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## HD-DVD Based Microscale 3D Printer

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### Purpose

Here, we present a 3D printing system built for producing micro- and nanoscale devices. The system applies a HD-DVD optical pickup unit (OPU) as the core optics to crosslink photopolymers, thereby microscale 3D structures can be formed through layer-by-layer printing. Furthermore, the HD-DVD OPU has the potential of printing nanoscale voxel by precisely controlling exposure parameters.

### Introduction

It is challenging to 3D print complex structures with micro- and nanoscale features as printing resolution of current 3D printing systems is limited. Currently, the most advanced stereolithography (SL) system is restricted to about 5  $\mu\text{m}$  spatial resolution. Multiphoton 3D printers can print nanoscale features, but the intricate stitching process makes it tedious to mass print at the scale of hundreds of microns [1, 2].

To extend the resolution capabilities of SL, we developed a HD-DVD OPU based 3D printer. The OPU equips a 405 nm laser and an objective lens with a numerical aperture (NA) of 0.65, which results in a focal spot of 400 nm (full width at half maximum, FWHM) [3,4]. The OPU laser spot is potent for crosslinking photopolymers at voxel sizes from tens of microns to sub-micron dimensions. Moreover, the mass-produced HD-DVD OPU is cost effective and compact in size. These merits could simplify the SL 3D printing technology.

The HD-DVD-based 3D printer uses a National Instrument myRIO 1900 card and XYZ nano-resolution linear stages to precisely control the OPU laser intensity and movement, respectively (Fig 1). To verify the HD-DVD printer characteristics, we use a commercially available photopolymer (RS-F2-GPWH-04, Formlabs).

### Result

The size of crosslinked voxels is proportional to the resin exposure parameters, which are printing speed and laser intensity. Printing speed is gradually increased from 89 to 208  $\mu\text{m}/\text{s}$ . Higher printing speed results in the crosslinking of smaller voxel, which ultimately leads to the formation of thinner lines (Fig 2). At the highest speed, all lines are below 6  $\mu\text{m}$  in width. Reduced laser intensity (from 2.30 to 1.46  $\mu\text{W}$ ) decreases the line width as well. However, the latter circumstance cannot be exploited to boundlessly tune printing resolution as the laser becomes unstable when the driving voltage is lower than the lasing threshold.

Fig 3 shows a SEM image of stably 3D printed lines with sizes of 2.86  $\mu\text{m}$  (X axis) and 2.58  $\mu\text{m}$  (Y axis). The printing speed and laser intensity were 125  $\mu\text{m}/\text{s}$  and 1.87  $\mu\text{W}$ , respectively. A close-up image on the right in Fig. 3 demonstrates a protruding line, which is 659 nm in width. This nanoscale feature was achieved by ramping up the laser intensity, thus demonstrating the potential for nanoscale 3D printing with further fine tuning of the exposure parameters.

Moreover, we 3D printed different microstructures to verify the HD-DVD printer performance. Fig 4a shows an 850  $\mu\text{m}$  tall pyramid. Except for the two thicker base layers, which act as a 3D structure foundation, the object was printed at a 25  $\mu\text{m}$  layer height. Fig 4b and Fig 4c show a tilted square-tower and a twisted tower, respectively. Their oblique structures show overhang printing capability. Our goal is to 3D print micro- and nanoscale features in a shorter time with higher laser intensity and faster printing speed.

- [1] S.C. Ligon, R. Liska, J. Stampfl, M. Gurr, R. Mülhaupt, Chem Rev. 2017 Aug 9; 117(15): 10212–10290.  
[2] R.R. Reiner, Y. Tanguy, J. Hoffmann, Process for producing a three-dimensional structure, United States, US20160332365A1, 2016-11-17  
[3] M.J. Koster, A compact fluorescence detection system that uses a DVD pickup for the optical detection of beads, Master Thesis, Department of Electrical Engineering, University of Twente, 2011  
[4] E.T. Hwu, A. Boisen, ACS Sens. 2018, 3, 1222–1232

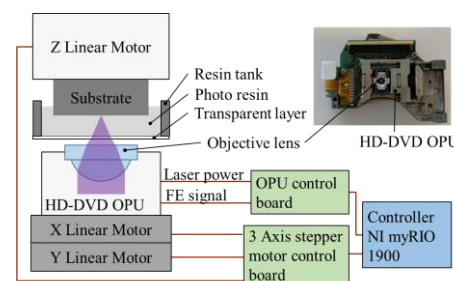


Figure 1. System diagram of the HD-DVD based 3D printer.

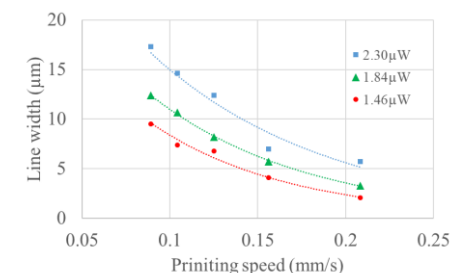


Figure 2. Line width vs. printing speed and laser intensity.

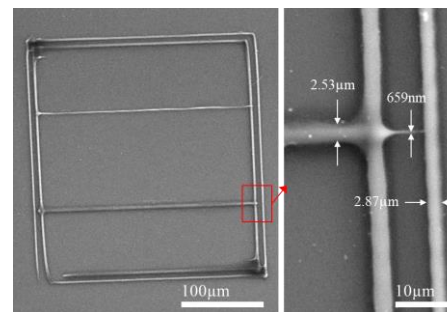


Figure 3. SEM image of optimized printing parameter. The stably printed lines are 2.53 and 2.87  $\mu\text{m}$  in Y and X direction, respectively. On the right, a 3D printed nanoscale feature is shown.

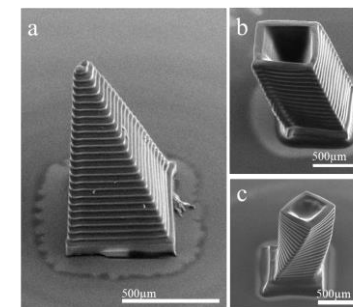


Figure 4. SEM images of 3D printed a). pyramid structure with total height of approximately 850  $\mu\text{m}$ , and each layer was 25  $\mu\text{m}$  in height, b) tilted square-tower and c) twisted tower.