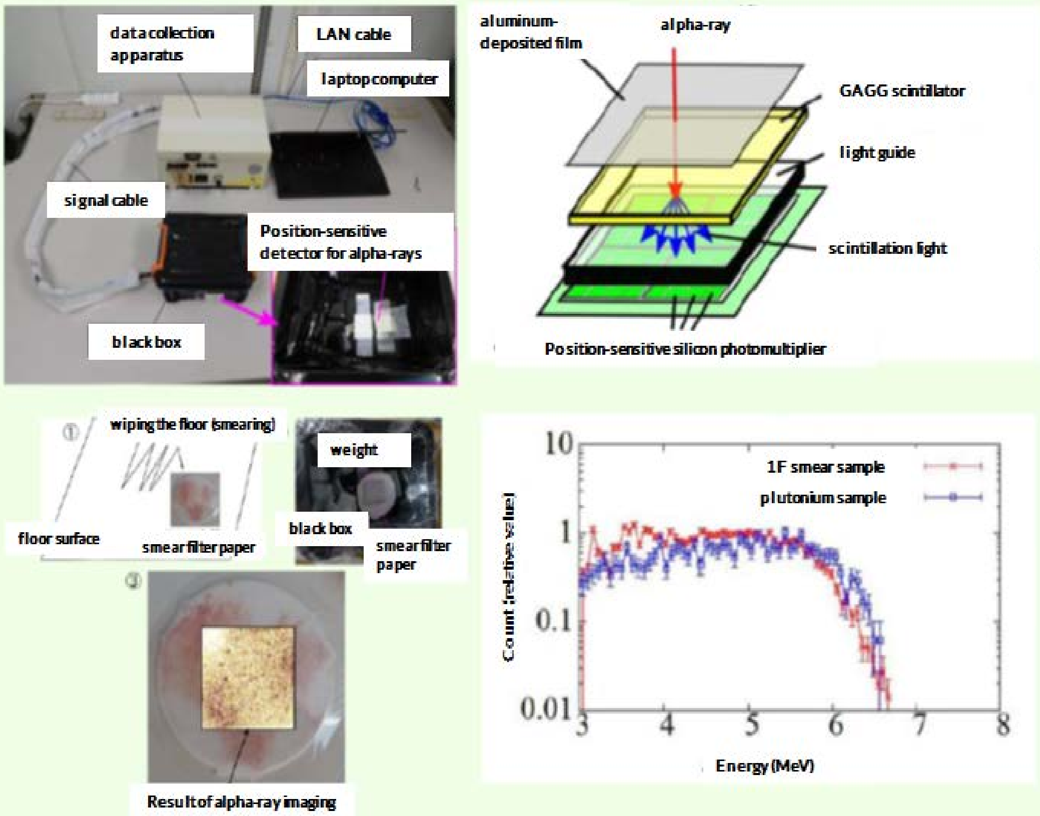
Topics Fukushima April 1, 2019 No.91



New technology to measure alpha-ray emitting nuclides originating from nuclear fuels "on site" and "instantaneously" was developed.

The technology will contribute to the smooth promotion of decommissioning works at the Fukushima Daiichi Nuclear Power Station.

The Collaborative Laboratories for Advanced Decommissioning Science (CLADS), Japan Atomic Energy Agency (JAEA), has developed "detector for visualizing alpha-ray[1)] emitting nuclides" that can detect the contamination by alpha-ray emitting nuclides with high precision towards the smooth decommissioning works for the Fukushima Daiichi Nuclear Power Station (1F), Tokyo Electric Power Company

Holdings., Inc. Using this new detector, radioactive materials adsorbed on smear samples[2)] that had wiped the floor of the 1F reactor building were measured. As a result, the distribution status of alpha-ray emitting nuclides that are considered to originate from nuclear fuels was successfully detected with high precision.

The newly developed detector can measure the distribution of particles containing alpha-ray emitting nuclides simultaneously with the energy distribution of the alpha-rays. Owing to this performance, it is expected that the detector will be applied to various important works for the smooth promotion of the decommissioning works such as the elucidation of distribution status of alpha-ray emitting nuclides, radiation management of working environment and radiation protection for workers.

What is the difference between conventional detectors and the newly developed one?

