CO1-1 **Boron Neutron Capture Therapy for Malignant Brain Tumors Using Epithermal Neutron**

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INTRODUCTION: Between June 2012 and Februarry 2013, we applied BNCT using epithermal neutron for
1) newly diagnosed GBM (4 cases),
2) recurrent malignant gliomas (4 cases)
3) high-grade meninigiomas (HGM)(6 cases).
These BNCT were applied in KUR.
Here we reported our results of BNCT on 20 consecutive HGMs from 2005 to 2011, which were observed more than a year, after BNCT [1,2].

METHODS: The patients were administered 500 mg/kg of BPA intravenously for 3 hours before the irradiation. The neutron irradiation time was determined not to exceed 15 Gy-Eq to the normal brain. 20 HGMs were composed of 12 anaplastic, 4 atypical, 2 papillary, and 1 rhabdoid meningioma and 1 sarcoma that began as an anaplastic meningioma. All cases were recurrent after repetitive surgeries and radiotherapies.

RESULTS AND DISCUSSION: Typical tumor shrinkage is depicted in Fig.1.
All cases showed marked tumor shrinkage after BNCT.
2)The median survival times after BNCT and after diagnosis are 14.1 (95%CI: 8.6 - 40.4) and 45.7 (95%CI: 32.4 - 70.7) months, respectively.
3) Major causes of treatment failure were recurrence out of field of neutron irradiation, CSF dissemination and systemic metastasis.
HGMs are seemed to be good candidate for BNCT [3].

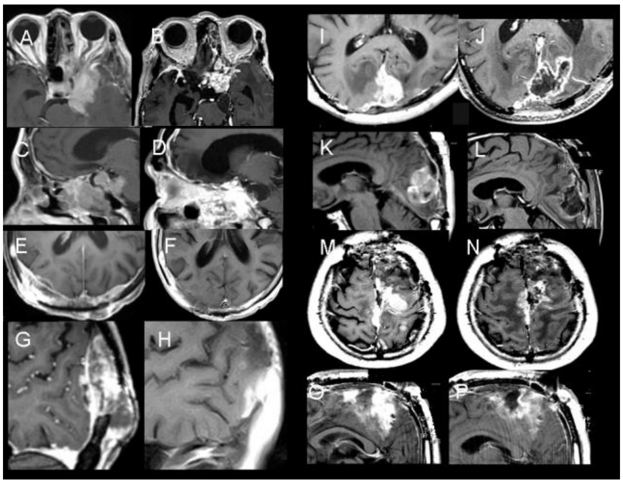

Fig. 1. Representative tumor shrinkage after BNCT on enhanced MRI.
A, B, C, D: Case 17 (anaplastic meningioma). A, C, pre-BNCT; B, D, 10 months after BNCT.
E, F, G, H: Case 14 (atypical meningioma). E, G, pre-BNCT; F, H, 6 months after BNCT.
I, J, K, L: Case 18 (anaplastic meningioma). I, K, pre-BNCT; J, L, 10 months after BNCT.
M, N, O, P: Case 20 (atypical meningioma). M, O, pre-BNCT; N, P, 4 months after BNCT.
Each case shows marked tumor volume reduction after BNCT.

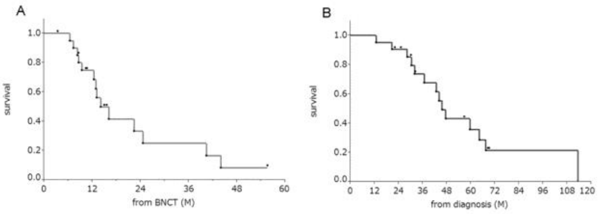

Fig. 2. Survival analysis after diagnosis and BNCT.
A, Kaplan-Meyer curve after BNCT, B, Kaplan-Meyer curve after diagnosis. The median survival times after BNCT and after diagnosis are 14.1 (95%CI: 8.6 - 40.4) and 45.7 (95%CI: 32.4 - 70.7) months, respectively.

REFERENCES:

[1] Y. Tamura *et al.*, Case report. J Neurosurg **105** (2006) 898-903,.
[2] S. Miyatake *et al.*, Neurosurgery **61** (2007) 82-90, discussion 90-81,.
[3] S. Kawabata *et al.*, J Neurosurg. In press.

採択課題番号 24027　熱外中性子を用いた悪性脳腫瘍に対する非開頭中性子捕捉療法の　共同通常
臨床的研究
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CO1-2 Development of Neutron Devices for Fundamental Physics

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INTRODUCTION: Neutrons can be used for studying fundamental physics. Neutron lifetime is quite important for the parameter in Big Bang Nucleosynthesis. The permanent electric dipole moment of neutrons (nEDM) signals the violation of time-reversal (T) invariance. Cold neutron beam line 'NOP' was constructed at BL05 in Material Life science Facility at J-PARC for fundamental physics experiments [1]. We are developing neutron optical devices for the experiments.

