Electronic Supplementary Information (ESI)

Novel room-temperature spin-valve-like magnetoresistance in magnetically coupled nano-column Fe_3O_4/Ni heterostructure

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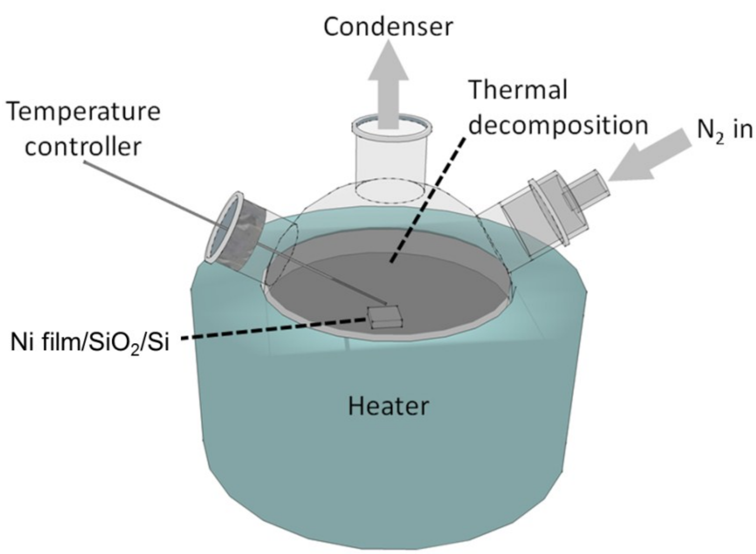

Scheme S1 Schematic setup of thermal decomposition synthesis of self-assembled Fe_3O_4 nano-column film on Ni/1μ-SiO_2/Si substrate.

