Development of Cold Neutron Activation Station at HANARO Cold Neutron Source

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1. Introduction

A new cold neutron source at the HANARO Research Reactor had been constructed in the framework of a five-year project, and ended in 2009[1,2]. It has seven neutron guides, among which five guides were already allocated for a number of neutron scattering instruments. A new two-year project to develop a Cold Neutron Activation Station (CONAS) was carried out at the two neutron guides since May 2010 [3,4], which was supported by the program of the Ministry of Education, Science and Technology, Korea. Fig. 1 shows the location of CONAS.

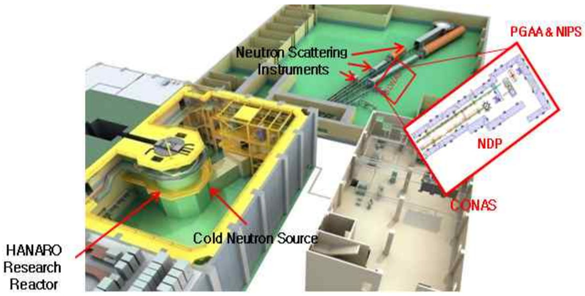

Fig. 1. Location of Cold Neutron Activation Station (CONAS) constructed on the cold neutron guides.

CONAS is a complex facility including several radioanalytical instruments utilizing neutron capture reaction to analyze elements in a sample. It was designed to include three instruments like a CN-PGAA (Cold Neutron - Prompt Gamma Activation Analysis), a CN-NIPS (Cold Neutron - Neutron Induced Pair Spectrometer), and a CN-NDP (Cold Neutron - Neutron-induced prompt charged particle Depth Profiling). Fig. 2 shows the conceptual configuration of the CONAS concrete bioshield and the instruments.

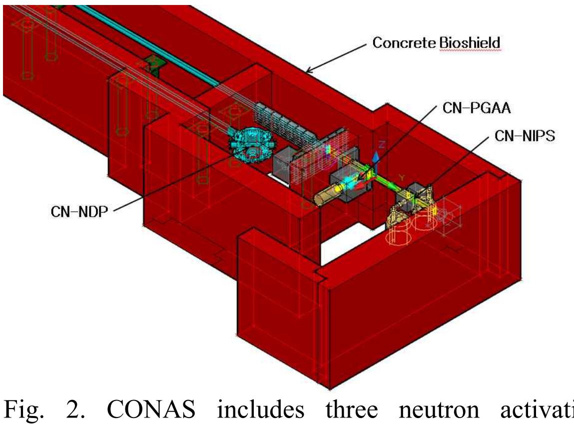

Fig. 2. CONAS includes three neutron activation analysis instruments like CN-PGAA, CN-NIPS and CN-NDP.

CN-PGAA and CN-NIPS measure the gamma-rays promptly emitted from the sample after neutron capture, whereas CN-NDP is a probe to measure the charged particles emitted from the sample surface after neutron capture. For this, we constructed two cold neutron guides called CG1 and CG2B guides from the CNS.

2. Concrete bio-shield and cold neutron guides

To protect users from radiation exposure, a concrete bioshield was constructed around the cold neutron guides and experimental instruments as shown Fig. 3(a). This concrete bioshield is called CONAS bunker, which has three sections for neutron guides room, CN-NDP experimental room and prompt gamma experimental room. Fig. 3(b) shows the neutron guides room. CG1 guide was allocated for CN-NDP and CG2B guide was allocated for two prompt gamma instruments.

Fig. 3. CONAS concrete bioshield (a) and two cold neutron beam guides (b). CG1 for CN-NDP and CG2B for CN-PGAA and CN-NIPS.

Ni/Ti Super mirrors with m=2 grade for neutron guide were domestically fabricated by using a sputtering machine of the KAERI neutron guide team. A CG1 guide was extended from the REF-V monochromator position and a CG2B guide was newly extended from the primary shutter. The beam divergence and the wavelength distribution at the end of each guide is shown in Fig. 4.

The average neutron wavelength is calculated from the wavelength distribution to be 4.01 Å corresponding to 59.0K at the end of the CG1 guide and 4.68 Å corresponding to 43.3K at the end of the CG2B guide, respectively. After installation, we determined the neutron flux by using a gold activation method. For the CG1 guide, the thermal eq. flux is 7.16×10^8 n/cm^2/s and the real flux is 3.21×10^8 n/cm^2/s, and for the CG2B guide, the thermal eq. flux is 1.59×10^9 n/cm^2/s and the real flux is 6.13×10^8 n/cm^2/s. Flux is a maximum value within the cross section.

