Evalution of neutron self-absorption in gold and application to measurement of neutron flux

Evaluation of neutron self-absorption in gold and application to measurement of neutron flux

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INTRODUCTION

The stable isotope of gold is only ^{197}Au. It has large cross-section for thermal neutron (98.7 b), and becomes ^{198}Au ($T_{1/2}$ = 2.69 d) by neutron capture reaction (^{197}Au (n, γ) ^{198}Au). The neutron detector using this reaction has advantage of no electricity, maintenance free, excellent cost performance and portability compared with the ^{3}He neutron counter. Moreover, the detector can be set up under high and low temperature, in water and in soil because of chemical stability of gold. It became possible to measure low-level ^{198}Au induced by environmental neutron irradiation (c.a. 10^{-2} n$\cdot$cm$^{-2}\cdot$s^{-1}) by using the extremely ultra low background Ge detectors installed at the Ogoya Underground Laboratory (OUL). However, large cross-section of ^{197}Au for neutron generates neutron self-absorption, and then underestimate of neutron flux from ^{198}Au activity may occur at the calculation. Therefore it is necessary to evaluate the self-absorption beforehand, and to correct the influence.

In this study, we experimentally evaluated self-absorption of neutrons in gold target by using Kinki University nuclear reactor (UTR-KINKI) and natural neutron irradiation to use gold as excellent neutron detector.

EXPERIMENTAL

Seven gold grain samples, diameter of which were ranging from 0.8 to 3.4 mm, were irradiated 10 minutes by neutrons in center of UTR-KINKI (neutron flux: 1×10^{7} n$\cdot$cm$^{-2}\cdot$s^{-1}). Piled up thirty gold plates, sizes of which were c.a. $10 \times 10 \times 0.15$ mm, were irradiated for 10 minutes by neutrons in center of UTR-KINKI. Ten gold plates, sizes of which were c.a. $40 \times 30 \times 0.2$ to 0.7 mm, were irradiated by leakage neutrons for 6 hours at outer wall of UTR-KINKI (neutron flux: 10 n$\cdot$cm$^{-2}\cdot$s^{-1}). Piled up many gold plates, sizes of which were c.a. $40 \times 150 \times 0.1$ mm, were irradiated by environmental neutron (neutron flux: 10^{-1}~10^{-2} n$\cdot$cm$^{-2}\cdot$s^{-1}) at our laboratory and hillside in Mt. Hakusan (c.a. 2000 m above sea level). The ^{198}Au activities in the gold targets were measured by using high pure Ge detectors. The ^{198}Au activities were decay-corrected.

RESULTS AND DISCUSSIONS

The ^{198}Au activities per 1g of gold in seven gold grains were shown in Fig. 1. The activities decreased with increase of grain size, and those of a 3.4 mmϕ grain sample were half of 0.8 mmϕ sample. In these results, we found that neutron flux decreases by about 25% if neutron passes through 1 mm thickness of gold.

The ^{198}Au activities per 1g gold in piled up thirty gold plates is shown in Fig. 2. The activities decreased considerably within 1 mm from both sides of the gold plates, but were almost constant over

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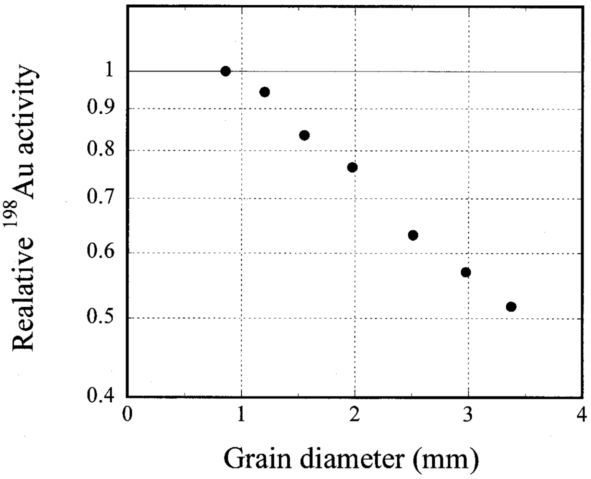

Fig. 1 Relative ^{198}Au activity in pure gold grain samples neutron-irradiated by UTR-KINKI reactor.

