Estimation of thermal neutron flux from ^{nat}Zr activity

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Introduction

Neutron transmutation doped (NTD) Ge thermistors are developed as low temperature thermometry (in mK range) in the cryogenic Tin bolometer, The India-based TIN detector (TIN.TIN)[1]. For this purpose, semiconductor grade Ge wafers are irradiated with thermal neutron at Dhruva reactor, BARC and dopant concentration critically depends on thermal neutron fluence. In order to obtain an independent estimate of the thermal neutron flux, ^{nat}Zr is used in one of the irradiations. The irradiated ^{nat}Zr samples have been studied in the Tifr Low background Experimental Setup (TiLES)[2]. The thermal neutron flux is estimated from the activity of ^{95}Zr.

Experimental Details and Data Analysis

A total of six ^{nat}Zr samples (mass $\sim$ 1.3 mg) were irradiated at Dhruva reactor for about $\sim$ 4 days, together with Ge samples. The irradiated ^{nat}Zr samples (M2, N2, N4) were counted in the TiLES initially at 10 cm and in a close geometry for higher efficiency. Figure 1 shows the gamma-ray spectra of Zr sample in a close geometry counted for a period of 6 h in the TiLES. The reaction products were identified with characteristic gamma rays and are given in Table I. For unambiguous identification half-lives ($T_{1/2}$) of the observed gamma rays are estimated.

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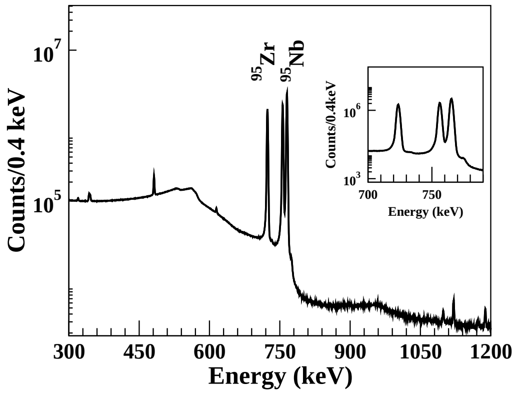

FIG. 1: Gamma-ray spectra of neutron irradiated Zr sample (N2) in a close geometry in the TiLES (counting time = 6 h). The inset shows the gamma rays of interest.

TABLE I: The n-induced reactions together with the main γ-rays and $T_{1/2}^{ref}$ of the products.

Sample	Reaction	E_γ (keV)	$T_{1/2}^{ref}$ [3] (d)
Zr	$^{94}Zr(n,\gamma)^{95}Zr$	724.2	64.032 (0.006)
Zr	$^{95}Zr \xrightarrow{\beta^-} {}^{95}Nb$	765.8	34.991 (0.006)

Figure 2 shows the decay curve for 724.2 keV γ-ray formed in neutron capture reaction in the ^{nat}Zr sample. The measured half-life of the gamma ray $T_{1/2}^{exp}$ = 66 (3) d is found to be in very good agreement with the literature value $T_{1/2}^{ref}$ = 64.032 d [3].

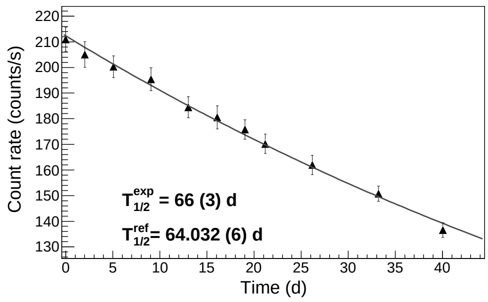

FIG. 2: Decay curve for 724.2 keV gamma-ray formed in the ^{nat}Zr (M2) sample.

Estimation of neutron flux

The yield of the reaction product ($N_{^{95}\mathrm{Zr}}$) is related to that of the parent isotope ($N_{^{94}\mathrm{Zr}}$) and the neutron flux (ϕ_n). Following the procedure described in Ref. [1], the neutron flux is calculated from the measured $N_{^{95}\mathrm{Zr}}$ yield using eq. 1

$$\phi_n = \frac{N_{^{95}Zr}\ \lambda}{N_{^{94}Zr}\ (1 - e^{-\lambda t_{irr}})\ \sigma_c} \qquad (1)$$

where λ is the decay constant of ^{95}Zr and $\sigma_c =$ 50 mb for the $^{94}Zr(n,\gamma)^{95}Zr$ reaction [4]. The uncertainty in the neutron flux includes the error in measured gamma ray yields, mass of the Zr sample and the computed photopeak efficiency of the detector.

The ^{123}Sb impurity (119 $\pm$ 7 ppt) was observed in NTD Ge sample, which is also used to estimate the thermal neutron flux [1]. Table II gives the neutron flux estimated from ^{nat}Zr sample and ^{124}Sb activity in NTD Ge sample.

TABLE II: Estimated thermal neutron flux.

Source of measurement	$\phi_n(\times10^{12})$ $(\mathrm{cm}^{-2}\mathrm{s}^{-1})$
^{95}Zr	6.44 (0.07)
^{124}Sb in NTD Ge	7.1 (0.5)

It can be seen that neutron flux estimated from ^{124}Sb activity is in good agreement with that from resonant neutron capture data in ^{94}Zr. It should be mentioned that this is also consistent with expected flux during irradiation ($\sim 6\times10^{12}$ cm^{-2}s^{-1}).

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References

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