Electronic Supplementary Material (ESI) for RSC Advances

Electronic supplementary results

Nanocomposite of superparamagnetic maghemite nanoparticles and ferroelectric liquid crystal

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Additional characterization of the MNPs and the nanocomposites

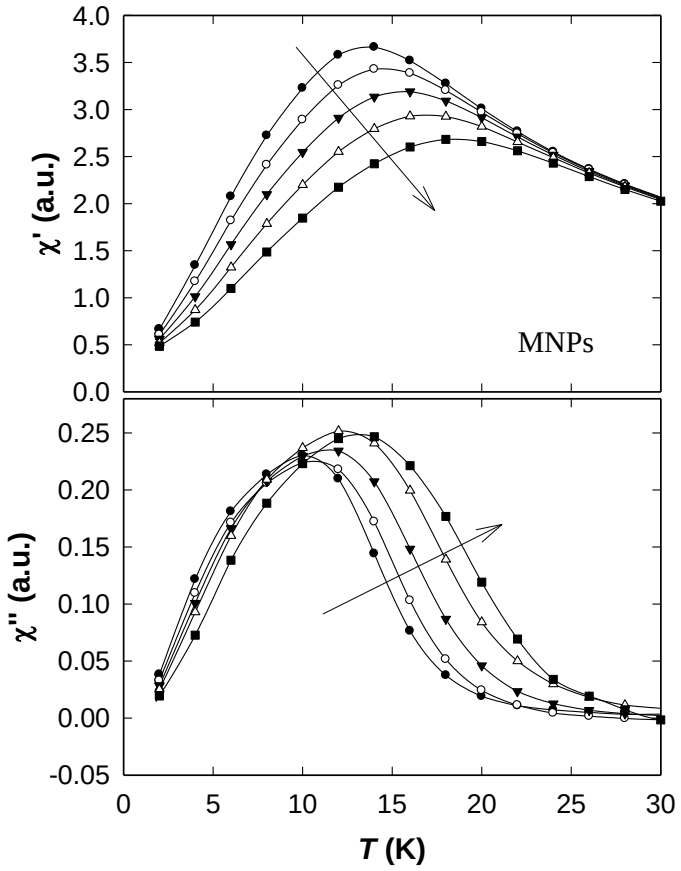

Figure S1
Detail of the low temperature real and imaginary part of the a.c. susceptibility of the original MNPs at selected frequencies, used for evaluation of the VF parameters.

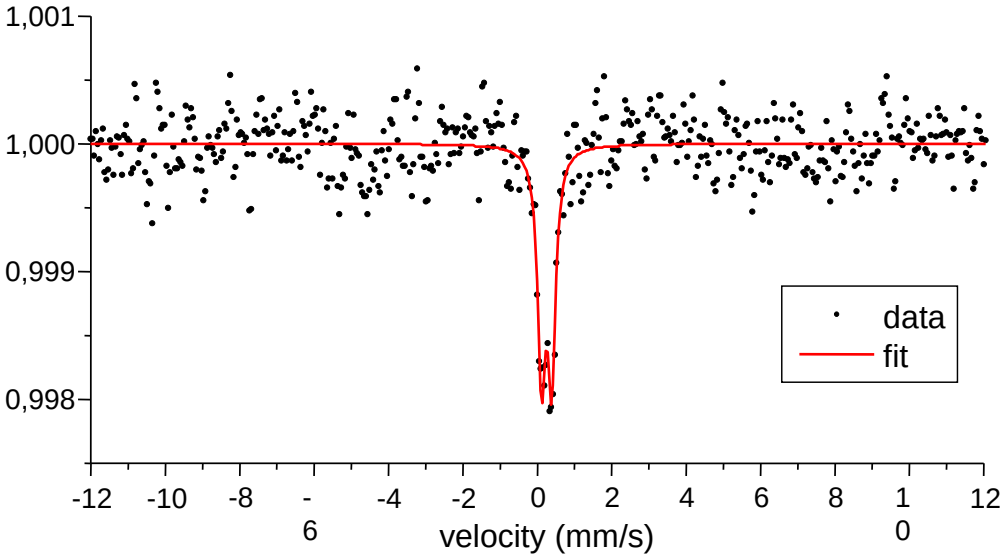

Figure S2
The room temperature Mössbauer spectrum of the 5.6 % γ-Fe_2O_3 in 9HL.

