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SYNTHESIS AND CHARACTERIZATION OF IRON AND ALUMINUM NANOPARTICLES VIA LASER ABLATION IN WATER

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ABSTRACT

Iron and aluminum nanoparticles were synthesized by irradiating the Nd:YAG laser with the wavelength of 1064 nm on the surface of the target immersed in distilled water. The laser used in this research was a millisecond pulsed laser. The synthesized nanoparticles were suspended in the water. However, with the limitation of the SEM used many nanoparticles were difficult to observe. Instead, the clusters of nanoparticles were presented as a preliminary data and guidance for synthesizing metal nanoparticles under these conditions. The size of the iron clusters was in the range of 0.6-1.5 μm and the size of the aluminum clusters was in the range of 0.8-1.5 μm. UV-Vis spectra showed that the suspension of iron and aluminum nanoparticles absorbed light in the UV range.

KEYWORDS: Iron nanoparticle, Aluminum nanoparticle, Laser ablation

1. INTRODUCTION

It has been reported that nanoparticles of metal, such as Au, Ag, Li, Na, and Cu, with a variety of dimensions offered many size-dependent properties, e.g. optical, electronic, magnetic, and chemical properties. Thus, these will lead to many applications related to optoelectronic devices, catalysts, chemical- and bio-sensors [1, 2, 3]. Iron nanoparticles have been investigated for their ability in power-transformer cores, magnetic storage media, and catalysts [4, 5, 6].Aluminum nanostructures has been reported to improve the plasmon resonances, which will lead to progress in the surface enhanced Raman spectroscopy (SERS) [7, 8]. Nanoscale Al particles were also reported to have a capacity in hydrogen storage materials [9]. Therefore, many research groups have put many efforts on the development of synthetic methodologies for iron and aluminum nanoparticles of their desired properties [10, 11, 12,13].

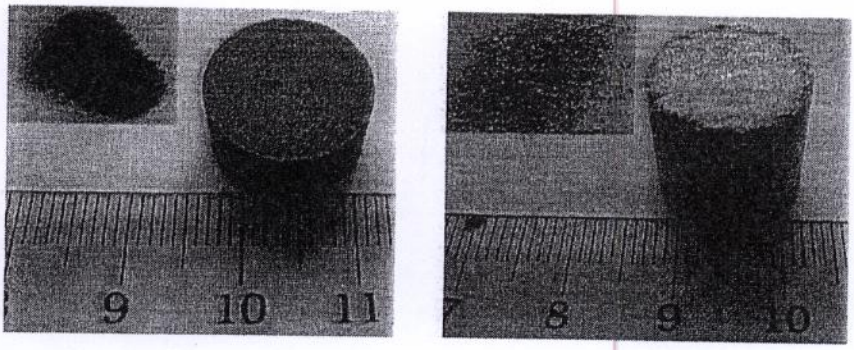
Different techniques have been used to synthesize nanomaterials such as arc discharge, vapour and electrochemical deposition, and ball milling [14,15]. Pulsed laser ablation in liquid media (PLAL) is a selected technique to fabricate various kinds of nanomaterials via rapid reactive quenching of ablated species at the interface between the plasma and liquid [16].The advantages of this method are as follows. The nanoparticles are chemicals pureness and do not require the vacuum chamber. Moreover, surfactants can be added to the liquids in order to control size or even aggregation of the nanoparticles. The controllability of particle size is shown to be dependent upon operating conditions (wavelength, laser power, etc.) [17].

In this work, the preliminary resultson our workwere reported. Iron and aluminum nanoparticles were synthesized using pulsed laser ablation in water of the same condition.The size and morphology of nanoparticles were investigated by scanning electron microscopy (SEM) and their optical properties were examined by UV-visible spectroscopy.

