APPLICABILITY ASSESSMENT OF Fe_3O_4-SiO_2-Au NANOPARTICLES FOR THE CANCER RADIOTHERAPY

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To date radiotherapy is one of the most common methods of cancer treatment. One of the methods of raising the effectiveness of radiation therapy is to increase the absorbed radiation dose in the tumor localization area by infusing nanoparticles with a high atomic number into a given area. The high cross-sections of the interaction of heavy materials with radiation provide a significant output of low-energy secondary electronic and electromagnetic radiation. Secondary radiation leads to a significant increase of the absorbed dose near the irradiated nanoparticles.

The general purpose of this work is to experimentally determine of the secondary electromagnetic radiation energy spectrum from Fe_3O_4-SiO_2-Au nanoparticles during irradiation γ-radiation flux from ^{137}Cs.

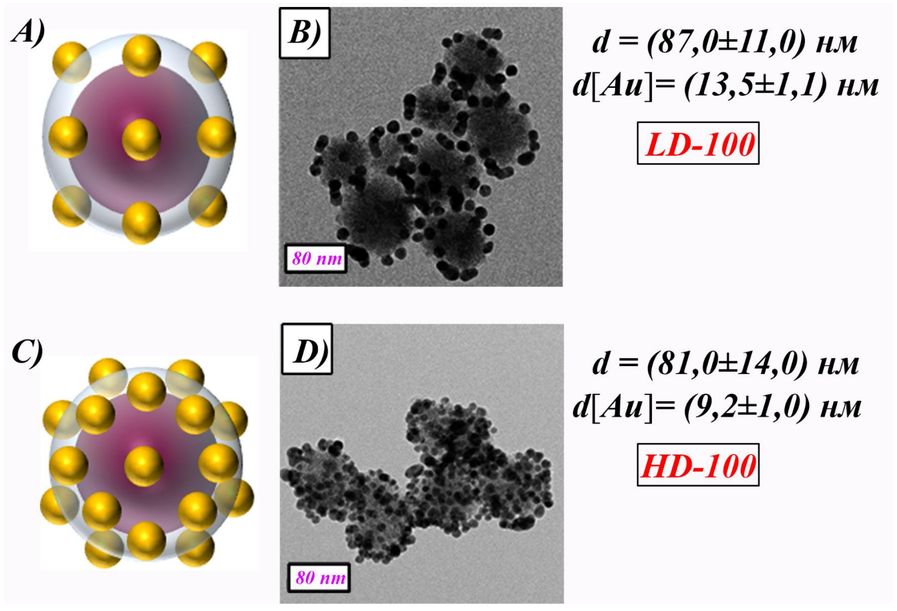

Fig.1. Characteristics of Fe_3O_4-SiO_2-Au nanoparticles
A, C - model of nanoparticles; B, D – TEM- image of nanoparticles

Transmission electron microscopy studies have shown that the nanoparticles used for conducting experiments are represented by a core-shell structure (Fig. 1). A large spherical core of magnetite is covered with a thin silica shell. Gold nanoparticles are grown on the surface of the shell.

To register the spectrum of secondary electromagnetic radiation generated by irradiation of nanoparticles with a gamma-ray flux, we have designed an unit, the scheme of which is shown in Figure 2.