Radioactive materials were released inside and outside of the reactor buildings by the 1F accident. Up to now, gamma-ray emitted from radioactive cesium has been main our concern. However, it should be noted that there are also alpha-ray emitting nuclides among the released radioactive materials. The typical alpha-ray emitting nuclides are plutonium[3)] and uranium that are produced inside the reactor. If these nuclides are inhaled into our body, the internal tissue and organs will be continuously exposed to alpha-rays, resulting in the internal radiation exposure. For this reason, the detection of alpha-ray emitting nuclides is quite important for the people working on the decommissioning.

However, a commercially available ZnS(Ag) survey meter (right photograph) has a drawback that only information on the intensity (count rate) of alpha-ray emitting nuclides is obtained. Therefore, a survey meter cannot distinguish natural radioactive nuclides such as radon from plutonium or uranium. In addition, a conventional survey meter cannot specify the position and distribution of alpha-ray emitting nuclides.

Under these circumstances, CLADS has newly developed “detector visualizing alpha-ray emitting nuclides”. Using this detector, the radioactive materials adsorbed on smear samples collected in the 1F reactor building were measured. As a result, it was demonstrated that the new detector is useful to measure the position and energy distribution of alpha-ray emitting nuclides, which could not be measured by the conventional ZnS(Ag) survey meters.

■ How to measure alpha-rays? (Distinguishing “natural nuclides” from “nuclear-fuel-related nuclides”)

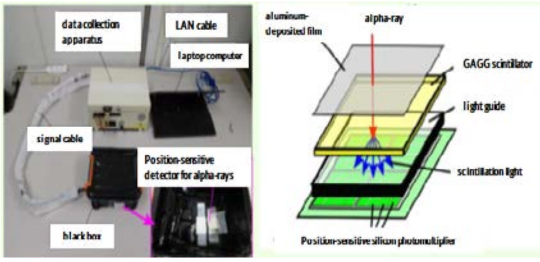


Fig. 1 Newly developed detector visualizing alpha-ray emitting nuclides (left) and its principle (right).
(The detecting surface is upward. The detector is placed in a black box during the measurement.)

Figure 1 shows the newly developed detector visualizing alpha-ray emitting nuclides. Compared with beta-rays and gamma-rays, alpha-rays have a characteristic that the flight distance (range) is extremely short. Therefore, in order to measure alpha-rays with high precision, a thin film of GAGG[4] scintillator[5] of 50 μm thickness and optical waveguide (light guide) were used. As a photodetector, a position-sensitive silicon photomultiplier was used. When an alpha-ray is injected into the GAGG detector, light is emitted, and the light is introduced into the position-sensitive silicon photomultiplier through the light guide. After the light is converted to electric signal by the position-sensitive silicon photomultiplier, the positions of the alpha-rays are two-dimensionally visualized. In addition to the position, the detector can simultaneously measure the information on alpha-ray energy. Therefore, we can distinguish whether the alpha-ray emitting nuclide is natural nuclide or artificial one.

As a demonstration of the newly developed detector, radioactive materials adsorbed on the smear samples collected in the 1F reactor building were measured in cooperation with the Tokyo Electric Power Company Holdings., Inc. (Fig. 2). In order to distinguish the spectrum of alpha-rays from that of beta-rays, a sheet of paper was placed between the detector and the smear sample. Since alpha-rays are stopped by this sheet of paper but beta-rays transmit it, we can obtain the spectrum of only alpha-rays by taking the difference between the spectra with and without the paper.

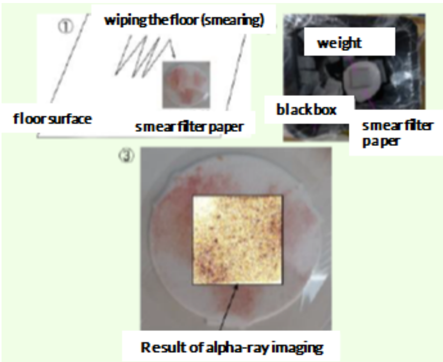


Fig. 2 Smear sample collected in the 1F reactor building. The measurement is carried out in the order of ① to ③. The detailed procedure in each step is as follows.
① The floor of the reactor building is wiped using a smear filter paper.
② The measurement is carried out by setting the smear filter paper on the measuring surface of the detector.
③ Two dimensional distribution of radioactive nuclides including alpha-ray emitting nuclides on the smear filter paper is obtained. Also, the energy spectra of alpha-rays can be simultaneously measured.

