APPLICATION OF CdTe (CdZnTe) DETECTORS FOR RADIOACTIVE WASTE CHARACTERIZATION*

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The radiation detectors based on wide-zone semiconductor CdTe (CdZnTe) monocrystals have promising advantages for their application in investigation (characterization) of radioactive waste. Among these advantages there are the wide range of photons flux and energy, high registration efficiency and satisfactory energy resolution without deep cooling of the detector. This report discusses the obtained data concerning radiation stability of detectors, influence of different conditions (filters, collimators, registration channel fill etc.) on their energy resolution in spectrometric regime, as well as a dependence of radionuclide identification accuracy on detector size.

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1. INTRODUCTION

The counting and spectrometric measurements are widely used for determination of a partial activity of radioactive waste.

Application of spectrometers based on Ge(Li) detectors, having high sensitivity and energy resolution, allows to solve the problems of analysis of the count samples (see, for example, [1]). However, these problems are solved mainly under conditions of laboratories and measurement stands. The use of such detectors for a remote monitoring is impeded or impossible at all because of the necessity of their cooling up to fluid nitrogen temperature. Besides, Ge(Li) detector to be placed in a cryostat has the considerable dimensions. Therefore a development of spectrometers on a basis of CdTe (CdZnTe) monocrystal having enough resolution and not requiring severe cooling is an urgent problem of the field gamma-spectrometry.

The purpose of this work is the improvement of energy resolution of a spectrometer using CdZnTe detector by means of a noise characteristics improvement of the preamplifier and magnification as much as possible of permissible statistical fill of the spectrometer circuit.

2. DESIGN OF SPECTROMETER

Spectrometer is executed structurally as a block of detection (it consists of CdZnTe detector, preamplifier and feed filter) supplied with the thin (20 μm) Be window and block of the amplifier - shaper.

The basic problem faced during development of the spectrometer was the improvement of its energy resolution in a given range of the gammas energy. A resolution of spectrometer with a semiconductor detector is determined by a number of parameters. First of all it depends on a collection efficiency of charge carriers generated by gamma radiation in the detector volume, on a performance of detector material (the lifetime, mobility of charge carriers), its homogeneity, and on a voltage applied to the detector. Other factor giving the essential contribution to quantity of the energy resolution, is the electric noise of detector-preamplifier system connected with fluctuations of detector current.

The measuring circuit of the spectrometer is executed using Analog Devices elements. The block diagram of the spectrometer is represented in Fig. 1.

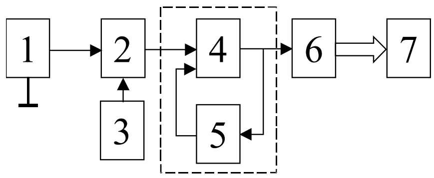

Fig. 1. *Block diagram of counter - spectrometer (CS) with CdZnTe detector: 1 - detector; 2 - preamplifier; 3 - high-voltage feed; 4 - pulse shaper-amplifier; 5 – stabilizer of datum level; 6 - analogue-digital converter (ADC); 7 - IBM-PC*

A signal from CdZnTe detector output acts on the preamplifier. From the latter a pulse acts on the shaper amplifier with a stabilizer of datum level and a rejecter of superimpositions. Then a signal is digitised in the 12 bits ADC. The detector is connected directly to gate of first stage transistor of the preamplifier for elimination of noise of the input capacitor.

A dependence of the CS energy resolution on detector voltage U_d demonstrates the spectrums, which are given in Fig. 2.

A collimating of gammas flux improves the energy resolution of spectrometer (see Fig. 3). Its calibration was carried out with use of standard Am-241 source.

