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Al/Al_2O_3 Nanoparticles Prepared by Pulsed Laser Ablation in Liquid

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Abstract: This research aims to study the optical properties of Al_2O_3 nanoparticles using pulsed laser beams. Pulsed laser ablation in liquid is cheap. We considered the optical properties of Al/Al_2O_3 nanoparticles obtained by pulsed laser ablation in liquid. An Nd:YAG RG190 laser with a wavelength of 1064 nm and focus energy of 950 mJ was used. The recurrence was 5 Hz, and the number of pulses was 300. The experiment was conducted at 25°C. A high-purity metallic plate was submerged in distilled water for the experiment. We found that the transmittance rises to 95%, which leads to a reduction in the absorbance and energy band gap. It can be concluded that pulsed laser ablation in liquid produces Al/Al_2O_3 nanoparticles with good optical properties.

Keywords: pulsed laser ablation, colloidal nanoparticles, surface plasmon resonance, Fourier transform infrared spectroscopy, field-emission scanning electron microscopy.

液体中脉冲激光烧蚀制备铝/氧化铝纳米颗粒

摘要：本研究旨在使用脉冲激光束研究氧化铝纳米颗粒的光学特性。液体中的脉冲激光烧蚀很便宜。我们考虑了在液体中通过脉冲激光烧蚀获得的铝/氧化铝纳米颗粒的光学特性。使用波长为1064纳米且聚焦能量为950兆焦耳的钕：YAG RG190激光器。重复频率为5赫兹，脉冲数为300。实验在25℃下进行。将高纯金属板浸入蒸馏水中进行实验。我们发现透射率上升到95%，这导致吸光度和能带隙减小。可以得出结论，液体中的脉冲激光烧蚀产生具有良好光学性能的铝/氧化铝纳米颗粒。

关键词：脉冲激光烧蚀、胶体纳米粒子、表面等离子体共振、傅里叶变换红外光谱、场发射扫描电子显微镜。

1. Introduction

Alumina (Al_2O_3) is commonly used to obtain metal oxide nanoparticles (NPs) for a few centuries now [1]. NPs can be modified by using coating techniques. Various coating materials have already been researched, but the preeminent common [2] for Al_2O_3. Al_2O_3 NPs are manufactured by solid–liquid blended casting combined with ultrasonic treatment [3]. The ultrasonic vibrations during the solidification were beneficial to refine the grain structure and to upgrade the final structure and properties of the Al_2O_3 NPs [4, 5]. Aluminum is one of first inexhaustible components discovered in soil and is widely utilized in numerous products due to its unique properties.

2. Experimental Details

A high-purity metallic plate (98.88%) had a smooth surface and was first washed multiple times in an ultrasonic bath containing distilled water; then, it was rinsed with water 15 min before the start of the experiment. Colloidal NPs were obtained by using pulsed laser ablation in liquid (PLAL) using an Nd:YAG RG190 laser. The focus energy was 950 mJ, laser wavelength was 1064 nm, and number of pulses applied was 300, as shown in Fig. 1. The high-purity metallic (Al) plate was placed on the bottom of an open quartz vessel containing 3 ml of ultrapure distilled water; the space between the plate and laser was 12 cm.

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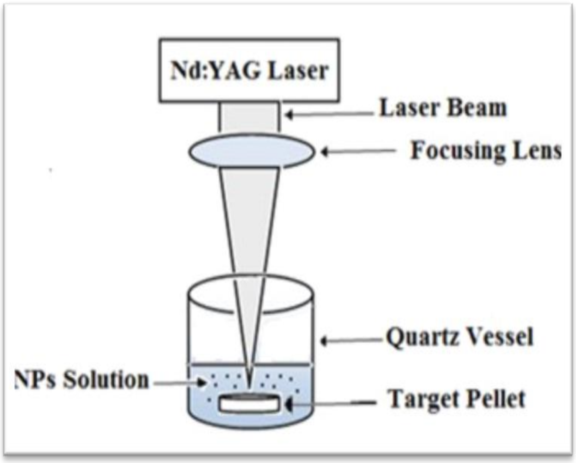

