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Electronic Supplementary Information

Stable single domain Co nanodisks: synthesis, structure and magnetism

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1. TEM and HRTEM images

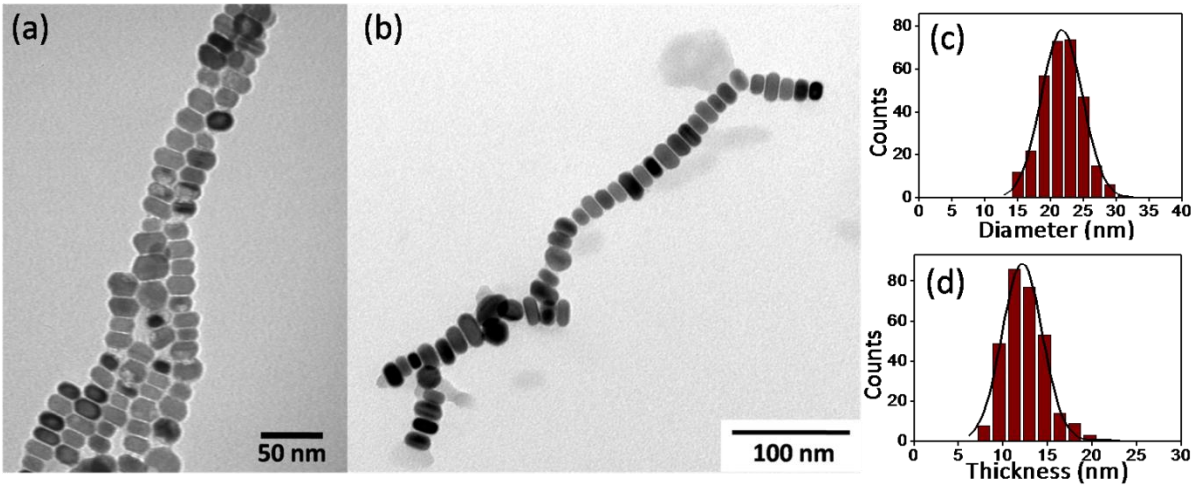

Figure S1. (a,b) Low magnification TEM images of the Co nanodisks. (c,d) Size histograms of their diameter and thickness, respectively.

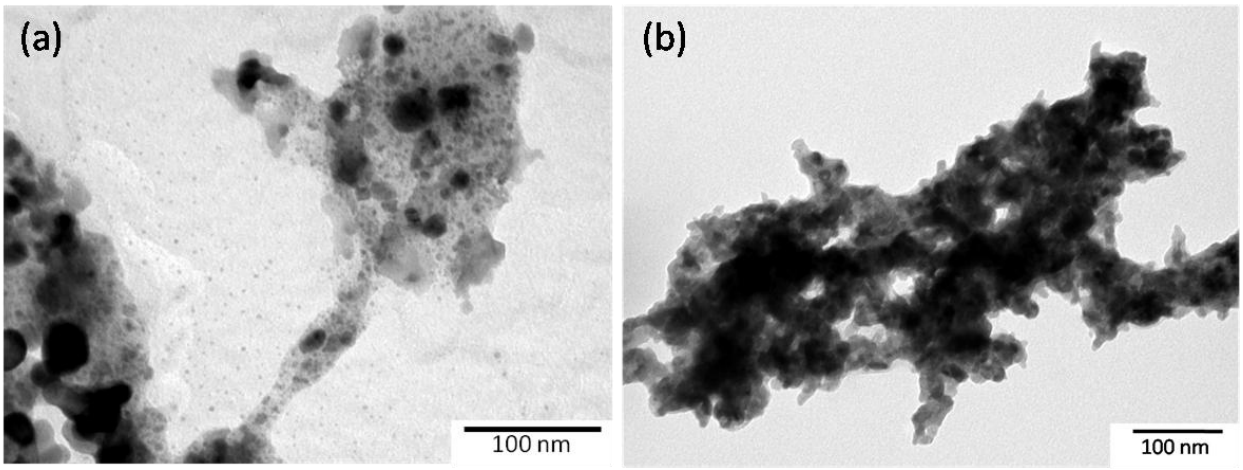

Figure S2. TEM images of control experiments in which the reaction was performed with Rhodamine B (a) and HDA (b) as unique stabilizers, respectively.

