Formation of Fe, Pt and (Pt/Fe) ultra-fine metal nanoparticles in different solution polarity prepared by Nd-YAG pulsed laser

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Abstract. Iron(Fe/FeO), Platinum (Pt) and (Pt/Fe) ultra Fine(UF) nanoparticles (NPs) were synthesized by pulsed (Q-switched, 1064 doubled frequency-Nd: YAG). The laser ablation of Fe and Pt metal plates has been performed by immersing these metal plates in deionised water (DDW) and ethanol alcohol solvent. The pulsed laser ablation in liquids (PLAL) process preformed with 100 pulse energy of 700 mJ and liquid depth is 5 mm. The formation efficiency of PLAL process was quantified in term of the absorption spectrum peaks and TEM images anlaysis. The absorption spectra of Iron (Fe/FeO, Pt) in DDW reveal a sharp and single peak around (292/363 and 234)nm, respectively, indicates the production of pure and spherical shape of Fe/FeO, Pt UF NPs with an average size in the range of 2-5 nm. While, it was notice absorbance peaks wavelength shifted to the shorter wavelength in ethanol alcohol due to high polarity of alcohol in both bimetallic nanoparticles (Fe and Pt). By changing the solution polarty it can open an easy way to control the size and shape of Fe and Pt and Bimetals (Pt/Fe ) colloidal nanoparticles.

1. Introduction
Nanoparticles produced by Pulsed Laser Ablation in Liquid (PLAL) technique are completely pure particles and contain no by product or toxic chemicals compared to other techniques used. Therefore, this process opens the door to using and applying the produced nanomaterial without the need for further purification techniques in many applications, especially medical treatments [1]. Several works investigated the production metal nanoparticles by PLAL in several solvents. Different oxidation or carbonization states can be achieved, because of the chemical reactions between the iron metal vapour and the liquid surrounding during the NP formation phase [2, 3]. Thus, PLAL managed to create a variety of nanomaterial by choosing the right laser parameters and liquid solvent [4].

Furthermore, the application of spinel iron can be expanded when it relates to nanostructured forms such as thin films, nanoparticles [5]. Since iron-based nanoparticles (NPs) possess magnetic and catalytic properties, and are bio-compatible, those make it have a great interest in several fields of research, e.g., magnetic aids [6], and bio-medical applications [7]. On the other hand, nanoparticles of noble metals such as Gold, silver, platinum and their counterparts have combined great interest from the scientific community because of their enormous properties and diverse applications [8-10].
Pt and alloy nanoparticles have attracted extremely interest because they are perfect catalysts for many purposes [11-14]. However, small platinum (Pt) nanoparticles (< 5 nm) have shown great potential in therapeutic applications, such as DNA dissociation, radiation therapy, and oxidative stress treatment. Thus, obtaining a small sized Pt nanoparticle tends to aggregate, and are difficult to target [15].

In this research Pt, Fe and Pt/Fe nanoparticles have been set up by physical blend approach. The point of this work is to exhibit the impacts of incorporating Pt, Fe and Pt/Fe particles on nucleation, development instruments and size conveyance. The Fe/FeO carriers provide stability to the small Pt nanoparticle decorated by Fe/FeO nanoparticles. Changes in the fluid environment utilized as a part of laser removal give a basic and adaptable strategy to adjust the properties of Pt, Fe and Pt/Fe nanoparticles and it will be presented in this paper.

2. Experiment

Iron (Fe/FeO) and platinum (Pt) nanoparticles (NPs) were prepared by laser ablation of the two metal targets. The samples with 3mm thickness and an impurity of 99.99 were washed with ethanol and double deionized water (DDW) to clear trademark blends in an ultrasonic cleaner. The DDW and ethanol alcohol were used as liquid environment for laser ablation.

The sample's surface was kept at 10 mm. The nanoparticles prepared using (Q- switched, 1064 or 532 nm Nd: YAG) with a single wavelength of 1064nm in various liquid media (DDW, ethanol alcohol). The rest of the variables were fixed for all samples. The number of pulses used was 100 pulses, the energy value was 700mJ, the frequency was 5 Hz, the liquid volume used was 2 ml, and the samples were prepared at room temperature. The natures of the resulting nanoparticles were characterized and analysed using UV-Visible Spectrometer and Transmission Electron Microscopy (TEM).

3. Results and discussion

3.1 UV–vis spectroscopy characterization

The formation of Fe/FeO and Pt NPs were characterized by UV–vis spectrophotometer. Figure 1 shows the UV–visible spectra of Fe/FeO NPs in DDW and ethanol alcohol. In Figure 1 the peak located at 292 nm indicates the formation of Fe NPs while, the peak wavelength located at 363 nm related to the formation of FeO NPs in DDW. Also, the peak located at 280 nm related to the formation of Fe NPs in ethanol with the absences of FeO NPs peak.

