Materials Opportunities on Layered Manufacturing Technology 2 - (MOLMT-2)

**Micro-fabrication Employing UV Microstereolithography**

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Fabrication of high aspect ratio 3D micro-components

- Develop a new microstereolithography technique that operates in the UV and Visible part of the spectrum

- Manufacture micro-components which are complex in shape and have micron resolution
Existing Technologies for MicroFabrication

- Lithography

Components constructed by superimposing a limited number of thin film layers or by using deep UV lithography.

Permits only limited complexity in the third dimension.
Meshing gears on a moveable platform.

A laminated comb actuator results in nearly five times the electrostatic force of a single level actuator.

Grain of pollen and red blood cells
$$I(x) = I_0 \cdot (1 + m \cos(kx))$$
Cibatool™ SL 5180 and Somos™ 6100

Experimental Conditions:
Sample Thickness = 100 μm
Temperature 19 °C
Relative Humidity 50-60%

Cibatool™ SL 5180: non-viscous, good quality samples
Somos™ 6100: viscous, suffers from ‘bubble trapping’ that causes scattering
Delay

- Ciba-Geigy Cibatool™ SL 5180
- DuPont Somos™ 6100
- DuPont Somos™ 7100

Rate

- Ciba-Geigy Cibatool™ SL 5180
- DuPont Somos™ 6100
- DuPont Somos™ 7100
STL Interface
Slices from STL Model
Experimental Set-up

Microstereolithography System Diagram

- **UV LASER** (351 or 363nm)
- **Shutter**
- **SLM**
- **D.O.E**
- **Slice Images**
- **Polarizer**
- **lens**
- **Translation Stage**
- **Encoder Module**
- **I/O Interfacing** (AT-MIO-16DE-10)
- **I/O Ports** (PC-DIO-10)
- **RS-232**
- **T132 Shutter controller**
- **Sync.**
- **Frame Grab (Ultra-II drive)**
- **Encoder driver Card (37-1039)**
- **Parallel Interface of data acquisition**
- **Serial DDI**
- **Network (ftp) or GPIB Interfacing**
- **Resin Bath**
- **I/O Ports**

Technology Hub
Basic Control Process

1. Measurement and control of position
2. Send an image slice to SLM
3. Shut off “ON” for laser beam exposure
4. Vision system to observe the condition of the cured $\mu$-component
5. Move translation stage for re-coating
6. PC - Windows NT

Process Control
Translation Stage

Features

- 20nm resolution
- 0.1μm accuracy
- 50mm travel range
- DC servo motor
- PID feedback control with encoder actuator
- Gearhead ratio of 485:1
Spatial Light Modulator (SLM)

- Features
- VGA and SVGA
- Ultra-II PCI Frame Grab with video and VGA frame buffers (2Mb each)
- CCIR/PAL camera
- Overlay display
Twisted Nematic Liquid Crystal

Diagram:

- **Mirror**
- **Rotated Polarized Transmitted Light**
- **Linearly Polarized Incident Light**
- **Unpolarized Incident Light**
- **Polarizer**
- **Analyzer**
- **Linearly Polarized Emergent Light**
- **No Transmitted Light**

**a. Offstate**

**b. Onstate**

**Elliptically Polarized Transmitted Light**

**Linearly Polarized Incident Light**

**Rotated Polarized Emergent Light**

**Transmitted Light**
Reduction Lens and Photo-polymer Bath
Main Programme Control Panel

Control Program for the Three Dimension Rapid Prototyping System

Display for System performance
Translation Stage Position
Programmable Stop
Translation Stage Position
1.15400 mm
STOP

Image Size/Position Control
Slice Image for Sp...

Control for the Image Slices to LCD in SLM
Selected碌nd
BMP for Path
map format
Interpolated Time Control
BMP File Name
NAME
Interval Time
5000
Image Layers
20
Height
480

Shutter Control (T132) for Normal Close
Port Number
Action
open duration
close duration
UN
White
0
100
100

Translation Stage Control using DC Servo
(For a 2μm MOVING STEP)
Power
Actual Position
Target Position
0.09500
0.09500

Hub
Micro-SLA System

Interface Control

Lithographic Lens

Resin Bath
Micro-SLA System
MicroSLA System
A micro-gear (50 micron layers)
A case for a micro-motor (50 micron layers)
A helix (50 micron layers)
A double helix (50 micron layers)
A micro-pyramid (35 micron layers)
Micro-pyramid (50 micron layers)
Detail of the centre of a micro-pyramid (25 layers of 50 microns each)
A micro-wheel (5 micron layers)
Photopolymer Rapid Opto-electronic Manufacture of Macro/micro Prototype Products - BRITE-EURAM

Alumina ($\text{Al}_2\text{O}_3$) Powder: Average diameter 0.5$\mu$m; Refractive index 1.7

Monomer: hexane-diol-diacrylate (HDDA)

Photoinitiators:
- Igracure 651 (DMPA) absorbs 300-390 nm
- Igracure 819 absorbs up to 450 nm

50 mJ/cm$^2$ for 100 $\mu$m cure depths, resolution of 40 $\mu$m
Photopolymer Rapid Opto-electronic Manufacture of Macro/micro Prototype Products - BRITE-EURAM

Mask

Cured at 365 nm with Hg Lamp

Ceramic parts produced with visible source and CRL XGA mask

8mm x 8mm 120 micron thick polymerised layer, resolution 50 microns; 80 wt% alumina, 0.5 wt% DMPA wrt HDDA monomer
Micromachining - Electronics & Sensors

Lambda Physik LPX 201i, 125W mean power, 2.5J/pulse, 100 Hz prf, 10 to 50 ns pulse width

Chrome on Quartz Mask

Micro-fluidic systems
References

1) C Chatwin, M Farsari, S Huang, M Heywood, P Birch, R Young, “UV microstereolithography system that uses spatial light modulator technology,” Applied optics 37 (32), 7514-7522, 1998
9) P Birch, R Young, C Chatwin, M Farsari, D Budgett, J Richardson, “Fully complex optical modulation with an analogue ferroelectric liquid crystal spatial light modulator,” Optics communications 175 (4), 347-352, 2000