Table S1 The isomer shift, $\boldsymbol{\delta}$ and quadrupolar splitting, $\boldsymbol{\Delta E_Q}$ obtained for the original MNPs and the nanocomposite, respectively, at room temperature. The parameters correspond to the superparamagnetic maghemite (γ-Fe_2O_3) phase.

	Subsp. (Fe^{3+}) γ-Fe_2O_3 MNPs	Subsp. (Fe^{3+}) 5.6 % γ-Fe_2O_3 in 9HL
Isomer shift $\boldsymbol{\delta}$	0.25 mm/s	0.25 mm/s
Quadrupole splitting $\boldsymbol{\Delta E_Q}$	0.28 mm/s	0.29 mm/s
Full line width at half height (FWHM doublet)	0.25 mm/s	0.26 mm/s

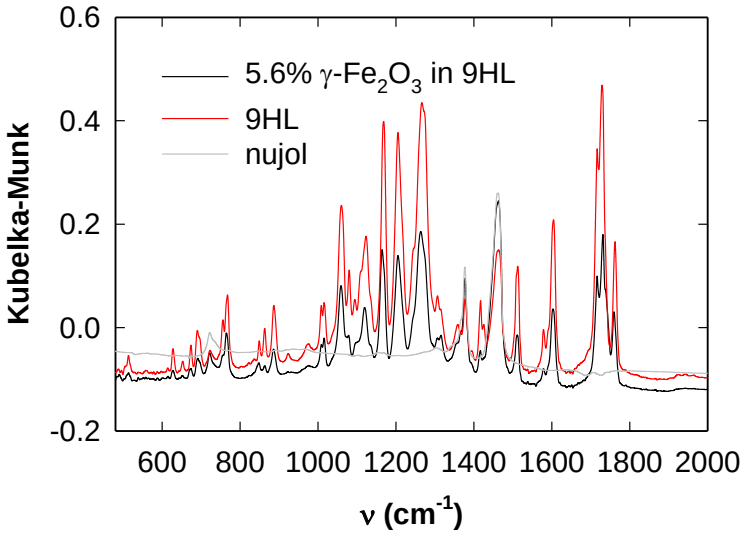

Figure S3
FTIR spectra of the nanocomposite in comparison to the 9HL, measured in nujol. There is no evidence of direct chemical bond of the surfactant molecule (oleic acid) to the 9 HL.

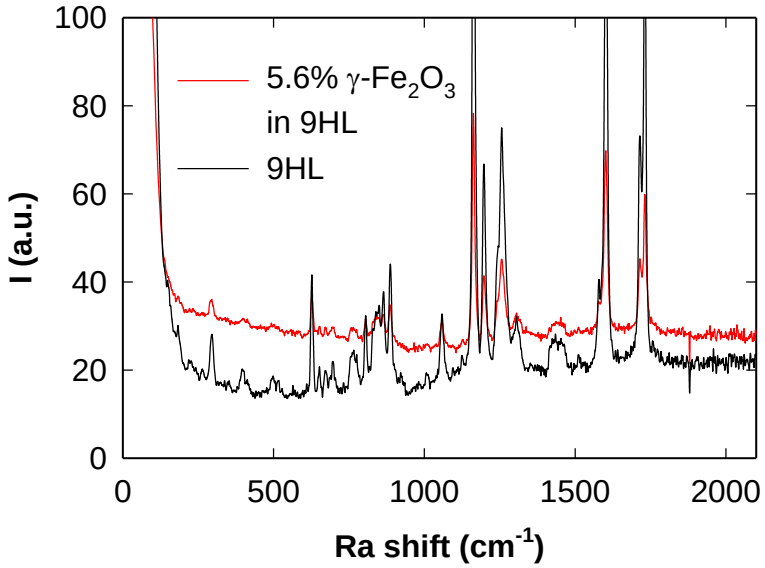

Figure S4
Raman spectra of the nanocomposite (5.6% Fe_2O_3 in 9HL) compared to the pure liquid crystalline compound 9HL (λ = 732 nm).

