J. Korea Asso. Radiat. Prot.
Vol. 30 No. 1 : 35~37 (2005)

■ 論 文 ■

Design of a High Efficiency Neutron Detector Using a GEM

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GEM을 이용한 고효율 중성자 검출기 설계

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(2004년 10월 27일 접수, 2005년 2월 23일 채택)

Abstract – The radiation detector research group at KAERI has developed a high efficiency neutron detector using a Gas Electron Multiplier (GEM). The double GEM was fabricated and operated in an Ar/Isobutane mixture. For an application to a high efficiency neutron detector, ^{6}Li or ^{10}B neutron converters coated on each surface of the multi GEM foils were considered. The optimized thickness of the thin film for a neutron detection was calculated with the MCNP and SRIM. The neutron efficiency was calculated by changing the chemical components of the thin film, and the thickness of the thin film. The thermalized neutrons were measured by a GEM detector with a thin neutron converter on the drift plate.
Key words : neutron detector, neutron measurement, ^{6}Li or ^{10}B neutron converter, GEM

요약 – 한국원자력연구소의 방사선 검출기 연구팀에서는 가스 전자 증폭기를 이용하여 고효율 중성자 검출기를 개발하고 있다. 이중 가스 전자 증폭기를 제작하였고 Ar/Isobutane 혼합기체에서 동작시켰다. 고효율 중성자 검출기에 적용하기 위해서 다중 가스 전자 증폭기 포일 양면에 중성자 변환 물질인 ^{6}Li 또는 ^{10}B를 코팅하는 것이 고려되었다. 중성자 검출을 위한 박막의 최적화된 두께를 MCNP와 SRIM으로 계산하였다. 중성자 검출 효율은 박막을 구성하는 화합물과 박막 두께를 변화시키면서 계산하였다. 열중성자는 drift plate에 중성자 반응 박막을 입힌 GEM 검출기에 의해서 측정되었다.
중심어 : 중성자 검출기, 중성자 측정, ^{6}Li 또는 ^{10}B 중성자 변환물질, 가스 전자 증폭기

Introduction

Thermal neutrons can be detected with a ^{3}He gas tube. Semiconductors coated with neutron converter films, such as ^{6}Li and ^{10}B, were also studied as a neutron detector [1]. The nuclear interactions of ^{6}Li and ^{10}B for the thermal neutron detection are

$$n + {}^{6}Li \rightarrow {}^{4}He + {}^{3}H + 4.79\ MeV,$$

$$n + {}^{10}B \rightarrow {}^{7}Li + {}^{4}He + 0.48\ MeV\ \gamma + 2.3 MeV \quad (93\%)$$

$$\rightarrow {}^{7}Li + {}^{4}He + 2.8\ MeV \quad (7\%)$$

Currently the Gas Electron Multiplier (GEM) is being studied in various application fields [2]. We have developed a GEM for a thermal neutron detector. Since a GEM coated with a neutron converter can be designed with a multi-layer structure, the neutron efficiency of the GEM-based detector can be increased significantly [3]. The design concept is illustrated in Fig. 1.

Methods and Results

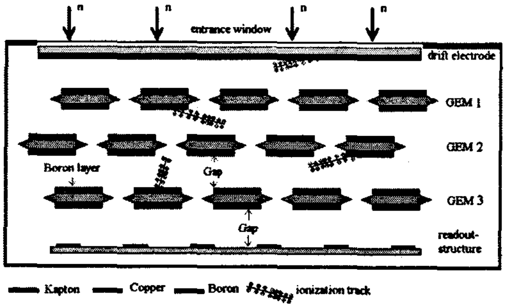

Fig. 1. The design concept of a high efficiency neutron detector using a GEM.

1. Optimized Thickness of the Thin Film

The optimized thickness of the thin film for a neutron detection was calculated by using the MCNP and SRIM codes. Thermal neutrons assumed to incident on the thin film, and the probability of a neutron conversion into the charged particle inside the film was calculated with MCNP. The escape probability of the generated charged particle from the thin film was calculated with SRIM (Fig. 2).

The neutron efficiency was calculated by changing the chemical components of the thin film, and the thickness of the thin film. The optimum thickness of the thin film for each chemical compound was obtained from the calculation (Fig. 3). The neutron efficiency of the multi GEM's coated with the solid converter was also calculated by changing the number of the GEM foils. Fig. 4 shows the result of the calculation. Also the effect of the threshold of the charged particle on the neutron efficiency was calculated. The neutron efficiency of the detector for high energy neutrons was also calculated.

2. Deposition of the Thin Film Neutron Converter

Thin films such as ^{6}LiF, ^{10}B, and $^{10}B_2O_3$ were deposited with a high vacuum evaporator. ^{6}LiF and $^{10}B_2O_3$ films were suitable for using the thermal evaporation method. But an e-beam evaporator was used to deposit the ^{10}B thin converter.

