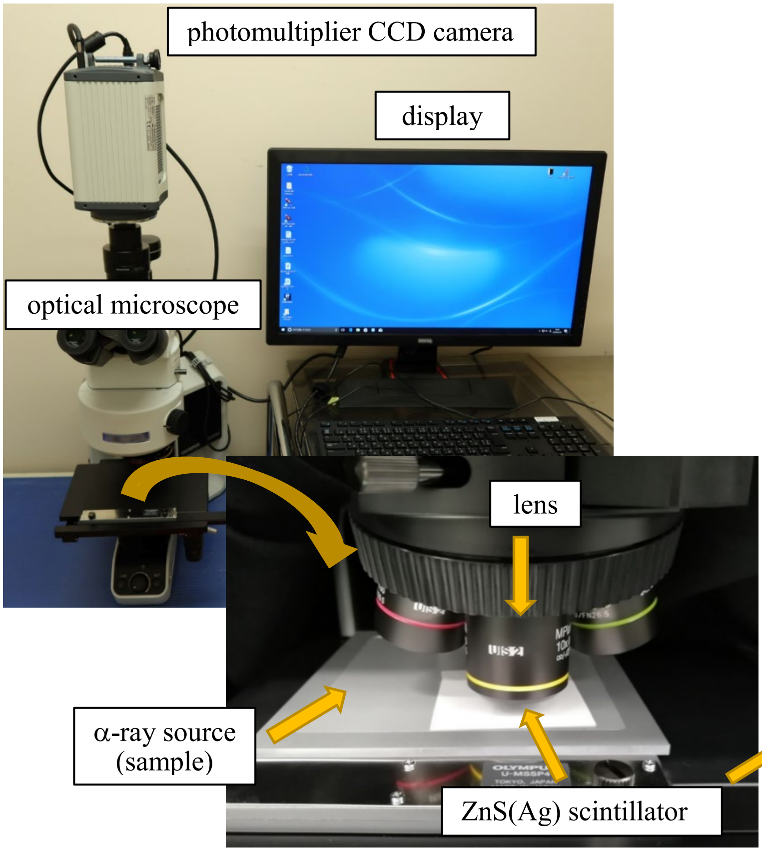
Topics Fukushima No.105 August 31, 2021



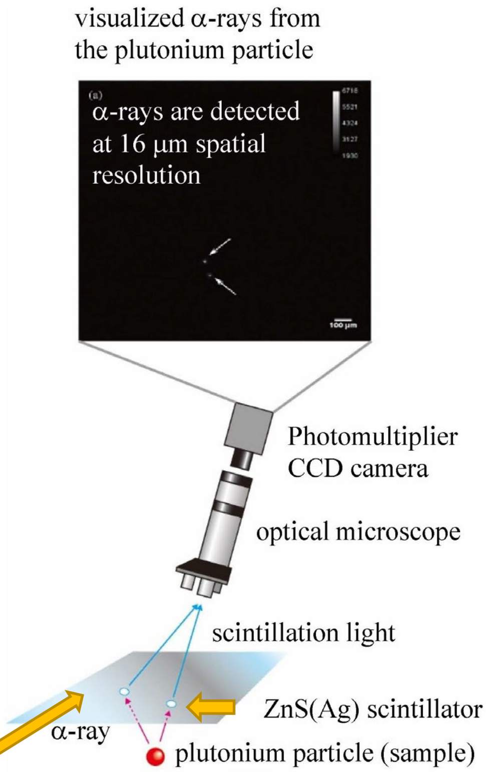


Fig. 1 Ultra-high spatial resolution α-ray imaging detector and visualization of α-rays from a plutonium particle.

Ultra-high spatial resolution α-ray imaging detector that combines a photomultiplier CCD camera and an optical microscope. It can visualize an α-ray at real time one by one at 16 μm[*1)] spatial resolution without being overlapped each other.

The α-ray emitted from the plutonium particle is visualized as a light by the scintillator.
By counting the α-rays at real time, it becomes possible to know the amount of plutonium and evaluate the size of the particle.
The higher the spatial resolution is, the easier the neighboring plutonium particles can be distinguished.