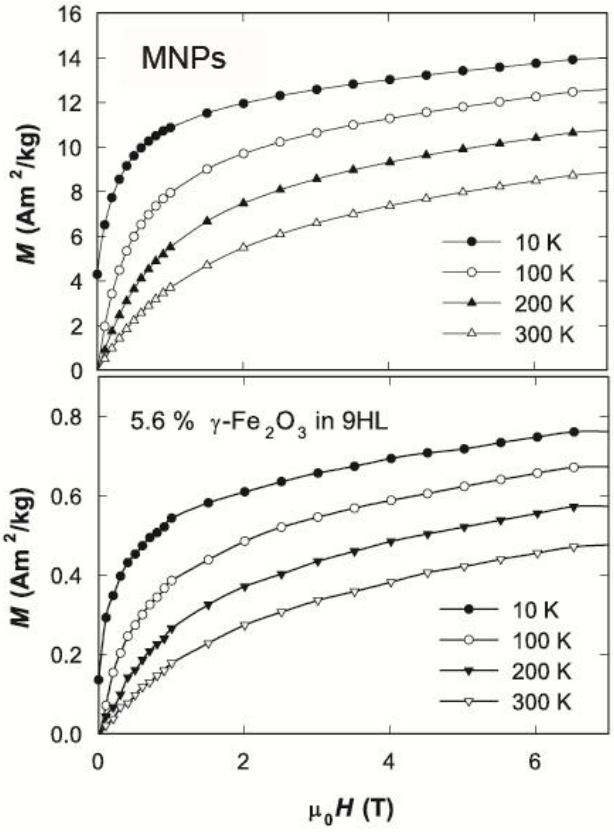

Figure S5
Magnetization isotherms at selected temperatures for the MNPs and the sample containing 5.6 % Fe_2O_3 in 9HL.

Liquid crystalline textures

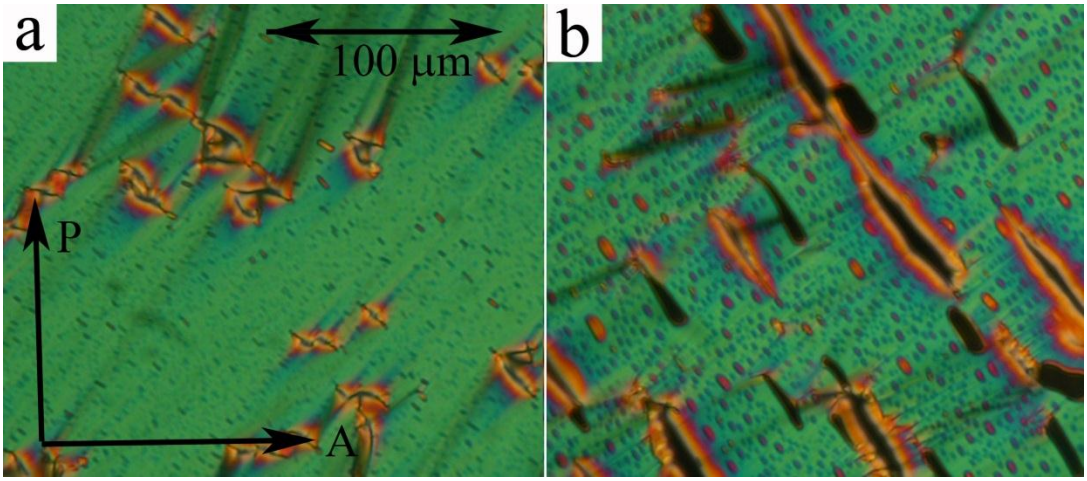

Figure S6 Planar textures observed under the polarizing microscope for two different composites (a) 2.8 % Fe_2O_3 in 9HL and (b) 5.6 % Fe_2O_3 in 9HL.

