Synthesis and characterization of $Fe_3O_4/CoFe_2O_4$ building blocks and soft/hard magnetic nanoclusters

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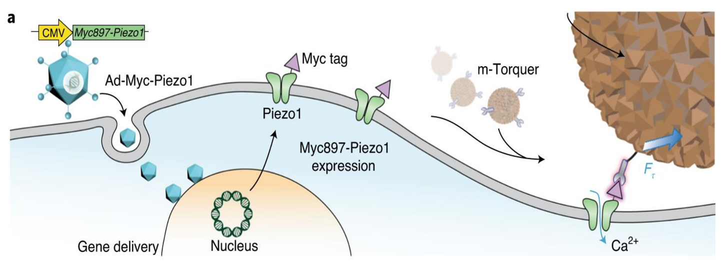
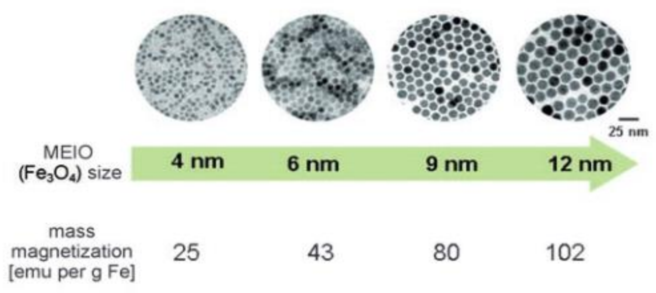
Introduction

Magnetic nanoparticles (MNPs) have potential for a wide range of applications due to their unique magnetic properties. They can be used for in-vivo medical application or electronic device through magnetic control.



Recent studies have focused on exploring various properties by tuning their size and assembling nanometer-scale building blocks. Thus, we aimed to measure and control various properties of iron oxide and cobalt ferrite, which represent soft and hard magnetic materials, respectively.



This study devised synthesis methods for monodisperse building blocks of various sizes with reaction temperature, precursors, and surfactants as variables. We explored how their morphology and magnetism change in single building blocks, simple physical mixtures, and nanoclusters. We confirmed the relationship between particle size and magnetism of each single building block. Also, We verified their tuned magnetic properties through their interaction, which means it is possible to figure out the novel properties arising from these assemblies.