Measuring the size of α-ray emitting particles at real time

— Ultra-high spatial resolution α-ray imaging detector has been developed. —

In order to apply to nuclear facilities, the Collaborative Laboratories for Advanced Decommissioning Science (CLADS), Sector of Fukushima Research and Development, Japan Atomic Energy Agency (JAEA) has developed “ultra-high spatial resolution α-ray imaging detector” which combines an ultra-thin scintillator[*2)], a photomultiplier CCD (Charge Coupled Device), and an optical microscope. This new instrument was developed based on the α-ray imaging detector that is being developed in the medical field, etc. in collaboration with Tohoku University and Mitsubishi Electric Co.

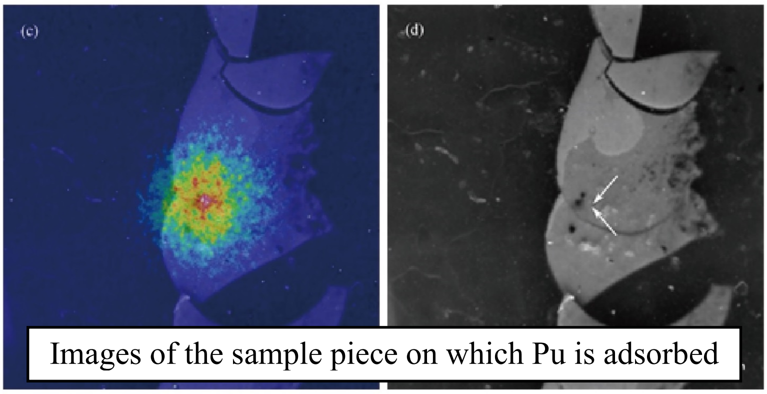
In this instrument, only α-rays emitted from a plutonium (Pu)[*3)] particle are first converted to scintillation light by a thin (about 8 mm) ZnS(Ag) scintillator. Then, the scintillation light goes through an optical microscope, and it is visualized by taking pictures with a photomultiplier CCD camera. When the instrument was actually applied to a PuO_2 sample, it was successful to visualize an α-ray one by one at real time. Further, the spatial resolution[*4)] of α-rays was obtained to be 16 μm, which demonstrated that the performance of the present instrument is superior to those of conventional detectors.

◆ Outline of the development

In nuclear facilities, etc., it is important to know how large are the particles that emit α-rays in a working site for evaluating the internal radiation exposure to workers. Conventional detectors had a drawback that the real time measurement was not possible. In addition, since some of the conventional detectors had the sensitivity to radiations other than α-rays, it has been required to distinguish α-rays from the other kinds of radiation such as X-rays, γ-rays, β-rays and neutrons.

When a real PuO_2 sample was measured with the ultra-high spatial resolution α-ray imaging detector, it was successful to visualize an α-ray one by one at real time without being overlapped. Also, the spatial resolution of α-rays was obtained to be 16 μm. Although the performance cannot be simply compared due to the different measurement principles, it was verified that the present instrument has the performance that the information on the detected position of an α-ray can be identified at finer spatial resolution than the conventional 25 μm. Using this instrument, it will become easy to identify multiple Pu particles that exist next to each other.

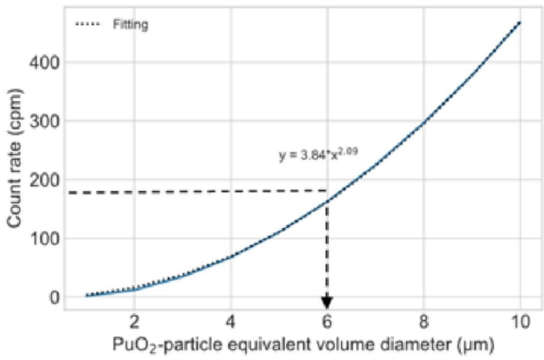
The lower figure shows the results of imaging for a real Pu particle (PuO_2). It is seen that the position of the Pu particle in the optical image of the PuO_2 sample could be precisely identified.



Images of the sample piece on which Pu is adsorbed

Left: Superposition of the optical image for the sample and α-ray distribution of the plutonium particle.

