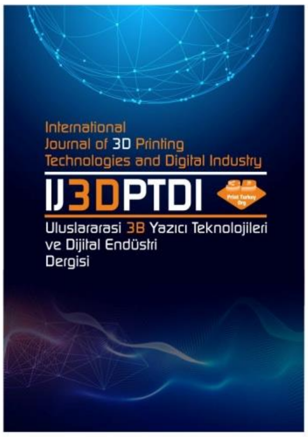

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ABSTRACT

This study aims to fabricate Electro-Thermal Micro Actuator based on Micro Electro Mechanical System (MEMS) with a 3D printer using Projection Micro Stereo Lithography (PµSL) technique. The production of the actuator produced by traditional MEMS fabrication methods with a 3D printer has been carried out in this study. The cost of traditional MEMS fabrication methods is high, and there are many techniques to achieve the process. On the other hand, some methods have been developed to obtain better quality and low-cost production as a parallel to the development of technology. One of these methods is to use 3D printers employing the PµSL technique. By means of these printers, it is possible to reduce both the cost and workload of the production process the MEMS systems. In this study, it is investigated and stated that Nano level fabrication would be possible with 3D printers in the following years. It can also be predicted that traditional MEMS production methods will be replaced by 3D printers soon.

Keywords: 3D Printing, MEMS, Fabrication, PµSL,

1. INTRODUCTION

Due to the development of technology, many 3D printer technologies have developed. Many studies have been done with 3D printer techniques. Educational studies [1,2], Fused Deposition Modeling (FDM) technique studies [3], Selective laser sintering (SLS) technique studies [4], Powder Bed Fusion (PBF) technique studies [5-7].

PµSL is a new 3D micro-production technology that allows the fabrication of layered and highly sophisticated 3D microstructures. PµSL uses the most advanced digital micro-display technology with digital and dynamic structures. By combining the advantages of conventional Stereo Lithography (SLA) and projection lithography, this technique enables rapid photo-polymerization of the entire layer with an Ultraviolet (UV) light at the micro-layer resolution. At the same time, as a digital dynamic mask, it can control the light intensity at a single-pixel level. Furthermore, the materials can be easily changed during the manufacturing process. A variety of functional material sets are available, including polymers, sensitive hydrogels, shape memory polymers, bio-materials [8].

Although this technology is new, it is open to development. In the last few years, many studies have been performed with this method. In the field of micro-optics [9-11], the micro biomedical field [12,13], micro machines [14-16], and microfluid area [17-19] were studied. It is seen that all of these studies were implemented with traditional MEMS fabrication methods. However, the method of PµSL based 3D writing has the most crucial advantage among these studies.

In this study, Electro-Thermal Micro Actuator was fabricated by using a PµSL technique based 3D printer. It has been observed that the use of 3D printers in the MEMS field is possible with this study. Considering that the variety of materials used in the PµSL method will increase in the coming years, it will be inevitable that the production of MEMS and NEMS devices with 3D printers will be much more comprehensive.

2. PμSL TECHNIQUE

PμSL is a versatile and cost-effective process that can be used to rapidly generate ceramic products with electrolysis or resin additives [20,21]. This method starts by creating a 3D structure using computer-based design (CAD) software and then turns the structure into a set of mask images (digital mask).

The working principle of PμSL is shown in Figure 1. Each image represents a thin layer of the 3D structure. During a production cycle, a single image is displayed on the reflective LCD panel. The image on the LCD is cured to the hardened liquid surface. The whole layer (usually 5-30 μm thick) is polymerized. Once a layer has been solidified, it is re-immersed in the resin to allow a new thin layer of liquid to form. Repeating the loop creates a 3D microstructure from a layer stack [22,23].

