Fabrication and Characterization of the Metallic Nanoparticles using Pulsed Laser Ablation Technique

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Abstract

Laser ablation occurs when high fluence laser radiation interacts with materials. We have used this technique to produce nano colloids of metal oxides from the targeted metal slabs of Fe, Al, and Cu immersed in distilled water. A high-energy Nd:YAg laser having energy 300mW/pulse at wavelength 532nm is used for bombardment purposes. The UV-vis absorption spectrum of the prepared colloids is used to determine the bandgap energies using Tauc formalism for further analysis. The environmental parameters of the experiment are also studied to obtain an efficient combination of the production.

Introduction

Synthesis of metallic nanoparticles has been an widely studied area of research recently due to its enormous range of potential applications in diverse Sectors i.e. Industrial , Biological [1,2]. Among various methods of preparing nanoparticle Pulsed Laser Ablation is a good approach due to its simplicity and independence of controlling the environment easily [3].

Objective

1.Preparation of nano-colloids of magnetic metals
   1. Ferromagnetic: Iron (Fe)
   2. Diamagnetic: Copper (Cu)
   3. Paramagnetic: Aluminium (Al)

2.Optical characterization of the prepared nano-colloids with UV-Visible spectroscopy
3.Bandgap measurements for suitable applications

Experimental setup and method

In this method, a small slug of target material was immersed in 30 ml of distilled water . The laser was then focused at the metal surface with a 7cm biconvex lens. The ablation process were performed for 1 and 2 hour for all three metals.

Prepared Fe, Al and Cu-NPs colloids under different ablation times were characterized by UV-vis spectroscopy in the range 190-1100 nm. Fig.[1] shows the Schematic Diagram of the PLA technique .

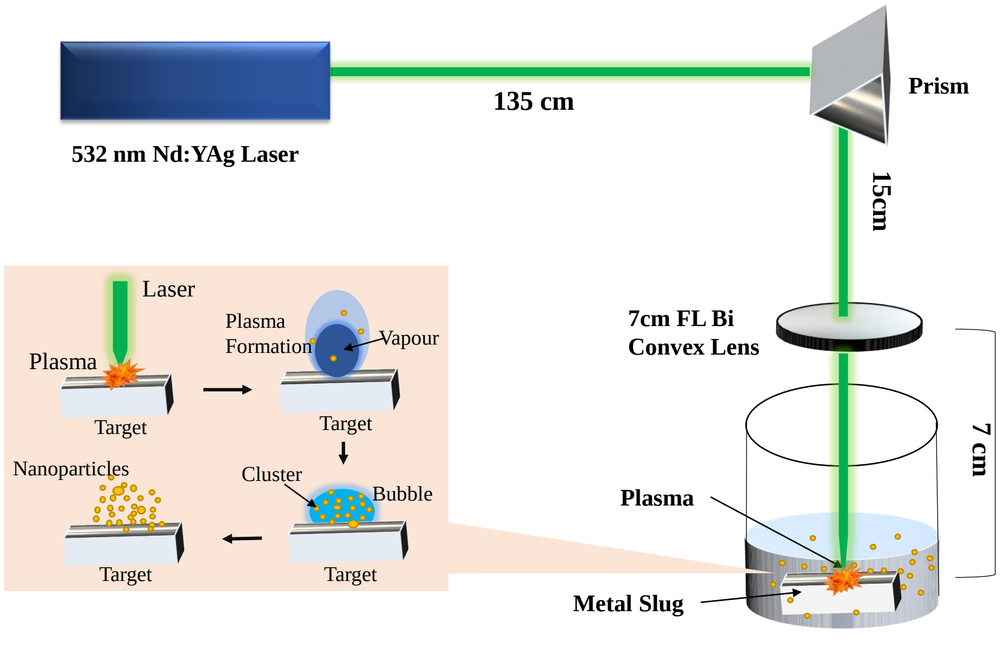

Fig. 1 . Laser ablation and nanoparticle formation process

Results

The UV-vis spectra were obtained for all samples of Ferromagnetic, Diamagnetic and Paramagnetic materials in distilled water. The Fe produces higher absorption compared to the Cu and Al. Cu produces absorption peak at 213nm whereas Al and Fe produces peak at 191nm and 201nm respectively.

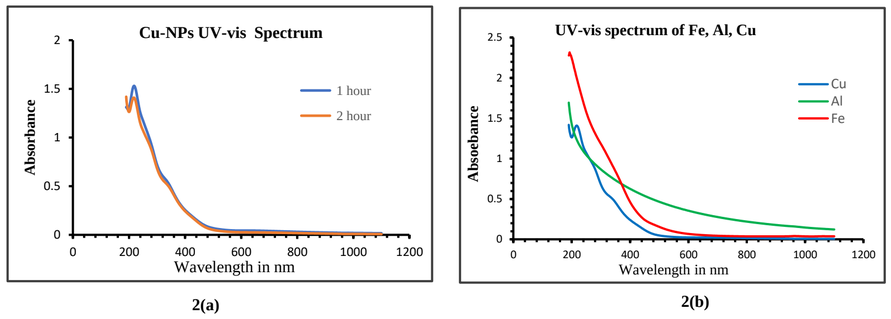

Figure 2: Absorption spectra of (a) Cu-NPs at different ablation time. (b) Fe, Cu , and Al NPs for 1 hour ablation time.

