Supporting Information

Switching magnetic strip orientation using electric fields

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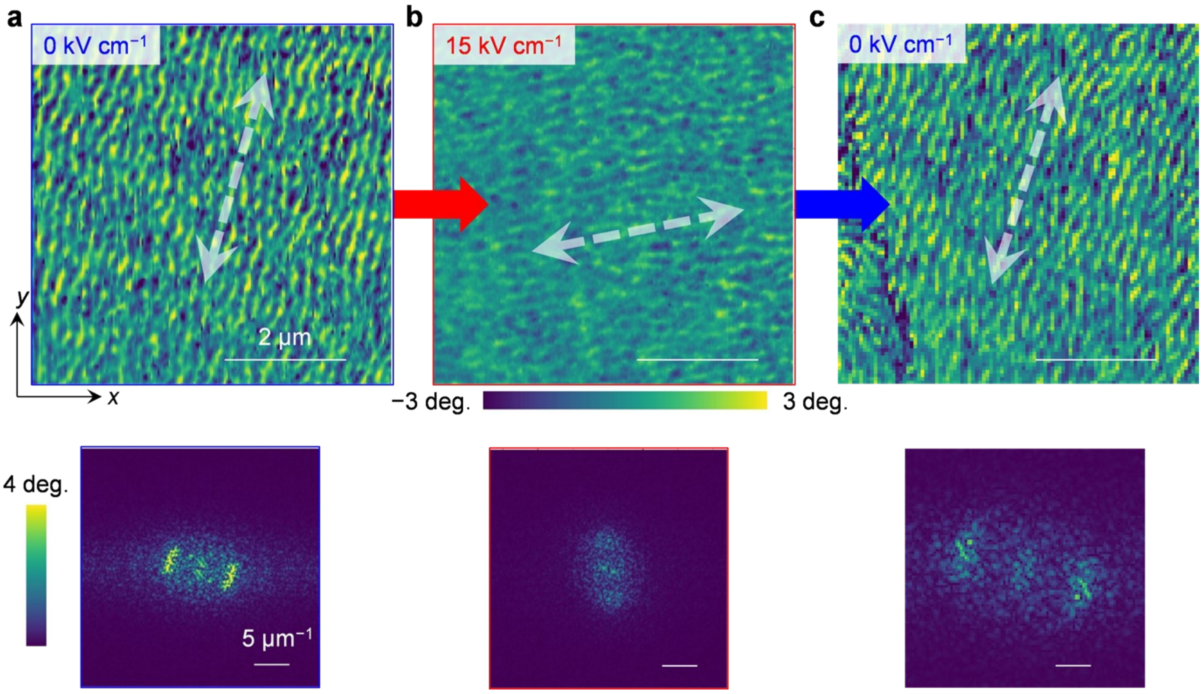

Fig. S1. Evolution of the ordered magnetic strip domains with and without an electric field of 15 kV cm^{-1}. The white dashed double-headed arrows show the orientations of the ordered magnetic strip domains. The bottom panels show the two-dimensional fast Fourier transform analysis of the MFM images. The orientation of the strip domains is almost along the *y*-axis at 0 kV cm^{-1} (Fig. S1a), then it rotated to *y*-axis by applying an electric field of 15 kV cm^{-1} (Fig. S1b). After removing the applied electric field, the strip domains rotated back to the *y*-axis as shown in Fig. S1c. In this way, the striped domains can be reversibly switched between *y*- and *x*-axes by applying electric field to the ferroelectric substrate.

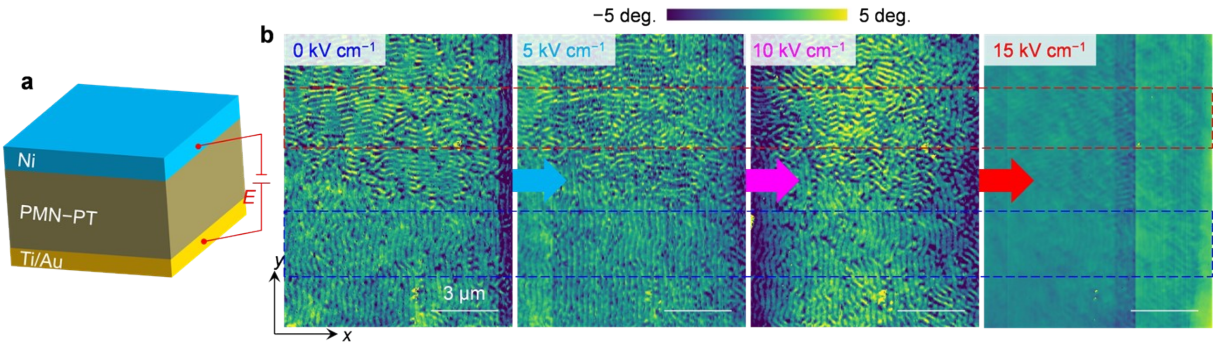

Fig. S2. a) Schematic of Ni film directly deposited on the PMN−PT substrate and b) the evolution of magnetic domains under increasing electric fields. It can be seen that the orientation of the magnetic strip domains does not have much change.

