Development of Neutron Detectors for Scattering Experiments

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1. Introduction

Since neutron detector measures the distribution of scattered neutrons from the sample, it plays a very important role in neutron scattering experiments. Various types of neutron detectors can be used in each neutron spectrometer such as conventional tubes, one-dimensional and two-dimensional detectors.

Korea Atomic Energy Research Institute (KAERI) started to develop position-sensitive neutron detectors in 1997 in collaboration with Prof. Kang's group in Kyungpook National University. The first position-sensitive neutron detector in Korea was successfully developed in 1999 for residual stress instrument. After 2000 various detectors were developed for mainly neutron scattering experiments. Some characteristics of developed neutron detectors by us describe herein, and the future of advanced detector for scattering experiments is presented.

2. Developed detectors

2.1 Tube detectors (Zero-dimensional detector)

The most conventional type of neutron detector is tube. The thin wire which is located in the center of tube collects primary electrons from the ^{3}He(n, p) or ^{10}B(n, α). Since the detection efficiency depends on neutron wavelength, gas pressure and detection depth, there are only two ways to increase the efficiency, the higher pressure and the deeper detection thickness, respectively. The commercial tube detector has 1 inch or 2 inches diameter. To hold thin wire in tube detector it needs two blocks in each edge. The block across wire is made of ceramic and its thickness is more than 1 cm. Therefore the incident beam direction is perpendicular to thin wire to avoid the block.

We developed a special tube detector to increase the detection thickness. It has very thin wire holding block. Then, the detection depth depends on the detector length. One of lab-made tube detector is installed in Four Circle Diffractometer (FCD) [Fig. 1].

Figure 1. A tube detector with very thin wire hold block for FCD.

Additionally we have developed very low efficiency detector for neutron monitor counter. The cross-section of neutron beam profile is different for each scattering experiments. There are only few types of low efficiency detectors in commercial. Even though the general idea of low efficiency is same as conventional tube type detectors, the difference is that ours have several thin multiwires inside the detector. Therefore the detection area can be easily increased. We have developed low efficiency neutron beam flux monitor detector which has long and wide cross-section. These types of detector can be easily used in neutron guide instrument including normal neutron spectrometers installed in research hall. Some low efficiency detectors are shown in Fig. 2.

Figure 2. Low efficiency detectors with broad window.

2.2 One-dimensional detectors

Since most commercial position sensitive neutron detectors are co-axial types, the detection window height is limited to ≤ 50mm. We have developed several one dimensional position-sensitive detectors with delay line readout for residual stress measurement and neutron powder diffractometers. The height of the detecting window can be increased up to 200 mm [Fig. 3]. The detector with 200mm active window height was compared with the conventional co-axial type position-sensitive detector (from Ordela, 25mm window height). The comparison showed that the intensity increased about 8 times because of the enlargement of the active window height [1-3].

Recently KAERI is developing neutron powder diffractometer which uses 8 1-dimensional position-sensitive detectors. All detectors and their electronics have been developed by KAERI itself. Besides KAERI's own purpose some different sized one-dimensional detectors developed by KAERI are used at

IMP (Institute of Metal Physics) in Russia, INP (Institute of Nuclear Physics) in Czech Republic and JAEA (Japan Atomic Energy Agency) in Japan.

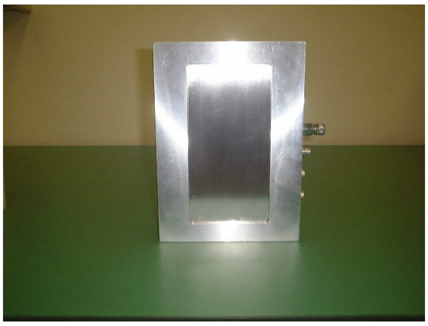

Figure 3. 1-dimensional detector for residual stress instrument.

2.3 Two-dimensional area detectors

Two-dimensional detector is similar to neutron camera. Though the fabrication process of two-dimensional detector is same as one-dimensional one, it takes a lot effort and time due to its internal complexity and dust clearance. The main characteristics of two-dimensional detector are spatial resolution and detection efficiency. To get higher spatial resolution a lot of quenching gases which have high stopping power such as CF_4 or C_3H_8 gases are used [4].

Two types of two-dimensional detector were developed for single crystal diffraction and small angle neutron scattering. The detector for single crystal diffraction should have high resolution and high detection efficiency since it uses for short neutron wavelength and very small sample. For small angle neutron scattering the spatial resolution and efficiency are relatively poorer than single crystal diffraction. The difficulty in detector fabrication for a small angle neutron scattering is its effective area up to $1m^2$. Recently we have successfully developed large detector which has 65cm×65cm effective area for small angle neutron scattering. The detector is running on SANS in HANARO after March 2006.

Figure 4. Two-dimensional position-sensitive detector for small angle neutron scattering.

A low efficiency two-dimensional position-sensitive detector has been developed for monitoring thermal neutron beams. It is filled with CF_4(4 atms) and a small quantity of ^{3}He, and has 1.2mm spatial resolution, 0.1% efficiency (@0.18 nm) and can achieve a count rate of 350 kHz. Experiments at the 30 MW HANARO reactor showed that the fabricated detector is a very useful and convenient tool for adjusting spectrometer components such as neutron monochromators, especially focusing monochromators, and for monitoring monochromatic beams under different geometric conditions. It can be used for various neutron optics experiments [5].

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3. Conclusion and perspective

Various types of neutron detectors are developed for neutron scattering experiments. Most of them are running in neutron scattering instruments in the inside and outside of the country. Even this technology based on gas detector can be well utilized for X-ray scattering in laboratory and synchrotron applications.

The advanced detectors such as curved two-dimensional one and very large area detector with active window of 1 m^2 have been under development in KAERI. The use of advanced detector not only can decrease the measurement time but also can open new scientific fields.

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