Radioactive Contaminations within Scintillation Crystal

S. Umehara[a], T. Kishimoto[a], I. Ogawa[a] and S. Yoshida[b]

[a] *Faculty of Science, Osaka University, Toyonaka, Osaka 560-0043, Japan*
[b] *Research Center for Nuclear Physics (RCNP), Ibaraki, Osaka 567-0047, Japan*

Radioactive contaminations within a detector deteriorate its sensitivity when the detector is used for low-background measurements, such as the dark matter search and the measurement of double beta decays. We apply CaF_2(pure) scintillators and develop a detector system CANDLES to search for double beta decays of ^{48}Ca[1].

The least background rate is expected by using CaF_2(pure) scintillator, because of the large $Q_{\beta\beta}$-value(4.27MeV) which is higher than the end point of natural background γ-ray energy. The serious backgrounds are β-ray and α-ray from radioactive isotopes within CaF_2 crystal[2] Thus it is important to prepare the high purity crystal and to measure the amounts of the contaminations in order to estimate their effects on the measurements of double beta decays.

The delayed coincidence method is sensitive to extract characteristic decay which belong to the series[3]. In this work, α-rays from ^{214}Po($T_{1/2} = 164\mu$s) which decays immediately after the β decay of ^{214}Bi in U-series were extracted by using the β-α delayed coincidence, and α-rays from ^{216}Po($T_{1/2}$ = 145ms) after the α decay of ^{220}Rn in Th-series by the α-α delayed coincidence.

Three CaF_2(pure) crystals listed in Table 1 were measured. Each CaF_2(pure) crystal grew from different raw materials. It is assumed that the purity of the raw materials affects the amounts of the contaminations in CaF_2 crystal.

In the measurements, CaF_2(pure) crystal was covered with two CsI(Tl)($65\times65\times250$mm^3) and a NaI(Tl)($102\times102\times178$mm^3) detectors which acted as veto-counters and shieldings. The detectors were shielded from environmental radiations with oxygen-free high-conductive copper of 5cm in thickness and lead of 10cm in thickness. The energy of the prompt and delayed events were measured by two charge sensitive ADCs. In order to reduce the loss of the ^{214}Bi β-rays(Q_β=3.27MeV), the energy threshold was set down to $\sim$ 70keV. The time lags between the prompt and delayed trigger were measured by a scaler and two clocks(10MHz and 10kHz). The detection efficiencies for ^{214}Po and ^{216}Po α-rays ware above 90%.

Fig.1 shows the energy spectra obtained by the delayed coincidence measurement. The chance-coincidence energy spectrum was obtained from the single event rate and the single energy spectrum. The radioactivities of ^{214}Po and ^{216}Po were obtained by the yields of the peaks in Fig.1 and the detection efficiencies. The radioactivities of Po nuclei and the scintillation efficiency $f_\alpha(=E_o/E_\alpha)$ for the CaF_2(pure) scintillators are summarised in Table 2.

In the present work, we measured the concentrations of ^{214}Po in U-series and ^{216}Po in Th-series. We will measure the radioactivities in the CaF_2 raw materials to investigate these effects to the crystal products.

References

[1] T. Kishimoto, OULNS Annual Report(2000).
[2] I. Ogawa et al.,this volume.; I. Ogawa, talk given at APS & JPS meeting,October 2001.
[3] S. Umehara et al., Nucl. Instr. and Meth.,to be published.

Table 1: A list of sample CaF_2(pure) crystals. The scavenger is used for the purification of CaF_2(pure).

Crystal	Dimension	CaF_2 Raw Material	Scavenger
Sample A	$50\times50\times50$ mm^3	A	PbF_2
Sample B	$50\times50\times50$ mm^3	B	no
Sample C	$30\times30\times30$ mm^3	C	PbF_2

Table 2: Measured radioactivities within CaF_2(pure) crystals and the scintillation efficiencies f_α.

Crystal	U-series		Th-series	
Sample	$dN_{^{214}\mathrm{Po}}/dt$ (mBq/kg)	$f_{^{214}Po\alpha}$	$dN_{^{216}\mathrm{Po}}/dt$ (mBq/kg)	$f_{^{216}Po\alpha}$
A	0.057 ± 0.008	0.30	0.0297 ± 0.0057	0.26
B	2.127 ± 0.084	0.29	0.406 ± 0.034	0.28
C	1.11 ± 0.12	0.27	—	—

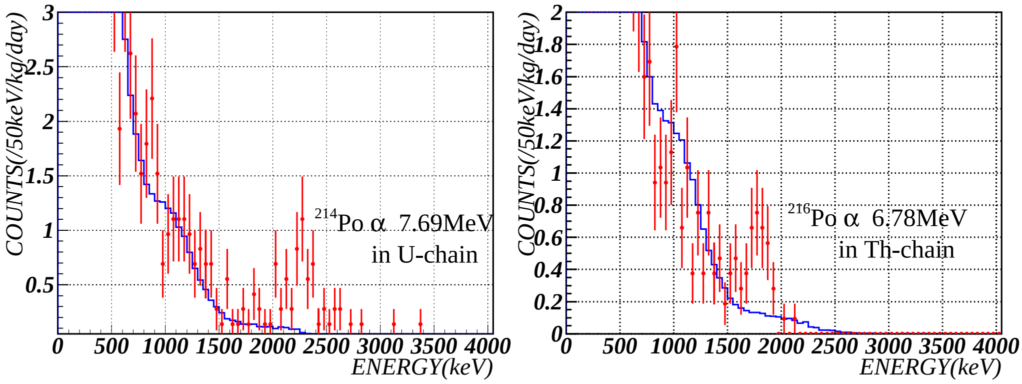

Figure 1: Energy spectra obtained by the delayed coincidence measurement of Sample A. Closed circles and solid line show the the delayed events and chance-coincidence events, respectively. The horizontal axis is the electron equivalent energy. **Left:** The energy spectra obtained by measuring the delayed coincidence of ^{214}Bi $\rightarrow$ ^{214}Po $\rightarrow$ ^{210}Pb in U-series. The peak around 2.3MeV is due to α-rays from ^{214}Po. **Right:** The energy spectra of ^{220}Rn $\rightarrow$ ^{216}Po $\rightarrow$ ^{212}Pb decays in Th-series. The peak around 1.8MeV is due to ^{216}Po α-ray events.