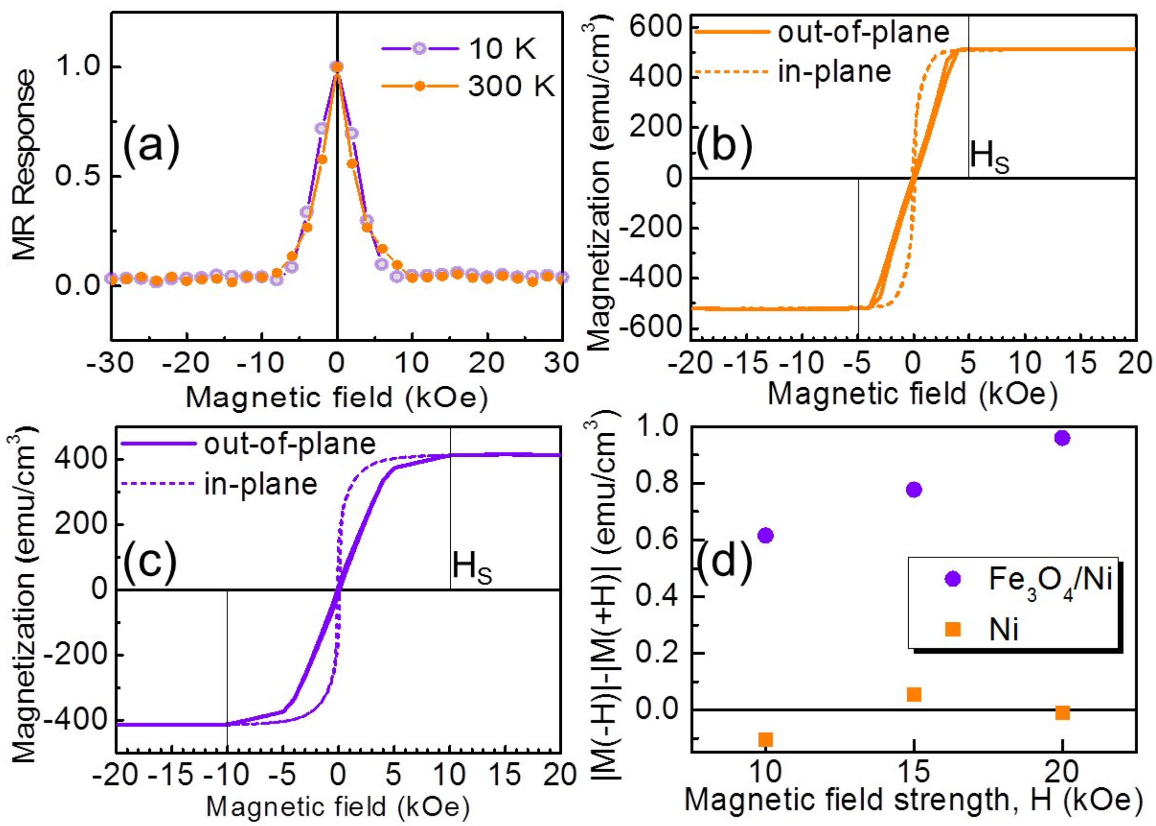

Fig. S1 (a) Magnetoresistance response as a function of out-of-plane magnetic field strength of pure Ni film at room temperature (orange dot) and at 10 K (purple circle). MR response under positive- and negative- magnetic fields is symmetric without showing a spin-valve-like magnetoresistance in pure Ni. (b-c) Room-temperature out-of-plane and in-plane magnetic hysteresis loops of (b) Fe_3O_4 nano-column film on Ni heterostructure and (c) pure Ni film. (d) Difference between out-of-plane positive- and negative-field magnetization for Fe_3O_4/Ni heterostructure (purple dot) and pure Ni film (orange square) under magnetic field strength of 10 kOe, 15 kOe and 20 kOe at room temperature. Negligible difference is observed for the pure Ni film and the values of |M(-H)|-|M(+H)| are close to zero. It shows that the pure Ni film does not exhibit out-of-plane unidirectional magnetic anisotropy at room temperature. In contrast, unambiguous positive values of |M(-H)|-|M(+H)| for Fe_3O_4/Ni heterostructure indicates significant unidirectional magnetic anisotropy.

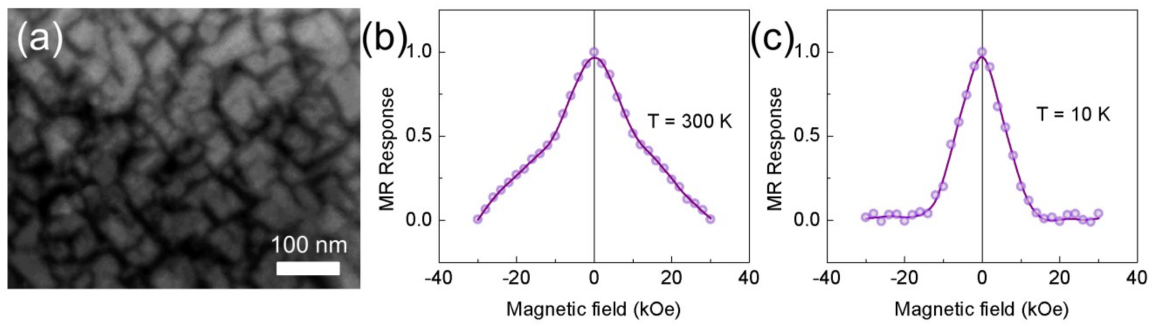

Fig. S2 (a) SEM image of ~10 nm Fe_3O_4 nano-column film on Ni underlayer. (b-c) Magnetoresistance response as a function of magnetic field strength of the Ni layer under Fe_3O_4 nano-column film at (b) room temperature and at (c) 10 K, respectively.

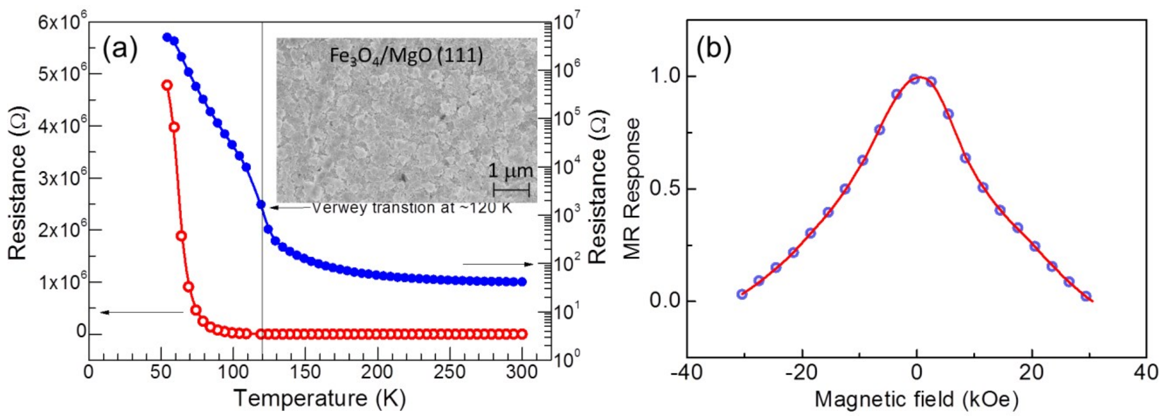

Fig. S3 (a) Temperature-dependent resistance of tFe_3O_4 on MgO (111) substrate demonstrates the Verwey transition of Fe_3O_4 at ~120 K. It is noted that the resistance is too high to be measured for temperature below 50 K, because the Fe_3O_4 becomes electrically insulating at low temperature due to Verwey transition. (b) Magnetoresistance response as a function of magnetic field strength of the Fe_3O_4 on MgO (111) substrate in (a) at room temperature.

