**Supplementary Materials**

# Perpendicular compensated ferrimagnetic tunnel junctions

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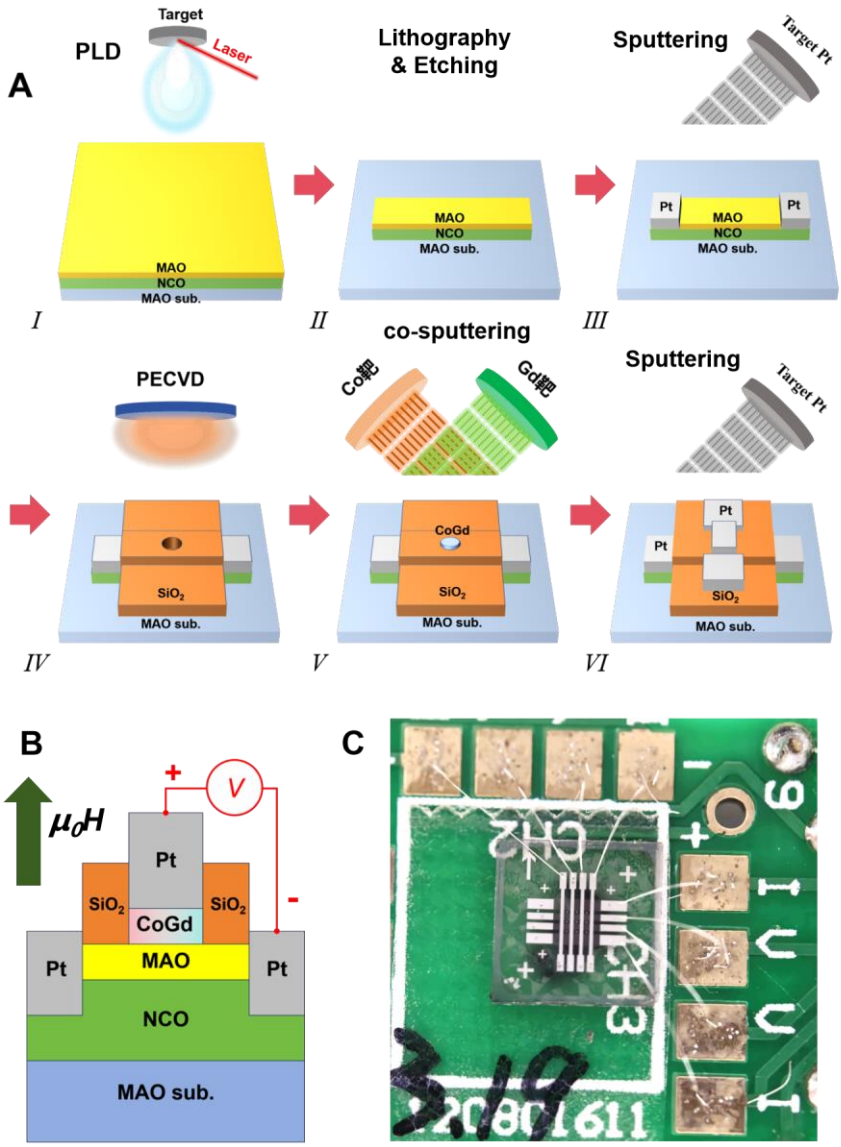
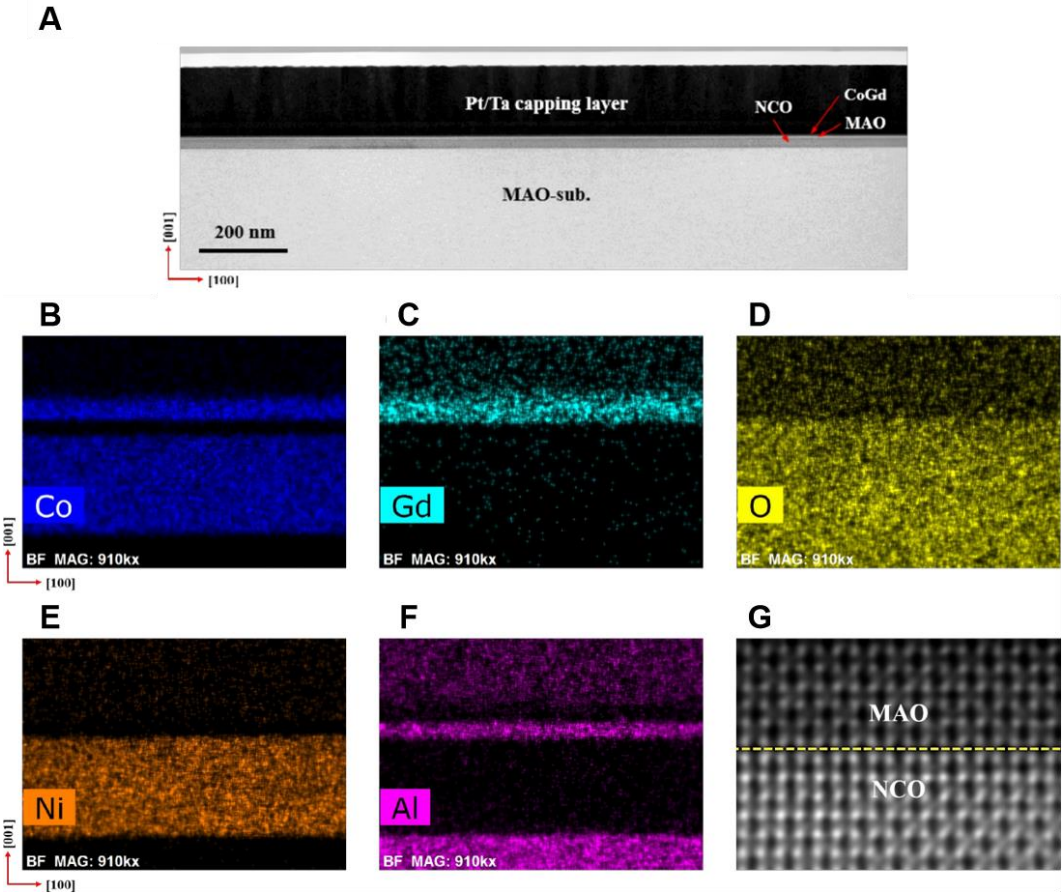
**SI 1. Flow chart for fabrication of tunnel junction devices.**



