Supplementary Material: Single-material anomalous Nernst heat-flux sensor enabled by heat-assisted magnetization reversal

Weinan Zhou,[a] Hirofumi Suto, and Yuya Sakuraba

Research Center for Magnetic and Spintronic Materials, National Institute for Materials Science, Tsukuba 305-0047, Japan

[a]Electronic mail: ZHOU.Weinan@nims.go.jp

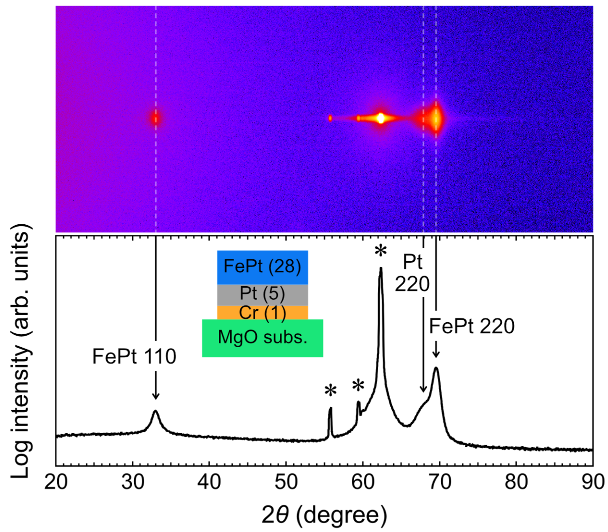

FIG. S1. Out-of-plane XRD pattern of the thin film used in this study. The color map at the top shows the corresponding two-dimensional diffraction image. A clear 110 superlattice peak of $L1_0$-FePt is observed. The diffraction peaks labeled by $*$ originated from the MgO substrate. The inset illustrates the stacking structure of the thin film, with the thickness of each layer given in nanometer in parentheses.

Alt text: Out-of-plane XRD pattern of the thin film used in this study.

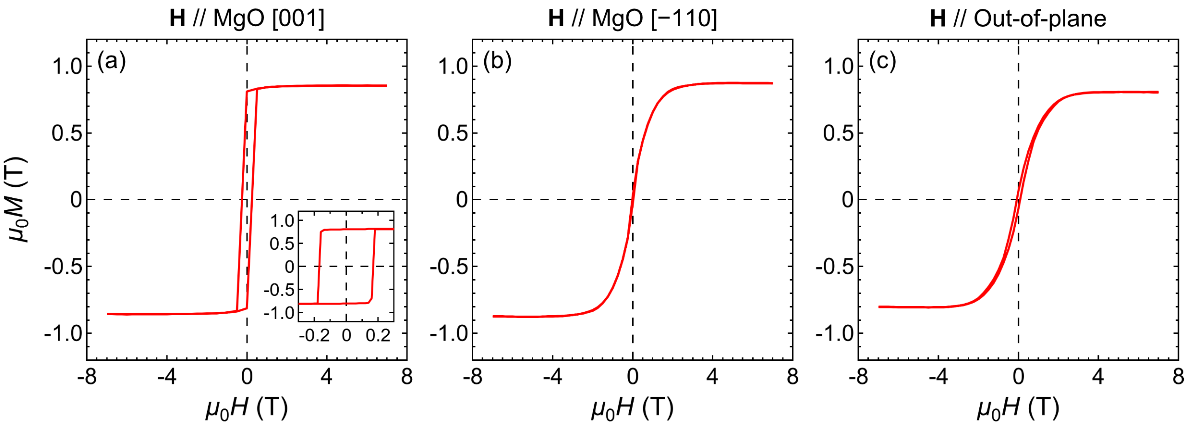

FIG. S2. (a) M-H curves of the thin film measured at 300 K with $\mathbf{H}$ along the MgO [001] direction, (b) the MgO [$-$110] direction, and (c) the out-of-plane direction. The inset in (a) shows the curve measured with a small H increment around zero field. These results indicate that the magnetic easy axis of FePt is along the MgO [001] direction.

