Influence of applying the additional continuous laser on photoluminescence properties of silicon nanoparticles produced by laser ablation in liquid

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ABSTRACT

Silicon-based nanoparticles were produced by irradiating a single crystal silicon target in de-ionized water with Nd:YAG laser at wavelengths of 1064 nm. The additional continuous laser was applied immediately prior and during the ablation. The noticeable shift of nanoparticle size distribution caused by using the additional continuous laser was reported. In the paper we focused our attention at the photoluminescence properties on nanoparticles produced by LAL when the additional continuous laser was employed.
Keywords: silicon nanoparticles; laser ablation in liquid; picosecond laser; continous laser; photoluminescence (PL)

1 INTRODUCTION

Silicon nanoparticle (Si-NPs) is attracting attention of authors in numerous fields of science and engineering. For instance, interest in design and synthesis of silicon-based nanostructured materials for bioapplications has been rapidly increasing [1]. The photoluminescence (PL) properties of Si-NPs make them a candidate for bioimaging applications [2,3]. The one of the most promising and the simplest method for the producing of Si-NPs is the laser ablation of solid target in liquid (LAL).

In our previous work, we studied the effect of the (TEA) CO_2 laser pulse energies and repetition rate of applied pulse laser on the LAL process and interpreted them through thermal effects, such as temperature of the target [4]. In experiments that followed, the pulsed Nd:YAG laser was employed, and the focus of the work was the analyzing of the role of the applying the additional continuous (CW) laser on the LAL process [5,6]. In the work presented here, focused our attention at the role of applying the additional CW laser on the PL properties on NPs produced by LAL. The use of picosecond pulse duration in our experiment provides that the nonthermal photon-based ablation could be neglected [7].

2 EXPERIMENTAL METHODS

The Nd:YAG laser at wavelengths of 1064 nm (pulse duration 150 ps, energy 7mJ/pulse, repetition rate 10 Hz) was employed for 15 minutes. The additional green CW laser (532 nm, 200mW) was applied during the LAL process and for 15 minutes immediately prior to the application of the pulse laser. Single crystalline silicon plates (10.00 mm x 10.00 mm x 0.69 mm in size) were placed in a container filled with 5ml of de-ionized water. Both laser spots, continuous and pulsed, were placed at a fixed position in the centre of the silicon substrate. The water layer thickness was kept to about 3mm during the experiments and the silicon target was fixed at the position during laser irradiation.

The solution obtained by the LAL was dropped onto the silicon substrates and allowed to dry under atmospheric pressure at room temperature. The dried substrates were inspected using a JEOL 840A instrument equipped with an INCA Penta FETx3 EDX microanalyzer (SEM). For EDX analysis the aluminum substrate was used. All SEM/EDX images were recorded within the 24 hours after the laser irradiation of the targets.

The photoluminescence spectra of produced silicon NPs in de-ionized water were recorded for excitation at 270 nm and 300 nm.

3 RESULTS AND DISCUSSION

Figures 1a,b show the size distribution of NPs prepared by LAL (a) with and (b) without applying the additional CW laser. The size distribution of produced particles obtained by counting approximately 1000 particles in SEM image. It could be noticed that the application of the CW laser changes the NPs size distribution, shifting the distribution maximum to smaller values. We considered only particles in the 50nm–400nm size range to achieve a size distribution due to the fact that larger ones were uncommon. All particles taken into consideration have a spherical or a nearly spherical shape.

Namely, we showed here that the introduction of the additional CW laser prior and during LAL experiment increased the amount of oxygen in the NPs. On the other hand, such application of the CW laser affects the PL properties of the produced NPs.

