FUPRE Journal of Scientific and Industrial Research
Vol.3, (1), 2019
ISSN: 2579-184 (Print) ISSN: 2578-1129 (Online)

Laser Surface Micro/Nano Texturing Using Imaging Projection by Particle Lens Array

Otanocha, B. Omonigho[1*], Oreko U. Benjamin[1]
[1]Department of Mechanical Engineering, College of Technology, Federal University of Petroleum Resources, P.M.B 1221, Effurun, Delta State, Nigeria.
Corresponding Author: * (otanocha.omonigho@fupre.edu.ng).

Abstract

The viability of projecting a macroscopic image into millions of nano-scale structures is a step forward in nanofabrication and development. A scheme at reproducing arrays of small repeated structures by the projection of a macroscopic image (square mask) into millions of nano structures through the application of an ordered array of particle lens is presented. With this technique, well arranged patterns with aggregate features size smaller than 300 nm can be achieved. Feature size reduction of approximately 10^4 in one step is attainable. From the result obtained, the object distance affects the laser fluence with regards to the sample type and the particle (SiO_2) size could effectively determines the patterned shape dimensions.

Keywords: **Laser Surface, Nano texturing, nanofabrication, particle lens array,**

1. Introduction

The growing demand for miniature electro-mechanical and optical devices is a driving force for nano/micro-scale fabrication and research (Santhanam *et al.* 2003; Li *et al.* 2009; Guo *et al.* 2007). It is normally difficult to achieve nano-scale patterned attributes with far-field optics, due to diffraction limits of the laser beam wavelength. Near field optics (NFO) has the advantage of high quality imaging below the diffraction limits (Li *et al.* 2009; Chong *et al.* 2010; O'connell *et al.* 2010). Figure 1 is a representation of the processes involved with laser fabrication with an array of particle lens. An Excimer Laser with an output wavelength of 248 nm (KrF lasing medium); average power ranging between 80 W and 100 W; operating mode: pulsed (at pulse width of 10 to 20 ns); with repetition rate up to 200 Hz; Pulse energy between 100mJ and 500mJ; and raw beam size of 25 X 15 mm^2.

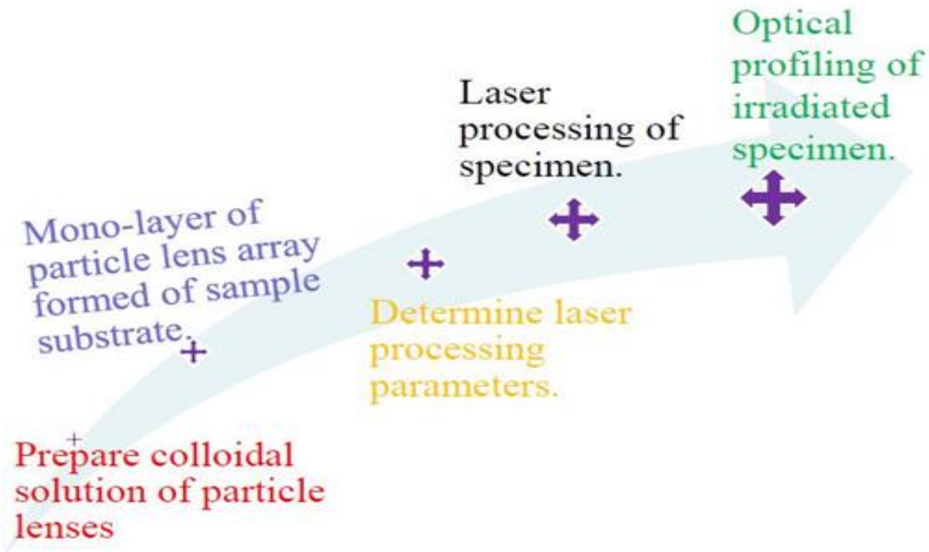

Figure 1: Schematic representation of Laser Processing using Particle Lens Array (PLA)

2. Experimental Set-Up

Figure 2 is a process flow representation of the experimental set up. The red arrows show the path of laser beam for the fabrication processes. A patterned mask is installed along the laser beam path, as shown, pattern image projection purposes.