Dielectric spectroscopy of composites

Dielectric properties were studied using Schlumberger 1260 impedance analyser. The frequency dispersions were measured on cooling at a rate of about 0.2 K/min, keeping the temperature of the sample stable during the frequency sweeps in the range of 10 Hz ÷ 10 MHz. The frequency dispersion data were analysed using the Cole-Cole formula (1) in a generalized form. For the frequency dependent complex permittivity $\varepsilon^*(f) = \varepsilon' - i\varepsilon''$ we have utilized:

$$\varepsilon^* - \varepsilon_\infty = \frac{\Delta\varepsilon}{1 + (if / f_r)^{(1-\alpha)}} - i\left(\frac{\sigma}{2\pi\varepsilon_0 f^n} + Af^m\right) \qquad (1),$$

where f_r is the relaxation frequency, $\Delta\varepsilon$ is the dielectric strength, α is the distribution parameter of the relaxation, ε_0 is the permittivity of a vacuum, ε_∞ is the high frequency permittivity and n, m, A are the parameters of fitting. The second and the third terms in the equation are used to eliminate a low frequency contribution from d.c. conductivity σ and a high frequency contribution due to the resistance of the electrodes, respectively.

Dielectric spectroscopy measurements have been performed for all composites and results compared with pure liquid crystalline compound 9HL. Measured values of real, ε', and imaginary, ε'', parts of the dielectric permittivity $\varepsilon^*(f) = \varepsilon' - i\varepsilon''$ were simultaneously fitted to formula (1), which gives the relaxation frequencies, f_r, and dielectric strength, $\Delta\varepsilon$, values. The results are presented in Figure S6. The relaxation frequency linearly decreases on cooling when approaching the transition from the SmA* to SmC* phase and shows a pronounced minimum at the transition temperature. Dielectric strength starts growing at the SmA-SmC* phase transition on cooling. This behaviour is typical for the tilt angle fluctuations known as the soft mode. In the SmC* phase the Goldstone mode (azimuthal tilt fluctuations) is present, which is practically temperature independent and is characterised with high $\Delta\varepsilon$ values and low relaxation frequencies. The all down of $\Delta\varepsilon$ detected on cooling at lower temperatures is connected with a gradual crystallization.

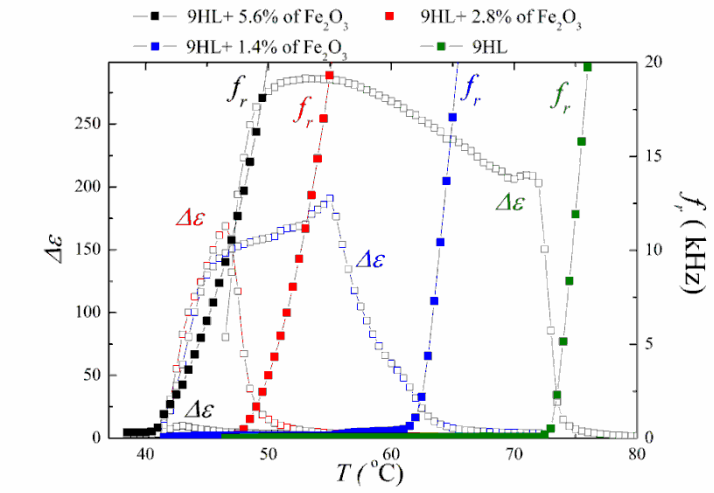

Figure S7 Temperature dependences of the dielectric strength, $\Delta\varepsilon$, and the relaxation frequency, f_r, in liquid crystalline mesophases for pure 9HL (green colour) and composites 1.4% Fe_2O_3 (blue colour), 2.8% Fe_2O_3 (red colour) and 5.6 % Fe_2O_3 in 9HL (black colour).