Development of a Quantitative Analysis of B-10 for Boron Neutron Capture Reaction based on IEC and TMFD Systems

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We are developing a novel quantitative analysis method of ^{10}B for BNCT based on the detection of α-particles generated from the nuclear reaction between ^{10}B and thermal neutrons. Which, in principle, differs from the conventional techniques that are looking for γ-rays. This work aims to evaluate the proposed method and determine the neutron flux limitation to detect α-particles from the method.

Keywords: Boron neutron capture therapy (BNCT), C-TMFD, Cancer therapy, IEC, KUR

1. Introduction

Using nuclear reactors for BNCT becomes difficult, while alternative methods to accelerate the development of BNCT research and treatment is a crucial issue. The ^{10}B atoms, delivered to the cancer cells by the drug, capture thermal neutrons and release α-particles and ^{7}Li nuclei associated with γ-rays:

$$^{10}B+n\rightarrow\alpha\ (1.47MeV)+{}^{7}Li\ (0.84\ MeV)+\gamma(0.48\ MeV)\ (94\%) \quad \text{or} \quad \rightarrow\alpha\ (1.78MeV)+{}^{7}Li\ (1.01\ MeV)\ (6\%)$$

The short range of the produced particles (≤ 10 μm) limits the damage to the cells containing ^{10}B. The conventional methods to provide pure thermal neutron flux are a nuclear reactor or accelerator-based neutron source, which generate ~10^{13} and 10^{11} n/cm^2/s, respectively. Reaction efficiency evaluation relies on measuring the emitted γ-rays.

2. The proposed method and proof of principle experiment

The centrifugal-tensioned metastable fluid detector (C-TMFD) is employed for detecting α-particles in the proposed method, while the Kyoto University research reactor (KUR) was used to provide the thermal neutrons to initiate the nuclear reaction with the ^{10}B during the proof of principle experiment.

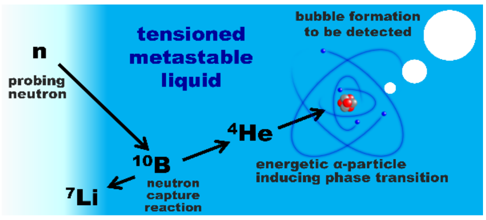

Fig. 1. Principle of the proposed method.

The principle of the method is: blood sample, including ^{10}B, is injected to the C-TMFD detector liquid. By rotating the C-TMFD liquid to proper rotation speed, a metastable state is induced inside the liquid. When a thermal neutron is hitting a ^{10}B atom inside the liquid, the B(n, α) nuclear reaction takes place. Hence, energetic α-particles induce phase transition by changing the liquid metastable state phase to gas in a stable phase, which appears like a bubble. This bubble is growing up from nanoscale to be visible and then counted by the IR sensor in the C-TMFD.

Proof of principle experiment has been performed using two different ^{10}B densities (0 & 40) ppm originated from a chemical compound. The KUR was used to provide pure thermal neutrons flux ~10^3 n/cm^2/s, which is ~25% of the nominal flux for BNCT conventional methods.

3. Preliminary results and conclusion

A clear difference was observed between (0 & 40) ppm densities of ^{10}B at different rotation speed for the C-TMFD using low neutron flux from the KUR. The preliminary results revealed that we could detect α-particles generated from the B(n, α) nuclear reaction using the proposed method, even with the low neutron flux. Details of the proposed method combined with the experimental conditions and results will be discussed. Moreover, the feasibility of using a compact neutron source, inertial electrostatic confinement (IEC), will be discussed based on the results.