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Fabrication of ceramic component using constrained surface Microstereolithography

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Abstract

Microstereolithography (MSL) is one of the solid free form fabrication (SFF) techniques which involve fabrication of 3 dimensional (3D) objects by means of laser assisted photopolymerization of resin. The resolution and capability to fabricate high aspect ratio structures makes it suitable technique for the fabrication of Micro Electro Mechanical Systems (MEMS) and biomedical devices. Silicon micromachining technique on the other hand has the limitation in fabricating high aspect ratio structures. Also, the ability to fabricate 3D components using wide range of resins makes MSL a versatile technique. Recently resins loaded with ceramic particles have been used to fabricate sub millimetre ceramic devices for MEMS application. However challenge of processing ceramics lies in reducing the viscosity of the suspension for successful recoating and achieving the minimum layer thickness to improve resolution of the part. In the present study ceramic suspensions is prepared using carboxylic acid as dispersant and 1, 6 Hexanediol diacrylate resin. A ceramic structure containing three layers of 50 microns each was fabricated using constrained surface technique and merits and limitations of this technique were investigated.

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1. Introduction

Micro Electro Mechanical System (MEMS) devices have been found in many sensing applications such as chemical and biological sensors. These MEMS devices are fabricated using micromachining processes which are

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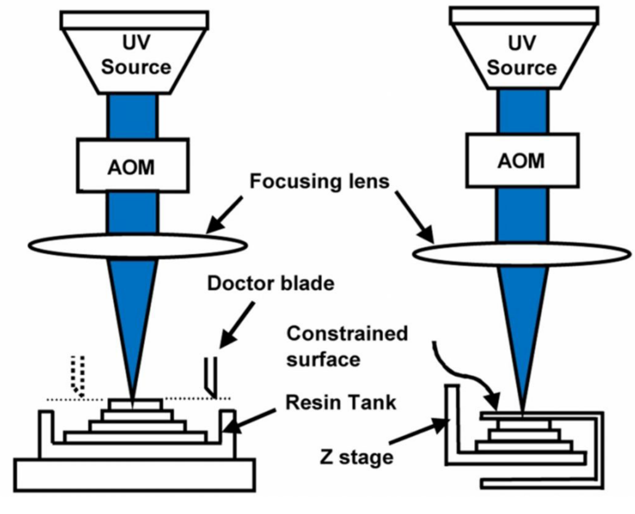
mainly based on soft lithography technique. These techniques provide higher resolution but involve the use of costly mask and limited capability to fabricate true 3D components [J Stampfl et al. 2008]. Currently 2-Photopolymerization process (2PP) is known to be a free form fabrication process with very high resolution [Satoshi Kawata et al. 2001]. In 2PP process the resolution much beyond the diffraction is achieved by controlling the laser pulse energy and number of applied pulses. However the main limitations of 2PP are low writing speed and maximum height of the fabricated parts [J Stampfl et al 2008]. Another SFF process X-ray lithography was developed to fabricate high aspect ratio microstructures [Christophe Marques 1997] but it couldn't find industrial applications due to limited accessibility to industries and high operational cost. In the year 1992 Ikuta et al. (1993) introduced a novel microfabrication process 'Microstereolithography' to fabricate high aspect ratio structures. This process has been applied for fabricating micro-fluidics devices for biomedical applications where the feature resolution is in the range of 1-10 microns. These 3D components are fabricated in microstereolithography by polymerizing a photosensitive resin with computer controlled laser scanning technique. The spot size of laser used to photo polymerize liquid resin is of the order of 1-2 microns [Chrristope Provin et al. 2003; X. Zhang et al. 1993]. The ability to fabricate wide range of materials makes MSL as a versatile technique to fabricate high aspect ratio structures.

Recently some research groups reported fabrication of complex 3D ceramic parts in millimeter and sub millimeter range using microstereolithography apparatus [X. Zhang et al. 1999; X.N. Jiang et al. 2000; S. Monneret et al. 2002; Arnaud Bertsch et al. 2004]. When ceramic particles are dispersed in a (photosensitive) resin the resulting fluid will be a thick paste. During fabrication of 3D structures successive layer recoating becomes an issue owing to high viscosity of suspension. There are two methods available for successive recoating of ceramic suspension. One method uses a doctor blade technique to coat a uniform layer on the top of the previously fabricated layer.(Refer Fig. 1.) Doctor blade utilizes shear thinning behaviour of ceramic suspension and the blade speed is adjusted such that suspension can be spread easily attaining the lowest apparent viscosity at close shear rate. Equation which relates velocity of blade ($\boldsymbol{v}$), layer thickness ($\boldsymbol{t}$) and shear rate ($\dot{\boldsymbol{\gamma}}$) is given as follows [Olivier Dufaud et al. 2002].

$$\boldsymbol{Shear\ rate}(\dot{\boldsymbol{\gamma}}) = \frac{\boldsymbol{v}}{\boldsymbol{t}} \tag{1}$$



(a) (b)

Figure 1.(a) Scanning Microstereolithography with free surface (doctor blade) technique and (b)with constrained surface technique

Since thickness of recoated layer is of the order of 10-20 microns and amount of pure resin deposited on top of the previous layer is very less, doctor blade or scraper cannot be used as it may destroy the previously fabricated