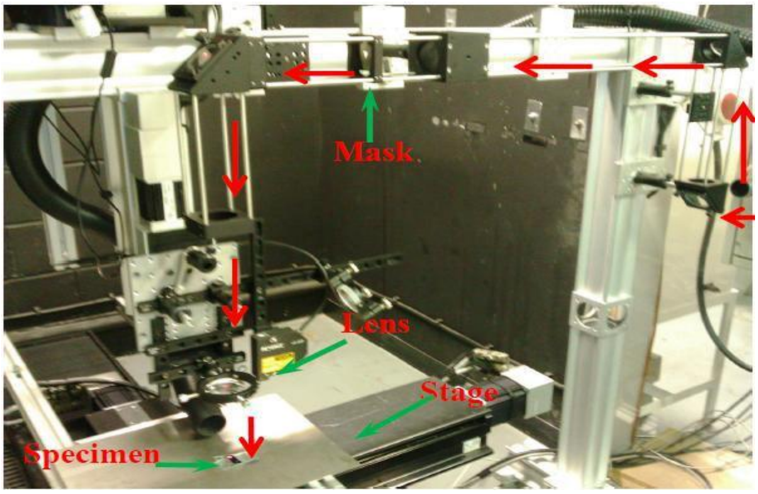

Figure 2: Excimer laser, with a mask and mirrors incorporated.

Figure 3 are images of assemblies of colloidal solution drops of 5μm SiO_2 micro-spheres, used to form monolayer of particle lens arrays on the substrate of the target material for laser irradiation (polycarbonate coated with 100 nm thick $GeSb_2Te_5$). The colloidal solution drops are allowed to dry up on the specimen substrate after 48 hours, to form monolayer of particle lens array as shown in figure 4.

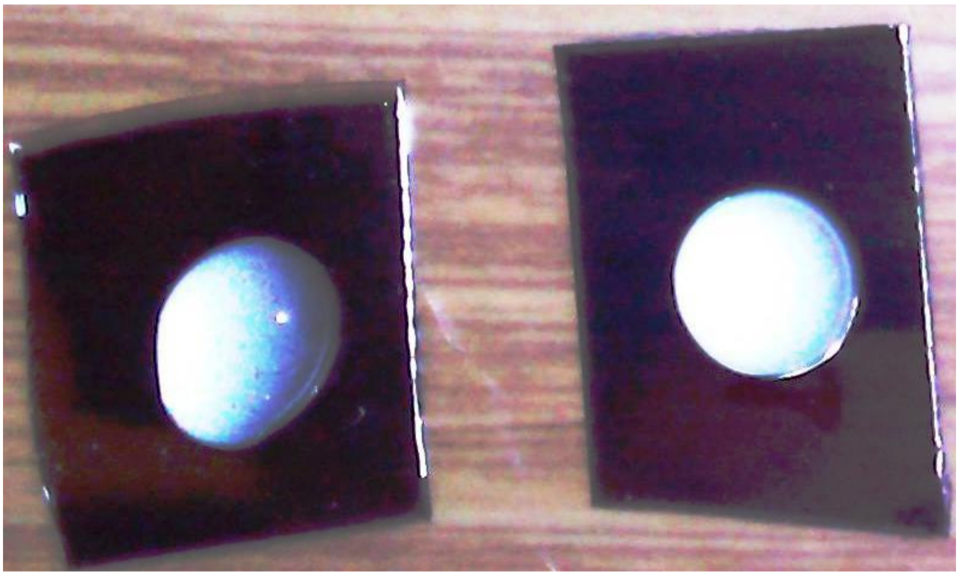

Figure 3: Sample (polycarbonate coated with 100nm thick $GeSb_2Te_5$) with colloidal solution drops of 5μm SiO_2 micro-spheres.