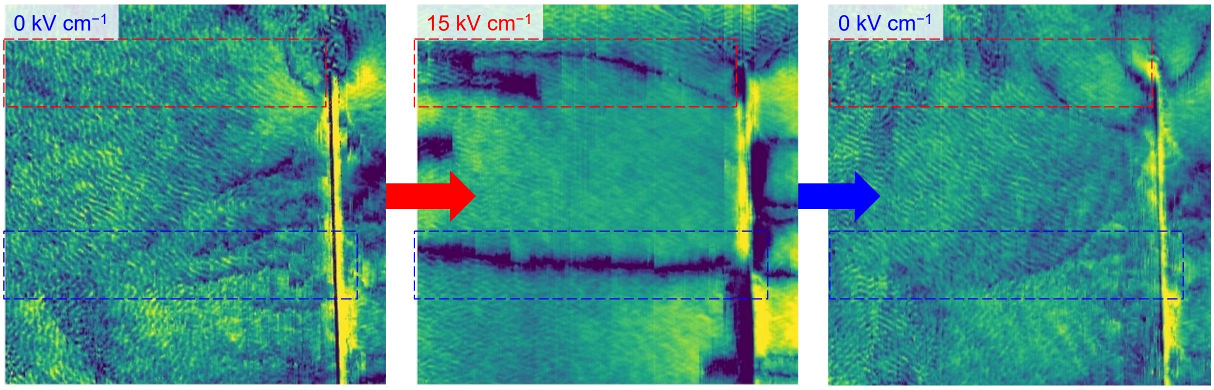

Fig. S3. MFM images with and without an electric field of 15 kV cm^{-1} for the Ni film deposited on the PMN−PT substrate with a PMMA nanotrench along the *y*-axis. In the dashed-line boxes, the dark lines appeared when applying an electric field of 15 kV cm^{-1}. Then the strip domains can be recovered after removing the applied electric-field.

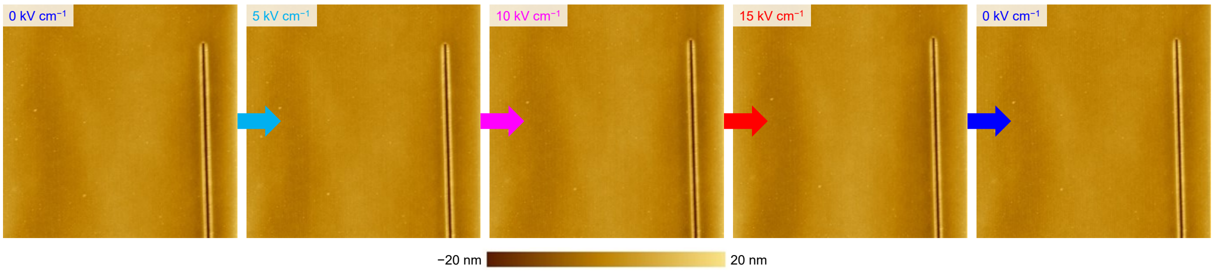

Fig. S4. AFM images under various electric fields without obvious change, which indicate that the electric-field-induced strain does not have any effect on the surface morphology.

Note S1. Calculation of the power consumption

For the energy dissipation in our system, the power consumption per unit area can be estimated by CV^2/A,[1,2] where C, V and A denote the capacitance of the piezoelectric layer, the applied voltage and the area of the device, respectively. The capacitance can be written as $C = \varepsilon_r\varepsilon_0 A/d$,[1,2] assuming a parallel plate capacitor (A is the area of the electrode, d is the thickness of the piezoelectric layer, ε_r is the relative dielectric constant of the piezoelectric and ε_0 is the vacuum dielectric constant). Thus, the power consumption per unit area can be expressed as $\varepsilon_r\varepsilon_0 V^2/d$. In our system, the thickness d and the relative dielectric constant ε_r of PMN-PT substrate are 0.5 mm and 3000 [Appl. Phys. Lett. 99, 182903 (2011)]. The largest operation electric fields is 15 kV cm^{-1} with an operation voltage of 300 V. Therefore, the power consumptions per unit area is about 1.2 mJ cm^{-2} with an applied electric field of 15 kV cm^{-1}.

For the spin transfer torque control of magnetic strip domains,[4] the power consumption per unit area can be estimated by I^2Rt/A, where I, R, t and A denote the current, resistance, pulsed current width and the area. The area A can be written as $A = l^2$, where l is the hall bar width (50 μm). Considering $R = 300\ \Omega$, $t = 10\ \mu\text{s}$, and current density $I/ld = 2 \times 10^5\ \text{A/cm}^2$, where d is the thickness (150 nm), the power consumptions per unit area is about 27 mJ cm^{-2}, which is much larger than that of our method using electric field.

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