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Design and operation of the double crystal monochromator for energy selective neutron imaging at ENF

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1. Introduction

Energy selective neutron imaging is one of advanced neutron imaging techniques [1-2]. Although conventional neutron imaging can't visualize a complex structure of polycrystalline because polychromatic thermal and cold neutron beams are mainly used, the detailed structure of the welded steel sample can be visualized using energy selective neutron imaging [3]. Neutron imaging experiments have been performed at Ex-core Neutron irradiation Facility (ENF) in HANARO research reactor [4-5]. To perform energy selective neutron imaging at ENF, a neutron beam with narrow energy band is needed. The ENF can provide monochromatic thermal neutron beam as installing a double crystal monochromator, and more applications of neutron imaging can be performed. A schematic of energy selective imaging system is shown in Fig 1.

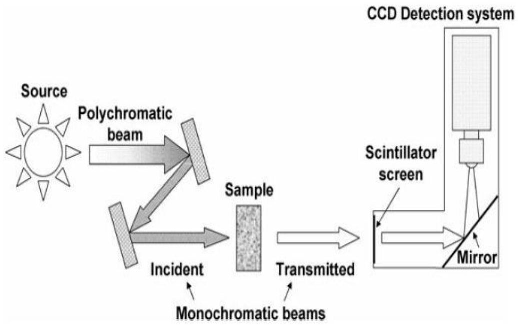

Fig. 1. A schematic of energy selective neutron imaging system

2. Methods and Results

A double crystal monochromator was designed as shown in Fig 2 and prepared as shown in Fig. 4 using two graphites, motorized linear stages, and motorized tilting stages.

2.1 Graphite monochromator

The graphite monochormator (ZYH, Momentive Inc.) is highly-oriented forms of high-purity pyrolytic graphite that may diffract neutrons with great efficiency. This graphite plate is produced as flat shape, mosaic spread that is presented half maximum height peak width of the Cu-K a rocking curve is 3.5°±1.5°. The size of graphite plates are 50mm x 75mm and thickness is 2mm. Typical physical characteristics are in Table I.

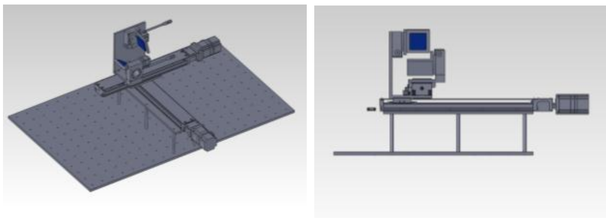

Fig. 2. The assembling drawing of double crystal monochromator

Table I: Typical physical characteristics of graphite monochromator at 300K

Spacing of Reflecting Planes	3.355 ~ 3.359 Å
Mosaic Spread	≧0.4°
Density	2.255 ~ 2.265/cm^3
Thermal Conductivity	1600 ~ 2000 W/m·K
Thermal Expansion	Slightly negative
Electrical Resistivity	3.5 ~ 4.5 x 10^{-5} Ω·cm

2.2 Motorized linear and tilting stages

The motorized stages have to be installed to operate double crystal monochromator at ENF beam line for position control based computer. In this system, there are 2 types of motorized stages that are driven as linear, tilting respectively. Two linear stages (PK569NAW, VEXTA oriental motor Co,. LTD.) are jointed orthogonally, one is x-direction linear stage and the other is y-direction linear stage. Also, two tilting stages (C005C00215P, VEXTA oriental motor Co,. LTD.) control pitch motion of each double crystal are installed in the system. The motorized stage system was well made to satisfy technical conditions, and these all driving parts are connected with motor controller to be controlled by computer. Stages can move accurately and precisely in minimum step as 0.05° and 0.1mm. Details are presented in Table II and Table III.