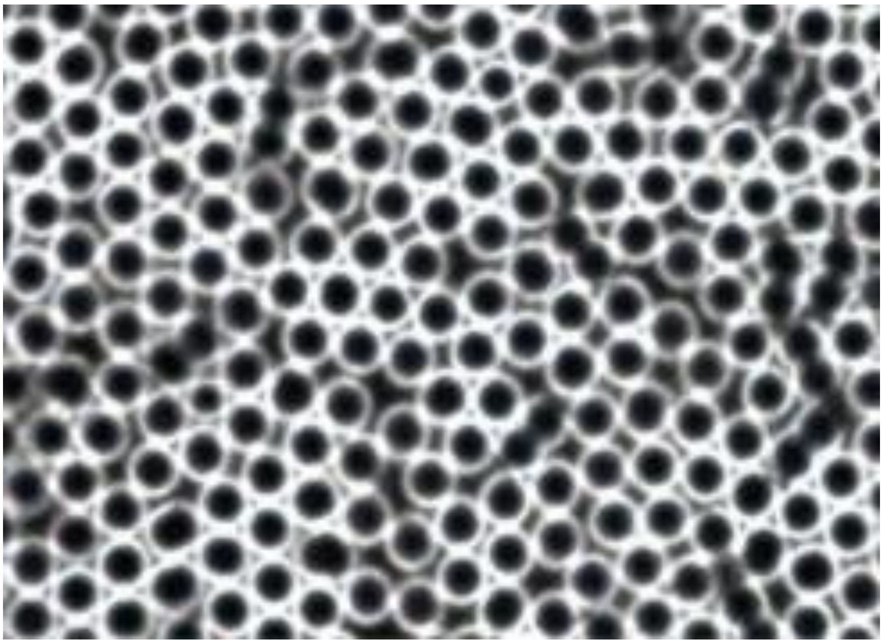

Figure 4: Mono-layer of particle lens array (5µm SiO_2 micro-spheres).

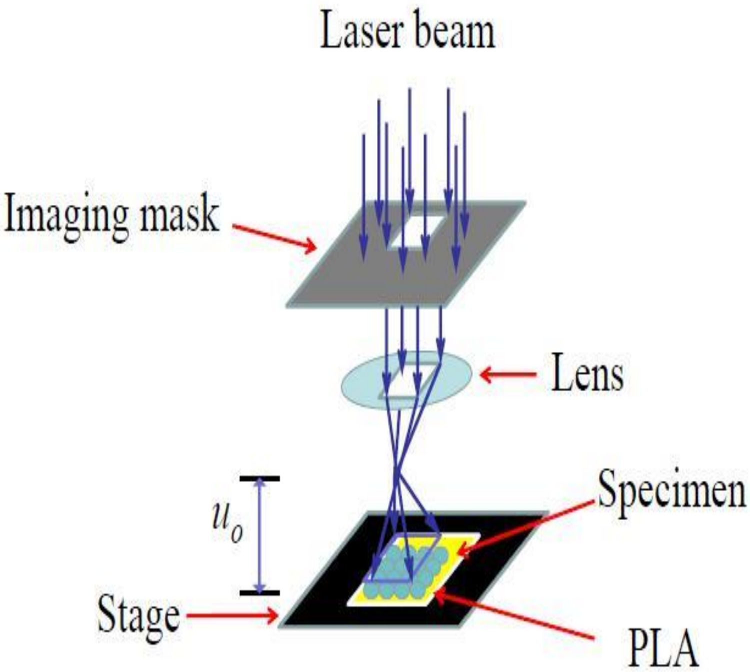

Figure 5: An illustration of PLA patterning with 'mask'.

The specimen substrate is Polycarbonate, coated with 100 nm thick $GeSb_2Te_5$ (GST). Figure 5 is a schematic representation of the experimental set up for the laser irradiation of GST using particle lens array (PLA). The object distance from the centre of lens, is represented by object distance, u_o. the configuration of lens imaging set-up is shown in figure 6.

In this experiment; u_o= 15 mm (115 mm – 100 mm) and $f = 4 \times 10^{-4}$mm (0.4 µm). The 0.5µm SiO_2 microsphere ensured nano-scale structures.

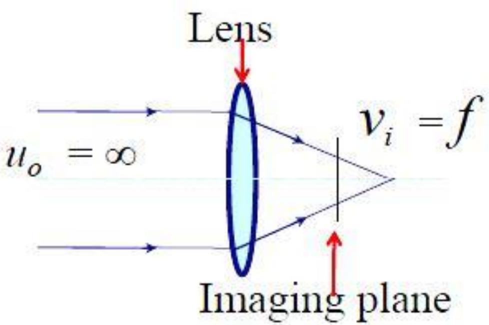

Figure 6: Arrangement for lens imaging set-up.