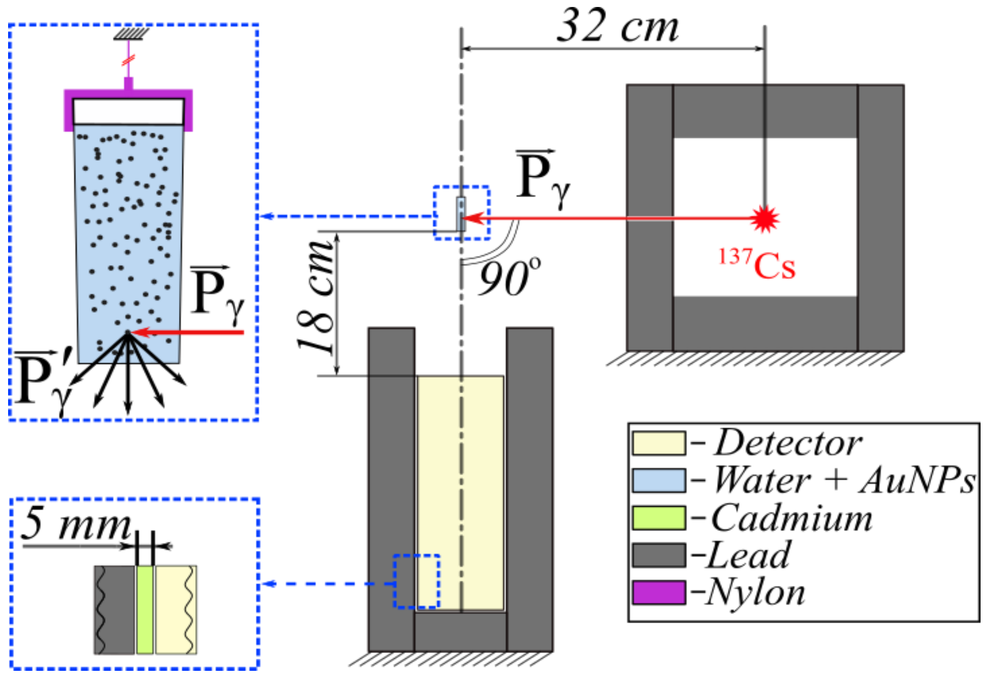

Fig.2. Experimental unit scheme

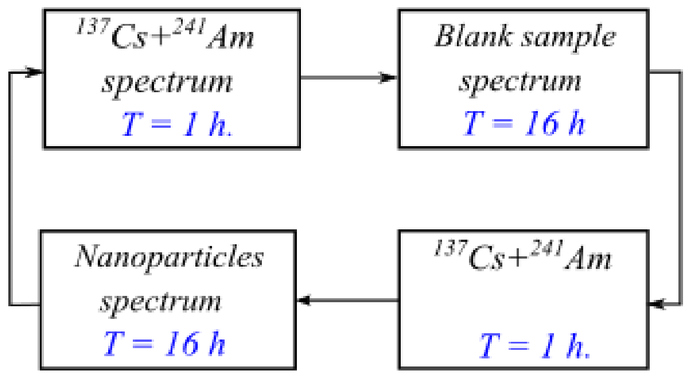

Fig.3. Measurement protocol

Samples (1 ml of suspension of nanoparticles in water, concentration of nanoparticles 0.5 mg/ml) were packed in plastic cuvettes (Eppendorf type) with a volume of 1.5 ml and fixed in the appropriate position of the samples holder. To account for the background component of the obtained data, the energy spectrum of the blank sample was measured. As a blank sample, 1 ml of bidistilled water packed in a similar cuvette was used.

In order to avoid energy drift of the detector, the duration of spectra measurements was 16 hours. To account for the thermal drift of the equipment, measurements were carried out sequentially – alternating the test and idle samples. To control the operating parameters of the detector (energy calibration, resolution, registration efficiency), at the end of each measurement stage, the energy spectra of the standart gamma-ray source (^{241}Am and ^{137}Cs) were measured. The scheme of the measurement protocol is shown in Figure 3.

To process the obtained experimental data, the measured energy spectra were conditionally divided into several ranges. The width of each ranges was selected according to the resolution of the device. In a result 25 sites in the analyzed spectrum were identified. The next step of the processing was summing up the number of registered events in each of the selected range.

