Comprehensive study of transparent ceramic and single crystal for scintillator

Hafnium based transparent ceramics for scintillation materials were fabricated with Spark Plasma Sintering (SPS) method. $La_2Hf_2O_7$ doped with Tb had green emission under alpha ray and gamma ray excitation, and these materials can be used for current-mode scintillation materials with high detection efficiency.

Scintillators are required in various fields such as medical imaging or astronomy, and high gamma-ray stopping power is required; cross-section of the photo-absorption σ is proportional to Z_{eff}^{a}, where a = 4-5 and Z_{eff} is effective atomic number. Lu_2SiO_5:Ce (LSO), $(Lu,Y)_2SiO_5$:Ce (LYSO) or $Lu_3Al_5O_{12}$ scintillators are used in medical imaging or other applications, because Lu has a high atomic number of 71 and the materials have high stopping power. On the other hand, such a crystal has intrinsic background due to ^{176}Lu decay, and the resulting noise worsens the gamma-ray detection sensitivity.

Hafnium has a high atomic number of 72, and total abundance of its radio isotopes is less than 0.2% (^{174}Hf, half-life is more than 10^{15} year). Thus, a new scintillator consisting of Hafnium can have low intrinsic background and high detection efficiency, thus an efficient scintillator can be developed. However, hafnium itself and hafnium compounds have generally high melting temperatures of more than 2,300 °C. Due to the high melting- temperature, it is difficult to grow the crystal from the melt using conventional crystal growth methods such as Czochralski, Bridgman, and micro-pulling down method [1].

This time, we have fabricated RE-doped $La_2Hf_2O_7$ (LHO), where RE=Tb, Eu. $La_2Hf_2O_7$ has Pyrochlore superstructure. Figure 1 shows the Tb:LHO ceramics sample and its emission spectrum excited by alpha rays. Moreover, Eu-doped LHO had red emission. These emissions were originating from Tb^{3+} or Eu^{3+} 4f-4f transitions, whose decay times were over 10 µsec. Thus, we can use these scintillation materials in current mode detection, not single photon counting method.

We succeeded in preparation of green emission scintillator with high effective atomic number of around 61-62. Here, a Si-avalanche photodiode (Si-APD) has high quantum efficiency than conventional photo-multiplier tube, and the Si-APD has maximum quantum efficiency around the green region.

Thus, these materials can be used for some radiation dose monitor with current-mode using Si-APD or other Si-based detectors.

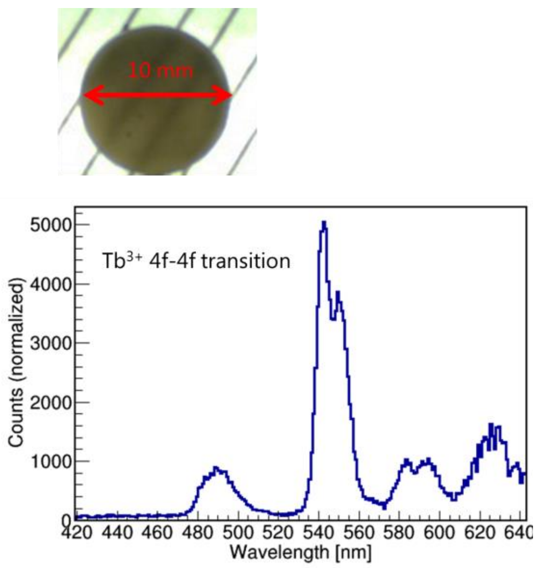

Fig. 1 Tb:LHO ceramic sample and its emission spectrum.

References

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