2. MATERIALS AND METHODS

2.1. Sample Preparation

Iron (~60 μm) and aluminum (~15 μm)powders were pressed into pellets by the hydraulic presses with a constant pressure of 200 mbar. Using the pallet instead of the powder form offered a better way to handle the samplesunder laser ablation. The iron and aluminum pellets were shown in Fig.1. The experimental setup on laser ablation was showed in Fig. 2. The first harmonic Nd:YAG has a wavelength of 1064 nm with the laser energy of pulse duration of 5 ms and the repetition rate of 2 Hz. The beam was focused using the 6.5 focal-length lens onto a target (iron / aluminum pellet), which is at the bottom of glass vessel. The distilled water was poured into the vessel until it is about 0.2 cm above the target. After 1000 pulses of laser ablation, the suspensions were mixed with sodium dodecyl sulfate (SDS) and sonicated in bath sonicator for 30 minutes. The surfactant was used to reduce the aggregation of nanoparticles after the synthesis.



(a) (b)

Figure 1 Metal pellets: (a) iron pellet and (b) aluminum pellet

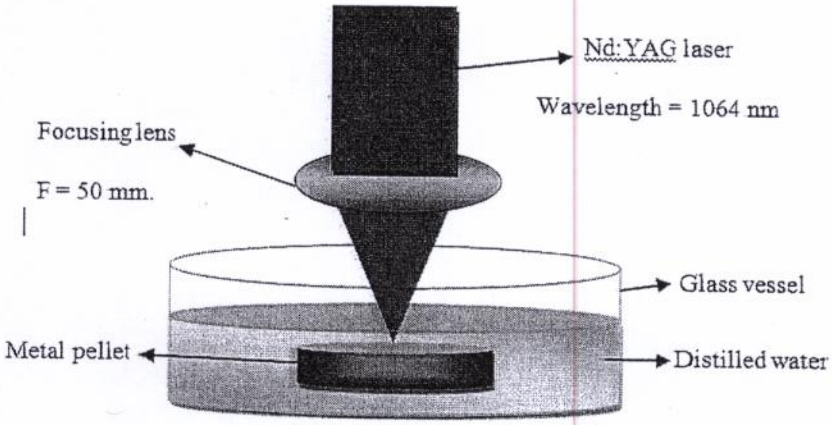


Figure 2 Experimental setup for preparation of nanoparticles by laser ablation in water.

2.2. Characterization

The size and morphology of the particles were investigated using scanning electron microscopy (SEM, JEOL-JSM 6510) by dropping the suspension on carbon tape and dry in air for about one day. The absorption spectra of the particle suspensions were recorded by UV-Vis spectrophotometer (Jasco, V570) operating in the wavelength of 190 – 800 nm.

3. RESULTS AND DISCUSSION

3.1 Size and morphology

The metal nanopaticle suspensions were shown in fig.3. The color of the suspension was changed to yellow brown for iron nanoparticles and it was opaque white for aluminum nanoparticles.

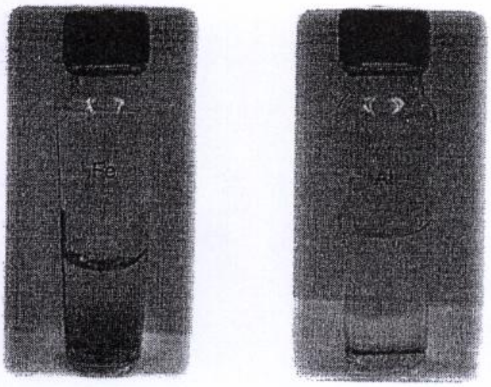
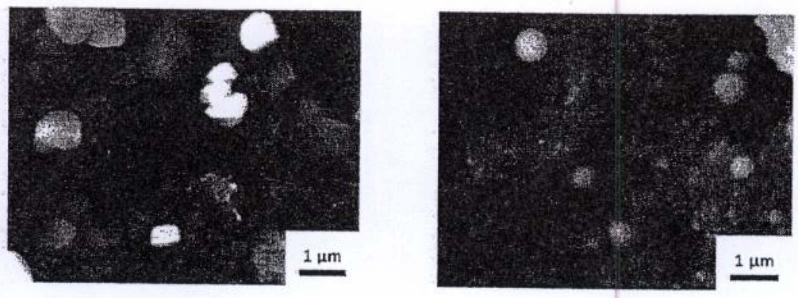


Figure 3 Iron and aluminum nanoparticle suspensions.

