Characterization of Pulsed Laser Ablation Technique in Liquid for the Production of Aluminum Nanoparticles

D. C. Choi[1] and H. S. Kim[2*]

[1] Department of Mechanical Engineering, Graduate School of Seoul National University of Science and Technology, Seoul, South Korea
[2] Department of Mechanical and Automotive Engineering, Seoul National University of Science and Technology, Seoul, South Korea

[*]Corresponding author: hongseok@seoultech.ac.kr

1. Introduction

Metallic nanoparticles are very popular research topics because they exhibit different physical or chemical properties when compared to bulk metals. Particularly, in the combustion and reaction process of aluminum, nanoparticles have a larger negative enthalpy than bulk aluminum, so research is being conducted to use aluminum as explosives and propellants [1]. However, the reactivity of aluminum nanoparticle is so good that there is a problem that the particle surface is rapidly oxidized during the synthesis. Therefore, there is a need for new techniques to slow the surface oxidation while ensuring excellent combustion efficiency of aluminum nanoparticles.

In this study, aluminum nanoparticles were synthesized by pulsed laser ablation using several solvents. This process is much more efficient, simple, and environmentally-friendly compared to traditional chemical and physical processes for nanoparticle. After the pulsed laser synthesis, the nanoparticles showed different surface composition and properties depending on the solvent characteristics and laser parameters. The surface oxidation of the aluminum nanoparticles could be also delayed by controlling the structure and composition of aluminum nanoparticles. The size and shape of aluminum nanoparticles after synthesis were observed using scanning electron microscope (SEM), and the composition of nanoparticles were evaluated by using energy dispersive spectroscopy (EDS).

2. Experimental set-up

There are various chemical and physical processes for synthesizing aluminum nanoparticles. Among them, pulsed laser ablation in liquid is a very efficient process in synthesizing pure metal nanoparticles. In addition, this process is very safe and environment-friendly since it does not require any stabilizer or surfactant in synthesizing nanoparticles [2].

The laser used in this study was an Nd:YAG pulsed laser with a wavelength of 1064 nm and a pulse width of 10 ns. Target materials was aluminum. The solvents were water and acetone

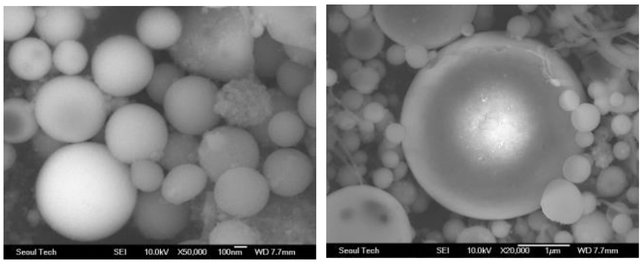

Fig.1 SEM images of Al nanoparticles synthesized in water environment with different magnifications

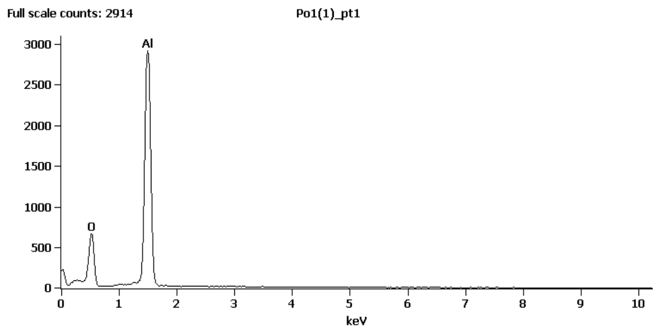

Fig.2 EDS analysis of aluminum nanoparticles synthesized in water environment

Pulsed laser ablation in liquid was performed to produce aluminum nanoparticles by irradiating aluminum for 10 minutes at a repetition rate of 8 Hz with an energy of 1J.

3. Result and discussion

The SEM image of nanoparticle synthesized in water is shown in Fig. 1. Aluminum nanoparticles are predominantly spherical and the size was in the range from hundreds of nanometers to micrometers.

The composition of the aluminum nanoparticles synthesized in water was analyzed by EDS and the result is shown in Fig. 2. Aluminum and oxygen were found on the surface of the nanoparticles. It seems that aluminum reacts with oxygen during ablation or drying. Therefore, the degree of oxidation can be controlled by changing the solution characteristics. By simply changing the laser parameters such as energy, pulse width, and irradiation time, aluminum nanoparticles with various sizes and shape could be produced. It was also confirmed that the composition of the nanoparticles is strongly dependent on the liquid properties where the ablation process occurs.

Acknowledgment

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2017R1D1A1B03035818)

References

[1] A. Rai, K. Park, L. Zhou and M. R. Zachariah, Understanding the mechanism of alumininum nanoparticle oxidation, *Combustion Theory and Modelling,* 10 (5) (2006) 843-859.
[2] B. Arash and S. M. Rasoul, Investigation of different liquid media and ablation times on pulsed laser ablation synthesis of aluminum nanoparticles, *Applied Surface Science*, 256 (2010) 7559-7564