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Application of a developed setup to β-rays to improve the β energy spectrum

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Abstract. In this work, a spectrometric method is described to obtain a clear β energy spectrum of radiocarbon (^{14}C). The spectrometer is simple and uses a pulse shape discrimination timing technique with a Si semiconductor detector. The experimental result showed that the method in the present work was successful for obtaining the clear β energy spectrum.

Key words: β-rays • pulse shape discrimination method • Si semiconductor detector • energy and timing spectroscopy • ^{14}C

Introduction

Energy spectra of radioisotopes have a great importance in the evaluation of the interaction in a medium of the particles emitted from radioisotopes. While the energy spectra are being stored, the main characteristic is the fact that they are clear, i.e. the energy spectrum is only of the particles emitted from the radioactive source (discriminated from any other artificial pulses such as background). Unfortunately, background and noise, which are unwanted signals, are always observed in the energy spectra. These effects cause some difficulties in observing pure particle spectra and can prevent detection of signals from particles especially in the low-energy region.

Distinguishing the different types of particles is known as pulse shape discrimination (PSD). PSD is widely used as a method to suppress energy signals of unwanted particles. The difference in pulse shapes from different classes of particles can be transformed into a measurable quantity [5]. Further information about the PSD is available from numerous works [1–4].

By means of the PSD method, in this respect, the clear β energy spectrum of ^{14}C by rejecting some of the noise contributions was obtained in the present work.

Materials and methods

Figure 1 shows the schematic block diagram of the experimental setup used in this work.

β-rays emitted from a radioisotope were detected by an Ortec CA 18-50-100 Si surface barrier semi-

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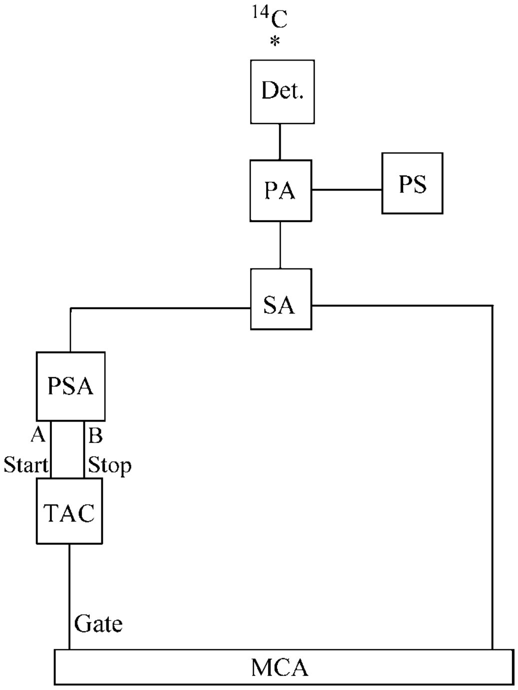

Fig. 1. Schematic diagram of the spectrometer. ^{14}C – radioisotope; Det. – detector; PA – preamplifier; PS – power supply; SA – spectroscopy amplifier; PSA – pulse shape analyzer with its inputs A and B; TAC – time to amplitude converter; MCA – multichannel analyzer.

conductor detector that was placed in a vacuum chamber and fed with a power supply (Ortec 428: PS). The detector signal was sent to a preamplifier (Ortec 142: PA) and then further amplified by another amplifier (Ortec 472: SA). Two outputs from the amplifier were acquired in order to produce both energy signals and time signals. The first output of the amplifier was fed into a pulse shape analyzer (Ortec 552: PSA). This device generates two timing output signals. The first signal is produced when the pulse has 10% of its maximum amount in the leading edge of the input signal. This signal is the 'start' signal for the time to amplitude converter (Ortec 566: TAC). The second is generated when the pulse has 90% of its maximum amount in the leading edge of the input signal. This signal forms the 'stop' signal of the TAC. The time between these signals is called the rise time of the input signal, which is measured by the TAC. If any radiation different from the energy signals of the β source is detected in this time interval, this radiation will be recorded with a different pulse height in the multichannel analyzer (MCA, Ortec Trump 8k) because of its unusual rise time. Coincidence connection of this time signal from the TAC and the second output from the amplifier in the MCA gives the clear energy spectrum. This is the main advantage of the PSD method.

In order to check the spectrometer performance on rejection of noise contribution to the β-ray energy spectrum, a low-energy β-ray emitter such as ^{14}C was used in the experiments. The radioactive source used in the measurements has the activity of 100 μCi and this point source, placed on 5 mm far away from the detector, emits low-energy β-rays of maximum 156 keV.

Experimental results and conclusions

The β energy spectra, which were acquired in a 300 s run time at room temperature of 294 K, were stored in the MCA. The experimental energy spectrum of ^{14}C through the Si semiconductor detector is shown in Fig. 2.

Figure 3 illustrates the time spectrum obtained from the TAC output by directly connecting the MCA input. In this figure, lower channels approximately from 160 ch. contain β and noise signals. Channels 160 > correspond to the signals of the source particles. The time resolution of the spectrometer was found to be 209 ps.

To estimate the minimum width of the noise band, a background spectrum was acquired as can be seen in Fig. 4.

Comparison of the energy spectra of the radiocarbon with and without the spectrometric method presented in this work is illustrated in Fig. 5.

