Supplementary Information

Simple phase transfer of nanoparticles from aqueous to organic media using polymer colloids as carriers

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Synthesis of polystyrene microspheres

Prior to synthesis of polystyrene (PS) microspheres, styrene (Sigma-Aldrich, 99.5 %) was purified from a stabilizer (4-*tert*-butylcatechol) by vacuum distillation. Monodisperse polystyrene microspheres with an average diameter of 545 nm and zeta potential of –29 mV were synthesized by emulsifier-free emulsion polymerization of styrene using potassium peroxodisulfate $K_2S_2O_8$ (Sigma-Aldrich, 99.99 %) as an initiator.[S1] The mixture with molar ratio 1 C_8H_8 : 0.003 $K_2S_2O_8$: 58 H_2O was intensively stirred for 24 h at 343 K. The suspension of polystyrene particles with an average diameter of 80 nm and zeta potential of –40 mV was provided by E.V. Samsonova (Lomonosov Moscow State University). All colloidal solutions after synthesis were cleaned from remaining initiator and surfactant by water. In this work all the solutions were prepared using deionized water (18.2 MΩ cm) obtained by water purification system MilliQ (Millipore).

Preparation of the sintered polystyrene film

Polystyrene film (Fig. S1b) was prepared by sintering of PS microspheres deposited onto a glass slide (Fig. S1a) by a vertical deposition method.[S2] At first, glass slide with surface area of 1 cm^2 was placed vertically in a suspension of PS microspheres (D = 545 nm) with concentration of 0.2 wt.% in a drying oven at T = 45±2 °C for 36 hours. Then, the obtained film was sintered at 110 °C for 140 minutes.

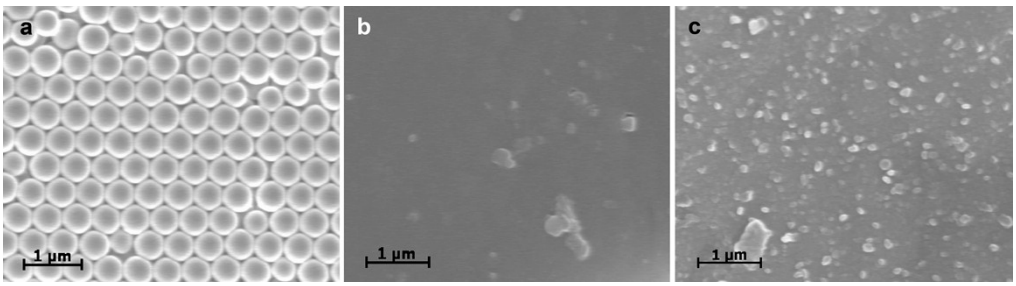

Fig. S1. (a) Top-view SEM image of the as-prepared PS film on a glass slide. (b) Top-view SEM image of the PS film sintered at T = 110 °C for 140 minutes. (c) Top-view SEM image of the sintered PS film after aging in a water suspension of SrM nanoplatelets.

Synthesis of strontium hexaferrite nanoplatelets

Strontium hexaferrite nanoplatelets with an average diameter of 35 nm and average thickness of 6 nm were prepared by a glass ceramic route.[S3-S5] A glass with composition 12 SrO-6 Fe_2O_3-8 B_2O_3 [S4, S5] was heated with a rate of 5 °C min^{-1} to the annealing temperature T = 680 °C and then air quenched. For dissolution strontium borate phases and preparation of the suspension of hexaferrite nanoparticles the prepared glass-ceramic samples were treated with 10 wt. % aqueous solution of acetic acid (reagent grade) using a procedure described earlier.[S6] The concentration of the prepared suspension of SrM nanoplatelets in water was 19 mg L^{-1}.

Synthesis of CdTe nanoparticles

Aqueous colloidal solution of thiol-caped fluorescent CdTe quantum dots (QDs) was prepared using general procedure developed by A. L. Rogach and coworkers[S7] with some changes. Cysteamine was chosen as capping reagent because it provides positive charge on the particle surface (zeta potential +45 mV). Forming and growth of 4.4 nm CdTe QDs took place by over night refluxing of reaction mixture containing H_2Te saturated $CdCl_2$ (reagent grade) solution and cysteamine (reagent grade) at pH=5. Removal of unreached reagents was achieved via dialysis of quantum dots solution using cellulose membrane.

Phase transfer of SrM and CdTe nanoparticles from water to non-polar organic solvents using PS microspheres as carriers

4 ml of PS microspheres (D = 545 nm for transfer of SrM nanoplatelets and D = 80 nm for transfer of CdTe nanoparticles) aqueous suspension with fixed concentration (0.03, 0.04, 0.09, 0.10, 0.17, 0.20, 0.30, 0.34 wt. %) was added to the 4 ml of SrM nanoplatelets (c = 19 mg L^{-1}) or CdTe nanoparticles (c = 0.5 µM) aqueous suspension followed by intense mixing using Bio-Vortex V1 (Biosan) for 1 minute. Hereafter 4 ml of organic solvent (toluene, benzene, styrene or chloroform, reagent grade) was added to the mixture and quickly stirred using the vortex agitator for 1 minute. After fractionalization, the SrM or CdTe nanoparticles were transferred to organic phase.

Phase transfer of SrM nanoplatelets from water to toluene using the sintered polystyrene film as a carrier

The sintered PS film with surface area of ca. 1 cm^2 on a glass slide was placed in 4 ml of SrM nanoplatelets suspension (c = 19 mg L^{-1}) followed by intense stirring for a 1 minute. Then, the PS film was taken out, rinsed by deionized water and air dried. The dried PS film (Fig. S1c) was placed into a toluene until complete dissolution of polymer. Finally, the glass slide was removed from the toluene based colloidal solution of SrM nanoplatelets.

