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Development and Characterization of Micromeshonvarious UV Laser ExposureConditionsUsing Scanning Microstereolithography

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***Abstract*—Microstereolithography is one of the additive manufacturing technique to fabricate micro components by photopolymerization of liquid monomer upon UV light exposure.In this work optimization of UVLaser (Ar^+ ion) exposure on the photocurable mixture of 1,6Hexane dioldiacrylate (HDDA) monomer andphotoinitiatorBenjoin ethyl ether(BEE) isachievedby using Scanning Microstereolithography(SμSL)system with computer controlled precision linear positioning X-Y-Z stages. Micromesheswere fabricated successfully for various laser power and laser scan rate.Characterizations of micromeshesare observed underLext 3D image viewingConfocal microscope and Scanning Electron microscope. Micromeshes were compared with parameters likeCure width, surface finish and dimensional integrity. Effects of laser exposure parameters on polymer Microstereolithography of micromesh were observed.An optimized UV Laser exposure parameters were fixed for the photopolymerization of 1,6HDDA.Based on the results, multilayeredMicromeshes are successfully fabricated with less thermal distortion. Micromeshes with high aspect ratio and good structural integrity broadens application for Microstereolithography.**

***Index Terms*— Scanning Microstereolithography, 1, 6 HDDA, Cure width, micro mesh, Rapid Prototyping.**

I. INTRODUCTION

The advancement of Rapid Prototyping techniques has significant improvement in development of computer aided micro manufacturing processes.There are many rapid prototyping techniques employed for fabricating polymer andceramic micro parts. Some of advanced processes selective laser sintering, 3Dprinting,fused deposition modelling, laminated object manufacturing and Microstereolithography[1].Among all these processesMicrostereolithography technology creates interest in both Rapid prototyping and microfabrication techniquesince it has the capacity to develop prototypes with high resolution and microparts with precise

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geometries.[2]
Microstereolithography was first introduced in 1993 by Takagi et al and Ikuta et al. to fabricate 3D microstructures for MEMS applications. For the first time in 1998 Zhang et al.designed advanced Scanning Microstereolithography to develop complex 3D geometries with high aspect ratio[3].Microstereolithography is a novel micro fabrication technique in which complex 3D micro structures are developed by photopolymerization of liquid resin upon UV laser exposure in a layer by layer fashion. Scanning Microstereolithography system works based on a vector by vector scanning of every layer of the object with a laser beam having a small spot size. In Scanning Microstereolithography3D microparts are fabricated in a layer by layer fashion according to the designed CAD solid models.
There are many parameters which influence on dimensional stability and surface integrityof polymer micro parts in Scanning Microstereolithography system, laser wavelength, laser power, laser scan rate, pitch of the laser beam, laser scanning pattern, precision of positioning stages,monomerused, thickness of the liquid monomer layer, photoinitiator and photoinitiator concentration. It is important that controlling the appropriate laser exposure and beam diameter is the key to achieve high definition microparts inMicrostereolithography[4]
Polymer micro grids find applications in biomedical and MEMS field such as Scaffolds Tissue engineering,[5] hernia replacement, acts as supporting structure to insert LEDs for health monitoring and drug delivery,Micromolds for MEMS.[6]

II. Scanning Microstereolithography System Configure:Uration

A scanning Microstereolithography system was setup in CMTI.Figure:.1 below shows the setup up developed and the main comoponents in the syste.UV laser Ar+ ion is used.

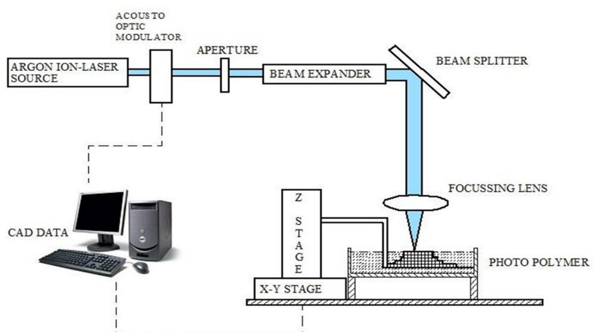


Figure1: Schematic representation of Scanning Microstereolithography system developed at CMTI