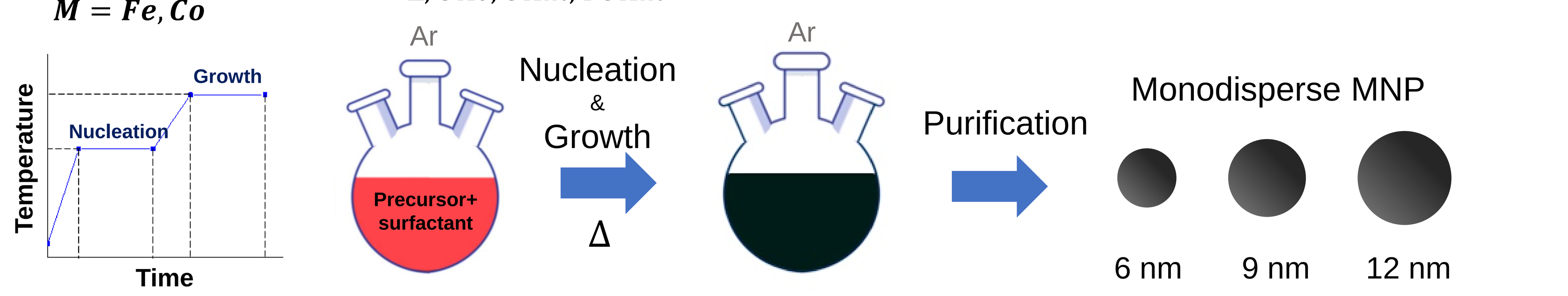
Experimental Methods

I. Synthesis of Building Block (Fe_3O_4 & $CoFe_2O_4$)

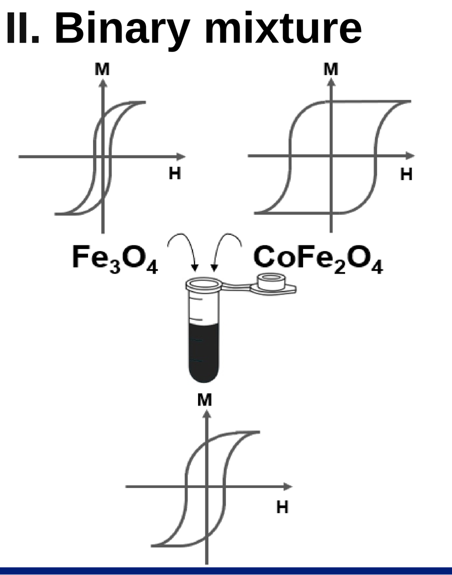
$Fe(acac)_3$: Iron (III) Acetylacetonate, precursor
OAm: Oleylamine, co-solvent/surfactant
OAc: Oleic acid, co-solvent/surfactant
TOAm: Trioctylamine, solvent

