

## Production of silver nanoparticles by continuous wave laser in water

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### Abstract

Silver nanoparticles have attracted much attention as a subject of investigation due to their well known properties, such as good conductivity [1], antibacterial and catalytic effects [2-4], etc. They are used in many different areas, medicine [5-6], industrial applications [7], and scientific investigation [8], etc. The size as well as the shape is very important for certain applications. There are different techniques for producing Ag nanoparticles, chemical, electrochemical, sonochemical, etc. These methods often lead to impurities together with nanoparticles or colloidal solutions. Laser ablation of solids in liquids (LASL) enables obtaining nanoparticles with no need of chemical precursors. In almost all publications reporting synthesis of nanoparticles by LASL a pulsed laser is used, especially nanosecond and femtosecond lasers. Nevertheless nanoparticles can be obtained in liquid media using long pulse lasers and continuous wave (CW) lasers. In previous works we have already reported the formation of nanoparticles by LASL using CW lasers [9,10]. In this work silver nanoparticles are obtained in water using CW laser. The obtained particles are analysed and the nanoparticles formation mechanism is discussed.

Targets plates of Ag were cleaned and sonicated to be attached to a bottom of a glass vessel and filled with water up to 1 mm over the upper surface of the Ag plate. The laser source system used was a monomode Ytterbium doped fiber laser (YDFL). This laser works in CW mode delivering a maximum average power of 200 W. Its high beam quality allowed setting the irradiance range between  $2 \times 10^5$  and  $10^6$  W/cm<sup>2</sup>. The laser beam was coupled to an optical fiber of 50  $\mu$ m core diameter and focused on the upper surface of the target. The laser beam was kept in relative movement with respect to the metallic plate at a scanning speed of 5 mm/s. After each experiment, the obtained colloidal suspensions were dropped on carbon coated copper microgrids substrates for examination of particle morphology and microstructure, while as prepared colloidal solutions were used for UV-vis absorption tests.

Taking into account that the used laser works in continuous regime, the interaction between the laser beam and the silver target is governed by thermal effect. Several parameters depending on the laser radiation and the target nature are involved. When a laser beam strikes a silver target submerged in liquid, delivering irradiance of around  $10^6$  W/cm<sup>2</sup>, a thin layer of metal is heated up above its melting point leading to a combination and boiling which give place to nanoparticle formation. According to the collected material, the obtained particles exhibit rounded shape with certain tendency to agglomeration, as can be seen from figure 1. This confirms that the main formation mechanism is melting and rapid solidification in the surrounding water. Several EDS microanalysis performed on individual particles confirmed that the obtained particles are metallic Ag. The HRTEM images of obtained nanoparticles revealed that they are crystalline, as can be seen from figure 2 which shows clearly visible lattice fringes and their corresponding Fast Fourier Transform (FFT). The calculated interplanar distances from the FFT for particle obtained in water are compared with those of Ag in table 1.

Table 1. Measured interplanar distances from the FFT of figure 2 compared to those of Ag.

Measured d- (nm)	Ag, $d_{hkl}$ (nm)
0.2353	0.1359
0.2118	0.2044

The use of the CW laser with at moderate irradiance contributes to control the size distribution of the obtained nanoparticles, since the CW mode doesn't produce high peaks power which can provoke deep holes. Furthermore, the laser beam was kept in movement relative to the target in order to reduce the thickness of the melted layer. The reduction of the interaction time by increasing the scanning speed can lead to a reduction of the extracted layer from the metal plate and the formation of smaller particles. In conclusion, we have obtained colloidal nanoparticles of Ag in de-ionized water a CW laser to ablate metallic Ag target. The size distribution can be controlled by the scanning speed with mean diameter ranging from 5 to 80 nm. The obtained nanoparticles exhibit rounded shape.

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## Figures