Table II: The detail specification of motorized tilting stage

Stage side size	59mm
Tilting range	360°
Accuracy	0.05°
Backlash	≧0.05°
Starting torque	29.4N·cm

Table III: The detail specification of motorized linear stage

Stage length(x-direction)	500mm
Stage length(y-direction)	350mm
Accuracy	0.1mm
Backlash	≧0.02mm
Starting torque	10N·cm

2.3 The prepared double crystal monochromator

The wavelength is changed according to the length produced by tilting angle and translation of the motor in x direction, so a polychromatic thermal neutron beam delivered from ENF can transfer monochromatic thermal neutron beam. The characteristics and incident angle depending on x-length of double crystal monochromator as the translation are in Table IV. The schematic diagram of double crystal monochromator is as shown in Fig. 3.

Table IV: The change of characteristics according to translation in x direction

D-spacing(Å)	3.355								
Wavelength(Å)	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Incident angle, θ(°)	17.35	21.89	26.57	31.46	36.61	42.14	48.20	55.08	63.44
Tilting angle, 90-θ(°)	72.65	68.11	63.43	58.54	53.39	47.86	41.80	34.92	26.56
x(cm)	12.29	10.11	8.75	7.86	7.31	7.04	7.04	7.46	8.75
x'(cm)	10.10	7.30	5.24	3.58	2.11	0.70	-0.78	-2.57	-5.25

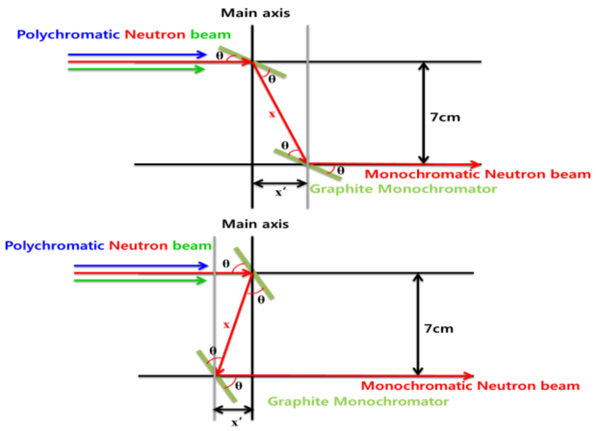

Fig. 3. The schematic diagram of double crystal monochromator

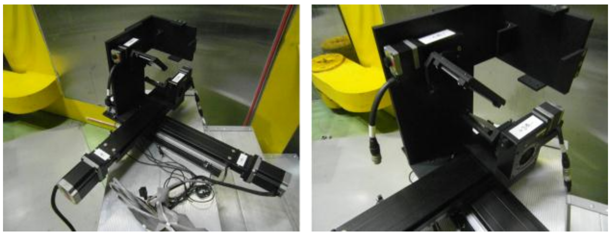

Fig. 4. The picture of prepared double crystal monochromator

3. Conclusions

The double crystal monochromator that is well designed and prepared will be set up for energy selective neutron imaging at the Ex-core Neutron irradiation Facility (ENF) in HANARO. After installation of the double crystal monochromator, the ENF can provide monochromatic thermal neutron beam, and more applications of neutron imaging can be performed.

REFERENCES

[1] S. Baechler, et al., New features in cold neutron radiography and tomography Part I: thinner scintillator and neutron velocity selector to improve the spatial resolution, Nucl. Instrum. Methods A 491, 481, 2002.
[2] N. Kardjilov et al., New features in cold neutron radiography and tomography Part II: applied energy-selective neutron radiography and tomography, Nucl. Instrum. Methods A 501, 536, 2003.
[3] Lidija Josic et al., Energy selective neutron radiography in material research, Appl. Phys. A 99: 515–522, 2010.
[4] Seung Wook Lee et al., A Neutron Dark-field Imaging Experiment with a Neutron Grating Interferometer at a Thermal Neutron Beam Line at HANARO, J. Korean Phys. Soc. 58, 730734, 2011.
[5] Jongyul Kim et al., Visibility evaluation of a neutron grating interferometer operated with a polychromatic thermal neutron beam, Nucl. Instrum. Methods A 746, 26, 2014