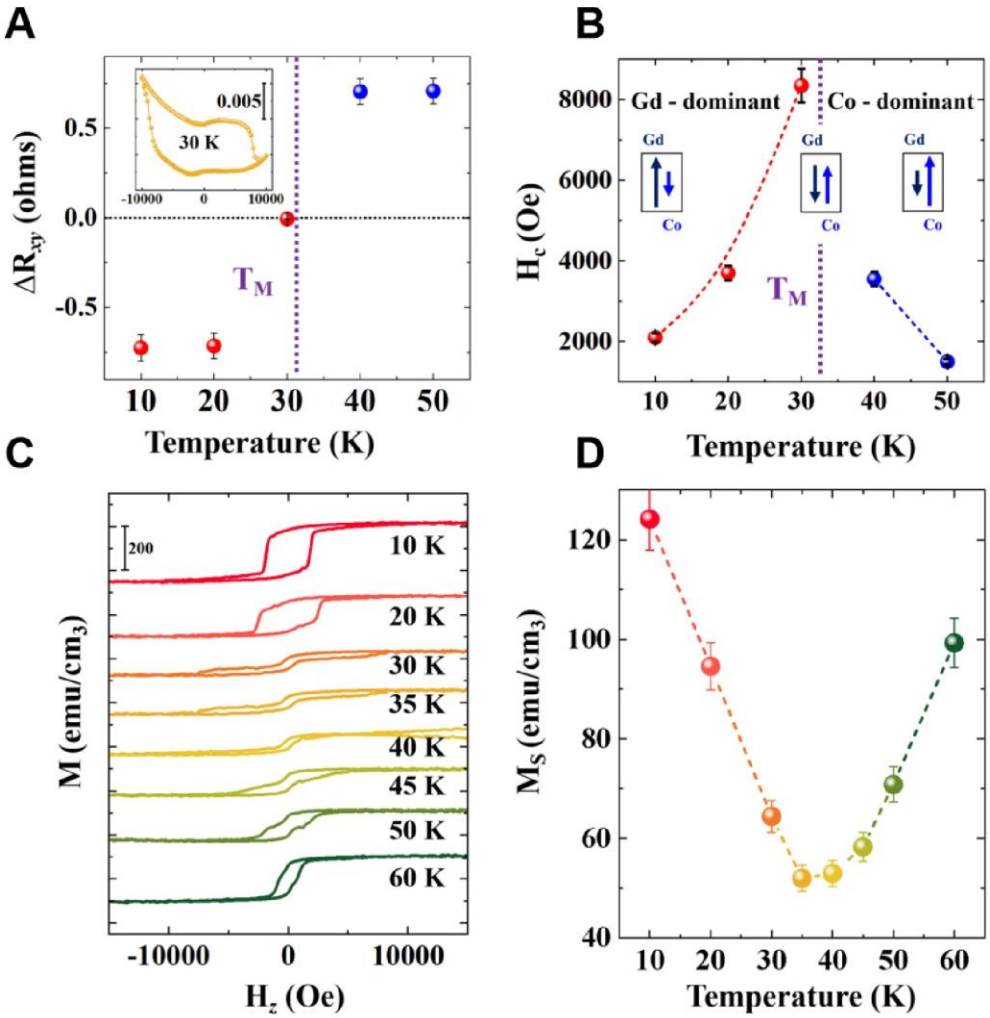

**Supplementary Figure 1.** (A) Flow Chart for Fabrication of Tunnel Junction Devices. (B) Schematic diagram of the device cross-section. (C) Optical photo and measurement wiring diagram of 4×4 device array.