Scanning Microstereolithography system developed at CMTI consists Beam lok™ Argon ion laser beam source, beam delivery system, Computer controlled precision linear positioning stages, and a CAD design tool.BeamlokAr+ ion laser source used in this system operates wavelength in range 333.1-364 nm and maximum current 60A.Newport™ precision linear positioning stage with 0.1nm resolution in x-y-z stages enables precision scanning of laser beam over the photocurable resin. Beam delivery system consists of Acousto Optic modulator,Aperture,Beamexpander,MirrorsandFocusinglens.Acousto optic modulator with system driver consists crystal controlled oscillator used as shutter. Focussing optics and Beam expander are essential to obtain small laser spot size.A fixture assembly is attached to linear positioning stage to hold Si substrate rigidly and allows uniform layer thickness in the multi layered microstructure.CAD design tool provides 3D model design of microparts, slicing and NC program generation.

III. Fabrication Of Micromeshs

Experiments were designed (i) to achieve optimization of the laser exposure parameters on the polymer Microstereolithography. (ii) to investigate the polymer grids with dimensional stability and structural integrity.
The laser system is allowed to stabilize to achieve stable beam intensity The laser wavelength used in this work is 364 nm.Photocurable resin prepared for polymer Microstereolithography includes 1,6Hexanediol di

acrylate monomer and photoinitiatorBenjoinethyether(Sigma Aldrich).Photoinitiator concentration for the fabrication of micro grids was fixed to 1 wt%.

In this work laser power are varied about 0.05-0.120 mw.scan rate or laser exposure time 0.25-1.5 mm/sec.Single layered and multi layered polymer meshes of size 5mmx5mm were fabricated for 0.1 mw increment of power and 0.25 increments of scan rate.

Polymer micromeshs were fabricated on Silicon substrate after the UV laser exposure on photocurable resin with the scanning Microstereolithographysystem. The unpolymerized resins were removed by rinsing the Si wafer carefully with Acetone and DI water.

IV. Results and Discussions

Single layered micromeshs were successfully fabricated by Scanning Microstereolithographysystem.Developed polymer grids were characterized under Confocal microscope by investing dimensional stability and cure line width, pitch of micromeshs.Microstructures are observed under Scanning electron microscope.After fabrication and post cleaning, shrinkage in the micromeshs is found be less than 4%.

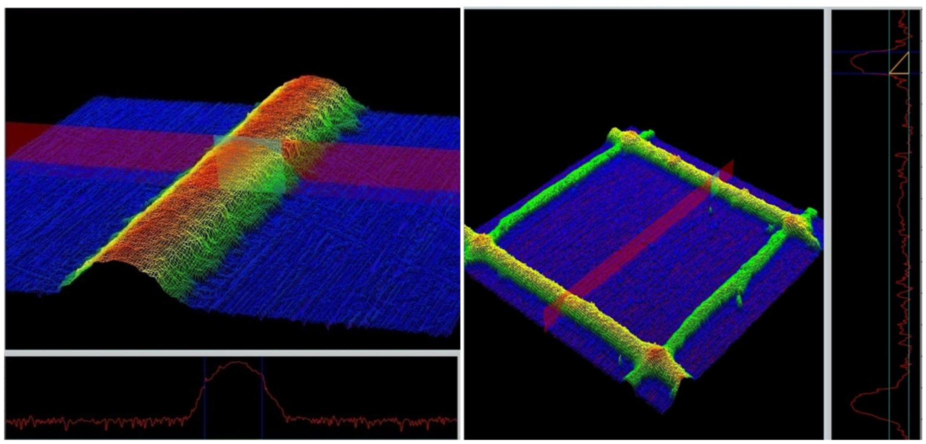
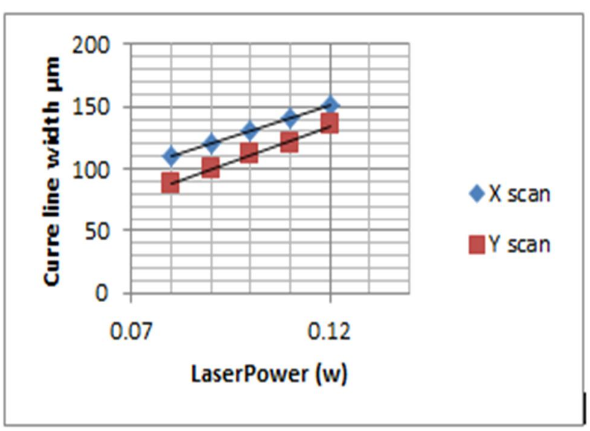


