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Synthesis and Characterization of FeCo Nanoparticle Colloid by Pulsed Laser Ablation in Distilled Water

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Abstract:

FeCo nanoparticle colloid was synthesized by ablating a high-purity FeCo target in distilled water using pulsed laser. The local surface plasmon resonance (LSPR) phenomena were investigated by UV-VIS spectrometer. By employing scanning electron microscope (SEM) and its scanning transmission electron microscope (STEM) mode, FeCo colloid's other properties were characterized, such as particle size and its distribution. The correlation between SEM/STEM results and UV-VIS absorption spectra is shown in this paper.

I. INTRODUCTION

In the last few decades, a lot of research interest in metallic nanostructured materials has arisen due to their unusual properties which are different from their bulk materials, such as their electronic, optical, magnetic, and chemical properties[1]. Among these, metallic colloids are of special attention owing to their potential technological applications in biosensor, drug delivery, biological labels, and catalysis[2]. These potential applications require optimizing the metallic nanoparticles in colloid by controlling their growth, and consequently their structure, the chemical composition, and the grain size[3]. Therefore, the key issue in the metallic colloid is to develop an optimized method that can synthesize stable and size-controllable nanoparticles with narrow size distribution. The usual techniques for synthesizing metallic colloid include mechanical milling, solution chemistry, vapour-phase synthesis, and sol-gel. Recently, a new method was developed to synthesize metallic colloid by using pulsed laser ablation of metal target in a liquid solution[4]. Compared to chemical synthesis, the advantages of this method are the simplicity of the procedure and absence of chemical reagents in solution. Pulsed laser ablation also has appeared to be the most flexible and promising technique because of its ability to ablate almost all kinds of materials due the ultra-high energy density and control over the growth process by manipulating the process parameters like irradiation time, duration, energy density, wavelength, etc[5].

FeCo nanoparticles have played an important role in technological applications such as ultrahigh-density storage media and biomarker[6] which require soft magnetic materials. FeCo nanoparticles due to their combination of low coercivity, large permeability, and very large saturation induction are candidates for such applications. This paper reports the synthesis and characterization of FeCo colloid by pulsed laser ablation of FeCo target in distilled water.

II. EXPERIMENT

FeCo (50:50 by atomic percentage) target was immersed in distilled water in a square glass vessel and later ablated by an Nd:YAG laser with wavelength of 532nm. The typical laser pulse duration is about 10 ns and repetition rate was set at 10 Hz. The volume of distilled water (with FeCo target) was adjusted so that the water surface is always 3 mm above the FeCo target surface. A convex lens with short focal length (75mm) was used to avoid focusing laser beam at the water surface. An X-Y motor stage was used to move the glass vessel randomly so that the laser irradiates the FeCo target surface at random locations. This arrangement provides uniform ablation of the FeCo target and avoids laser irradiation at a particular place.

The morphology of FeCo nanoparticles was investigated by JEOL JSM-6700F field emission scanning electron microscope (FESEM) equipped with electron energy dispersive X-ray spectrometer (EDS) and a scanning transmission electron microscope (STEM) mode. The specimens were prepared by dropping and drying the fresh FeCo colloid onto the Cu meshes with carbon films. SHIMADZU UV-VIS 2501 spectrophotometer was employed to determine the UV-VIS absorption spectra of FeCo colloid. To avoid FeCo nanoparticles aggregating and

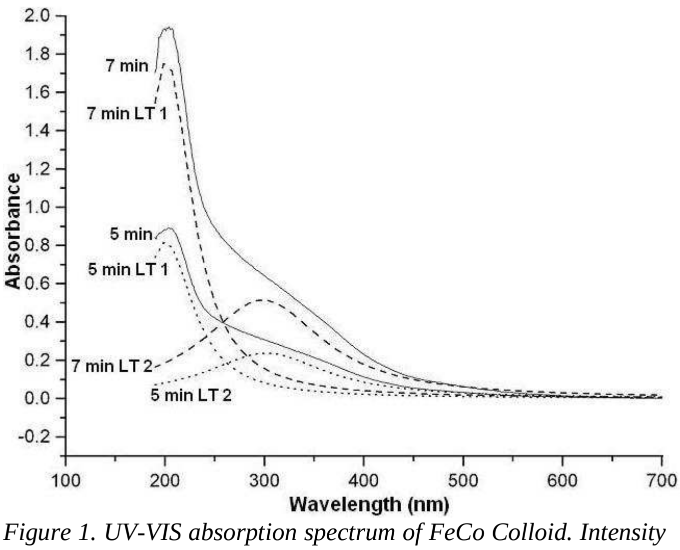

Figure 1. UV-VIS absorption spectrum of FeCo Colloid. Intensity of the peak at around 315nm increases and becomes apparent by fitting two peaks using Lorentzian method as the irradiation time increases from 5min to 7min.

affect its optical properties, FeCo colloid was redispersed in Kerry Ultrasonic Bath before UV-VIS absorption spectrum.

