# Supplementary Information

# Heavily Superparamagnetic-Magnetite Loaded Polymeric Worm-like Micelles That Have an Ultrahigh $T_2$ Relaxivity

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## S1 Experimental Sections

**Materials.** Poly(ethylene glycol)$_{113}$-*block*-poly(4-vinylpyridine)$_{60}$ (PEG$_{113}$-*b*-P4VP$_{60}$, $M_w/M_n$ = 1.16) was synthesized according to the literature.[1] Polydisperse linear DNAs (20k bps on average) and 1,4-dibromobutane (DBB) were purchased from Sigma-Aldrich. Iron(III) acetylacetonate (Fe(acac)$_3$), oleylamine, and benzyl ether were purchased from Aladdin. Anhydrous methanol, hexane, ethanol, chloroform ($CHCl_3$), and *N,N*-dimethylformamide (DMF) were purchased from Sinopharm Chemical Reagent and used without further purification.

**Synthesis of superparamagnetic magnetite nanoparticles (SMNPs).** SMNPs were synthesized according to the reported procedure.[2] Briefly, Fe(acac)$_3$ (2.118 g) was dissolved in the mixed solution of 30 mL of benzyl ether and 30 mL of oleylamine. The mixture was dehydrated at 120 $^oC$ for 1 h under $N_2$ flow. Then, the mixture was heated to reflux (300 $^oC$) for 2 h. After cooling to room temperature, the SMNPs were collected, washed with excess ethanol using centrifugation and redispersed in 30 mL of hexane. The obtained SMNPs have an averaged size of 5.1 ± 0.3 nm and stabilized by oleylamine.

**Preparation of PEG$_{113}$-*b*-P4VP$_{60}$ stabilized SMNPs by ligand exchange.** 60 mg of PEG$_{113}$-*b*-P4VP$_{60}$ was dissolved in 12 mL of $CHCl_3$/DMF (v/v = 2/1) mixed solvent. The solution was dropwise added to 1 mL of SMNP suspension in hexane. The mixture was then stirred at 35 $^oC$ for 48 h. After dissolving in methanol and precipitating in ethyl ether for 3 times, the precipitates were collected and redispersed in 30 mL methanol. The obtained suspension contains the SMNPs stabilized by PEG$_{113}$-*b*-P4VP$_{60}$ and free PEG$_{113}$-*b*-P4VP$_{60}$.

**Preparation of SMNPs-loaded composite micelles.** The SMNPs-loaded composite micelles were obtained by dropwise adding 12 mL carbon dioxide saturated water into 3 mL the obtained SMNPs methanol suspension in which the SMNPs were stabilized by PEG$_{113}$-*b*-P4VP$_{60}$. Afterward, the mixture was stirred for 30 min.

**Preparation of SMNPs-loaded composite worm-like micelles.** 1 mL of DNA aqueous solution (0.2 mg/mL) was dropwise added into 8 mL of the as-prepared SMNPs-loaded composite micelles suspension. After the mixture was stirred overnight, the SMNPs-loaded composite worm-like micelles were obtained.

**Characterizations.** Dynamic light scattering (DLS) was performed on an ALV-5000 laser light scattering spectrometer. Before the measurement, all sample solutions were filtered through 0.45 μm filter to remove dust. Transmission electron microscopy (TEM) observations were conducted using an FEI Tecnai G2 20 TWIN electron microscope at an accelerating voltage of 200 kV. The high contrast TEM observations were conducted using a Philips CM120 electron microscope at an acceleration voltage of 60 kV. The loading density of SMNPs in the polymeric micelles and Fe concentration was determined by Inductively Coupled Plasma-atomic emission spectrometry (ICP-AES, PerkinElmer, Optima 8000). The magnetization curve was measured at 300 K under a varying magnetic field using Vibrating Sample Magnetometer (VSM, EG&G Princeton Applied Research Vibrating Sample Magnetometer, Model155). $T_2$ relaxivities of SMNPs-loaded micelles were all measured at 3 T on the clinical MRI scanner (Siemens Trio TIM). The $T_2$-weighted were acquired with a conventional spin-echo acquisition (TR = 3000 ms) with TE values range from 15.2 ms to 167.2 ms. Before the relaxivity measurement, the core of the SMNPs-loaded micelles, both the composite micelles and the composite worm-like micelles, were cross-linked by DBB and the micelles were then dialyzed against water to obtain the SMNPs-loaded micelles aqueous suspension.

The cytotoxicity of SMNPs-loaded composite worm-like micelles (CWMs) with core crosslinked by DBB against HeLa cancer cells was tested by measuring the inhibition of cell growth using the cell counting Kit-8 (CCK-8) assay. HeLa cancer cells were treated with CWMs at various concentrations from 12.5 μg $mL^{-1}$ to 100 μg $mL^{-1}$.Firstly, HeLa cells were seeded with equal density in each well of 96-well plates (10000 cells/well). Then, CWMs suspensions at different concentrations were added and incubated with the cells for 15 h. Subsequently, CCK-8 dye was added to each well and the plates were incubated for another 2 h. Finally, the absorbance was measured by spectrophotometry at 450 nm using a microplate reader. Each treatment was repeated for five times. And the relative cell viability (%) was determined by comparing the absorbance at 450 nm with that of untreated control (untreated cells that incubated as the same time as the untreated control).