**SI 2. TEM of the heterostructures.**



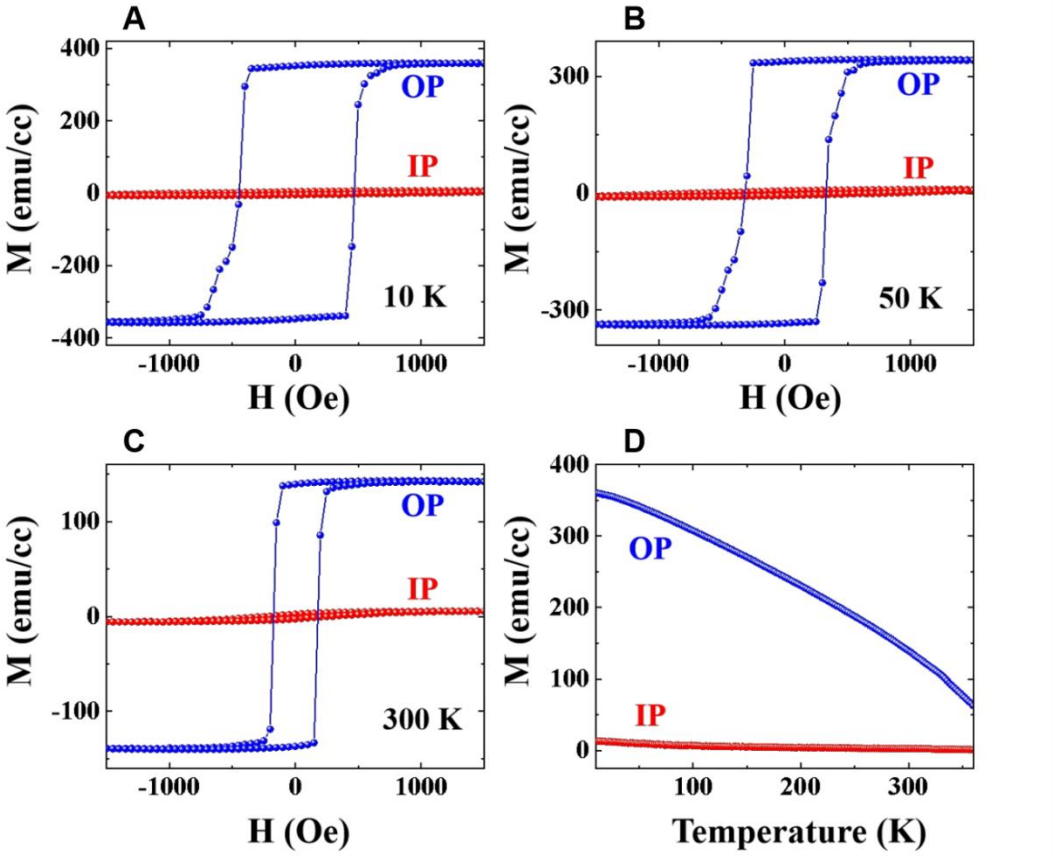

**Supplementary Figure 2.** (A) The low-magnification annular bright-filed STEM image of the MTJ multilayers along [100] axis, where the labels indicate the different layers. The length of the scale bar is 200 nm. (B)- (F) False-color EDS maps of the Co, Gd, O, Ni, and Al elements, confirming the presence of sharp interfaces in the heterostructures. (G) HAADF-STEM image taken from interface region between NCO layer and MAO barrier.

**SI 3. The temperature-dependent anomalous Hall effect (AHE) and magnetic characteristic of CoGd.