Right: The position of the plutonium particle can be precisely identified by the superposition.



Conversion from counting rate of α-rays to the size of the plutonium particle.

In this instrument, the position of an α-ray can be visualized one by one, so the count rate of each Pu particle can be directly evaluated by the number of α-rays. Using these results, a method to obtain the size of a particle (equivalent particle diameter[*5)]) has also been developed.

The size of a Pu particle can be analyzed by the count rate of α-rays corresponding to the radioactivity. However, in order to precisely obtain the particle size, it is required to consider the self-shielding effect of the α-ray and the attenuation by the contamination preventing film. Therefore, the calculation including these effects has been performed, and the conversion curve that analyzes particle size from count rate was obtained. Using the conversion curve, it became possible to convert the α-ray count rate measured at real time to the equivalent diameter of the Pu particle. For the equivalent diameter of Pu particle measured this time, there was no contradiction when being compared with the results measured by a conventional method, so the validity of the present method was confirmed.

Conventional methods had a drawback that it took 10 minutes～1 hour for a measurement depending on the radioactivity of α-rays, and the time to read the data was also required. In addition, the uneven distribution of Pu could not be clarified unless the measured image was confirmed, so the re-measurements sometimes became necessary. With the development of this detector, these drawbacks have been overcome, leading to real-time particle size measurement.

◆ Future plan

We have developed an "ultra-high spatial resolution α-ray imaging detector" that does not need the reading process and can evaluate the particle size distribution in a working site at real time. With this instrument, it has become possible to rapidly measure the size distribution of Pu particles. The instrument is expected to contribute to improve the precision to evaluate the internal radiation exposure to staff working in a nuclear power plant or a nuclear fuel facility.

From now on, we will expand the data by applying the method to various samples other than PuO_2. By comparing with the other methods to measure particle size, we will further improve the precision of the conversion and proceed its demonstration. Further, by applying the method to the measurement of real samples in the Fukushima Daiichi Nuclear Power Station, we plan to proceed to evaluate the particle size distribution of α-ray emitting nuclides at the working site to the highest priority. Through these measurements, JAEA will contribute to the improvement of the accuracy for the evaluation of internal radiation exposure and the radiation protection at the working sites.

【Terminology】

*1) μm: A unit of length, which is pronounced "micrometer". 1 μm corresponds to 0.001 mm (millimeter)

*2) scintillator: A substance that emits light when a radiation enters the substance and its energy is absorbed. ZnS(Ag) scintillator is a scintillator using silver-activated zinc sulfide, which is widely used for the measurement of α-rays. It is a white powder that is painted thinly on a transparent plate, and is used for the detection of α-rays.

*3) plutonium (Pu): A radioactive material generated by a process where a part of uranium in a nuclear fuel is converted when the nuclear power station is in operation. There are the isotopes such as plutonium 238, 239 and 240. The elemental symbol is "Pu". Since an α-ray emitted from plutonium travels only several centimeters in air, it can be stopped by a piece of paper, so the external radiation exposure by α-rays can be easily reduced. However, if α-rays are inhaled from mouth or nose into the body, they may cause severe effects (internal radiation exposure) on the cells, so Pu particles must be strictly managed. Since pure plutonium cannot be used in

Japan, plutonium nuclear fuels are being produced as plutonium dioxide (PuO_2: the same as PuO_2 described in the text) that is a powder mixed with uranium.

*4) spatial resolution of α-rays: Resolution means the ability (discrimination threshold) as to how finely signals to be measured can be detected. Here, it means the index as to how finely the position where α-rays are detected can be separated on the screen.

*5) equivalent particle diameter: Diameter of spherical particles that have the same volume.

This report is the edited version of the press release on August 3, 2021.

Topics Fukushima No. 105
Fukushima Administrative Department,
Sector of Fukushima Research and Development,
Japan Atomic Energy Agency (JAEA)

Address: 8F Taira Central Building, 7-1 Aza-Omachi, Taira,
Iwaki-shi, Fukushima 970-8026, Japan
Phone: +81-246-35-7650 Fax: +81-246-24-4031
Website: https://fukushima.jaea.go.jp/en/