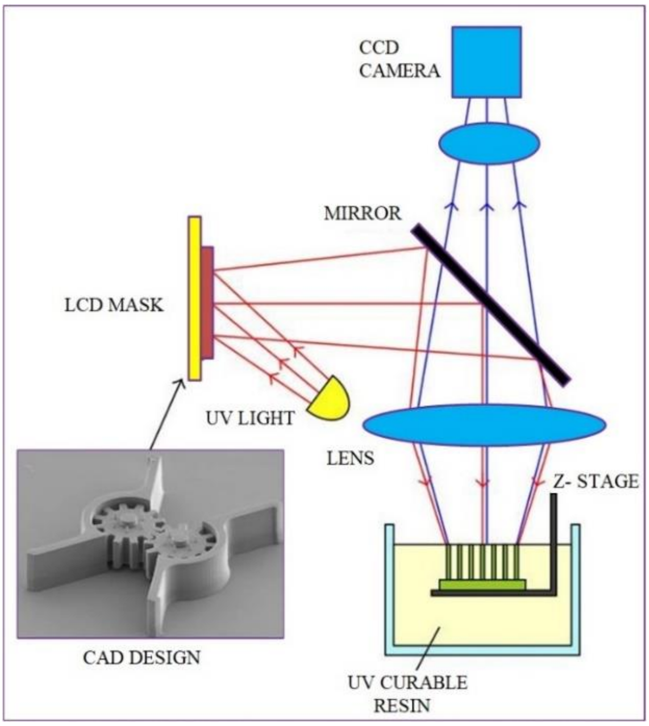

Figure 1: PμSL working principle [21].

This method is used by many companies nowadays. Especially with the development of technology, nanofabrication has become possible in a professional way. As shown in Figure 2, the NanoArch series device of BMF Material Technology company is manufactured by the PμSL method [23].

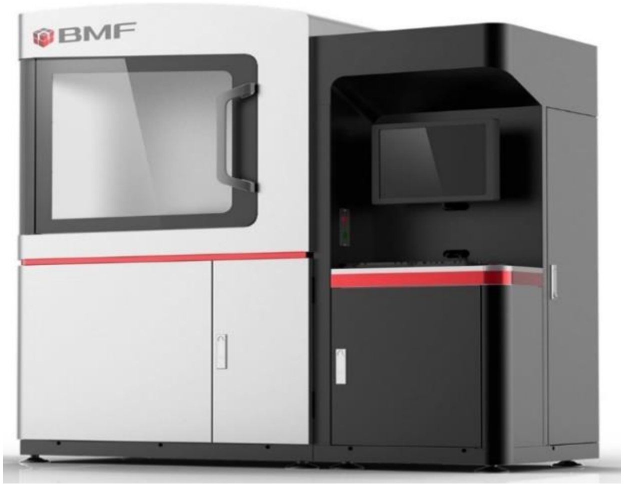

Figure 2: The NanoArch series device of BMF Material Technology company [23].

3. FABRICATION

3.1. Electro-Thermal Actuator Design

Design processes were carried out before going into fabrication processes. After the design process is finished, our STL format with the 3D printer will be produced. Figure 3-a shows the 3D design of the actuator. This design will be produced with a 3D printer. Since the right and left parts of the actuator are symmetrical, the dimensioning is given as in Figure 3-b. All dimensions of the actuator are shown in Table 1.

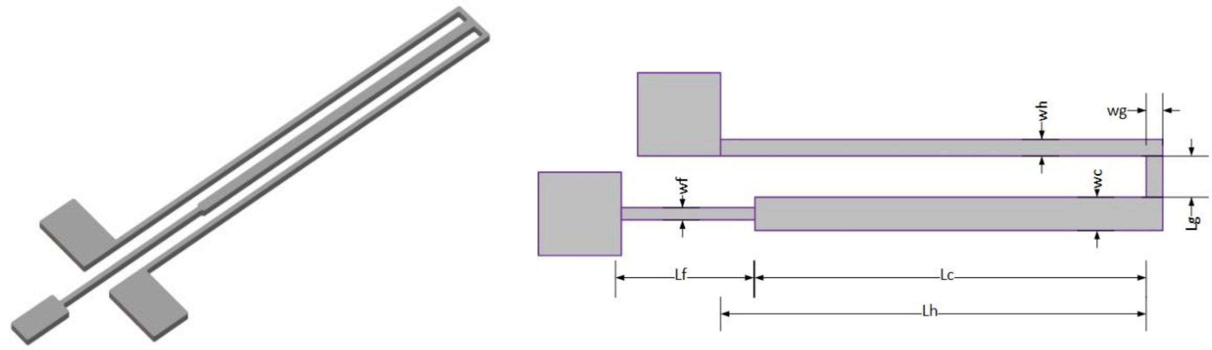

Figure 3: **a)** CAD design of the actuator, **b)** Dimensioning of the Electro-Thermal Actuator with symmetrical structure.

Table 1: The dimensions of the 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

It is a polymer which is the conductive property of the material used in a 3D printer. All properties of this material are shown in Table 2.