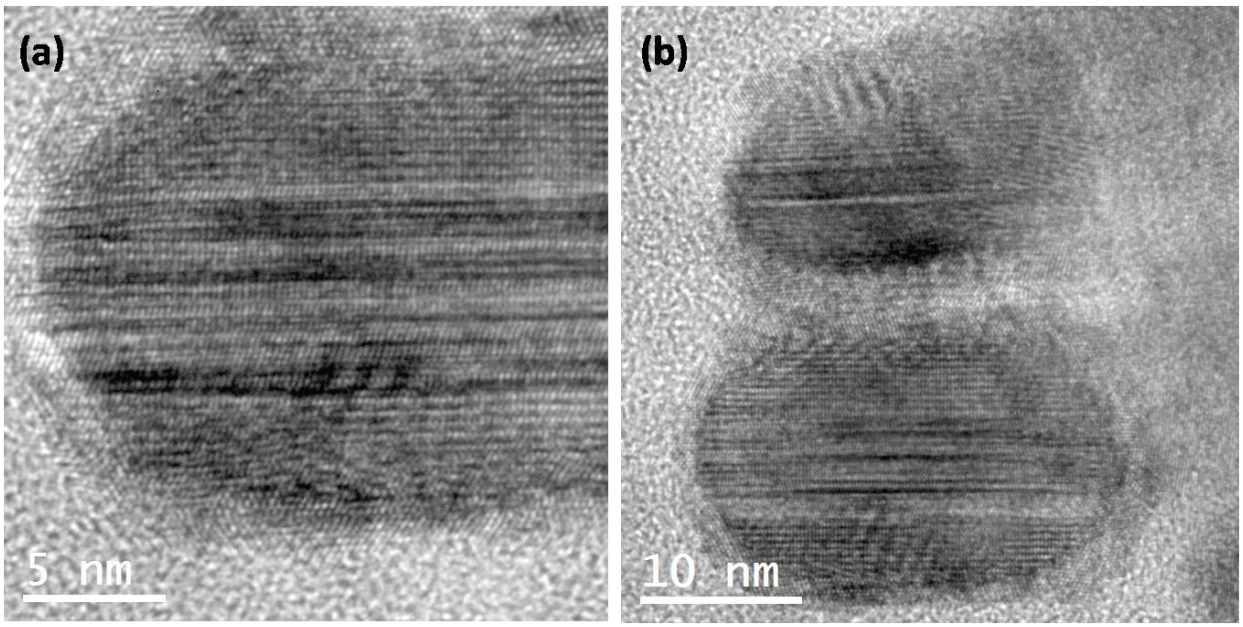

Figure S3. HRTEM images of Co nanodisks showing the high density of stacking faults along the c axis of the particles.

3. Temperature dependence of the magnetization

The measurements were recorded with a SQUID magnetometer, according to a ZFC/FC procedure varying the temperature from 2 to 300K under an applied field of 10mT. Although carried out on two different samples, the ZFC/FC curves are very similar evidencing the reproducibility of the preparation.

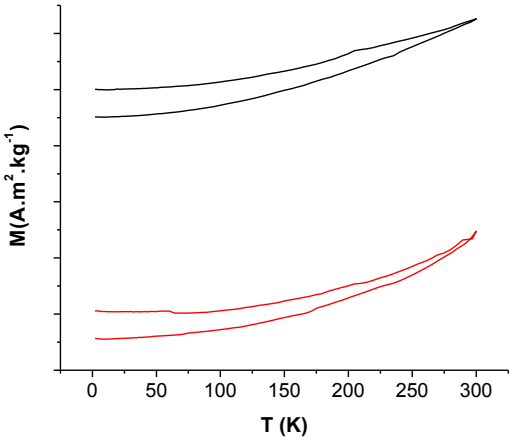

Figure S4: Typical ZFC/FC curves for nanodisks assemblies

4. Micromagnetic Simulations

We have calculated the magnetic behavior of one Co nanodisk using micromagnetic simulations with the OOMMF code.[1] Several parameters like shape, magnetization, exchange constant and magnetocrystalline anisotropy of the specimen had to be fixed in order to run the simulation. The dimensions of the NPs were obtained from TEM images (21 nm of diameter and 12 nm of thickness) while the rest of the parameters (magnetization (M), magnetocrystalline anisotropy (K) and exchange constant (A)) correspond to the bulk values (see Table S1). It is important to point out that these simulations do not take into account thermal fluctuations (T= 0 K).

The given sample geometry is divided in cubic cells, with the magnetization spin positioned at the center of the cell. In the simulation for every cell the Landau-Liftshitz-Gilbert (LLG) equation[2] is solved in order to compute a time dependent evolution of the magnetization.

$$\frac{d\boldsymbol{M}(\boldsymbol{r},t)}{dt} = -\gamma\left(\boldsymbol{M}(\boldsymbol{r},t)\times\boldsymbol{H}_{eff}(\boldsymbol{r},t)\right)+\frac{\alpha}{M_S}\left(\boldsymbol{M}(\boldsymbol{r},t)\times\left(\boldsymbol{M}(\boldsymbol{r},t)\times H_{eff}(\boldsymbol{r},t)\right)\right)$$

where $\boldsymbol{M}$ is the magnetization of the particular cell positioned at $\boldsymbol{r}$ and *Ms* is the saturation magnetization of the system. α is the dimensionless damping coefficient and γ is the gyromagnetic ratio defined as:

$$\gamma = \frac{g\cdot\mu_B}{\hbar}$$

$\boldsymbol{H}_{eff}(\boldsymbol{r}, t)$ is effective field at position $\boldsymbol{r}$, which is given by:

$$\boldsymbol{H}_{eff}(\boldsymbol{r},t) = \frac{\delta E}{\mu_0\cdot\delta\boldsymbol{M}(\boldsymbol{r},t)}$$

The average energy density E is a function of $\boldsymbol{M}$ specified by Brown's equations[3] and including anisotropies, exchange, demagnetization and applied field:

$$E = E_{ani} + E_{ex} + E_{dem} + E_{ext}$$

The micromagnetic simulations of magnetic spectra are performed in two steps. Firstly, the equilibrium magnetization configuration of element is obtained by the minimization of energy density function. Secondly, the external field is increased and the time evolution of magnetic configuration by solving LLG equation is calculated.