**



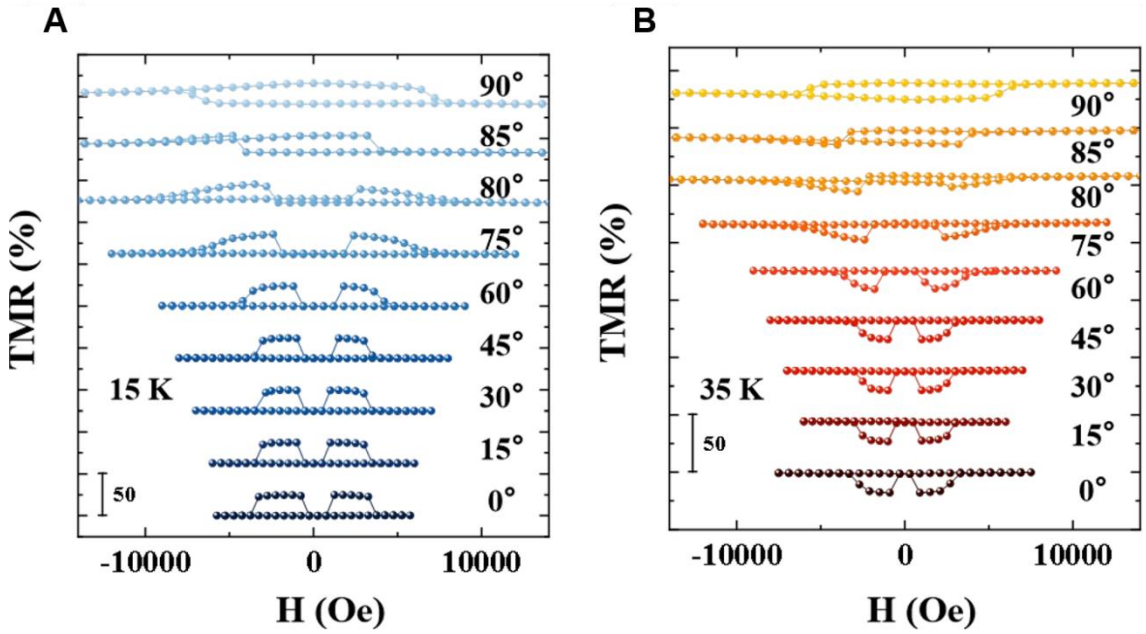

**Supplementary Figure 3.** (A) Temperature dependence of magnitude of Hall resistance change of $Co_{82}Gd_{18}$ (5 nm) /Pt (50 nm) bilayers, $\Delta R_{xy}=R_{xy}(+\mu_0 H)-R_{xy}(-\mu_0 H)$. Inset: the AHE loop at 30 K. (B) Temperature dependence of coercive field $H_C$. (C) Out-of-plane magnetic hysteresis loops of $Co_{82}Gd_{18}$ /Pt bilayers at different temperatures. (D) Temperature dependence of saturation magnetization value of $Co_{82}Gd_{18}$ /Pt bilayers.