Table 2: Physical properties of polymer material [22]

Parameter	Symbol	Value	Unit
Photosensitive Resin Density	D	0.89	$g/(cm^3)$
Young's Module	E	$0.9x10^9$	GPa
Poisson Ratio	v	0.89	-
Thermal Conductivity	k_p	$0.04x10^{-4}$	$W.\mu m^{-1}.C^{-1}$
Refractive index	n	5.48	-

3.2. Fabrication of Electro-Thermal Actuator

For fabrication, the silicon wafer was coated with silicon nitride. Silicon nitride is known as the sacrificial layer. So it is the soluble layer. After printing, this layer is removed with a liquid. Because this step required more time and processing, the ready-made coated wafer was used. Then printed with the 3D printer, as shown in Figure 4.

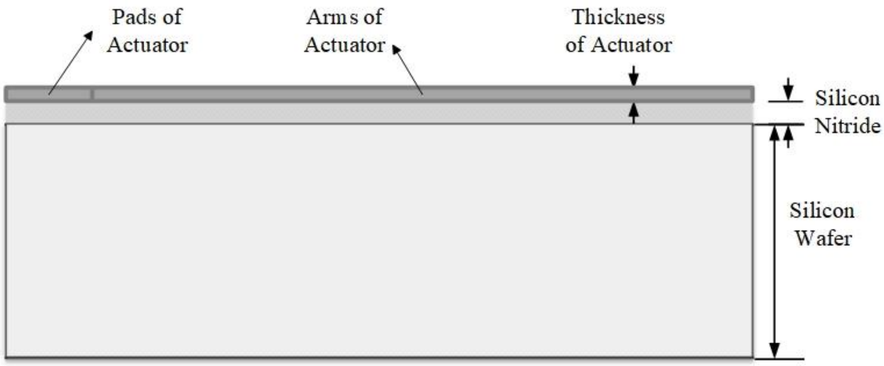

Figure 4: Printing the Elecro Thermal Actuator on the silicon wafer

The produced actuator was taken with the camera of the 3D printer in Figure 5. As can be seen from the image, successful results were obtained in the micro dimension.

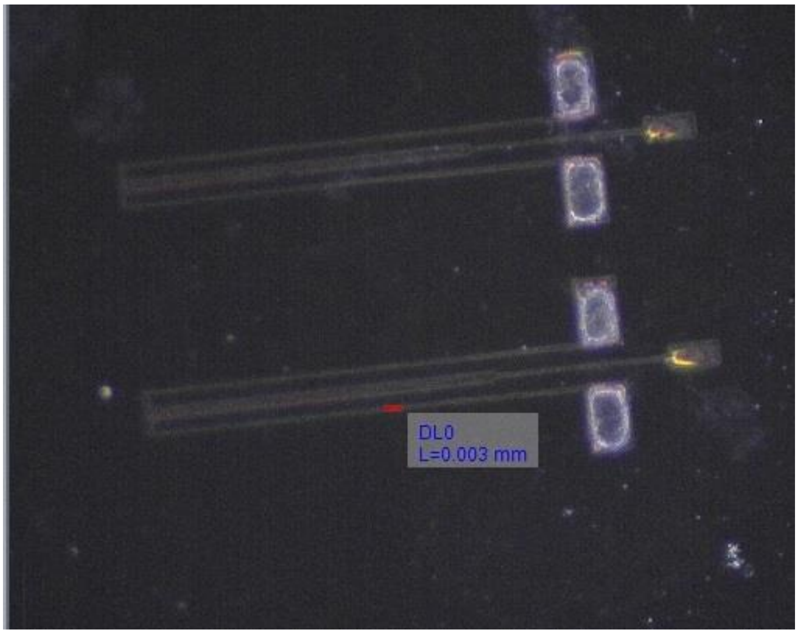

Figure 5: Top view of fabricated Electro-Thermal Actuator obtained by 3D printer camera

4. CONCLUSIONS

Many companies and organizations are conducting R & D studies because traditional MEMS fabrication methods take considerable time, require many operations and high cost. Besides, professional personnel is also required in traditional MEMS fabrication. Because some operations are quite tricky, all these negative reasons have led to the development of some techniques. In particular, studies on 3D printers are increasing day by day. Until a few years ago, the production of MEMS with 3D printers was only possible in theory.

In this study, Electro-Thermal Micro Actuator was produced by using PμSL based 3D printer. Production of MEMS with 3D printers is very advantageous in terms of time, process, and cost. There is also no need for professional personnel due to being a single device. When the experimental studies are examined, it is seen that 3-micron length structures are produced very clearly.

With this study, it was concluded that nano level fabrication would be possible with 3D printers in the following years. It is also claimed that 3D printers will replace traditional MEMS production methods.

ACKNOWLEDGMENT

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