The response of the thin film to the neutron was measured using the ionization chamber. We designed and fabricated the ionization chamber for a neutron detection. The collecting volume of the chamber is 1500 cc, and the thin film can be placed inside the chamber.

Neutrons from ^{252}Cf were measured with the ionization chamber, and the 4-cm thick neutron moderators were placed between the neutron source and the ionization chamber to thermalize the neutrons. The neutron efficiency was increased as the number of neutron moderators was increased.

3. Neutron Spectrum Measurement

The thermalized neutron was measured at

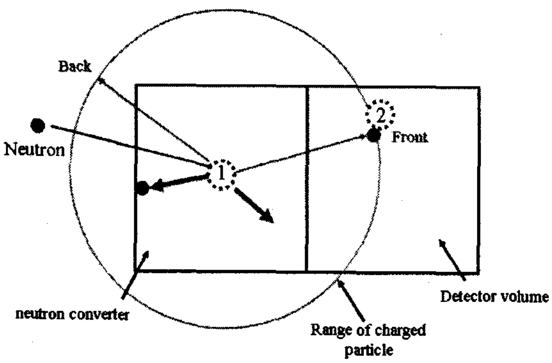

Fig. 2. The cross sectional view of a typical neutron detector. 'Front' means the same direction to the incident neutron, 'Back' means the opposite direction. Neutron conversion occurs at point 1 and the produced charged particle stops at point 2.

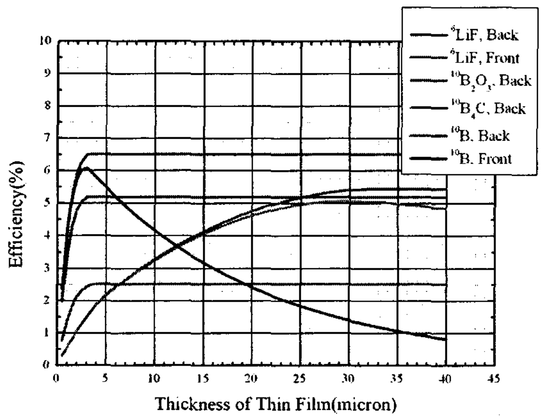

Fig. 3. Efficiency of the neutron detection with single foils according to the thickness.

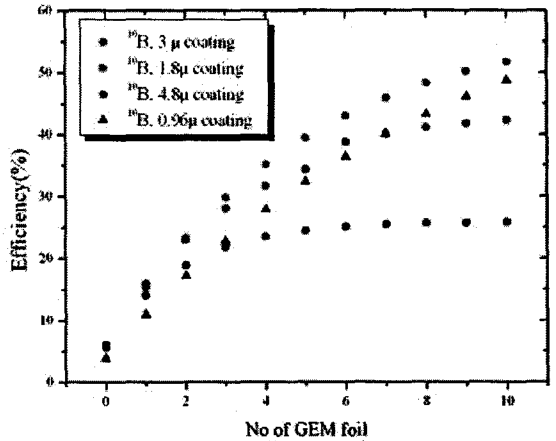

Fig. 4. Result of the efficiency calculation of the multi GEM neutron detectors. A high efficiency of more than 50% can be attained at the 1.8μ ^{10}B thin films coated on each side of the ten GEM foils.

KAERI with a drift plate coated with a neutron converter thin film, and the neutron response was evaluated. We used a double GEM[4, 5] and the neutron converter was only coated on the drift plate. A ^{252}Cf neutron source was used and the neutron moderator was placed between the source and the detector. The measured spectrum is shown in Fig. 5.

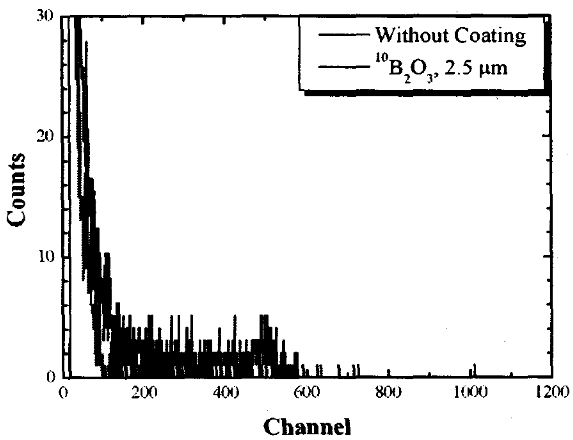

Fig. 5. The measured neutron spectrum using GEM.

Conclusion

We have designed a high efficiency neutron detector using a multi GEM detector. The optimized thickness of the converter was obtained from the MCNP and SRIM calculation. A thin film such as the ^{6}Li and ^{10}B compounds was deposited by a high vacuum evaporator. The efficiency of the converter was measured by placing the thin film inside the ionization chamber. The thin film neutron converter techniques are essential tools for the fabrication of neutron detectors.

Acknowledgement

This work has been carried out under the Nuclear R&D Program of the MOST of Korea and partially supported from the KOSEF ERC program of iTRS at Hanyang University.

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