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Study of $CdWO_4$ and CsI:Tl Scintillators with Various Photo Detectors

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1. Introduction

Scintillators, such as NaI:Tl, CsI:,Tl. $Bi4Ge_3O_{12}$ (BGO) and $CdWO_4$, are used to applications in the fields of nuclear and high energy physics, astrophysics, nuclear physics, medical science, radiation imaging and homeland security [1]. The scintillation properties, such as decay time, emission wavelength, and light yield, is depended on their band gaps, and vary by scintillators [2].

The various photo sensors, such as photomultiplier tube (PMT), photodiode and charged coupled detector (CCD), are used for radiation detectors with scintillators. The quantum efficiency differs from photo sensor to photo sensor. As shown in the Fig.1, the maximum quantum efficiency of the PMT is around 400 nm and photodiode is around 600 nm [3].

Among scintillation properties, emission wavelength of scintillator is need to consider before matching photo sensors because of the quantum efficiency of photo sensor. The maximum emission peak of CsI:Na is around 400 nm and $CdWO_4$ is around 500 nm [4]. Thus the PMT is more suitable than photodiode as photo sensor of CsI:Na scintillator. However the $CdWO_4$ is suitable with photodiode.

We measured scintillation properties of the CsI:Tl and $CdWO_4$ with PMT (Hamamatsu, H7195) and photodiode (Hamamatsu, S8650) for studying the correlation between emission wavelength of scintillator and quantum efficiency of photo sensor. At this study, the grown the $CdWO_4$ single crystal is used. The CdWO4 single crystal is grown in oxidizing atmosphere by using the Czockralski method at KAERI (Korea Atomic Energy Research Institute). The light yields of the CsI:Tl and $CdWO_4$ are measured under various ɣ-ray sources.

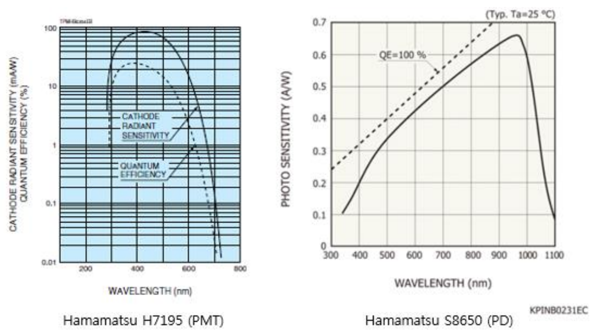

Fig. 1. The quantum efficiency of PMT (left) and photodiode (right).

2. Methods and Results

2.1 $CdWO_4$ scintillator

$CdWO_4$ single crystals are grown three times in oxidizing atmosphere by the Czochralski technique at the radiation equipment Fab. Center. The 1st $CdWO_4$ single crystal is grown in the oxidizing atmosphere, 2nd $CdWO_4$ single crystal is grown by using recycled $CdWO_4$ material in the oxidizing atmosphere, and 3rd $CdWO_4$ single crystal is grown as changing the pulling and rotation speed. Each grown $CdWO_4$ single crystal are annealed in the air over the temperature range of 1100 ℃, and then cut by diamond wire and polished with various SiC papers. The dimensions of 1st and 2nd samples are 10 X 10 X 10 mm^3, and 3rd sample are 10 X 10 X 5 mm^3. Figure 2 shows polished samples.

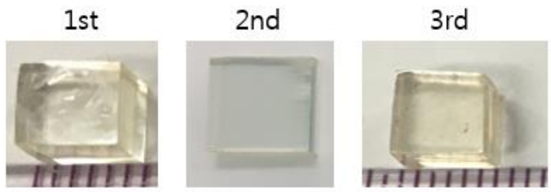

Fig. 2. The photographs of the polished samples.

2.2 Experiment setup

In this study, the CsI:Tl scintillator is used for comparing the scintillation properties with $CdWO_4$ scintillator. Table 1 shows the scintillation properties of CsI:Tl and $CdWO_4$ [4-6].