**SI 4. Temperature-dependent magnetization of NCO.**



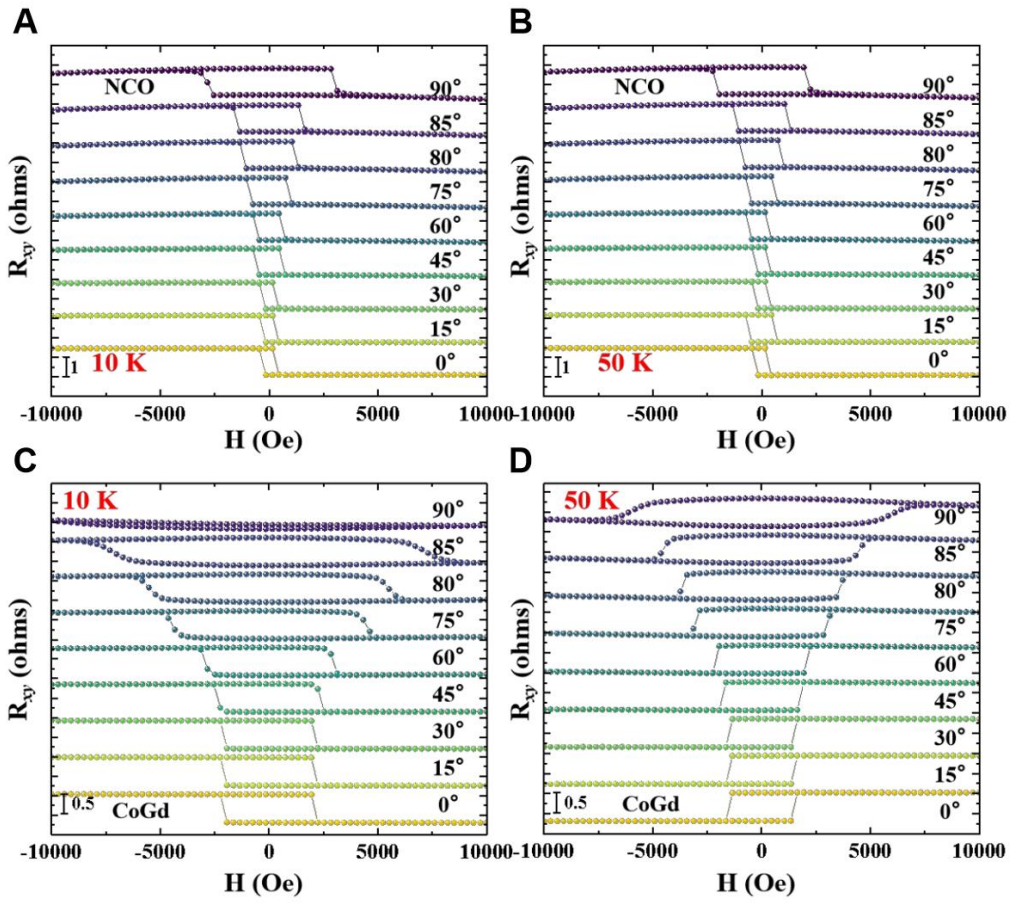

**Supplementary Figure 4.** Magnetic hysteresis loops with different directions at (A) 10 K, (B) 50 K, and (C) 300 K of NCO/MAO bilayers. OP and IP correspond to out-of-plane and in-plane directions, respectively. (D) Temperature dependence of the magnetizations with different directions of NCO/MAO bilayers. For all the M-T measurements, the sample was cooled from 380 to 10 K under a maintained magnetic field of 3000 Oe. Subsequently, the applied fields were decreased to zero and the magnetization was measured with increasing temperature.

