Magneto-optical modulation on colloid Cu-Ni nanocomposite

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Electronic Supplementary Information

Materials, syntheses and methods

Conditions of synthesizing the Cu-Ni nanocomposite:

Synthesis of the Cu-Ni nanocomposite was performed using polyol reduction of the copper $Cu(NO_3)_2 \cdot 3H_2O$ (Aldrich, 99%) and nickel $Ni(NO_3)_2 \cdot 6H_2O$ (Aldrich, 99%) precursors (with the molar ratios $[Cu^{2+}]:[Ni^{2+}]$ as 3:1) in ethylene glycol in the presence of NaOH. For this, 0.2 M of a metal ion precursor was dissolved in a 1M alkali solution in ethylene glycol at a temperature of 55 °C. A change in solution color from light green to saturated indigo caused by the formation of nickel and copper glycolates was observed. The obtained solution was heated to 190 °C and maintained at this temperature for 6 hours with a subsequent slow (up to 12 hours) cooling. The produced nanoparticles were washed in isopropyl alcohol to completely dissolve by-products and partially decompose ethylene glycol. Then, the alloy nanoparticles were washed with distilled water on a magnet. Despite high solubility of ethylene glycol in water, alloy nanoparticles with a size of about 5 nm are aggregated in clusters of about 100 nm with narrow particle size distribution, which, originally possessing magnetization, formed prestructures of elongated clusters. Formation of elongated thread-

like structures occurred under the influence of an external magnetic field. This mechanism of growth was first studied in Ref.[23] using nickel nanoparticles as an example**.**

Conditions of synthesizing the Ni nanoparticles:

To produce the nickel nanoparticles, we employed polyol reduction of nickel(II) nitrate hexahydrate $Ni(NO_3)_2 \cdot 6H_2O$ (Aldrich, 99%) with hydrazine N_2H_4 (Aldrich, 33% aqueous solution) in the presence of NaOH. Three solutions were prepared for this purpose: a 15 mM solution of the nickel salt in ethylene glycol, a 1M NaOH solution, and a 0.15M hydrazine solution. Volume ratios for the solutions were 2:1:0.1, respectively. Then, the solution was heated to 125 °C under constant stirring. The color of the obtained solution gradually changed from light green to dark graphite. The formation of the product was ensured in 30 minutes. The produced powder was precipitated from the solution using a magnet with a subsequent washing in isopropyl alcohol and distilled water. Given the solution approach to producing nickel nanoparticles, on their surface there is a nanometer-thick layer of nickel oxide phase amounting to 5 wt.%[1] of pure nickel phase.

Characterization techniques

Wide-range X-ray powder diffraction data were processed using Bruker D8 Advance equipment with CuKα (λ = 154.18 pm).

The samples for transmission electron microscope (TEM) characterization were prepared by dispersing a small amount of sample in ethanol to form a homogeneous suspension. A drop of the suspension was deposited on a carbon-coated copper grid for HRTEM observation (FEI TECNAI G2 F20, operated at 200 kV).

To study the samples using EDS analysis, a carbon-coated copper grid was coated with a solution of the sol and, after complete drying in a vacuum desiccator, was investigated without additional sputtering with an ultra-high resolution electron microscope Magellan 400L (Field Emission Inc.).

The magnetic properties of the Ni nanoparticles and Cu-Ni nanocomposite were measured using a VSM technique. All samples were measured as a powder.

1. X-Ray powder diffraction of as-synthesized Cu-Ni-alloy composite

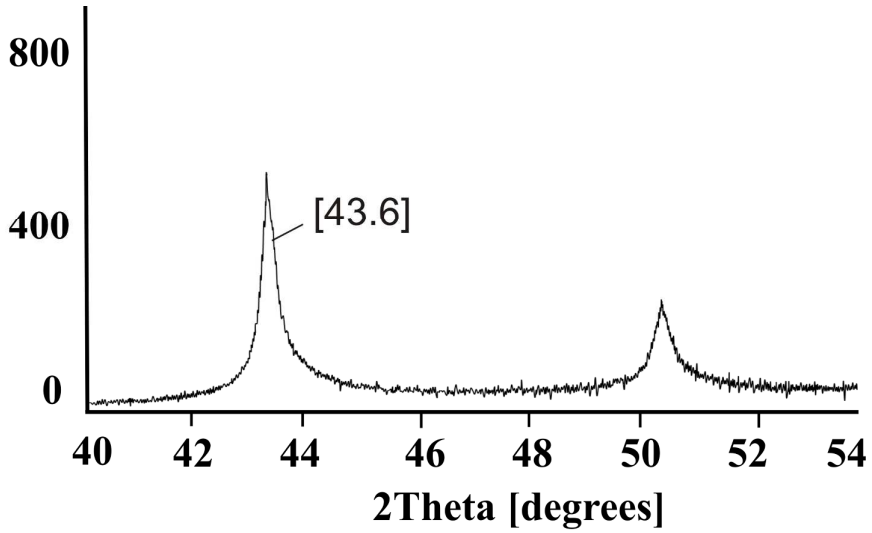

Fig. S1. X-Ray diffraction of as-synthesized Ni-Cu composite.