![Figure 1. UV-Vis absorption spectra of Fe nanoparticles prepared in different solutions.](image-url)
From these results, it can be seen that the peak wavelength of Fe NPs was shifted to the shorter wavelength in ethanol alcohol due to high polarity of alcohol. While the absorption value was the same in both solutions with the present of the FeO peak in DDW sample.

Figure 2 shows the UV-visible spectra of Pt NPs in DDW and ethanol alcohol. In Fig 2 the peak presented at 234 nm indicates the formation of Pt NPs in DDW. While, the peak located at 242 nm indicates the formation of Pt NPs in ethanol. From these results, it can be seen that the Pt NPs peak wavelength shifted to the shorter wavelength (blue shift) in ethanol alcohol due to high polarity of alcohol, while the absorbance value was higher in DDW sample.

![Figure 2](image)

**Figure 2.** UV-Vis absorption spectra of Pt NPs prepared in different solution.

Figure 3 shows the absorption spectrum of Pt/Fe NPs colloid in ethanol. The Pt NP colloid exhibits an absorption band with sharp peak located in the wavelength of 222 nm and an absorbance value of 0.45, while, the FeNP colloid showed an absorption band with a wide peak located in the wavelength of 290 nm and an absorbance value of 3.85.

3.2. TEM characterization

Fe and Pt NPs size were further confirmed by TEM images. Figure 4 shows the TEM image and the size distribution of the Fe/FeO NPs produced in DDW. It was observed the Fe/FeO NPs have spherical shape and the diameter of Fe NPs was ranged from 0.4 to 2 nm with an average size of 0.95 nm. While, the average size of the Fe NPs in ethanol was ranging from 0.5-3 nm and the average size was 1.14 nm as shown in Fig 5. This indicated that as the polarity of solution increased the particles size increased due to the inducing of electrical charge which surrounded the surface of nanoparticles and tend to increase the interaction between the particles.
**Figure 3.** UV-Vis absorption spectra of Pt/Fe nanoparticles prepared in ethanol solution.

**Figure 4.** TEM image (a) and size distribution (b) of the Fe/FeO NPs in DDW.
Figure 5. TEM image (a) and size distribution (b) of the Fe NPs in ethanol alcohol.

Figure 6 shows the TEM image and the size distribution of the Pt NPs produced in DDW. It can be seen that the diameter of Pt NPs was ranged from 0.5 to 2nm and have a spherical shape. The average size of Pt NPs was 0.98 nm. These results closed to that obtained by Nguyen et al [16].

Figure 6. TEM image (a) and size distribution (b) of the Pt NPs in DDW.

Figure 7 shows the TEM image and the size distribution of the Pt NPs prepared in ethanol alcohol. It can be seen that the diameter of Pt nanoparticles ranged from 0.5 to 2.5nm. The average size of Pt nanoparticles was 1.30 nm. As the polarity of solution increased the Pt particles size increased which support of the size control by choosing different polar solution.
Figure 7. TEM image (a) and size distribution (b) of the Pt NPs produced in ethanol alcohol.

Figure 8 shows the TEM image and the size distribution of the Pt/FeNPs produced in ethanol alcohol. It can be seen particles size diameters of Pt/Fe NPs ranged from 0.5 to 3.5 nm. The average size of Pt/Fe NPs was 1.36 nm. The present of Fe NPs and FeO NPs within Pt NPs solution could be preventing the aggregation of Pt NPs due to the effect of Fe and FeO NPs in acting as carriers which provide a stability to the small Pt nanoparticles [16].

Figure 8. TEM image (a) and size distribution (b) of the Pt/Fe NPs produced in ethanol alcohol.
4. Conclusion
The effect of PLAL method in the preparation of Fe,Pt and Fe/Pt nanoparticles in different solutions media had been utilized and investigated. The size and the optical properties of Fe/FeO NPs, PtNPs and Pt/Fe NPs were examined in different liquid media (DDW and ethanol solvent). The prepared FeNPs in ethanol alcohol showed a blue shift in the peak wavelength and a decreased in absorption due to high polarity of alcohol. Also, Fe NPs in DDW showed a narrow size scattering and a peak wavelength located at 292nm with an existing of oxide metal (FeO) peak located at 363 nm, While, in ethanol Fe NPs showed a single sharp peak wavelength located at 280 nm. In addition, the Pt NPs in DDW showed a small size scattering and a peak wavelength located at 234nm. However, in ethanol Pt NPs exhibited a single sharp peak located at 224nm. The preparation of Pt/Fe in ethanol showed an average size diameter of 1.36 nm in which it could be prevented the aggregation in solution especially with very small nanoparticle.

Acknowledgment
The authors would like to acknowledge the assistance offered by NAMRU in Faculty of Engineering University of Kufa /IRAQ.

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