Figure 2: 3D images of Micromeshs obtained from Confocal microscope at CMTI

Effect of laser power and scan rate on cured line width of micro grids were observed. It is noted that increase in scan rate reduces cure line width for a fixed photoinitiator concentration. Increase in laserpower results in increased cure line width of the micromeshs.



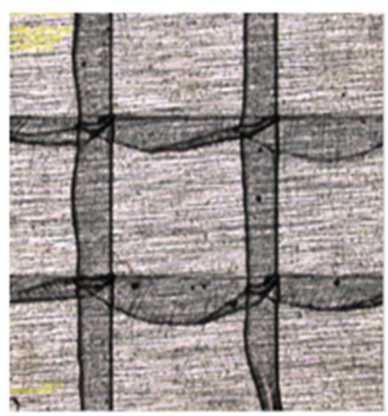


Figure 3: Scan rate-1.0mm/sec

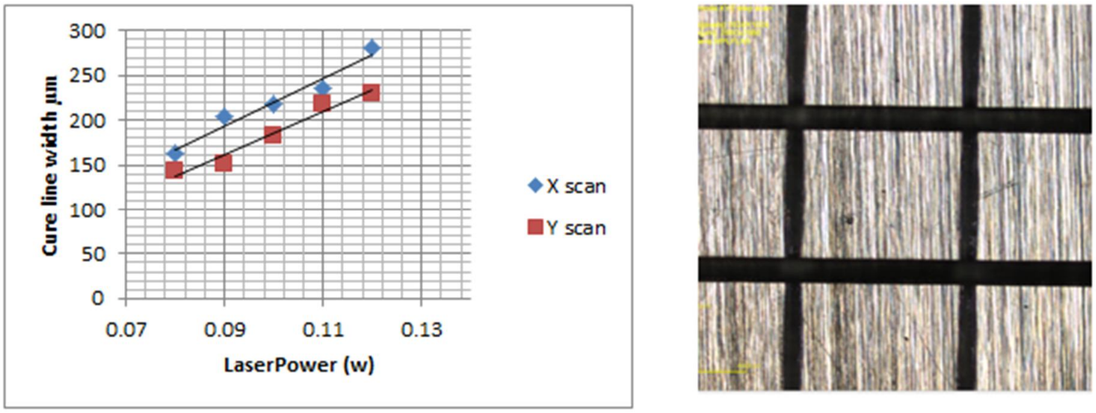


Figure 4: Scan rate-0.5mm/sec

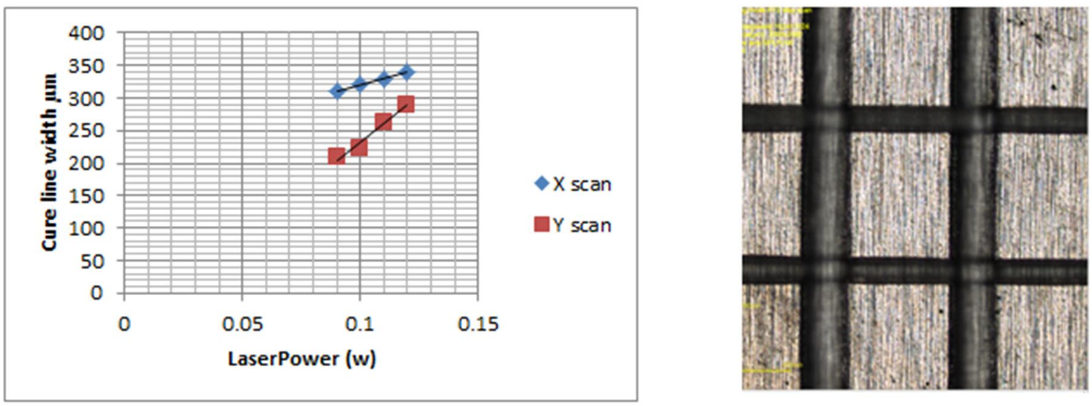


Figure 5: Scan rate-0.25mm/sec

It is observed that for higher scan rate cure line width reduces but there is distortion in the structure due to thermal stresses induced during laser scanning (Figure:4.2). Lowering the scan rate results less distorted structure but increase in the cure line width and also the process time (Figure:.44).For scan rate 0.5mm/sec and laser power 0.1 watts (Figure: 4.3) fine cure width micromeshs with less distortion are developed. For the successful microfabrication of high aspect ratio structure with dimensional stability and surface integrity optimum laser exposure parameters are required.

