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Development of neutron detectors for neutron scattering experiments

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1. Introduction

Since the base of the neutron scattering experiment is measuring the angular distribution of the scattered neutron by the sample, neutron detectors play an important role in neutron scattering experiments. Various kinds of detectors are used in accordance with the experimental purpose, such as zero dimensional detector, 1-D or 2-D position-sensitive detectors. Most of neutron detectors use He-3 gas because of its high neutron sensitivity. Since the He-3 supply shortage took place in early 2010, various He-3 alternative detectors have been developed even for the other neutron application.

We have developed a new type alternative detector on the basis of He-3 detector technology. Although B-10 has less neutron detection efficiency compared with He-3, it can be covered by the use of multiple B-10 layers. In this presentation, we would like to introduce the neutron detectors under development and developed detectors.

2. Detector development

The radiative capture cross section of He-3 and B-10 are respectively 5300 barn and 3800 barn at 0.025eV. He-3 has an advantage to increase gas pressure to increase higher detection efficiency. Therefore, He-3 detectors are widely used in neutron scattering experiment. Neutron interaction process is following.

neutron + He-3 → p + t + 764keV

Measurement of the energetic proton and triton from the reaction result is the principle of the neutron detection process.

2.1 Tube detector (0-dimension detector)

The Four Circle Diffractor (FCD) is one of typical neutron scattering instrument. Generally it uses a small crystal. Therefore the dimension of the scattered neutrons will be small, roughly less the $2cm^2$. Thus, the local detection area of the FCD can be a small size. Generally FCD uses about 0.08eV energy i.e. nearly 1 angstrom wavelength. Then, to get reasonable detection efficiency we need more detection thickness (or higher He-3 pressure).

The detection efficiency depends on neutron wavelength, detector thickness, and gas pressure. To increase the detection efficiency, one should use high pressure detector or increase detection thickness. Due to a small and single crystal sample of the FCD the shape of diffraction pattern represents as a small spot. Therefore small and effective detector is enough for the FCD.

We have developed very effective detector for FCD. Compare to the conventional tube detector, the incident neutrons enter through the coaxial direction. Figure 1 shows the tube detector which has very thin window at left direction. Finally the detection efficiency of the 0.08eV neutron energy could be reached more than 90%.

Figure 1. Tube detector for FCD.

2.2 Position sensitive detectors

We have developed three types of the position-sensitive one-dimensional, two-dimensional and curved two-dimensional detectors for scattering experiments. All detector use delay line position readout method. The size of the detectors is from 10cm x 10cm to 65cm x 65cm. Figure 2 shows the two-dimensional detector for small angle neutron scattering. It can be worked in vacuum condition.

Figure 2. Two-dimensional detector for small angle neutron scattering.

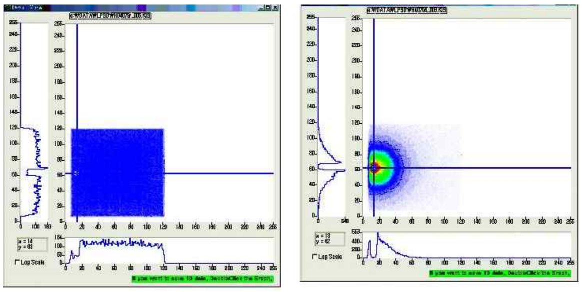

Figure 3. Neutron scattering data taken by two-dimensional detector for small angle neutron scattering.

2.3 Curved position sensitive detectors

Because measurement of the angular distribution of the scattered neutron is basic on the neutron scattering experiment, the curved structure detector is most powerful instrument. A curved area detector is simply considered to be an extension of a flat detector, but significant technical advances are needed in to develop curved detector structure. First, we developed a prototype curved detector with a 650x470mm2 linear active area and a radius of 550mm. It works well and finally we decided to develop active angular range of 110^o x 56^o with radius of 530mm [1].

Figure 4. Functional test of the curved two-dimensional position-sensitive neutron detector at the laboratory and installation at the four circle diffractometer at HANARO research reactor.

2.4 B-10 neutron detectors

Since the He-3 supply shortage took place in early 2010, it is very difficult to obtain He-3 gas even enough money. Therefore, the He-3 alternative detector development required. We used B-10 thin layer around 3 micron by sputtering method[2].

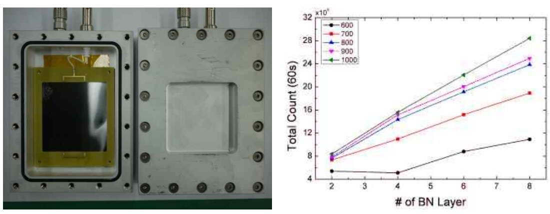

Figure 5. Fabricated B-10 detector and its test result.

3. Conclusion

Various types of detector were successfully developed and result of the technical test performance is promising. Even though the detection efficiency of the B-10 detector lower than He-3 one, the continuous research and development is needed for currently not available He-3.

REFERENCES

[1] Myungkook Moon et al.,Development of a large area, curved two-dimensional detector for single-crystal neutron diffraction studies, Nucl. Instrum. Methods A 717, 14, 2013.
[2] Changhwy Lim et al., Development of B4C thin films for neutron detection, Journal of radiation protection and research, Vol. 40. No. 2, 2015