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## Direct Fabrication of Microstructured Surfaces by Additive Manufacturing

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### Abstract

Different fabrication methods can be applied for micro fabrication, all characterized by their specific processing time and cost. However, by using the additive manufacturing (AM) technologies for direct micro manufacturing of complex micro geometries the average production time and cost can be drastically reduced. This study investigates an AM-based fabrication method for the production of microstructure surfaces with different feature sizes (50-150  $\mu\text{m}$ ). The experiments presented in this work have been carried out in a specifically designed vat photopolymerization AM machine suitable for precision printing developed, built and validated at the Technical University of Denmark (DTU). The AM method was evaluated in terms the capability of the system to produce micro pillars and holes array in different sizes and with increasing geometrical complexity.

**Keywords:** Additive Manufacturing; Vat Photopolymerization; Micro Manufacturing; photopolymer;

### 1. Introduction

Recent developments of Additive Manufacturing (AM) technologies are significantly growing the number of applications in different industries, particularly for the fabrication of customized parts with high geometrical complexity, including micro manufacturing. For instance, in the case of micro-fluidics, a lotus-like characteristic, corrosion resistance and water repellence surfaces with self-cleaning properties structures are requested for different applications [1][2]. Printing micro features with higher accuracy in a final product need more attention for the printing process and better understanding the performance and capability of the AM machine [3][4]. In this study, the capability of a vat photopolymerization (VP) AM machine is studied. For this purpose, different micro parts have been designed with features having both circular and hollow shapes in order to evaluate the system capability for direct fabrication of micro scale features.

### 2. Method and Materials

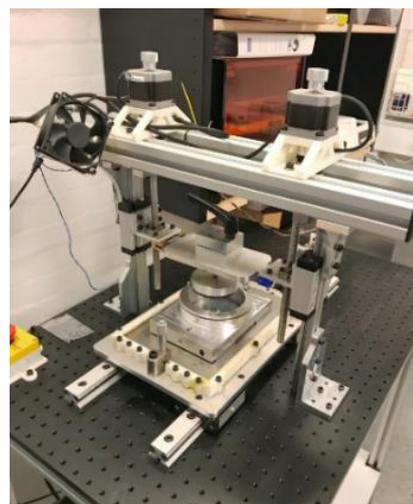
#### 2.1. Digital Light Processing (DLP) Technology

In a vat photopolymerization process, the liquid photopolymer resin is placed in a vat, where an Ultraviolet (UV) light is radiated, curing the liquid resin, layer by layer. This method uses a Digital Light Processing (DLP) projector with optical micro-electro-mechanical technology that uses a Digital Micromirror Device (DMD) as a consolidation tool. The light is projected from a source into the DMD and out of the optical lens of the projector, before reaching the transparent vat surface. The fabrication of the part was on the build plate and the features were oriented along with the Z direction perpendicular to build plate. Printing process carried out in different steps from CAD model, selecting the printing parameters (layer thickness, exposure time, etc.), slicing and printing the part. The selected parameters for this work are based on a previous experiment [3] [5] and are listed in Table 1. All the parts were printed perpendicular to the build plate as shown in Figure 3. The next step after printing the parts is the post-processing to clean the part that is covered with

uncured polymer resin and make sure no reactive resin residue is left on the samples so that ideal mechanical properties are reached. A bath of isopropanol in a vibration plate ultrasonic cleaner bath was used for removing the excess resin. For the curing process a UV oven (with a diffuse UV light with an irradiant flux density of 300  $\text{W}/\text{m}^2$ ) for 30 minutes were applied.

**Table 1.** Experimental Conditions

Parameters	Selected Parameters
Layer thickness / $\mu\text{m}$	15
Exposure time /s	3.5
Photopolymer resin	FTD red pigment
Printing resin temperature/ $^{\circ}\text{C}$	23



**Figure 1.** DLP Machine

#### 2.2. Test Parts

Different test parts that have been designed with the shape of holes and pillars as shown in Figure 2 containing shaped pillars in a hierarchical structure with the neck diameter of 400  $\mu\text{m}$  and a 20° draft angle surface. On top of the array, pillars with diameter from 90  $\mu\text{m}$  down to 60  $\mu\text{m}$  were placed.

### 2.3. Measurement Procedure

The assessment of the printed micro holes arrays 150  $\mu\text{m}$  and 110  $\mu\text{m}$  pitch features were selected for analyzing the result of the experiments. The Alicona Infinite Focus 3D Microscope was employed to perform the measurements. The sample surface for the holes geometry was divided into five regions, four in each corner and one in the center of the part, and each region was subjected to a randomized sampling measurement. The software SPIP was used for analyzing the obtained data.