The smear samples collected at the 1F were measured using the detector. As a result, the following results were obtained.

(1) The energy spectra of the smear samples collected in the 1F were compared with those of the samples taken at the nuclear facilities in JAEA. As a result, it was found that these two spectra were in good agreement (Fig. 3).

(2) The two-dimensional distribution of alpha-ray emitting nuclides (result of alpha-ray imaging) was measured. As a result, two kinds of the particle distribution states were observed; one is the localized distribution (granular state) and the other is the homogeneous distribution (fine-grained state) (Fig. 2). Although the cause of the existence of such two distribution states has not been clarified, the present detector was able to observe the distribution of alpha-ray emitting nuclides, which had been difficult to be observed by the commercially available detectors. From now on, we will investigate the cause and the more detailed distribution of nuclides.

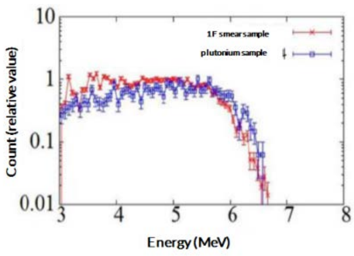


Fig. 3 Comparison of alpha-ray energy spectra between a smear sample and a plutonium sample. The two spectra accord at the energy of alpha-rays from plutonium around 5.5 MeV.

As described above, the present detector can simultaneously measure the distribution and energy of alpha-rays in particles including alpha-ray emitting nuclides. Therefore, it is expected that the detector will be applied to various works that will be important for the smooth promotion of decommissioning, such as the observation of the distribution of alpha-ray emitting nuclides, radiation management in working environment and radiation protection for workers. By this detector, we would like to contribute to the promotion of the 1F decommissioning works. From now on, we will make improvements as required so that the detector can be quickly applied to the on-site works.

From the researcher

The CLADS has been making efforts in developing the detector for three years, and finally completed the demonstration test of the detector at the 1F. Dr. Yuki Morishita, a researcher responsible for this project, explained about the hard time in the development, saying “Originally, this detector has been developed to measure the contamination by plutonium in nuclear fuel facilities. This time, the detector was tried to be applied to the 1F samples. As a result, we succeeded in detecting alpha-ray emitting nuclides originating from nuclear fuels. The measurements were carried out outside warehouse in midwinter. During the measurements, there were some troubles. For example, the detector suddenly stopped working. In such case, we solved the problem by accumulating our experiences. This time, the measurements were carried out at 1F in cooperation with the Tokyo Electric Power Company Holdings., Inc. We were able to clarify that the distribution of alpha-ray emitting nuclides are different from the previous results. We are planning to further improve the performance of the detector to clarify the characteristics of the distribution.”

【Explanation of technical terms】

1) Alpha-ray

One of the kinds of ionizing radiation. It is composed of helium nucleus. It flies several centimeters in air, and transmits only several tens μm in tissue. This means that it gives large energy to the target material in a short distance. Therefore, when inhaled, it has a large effect (internal exposure) on the human body.

2) Smear sample

Circular filter paper to collect contaminants on material surface. The surface contaminants are collected by wiping the surface with it.

3) Plutonium

A radioactive element which is one of the alpha-ray emitting nuclides. It generally exists in the form of oxide (PuO_2). It enters the human body by inhalation and ingestion. The inhalation is the riskiest process. If it is inhaled, tissues in the body will continue to be exposed to alpha-ray radiation.

4) GAGG scintillator

One of the scintillating crystals. It is composed of gadolinium, aluminum, gallium and garnet. Since it has characteristics that the amount of light emission is large and the wavelength of the emitted light fits a silicon photomultiplier, high energy resolution can be obtained for alpha-rays. In addition, since there is no concern that it degrades by moisture in the air due to its no deliquescent property, it can be used stably for a long time.

5) Scintillator

A fluorescent material that emits light (scintillation light) by ionizing radiation. The number and energy of ionizing radiation can be measured by converting the scintillation light to the electric signals.

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