish between gamma rays and thermal neutrons in the high-dose environment over 10Gy/h. In this field, scintillators with high sensitivity only to neutrons, fast decay (<20ns), and high neutron-gamma discrimination performance are required. Especially ^{6}Li is high thermal neutron capture cross-section elements and scintillators containing ^{6}Li have been commercialized such Ce,Eu:LiCaAlF$_6$, Ce:Cs$_2$LiYCl$_6$, Tl:(Na,Li)I etc. However, there has been no scintillator that satisfies the sensitivity and fast decay required for the above application. In contrast, we have reported eutectic scintillators containing high Li concentration and scintillator phases such LiBr/CeBr$_3$, LiBr/LaBr, LiBr/CsI etc. Scintillators must offer a high light yield and be transparent to the generated light. Sufficient transparency can be achieved by combining crystal phases with closer refractive indices. At the point view of scintillation properties, fast and high light yield scintillators such BaCl$_2$, LaCl$_3$, CeCl$_3$, BaBr$_2$, LaBr$_3$, CeBr$_3$ with Eu^{2+} or Ce^{3+} doping were selected as the scintillator phase. A systematic study of combinations of each scintillators and Li-containing halides is introduced.

[1] K. Kamada, et al.Jpn. J. Appl. Phys., vol. 60, no. SB, 2021.

[2] R.Yajima, K. Kamada, et al. Ceram. Int. (2023) DOI: 10.1016/j.ceramint.2022.12.264.