$$MCl_2 + Fe(acac)_3 \xrightarrow{\Delta,\ OAc,\ OAm,\ TOAm} MFe_2O_4$$

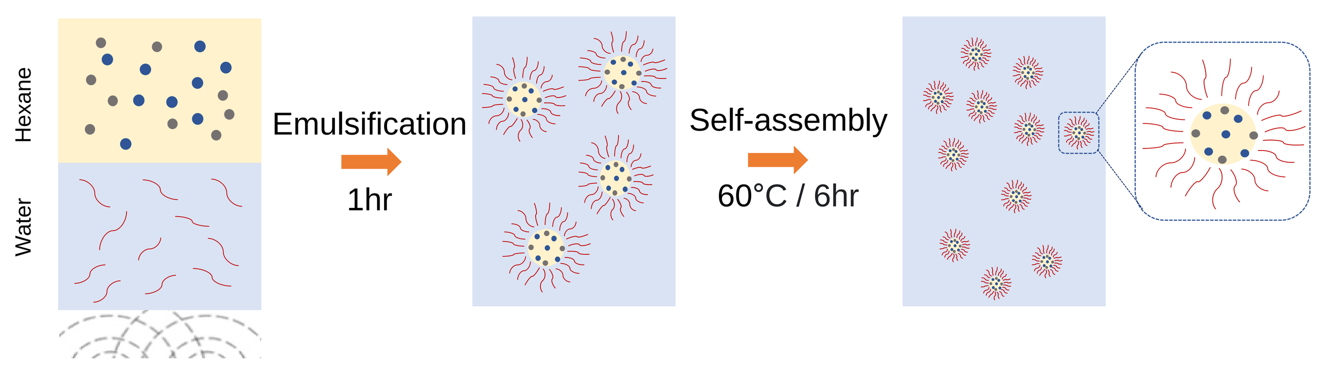
$M = Fe, Co$



II. Binary mixture



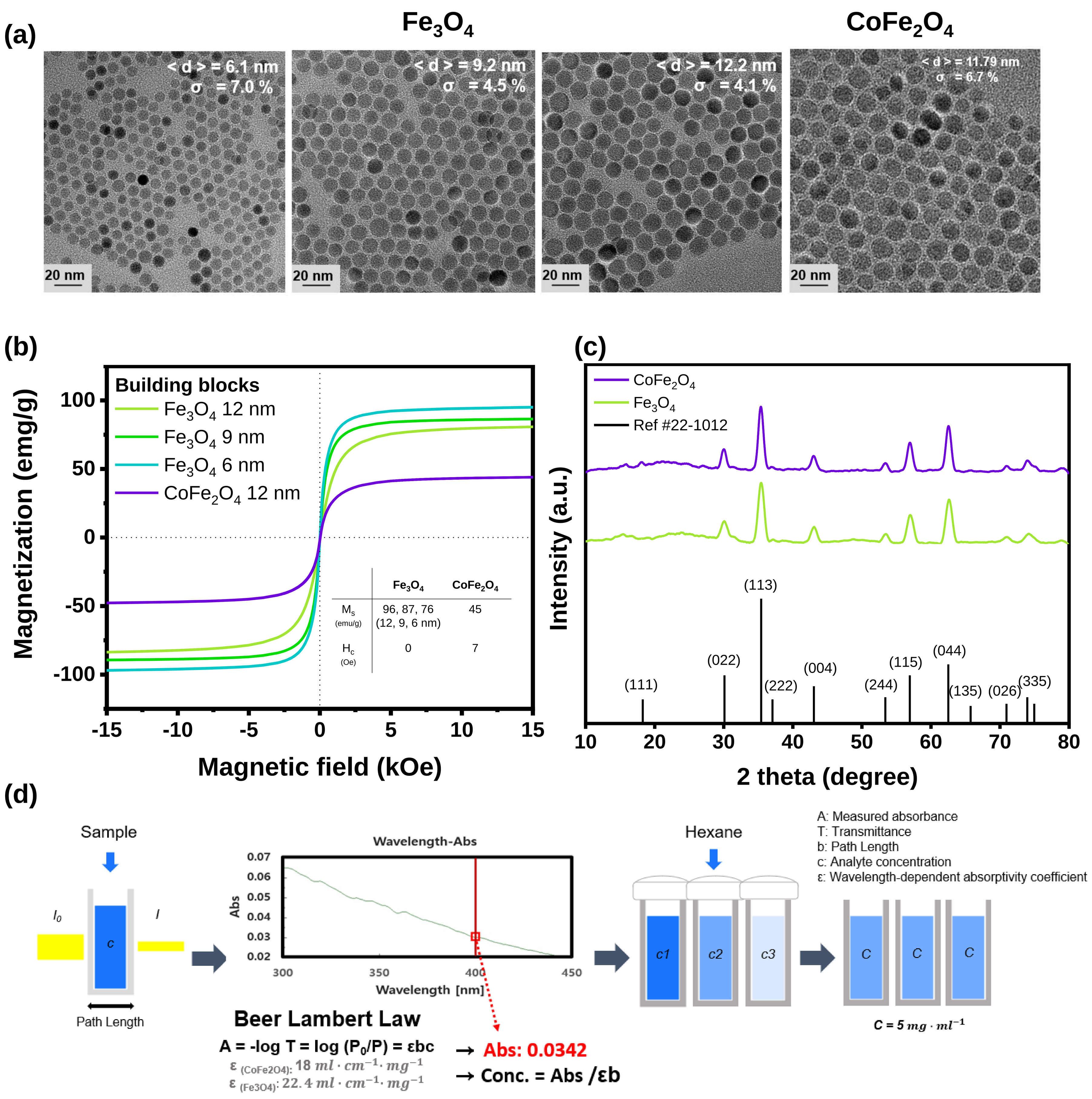
III. Binary nanocluster



[o/w emulsion]
Water phase: Deionized-water + Sodium dodecyl sulfate
Oil phase: hexane

Results

Ⅰ. Monodisperse MNP building block



	Fe_3O_4	$CoFe_2O_4$
M_s (emu/g)	96, 87, 76 (12, 9, 6 nm)	45
H_c (Oe)	0	7

Fig 1. Analysis of morphological, physical and crystallographic properties. (a) Transmission Electron Microscopy (TEM) images, (b) Vibrating-Sample Magnetometer (VSM), and (c) X-ray diffraction (XRD) patterns of monodisperse soft and hard MNP building blocks with different size of 6, 9, 12 nm, respectively, (d) concentration analysis of synthesized MNP samples.

