Performance of plasma produced by pulsed laser deposition (PLD) system for thin film nanoparticles and GeS quantum dot

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In the present work we performing the PLD system based on XeCl Eximer Laser 308 nm, energy per pulse 0-13 mJ, pulse duration 6 ns and reputation rate 0-200 Hz, Nd-Yag Laser 1J, 1064 nm, high power Ps laser and fs laser with high vacuum system 10^{-7} Torr. According to the optimization deposition parameters, we obtained layers indicates the reproducibility in the system. Moreover we obtained same layer of GeS, ZnS, PbSnSe, PbS, LiCu and Al2O3, the last material was used as capping layer in order to obtain clear quantum dot layer of GeS. Moreover the diagnostic techniques during Laser ablation and after PLD processing as LIBS, heating, interferometry, XRD, EDX and Atomic Force Microscope (AFM) were done. In the present work the system for PLD based on XeCl Eximer Laser aimed the fabricated GeS layer. It was examined by atomic force microscope (AFM) and indicates the quantum dots structure of the layer with the domain of 6-8 nm height and less than 100 nm. Recent we have developed PLD system using high power IR fs, ps and ns Laser based in high vacuum, high gas pressure and under water. Also photo acoustic effect associated PLD of Mo are investigated.

1. Introduction: This paper describes the deposition setup used for the preparation via PLD [1]. PLD systems were used in the preparation of nanostructured thin film layer to be used as optical detector [2]. Also fabrication of silver nanoparticles by laser ablation in liquid solution achieved by [3]. change material characteristics we need to change its chemical composition or we need to mix materials in different modes or conditions, remained no more isolated. A radically different approach to understand materials emerged which converged to the finding that material characteristics could now also be changed by changing the size keeping the chemical composition [4, 5]. However the methodology of varying the material characteristics with size was feasible only in a specific size regime, called the quantum confinement regime and the variation in a specific material characteristic invariably affected the other characteristics of the same material as well [6]. Possibility to tailor the material properties by varying the size alone provided the mankind a revolutionary wisdom of materials science, which
Enabled the emergence of a new branch of technology called Nano technology. Fastest growing branches of science and technology, Nanostructured Semiconductor lasers, Solar Energy, Nano-electronics and Devices [7, 8]. When the confining system of the comparable size. As a result the surface area dependent material properties start dominating or anomalous behaviours are observed
In the nanoscale regime.

One of the most significant aspects of any technology is to fabricate materials compatible to that technology. This aspect is rather demanding so for as the Nanotechnology is concerned. This is because fabricating material structures of nanometre size with comprehensive control is an intricate problem. However a host of methodologies have indeed been evolved to grow nanometre size structures of different materials under variety of conditions with varying degrees of controls on shapes, structural qualities and sizes. In fact Nanofabrication is a contemporary field of research and technology development. But in this work, to provide reasonably thorough and deep knowledge, we will confine ourselves to a narrow slice of this field, which deals with the nanofabrication of semiconductors using a very specific methodology of Pulsed Laser Deposition (PLD). In our last previous work [2] PLD system was used in the preparation of nano structured thin film layers to be used as optical detectors. Recent [9] we defined the effect on thermal annealing on structural and optical properties of organic semiconductor thin films to be used IR Laser detectors.

2. Experimental Work:

Any Physical vapour deposition process must have three essential components: a source material, a substrate and an energy supply to transport material from the source to the substrate during the deposition of a material structure. Pulsed laser deposition technique uses a high energy and short duration pulsed laser as an external power source to Vaporize the target material. Interaction is short but intense and includes ablation via a cascade of complex events. Although the understanding of Complex processes involved in the laser material interaction is still not comprehensive, the ablation process is effectively used to transport the material from the target to the substrate. The laser vaporized materials generally contain energetic neutrals, ions, and electrons etc., also known as plume, expand rapidly away from the target surface and condense on a heated substrate to grow thin films. Figure (1) shows the schematic of a typical PLD set up.

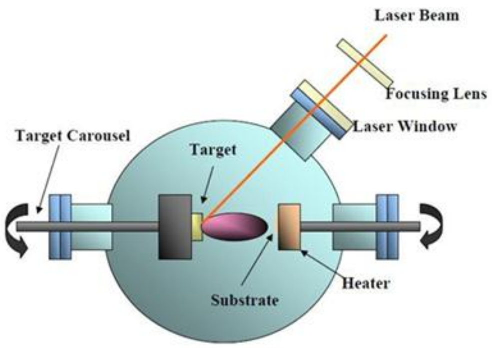

Figure (1): Schematic of pulsed laser deposition setup.

