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Short Communication

Generation of Al Nanoparticles via Laser Ablation in Deionized Water with Structural and Morphological Study

H.R. Dehghanpour, H. Hashemi, H. Asefi

Physics Department, Tafresh University, Tafresh 3951879611, Iran

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In this work, Al nanoparticles were generated using Pulsed Nd : YAG laser (1064 nm) ablation in water confined plasma. Productions were characterized by transmission electron microscopy (TEM), X-ray diffraction (XRD) and selected area electron diffraction (SAED). Laser ablation of the Al target in deionized water leads to fabrication core-shell type structure due to partial oxidation in the water medium. The Nano sized core-shells are spherical in shape and have mean size ~ 16 nm. NPs were in the crystalline form as bulk Al. Obviously, the chemical composition of the Nano sized core-shells surface must be Al_2O_3 because of water medium.

Keywords: Al nanoparticles, Laser ablation, Deionized water.

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1. INTRODUCTION

According to utilize of laser ablation of a solid target in liquid medium, the expectation is an advantageous in the generation of nanoparticles (especially, metastable phases). The Laser ablation in liquid includes mechanisms in nucleation, phase transition and growth of the nanoparticles during laser ablation in liquid which those mechanisms are not well understood. Laser ablation of solid target in the liquid medium for nanoparticle fabricating was done for metals [1-5], alloy [6-8] and ceramics [9, 10]. Al nanoparticle generation using short laser pulses in liquid medium was reported [11-13].

Good heat releasing in the exothermal oxidation of Al nanoparticles makes them as a probable fuel candidate in the new energetic materials [14-16]. Moreover, Al nanoparticles were considered as hydrogen storage material with high capacity [17-19]. Optoelectronic applications are other capability of Al nanoparticles. For example they were utilized in surface enhanced Raman scattering [20]. In this work, we have fabricated Al nanoparticles in deionized water medium. Then, characterization and investigation of structural and morphological properties of the nanoparticles were done so that it completes the mentioned reports in [11-13].

2. EXPERIMENT

Q-switched Nd : YAG laser (VmTim, 1064 nm, 12 ns, 80 mJ/pulse, 5 Hz, spot size on the target ~ 700 μm) was used as coherent beam source. Laser beam was expanded by two lenses with 20 and 10 cm focal distances and focused at 2 mm distance from the target using a 15 cm focal distance concave mirror. Al target supplied by Fluka with 99.9 %, was cut in 2 cm × 2 cm square with 2 mm thickness. It was situated at the bottom of glass beaker filled with 10 ml distilled water so that 10 mm of water height was above the target at room temperature. The exposure time was performed on 10 min. After laser irradiation, drops of suspension were placed on a plate of glass using pipet. Then after water evaporation, we have collected remained materials.

TEM and SAED were used for morphology and structural characterization of the nanoparticles. It was done by Philips CM 30 equipment. XRD of the sample was performed with X'PertPro equipment.

3. RESULTS AND DISCUSSION

TEM measurement was done to determine sizes and shapes of the nanoparticles. TEM image of the fabricated nanoparticles shows nearly spherical shape for the nanoparticles. Fig. 1 depicts the nanoparticle size distribution. The mean size is ~ 16 nm.

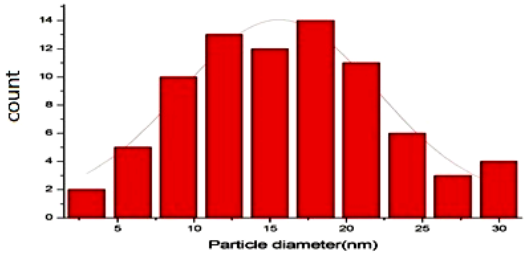

Fig. 1 – Size distribution of nanoparticles generated by Nd:YAG laser (1064 nm, 12 ns, 80 mJ/pulse, 5 Hz, spot size on the target ~ 700 μm, 10 min exposure time)

For calculating the lattice spacing corresponds to each crystallographic surface we have used below equation:

$$Rd = \lambda h$$

Where d, λ, h and R are the lattice spacing, wavelength of accelerating voltage, camera length and ring radius respectively. The selected area electron diffraction (SAED) patterns were utilized to measuring the crystallographic surface of Al. Table 1 shows calculated lattice spacing based on SAED and exact value ones as well as surface reflection related each spacing. It denotes the crystalline structure of the bulk Al would be unchanged after nanoparticle generation by laser irra-

diation on the bulk target at the liquid media. Recognition of Al crystallographic surfaces in the nanoparticles was detected by XRD pattern of the nanoparticles too. After TEM micrograph imaging, the powder of the nanoparticles was characterized by XRD. Measuring the width of the peaks and using well known Scherrer equation

$$L = \frac{k\lambda}{\beta \cos\theta_B}$$

the sizes of the crystallites were measurable. Where L is the size of the crystallite, λ is the wavelength of the incident beam, β is full width of half maximum (in radians),

Table 1 – Characterization of the nanoparticles using electron diffraction rings

Ring number	Experimental spacing (d) (nm)	Exact spacing (d) (nm)	Reflection
1	0.269	0.234	<111>
2	0.100	0.100	<400>
3	0.077	0.076	<333>
4	0.058	0.058	<444>

θ_B is the Bragg angle which the peak is occurred and K is a constant between 0.87 and 1 (commonly for spherical particle it takes equal to 0.94). With λ equal to 0.154 nm and measuring β and the peak's Bragg angle equal to 38° the mean size of the crystallites was calculated ~ 12 nm. In the powder crystallography, characterized crystallographic surface, and the measured sizes represent a mean value for the entire sample. The mean size of the nanoparticles obtained by TEM could be compared with mean size of crystallites obtained by XRD. As it is expectable, those mean sizes are compareable.

4. CONCLUSIONS

Laser ablation of the Al target in deionized water leads to fabrication core-shell type Al nanoparticles due to partial oxidation in the water medium. The nanoparticles are spherical in shape and have mean size ~ 16 nm. The crystallographic structure of Al nanoparticles is similar to the bulk one. Produced Al nanoparticles are highly desirable properties for advanced energetic applications.

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