Characterisation

Micrographs of colloids were recorded using a LEO 912 AB Omega transmission electron microscope and field emission scanning electron microscope LEO Supra 50VP. ζ –potential measurements were carried on a Malvern ZetaSizer Nano ZS system. A Perkin-Elmer Lambda 35 spectrophotometer was used to record UV-Vis absorption spectra. Optical properties of the colloidal solutions in polarized light under applied external magnetic field (170 Oe) were studied using a specially constructed transmission spectroscopy setup described earlier.[S6] Photoluminescence (PL) spectra were obtained using Perkin-Elmer LS-55 fluorescence spectrometer.

In the range from 400 to 800 nm the absorption spectra of the toluene and water based SrM suspensions are similar (Fig. S2), which allows us to use UV-vis spectroscopy for the quantitative evaluation of transfer efficiency.

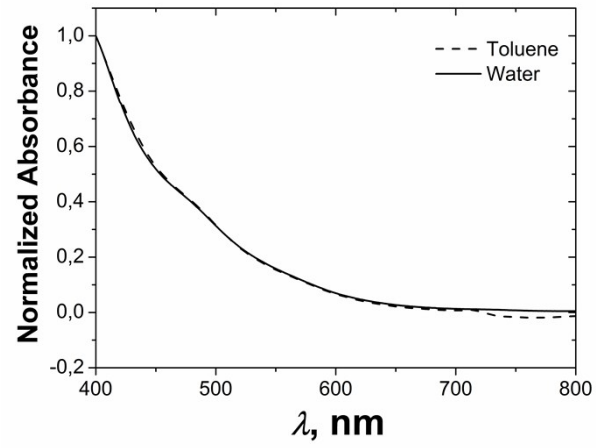

Fig. S2. Wavelength dependences of normalized absorbance of the toluene and water based SrM suspensions.

According to the statistical analysis of several TEM micrographs (Fig. S3) the upper bound for the degree of SrM nanoplatelets aggregation in organic solvent is of ca. 35%.

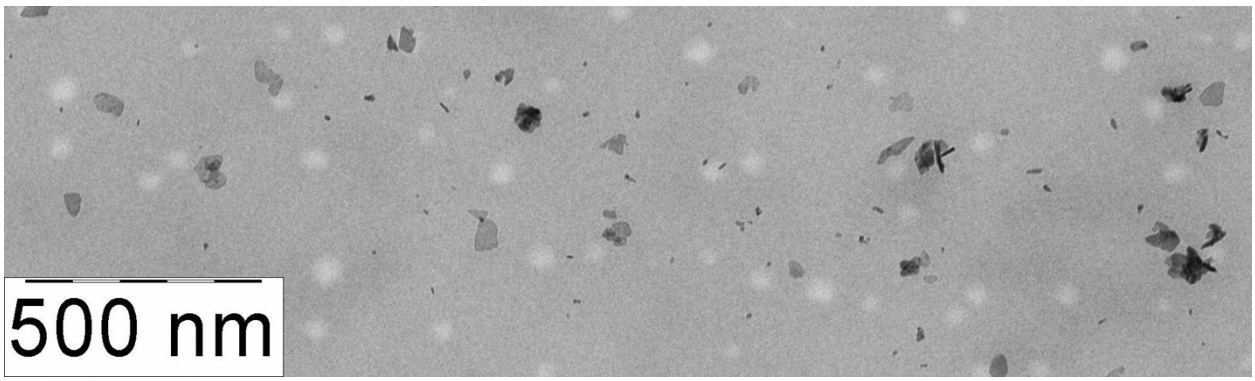

Fig. S3. TEM micrograph of dried colloidal solution of SrM nanoplatelets in benzene. The SrM nanoplatelets are located inside a polystyrene thin film formed from polystyrene chains during solvent evaporation.

A red shift (ca. 6.5 nm) of the maximum in the PL emission spectrum is observed after the phase transfer (Fig. S4). Similar behaviour was observed earlier during phase transfer of CdTe nanoparticles.[S8-S10]

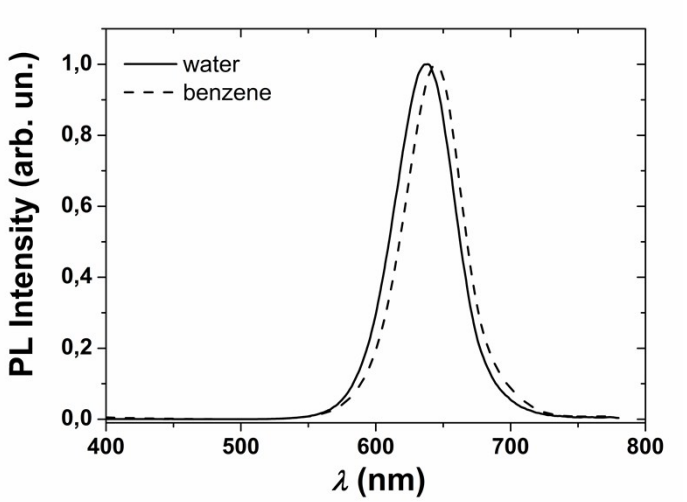

Fig. S4. Normalized photoluminescence emission spectra of CdTe nanoparticles in water and benzene. The excitation wavelength for PL measurements was fixed at 310 nm.

References

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