BEAM DIVERGENCE MEASUREMENT: For precision measurements using neutron beam, for example, neutron lifetime, the understanding of the phase-space distribution of the incident beam is important. It enables us to verify the upstream optics of the beam line and to investigate its downstream effects. Beam divergence measurement system was developed. It consists movable pinhole and 2D position sensitive detector. We can measure the beam divergence through the pinhole with time of flight. After the system was tested at cold neutron beam line CN3 in KUR, it was installed into the polarized beam branch of BL05 (Fig. 1).

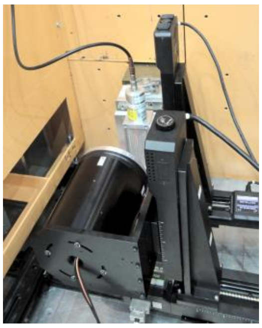

Fig. 1 The beam divergence measurement system on BL05.

OPTICS FOR DOPPLER SHIFTER: At the unpolarized beam branch of BL05, the Doppler shifter is working to provide Ultra Cold Neutrons (UCNs) by reflections off the rotating mirror. The UCNs are mainly used for developments of devices for the experiment to search nEDM. New neutron guide tubes and monochromatic mirrors were installed in order to increase the incident slow neutrons to Doppler shifter and the extracted UCNs (Fig. 2). Supermirror guide with m = 2 was installed after the beam bender of BL05 instead of vacuum tube. The monochromatic mirrors which extract 3nm-neutrons for the Doppler shifter was replaced with the new one with wider bandwidths. The mirrors were fabricated by ion beam sputter in KURRI. The new tapered neutron guide tubes were also installed after the mirrors to gather neutrons to the rotating mirror. The mirrors in this tapered guide were made by vacuum evaporation machine in KURRI. The intensity of neutrons from the Doppler shifter, which consists UCNs and faster neutrons, was 49 cps with 300 kW proton beam power. It means that the improvement of neutron optics gained about 20 times of the intensity. The result was consistent with a simulation within 15%.

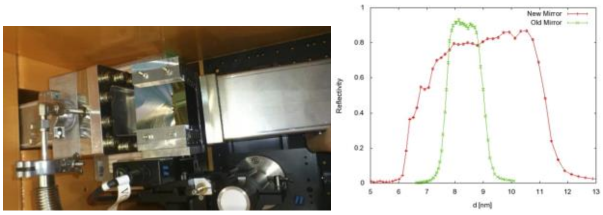

Fig. 2 Optics for Doppler shifter. (Left)
Reflectivity for mirror lattice constant of the monochromatic mirror. Green and red lines are for old and new mirrors respectively. (Right)

NEUTRON ACCELERATOR FOR FOCUSING: For improvement of sensitivity of nEDM experiment, the density of UCNs is quite important in order to reduce the systematic errors from the uncertainty of the environment. In the case of pulsed neutron source, when fast neutrons are decelerated and/or slow neutrons are accelerated properly, these neutrons can be focused on the experimental area at the same time with recovering the density. We developed a neutron accelerator and successfully observed the focusing of UCNs at the PF2 TES beam line in the High Flux Reactor at Institut Laue Langevin [2]. The accelerator controlled the UCN velocity by selecting the frequency of the RF spin flipper. The observed TOF spectra were in good agreement with Monte Carlo simulations with focusing (Fig. 3). Now we are developing a new accelerator with wider velocity range and high power. It will be tested by using the UCNs from the Doppler shifter at BL05.

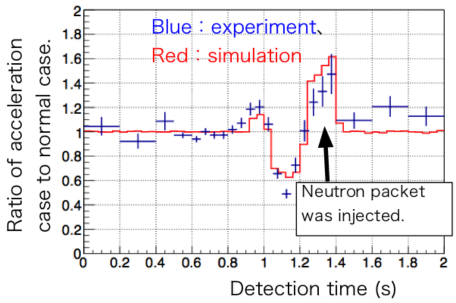

Fig. 3 The ratio between TOF spectra with RF ON and RF OFF. Focusing was observed.

