Development of Pulsed Magnetic Field System for Functional Magnetic Materials

A Pulsed High Magnetic Field Measurement System has been developed, and its parameters have been tested. The System's ability to produce pulsed magnetic fields of 10–16 T has been confirmed, as has the temperature range achievable using the system (77–350 K). It has been demonstrated that the System's measurement capabilities allow for the measurement of magnetic moment, magnetoresistance, dielectric permittivity and magnetocaloric effect parameters. Further tests performed on representative samples of magnetic shape memory alloys confirmed the planned measurement capabilities. The System had been transferred to the V. G. Baryakhtar Institute of Magnetism of the National Academy of Sciences of Ukraine in Kyiv.

1. Introduction

Magnetic shape memory alloys (MSMAs) represent a unique class of functional materials that combine strong magneto-mechanical coupling with rapid, reversible deformation under external stimuli. Their ability to undergo large strains driven by magnetic fields makes them highly promising for applications in actuators, sensors, and energy conversion systems. However, the fundamental mechanisms governing their behavior – such as twin boundary motion, magnetic domain reorientation, and phase transformations – are strongly field-dependent and often nonlinear, particularly at elevated magnetic field strengths. As a result, understanding their full functional potential requires experimental investigation beyond low-field regimes.

High magnetic field measurements are therefore essential for accurately characterizing the intrinsic properties of MSMAs and revealing phenomena that remain inaccessible at moderate fields. Such measurements enable the determination of saturation magnetization, critical switching fields, magneto crystalline anisotropy, and field-induced phase transitions with greater precision. Moreover, they provide insight into energy barriers and hysteretic effects that directly impact material performance and efficiency in real-world applications. By extending the experimental parameter space, high-field studies play a crucial role in both validating theoretical models and guiding the design of advanced magnetic shape memory materials with optimized functional properties.

The aim of this work was to put into operation the Pulsed High Magnetic Field Measurement System developed by Prof. Hiroyuki Nojiri and his group at the Institute for Materials Research (Tohoku University) and carry out test measurements on the samples of magnetic shape memory alloys. The next step consists in the installation of the System in the V.G. Baryakhtar Institute of Magnetism of the NAS of Ukraine in Kyiv (Ukraine).

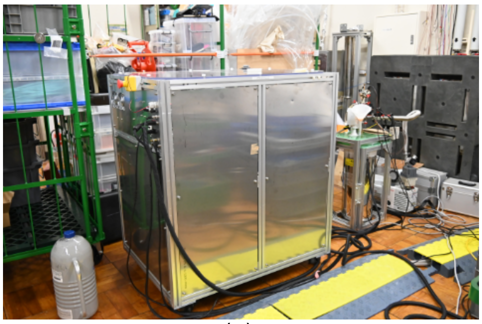
2. Experimental results

The first phase of the experiments involved examining the working parameters of the Pulsed High Magnetic Field Measurement System (Fig. 1a). The System's ability to produce pulsed magnetic fields of 10 – 16 T was confirmed. The temperature range achievable using the System was also tested. It was concluded that the reliable operating temperature range was 77–350 K.

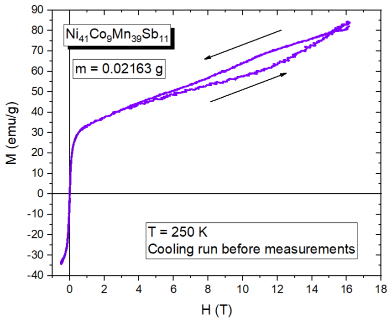
During the first phase of testing the System's parameters, it was demonstrated that the System's measurement capabilities allow for the measurement of magnetic moment, magnetoresistance, dielectric permittivity, and magnetocaloric effect parameters. During the project implementation, all System parameters were calibrated.

Given that the System allows for the measurement of all these parameters in strong magnetic fields and over a wide temperature range, this makes it unique for experimental studies, especially for understanding the behavior and processes in complex magnetic systems including magnetic shape memory alloys.

Further tests were performed on representative samples of magnetic shape memory alloys ($Ni_{50}Mn_{38}Sb_{12}$, $Ni_{50}Mn_{37.5}Sn_{12.5}$ and $Ni_{41}Co_9Mn_{39}Sb_{11}$) in order to evaluate the measurement capabilities. The magnetic, magnetoresistance and magnetocaloric parameters were measured. It was demonstrated that the measured parameters correlate with those reported in the literature [1,2]. Figure 1(b), for example, shows the magnetization versus magnetic field dependence for a $Ni_{41}Co_9Mn_{39}Sb_{11}$ sample.



(a)



(b)

Fig. 1. (a) Pulsed High Magnetic Field Measurement System – a general view. (b) Magnetization vs magnetic field dependence for a $Ni_{41}Co_9Mn_{39}Sb_{11}$ sample, obtained with the use of the System.

The next phase involved transferring the System to the V. G. Baryakhtar Institute of Magnetism of the National Academy of Sciences of Ukraine in Kyiv. The system was successfully transported to Kyiv. It was unloaded at the Institute of Magnetism an installed and assembled for operation. (Fig. 2).

3. Conclusions

The Pulsed High Magnetic Field Measurement System developed at the Institute for Materials Research (Tohoku University) has been put into operation and its parameters have been examined. It has been confirmed that the measurement capabilities correspond to those planned. Test measurements on the samples of magnetic shape memory alloys confirmed the system's excellent performance. The system was transferred to Kyiv and it is in commissioning at the V. G. Baryakhtar Institute of Magnetism of the National Academy of Sciences of Ukraine in Kyiv.

Fig. 2. Transportation and further works on the installation of the Pulsed High Magnetic Field Measurement System at the V. G. Baryakhtar Institute of Magnetism of the National Academy of Sciences of Ukraine in Kyiv (https://imag.kyiv.ua/index.php/en/japan-grad.html).

4. Contributions by young researchers

Dr. Dmytro Velyhotskyi (35 years old), a junior researcher at the V. G. Baryakhtar Institute of Magnetism of the National Academy of Sciences of Ukraine, took part in testing the system in Japan. He will operate the System and perform measurements in Ukraine.

References

1. Rie Umetsu, Xiao Xu, Wataru Ito *et al.*: Metals **4** (2014) 609.
2. Anna Kosogor, Rie Umetsu, Vladimir Golub *et al.*: J. All. Comp. **988** (2024) 174130.

Keywords: magnetism, high magnetic field, calorimetry
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