What's new in laser based nanofabrication for the fast uptake in industrial application

Taj Muhammad Khan [1, 2*], Morten-Christian Meyer [3]

[1] School of Physics, Trinity College Dublin, the University of Dublin, Dublin, Ireland

[2] Materials division, National institute of lasers and optronics (NILOP), Nilore, Islamabad, Pakistan,

[3] Department of Mechanical & Manufacturing Engineering, Trinity College Dublin, the University of Dublin, Dublin, Ireland

*Corresponding Author Email: khanta@ tcd.ie; Contact: +92 (51) 2208051, +92 (333) 1930993

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Abstract: Laser based efficient new nanofabrication methods with technical feasibility for the fast uptake in industrial application are of significant global demand. A recent simplest approach in this way is the standard pulsed laser deposition (PLD), used since 1960s after the development of high power lasers. Over all, PLD is a fit method towards the preparation of a variety of nanomaterials only for research purpose. Nevertheless, the method is relatively slow and was not that much used in industrial scale application. A recent new-fangled development in this direction is the atmospheric-PLD (APLD), where ablation of the target by a laser pulse occurs at atmospheric gas pressure and the ablated material is delivered to the substrate using a flowing medium such as gas or atmospheric plasma. With this method, a variety of nanomaterials such as plasmonic metal NP film could be produced for practical applications in surface-enhanced Raman spectroscopy (SRES), catalysis and solar cell.

Keywords: atmospheric-PLD; nanofabrication; SERS, flowing gas; flowing plasma

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1. Introduction

In this mini letter a recently emerged idea of nanofabrication the so-called atmospheric-pulsed laser deposition (APLD) is presented. APLD is a modified version of classical pulsed laser deposition (PLD) with technical feasibility for industrial scale application [1]. What happens in APLD and what makes it different from a conventional PLD? PLD is a well understood deposition method of thin film and has been investigated intensively. In this method the interaction of a high power pulsed laser of sufficient fluence leads to the removal of small amount of material (ng per pulse) from surface of the target. The material removed expands away from the surface in form of a luminescence plasma plume called the plasma ablation plume [1-5]. In vacuum or low pressure gas, the ablation plume is highly forward directed and freely expands normal to the target surface up to several cm (typically 5 - 8 cm) and recondenses on a substrate to build up a NP film or a continuous film, depends upon the quantity of the ablated material. This scenario is entirely different for ablation at atmospheric pressure and hence modifies the entire process of APLD. At these conditions, the ambient gas strongly limits the plasma plume expansion and restricts it in the close vicinity of the ablation zone above the target surface and thus forms a NP aerosol by collisional condensation [6]. The NP aerosol of the ablated material can be entrained in gas flow or flowing atmospheric plasma, to carry it away from the ablation zone to the target for deposition to make NP film. Because of the different flow dynamics, the formation of NP film is different in a gas flow than the flowing plasma. One thing is quite obvious that with plasma the deposition rate is significantly higher compared to a gas flow. The increased the deposition rate with the plasma is expected due to a well-known phenomenon called electro-hydrodynamic gas pumping or the electric wind where ions in a weekly ionized plasma impart a bulk momentum to the gas. Plasma also has pronounced effect on the

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formation of NP film and alters the film morphology and spatial distribution of NPs. We observed that with Ar plasma from a dielectric barrier discharge (DBD) source, agglomerated or sparsely distributed NPs were formed. In another observation, the formation of NPs in the form of a ring with diameter of the ring up to several micrometres were obtained. In APLD, the formation of a NP film with plasma strongly to depend on length of the plasma jet, developed in flowing Ar or He and hence on the interaction of the plasma jet with the surface of the substrate. The formation mechanism of the plasma jet is different for Ar and He and hence leads to different morphologies and particulate structures. Recently, we successfully applied APLD method in the lab and plasmonic metal NP films of silver and gold were produced for practical application in SERS[7, 8]. The method was also previously applied to hard coating and NP films[9, 10]. The method of APLD further offers to produce plasmonic hard coating of TiN and thermal-barrier coatings (TBCs) of yttrium- stabilized zirconia (YSZ), widely used in aerospace-related mechanical and electrochemical components for improved performance in the extreme conditions of gas turbulence and heat corrosion.

2. Conclusion

A newly emerged versatile method of APLD was introduced and briefly discussed. This method brings the process of standard PLD one step closer to make nanomaterials for practical application. A flowing gas or flowing atmospheric is effective to transport the ablated material to the substrate to build up a NP film. The efficacy of gas flow approach is different than a flowing plasma due to their different flow dynamics. Plasma assist APLD seems more effective with a significant effect on the formation of NP film. There are several open questions for debate to answer for improving this method. The uptake of the newly introduced APLD method for industrial application is quite fast and it seems that in near future the method will prevail to combat the co-existing chemical and physical methods in several aspects.

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