**SI 5. Angular dependence of the TMR.**



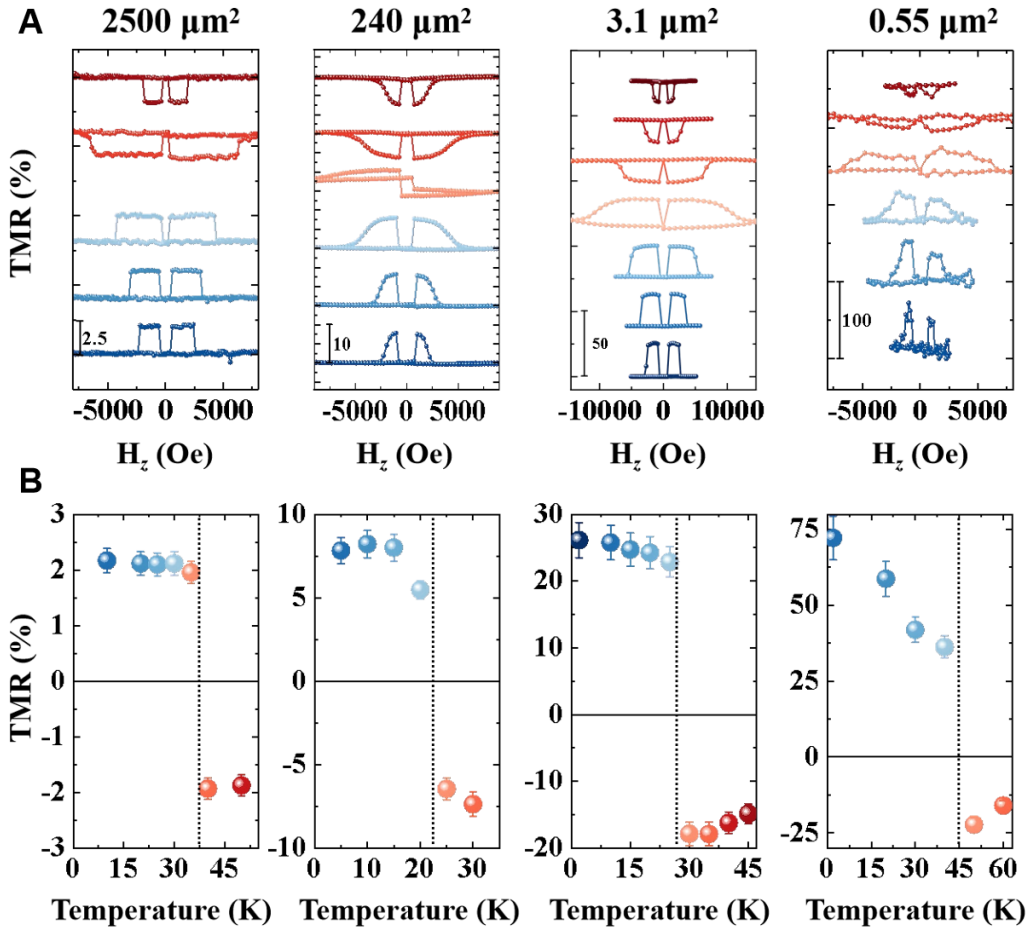

**Supplementary Figure 5.** The TMR loops with the magnetic field along different angles at (A) 15 K and (B) 35 K, where 0° and 90° correspond to the out-of-plane and in-plane magnetic field directions, respectively.

**SI 6. Angle-dependent AHE loops.**



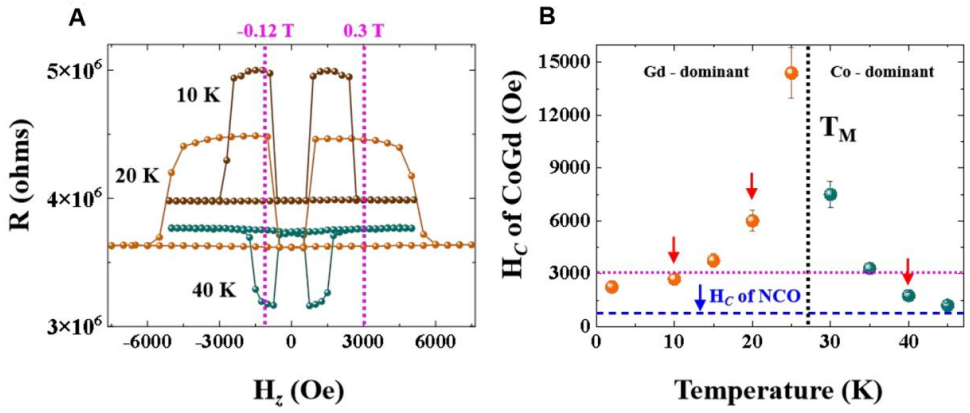

**Supplementary Figure 6.** The AHE loops with the magnetic field along different angles of NCO/MAO: (A) at 10 K and (B) at 50 K. The AHE loops with the magnetic field along different angles of $Co_{82}Gd_{18}$/Pt: (C) at 10 K (Gd - dominant) and (D) at 50 K (Co - dominant).

