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Determination of the Spontaneous Fission Rate of ^{238}U Using Solid State Track Recorder

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=Abstract=

The spontaneous fission rate of ^{238}U has been determined using a solid state track recorder that was a pre-etched mica. Counting the tracks revealed in mica made it possible to calculate the spontaneous fission rate. The mica remained in close contact with a $^{238}UO_2$ foil for about five years.

The resulting fission rate was 5.21±0.33 fissions/g-sec.

1. Introduction

The ^{238}U fission fragment emitter foil in combination with the mica solid state track recorder has been used in the fast neutron dosimetry[1]. The reliable dosimetry by this foil in the extremely low neutron environment depends upon the accurate knowledge of the spontaneous fission rate. Unfortunately, there is a discrepancy between the values obtained by several investigators using different methods[2~6].

The present work is to determine the spontaneous fission rate by using the track counting techniques. The mica solid state track recorder(SSTR) was kept in close contact with a depleted uranium foil for about five years. Spontaneous fission fragment tracks registered in the mica were selectively etched in a HF solution and then counted with an optical microscope. The chemical etching and track counting methods adopted here in this study are essentially the same as those of Ro et al.[7]

2. Theoretical Background

The fission fragment track density, H(tracks/cm^2), on the solid state track recorder irradiated for a contact period, T, is given by[7]

$$H=\varepsilon d\rho PFT \quad (1)$$

$$F=C_5F_5+C_8F_8 \quad (2)$$

Where ε: track registration efficiency of the SSTR=0.919±0.019 for mica)[8]

d: thickness of the foil(cm)

ρ: foil density(=10.9 g/cm^3)

P: escape probability of the fission fragments from the emitter(for thick fission fragment emitter, P=1/2)[9]

C: isotopic composition

F: spontaneous fission rate

The subscripts 5 and 8 in the Eq. (2) refer to ^{235}U and ^{238}U, respectively. For relatively thick foils compared to the ranges of the fission fragment in the emitter, d should be replaced by the range (R) which is 5.51×10^{-4} cm.[10]

The first term, C_5F_5, in the righthand side of Eq. (2) is negligible in comparison with the second term if the foil is natural or depleted one. The track density at the end of contact period is then

$$H=\varepsilon R\rho PC_8F_8T \qquad (3)$$

and

$$F_8=\frac{H}{\varepsilon R\rho PC_8T}\ (\text{fissions/g-sec}) \qquad (4)$$

3. Experimental

Clean mica samples from Australia were selected, cleaved and used as the SSTR in this study. The circular mica slices, typically 1.50 cm in diameter by about 0.005 cm thick were placed next to the fission fragment emitters, UO_2 foils. The foils purchased from Reactor Experiments Inc., USA were pure uranium metal but formed a uranium oxide after extended exposure to the atmosphere. Some of their physical properties are given in Table 1. Fig. 1. shows the exploded view of the uranium foil and the SSTR in a brass sample holder which is a cylindrical capsule having 1.5 cm of inner diameter. The holder is furnished with a screw so as to ensure good surface contact between the SSTR and the uranium foil. As Can be seen in Fig. 1, mica-1 which was incorporated with the U_1 foil is covered with 1-mm thick cadmium to eliminate the possible influence of external thermal neutrons. Mica-2 is employed in order to estimate a contribution by thermal neutrons while mica-3 is for the measurement of background tracks.

Table 1. Some physical properties of uranium* foil

Foil	U_1	U_2
Thickness (cm)	0.0048	0.0051
Diameter (cm)	1.27	1.27
Purity (%)	99.935	99.935

*Depleted to 0.22% ^{235}U.

