Deposition of metal nanoparticles using multi-picosecond laser pulses

Nanostructures of different materials are of great interest in nonlinear optics due to their special properties arising due to their physical dimensions being much smaller than the light wavelength. Pulsed laser deposition is used as the standard technique for nanoparticle deposition. It is well accepted that when a solid target is ablated by the laser radiation, the ablating material is in the form of atoms, ions (and electrons), and clusters. These atoms and clusters tend to aggregate during the laser pulse or soon afterwards, leading to the formation of larger clusters. In addition, heterogeneous decomposition, liquid phase ejection and fragmentation, homogeneous nucleation and decomposition, and photomechanical ejection are among the processes known to lead to nanoparticles production. Many of these processes would be governed by the intensity and pulse duration of the laser beam used for ablation. The lasers used for pulsed laser deposition for making solid clusters are normally of few fs to few ps duration. At Laser Plasma Laboratory, pulsed nanoparticle deposition of various metals has been carried out using sub-nanosecond duration pulses (300ps) at different focussing conditions.

The experiments were carried out using the uncompressed pulses (300 ps duration, 30 mJ energy) from a chirped-pulse amplification based 10TW Ti:sapphire laser system. The samples were placed inside a vacuum chamber and the laser pulses were focussed on the targets at two regimes of focussing. In the first case (referred to as tight focussing), the intensity of laser radiation was in the range of 2×10^{12} Wcm^{-2}, and in the second case (referred to as weak focussing), the intensity was considerably lower (4×10^{10} Wcm^{-2}). Silver, indium, stainless steel, and chromium were used as targets.

The structure of the deposited films was analyzed using different techniques. The absorption spectra of the deposited films were analyzed using a spectrograph. The analysis of the sizes of deposited nanoparticles was carried out using the total reflection x-ray fluorescence (TXRF). The structural properties of the deposited films were analyzed using a scanning electron microscope, a transmission electron microscope), and an atomic force microscope. The first three facilities are at SUMRD, RRCAT and the last one at LSED, RRCAT. Float glass, silicon wafer, and various metal strips (silver, copper, and aluminum) were used as the substrates for nanoparticle deposition for use with the above facilities.

The absorption spectra of the materials deposited on float glass were used to determine the presence or absence of nanoparticles from the appearance of strong absorption bands associated with surface plasmon resonance (SPR). In all metals, in the case of tight focusing, the peaks of SPR were centered in the range of 440 to 490 nm, indicating presence of nanoparticles. In the case of the deposition of silver film at the weak focussing conditions, no absorption peaks were observed in this region, indicating the absence of nanoparticles.

The structure of the deposited films was analyzed using TXRF, which identified the presence of nanoparticle deposition in tight focussing condition of the laser. In the case of weak focussing, it showed a thin film-like deposition of metal, without any presence of nanoparticles. X-ray fluorescence measurements and SEM studies gave the average size of the silver nanoparticles to be 60 nm. The TEM measurements also confirmed the presence of silver nanoparticles in these deposited films. The atomic force microscopy also gave the average size of silver nanoparticles to be 65 nm. The details of this study can be found in *Ref.1*

Indium nanoparticles are quite important as they have a number of practical applications like potential nano-lubricants, as possible candidate for single electron transistors, as tags for detection of DNA hybridization, as printing blocks in nano-xerography, and as starting material for convenient synthesis of InP. Hence, a detailed study of the structural, optical and nonlinear optical properties the indium nanoparticles prepared by the laser ablation of bulk indium target in the vacuum at the tight focusing conditions and those prepared by laser ablation in liquids, was carried out. Details of this study are given in *Ref.2.*

References :

1) Pulsed laser deposition of metal films and nanoparticles in vacuum using subnanosecond laser pulses
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2) Structural, optical, and nonlinear optical properties of indium nanoparticles prepared by laser ablation
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