Where:

u_o. is object distance from the centre of lens,

v_i is imaging distance, and

f is focal

From Len formula, we have;

$$\frac{1}{f} = \frac{1}{u_o} + \frac{1}{v_i} \qquad (1)$$

And the imaging distance v_i could expressed as;

$$v_i = \frac{u_o}{u_o - f} \cdot f \qquad (2)$$

3. Results and discussion

Laser fluence of 185 mJ/cm^2 after masking, was used to irradiate the specimen substrate, with the monolayer of particle lens array (PLA) in place. From the result obtained, the patterned features were regular and dip circular holes, shown in Figures 7 and 8, respectively.

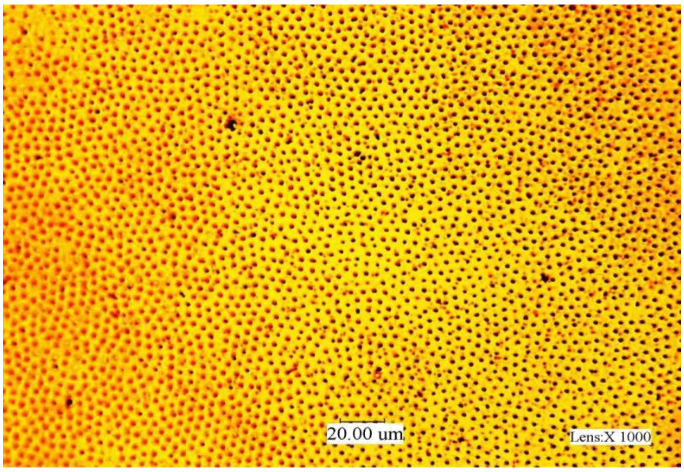

Figure 7: Optical microscopic image of patterned GST coated polycarbonate substrate using a triangular mask with PLA technique.

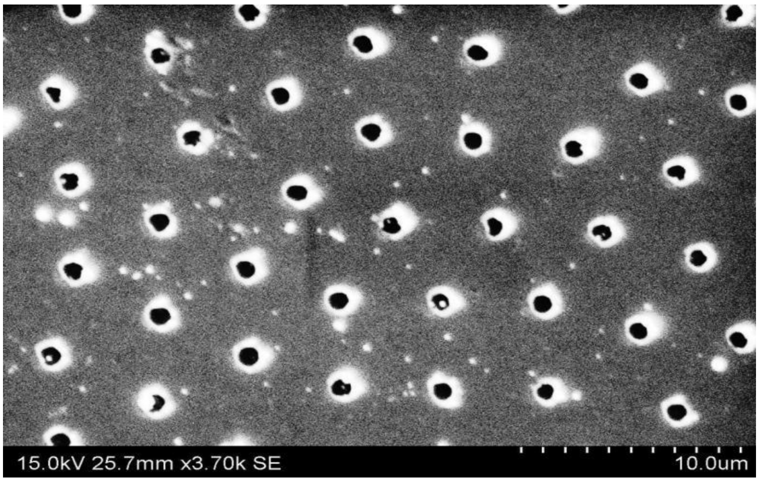

Figure 8: SEM image microscopic image of patterned GST coated polycarbonate substrate using a triangular mask with PLA technique.

Also, light through a particle is confined to a circular spot on the receptor substrate (Li *et al*, 2009; Chong *et al*, 2010; Betzig & Trautman 1992; Lu & Chen 2003). Fabricated patterns on GST were unaffected by the mask shapes due to poor imaging. Proper determination of *u*o (object distance) influence better image projection and laser processing fluence.

Conclusions

The following conclusions could be made from the research work:

i. Object distance (*uo*) affects the laser fluence with regards to the sample type.

ii. The particle (SiO_2) size effectively determines the patterned shape dimensions.

iii. This particle lens array (PLA) technique could be adapted to nano/micro-patterning of curved surfaces.

Acknowledgement

One of the authors acknowledges the doctoral research scholarship provided by the Federal Government of Nigeria (TETFUND) in conjunction with the Federal University of Petroleum Resources Effurun (FUPRE). The authors are grateful to Prof. Lin Li and the LASER PROCESSING RESEARCH CENTRE (LPRC) team at the School of Mechanical, Aerospace and Civil Engineering (MACE), The University of Manchester, for the facilities used for this research output.

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