

# Chapter 7

## Laser Sub-Micron Patterning of Rough Surfaces by Micro-Particle Lens Arrays

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### ABSTRACT

*Laser surface patterning by Contact Particles Lens Arrays (CPLA) has been widely utilized for patterning of smooth surfaces but there is no technique developed by which CPLA can be deposited on a rough surface. For deposition of CPLA, conventional techniques require the surface to be flat, smooth and hydrophilic. In this study, a new method for the deposition of CPLA on a rough surface is proposed and utilized for patterning. In this method, a hexagonal closed pack monolayer of  $\text{SiO}_2$  spheres was first formed by self-assembly on a flat glass surface. The formed monolayer of particles was picked up by a flexible sticky surface and then placed on the rough surface to be patterned. A Nd:YVO<sub>4</sub> laser was used to irradiate the substrate with the laser passing through the sticky plastic and the particles. Experimental investigations have been carried out to determine the properties of the patterns.*

### INTRODUCTION

Within the last two decades research in novel manufacturing techniques on sub-micron, nano and even atomic scales has been accelerated by the increasing demand for miniaturized devices. Ever

smaller devices can only be realized with modern precision manufacturing techniques which are also economical. With the reducing size of these devices surface patterning is also gaining more importance. Lasers have been extensively used for surface patterning at micron scale (Bäuerle, 2000; Hon et al., 2008; Pena et al., 2009). Laser is a tool which is widely utilized for manufacturing because

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of the advantages of being a non contact process, capable of generating complicated structures without the need of photomask and able to work in air, vacuum or water. These advantages have earned lasers a reputable position in the manufacturing industry. Moreover the laser can easily be focused down to a micrometer scale which makes it a tool of choice in the micro device fabrication.

Laser assisted Lithography is one of the commonly used industrial technique for submicron and nano production. However, lithography is also reaching its limit. Although smaller features can be generated by using  $F_2$  157 nm and Extreme Ultra Violet lithography (EUV) but high resolution comes with the drawback of high cost, low output and unstable light intensity. Also these lasers need to carry the process in vacuum or high purity dry nitrogen because of the high absorption of the laser in air. Moreover there is a need of special reflective mirrors, and need very high power to achieve intensities suitable for lithography (Bjorkholm et al., 1990; Ito et al., 2000; Chong et al., 2009). These limitations have thus restricted the use of EUV for industrial production. Lithography techniques and their limitation have summarized by Ito et al. (Ito et al., 2000). The direct use of laser in sub-micron patterning is limited because of the fact that light cannot be confined to a lateral dimension smaller than half its wavelength called the diffraction limit of light (Abbe, 1873). However, this limitation can be overcome by utilizing near-field enhancement. Laser processing in the near-field has been successfully utilized to generate features with sizes smaller than 100 nm (Chong et al., 2009). Several techniques for utilizing the advantages of near-field have been developed including Near-field Scanning Optical Microscope (NSOM) patterning (Betzig et al., 1992; Chong et al., 2009), Plasmonic Lithography (Srituravanich et al., 2004; Liu et al., 2005; Chong et al., 2009) and Laser in combination with Scanning Probe Microscopy (SPM) for tip patterning (Chimmalgi et al., 2003; Chong et

al., 2009; Miyashita et al., 2009), Microlens array (MLA) nanolithography.

In laser assisted NSOM method an optical fibre cone with a nano scaled output aperture diameter is used to transmit laser for surface processing in the near field region. The tip surface is coated with metal thin film for improved transmission of the fibre. The fibre tip can have output aperture diameter of about 50 nm. The process was utilized by Korte et al. (1999) to generate 200 nm wide and 100 nm deep grooves on a Cr thin film by using a frequency tripled Femtosecond laser ( $\lambda \sim 260$  nm) with an aperture size of 100 nm (Korte et al., 1999). The technique was used by Lieberman et al. to remove the manufacturing defects from a Cr thin film mask (Lieberman et al., 1999). Laser in combination with Scanning Probe Microscopy (SPM) is a modification of Scanning probe microscopy. In SPM a fine tip is scanned over the sample to be characterized and the morphology of the surface is recorded by the movement of the tip. In this method a laser is focused on a SPM tip. During laser irradiation the SPM tip acts as a source of near field enhancement. The high electric field in the near field region causes the material removal and generates nano features on the substrate surface. Grigoropoulos et al. use the technique with a femto-second laser to achieve spatial resolution down to 10 nm (Chimmalgi et al., 2003). The technique has the advantage/capability to fabricate complicated designs. Alphabets "DSI" abbreviation for Data Storage Institute were written by this technique in a space of 400 nm x 400 nm (Hong et al., 2003)

Micro Lens Array (MLA) patterning is a near field patterning technique which could be used to generate patterns over large area efficiently. The technique consists of micro lenses with same size and focal length fixed on a substrate. The lenses are arranged in a square or hexagonally packed structure. These micro lens arrays focus the laser into a series of parallel light spots. Each of the spots generates features on the substrate in the near field. The technique was used by Kato et al.

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