V. MICROSTRUCTURE STUDIES

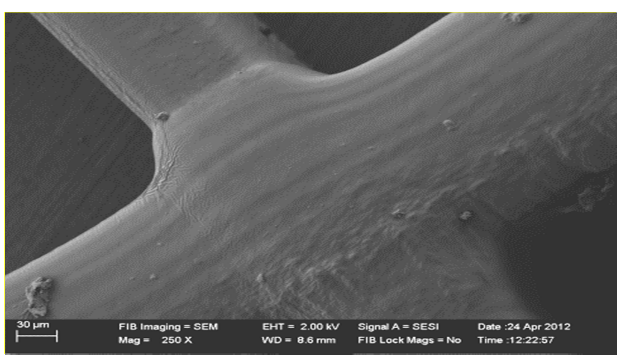


Figure 6: Microstructures observed under SEM for a) Laser power 0.08 w

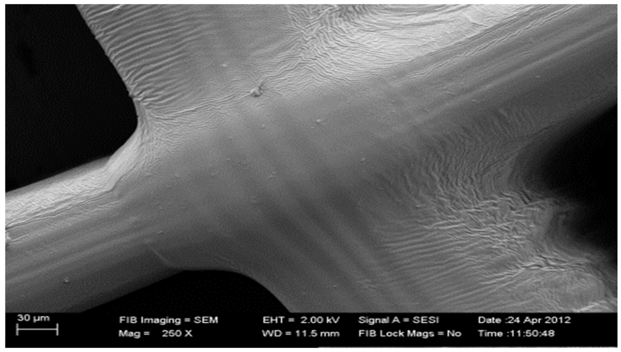


Figure 7: Laser power 0.10w

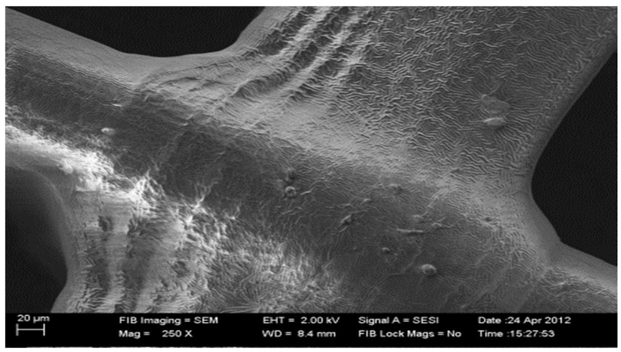


Figure 8: Laser power 0.120w

Figure:.5 shows the SEM images of the polymer micromeshes. The effect of laser power over surface morphology can be observed from the above images. Stresses can be observed at lower scan speeds and higher laser power. From Figure: 5.3 c) the amount of thermal stress formed on the surface is extremely high. Polymer micromeshes which are developed for the laser power 0.1watts shown in Figure: 5.2 b has the better surface morphology.

VI. Conclusions

Micromeshes with laser power 0.1mw and laser scan rate 0.5mm/sec found to be dimensionally stable with fine line width. It is also found that distortion in the micromeshs were less due to the thermal stresses. Control on the laser exposure parameters are very essential in 3D micro fabrication on polymer Microstereolithography.

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