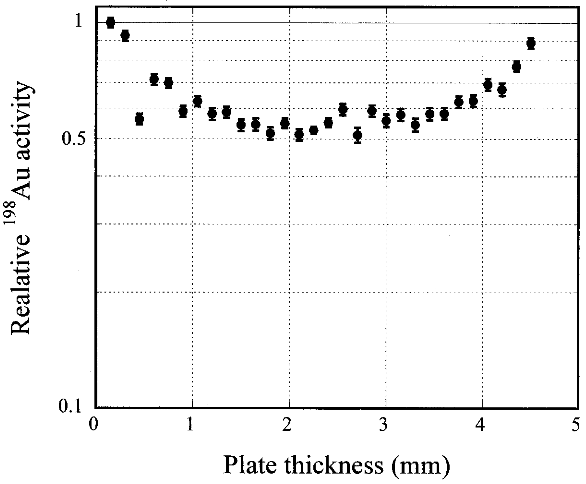

Fig. 2 Relative ^{198}Au activity in pure gold plates neutron-irradiated by neutron of UTR-KINKI reactor.

1 mm. We consider the gold plates near center were influenced by neutron irradiation from both sides in the same. The ^{198}Au activities of piled up gold plates is shown by following equation:

$$y = A \bullet e^{-ax} + B \bullet e^{-a(T-x)} \quad (1)$$

where y is the ^{198}Au activities, A the relative neutron flux of one side, B the relative neutron flux of other side, a the neutron absorption coefficient, T the total thickness of gold plates and x the position of gold plate, respectively. Using the value of ^{198}Au activities of both sides' samples, we determined that A is 1.0, and B is 0.9. We substituted 4.5 for T, and then did the regression analysis by fitting measured value of ^{198}Au activities to calculate the value of a. It was found that the value of a is 0.618, and then equation (2) was obtained.

$$y = 1.0e^{-0.618x} + 0.9e^{-0.618(4.5-x)} \quad (2)$$

If A is 1.0 and B is 1.0, equation (1) is as follows:

$$y = e^{-0.618x} + e^{-0.618(T-x)} \quad (3)$$

The equation (3) was integrated to estimate attenuation of neutron flux from ratio of area formed by ^{198}Au activities.

$$\frac{2}{0.618}\left(1 - e^{-0.618T}\right) \quad (4)$$

Assuming neutron self-absorption dose not occur, the area must be 2T, and therefore ratio of area is as follows:

$$\frac{1}{0.618T}\left(1 - e^{-0.618T}\right) \quad (5)$$

The equation (5) was plotted at Fig. 3 with other experimental data to investigate neutron self-absorption. The data of gold grains almost corresponded to that of gold plates, which was neutron-irradiated in the same reactor (UTR-KINKI). However, there is a little discrepancy between gold targets neutron-irradiated in reactor and in environment. We think these results were caused by difference of energy spectra between reactor neutron and environmental neutron. These data of neutron absorption will be useful for measurement of natural neutron flux by using gold detector.

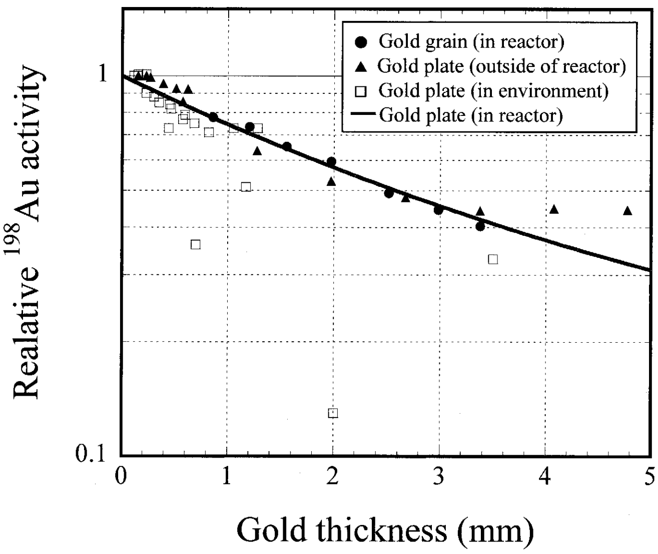

Fig. 3 Relative ^{198}Au activity obtained by many experimental to investigate neutron self-absorption of gold.