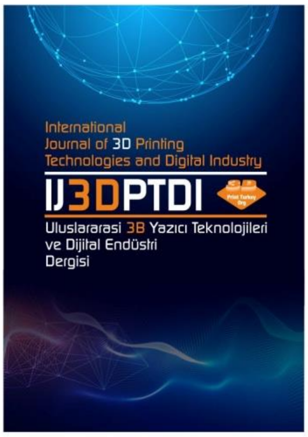

ULUSLARARASI 3B YAZICI TEKNOLOJİLERİ
VE DİJİTAL ENDÜSTRİ DERGİSİ

INTERNATIONAL JOURNAL OF 3D PRINTING
TECHNOLOGIES AND DIGITAL INDUSTRY

ISSN:2602-3350 (Online)

URL: https://dergipark.org.tr/ij3dptdi

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Bu makaleye şu şekilde atıfta bulunabilirsiniz (To cite to this article): *Ertuğrul İ, Akkuş N., Aygül A., Yalçınkaya S.“ Mems Fabrication Using 2pp Technique Based 3d Printer”, Int. J. of 3D Printing Tech. Dig. Ind., 4(1): 12-17, (2020).*

Erisim linki (To link to this article): https://dergipark.org.tr/en/pub/ij3dptdi/archive

DOI:

MEMS FABRICATION USING 2PP TECHNIQUE BASED 3D PRINTER

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(**Geliş/Received:** 19.01.2020; **Düzeltme/Revised:** 02.02.2020; **Kabul/Accepted:** 29.04.2020)

ABSTRACT

This study aims to fabricate Electro-Thermal Micro Actuator with a support structure by using the Two-Photon Polymerization (2PP) technique based 3D printer. This study was carried out with the 3D printer, which is possible to fabricate the actuator, which can be fabricated by the traditional Micro Electro Mechanical System (MEMS) methods. Due to the high cost of traditional MEMS methods, excessive and challenging processing, many studies have been carried out for new fabrication methods. 2PP is the most widely used and developed method of production. With this method, direct fabrication up to the nano level is possible. Also, many chemical processes used in traditional methods will not be applied using 2PP based 3D printers.

The design of the bi-directional movable Electro-Thermal Micro Actuator is carried out in this study. Supporting structures with a diameter of 2 microns allow the Actuator to be fabricated without breakage. 2PP method of the 2-micron length of the very easy and low-cost production was seen in this study. Thanks to this method, traditional MEMS production methods will be replaced by 3D printers in the following years.

Keywords: 3D Printing, MEMS, Fabrication, 2PP

1. INTRODUCTION

3D printers are becoming increasingly popular in terms of rapid and efficient prototyping methods. Furthermore, thanks to the development of conductive polymers in the printing process, 3D printers are very much involved in the fabrication of MEMS devices. The focus of this study is the fabrication of the MEMS-based Electro-Thermal Micro Actuator, which is capable of bi-directional movement using a conductive material.

Much work has been done on 3D printers today. Studies on Powder Bed Fusion (PBF) based 3D printers [1,2], Selective laser sintering (SLS) studies on 3D printer based printers[3,4], Fused Deposition Modeling (FDM) technique based studies [5], Studies on the use of 3D printers in education [6,7].

2PP is a laser-based technology that can be classified as Stereolithography (SLA). It is based on the same principle [8]. The essential elements of the two-photon polymerization consist of femtosecond pulses, suitable light-sensitive materials (photoresistors), a precise positioning step, and a computer controlling the procedure. 2PP is a non-linear optical process based on the simultaneous absorption of two photons in a light-sensitive material (photoresist). This process replaces the light-sensitive material, that is to say, initiating photoinitiators in the resist, leading to a polymerization. In the next step, the non-polymerized photoresist is washed to expose the structure [9].

Many MEMS fabrication studies related to 2PP methods have been carried out in recent years. Optical MEMS systems [10, 11], Biomedical MEMS devices [12], Medicine and Cell [13, 14], and Microfluid devices [15, 16] have been studied.

