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Fine Magnetic Pattern Transferred on Nd-Fe-B Magnets Using High Heat-resistant Nd-Fe-B Magnets

Keita NAGAI[1], Naohiro SUGITA[2], and Tadahiko SHINSHI[2,#]

1 Department of Mechanical Engineering, Tokyo Institute of Technology, R2-38, 4259 Nagatsuta-Cho, Midori-Ku, Yokohama, 226-8503, Japan
2 Institute of Innovative Research, Tokyo Institute of Technology, R2-38, 4259 Nagatsuta-Cho, Midori-Ku, Yokohama, 226-8503, Japan
Corresponding Author / Email: shinshi.t.ab@m.titech.ac.jp, TEL: +81-45-924-5095, FAX: +81-45-924-5046

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High-performance electromagnetic MEMS devices are desired in IoT development. Fine-pitch and multi-pole magnetization are necessary to reduce the demagnetization field in the magnet and increase the surface magnetic flux density. Efficient magnetic circuits can be realized by forming various micro magnetic patterns. Laser-assisted heating magnetization has been developed for the fine-pitch and multi-pole micro magnetization of Nd-Fe-B magnets. However, it has the disadvantage of long patterning time due to laser scanning along with the desired magnetic pattern, making it unsuitable for mass production. This study aims to develop a batch transfer method for micro magnetic patterns of electromagnetic MEMS devices. The micromagnetic patterns are generated by laser-assisted heating on a master Nd-Fe-B magnet having high heat resistance. The magnetic pattern is transferred to the target Nd-Fe-B magnets by utilizing the difference in coercive forces between the master and target magnets when the temperature rises. The master Nd-Fe-B magnet can be used multiple times due to its high heat resistance. We have successfully transferred the line type alternating poles of 16 with a pitch of 0.3 mm to a target Nd-Fe-B magnet (5×5×t0.5 mm, Br: 1.19 T, Hcb: 868 kA/m) at a temperature of 160 ℃. A thin plate Nd-Fe-B magnet having a high heat resistance (5×5×t0.3 mm, Br: 1.29 T, Hcb: 907 kA/m, Work. Temp.: 200 ℃) was used as a master magnet. The measured surface flux density on the target magnet is 137 mT in amplitude, which is 54.4 % of the ideal value.

1. Introduction

High-performance electromagnetic MEMS devices such as energy harvesters and microactuators are desired in IoT development. Fine-pitch and multi-pole magnetization methods of the permanent magnet are necessary to reduce the demagnetization field in the magnet and increase the surface magnetic flux density. In addition, efficient magnetic circuits can be realized by forming various micro magnetic patterns. Laser-assisted heating magnetization [1] has been developed for the fine-pitch and multi-pole micro magnetization of Nd-Fe-B magnets. However, it has the disadvantage of long patterning time due to laser scanning along with the desired magnetic pattern, making it unsuitable for mass production. The ultra high magnetizing (UHM) process [2] for fine batch magnetization was developed for the mass production of micro motors. In UHM, the coercivity of a target Nd-Fe-B magnet is weakened by heating it above the Curie temperature. This magnet is rapidly cooled in a multi-pole magnetizing field formed by multiple small SmCo magnets.

However, the limitation is being reached in the miniaturization and multi-polarization by assembling many unidirectionally magnetized micro SmCo magnets. This study aims to develop a magnetization method that can be used for magnetic MEMS, using advantages of the batch process by UHM and the miniaturization features of laser-assisted heating magnetization. In this paper, an alternating magnetic pattern is formed on a heat-resistant Nd-Fe-B plate magnet by laser-assisted heating magnetization. In addition, the fine magnetic pattern is transferred to another Nd-Fe-B magnet with a lower coercivity at a high temperature to verify the proposed method.

2. Micromagnetic Pattern Transfer Method

Figure 1 shows the principle of the proposed micromagnetic pattern transfer method. In the 1 aser-assisted heating magnetization method, a master magnet surface is locally heated by laser scanning, and the coercivity of the magnet is lowered only in the heated area. A relatively weak external magnetic field of less than 1T changes the direction of magnetization in the heated area, resulting in

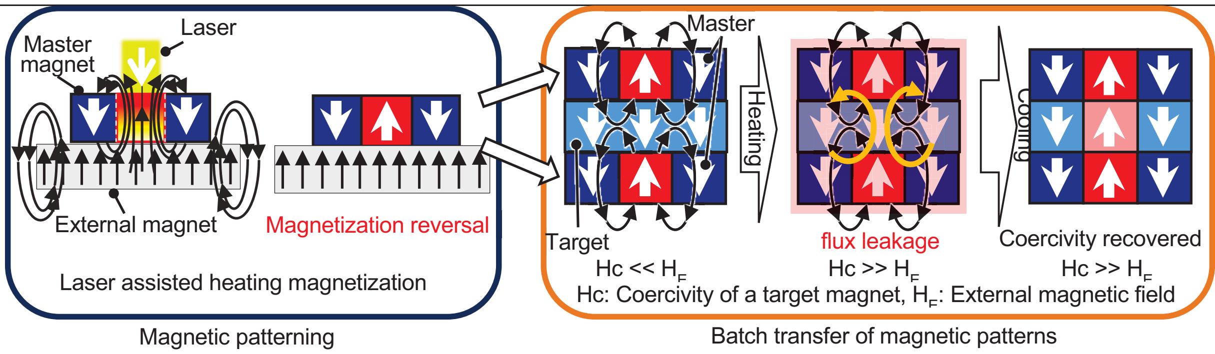

Fig. 1 Principle of the micromagnetic transfer method

a fine magnetization pattern. This method enables the generation of micro-order magnetic patterns by reducing the laser spot diameter.