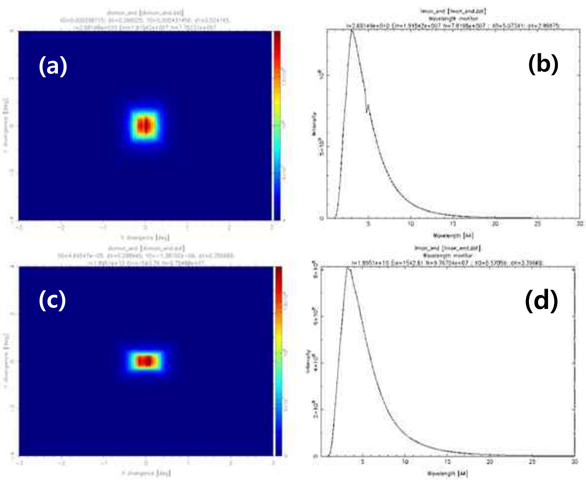

Fig. 4. Beam divergence (a) for CG1 and (c) for CG2B and wavelength distribution for CG1 (b) and (d) for CG2B.

3. Prompt gamma instruments

Two prompt gamma instruments like CN-PGAA and CN-NIPS were installed on the Teflon vacuum guide, which is extended from the end of CG2B guide. To reduce the gamma-ray background, we made the extended tubes from Teflon instead of aluminum. The Teflon tube has double layers, between which $^{6}Li_2CO_3$ powder was filled to catch the neutrons scattered by air particles. Sample boxes for CN-PGAA and CN-NIPS are also made of Teflon.

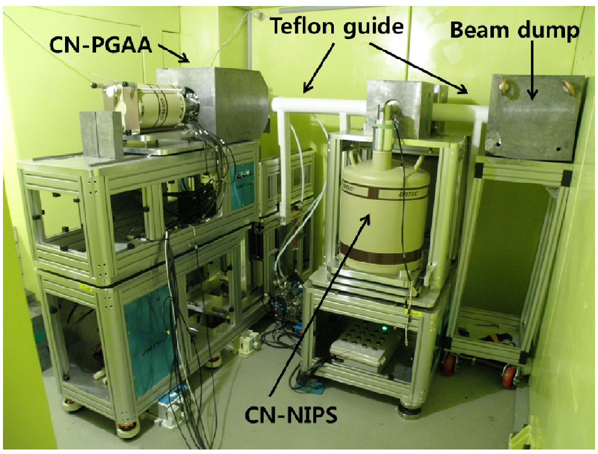

Fig. 5. Two prompt gamma measuring instruments on the Teflon neutron guide, which is extended from the end of CG2B guide.

Detector system of CN-PGAA consists of an n-type HPGe detector with a relative efficiency of 40%, which is fully covered by an annulus BGO and catcher BGO detectors without a small solid angle of forward and backward directions. The BGOs serve as a passive shield along with the lead shield surrounding the composite detector for the external radiation. Besides they catch the Compton-scattered gamma-rays or single- or double-escaped photons from the main detector. Hence, when the HPGe and BGOs are operated in anticoincidence, the composite spectrometer can reduce the background and obtain simpler spectrum. Two 40% n-type HPGe detectors of the CN-NIPS operate in coincidence to measure the pair gammas emitted from activated sample.

4. CN-NDP instrument

We described the CN-NDP in detail in another article [5]. CN-NDP is an absolute depth profiling probe for some elements like He, Li, B, O, N and so on, which are very important in industrial matters such as lithium ion batteries, semiconductors, glass and multilayered films and so on. It measures charged particles emitted after neutron capture. So, it requires an ultra-high vacuum sample environment. Fig. 6 shows a conceptual design for the CN-NDP and the real sample chamber, which has a 4 axis(X, Y, Z and R) sample scanner and two rotational detector mounts. Initially a conventional NDP was attempted, which adopts two silicon surface barrier detectors to measure the energy-loss spectrum of the charged particles, and then a time-of-flight NDP will be developed using two multichannel plate detectors. Preliminary experiments have been carried out to check the energy and depth resolutions in the conventional NDP system.

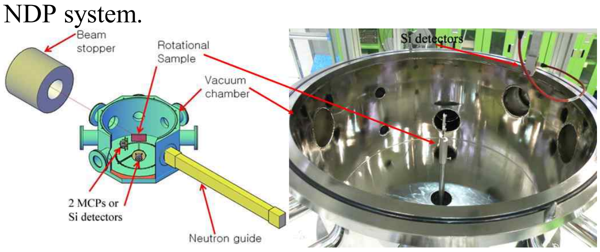

Fig. 6. Conceptual design of CN-NDP and its real sample chamber.

ACKNOWLEDGEMENTS

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