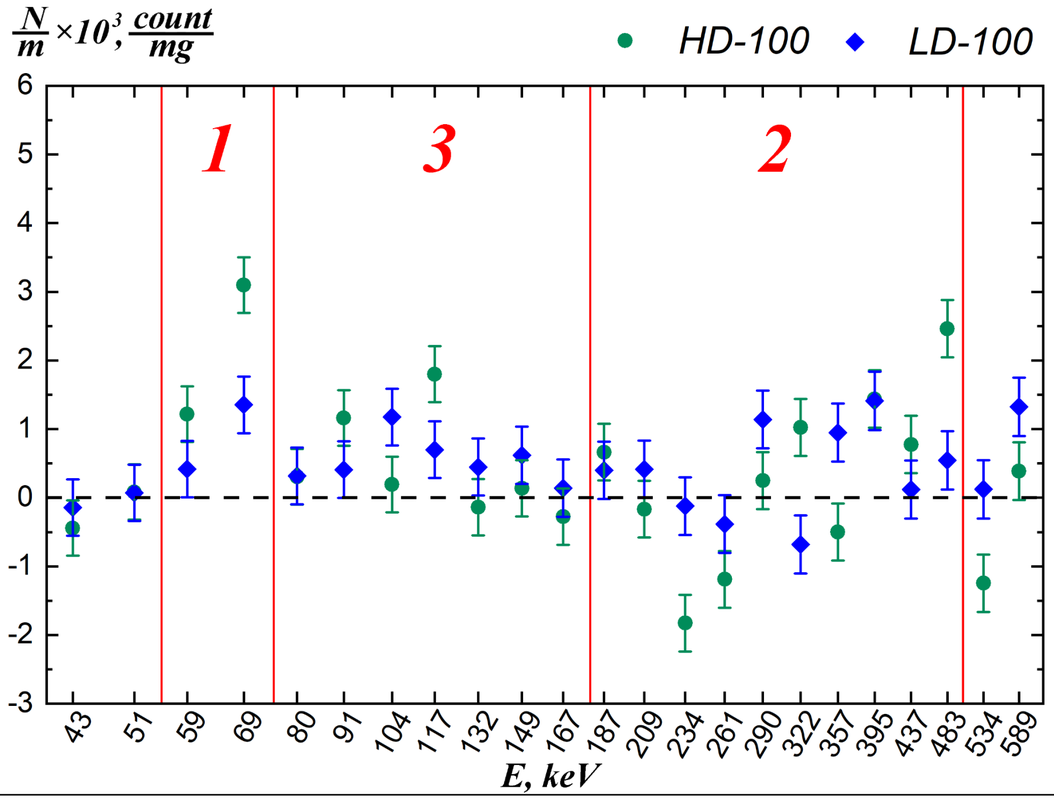

Fig.4. The spectrum of secondary electromagnetic radiation of Fe_3O_4-SiO_2-Au nanoparticles under irradiation of ^{137}Cs gamma ray
The normalization is done for the gold mass in the nanoparticles

The determination of the analytical signal of secondary radiation generated by irradiation of nanoparticles with a ^{137}Cs radiation flux is carried out in accordance with the equation:

$$\Delta N_i = N_i - N_i^{BG}$$

where: ΔN_i– the intensity of the analytical signal of secondary electromagnetic radiation; N_i – the average value of the intensity of the analytical signal in the spectrum of the sample, N_i^{BG} – the average value of the intensity of the analytical signal in the spectrum of the blank sample, – the number of the energy range.

The absolute error of determination is calculated by the method of determining the error of indirect measurements, in accordance with the equation:

$$\sigma(\Delta N_i) = \sqrt{N_i + N_i^{BG}}$$

where: $\sigma(\Delta N_i)$ – absolute error in determining the intensity of the analytical signal of secondary electromagnetic radiation;
The increase the signal intensity in region 1 is due to the characteristic ray of gold. The increase in signal intensity in region 3 is due to the registration of radiation scattered due to the Compton effect. The presence of an instrumental response in region 2 is probably caused by the registration of gamma-quanta repeatedly scattered in the sample volume.

Conclusions: a method for experimental determining the energy spectrum of secondary radiation generated by irradiation of Fe_3O_4-SiO_2-Au nanoparticles by a gamma-ray flux of a ^{137}Cs radionuclide source has been developed . It was being shown that the irradiation of Fe_3O_4-SiO_2-Au nanoparticles is accompanied by the generation of secondary gamma radiation caused by the photo- and Compton effect.

We acknowledge the Russian Ministry of Science and Higher Education. Synthesis and structural studies of nanoparticles were carried out with financial support the Russian Ministry of Science and Higher Education, State Order No. 0657-2020-0013. Radiological studies were carried out with financial support of the Ministry of Russian Ministry of Science and Higher Education, StateOrder No. 0205-2021-0002.