Alt text: M-H curves of the thin film measured at 300 K. (a) and (b) and (c) Measured with $\mathbf{H}$ applied along the MgO [001], MgO [$-$110], and out-of-plane directions, respectively.

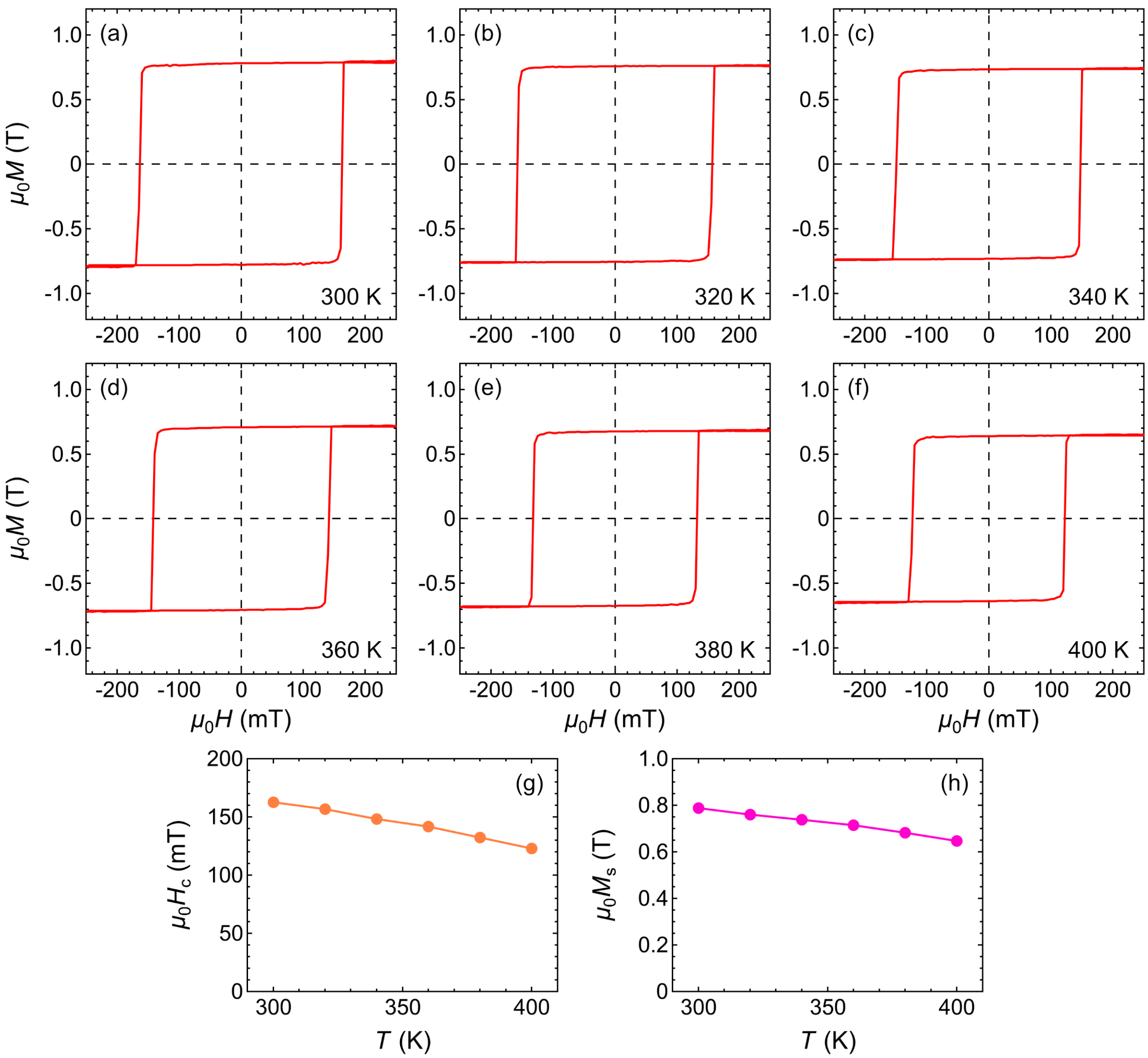

FIG. S3. (a) M-H curves of the thin film measured at 300 K, (b) 320 K, (c) 340 K, (d) 360 K, (e) 380 K, and (f) 400 K with $\mathbf{H}$ along the MgO [001] direction. (g) The coercivity (H_c) and saturation magnetization (M_s) of the FePt thin film as a function of temperature (T) extracted from the curves in (a)-(f). Both H_c and M_s decrease with increasing T. $\mu_0 H_c = 163$ mT at 300 K, consistent with that of a single FePt wire shown in Fig. 2(b). Meanwhile, $\mu_0 H_c = 123$ mT at 400 K. This value is comparable to the behavior of heat-assisted magnetization reversal with $I = 41.2$ mA, as suggested by the estimated wire temperature due to Joule heating shown in Fig. 4(b).

Alt text: M-H curves of the thin film measured with $\mathbf{H}$ along the MgO [001] direction at elevated temperature. (a) and (b) and (c) and (d) and (e) and (f) Measured at 300 K, 320 K, 340 K, 360 K, 380 K, and 400 K, respectively. (g) The coercivity as a function of temperature. (h) The saturation magnetization as a function of temperature.