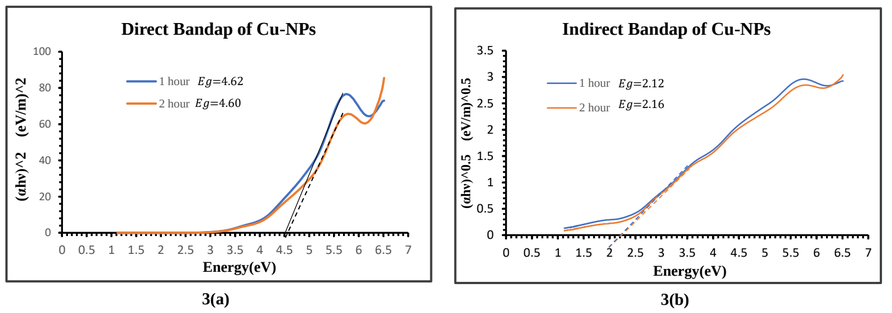

Fig. 3 . Tauc Plot of Cu-NPs for direct 3(a)and indirect 3(b) bandgap at different ablation time.

From UV spectrum, Tauc's relation yields the direct and indirect bandgap. Extrapolating the linear region of the curve corresponds to the value of bandgap. It shows bandgap remains same for any ablation time.

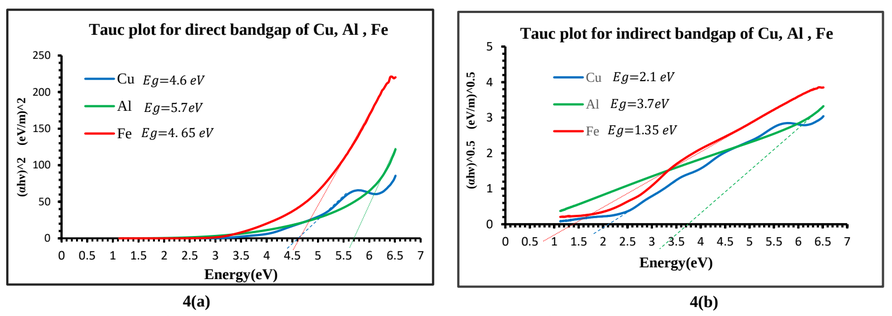

Fig. 4. Tauc plot for (a) direct bandgap (b) Indirect bandgap of synthesized Cu, Al, Fe-NPs .

Both direct and indirect bandgap of Aluminium is higher than Iron and Copper.

Discussions

Fig 2a. and 3a show that the absorbance and the bandgap does not alter with the ablation time. From the table we can see that our obtained bandgap of all magnetic metals are large in values; paramagnetic Al-NPs show greater bandgap value then diamagnetic Cu NPs and Ferromagnetic Fe NPs .
.We can also see our experimental data resembles some other work.

Table1. Obtained bandgap values in comparison with other study

	Direct Bandgap eV		Indirect Bandgap eV		Direct Bandgap according to other study	Indirect Bandgap according to other study
	1 hour	2 Hour	1 Hour	2 Hour		
Aluminium	**5.78**	**5.73**	**3.68**	**3.70**	**5.99 eV** [Song, T., Yang, M., Chai, J. *et al*].	**3.0 eV** [*Advances in Condensed Matter Physics*, vol. 2018, Article ID 7598978]
Iron	**4.75**	**4.70**	**1.35**	**1.39**	**2.1 eV** [Deotale, A. J., & Nandedkar, R. V. (2016]	**1.38 - 2.09 eV** [Deotale, A. J., & Nandedkar, R. V. (2016]
Copper	**4.62**	**4.60**	**2.12**	**2.16**	**3.85 eV** [Dhineshbabu, N. R., Rajendran, V., Nithyavathy, N., & Vetumperumal, R. 2016]	**2.4 eV** [Sayantan Das and T. L. Alford Journal of Applied Physics 113, 244905 (2013)]

Conclusions

Three types of magnetic metallic nanoparticles in liquid were successfully synthesized by laser ablation Method . The time of ablation does not effect the bandgap and absorption peak. Aluminium has higher bandgap value than iron and copper.

Reference

[1] Khanna, P. K., et al. "Synthesis and characterization of copper nanoparticles." *Materials Letters* 61.25 (2007): 4711-4714.
[2] Huber, Dale L. "Synthesis, properties, and applications of iron nanoparticles." *Small* 1.5 (2005): 482-501.
[3] G.W. Yang, Prog. Mater. Sci. 52 (2007) 648–698.