NAA and low-background ɣ-spectrometry for the analysis of U and Th in high purity silica used in electronic devices

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1. Introduction

It has been established that soft error of high precision electronic circuits can be induced by alpha particle emitted from the naturally occurring radioactive impurities such as U and Th[1-3]. Silica has used in electronic industries as the base materials and impurities must be controlled strictly. Recently, electronic circuits have become lower dimension and higher density, so alpha-particle emitting radioactive impurities have to be strictly controlled[4-9]. The objective of the present study was to develop of NAA and gamma-spectrometry for the sensitive (ng/g) and precise analysis of U and Th. A new NAA method has been established using the HTS irradiation facility which has been used to produce radioisotopes for industries and medicines. When the ultratrace impurities have to be analyzed by NAA, background gamma-ray spectra induced from ^{222}Rn and its progeny nuclides in atmosphere are serious problem. This unstable background was eliminated and stabilized by the use of a nitrogen purging system[10,11]. By the use of HTS-NAA and low background gamma-spectrometry ultratrace amounts of U (0.1ng/g) and Th (0.01ng/g) in high purity silica could be analyzed.

2. Methods and Results

For the sensitive and precise NAA of U and Th, neutron flux densities and experimental conditions are investigated. Nitrogen purging system was also developed to minimize background activity from ^{222}Rn and the daughter nuclides in air.

2.1 Neutron flux density Measurement

Neutron flux densities in HTSs and PTS irradiation facilities were measured. A set of two target nuclides such as Au and Co were used as flux monitors. Thermal and epithermal neutron flux densities were measured using ^{197}Au(n,ɣ)^{198}Au and ^{59}Co(n,ɣ)^{60}Co nuclear reactions.

Table 1 shows the neutron flux densities of three HTSs and one PTS irradiation facilities.

Table 1. Neutron flux densities of irradiation facilities

Facility	ϕ_{th}	ϕ_{epi}	ϕ_{th}/ϕ_{epi}
PTS	2.28×10^{13}	1.85×10^{10}	1,230
HTS-1	8.37×10^{13}	3.61×10^{12}	23
HTS-2	1.32×10^{14}	1.57×10^{13}	8.4
HTS-3	4.88×10^{13}	8.75×10^{10}	557

□$_{th}$: *thermal neutron flux density*
□$_{epi}$: *epi-thermal neutron flux density, n · s^{-1} · cm^{-2}*

HTS-2 facility has the largest neutron flux density and the smallest thermal to epithermal flux ratio. However, the PTS facility has the smallest flux and the largest flux ratio.

2.2 Low background Activity

Background activity induced from the atmospheric ^{222}Rn and its progenies are very unstable with the environmental circumstance such as ventilation, moisture and temperature. Fig. 1 shows the background activity variation at 295 keV photopeak repeated 11 times measurements with and without nitrogen purging system.

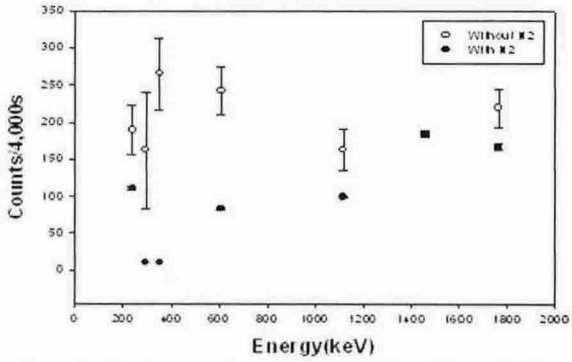

Fig. 1. Background activity and the effect of nitrogen purging system(closed circles mean BG with N_2 purging).

The background activity induced from ^{222}Rn progenies are minimized and stablized with the nitrogen purging system. On the other hand, the activities of ^{212}Pb(239keV, ^{232}Th progeny) and ^{40}K(1,460keV) are unchanged with the nitrogen purging system.

2.3 Optimum Experimental Condition

For the optimum NAA condition for U and Th analysis, various irradiation and cooling combinations were investigated. The activities produced from 1 μg of U and Th as well as the major impurities, such as Cl, Na, Br and Fe at each combination could be found in Fig. 2.

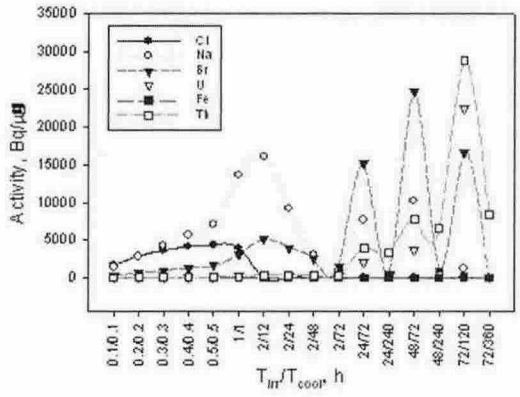

Fig. 2. Activity produced from 1 μg of element with the neutron irradiation and cooling combinations (T_{irr}/T_{cool}) at the PTS facility.

From Fig. 2, the optimum NAA conditions were 72h irradiation and 120h cooling combination for U, and 72h irradiation and 120h or 360h cooling combinations for Th. The analytical sensitivity of U, Th and other important impurities in high purity silica were compared with the irradiation facilities and the results were shown in Fig. 3 and Table 2.

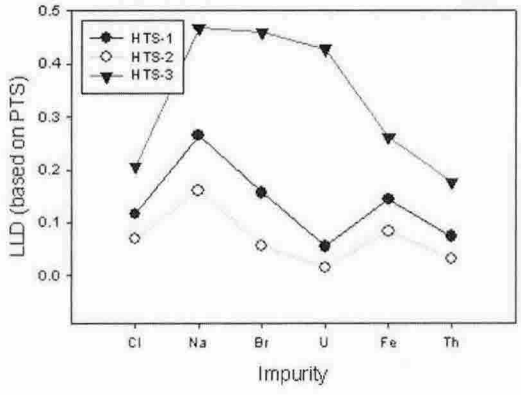

Fig. 3. Comparison the analytical sensitivity with HTS based on the PTS neutron irradiation facility.

3. Conclusion

The analytical sensitivities of U and Th could be improved by the use of HTS-2 irradiation facility and nitrogen purging system. The sensitivity acquired from the improved NAA and gamma-spectrometry was acceptable in the present electronic industries requirement.

Table 2. Optimum NAA conditions of U and Th in high purity silica by a new HTS-NAA/Gamma-spectrometry

Impurity	Irradiation facility	Irradiation time	Cooling time	LLLD(μg/kg) this work	LLLD(μg/kg) needs
U	HTS-2	72h	120h	0.1	0.5
Th	HTS-2	72h	360h 120h(absence Br)	0.01	0.2

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