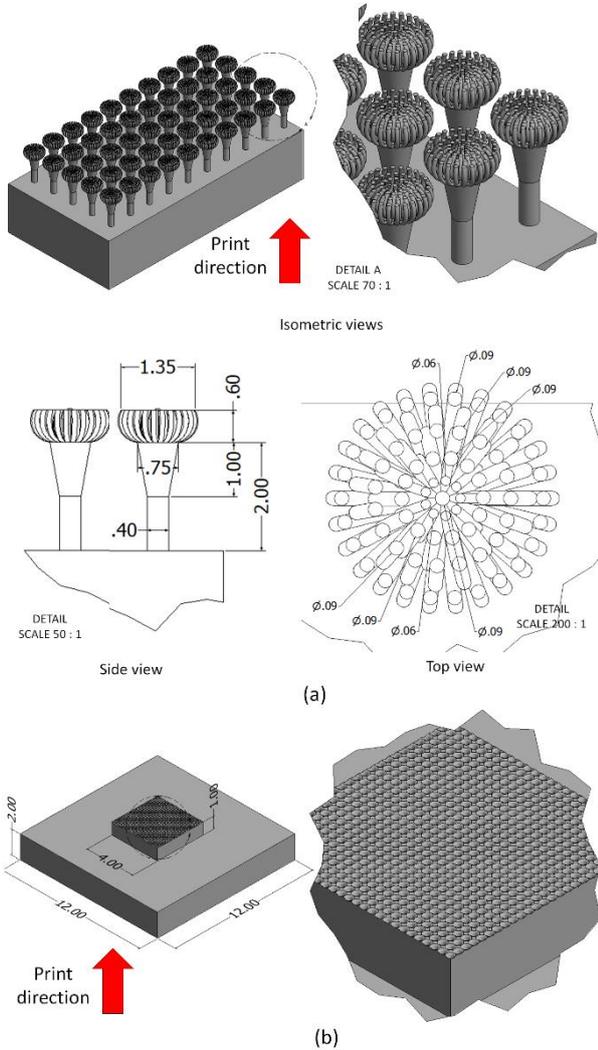


Figure 2. features design (a) micro-holes arrays (b) shaped pillars isometric, top and side views

### 3. Results

Figure 3 shows SEM images of the printed features. The pillars geometry were printed with the diameter of 60 to 90  $\mu\text{m}$  with the flower shape. The printed Gaussian holes array with 150  $\mu\text{m}$  pitch is shown in Figure 3. At higher magnification the printed layers and even the DMD pixels are visible. Different geometries at the micro scale were printed and distinct features can be observed indicating the capability of the AM process when proper printing and post processing parameters are applied. Figure 4 represents the diameter measurements in five selected areas of the micro holes array with diameter of D1 = 50  $\mu\text{m}$  and D2 = 150  $\mu\text{m}$ . Optimized results in terms of micro manufacturing accuracy were obtained with micro holes array pitch of 110 and 150  $\mu\text{m}$ .

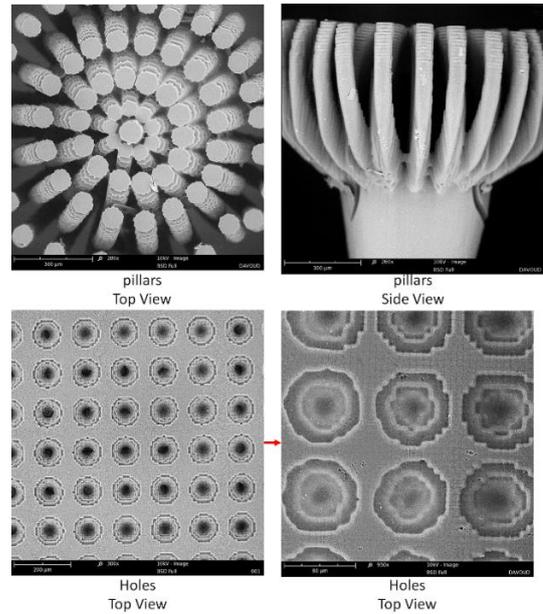


Figure 3. Printed flower shape micro pillars and micro holes array

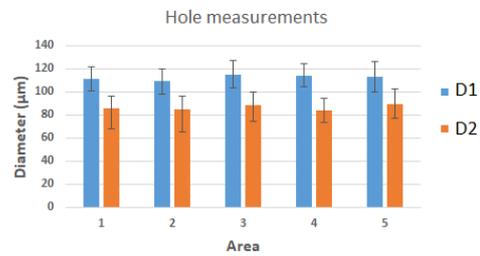


Figure 4. Hole diameter measurements in different areas

### 4. Conclusions

In this study, the performance of a DLP AM machine has been characterized using different test parts with hollow and pillar micro geometries. The features were evaluated in terms of printing accuracy for both types of feature. Micro pillars had diameter from 90  $\mu\text{m}$  down to 60  $\mu\text{m}$  and the Gaussian holes array had diameter from 50 to 150  $\mu\text{m}$ , with pitch between 110 and 150  $\mu\text{m}$ . Digital light processing has enabled the possibility of direct manufacturing of different range of dimensions by applying proper process parameters and post processing method.

### Acknowledgements

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