The positive effect of the spectrometric method presented in this work can be seen in Fig. 5. It is

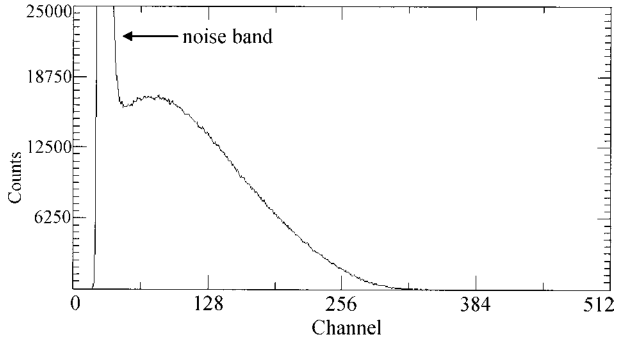

Fig. 2. β-ray energy spectrum of ^{14}C.

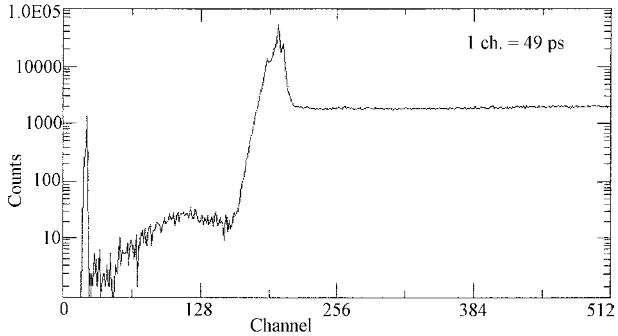

Fig. 3. Time spectrum of the spectrometer.

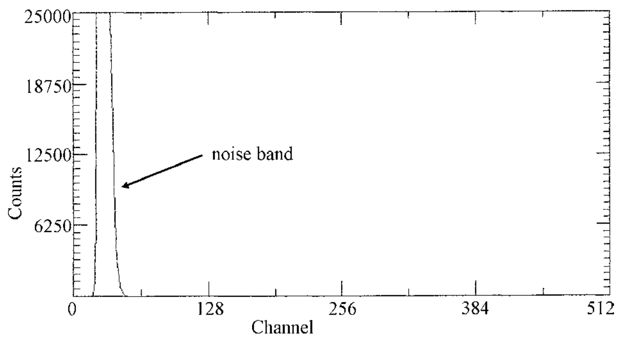

Fig. 4. Background spectrum of the Si semiconductor detector.

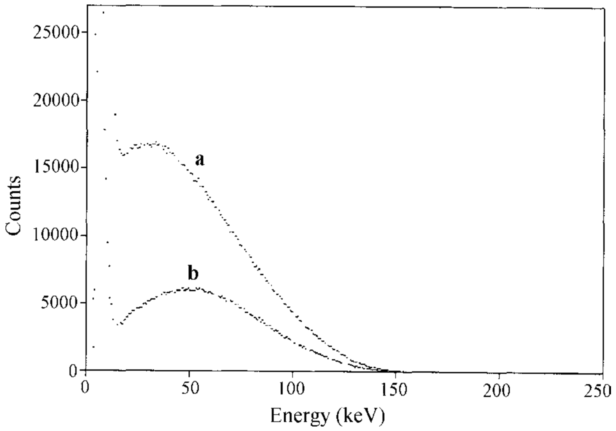

Fig. 5. Comparison of the β energy spectra with (b) and without (a) application of the spectrometric method in the present work.

concluded from this result that the method was helpful for obtaining the clear β energy spectrum.

Since the time spectrum contains β and noise signals in lower channel numbers (<160 ch.), the noise band has been appearing in the clear β energy spectrum in Fig. 5b. If a single channel analyzer (SCA) can be put between the TAC and the MCA, the final spectrum will not have the noise band in the low-energy part, and this will improve the clear energy spectrum. The SCA was not used after the TAC in the present work, so that the comparison can be done easily from the spectral shape point of view.

A PSD setup was developed and the PSD method was applied to the energy spectrum of a β radiation source (^{14}C), and the discrimination process of noise contribution was performed successfully at room temperature.

Temperature is very important in Si semiconductor detectors due to the leakage current. For this reason, a noise band will always be appearing in the energy spectrum of low-energy β emitters. In addition, some other factors such as scattering from detector and source holder, backscattering from the source material, ambient light, voltage degradation etc. expand this noise band. The large noise band superimposes on the low-energy part of the β energy spectrum and reduces the detector sensitivity especially in this energy region.

The obtained clear β energy spectrum in Fig. 5b is quite adequate in shape in comparison with Fig. 5a after the application of the experimental spectrometric process. It is concluded from the experimental results that the method followed in the present work can be applied to any β spectrometer to obtain the clear energy spectra even at room temperature for other β-ray emitters as well as routine analyses and studies in pure pulse height spectra. It is possible that better energy spectra without any noise contributions for detection of charged particles can be obtained by the PSD method with further experiments via the setup presented here.

$\sqrt{N}$ values where N is the number of counts per channels or energy were plotted vs. energy for the energy spectra with and without the timing method to check the obtained results whether TAC gating has introduced significant distortions. Both plots were linear and the end-point energies were almost the same for each other. This result shows that the TAC gating was not distorted the source spectrum significantly.

Finally, theoretical spectra of the source particles interacting with a medium and the calculations of the reaction parameters will be more reliable with the experimental pure source spectra. In this connection, the data from the experimental setup presented here can contribute to improve the results obtained from the theoretical calculations of β particle interactions with any medium.

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