Ⅱ. Simple binary mixture

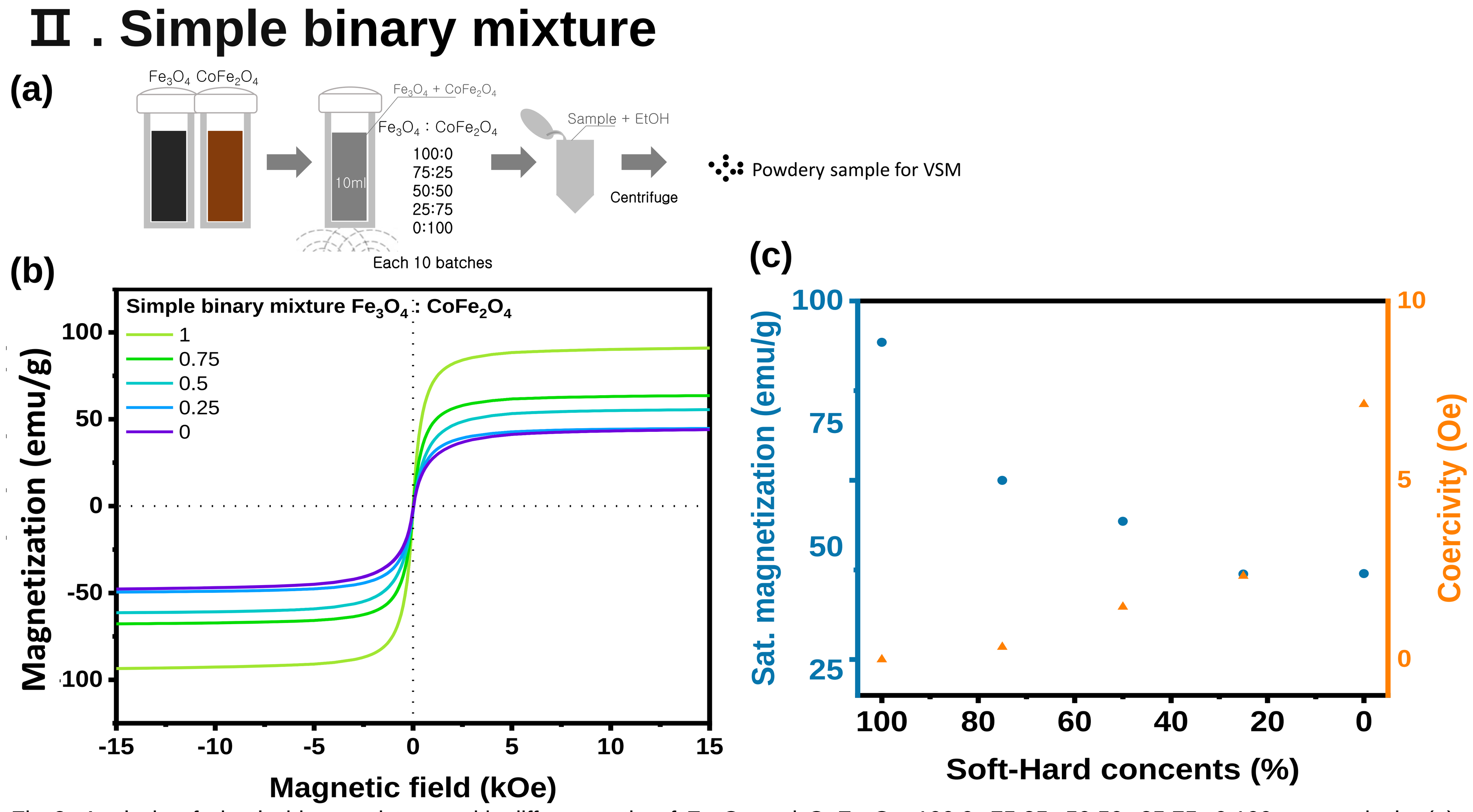


Fig 2. Analysis of simple binary mixtures with different ratio of Fe_3O_4 and $CoFe_2O_4$, 100:0, 75:25, 50:50, 25:75, 0:100, respectively. (a) Schematic illustration of synthesizing binary mixtures, (b) VSM, and (c) Correlation of soft-hard contents with saturated magnetization and coercivity of each simple binary mixture.

Ⅲ. Binary nanocluster (O / W emulsion)