2.TEM and HRTEM image of nickel nanoparticles

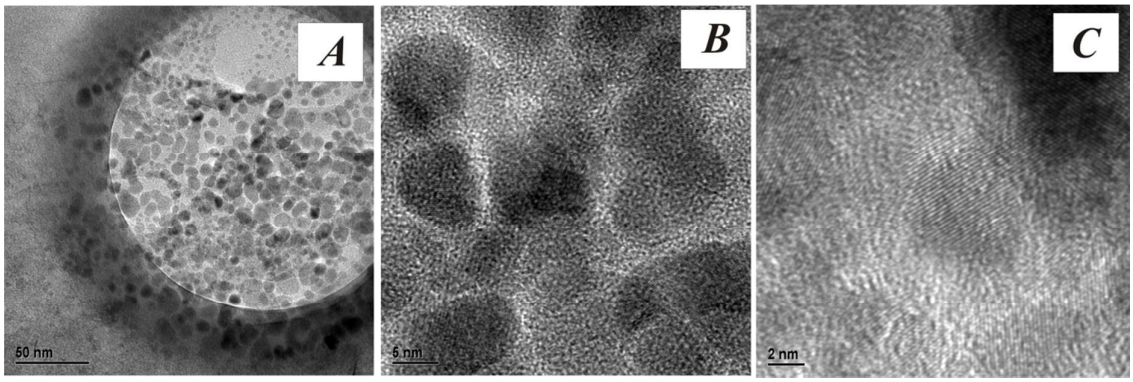

Fig. S2. TEM and HRTEM image of nickel nanoparticles.

3. Optical microscope images of Ni particles.

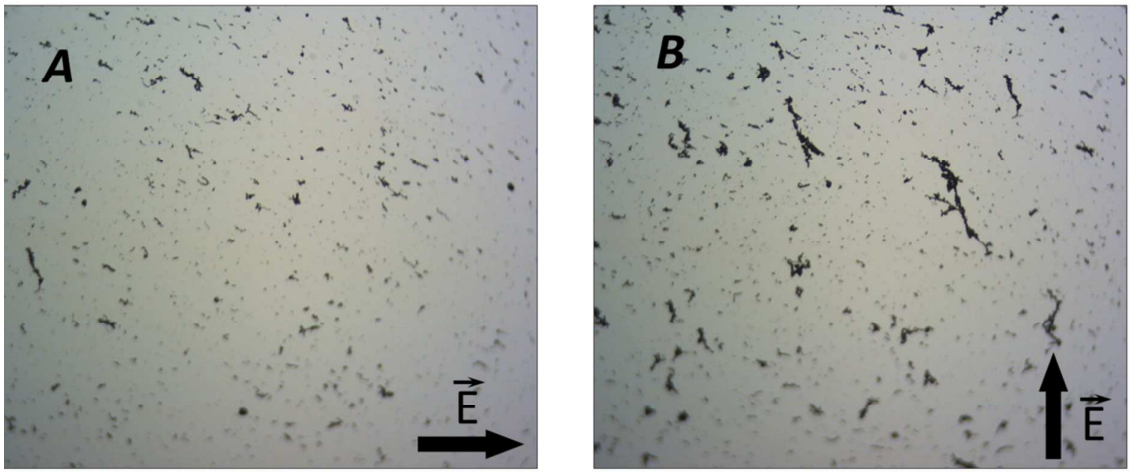

Fig. S3. Optical microscope images of Ni particles caused by rotation of magnetic field.

Table S1

Magnetic properties of as-synthesized Cu-Ni composite and Ni NPs

Sample	Specific saturation magnetization σ_S, emu/g	Specific remnant magnetization σ_r, emu/g	Coercivity, H_C, Oe
Cu-Ni composite	6,39	2,19	180
Ni powder	6,88	0,72	115

Description for Fig. 4A

A Micromed imager optical microscope was used to observe the orientational manipulation and assembly of peapods in an aqueous solution on the surface of thin cover glass. A NdFeB magnet was placed beneath the sample stage and could be manually moved vertically to change its distance to the sample.

Description for Fig. 4B

Light transmission kinetics was studied using transmission at 290 nm. A change in the magnet position angle amounted to 90° between extreme points. Rotation of the magnet was strictly limited to the horizontal plane. The measurements were performed using the Agilent 8454 spectrophotometer.