（ ※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。 ）

MLF Experimental Report	提出日 Date of Report 2016.05.10
課題番号 Project No. 課題番号 Project No.2014B0144 実験課題名 Title of experiment Nondestructive study of traditional Japanese forged iron artifacts using pulsed neutron imaging for evaluating crystallographic texture and microstructure and investigating their manufacturing techniques 実験責任者名 Name of principal investigator Manako Tanaka 所属 Affiliation Tokyo University of the Arts	装置責任者 Name of responsible person Kenichi Oikawa 装置名 Name of Instrument/（BL No.） BL10 実施日 Date of Experiment 02/20/2016～02/27/2016

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.

(1) Reproduction sample of Japanese sword, Fe, solid
(2) Reproduction sample of Japanese sword, Fe, solid
(3) Reproduction sample of Japanese sword, Fe, solid
(4) Reproduction sample of Japanese sword, Fe, solid
(5) Reproduction sample of Japanese sword, Fe, solid
(6) Reproduction sample of Japanese sword, Fe, solid
(7) Fragments of Japanese sword, Fe, solid
(8) Fragments of Japanese sword, Fe, solid
(9) Fragments of Japanese matchlock gun, Fe, solid

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.

【Experimental method】

The experiment was carried out by the pulsed neutron imaging using the TOF method (Fig.1) at J-PARC/MLF BL10. We observed the incident neutron TOF spectra and the transmitted neutron TOF spectra. The distortion of the incident spectrum was clearly observed in the transmitted spectrum due to the Bragg scattering. A 2D-PSD, μ-PIC (the spatial resolution: 400μm, detection area: 10cm×10 cm), was used to get the spatial dependent TOF data.

Measurements was performed at room temperature.

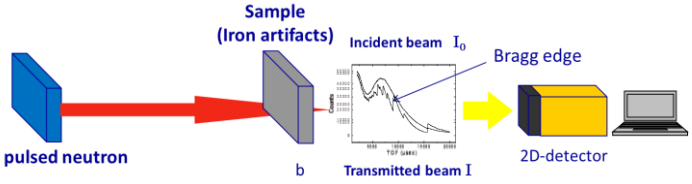


Fig.1. Experimental layout

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

【Results】

Although there was a trouble at J-PARC and a postponement of the experiment, the experiment itself was conducted as planned. One of the aim of this experiment is to analyze tamahagane steel samples manufactured by a contemporary sword smith which show the each manufacturing process of traditional Japanese sword (reproduction sample of Japanese sword) by pulsed neutron imaging and to evaluate their crystallographic texture and microstructure to clarify the details of the traditional Japanese sword making techniques nondestructively. We also want to check how detailed information (tracesmarks of the manufacturing process) we can get by pulsed neutron method.

Fig,2-5 show representative results of the Reproduction sample of Japanese swords. As shown in Fgi.2, the shape of the Bragg edge, especially the shape of the edge (110) changed in accordance with the outer steel making process. That implies that the texture of the sample was changed by folding and forge welding. From the position of each edges, (110), (200), and (211), lattice spacing were calculated. by RITS code (a Rietveld-type analysis code). Fig.3 shows quantitative analytical result of lattice constant. Lattice constant of Kowari sample shows large variation, however, lattice constant of Shita-gane sample and Agegitae sample become uniform. From the results, it is supposed that surface oxide (scale) and impurity were eliminated through outer steel making process (by folding and forge welding. As shown in Fig.4 and Fig.5, change of density, crystalline size, and texture were observed in

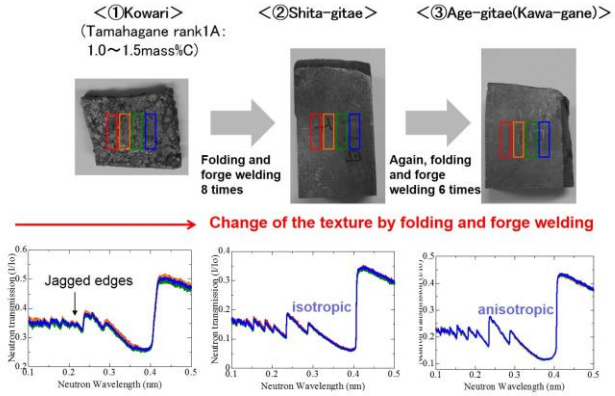


Fig.2 Change of the Bragg edge through outer steel(Kawagane) making process

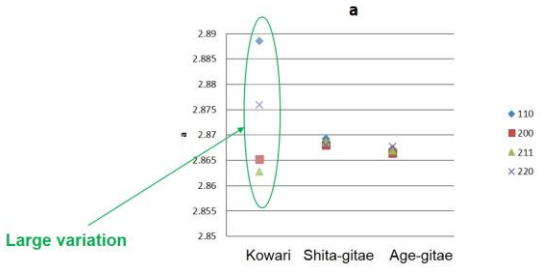
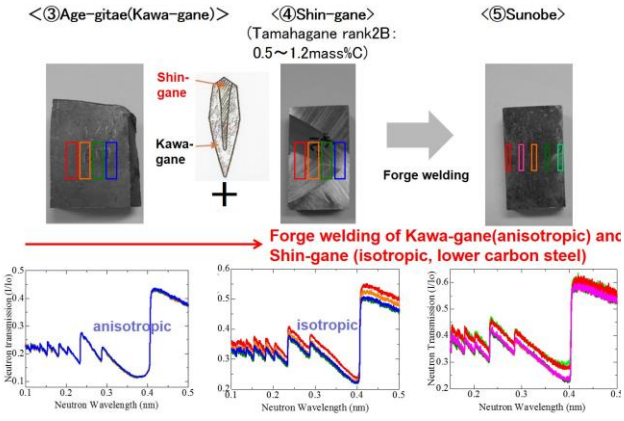


Fig.3 Quantitative analytical result of lattice constant



Fig,4 Change of the Bragg edge through forge welding process of outer steel(Kawa-gane) and inner steel (Shin-gane)

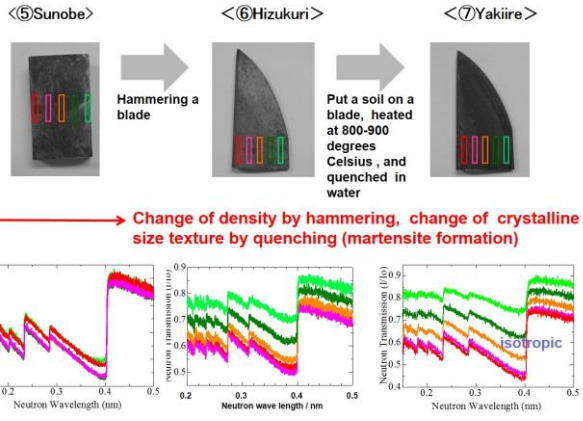


Fig.5 Change of the Bragg edge through hammering and quenching process

each manufacturing process of traditional Japanese sword. We continue to analyze the details of the results using RITS code, but so far, we confirmed that each steel sample showed a distinctive shape of Bragg edge which tells information of crystal structure, crystalline size, texture, and density. Those differences in microstructure remarkably reflect their material characteristics and the sword manufacturing techniques. It is concluded that by using pulsed neutron imaging, we can clarify the metallurgical characteristics and reveal the traditional Japanese sword making techniques nondestructively. We will continue to analyze the details and plan to use the results of this experiment as a basic data and extend our study towards a systematic nondestructive measurement of precious cultural heritage, such as Japanese swords by pulsed neutron.

Acknowledgement

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