Fabrication of Electro-Thermal Micro Actuator using a 2PP based 3D printer was performed in this study. It is expected that the fabrication of MEMS and NEMS devices with 3D printers will be much more comprehensive if the variety of materials used in the 2PP method increases in the following years. It has been seen that the use of 3D printers in the MEMS field is possible with this study. It is thought that this study will contribute to the literature in terms of both design, method, and fabrication techniques.

2. 2PP TECHNIQUE

The 2PP method is a widely used technology in the production of 3D microstructures in recent years. The simplicity and fastness of the fabrication, the production of complex structures, and the high resolution allowed the technology to be preferred [17-21].

This method has attracted the attention of some companies. As shown in Figure 1, the μFAB-3D device of Microlight3D Company can produce 3D devices in microstructure with 2PP technology. μFAB-3D, which is a 3D laser lithography system, produces maskless lithography. There are two different writing modes in one device. These; "Ultra-fast Piezo Mode" for optional 3D curves and "High-Speed Galvo Mode" for the fastest production in a layered construction. The μFAB-3D device produces high-resolution photomasks and other direct printing applications. Easy fabrication is possible with the STL file format. The high-precision microscope camera for real-time monitoring of the printing process is located on the camera. This device can produce up to 100 × 100 mm² dimensions [22-24].

Figure 1. The μFAB-3D device of Microlight3D Company [24]

3. FABRICATION

3.1. Electro-Thermal Actuator Design

Design processes were carried out before going into fabrication processes. After the design process is finished, the STL format actuator design will be produced with a 3D printer. The 3D design of the actuator is given in Figure 2-a. This design will be produced with a 3D printer. Supporting structures in the design are located on the upper surface of the Actuator. These supports will be in the lower part of the Actuator during fabrication. In other words, the supports will prevent the actuator from breaking during fabrication. Since the right and left parts of the Actuator are symmetrical, the dimensioning is given as in Figure 2-b. The length of the Actuator is given in Table 1.

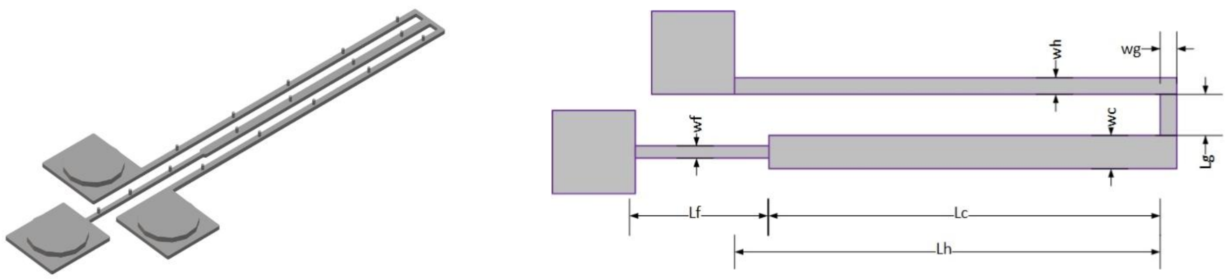

Figure 2. a) CAD design of the Electro-Thermal Micro Actuator, **b)** Dimensioning of the Electro-Thermal Micro Actuator with symmetrical structure.

Table 1. Geometrical dimensions of the electro-thermal actuator

Parameter	Symbol	Value	Unit
Hot Arm Length	L_h	250	µm
Cold Arm Length	L_c	200	µm
Flexure Arm Length	L_f	100	µm
Actuator Gap	L_g	7.5	µm
Hot Arm Width	w_h	3	µm
Cold Arm Width	w_c	6	µm
Flexure Arm Width	w_f	3	µm
Air Gap Thickness	t_a	4	µm
Actuator Thickness	t	3	µm
Thickness of Silicon	t_{si}	3	µm
Support Diameter of Pads	r_{ps}	40	µm
Support Diameter of Arms	r_{as}	2	µm
Support Heights	h_s	4	µm

The material used in this printer is a polymer and has a conductive property. The physical properties of this material are shown in Table 2.