Prior to making contact with the uranium foil, the SSTRs were heated to 600°C for one hour and then pre-etched in a 46% HF solution at an ambient temperature of about 20°C for five hours. This was done to expose the "fossil" fission fragment tracks that might have been produced over the geological period by spontaneous fission of the natural fissionable impurity material contained in the mica; these can easily be distinguished by

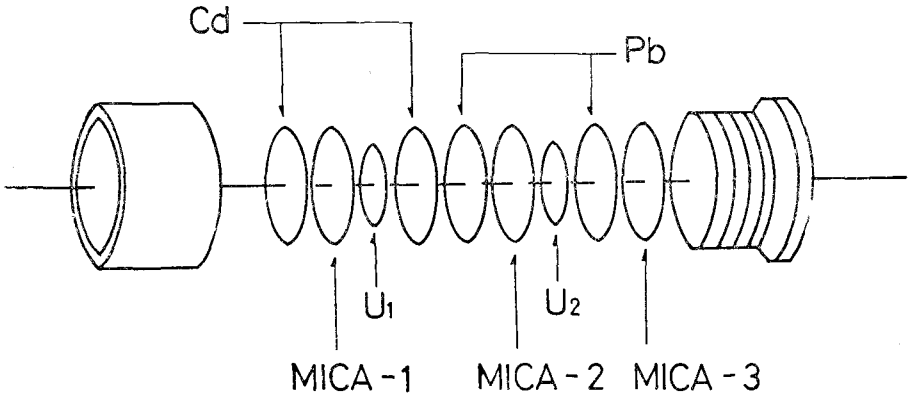

Fig. 1. Exploded View of the Depleted Uranium Foil and SSTR in the Brass Sample Holder.

Table 2. Values of spontaneous fission rate

10^{-3}F(Fissions/g-sec)	Ref.	Method	Year
6.98±0.24	2	Fission chamber	1952
5.30±0.64	3	SSTR	1964
5.54	3	^{40}K and ^{87}Rb dating	1964
6.26±0.72	4	Radiochemical	1966
5.64±0.09	5	SSTR	1968
5.86±0.13	6	SSTR	1971
5.21±0.33	Present Work	SSTR	1985

their size from the induced spontaneous fission fragment tracks.

The pre-etched mica SSTRs remained in close contact with the uranium foil for 5.003 years. These were then etched to reveal the tracks caused by the passage of the massively charged fission fragments, in 46% HF solution at an ambient temperature of about 20°C for three hours. After that they were rinsed in fresh water for about 10 minutes and dried. Scannings were done by an optical microscope at a magnification of 600. The track registered in mica are typically of a diamond-shape[3]. Depending on the track density, the number of scanning fields (area of one field of view is $2.1\times10^{-4}cm^2$) are varied to get the good statistical accuracy.

4. Results and Discussion

The track densities for mica-1, −2 and −3 were 2,570±110, 2,810±120, and 283±12 tracks/cm^2 which may be of background, respectively. The quoted deviations are those due to the random nature of track counting and are obtained from the Poisson statistics. It is noted that there is a contribution due to external thermal neutrons by comparing the results obtained with the mica-1 and -2 even if it is indistinguishable, provided that the statistical errors are taken into account.

Putting the track density values into Eq. (4), the spontaneous fission rate (fission/g-sec) can be readily obtained from mica-1 and -3 data. The results are summarized in Table 2. Data reported by several investigators[2~6] are included in Table 2 for comparison. As is shown in Table 2, there is a good agreement between our result and the values of Fleischer et al[3]., Roberts et al[5]., and Leme et al[6].

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固體飛跡檢出器를 利用한 ^{238}U의 自發核分裂率 決定

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요 약

固體飛跡檢出器인 雲母를 $^{238}UO_2$ 箔板에 約 5年間 密着시켜 두었다가 雲母만을 꺼내어 弗酸속에서 腐蝕시킨후, 光學顯微鏡으로 그 속에 생긴 核分裂破片의 飛跡을 觀測하여 ^{238}U의 自發核分裂率을 決定하였다.

이 實驗에서 얻은 ^{238}U의 自發核分裂率은 5.21±0.33 fissions/g-sec 이었다.