MLF Experimental Report	提出日 Date of Report
課題番号 Project No. 2014A0001 実験課題名 Title of experiment Development of a new elemental analysis system using negative muon capture 実験責任者名 Name of principal investigator Takahito OSAWA 所属 Affiliation Quantum Beam Science Center, Japan Atomic Energy Agency	装置責任者 Name of responsible person Yasuhiro Miyake 装置名 Name of Instrument/(BL No.) D2 実施日 Date of Experiment May 14 to 17, 2014

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.

Carbon (Graphite)

Imilac Meteorite (pallasite)

Brown Filed Meteorite (H3 chondrite)

JP-1 (peridotite)

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.

The new elemental analysis system using negative muon beam developed in 2014 is mainly composed of a water-cooled electromagnet, an Al flight tube, an Al sample chamber, a lead shielding body, and a Ge detector. The electromagnet was designed to generate magnetism up to 0.43 T to bend muon beam with the momentum of 45 MeV/c. Curvature radius of the magnet and the flight tube is 350 mm. The muon beam is bent below with an angle of 45 degree in the Al flight tube and irradiates a sample that is set in the Al sample chamber. The installation of the sample can be made easy by bending the muon beam with the magnet below. The flight tube and the sample chamber are made by A5052 and A1070 aluminum alloys, respectively. A beam incident port of the Al flight tube is a polyimide foil supported by an Al trellis window and most of muon beam can penetrate the polyimide foil. Therefore, muon beam passes through air between a beam outlet and the beam incident port and the distance is 140 mm. The muon beam is collimated by an Al collimator set under a mounting adaptor that is installed between the flight tube and sample chamber and the collimators can be exchanged easily. Three Al collimators were prepared in this work and the sizes of a round hole of them were ϕ30, ϕ50, and ϕ70. The sample chamber has a loading hatch which is used to exchange sample easily.

2. 実験方法及び結果（つづき） Experimental method and results (continued)

A sample is put on a beryllium plate and the plate set in the sample chamber. All the muons which do not irradiate a sample pass through the beryllium plate (10 × 10 mm) and stop at the bottom of the chamber. A lead shielding body sheathed by copper with the thickness of 3 mm is installed upon the sample chamber and a Ge detector is set in the shielding body. Muonic X-rays emitted from the collimator and from the bottom of the sample chamber can be shielded by the lead shielding body. Therefore, the geometry of the analysis system can effectively reduce the background level. The Al chambers are exhausted by a turbo molecular pump before measurement and the pressure is lower than 0.05 Pa. Ultra-high vacuum is not required in the measurement. The alignment of the analysis system can be adjusted using a three-axis movable mechanism. Excitation current of the electromagnet is supplied by a DC stabilization power supply which is externally controlled by a multifunction DAQ and a control program produced by LabVIEW.

Beam profile can be recorded through an acrylic fiber flange installed to the sample chamber. A plastic scintillator (2T × 120 × 120 mm) was horizontally put on a sample holder in the sample chamber and the picture of the luminescence from the scintillator was taken by a CCD camera equipped with an image intensifier. The CCD camera was installed with its optical axis inclined to the scintillator by 45 degree. Reflecting light from the inner surface of the sample chamber is prevented by a black film that is treated by alumite. The beam profiles were recorded in twelve conditions; the momentums of muon beam were 30, 35, 40, 45 MeV/c and collimators were ϕ30, ϕ50, and ϕ70. Recording duration depended on the momentum; such as 300, 60, 20, and 20 seconds for 30, 35, 40, and 45 MeV/c, respectively. Excitation current was gradually changed and the profiles were taken in each condition. The best excitation current can be determined by the profiles empirically. The effect of the beam collimators was checked in the next step. The spread of muon beam is unrelated to the momentum of muon beam and it is controlled only by the size of the hole of collimator. It became clear that the muon beam widely spread and not only the sample but also the aluminum sample holder is irradiated when the size of collimator's hole is large. ϕ30 collimator is, therefore, the most suitable among the three collimators to measure the sample.

Four samples, carbon (graphite, 5T × 50 × 50 mm), a standard reference material of peridotite (JP-1), Brownfield meteorite (H3 ordinary chondrite, ca. 40 × 30 mm), and Imilac meteorite (pallasite, ca. 30 × 20 mm) were measured after the background analysis. An aluminum dish with 50 mm diameter was filled with JP-1 powder and it was wrapped by aluminum foil to prevent the powder from overflowing out of dish in the vacuum chamber. Negative muon completely penetrates the aluminum foil and no X-ray is emitted from the foil because its thickness is only 15 μm. Other three samples were not wrapped by aluminum foil. The momentum was 40 MeV/c and ϕ30 collimator was used for all analyses. Only Be plate was measured in the blank analysis. Background level and S/N ratio are obviously improved compared with the previous work because the peaks of Al found in the spectrum of Murchison meteorite was mostly derived from the background noise. In all cases of our experiment, beautiful spectra were recorded and all major elements were detected. In the blank analysis no Be peak was found, indicating negative muon penetrate the plate completely. The result shows that muonic X-ray analysis using the new analysis system is available to the measurement of the extraterrestrial materials.