Electronic Supplementary Material (ESI) for Soft Matter

Supporting Information for the article: Evidence of Rouse-like dynamics in magnetically ratchetting colloidal chains.

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Fig. 1 illustrates the mechanism of motion of the paramagnetic colloids. The z component of the external field is normal to the film and displaces the domain walls by increasing (resp. decreasing) the width of the domains having parallel (resp. opposite) magnetization direction. The x component alternates the pinning sites located at the BWs between strong and weak walls depending whether the magnetic field lines are parallel (antiparallel) to the field direction. This modulation occurs every half cycle and particles cross one domain due to the local gradient generated between adjacent BWs. If the external field would be normal to the surface $\vartheta = 0$, the hopping across the domains would occur periodically in the forward or backward direction. A finite external field inclination is necessary to induce the particle motion. During the application of the field, each domain wall returns to its initial position after one cycle $T = 2\pi/\omega$ while, particles advance by one spatial periodicity of the stripe pattern. The particles pin to the domain walls when the external field is small $\omega t \sim \pi/2 + n\pi$, $n = 0, 1, 2, 3, ...$ and hop to the next domain wall during the times of maximum intensity of the external field $\omega t \sim n\pi$, $n = 0, 1, 2, 3, ...$ For the frequency used, ($\omega = 25\ s^{-1}$), the domain walls follow instantaneously the external field and thus do not introduce any delay in the particle motion.

To ensure sufficient statistics over time/space we drive the chains back and forth inside the microscope observation area ($\sim 154 \times 116\ \mu m^2$) by automatically switching the field direction each time they reach the last stripe. Since the switching could affect the MSD along the y-direction by introducing artifacts in the particle position, we modify our tracking routine in order to avoid registering the particle position at field reversal. Fig. 2(a) shows representative long time trajectories $x(t)$ and $y(t)$ of the particles at the ends of a chain composed of $N_p = 25$. The switching of the field corresponds in the reversal of the $x(t)$ trajectory. It is clear that the chain did not disintegrate over long time.

In Fig. 2(b) is a polarization microscope image showing part of the stripe pattern used to confine the colloidal chain. The shown crack line bends the BWs providing the lateral confinement of the chains.

Three video files:

- Video1 shows the Brownian motion of paramagnetic colloids deposited above the stripe pattern of a Garnet Film and without external field.
- Video2 shows the motion of one paramagnetic chain composed of $N_p = 10$ particles and driven above the magnetic stripe pattern at a frequency $\omega_H = 25\ s^{-1}$.
- Video3 shows the motion of one paramagnetic chain composed of $N_p = 23$ particles and driven above the magnetic stripe pattern at a frequency $\omega_H = 25\ s^{-1}$.