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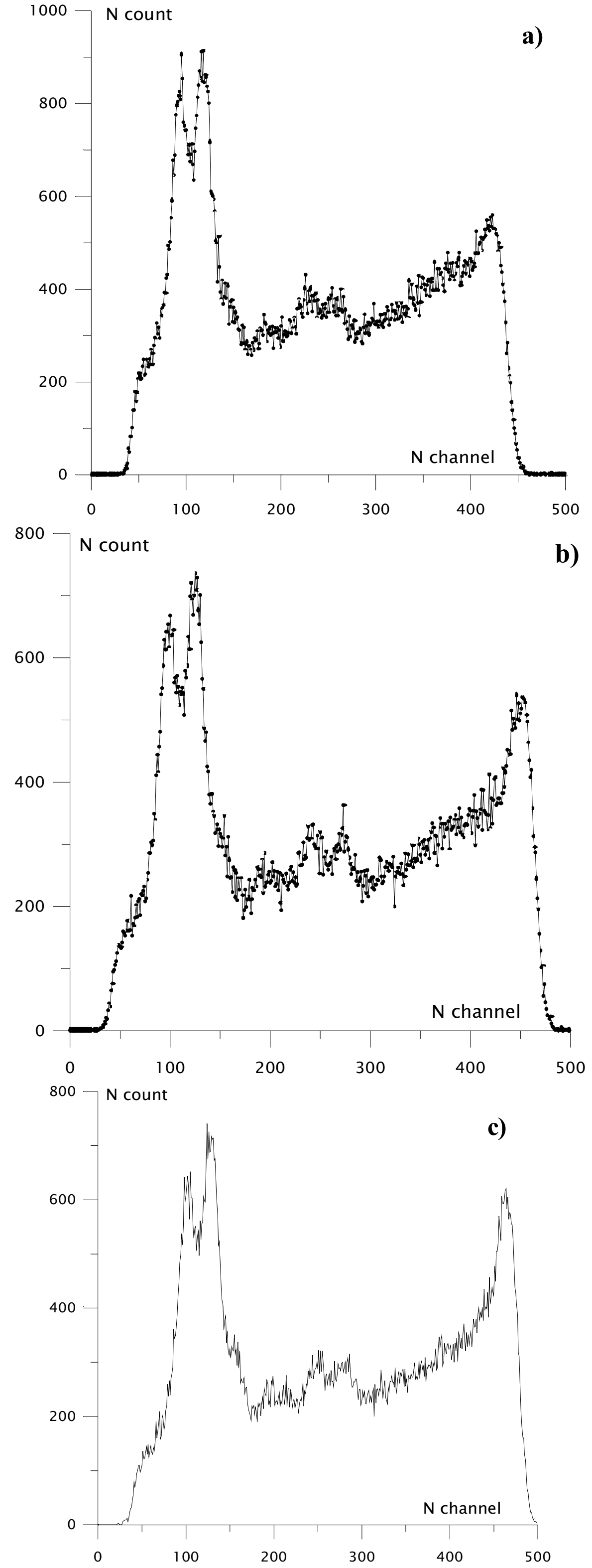
2. OPERATION OF SPECTROMETER UNDER MAJOR FILL

Tacking into account the CS operation with high-active samples its energy resolution dependence on input pulse frequency is of a great importance. The spectrums of high-active ^{99}Mo sample (exposition dose rate 100 mR/s) measured with CdZnTe detector are submitted in Fig. 4.



The CS energy resolution was measured along the line E_γ=140 keV (Tc-99m - daughter nucleus of the Mo-99 isotope). It is visible from spectrums obtained that at the fill less than $10^4 s^{-1}$ the resolution does not change practically. At the fill more than $2{*}10^4 s^{-1}$ the resolution is worsened, that can be explained by an overload of the spectrometer (preamplifier and amplifier - shaper).

