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ScienceDirect

Procedia CIRP 42 (2016) 87 – 90

www.elsevier.com/locate/procedia

18th CIRP Conference on Electro Physical and Chemical Machining (ISEM XVIII)

Fabrication of Polymer Micro Needles for Transdermal Drug Delivery System using DLP based Projection Stereo-lithography

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Abstract

Fabrication of micro needles, which reduce pain during insertion and lessen tissue injury, has recently attracted great interest. Different manufacturing systems have been utilized for the advancement of micro needles such as two-photon photo polymerization, bulk lithography, droplet-borne air blowing and injection molding [1]. This paper proposes a micro fabrication process for polymer micro needles, using DLP based projection-based stereo lithography that is capable of fabricating micro-needles using biocompatible polymers. The fabrication in the experimental setup is performed with continuous movement of the platform in the vertical direction hence good surface quality is obtained. The influence of polymerization time, light intensity of DLP projector and chemical composition of the resins on the production speed and the geometrical accuracy of the micro needles have been studied. The length and the tip diameter of the micro needle are shown to be controlled through these factors. The length and tip diameter of the fabricated micro needles were observed using SEM and optical microscope and measured to be around 520 µm and 40 µm, respectively. The results indicate that polymer micro needles with appropriate geometry can be fabricated using this technique.

Peer-review under responsibility of the organizing committee of 18th CIRP Conference on Electro Physical and Chemical Machining (ISEM XVIII)
Keywords: Micro Needle; DLP Projector; Micro Stereo-lithography

1. Introduction

Additive Manufacturing (AM) has been used in customized healthcare products to improve population health and quality of life. It can be used to make custom surgical implants in a solid or resorbable material [2]. AM technologies have been used for a variety of applications such as skull [3, 4], knee joint [5], elbow [6], and hip joint [7] implants.

Stereolithography is an additive manufacturing technique in which a liquid polymer resin is cured with a UV light as thin layers. As the process platform is moved across the axis of production after each layer, system forms a digitally defined 3D shape [8]. It is also possible to decrease the size of the fabricated structures to micron level as Zhang [9] made micro-channels and micro-tubes with 1.2 µm resolution and high aspect ratio of 16. Micro stereo-lithography can be used for medical purposes as Choi [10] proposed a way to fabricate human kidney scaffold with a system that is working with resolution of 2µm in x-y and 1µm in z-axis.

Micro needles are extremely small needles used to draw blood or manage drugs without entering the skin and underlying tissue as profoundly as conventional hypodermic

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doi:10.1016/j.procir.2016.02.194

needles or syringes. When it is utilized for medical purposes, rows of several hundred smaller scale needles are put onto modest patches that are then applied to the skin. The smaller scale needles make tiny holes in the furthest layer of the skin, and either draw minute amounts of blood or deliver a drug and this process sometimes called transdermal drug delivery. They cause minimal pain and trauma compared to traditional needles and is used for various medical purposes like immunizations, pain management, and blood glucose monitoring [11].

Various methods are used to fabricate micro needle devices which would be used in the health industry for different purposes. PDMS micro molds are generated and a novel vacuum-based method is used to fill the molds with various acids and polymers to form the needles in Park's research [12]. Yung [13] used micro injection molding to produce hollow high aspect ratio micro needles with 110µm tip diameter and 500 µm length. Ashraf [14] uses some cleanroom processes like deep reactive ion etching and inductively coupled plasma (ICP) etching to create silicon micro needles integrated piezo-electrically actuated device for transdermal drug delivery. Also other MEMS manufacturing methods like photo-lithography and one of the newer and effective techniques like drawing lithography [15] are used for the production of needles of different shapes and dimensions.

In this research, a mathematical model for the cure depth calculation has been used to find the optimal parameters for fabrication of various designs. Hence, a process of DLP based projection micro-stereolithography system has been developed to fabricate micro needles and also to verify the cure depth model. The positioning system has the capability of moving in nanometer level steps. The adjustment of this movement together with curing rate allows us to control layer thickness and creates a continuous production process. Therefore, needle structures are produced without observable layers.

2. Experimental Setup

An experimental setup has been designed for projection based micro stereo-lithography process (Fig.2) including a DLP projector and a high precision linear positioning system as shown in Fig. 1.

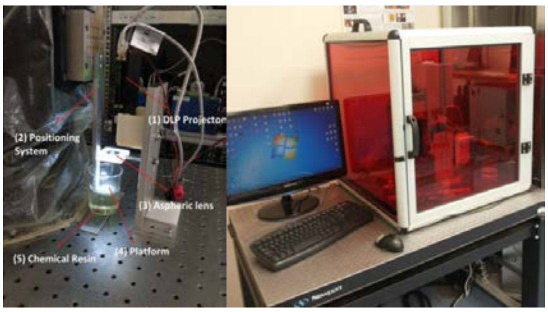

Fig. 1. (a) Working principle of the system (b) Overview of the PSLA system

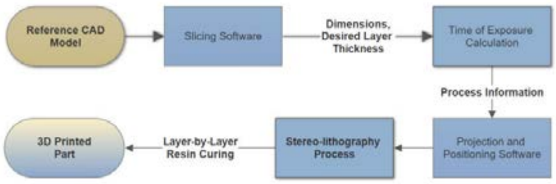

Fig. 2. Stereo-lithography process flow.

An optical lens is used to converge the light rays of the projected image on the platform. It decreases the chromatic and spherical aberrations and increases the layer image exposure quality on the fabrication platform. A PC system is used for the continuous control and positioning and projection devices during the process. An outer housing is designed, which blocks the outer lights in a specific wavelength interval, therefore minimizes the environmental effects as showed in Fig. 1(b). In this setup, process parameters such as light intensity, vertical speed of the platform and exposure time are used to fabricate micro structures. The optimal parameters are also taken into consideration for micro needle fabrication based on our previous study [16].

3. Cure Depth Model

3.1. Characterization of the Resin

In order to find cure depth of the resin under specific light intensity, the Beer-Lambert law has been used. The relation between the depth of cure (Cd) and the exposure on the resin surface (E) is given by Equation 1 as:

$$C_d = D_p \ln (E/E_c) \quad (1)$$

Depth of penetration (D_p) and critical energy (E_c) values depends upon the resin chemistry and in order to identify these values an experimental approach has been conducted as described in Limaye et al. [17]. Figure 3 shows the working curve of the resin used in this study.

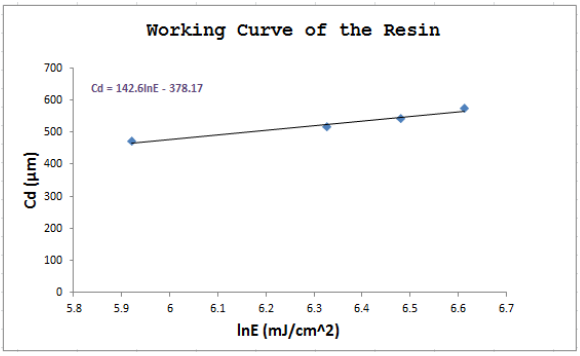

Fig. 3 The working curve of the resin

The slope of the graph shown in Figure 3 gives the value of the D_p , while the x-intercept value is equal to ln (E_c).