Effects of background gas in laser ablation of Al-doped ZnO

G. L. Ong[1], R. Kek[2], T. S. Ong[1], T. Y. Tou[1], C. H. Nee[1], S. S. Yap[3] and S. F. Lee[4]
[1]Faculty of Engineering, Multimedia University Malaysia
[2]Infineon Technologies (Kulim) Sdn. Bhd., Malaysia
[3]Department of Physics, Xiamen University Malaysia
[4]The Eduardo Torroja Institute for Construction Sciences (IETcc - CSIC), Spain
e-mail (speaker): seongshan.yap@xmu.edu.my

Laser-solid interactions provide a mechanism for materials processing for a variety of applications. The inherent interactions however, are complex as laser pulses interact with the solid, plasma, background gases while the created plasma expands and interact with the background gases. Consequently, materials are generated and deposited as a result of the interplay of both stages in a pulsed laser deposition process. Nucleation of nanostructures in laser produced plasma is, in particular of interest for nanomaterial synthesis and growth; for example, to obtained functional semiconducting quantum dots and wires for device applications [1].

Here, we investigate and discuss the process that govern the growth of Al-doped ZnO nanostructures by a pulsed 355 nm laser. Al-doped ZnO target is ablated in background gases O_2, N_2 and in inert gas of He and Ar [2]. The presence of background gases impeded plasma expansion, thereby resulted in a plasma plume with abundance of active species. Reaction and collision occur readily depending on the properties of the background gases. We compared the ions velocity and species for ns laser ablation while substrates are placed at on and off-axis positions for deposition at room temperature.

The ions velocity is highest for ablation in He, followed by N_2 and O_2/Ar; inversely scales with the atomic mass. Amorphous Al-doped ZnO films are obtained in O_2 while ZnO crystalline nanostructures are obtained in the presence of N_2, He and Ar. The deposition in Ar yield the most abundant nanostructures with a variety of characteristics.

Figure 1a shows the emission intensity from the Zn species for ablation in Ar, that increases with the gas pressure. At higher Ar pressure, larger nanostructures are obtained as shown in Figure 1b. Both Zn and ZnO crystallites are detected where the size also increases with the pressure of Ar. In addition, nanowires are also detected on the surface of the nanostructure by using TEM.

Ar with higher atomic mass and lower thermal conductivity results in high collisions and thermal confinement in the plasma that leads to such nanostructure formation as compared to those obtained in other gases. The results show that nucleation of nanostructures occurs in the plasma and the nanostructures formed can further catalyze the growth [3]. The results also suggest that controlled growth of desired nanostructure can possibly be remedied through monitoring and controlling the plasma properties.

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References

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(a) (b)

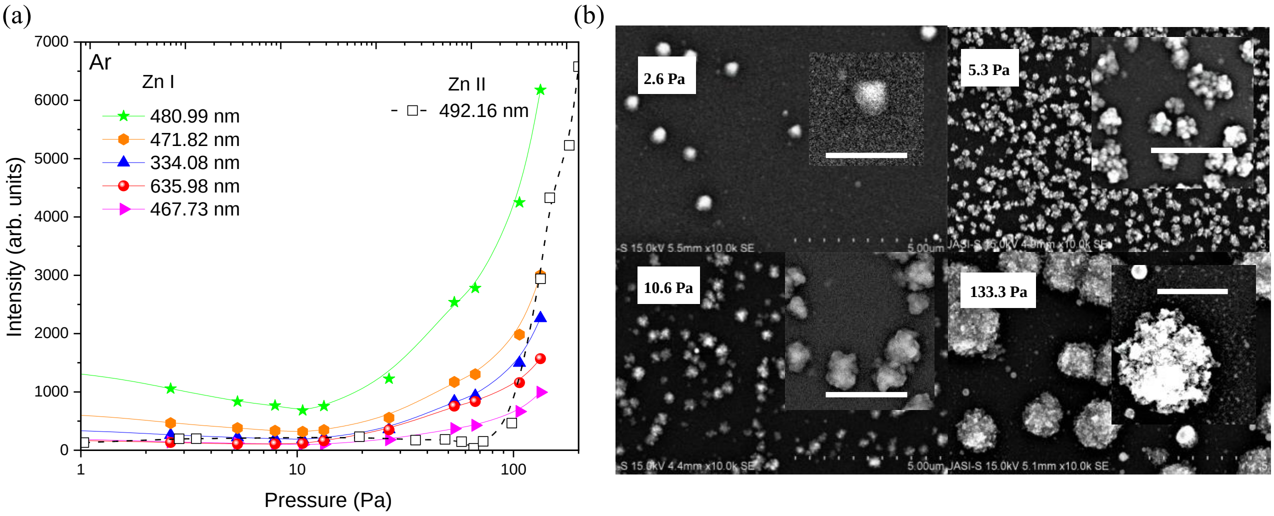

Figure 1 (a) Intensity of Zn species from the optical emission at different pressure for ablation in Ar. (b) The deposited nanostructures increases in size as Ar pressure increases. The scale bar of the inset is 1 µm.