Preliminary Experiment for the Implementation of a Neutron Activation Analysis System with a Compton Suppression Gamma-ray Spectrometer

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1. Introduction

Compton suppression gamma-ray spectrometer reduces the Compton background of a gamma-ray spectrum and enhances the detection sensitivity of interesting nuclides in radioactive samples. Thus, a spectrometer has been applied for an instrumental neutron activation analysis since 1990[1,2].

In this study, preliminary experiments were performed for the implementation of the Compton suppression spectrometer for a neutron activation analysis (NAA). For this purpose, the timing signal was optimized to reduce the Compton background to as low as feasible. Gamma-ray spectra between normal and suppression mode were compared by using a Cs-137 source and a neutron irradiated sample. Finally, a quantitative analysis with NIST SRM 2711-Montana Soil was carried out to validate the applicability of the Compton suppression spectrometer for NAA.

2. Experiments

2.1 Compton Suppression Spectrometer

The electronic modules of a Compton suppression gamma-ray spectrometer are comprised of a timing filter amplifier (TFA), constant fraction discriminator (CFD), gate and delay generator, high voltage power supply
(HV), single channel analyzer (SCA), time-to-amplitude
converter (TAC) and DSPEC^{PLUS}. Figure 1 shows a schematic diagram of this system. The detector system consists of a high-purity Ge detector encompassed by four BGO scintillators

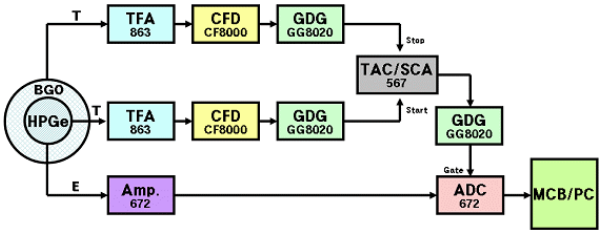

Fig. 1. Schematic diagram of Compton suppression system.

To optimize the performance of Compton suppression system, timing signal from two detectors, HpGe and BGO, was measured and adjusted. Conclusively, timing gap of an energy signal from HPGe detector with a gate signal from TAC/SCA was set to 4 μsec for anti-coincidence measurement. The result is shown in Figure 2.

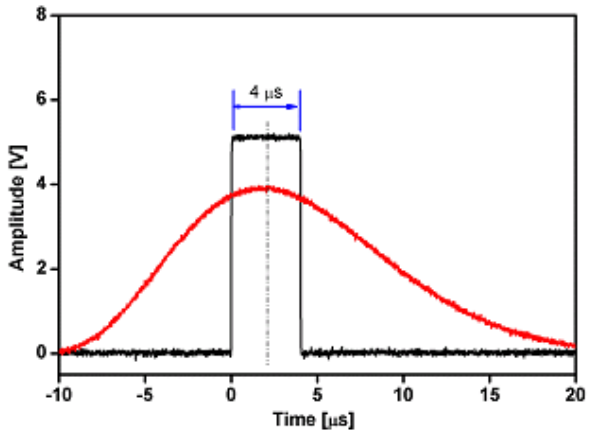

Fig. 2. Timing of an energy signal from HPGe detector with a gate signal from TAC/SCA.

2.2 Measurement of Cs-137

Gamma-ray spectrum with a normal mode, coincidence mode and anti-coincidence mode were acquired by using a Cs-137 source. Figure 3 shows a comparison of background between the three spectra. Background of the anti-coincidence (suppression) mode is reduced up to 60% of that of the normal mode

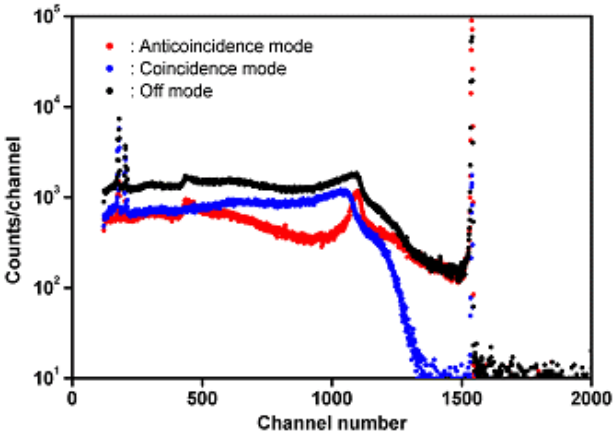

Fig. 3. Spectra measured at three modes. Anti-coincidence mode, coincidence mode and off(normal) mode. Live time = 3600 s.

2.3 Validation for NAA

For the method validation for NAA with the Compton suppression spectrometer, NIST SRM 2711-Montana Soil was irradiated by neutrons, measured and analyzed.
Background of the two spectra is compared in Figure 4. Table 1 summarizes the background reduction ratio along with the gamma-ray energy. The range of the reduction ratio is 52% ~ 68%.

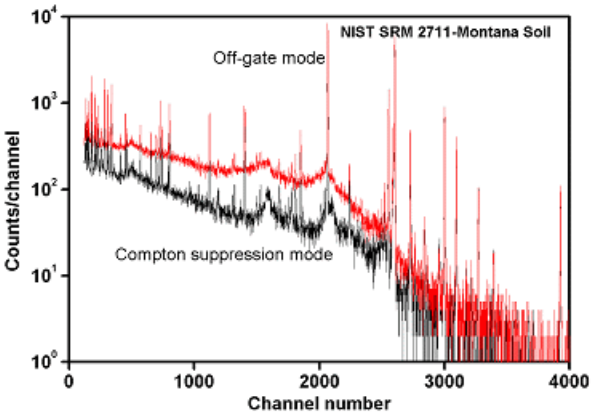

Fig. 4. Comparison of spectra from normal and suppression mode for NIST SRM 2711 sample.

Table 1: Background reduction ratio

Nuclide	Energy	Bg counts of normal mode	Bg counts of suppression mode	Bg reduction(%)
Hg-203	279	4056	1668	58.9
Cr-51	320	3783	1802	52.4
Hf-181	482	2909	1206	58.5
Cs-134	795	2178	693	68.2
Sc-46	889	4412	1872	57.6
Fe-59	1099	766	400	47.8
Co-60	1332	110	44	60.0

After the detection efficiency on a given position was measured, elemental contents in NIST SRM 2711 were quantified by the absolute NAA method. These results are shown in Table 2. The relative errors (%) of the six analyzed elements, except for Hg, are within 10%.

Table 2: Analytical results of NIST SRM 2711

Element	This work	Certified value	Unc.(2s)	Relative error(%)
Co	9.47	10		5.3
Cr	42.5	47		9.6
Cs	5.95	6.1		2.4
Fe	30440	28900	600	5.3
Hf	6.90	7.3		5.5
Hg	5.46	6.25	0.19	12.7
Sc	8.65	9		3.9

3. Conclusions

Compton suppression gamma-ray spectrometer has been implemented for NAA. It turned out that a background reduction by using an anti-coincidence mode can reach up to 68%. Analytical results of NIST SRM are agreed well with the certified values. This system will be used to achieve lower detection limits of interesting elements in actual samples such as geological and biological samples.

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