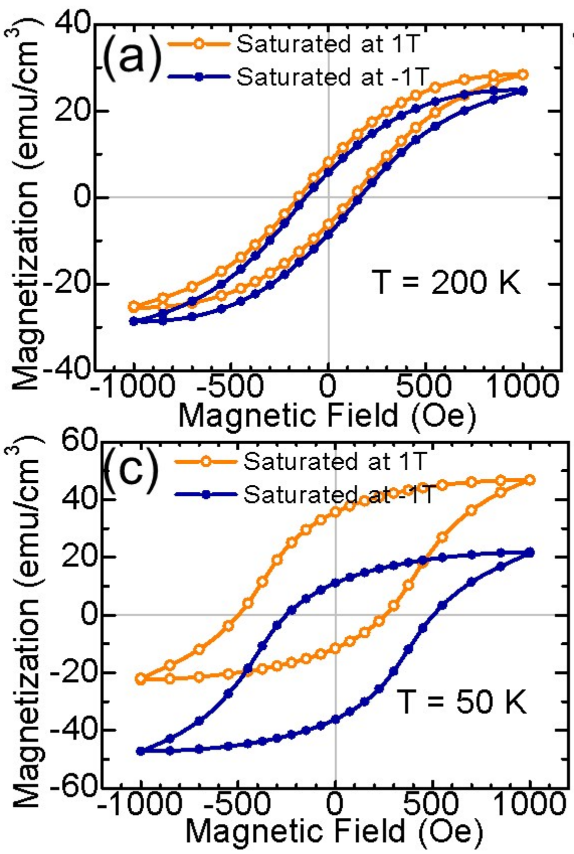

Fig. S4 (a-d) Low-temperature (200 K – 100 K) out-of-plane field-cooling (FC) MH minor loops of the Fe_3O_4/Ni heterostructure under cooling fields of ±10 kOe (±1 T) from 300 K.

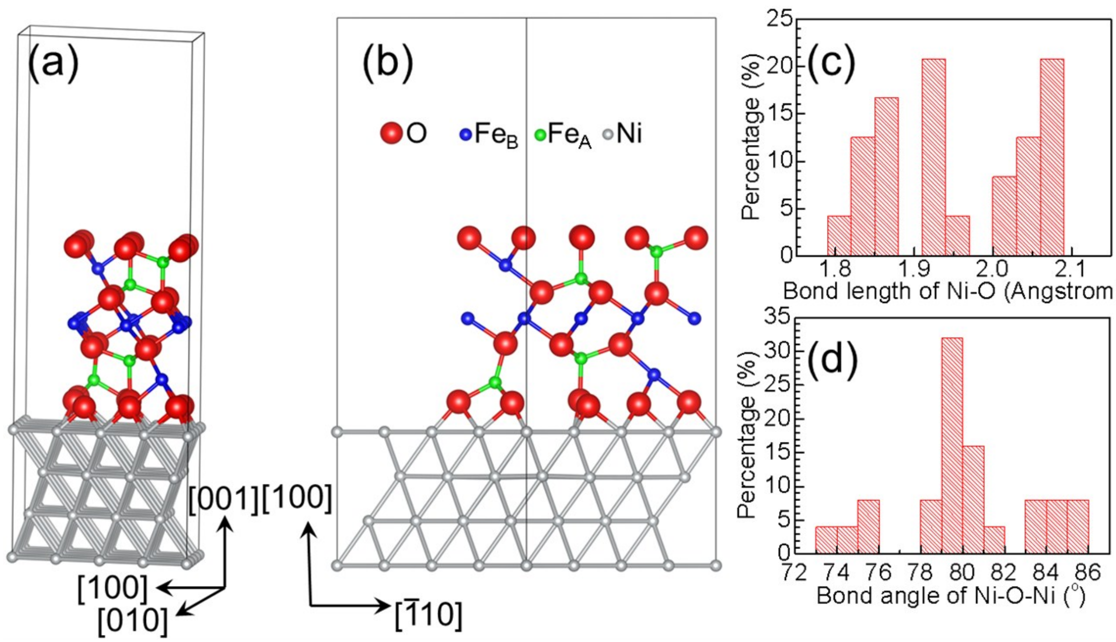

Fig. S5 (a-b) Atomic structures of Fe_3O_4/Ni model. (c-d) Distribution of (c) Ni-O bond length and (d) Ni-O-Ni bond angle at the Fe_3O_4/Ni interface in the model.