It contains a high vacuum deposition chamber made of compatible metal such as stainless steel. This chamber has a number of standard ports required for pumping, pressure and temperature gauges, gas inlets etc. PLD chamber essentially has a laser port sealed with a laser window. Recent much

Depending upon the wavelength of the laser beam the laser window of glass, Quartz or ZnSe is used to ensure maximum transmission of the laser beam. The Chamber is pumped down to a base vacuum of ~10^{-6} to 10^{-7} Torre using a suitable Turbo Molecular Pump with oil free backing pump. A pulsed laser system with desired wavelength is kept outside the chamber and is used to ablate the target material which is placed at a certain distance in front of the substrate. The laser beam is then focused on to the target surface using a suitable converging lens of either Quartz or Glass to achieve required energy density i.e. fluency for ablation. A Higher laser energy density can be obtained either by increasing laser energy or by reducing laser spot area. The substrate is loaded on to an appropriate electrical heater which can be heated to the growth temperature as high as 900 ^{o} C. The target is continuously rotated around the vertical direction to the target. The angle between laser beam and the beam focal plane is an important parameter. The angle should not be too small as the size. Location of spot are difficult to manage at grazing angles at the same time the laser beam at the larger angle of incidence could be hindered by the substrate heater. Laser incidence angles near 45 degree are preferred in most of the deposition schemes. In a conventional PLD arrangement the laser beam and thus produced plasma plume are horizontal, however vertical ablation scheme is preferred in some case where the target used is in a liquid form for example, in case of PLD of GaN which is in liquid phase at room temperature [10].

Further details of experimental work and methods of Measurments here are in our last work [2]. The laser used Xecl and the GeS thin film substrates are analysed using Atomic Forc Microscope as in the following.

3. Results and Discussions:

In this section we use the result given from the XRD measurements [2] to produce and a crystalline quantum dots film, first we use the Quartz as substrate and Germanium sulphide as material also the Al2O3 as capping material for the quantum dots. We use the dual target technique by fixing the two material in the centre of the target holder as shown in the previous chapter, the target holder in this case will move forward 160 degree then back 160 degree and repeat tell the number of the required laser pulses achieved then moved to the next material and doing the same procedure. We used a two target PLD to grow the GeS QDs embedded in Al2O3 matrix at temperature of 300 ^{o} C. Eximer Laser (308 nm, 6 ns, 50 Hz) with energy of 5mJ was used to ablate the Al2O3 and GeS targets mounted on a multi target holder. The deposition was carried out in pressure of about 10^{-6} Torre and the substrate to target distance was kept at about 3 cm. prior to the deposition of GeS QDs a base layer of Alumina was grown on the Quartz substrates. Six layer structures of Gees QDs and Alumina capping layer was grown by the alternate ablation of the respective targets. The capping layer of Alumina was grown for 2000 laser pulses in all the samples and 1000 pulses for each GeS layer. in different samples

Was chosen 500, 1000, 1500, 2000 and 2500 pulses to grow the QDs of five different sizes. At such short deposition times and at an intermediate
Laser energy about 5 mJ, the growth occurred preliminarily in its initial form of isolated islands. To study the initial growth of GeS on Quartz substrate we used Atomic Force Microscopy (AFM). Next Figure show the AFM micrographs of
The GeS QDs grown for 2000 pulses per layer. Well resolved atomic- terraces can be seen on the Quartz substrate. It can be seen that the initial growth of GeS on Quartz substrate achieve a desired size of the QDs before the onset of coalescence of the island and formation of continuous

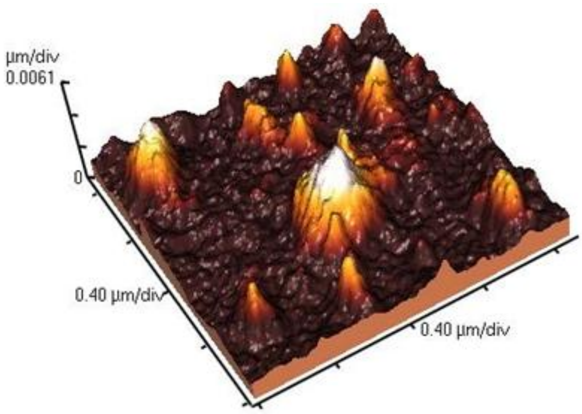

Figure (2) Three dimension AFM Layer thin film Image of GeS quantum dot.

Layer. Figure (2) shows three dimensions image getting by the AFM for GeS quantum dots caryated by our PLD technique, while Figure (3) shows the two dimensions image the same sample. It's clear that the dimension of the single quantum dot is in rang 6 – 8 nm scale as shown of figure (4). The optical emission spectroscopy of the ablated plasma demonstrated that the laser wavelength define the nature of the ablation process. UV Laser ablation is mostly a surface non thermal process that causes high photo fragmentation of the ablated species the spectra in [2] shows that going from 300 nm to 650 nm a broad background appear that the spectral emission intensity is very bright during the initial stage of plume expansion due to Bremsstrahlung emission (free-free transitions) from the hot plasma. This radiation appears in the visible part of the spectra in the form of a broad band continuum. The photoconduction results that shown in [2] are for two different samples GeS Q.D. Film that prepared under the same deposition conditions and on the same kind of quartz substrates.