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[2] Y. Arimoto *et al.*, Phys. Rev. A (2012)

採択課題番号 24053　　高効率超冷中性子輸送デバイスの開発　　共同通常
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CO1-3 Development of a DLC Coating for Polarized UCN Guide

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INTRODUCTION:

Ultra-Cold Neutrons (UCN) are extremely low energy neutrons which have a kinetic energy below a few hundred neV. Since most material have a potential for neutron, called Fermi potential, larger than UCN, UCN can be confined in a material bottle. Because of this characteristic, UCN are used for various experiments such as neutron electric dipole (nEDM) search, life time measurement, gravity experiments and so on. For nEDM search, UCN are confined in a cell which is in a magnetic and electric field and their spin precession frequency shift is measured. Polarized UCN are necessary for such experiment. Since UCN feel magnetic potential of 60 neV/T , a few T magnetic field can polarize UCN. Usually a magnetized iron foil or a super-conducting magnet are used for a polarizer. Polarized UCN are guided to the cell from the polarizer. High Fermi potential and low spin depolarization are required for such guide material. Hydrogen free diamond like carbon (DLC) is a one of the good candidate. In this report, Fermi potential of some DLC materials are measured by a neutron reflectometer at Kyoto University Research Reactor Institute will discussed.

EXPERIMENTS:

Four different DLC samples are prepared for this experiment. Samples are C_6F_6, pure Carbon, normal density Tetrahedral Amorphous Carbon (ta-C) and high density ta-C. These samples are fabricated by ionized physical vapor deposition on Si disk. C_6F_6 and pure Carbon are made by Nanotec Corp.[1], ta-C samples are made by Nanofilm Technologies [2].

DLC potential is measured by a cold neutron reflectometer. Fig. 1 shows a schematic drawing of the experimental setup. Incident cold neutrons of which wave length is 0.3 to 0.7 nm are bunched by chopper. Bunched neutrons are reflect at the sample surface and detected by ^{3}He counter. Time of flight between chopper and ^{3}He detector is measured. Since incident neutron beam has broad velocity distribution, detection timing is also have some width. Slow neutrons of which transverse energy against sample surface is lower than sample potential are total reflected at the sample surface and are detected. Critical velocity of reflection is measured in this measurement.

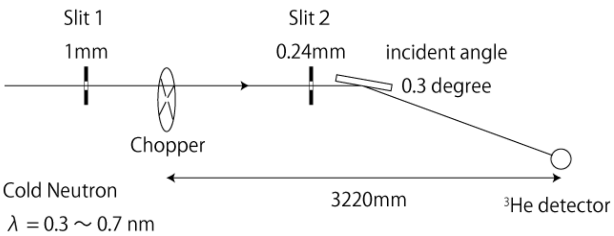

Fig. 1 setup

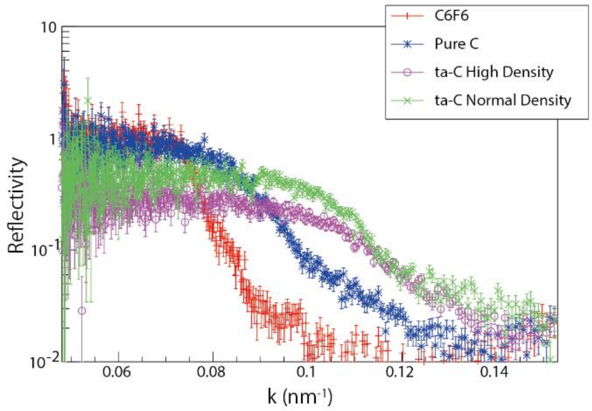

Fig. 2 : Reflectivity

RESULTS:

Reflectivity as a function of wave number is shown in Fig. 2. Assuming sample thickness is long enough, reflectivity is calculated to be $|R|^2 = (k-k')^2/(k+k')^2$, where k is incident wave number and k' is wave length in sample. Sample potential is determined by fitting of reflectivity with this function. Fitting result is shown in table below. Ta-C high density has highest potential of 260 neV. This value is good enough for guide material. We will investigate depolarization rate and make a polarized UCN guide by DLC.

Table 1 Sample potential

Material	Potential
C_6F_6	110 neV
Pure Carbon	150 neV
Ta-C normal density	230 neV
Ta-C high density	260 neV

REFERENCES:

[1] Nanotec Corp. http://www.nanotec-jp.com
[2] Nanofilm Technologies International http://www.nanofilm.com.sg/index.htm

CO1-4 Test of Mass Production of Neutron Supermirrors for Real Neutron Guide by Using KUR-IBS