Table 2. Physical properties of polymer material [14]

Parameter	Symbol	Value	Unit
Material Density	D	1.22-1.44	$g/(cm^3)$
Young's Module	E	$4.5x10^9$	GPa
Poisson Ratio	v	1.52	-
Thermal Conductivity	k_p	$1.4x10^{-4}$	$W.\mu m^{-1}.C^{-1}$
Refractive index	n	1.49-1.53	-

3.2. Fabrication of Electro-Thermal Actuator

Firstly, a glass wafer was used to fabricate the Actuator. The 2PP based 3D printer was printed directly on this wafer. In order to provide the gap between the actuator and the wafer, the support systems were designed, as shown in Figure 3.

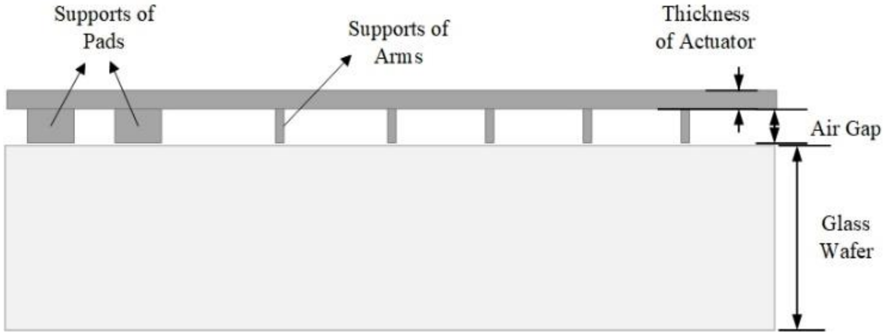

Figure 3. Printing the Electro-Thermal Actuator on the glass wafer

The produced actuator was taken with the camera of the 3D printer in Figure 4. As can be seen from the image, successful results were obtained in the micro dimension.

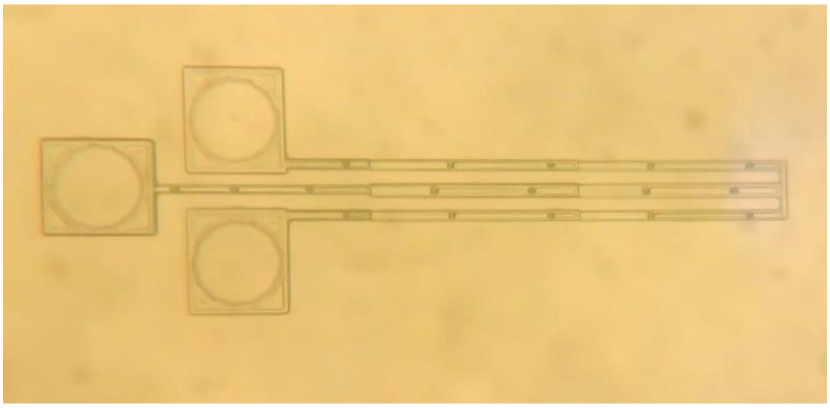

Figure 4. View of fabricated Electro-Thermal Actuator obtained by 3D printer camera

4. CONCLUSIONS

Fabrication of Electro-Thermal Micro Actuator with support structure using the 2PP technique based 3D printer was performed in this study. The designed actuator is capable of bi-directional movement. Although the material used is a polymer, it can act as it has a conductive property.

When the results are analyzed, 3D printing offers a good option for the rapid prototyping of MEMS devices. Thanks to the 2PP method, a printed component from a CAD model is completed in just a few hours. Electro-Thermal Actuator is supported to prevent the deformation of long arms during fabrication. Also, 4 microns of the gap between the Actuator and the Glass Wafer was designed, and the Actuator was allowed to move. When the experimental studies were examined, it was seen that the supports with 2-micron diameter and 3-micron width arms were fabricated without any errors.

This study shows that it is possible to fabricate MEMS devices with 3D printers and that in the years to come, traditional MEMS techniques will be replaced by 3D printers.

ACKNOWLEDGMENT

This study was supported by Marmara University Scientific Research Projects Commission with project number FEN-C-DRP-101018-0536. This study was summarized at the conference called 4th International Congress on 3D Printing (additive manufacturing) Technologies and Digital Industry.

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