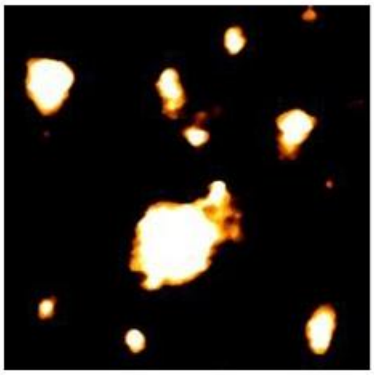

Figure (3) Two dimension AFM Image of GeS thin Film.

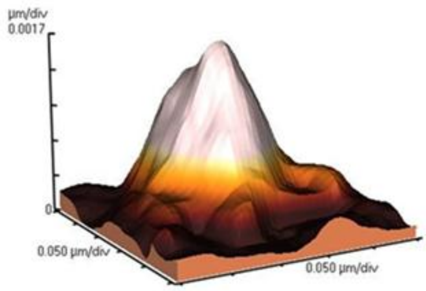

Figure (4): Three dimension of AFM of single GeS quantum dot image.

At different Incident laser diode powers at 808 nm wave length and different range of biasing voltage from 8 V to 46 V, we get acceptable liner photo voltage response. This indicate that the efficient performance of our optical detectors. Recent much development has been achieved in our system by using high 100 fs laser 800 nm in thin film technology, coating and deposition of nanoparticles. Also we are using infrared ns pulsed laser of PLD under water. For much understanding the mechanisms of the physical processes we have used photo acoustic diagnostics by recording the shock waves associated laser ablation in air and under water. This indicate that the efficient performance of our optical detectors. Recent much development has been achieved in our system by using high 100 fs laser 800 nm in thin film technology, and deposition of nanoparticles Fig. (6). Also we are using infrared ns pulsed laser of PLD under liquid [3]. For much understanding the mechanisms of the physical processes we have used photo acoustic diagnostics by recording the shock waves associated laser ablation in air and under water.

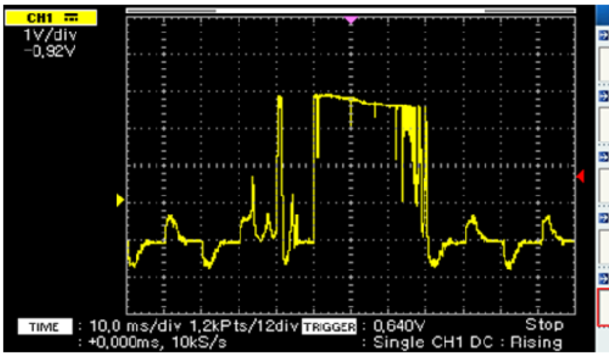

Figure (5) Acoustic wave signal associated 1064 nm, 300 mJ, 7ns Nd – Yag Laser interaction with LiCu target under water.

It was found that from photo acoustic spectroscopic the the 1st faster peak may be due to the electron and ion dynamics forces while the 2nd saturated peak is due to cluster nanoparticle motion due PLD under water as shown in Fig. (5). The intensity of shock waves are depending on the distance, target and laser power.

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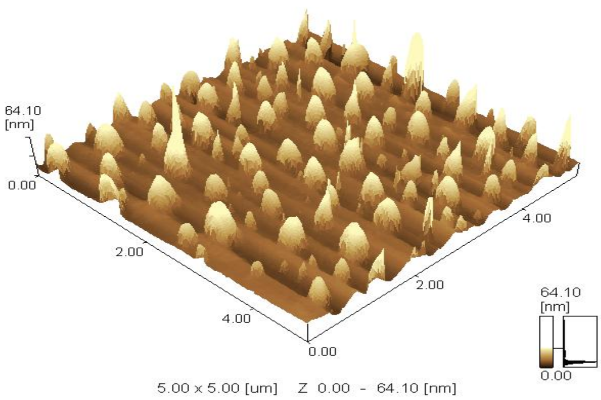

Figure (6) AFM image of LiCu thin film surface deposited by 800 mW femtoseconed laser in vacuum.

4. **Conclusion**: Al2O3 material aimed as capping layer to obtained clear quantum dot layer of Gees. The PLD system in vacuum, gas pressure and under liquids became very useful in preparation of nanostructure layers and increasing the efficient performance IR optical detectors, solar cells and nanotechnology. High power ultra-short IR fs laser shows much efficient PLD nanostructure as in the AFM image. Shock waves measurements associated PLD under water and high gas pressure will help us of understanding plasma physics processes due to photo acoustic effect in laser interaction with solids, ion gas phenomena and producing new materials with new physical characteristics.

5. References:

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