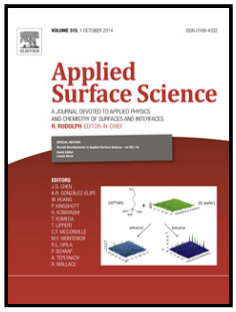

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Laser-induced agglomeration of gold nanoparticles dispersed in a liquid

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Abstract

Dynamics of gold nanoparticles (NPs) ensemble in dense aqueous solution under exposure to picosecond laser radiation is studied both experimentally and theoretically. Properties of NPs are examined by means of transmission electron microscopy, optical spectroscopy, and size-measuring disk centrifuge. Theoretical investigation of NPs ensemble behavior is based on the analytical model taking into account collisions and agglomeration of particles. It is shown that in case of dense NPs colloidal solutions (above 10^{14} particles per ml) the process of laser fragmentation typical for nanosecond laser exposure turns into laser-induced agglomeration which leads to formation of the particles with larger sizes. It is shown that there is a critical concentration of NPs: at higher concentrations agglomeration rate increases tremendously. The results of mathematical simulation are in compliance with experimental data.

Introduction

Pulsed laser interactions of nanoparticle (NP) colloidal solutions have been widely studied both experimentally and theoretically for the past decades. It was shown that this process leads to fragmentation of NPs dispersed in liquid in case of laser fluence high enough [1], [2]. The fragmentation process is size and shape sensitive. Its efficacy depends on the longitudinal plasmon resonance (and corresponding aspect ratio [3]) of NPs and on the wavelength of incidental laser radiation [4]. Fragmentation of sub-micrometer particles proceeds via detachment of small fragments [5]. The particles with size above 1 μm are supposed to split into equal parts [6].

The reverse process, leading to an increase of the NP size under exposure to nanosecond laser radiation, was described in [7]. In their work, authors generated so-called "nanonetwork" structure consisting of gold nanowires. The proposed mechanism of its formation included the fragmentation of initial NPs in the aqueous solution stabilized by Sodium dodecyl-sulfate and following coagulation of the small particles (with size less than 2 nm) into nanowires. In [8] laser induced Au agglomerates formation in pure water saturated with Oxygen was observed. The mechanism of agglomeration was ascribed to the combination reaction of cationic fragments generated by the laser-ablation of Au NPs with intact Au NPs with an original negative surface charge to produce large neutral species susceptible to further aggregation.

Dynamics of metal NPs colloidal solutions under pulsed laser irradiation was investigated both experimentally and theoretically in [5]. The concentration of particles in solution was relatively low (~10^{12}-10^{13} particles/cm^3), pulse duration was of 20 ns. Numerical model built for this case included the kinetic equation of size distribution function and the equation describing