III. RESULT AND DISCUSSION

Figure 1 shows the UV-VIS absorption spectrum of FeCo colloid synthesized by ablating FeCo target in distilled water with different irradiation time. As the irradiation time increased from 5 min to 7 min, the intensity of absorption spectrum increased, indicating an increase of the number of FeCo nanoparticles in colloid. By fitting two peaks using Lorentzian method, it was observed that an absorption peak at around 315nm became apparent as its peak intensity increased with the increase in laser irradiation time. It may be noted that this peak broad and has a large bandwidth. The position and full width at half maximum (FWHM) of the absorbance peak depend on the materials, solvent, particle size and its distribution according to Mie scattering theory[7]. Therefore, the wavelength of maximum absorption and the large FWHM lead to the assumption that FeCo nanoparticles fabricated by pulsed laser ablation are rather small and their size distribution is widely spread. The FWHM of absorption spectrum decreases to a certain extent and the peak slightly blue shifts at longer irradiation time, which can be explained that the yield rate of smaller sized FeCo nanoparticles is larger than bigger ones for longer irradiation. It also may due to the laser destruction of the initially ablated clusters formed by FeCo nanoparticles, so that the size of nanoparticles decreases and the colloid concentration becomes higher.

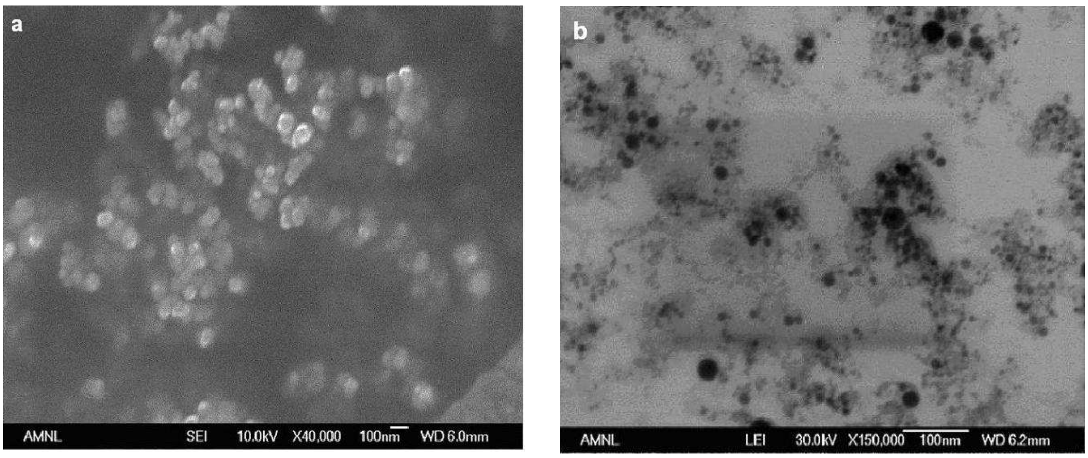

Figure 2 (a) SEM and (b) STEM images of FeCo nanoparticles in colloid synthesized by 7 min irradiation.

The SEM image of FeCo nanoparticle clusters in colloids synthesized using 7 min irradiation time is shown in Figure 2(a). FeCo nanoparticles tend to aggregate together to form bigger size clusters with wide range of sizes from about 50 to 100 nm. It may be one of the reasons to explain why the FWHM of UV-VIS absorption spectrum is large. It was observed that some brown flocks appeared at the bottom one week after synthesis, which can move by applying strong magnetic field and be re-dispersed by ultrasonic bath. The size of FeCo nanoparticles was evaluated by STEM images using JEOL JSM 6700F, as shown in Figure 2(b). The size of nanoparticles varies from 5nm to 40nm, which cause the large FWHM and attribute the long-wavelength tail in the UV-VIS spectra showed in Figure 1. In agreement with UV-VIS absorption spectra results, most of FeCo nanoparticles are at the range of 5nm to 15nm and give rise to the maximum absorbance at about 315nm.

IV. CONCLUSION

FeCo colloid was successfully synthesized by ablating FeCo target in distilled water in a glass vessel with high yield rate. UV-VIS absorption spectra indicate that FeCo nanoparticles synthesized by pulsed laser ablation are rather small with broad size distribution. The STEM shows that the size of nanoparticles varies from 5nm to 40nm and SEM images shows that these nanoparticles tend to aggregate to form clusters ranging from 50nm to 100nm. These observations are in agreement with the conclusions drawn from UV-VIS spectra results. It is shown that pulsed laser ablation is a promising technique for the fabrication of magnetic nanocolloid.

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