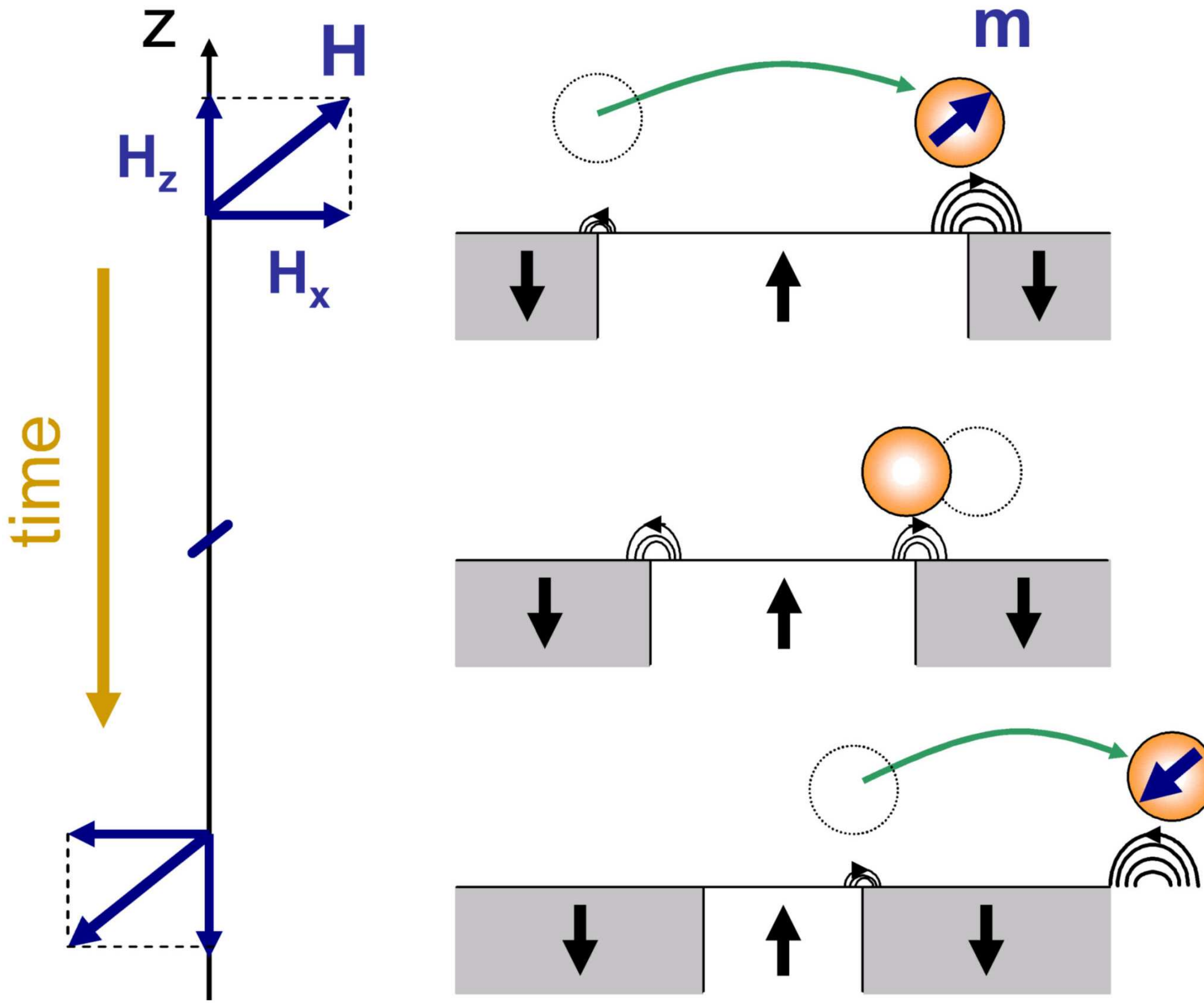

FIG. 1: Schematics showing the motion of one particle at three times, $t = \pi/2\omega$, $t = \pi/\omega$ and $t = 3\pi/2\omega$ (resp. from top to bottom). The tilted external field can be decomposed in two components. The z-component, $H_z = H\cos\vartheta$, being normal to the FGF displaces the BWs by increasing (resp. decreasing) the width of the domains with parallel (resp. opposite) magnetization direction. The x-component, $H_x = H\sin\vartheta$ strengths (resp. weakens) the pinning sites at the BWs according to where the local stray field is parallel (resp. antiparallel) to its direction. The result is a magnetic gradient along the x direction.

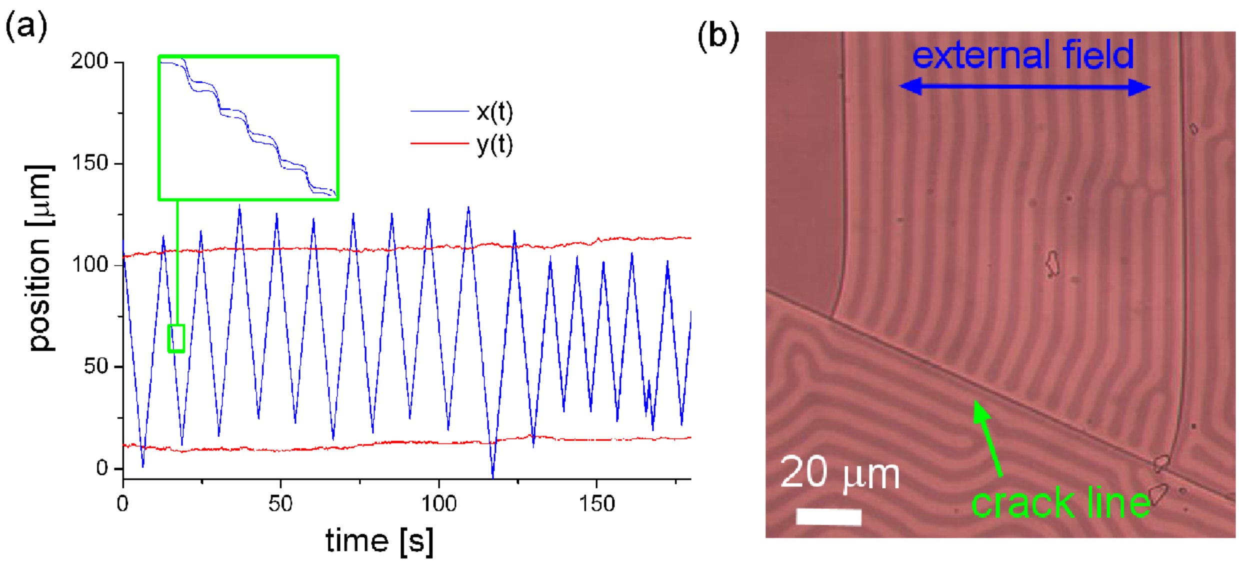

FIG. 2: (a) Positions $x(t)$ and $y(t)$ versus time for the particles at the end of a chain composed of $N_p = 25$ colloids. (b) Polarization microscope image showing the stripe pattern without the paramagnetic colloids. The magnetic confinement of the paramagnetic chains is provided by the crack line visible in the image. The spatial periodicity of the film is $\lambda = 6.9$ μm.