The SEM images of iron and aluminum clusters are shown in Fig. 4. From the limitation of the SEM used, the clusters of the nanoparticles have been observed. The results showed that the individual iron-nanoparticles were difficult to observe due to the limitation. The clusters of the nanoparticles have the sizes ranging from 0.6-1.5μm. In the case of aluminum nanoparticles, most of the observations were the cluster of nanoparticles with the sizes of 0.8-1μm with a spherical shape. It is suggested that distilled water may support the growth of iron and aluminum nanoparticles during laser ablation. It should be noted that as these results were the initial data, thus, further quantitative study is still required, i.e. using transmission electron microscope (TEM). The particle size and cluster size from these preliminary data were counted using naked eyes by changing brightness and contrast, thus, further concrete data is required, i.e. using commercial software.

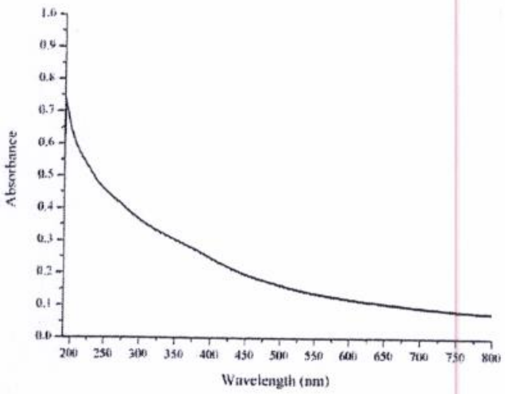


(a) (b)

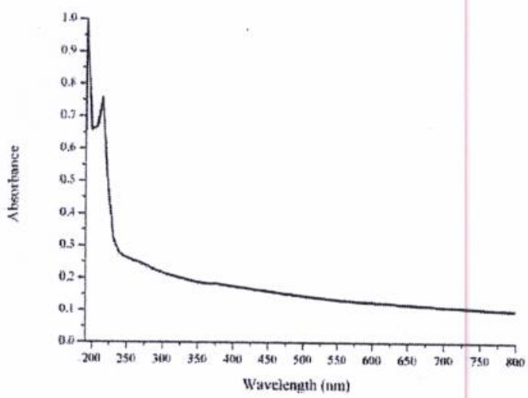
Figure 4 SEM images of clusters of nanoparticles prepared by laser ablation in water

(a) clusters of iron nanoparticles and (b) cluster of aluminum nanoparticles.

3.2 UV-Vis spectra



(a)



(b)

Figure5UV-visible spectra of (a) iron nanoparticles and (b) aluminum nanoparticles

In Fig. 5(a) shows absorption spectrum of iron nanoparticles, which presented that the absorption in the UV. The absorption spectrum of aluminum nanoparticles is showed in Fig. 5(b). The spectrum showed the absorption of light in the UV range and maximum absorption at a wavelength around 215 nm.

CONCLUSIONS

Iron nanoparticles and aluminum nanoparticles have been synthesized by laser ablation in liquid method. The iron and aluminum nanoparticles were difficult to observe due to the limitation of SEM.However, clusters of nanoparticles from iron and aluminum were observed. The clusters of iron nanoparticles have the sizes ranging from 0.6-1.5μm. For aluminum nanoparticles, most of the features from SEM were the clusters of nanoparticles with the sizes of 0.8-1μm with a spherical shape.Nanoparticles of iron and aluminum absorbed light in the ultraviolet range. Especially, aluminum nanoparticles have maximum absorption at wavelength around 215 nm. To have further information on the size and morphology of the nanoparticles, TEM is required.

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