Fig. 1 Laser ablation system

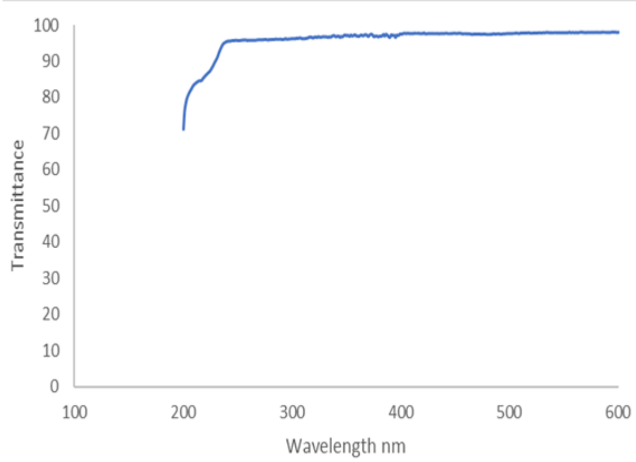

Fig. 3 Transmittance optical spectra of Al2O3Nps at 950 mJ

3. Results and Discussion

3.1. Optical Absorbance

An overview of the fundamental absorption bands of the conductor materials based on their absorbance spectra, transmittance details, and estimation can provide us with the optical properties, such as the energy band gap and UV–Vis absorbance spectra at room temperature (25°C).

3.2. Absorbance

The natural absorption band moved toward the shorter wavelength region. Surface plasmon resonance (SPR) was observed at 950 mJ and 217 nm, as shown in Fig. 2.

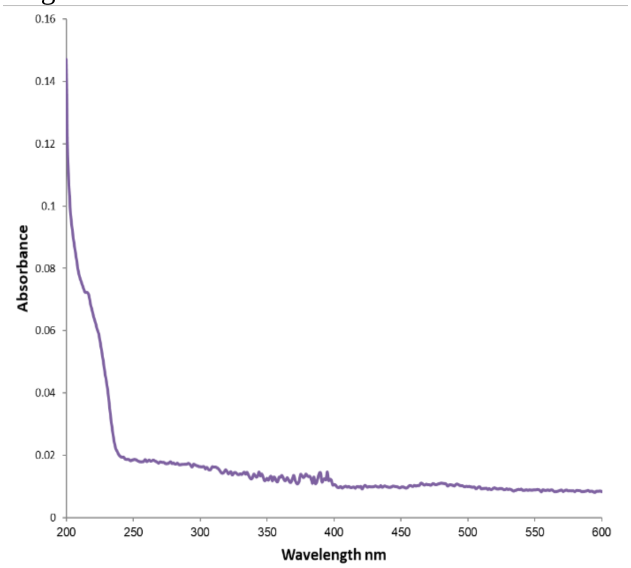

Fig. 2 Absorbance optical spectra of Al2O3Nps at 950 mJ

3.3. Transmittance

The transmittance band moved toward the longer wavelength region. SPR was observed at 950 mJ and 240 nm, as shown in Fig. 3.

3.4. Energy Band Gap

As shown in Fig. 4, the optical energy band gap for permitted coordinate move of the arranged colloidal NPs is evaluated using the Tauc plot, i.e., $(\alpha h\nu)^{1/2}$ versus hν. The optical band gap is significantly impacted by the chemical bonds of the components within the structure. Moreover, the band gap is influenced by the particle size.