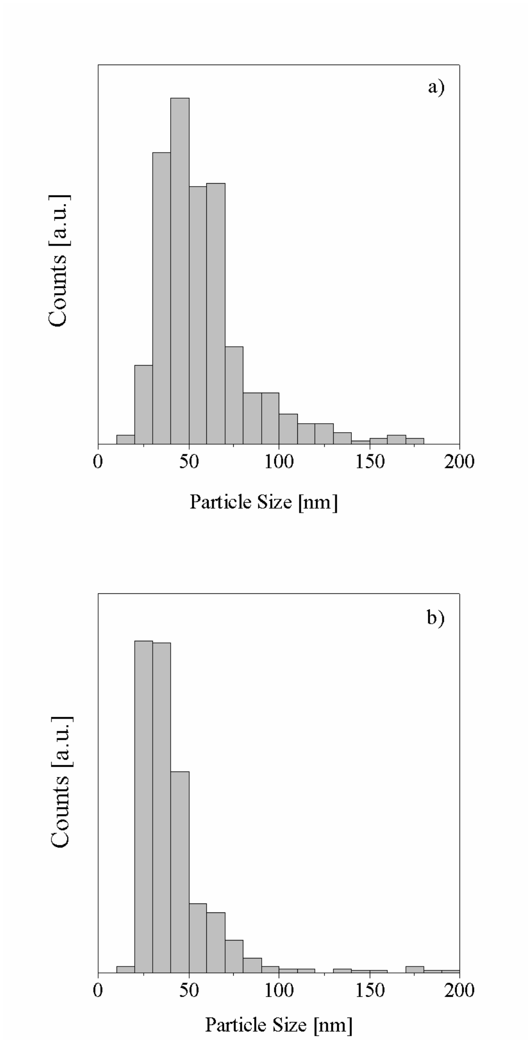

Figure 1. Size distributions of silicon nanoparticles prepared by the picosecond laser ablation in de-ionized water (a) without and (b) with applying the additional continuous laser.

The presence of some amount of oxygen in the produced NPs was confirmed by EDX measurements, i. e. the chemical composition of the produced NPs will be silicon oxide. The amount of oxygen in the NPs of approximately the same size produced by LAL with and without applying the additional CW laser was analyzed. The results showed that the introduction of the additional CW laser increased the amount of oxygen in the NPs.
The presence of the oxygen in the silicon based NP is important for biomedical application.

The photoluminescence spectra of produced silicon NPs in de-ionized water were recorded for excitation at 270 nm and 300 nm. From Figure 2 one could notice that the applying of the CW laser during LAL induce the change of shape and intensity of the PL spectra.
The increase in the PL intensity with the oxygen content of NPs was reported in the literature [8]. In a way it corresponds with our results presented in this paper.

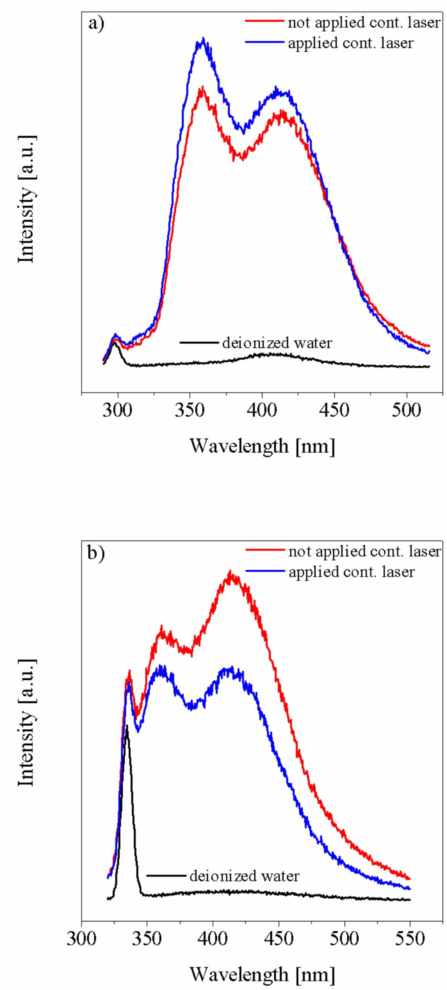

Figure 2. Photoluminescence spectra of silicon nanoparticles for excitation at (a) 270 nm and (b) 300 nm; Si NPs were produced by laser ablation in de-ionized water without and with applying the additional continuous laser

4 CONCLUSION

In this paper, we studied the production of silicon-based nanoparticles by irradiating the single crystal silicon target in de-ionized water with Nd:YAG laser at wavelengths of 1064 nm and pulse power of 7 mJ/pulse. The additional continual laser was applied during and immediately prior the ablation process. The work demonstrates that such application of the CW laser change the size distribution, oxygen content and PL properties of the produced nanoparticles. This may open a possibility for tailoring the properties of silicon and silicon-based nanoparticles by introduction of the continual laser during LAL experiment.

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