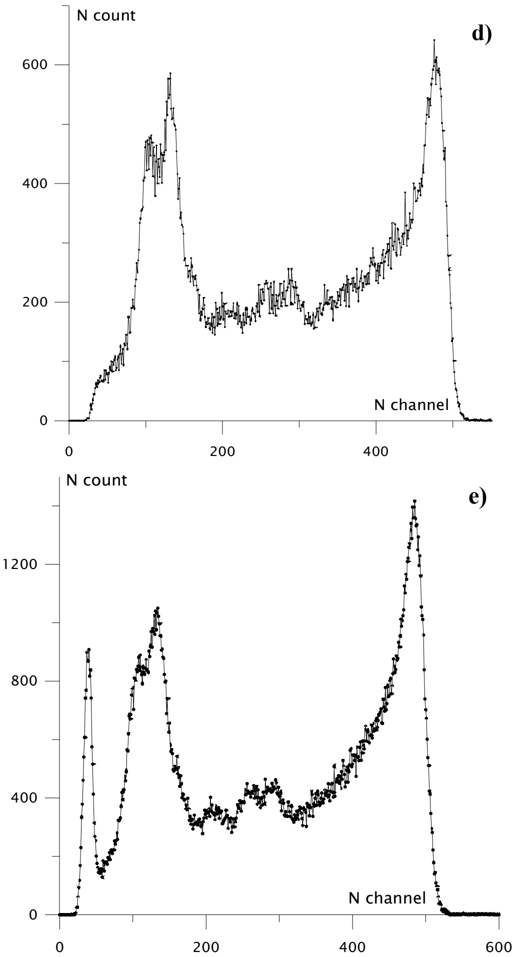


Fig. 2. *a) - U_d=50V; b) - U_d=75V; c) - U_d=100V; d) - U_d=150V; e) - U_d=200V*

The fill of the CS was varied by change of sample-detector distance. Besides the various filter materials were used (Fig. 5,6). The fill was checked using the software of pulse analyzer.

CONCLUSIONS

As a result of carried out examinations the small-sized not cooled counter - spectrometer with the following specification is designed: CdZnTe monocrystal size, mm – 6x6x1; rated detector temperature t, °C – 25; detector noise at t, кeV – no more than 1.6; maximum fill of spectrometer n_{max}, c^{-1} – $2{*}10^4$; resolution for energy of gammas E_γ=59.6 кeV (Am-241) at n_{max},% – no more than 10; detection block size, mm – 30x40x35; maximum detection block-amplifier-shaperdistance, m – not less than 50.

Last two parameters provide a possibility of detector operation with the remote controllable manipulators for analysis of the samples in hard-to-reach places or under high-level irradiation.