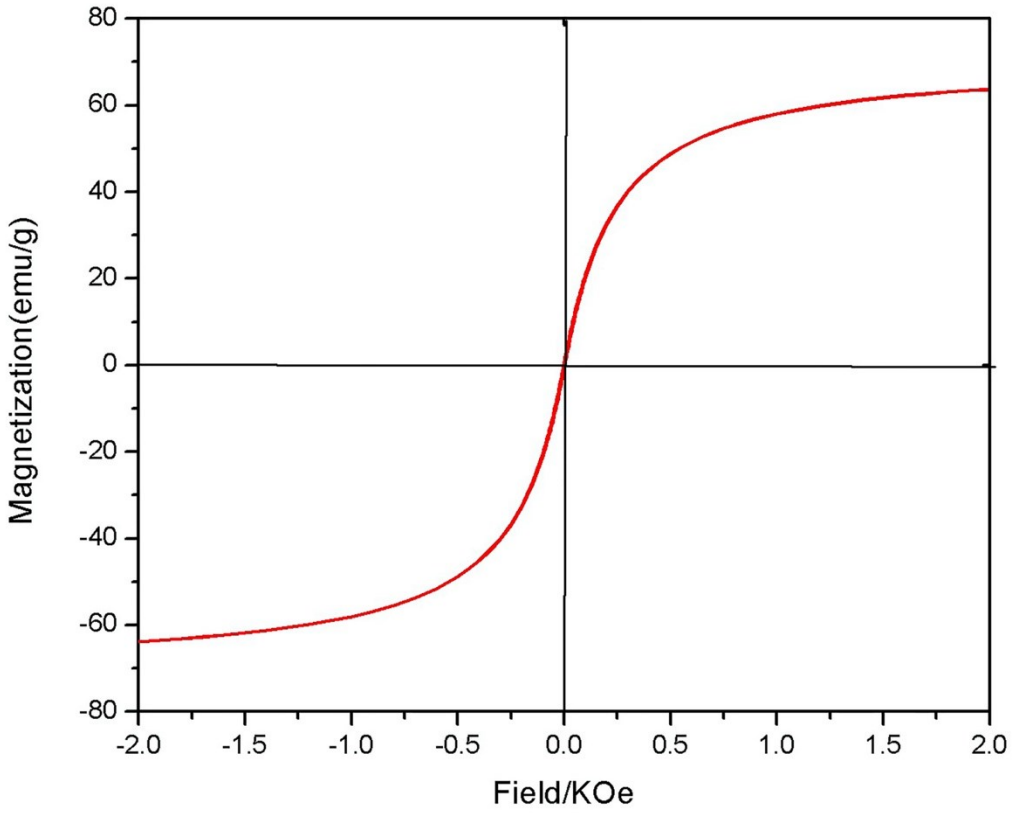


**Fig. S1** Magnetization curves of the SMNPs measured at 300 K, confirming the superparamagnetic property of SMNPs.

**Fig. S2** Photographs of self-assembly of the SMNPs-loaded composite micelles where excess free polymer existed (Left). When excess free polymer was removed by centrifugation, the self-assembly of the polymer-stabilized SMNPs alone under the same conditions only led to precipitation (Right).

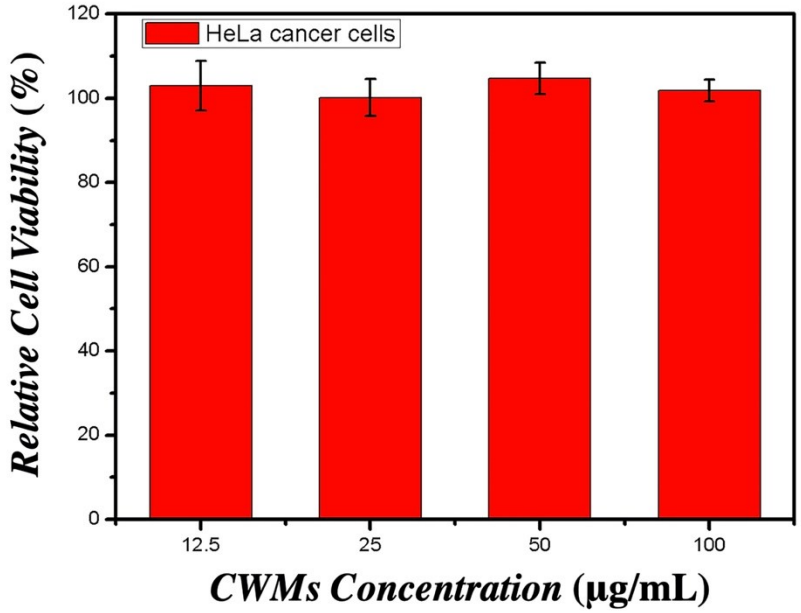


**Fig. S3** Cytotoxicity studies of CWMs against HeLa cancer cells at various CWMs concentrations.

**References**

1. J. Xia, X. Zhang and K. Matyjaszewski, *Macromolecules*, 1999, **32**, 3531-3533.

2. Z. Xu, C. Shen, Y. Hou, H. Gao and S. Sun, *Chemistry of Materials*, 2009, **21**, 1778-1780.