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INTRODUCTION: Supermirror is most important key component of neutron guide tube. The total length of neutron guide tube is, in general, longer than 10 m. Ion beam sputtering (IBS) technique enables us to fabricate smooth layer structure with sharp edge and we have succeeded in fabricating m>5 supermirrors and very small d-spacing multilayer [1]. The maximum substrate area at our KUR-IBS machine was limited to 200 mm in diameter until 2011. The maximum substrate area at JAEA-IBS machine is 500 mm in diameter and they are producing a lot of supermirrors for J-PARC project. In FY2011, Kyoto University and KEK started to construct a new beam line for neutron spin echo (NSE) spectrometers at BL06 at J-PARC/MLF. The NSE spectrometers are called “VIN ROSE” and it has been developed by KUR team and tested at C3-1-2-2(MINE1) beam line at JRR-3 reactor. We designed the BL06 beam line and started to fabricate supermirrors for the guide tube by using the KUR-IBS machine. The total length of the guide tube is about 29 m. We had to find out new scheme for mass production of supermirror to construct the neutron guide. It is important to accumulate such experience since we have a plan for next neutron beam facility after KUR.

EXPERIMENTS: Figure1 shows photograph of real substrate holder for fabrication of supermirrors for the BL06 guide tube at J-PARC. The substrate holder and attachments were developed at the workshop in KURRI. The reflectivity measurements were carried out by using two reflectometers at CN-3 in KUR and BL16 (SOFIA) at J-PARC/MLF. We checked reflectivity of monitor mirror at the CN-3 and most of supermirrors were measured by the SOFIA.

RESULTS: Figure 2 shows reflectivity by typical m=2.5, 3 supermirror on the silicon wafer. Most of supermirrors have been measured and performance of the average was high. We succeeded in fabrication of large scale neutron supermirror with high reflectivity for real neutron guide. This result also contributes to develop new monochromator for KUR-SANS [2]. As a next step, we are going to develop two-dimensional focusing supermirror in which shape is ellipsoid.

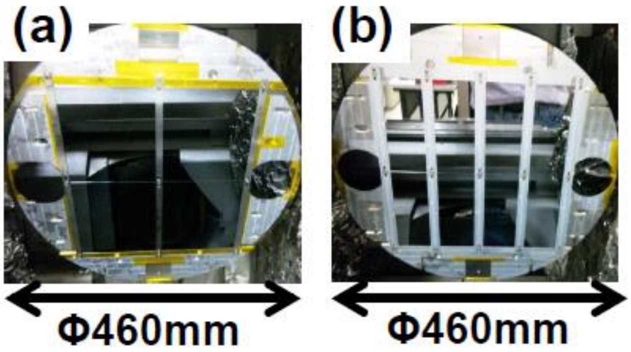

Fig.1 The photograph of substrate holder in which diameter is 460 mm and silicon wafers placed at the substrate holder in KUR-IBS.

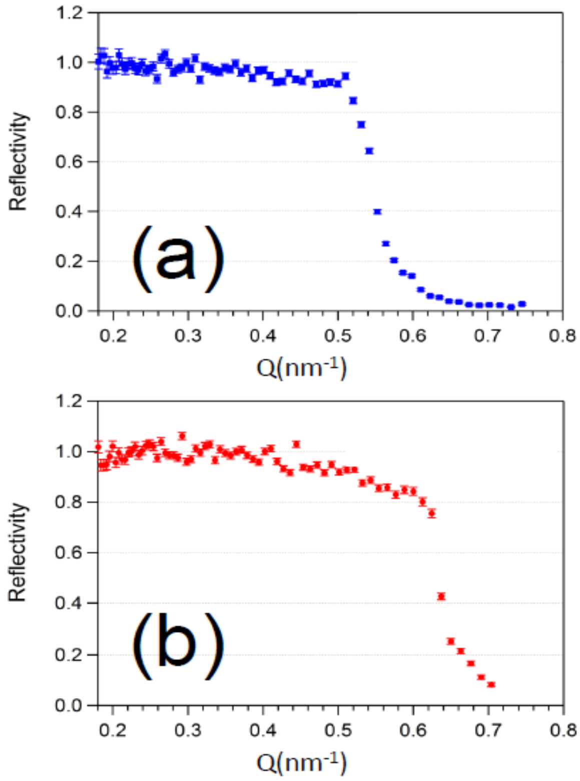

Fig.2 Measured reflectivity of (a) m=2.5 and (b) m=3 NiC/Ti supermirrors deposited on the silicon wafers.

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[1] M.Hino, *et al.*, Nucl.Inst.Meth. A **574** (2004)292.
[2] M.Hino, *et al.,* in this KURRI Progress report(No. 24P9-4).

採択課題番号 24087　　次期中性子ビーム科学施設のための中性子光学デバイス開発　　共同通常
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（高エネ機構・IMSS）山田悟史、瀬戸秀紀