Table S1. Parameters included in the simulation

Parameter	Value
Magnetization (M)	$1500 \cdot 10^{3}$ A/m
Uniaxial magnetocrystalline anisotropy (K_{uni})	$5 \cdot 10^{5}$ J/m^3
Exchange constant (A)	$30 \cdot 10^{-12}$ J/m

Table S2. Spatial coordinates used for the simulation of one chain of 6 nanodisks (in m).

	Coordinate x	Coordinate y	Coordinate z
Particle 1	$0 \cdot 10^{-9}$ to $21 \cdot 10^{-9}$	$0 \cdot 10^{-9}$ to $21 \cdot 10^{-9}$	$0 \cdot 10^{-9}$ to $12 \cdot 10^{-9}$
Particle 2	$0 \cdot 10^{-9}$ to $21 \cdot 10^{-9}$	$2 \cdot 10^{-9}$ to $23 \cdot 10^{-9}$	$14 \cdot 10^{-9}$ to $26 \cdot 10^{-9}$
Particle 3	$0 \cdot 10^{-9}$ to $21 \cdot 10^{-9}$	$1 \cdot 10^{-9}$ to $22 \cdot 10^{-9}$	$28 \cdot 10^{-9}$ to $40 \cdot 10^{-9}$
Particle 4	$0 \cdot 10^{-9}$ to $21 \cdot 10^{-9}$	$-1 \cdot 10^{-9}$ to $20 \cdot 10^{-9}$	$42 \cdot 10^{-9}$ to $54 \cdot 10^{-9}$
Particle 5	$1 \cdot 10^{-9}$ to $22 \cdot 10^{-9}$	$-1 \cdot 10^{-9}$ to $20 \cdot 10^{-9}$	$56 \cdot 10^{-9}$ to $68 \cdot 10^{-9}$
Particle 6	$0 \cdot 10^{-9}$ to $21 \cdot 10^{-9}$	$0 \cdot 10^{-9}$ to $21 \cdot 10^{-9}$	$70 \cdot 10^{-9}$ to $82 \cdot 10^{-9}$

5. Calculation of T_B and relaxation time of the nanodisks.

An estimation of the blocking temperature of an isolated magnetic NP can be made assuming a intrinsic relaxation time using the equation:

$$T_B = \frac{K_{eff} \cdot V}{k_b \cdot Ln\left(\frac{\tau_m}{\tau_0}\right)}$$

where K_{eff} is the effective anisotropy, V represents the volume of the NP, k_b is Boltzmann's constant and τ_m (100 s) and τ_0 (10^{-9} s) represent the measuring time of SQuID and the characteristic relaxation time of the NPs, respectively.

$$U = \left(\frac{\mu_0}{2}\right) N M_S^2$$

$$N = N_{out-of-plane} - N_{in-plane} = (0.5272 - 0.2364) = 0.2908 \quad \text{according to ref 4}$$

$$U = 3.845 \cdot 10^6 \frac{erg}{cm^3}$$

$$K_{eff} = K_{mc} - K_{sh} = 5 \cdot 10^6 - 3.845 \cdot 10^6 = 1.155 \cdot 10^6 \frac{erg}{cm^3}$$

$$Volume\ disk\ (aprox.\ hexahedral\ prism) = A_{base} \cdot h_{prism} = 6.2042 \cdot 10^{-18} cm^3$$

$$T_B = \frac{K_{eff} \cdot V}{25 k_b} = \frac{1.155 \cdot 10^6 \frac{erg}{cm^3} \cdot 6.2042 \cdot 10^{-18} cm^3}{25 \cdot 1.38065 \cdot 10^{-16} \frac{erg}{K}} = 2075\ K$$

For a Co nanodisk at room temperature:

$$\tau = \tau_0 \cdot e^{\frac{K_{eff} V}{k_b T}} = 10^{-9} \cdot e^{\frac{1.155 \cdot 10^6 \frac{erg}{cm^3} \cdot 6.2042 \cdot 10^{-18} cm^3}{1.38065 \cdot 10^{-16} \frac{erg}{K} \cdot 298K}} = 1.58 \cdot 10^{59} years$$

[1] M. J. Donahue and D. G. Porter, OOMMF User's Guide Version 1.2a3, http://www.math.nist.gov/oommf
[2] T. L. Gilbert, A Phenomenological Theroy of Damping in Ferromagnetic Materials, IEEE, 40 (2004), 6.
[3] Brown Jr., Micromagnetics, Krieger, (1978).
[4] J. A. Osborn, Phys. Rev., 67 (1945), 351.