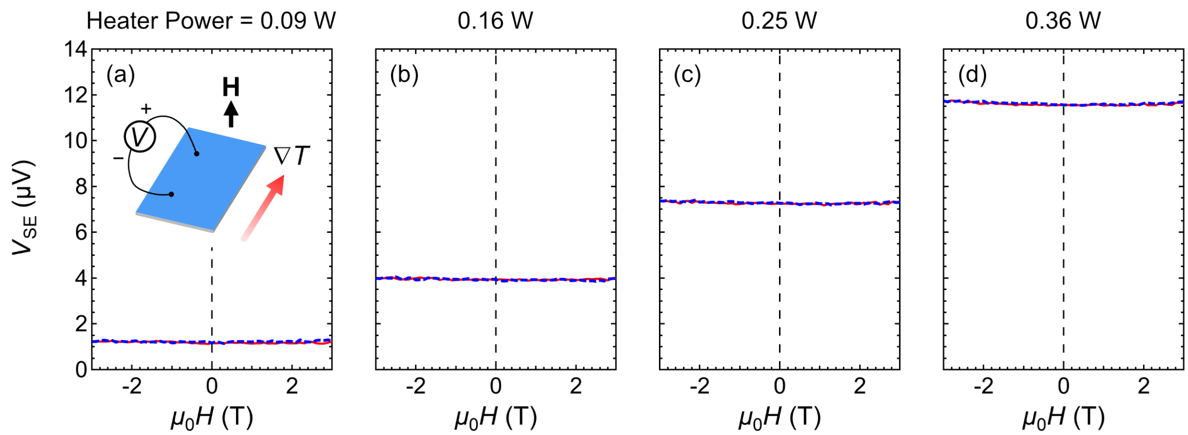

FIG. S4. (a) Seebeck voltages (V_{SE}) as a function of out-of-plane H measured with a heater power of 0.09 W, (b) 0.16 W, (c) 0.25 W, and (d) 0.36 W at one side of the sample to generate in-plane ∇T. The inset in (a) illustrates a schematic of the measurement setup. The overall V_{SE} values increase with increasing heater power. Meanwhile, the curves show little variation with sweeping H, and the values of V_{SE} in each curve are equal within the noise level at $\mu_0 H = \pm 3$ T, where $\mathbf{M}$ of FePt is aligned to the direction of H. These results indicate that the magneto-Seebeck effect of the FePt thin film is negligibly small.

Alt text: Seebeck effect of the thin film measured with in-plane temperature gradient and out-of-plane $\mathbf{H}$. (a) and (b) and (c) and (d) Seebeck voltages as a function of magnetic field with a heater power of 0.09 W, 0.16 W, 0.25 W, and 0.36 W, respectively.