A target magnet magnetized in one direction is sandwiched between master magnets. When the three magnets are heated together, only the coercivity of the target magnet significantly decreases due to the low heat resistance. The magnetic pattern of the master magnets is transferred to the target magnet. By magnetizing the target magnet in one direction in advance, it is possible to decrease the heating temperature compared to the UHM process [2]. The reason is that the magnetic field is enhanced using both the magnetic field generated by the target and master magnets.

Due to high heat resistance, the master Nd-Fe-B magnets can be used many times without demagnetization. Furthermore, large-area master magnets can simultaneously transfer the patterns to many target magnets, making them suitable for mass production.

3. Experiment

3.1 Fabrication of the master magnet

A 16-pole alternating magnetic pattern with a pitch of 0.3 mm is formed on a target Nd-Fe-B magnet with a high working temperature (5 × 5 × t0.3, Br: 1.29 T, Hcb: 907 kA/m, working temp.: 200 °C) using the laser-assisted heating magnetization. The wavelength, power, and scanning speed of the laser for heating are 532 nm, 6 W, and 160 mm/s, respectively. Figure 2 shows the measured flux density distributions at the height of 0.1 mm from the surface of the master magnets.

3.2 Transferring experiment

A target Nd-Fe-B magnet (Br: 1.19 T, Hcb: 868 kA/m, working temp.: 90 ℃) is machined by wire EDM to 10 × 10 × t0.5. Then, as

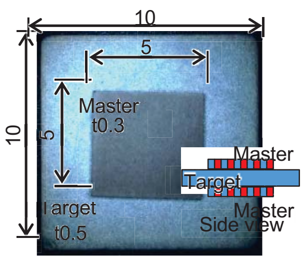

Fig. 2 Experimental setup of micromagnetic pattern transfer

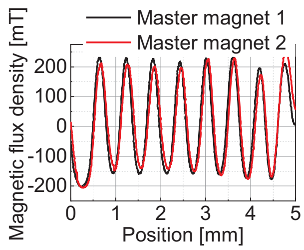

Fig. 3 Measured surface magnetic flux density of the master magnets

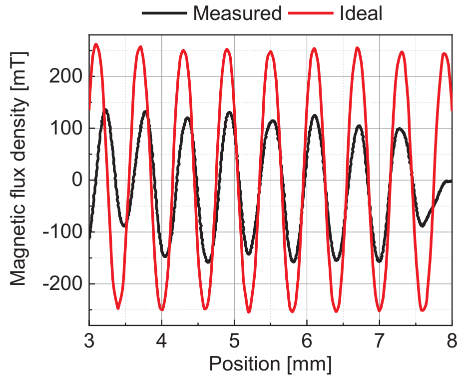

Fig. 4 Surface magnetic flux density of the target magnet after t he magnetic pattern transfer

shown in Fig. 3, the target magnet is sandwiched between the two master magnets. All the magnets are heated on a hot plate for 300 se conds to transfer the magnetic pattern. The heating temperature was changed between 100 and 200°C, and the surface flux density of the target magnet at each temperature was measured.

Figure 4 shows the measured surface magnetic flux density distribution at a heating temperature of 160°C. This result was the maximum surface magnetic flux density amplitude among the changed heating temperature between 100 and 200. The measured surface flux density on the target magnet 0.1 mm high from the surface is 137 mT in amplitude, which is 54.4 % of the simulated value. In the simulation, each pole is ideally magnetized. In order to improve the surface magnetic flux density generated in the future, it is necessary to change the magnet base material of the master magnet and strengthen the magnetization field.

4. Conclusions

This paper proposed and verified a method of transferring highly efficient fine multi-pole magnetic patterns onto permanent magnets. Using the laser-assisted magnetization, a 16-pole alternating fine magnetic pattern with a pitch of 0.3 mm was formed on the master Nd-Fe-B magnet with high heat resistance. The magnetic pattern was transferred to the target Nd-Fe-B magnet with low heat resistance. All the magnets were heated at 160℃, resulting in the measured flux density at the height of 0.1 mm from the surface beings 137 mT in amplitude, which is 54.4 % of the simulated value.

In the future, to improve the surface magnetic flux density generated, it will be necessary to change the material of the master magnet and strengthen the magnetization field.

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REFERENCES

1. D. Han, K. Nagai, T. Shinshi, Sensors and Actuators A: Physical, Vol. 311, 112050, 2020.
2. H. Komura, et al., IEEE Transactions of magnets, Vol. 44, No. 11, pp. 4266-4268, 2008.