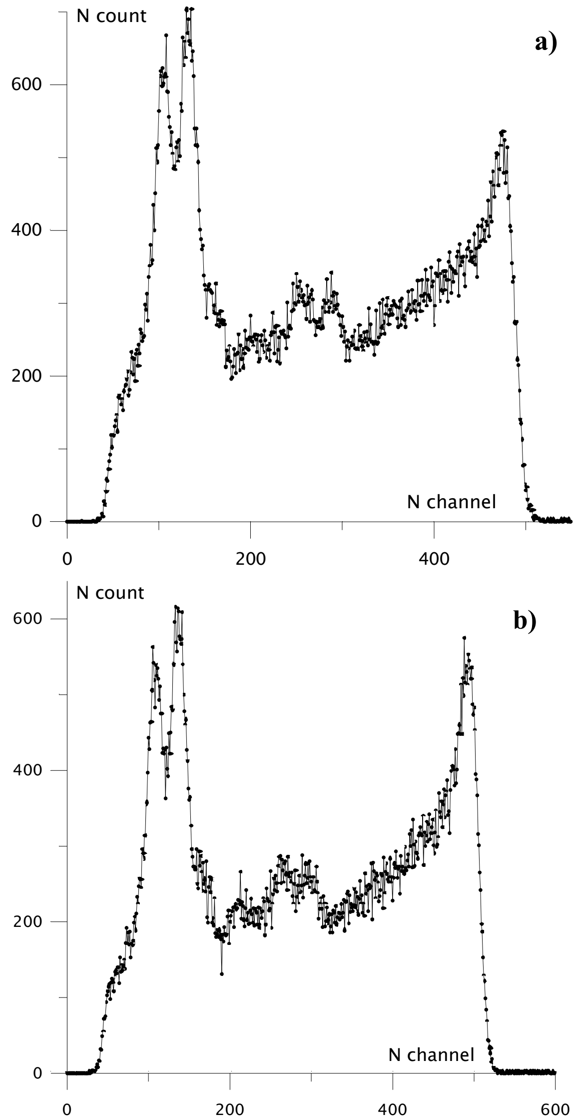


Fig. 3. *The same, that in Fig. 2 with 1.5 mm Fe collimator*

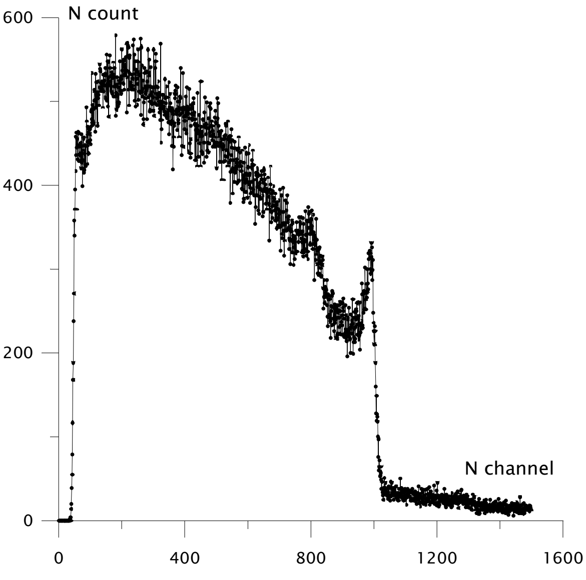


Fig. 4. *Spectrum of ^{99}Mo sample (Cu filter of 2 mm thick)*

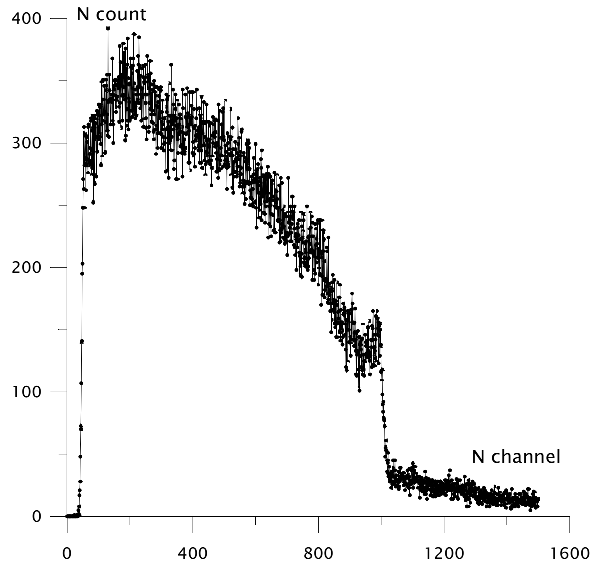


Fig. 5. *The same, that in Fig.4 with Al filter of 1mm thick and 1.5 mm Fe collimator*

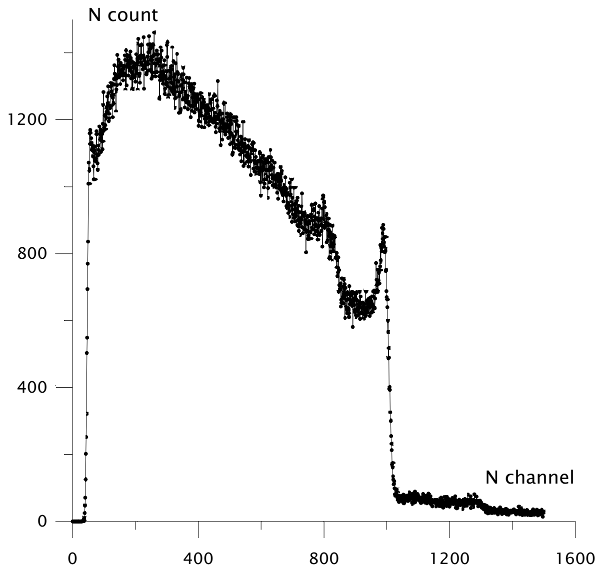


Fig. 6. *The same, that in Fig. 4, with Cu filter of 0.5 mm thick*

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