Two Dimensional Neutron Monitor with Thin B-10 Film

Chang Hwy Lim¹, Hyunok KIM¹, Jong-Yul Kim², Sang-Jin Cho³, Ho Kyung KIM³, Myung-Kook Moon⁴

¹Neutron Science Division, Korea Atomic Energy Research Institute, Daejeon 305-353, Korea
²Department of Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology, Daejeon 305-701, Korea
³School of Mechanical Engineering, Pusan National University, Busan 609-735, Korea
⁴Center for Advantaged Medical Engineering Research, Pusan National University, Busan 609-735, Korea

Introduction
- He gas has been generally used for the 2-dimensional neutron monitoring system as a neutron converter.
- Sensitivity, γ-ray discrimination, long time use, etc.
- Cost of ³He neutron monitoring system is getting more expensive in recent years due to shortage of ³He gas.
- To develop alternative He-3 neutron detector, many studies have been conducted worldwide.
- BF₃, ¹⁰B, ⁶Li etc.
- Advantage of neutron detector using ¹⁰B thin film
  - ¹⁰B: 20% of natural boron
  - High neutron cross-section
  - Non-toxic

Objectives
- The aim of this study is to develop MWPC (Multi-wire Proportional Chamber) with the thin boron film for a neutron beam profile monitoring at neutron irradiation system.
  - Fabrication of ¹⁰B thin film for neutron detection.
  - Calculation and measurement of neutron detection efficiency of neutron monitor with ¹⁰B using the MCNP 2.6.0 (RSICC, Oak Ridge, USA) & neutron irradiation experiment.
  - Development of 2-D MWPC for neutron measurement using ¹⁰B.

Background
- ¹⁰B+γ→Li+²He: 6%, 2.792MeV (ground state)
  \[ E_u = 0.840 MeV, E_{bg} = 1.470 MeV \]
- ¹⁰B+γ→Li+²He: 94%, 2.310MeV (excited state)
  \[ E_u = 1.015 MeV, E_{bg} = 1.777 MeV \]

Materials and Methods
- ¹⁰B thin film
  - Fabrication of ¹⁰B thin film using the argon ion sputtering method
  - Film thickness - designed values: 1.0, 1.5, 2.0 µm
    - real thickness: 0.844, 1.150, 1.989 µm

- Neutron detector model using MCNPX 2.6.0
  - Model 1: signal collection according to the thickness of B-10 neutron convertor
  - Model 2: signal collection according to the layer number of B-10 neutron convertor

- Counting monitor test using neutron beam
  - Cold Neutron Activation Station (CONAS@HANARO Center/Korea)
  - Neutron beam: 2 Å

- Experiment of neutron irradiation using 2D MWPC
  - Neutron Diffractometer (Bio-D)@ST3 port, HANARO Center/Korea)
  - Wavelength: 1.153 Å
  - Beam Flux: \( 10^6 \) #/cm²
  - Measurement of image resolution
    - Using Cd mask
      - Pitch 10 mm, hole 1 mm, Cd 1 mm

Results
- Thickness of ¹⁰B thin film
  - Simulation: 1 ~ 10 µm
  - Experiment: 0.844, 1.150, 1.989 µm

- The efficiency of absorbed energy in the reaction gas was increased till 4 µm thickness.
- Collection efficiency was decreased rapidly from 1 µm to 10 µm.

- Multi-layer ¹⁰B thin film
  - Simulation: 1 ~ 15 layers
  - Experiment: 2, 4, 6, 8 layers

- As shown in the results of simulation and experiment, the number of ¹⁰B layer and signal collection efficiency was a linear relationship.

Conclusions
- Considering the neutron absorption efficiency and the collection efficiency of generated secondary radiation, the optimal ¹⁰B thickness is 1~1.5 µm.
- In order to increase the collection efficiency of neutron detector, ¹⁰B of multi layer is to be installed in the detector.
- Development of neutron monitor using 2D MWPC with ¹⁰B thin film has been successful.