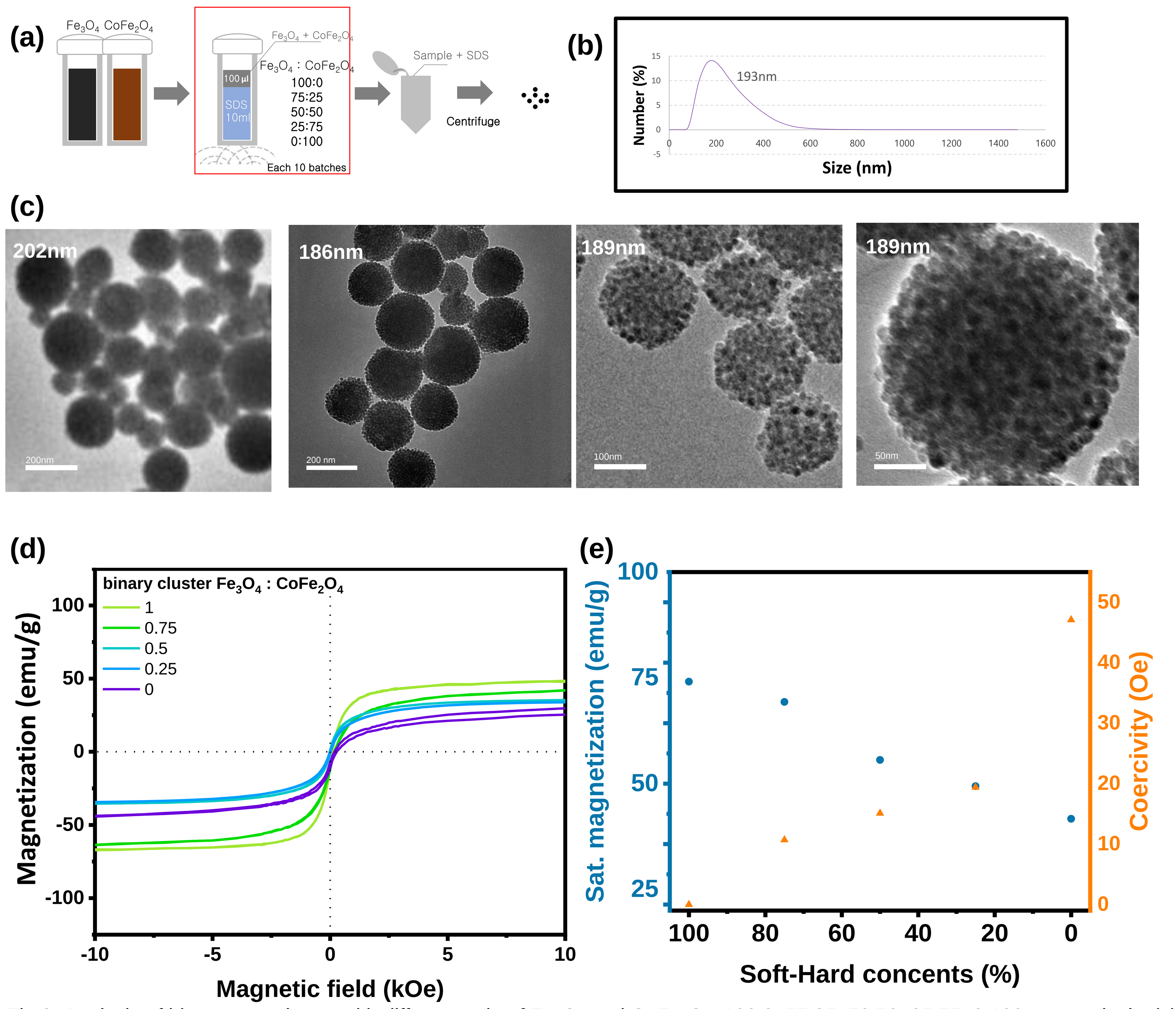


Fig 3. Analysis of binary nanocluster with different ratio of Fe_3O_4 and $CoFe_2O_4$, 100:0, 75:25, 50:50, 25:75, 0:100, respectively. (a) Schematic illustration of fabricating nanoclusters, (b) Dynamic Light Scattering (DLS), (d) TEM, (b) VSM, and (d) Correlation of soft-hard contents with saturated magnetization and coercivity of each binary nanoclusters.

Conclusion & Further Study

Three types of experiments are conducted for observing the behavior of magnetic nanomaterials and devise ways to control them. Three types of experiments are synthesizing various monodispersed building blocks with soft and hard magnetism, mixing different kinds of nanoparticles with various ratios, and fabricating magnetic nanoclusters for high encapsulation efficiency and stability.

In the first experiment, it was confirmed that Ms was proportional to the size of the particles. However, coercivity didn't show any correlation between particle size. Only in the case of $CoFe_2O_4$, showed that coercivity began to appear sufficient value at a scale of 12nm.

The second experiment discovered that it is possible to tune their magnetic properties with their consistent tendency. Ms was proportional to the amounts of soft magnetic material, Fe_3O_4, and coercivity was proportional to the number of hard magnetic material, $CoFe_2O_4$.

The final experiment showed similar results with the simple binary mixture. It was demonstrated that the magnetic properties are tuned depending on the composition ratio of soft/hard material. Additionally, coercivity was tuned with an expected tendency despite their larger scale than the binary mixture.

In the future, we plan to synthesize more uniform magnetic nanoparticle assemblies and two-dimensional binary nanoparticle super crystals to see what interaction and synergistic effects exist depending on their packing density and structure.

Reference

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