Table 1. Scintillation properties of CsI:Tl and $CdWO_4$

Property	CsI:Tl	$CdWO_4$
Light yield [ph/MeV]	40,000 ~ 60,000	12,000
Density [g/cm3]	4.53	7.9
Decay time [ns]	~1,050	~14000
Peak emission [nm]	550	475

The CsI:Tl and $CdWO_4$ crystal are wrapped by using a Teflon tape without one face which is attached to photo sensor. Pulse height spectra are measured with ^{22}Na (511 keV and 1,275 keV), ^{137}Cs (662 keV) and ^{60}Co (1,173 keV and 1.333 keV) ɣ-ray sources.

The scintillation signal is transferred to PMT and then the signal is fed to shaping amplifier (Ortec, 570). The signal is digitized by multi-channel analyzer (MCA, Ortec). Figure 3 shows the schematic diagram of pulse height measurements by using PMT.

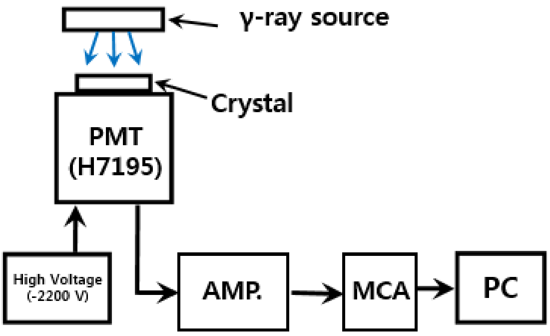

Fig. 3. Schematic diagram of the experiment setup by using PMT.

2.3 Pulse height spectra *measurements*

The pulse height spectra of CsI:Tl and grown $CdWO_4$ crystal under 662 keV ^{137}Cs γ-ray excitation are shown in Fig.4. Among three samples, the 1st $CdWO_4$ crystal have highest light yield. The energy resolution (FWHM) was measured to be 14%.

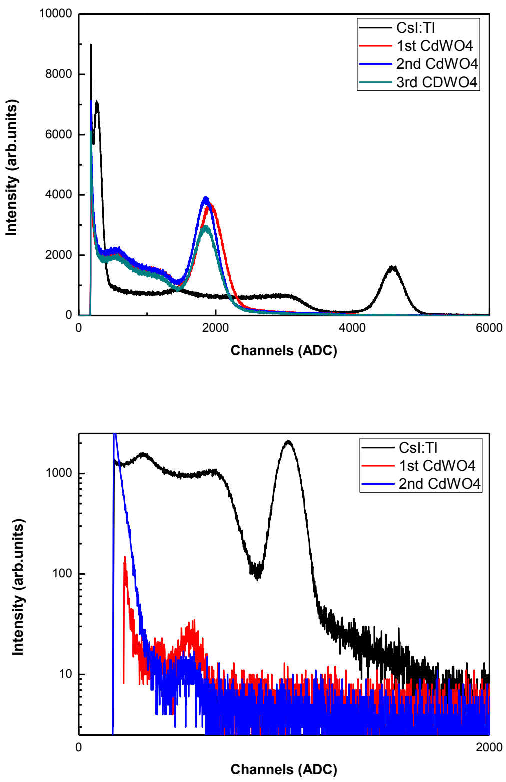

Fig. 4. The scintillation pulse height spectra of CsI:Tl and $CdWO_4$ crystal with PMT (upper) and photodiode (lower) at room temperature excited 662 keV γ-ray from a ^{137}Cs source.

3. Conclusions

In this experimental, the grown $CdWO_4$ single crystal and CsI:Tl crystal are used as radiation detector. We measured the scintillation properties of two scintillator crystals as changed photo sensors such as photomultiplier tube and photodiode. The energy resolution of the $CdWO_4$ with photomultiplier is measured to be 14% under 662 keV ^{137}Cs γ-ray excitation. The grown CdWO4 single crystal is more suitable than CsI:Tl as radiation detector with photomultiplier tube because of scintillation crystal's emission wavelength and quantum efficiency of PMT. Thus we need to select photo sensor according to scintillator's properties.

ACKNOWLEDGEMENT

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