（ ※本報告書は英語で記述してください。ただし、産業利用課題として採択されている方は日本語で記述していただいても結構です。 ）

CROSS TOKAI **Experimental Report** J-PARC	承認日 Date of Approval 2017/6/26 承認者 Approver Takenao Shinohara 提出日 Date of Report 2017/6/26
課題番号 Project No. 2016A0272 実験課題名 Title of experiment Neutron Transmission Spectroscopic Imaging for Analysis of Freezing Process of Lead Bismuth Eutectic 実験責任者名 Name of principal investigator Yasushi Saito 所属 Affiliation Kyoto University	装置責任者 Name of Instrument scientist Takenao Shinohara 装置名 Name of Instrument/（BL No.） RADEN/BL-22 実施日 Date of Experiment 2016/6/3～5, 2017/1/19～21

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。（適宜、図表添付のこと）
Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.

Sample : Lead-bismuth eutectic alloy (PbBi)

2. 実験方法及び結果（実験がうまくいかなかった場合、その理由を記述してください。）
Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.

- **Experiments**

The pulsed neutron imaging experiments were performed at BL22. A test section was installed in a front of the detector. In the present experiments, a GEM detector (nGEM, Bee Beans Technologies Co., Ltd.) was applied to get two-dimensional distributions of time-of-flight (TOF) information. The spatial resolution of this detector is 0.8 mm/pixel and the imaging area is 100 × 100 mm^2.

A schematic diagram of the test section for the solidification experiments is illustrated in Fig. 1. In order to simulate one-dimensional solidification process,

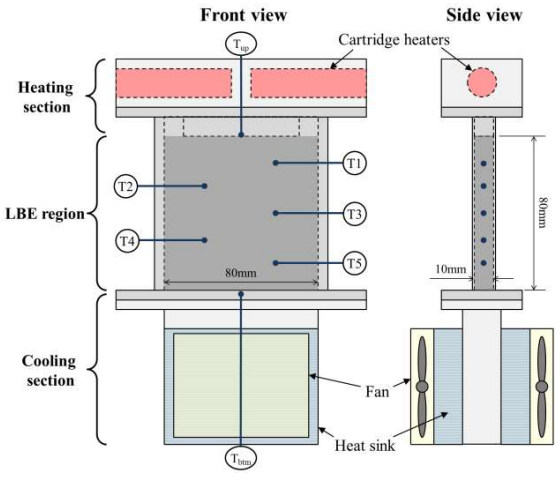

Fig.1 Experimental setup

a rectangular vessel was used. The LBE sample was encapsulated in the vessel and sealed. The walls of the test section have 1 mm thickness and were made of stainless steel which has similar thermal conductivity with the LBE. The size of the confined LBE was 80 mm in width, 80 mm in height and 10 mm in thickness. In order to decrease the influence of the convection of the liquid phase, the heating section was placed on top vessel and the cooling one was placed at the bottom. The heating and cooling sections were made of aluminum. In the heating section, two cartridge heaters were inserted and the power was controlled by a temperature controlling unit. The LBE vessel and the heating section were covered by thermal insulator to prevent the heat loss. Two heat sinks with fans were used in the cooling section. Five thermocouples were inserted from the side walls of the vessel, as shown in Fig. 1, and the axial temperature profiles in the LBE region were measured with a sampling frequency of 1 Hz during the experiments. Also, the temperatures at the upper and lower walls were recorded.

- **Results**

By heating the test section from upper side, the condition that the LBE sample in upper half is liquid state and that in lower half is solid state could be produced. Then, the neutron transmission spectra in the upper and lower area were compared. The estimated spectra are shown in Fig. 2. In the lower area, there is a large edge at 5.4 Å, which is corresponding to β(101). However, such characteristic edge could not be observed in the liquid area. Therefore, the Bragg edge at 5.4 Å was used to recognize the solid and liquid phases. Fig. 3 shows the Bragg edge images in the cooling process of the LBE. The jumps of the edge at 5.4 Å in the spectra which is averaged for 30 minutes were estimated at each pixel, and the images were made by using the amplitude of the jump. The solid and liquid phases can be identified by the image contrast and the interface is roughly visualized at the middle of the test section, as shown in Fig.3(a). During the solidification process, the solid part grows upward with time and finally the solid-liquid interface reaches to upside wall. From these results, Bragg edge imaging technique was successfully applied to study the LBE crystal structure. Further quantitative evaluation of the solidification process should be performed in future.

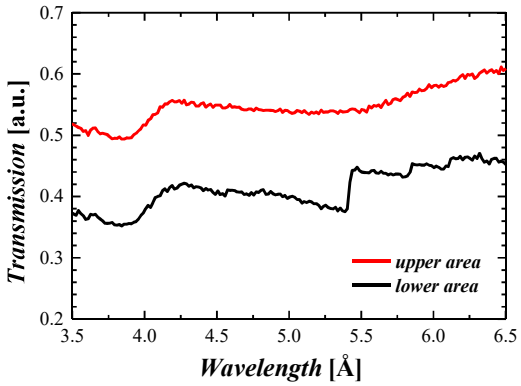

Fig.2 Neutron transmission spectra in the upper and lower area of the test section

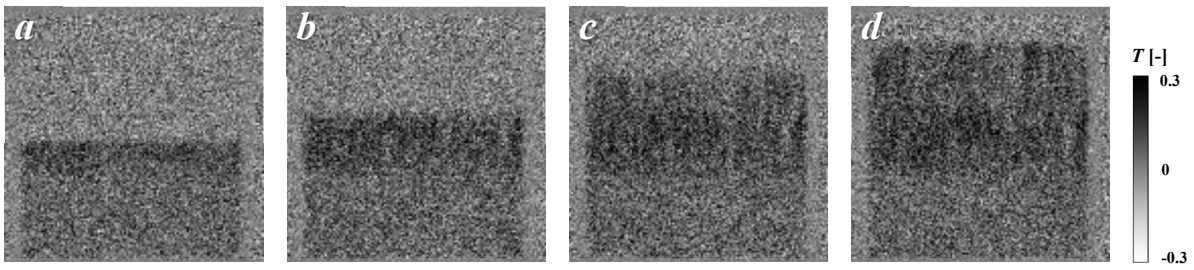

Fig. 3 Bragg edge images in LBE solidification process; (a) t = 0~0.5 hours, (b) t = 1~1.5 hours, (c) t = 2~2.5 hours, (d) t = 3~3.5 hours