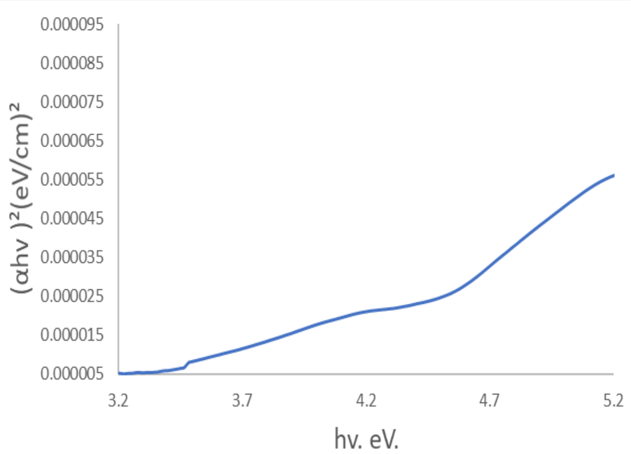

Fig. 4 The optical energy gap of Al2O3Nps at 950 mJ

Table 1 Optical properties of Al2O 3 Nps

Metal	Energy(mJ)	Wavelength(nm)	Absorbance %	transmittance%	Energy gap (eV)
Al2O3	950	1064	2	95	4.2

3.5. Field-Emission Scanning Electron Microscopy (FESEM)

The surface morphology of the obtained NPs is essential to analyze the shape of the obtained NPs and to study the NPs obtained in further detail. FESEM is employed for this. Fig. 5 shows the FESEM micrographs of the NPs, highlighting that the entire surface of the Si substrate is uniform. The NPs are completely developed, and their diameters are around 38.15–83.7 nm.

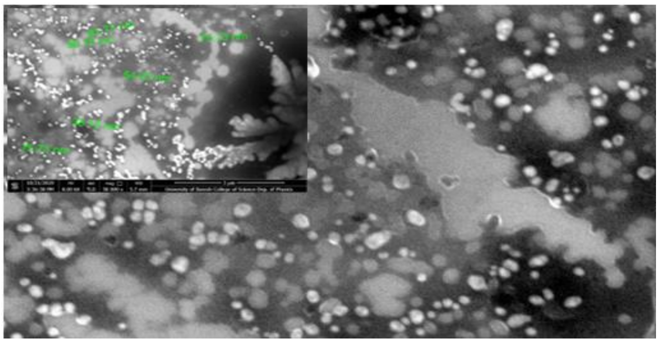

Fig. 5 FESEM of Al_2O_3 Nps at 950 mJ

3.6. Fourier Transform Infrared (FTIR) Spectroscopy

At wavelengths of 1450–4000 cm^{-1}, the FTIR spectra show the absorption results of only two atoms and not the absorption results of the entire molecule, as shown in Fig. 6. As the energy increases, the wavenumber also increases. Therefore, the bond energy increases with the transmittance, whereas the thickness decreases.

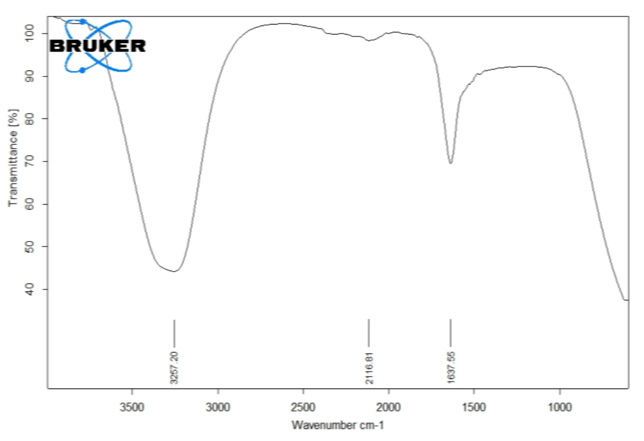

Fig. 6 FTIR of Al2O3 nanoparticle by pulsed laser ablation in 950 mJ

4. Conclusion

The laser removal strategy is quick, clean, and cheap, and has an amplified period of solidness. This could be a superior strategy to fabricate the internal structure of metal oxide and metal NPs. Manufacturing Al_2O_3 NPs by solid–liquid blended casting combined with a pulsed laser was beneficial to refine the grain structure and to upgrade the final structure and properties of the Al_2O_3 NPs. Finally, PLAL allows an amplified period of solidness and is cheap for conducting studies on Al/Al_2O_3 NPs, which have taken place for the first time in Iraq.

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