**SI 7. The size-dependent TMR of our ferrimagnetic tunnel junctions.**



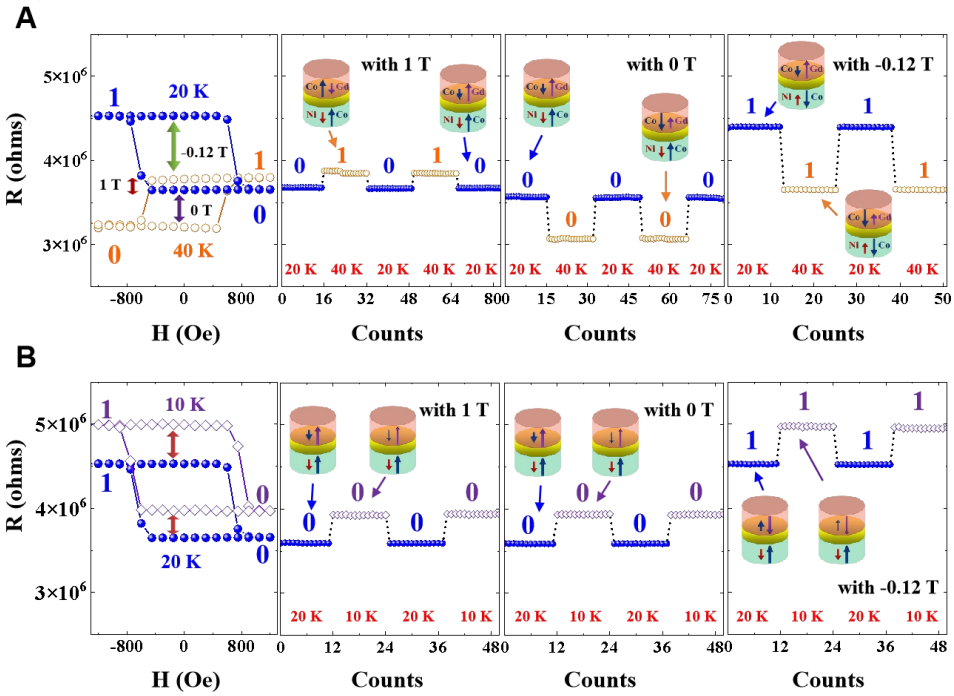

**Supplementary Figure 7.** (A) The TMR loops at different temperatures. (B) The temperature dependence of TMR values obtained from the MTJs with different sizes.

**SI 8. The range of assisted magnetic field for thermal modulation.**




**Supplementary Figure 8.** The assisted magnetic field marked in (A) *R*-*H* and (B) $H_C$-*T* images.

**SI 9. Temperature-dependent volatile resistance multilevel states.**




**Supplementary Figure 9.** TMR loops within a small magnetic field and temperature-dependent volatile multilevel **resistance** states assisted by different fixed magnetic fields (+1 T, 0 T, and -0.12 T) within (A) 20 ~ 40 K and (B) 10 ~ 20 K. “0” and “1” correspond to the low and high resistance states at the corresponding temperatures.

**Supplementary Table 1. Calculated magnetic moments of Gd and Co atoms, and the contribution of each state in $Co_{75}Gd_{25}$ alloy**

| Atom | *s* | *p* | *d* | *f* | $M (\mu_B)$ |
|---|---|---|---|---|---|
| Gd | 0.04 | 0.01 | 0.35 | 6.88 | 7.29 |
| Co | -0.02 | 0.00 | -1.49 | 0.00 | -1.51 |

The negative values in the Co column indicates the ferrimagnetic coupling between Gd and Co atoms.

**Supplementary Table 2. Calculated magnetic moments of $Ni_{Oh}$ and $Co_{Td}$ atoms, and the contribution of each state in NCO**

| Atom | *s* | *p* | *d* | $M (\mu_B)$ |
|---|---|---|---|---|
| $Ni_{oh}$ | 0.00 | 0.00 | -0.55 | -0.55 |
| $Co_{Td}$ | 0.03 | 0.08 | 2.30 | 2.41 |

The negative values in the $Ni_{Oh}$ column indicates the ferrimagnetic coupling between $Ni_{Oh}$ and $Co_{Td}$ atoms.