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Optimization of low background LaBr3:Ce3+ scintillation crystal for high temperature logging

LaBr3:Ce3+ scintillation crystal demonstrates superior performance for radiation detection. However, its application in extreme environments such as oil logging (high temperature, low count rate), astronomical exploration (extreme temperature, high precision), etc., is still limited. The main reason is that intrinsic background signals generated from radioactive isotopes 138La and 227Ac in raw materials. In addition, the high temperature in the well, the high temperature luminescence characteristics of the crystal and the deterioration mechanism of the high temperature performance are not clear, which further restricts its practical application.

This study developed an effective purification protocol based on vacuum distillation to selectively remove 227Ac from raw materials, reducing intrinsic background signals in LaBr3:Ce crystals by approximately 50%-60% (minimum value is 0.0163 counts/s/cm3@1.5–3 MeV). The GDMS test results show that Fe, Na and other metal impurities are also reduced. More importantly, crystal grown by purified material significantly enhances the energy resolution (2.47%@662 keV). Beyond background suppression, we investigated the temperature-dependent luminescence properties of Ce^{3+}cause its elusive. Utilizing intensity parameters from the spectra, we identified the impact of temperature on self-absorption effect of LaBr3:Ce, revealing a significant self-absorption effect at the high-energy peak for the first time. The high energy peak's self-absorption coefficient of 0.76 is much higher than the total coefficient of 0.15, confirming that high quantum efficiency of Ce guarantees efficient secondary emission after self-absorption, thereby suppressing the overall self-absorption. The energy spectrum at variable temperatures show that the synergistic effect of carrier transport relaxation and self-absorption leads to the law of light yield increasing first and then decreasing.

In general, the innovation of this study lies in the proposed key path for the preparation and optimization of LaBr3:Ce3+ crystals with low background, and the physical mechanism of their luminescence characteristics and performance changes at high temperatures. It also lays a technical foundation for the application of LaBr3:Ce3+ crystals in rare event detection.

Workshop topics

Sensor materials, device processing & technologies

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