

Development of Micro-lens array using Micro-EDM and Micro-Molding process

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Abstract- This research paper illustrates the simple and effective method for the fabrication of Poly(dimethylsiloxane) PDMS spherical convex micro-lens array. The research is consist of two main fundamental processes i.e. fabrication of micro-lens array mould cavity (master-mould) using micro-EDM and development of PDMS micro-lens array using micro-molding technique. Firstly a master mould array containing 25 concave hemispherical profiles using Micro-EDM process of diameter 190 micrometers and depth of 95 micrometers is fabricated. In second stage a 5 X 5 array of micro-lens of PDMS material is developed using the above machined master mould by micro-molding technique. Scanning electron microscopy (SEM) and optical observations confirms that the fabricated PDMS arrays are produced without defects and good surface finish. This method of fabrication is simple, productive and cost effective. Only the problem is control over the bubbles generation during curing of PDMS.

Key Words- Poly(dimethylsiloxane), Degassification.

I. INTRODUCTION

Micro-lens array contain multiple lenses formed in a one-dimensional or two-dimensional array on a supporting substrate. Refractive micro-lenses cover a range of 10 μ m to 2mm lens diameters. A micro-lens is a small lens, generally with a diameter less than a millimetre (mm) and often as small as 10 micrometres (μ m). A typical micro-lens may be a single element with one plane surface and one spherical convex surface to refract light. They are an interesting alternative for all applications where miniaturization and reduction of alignment and packaging costs are necessary.

Refractive micro-lenses are manufactured in Fused Silica or Silicon using standard semiconductor technologies. To date various fabrication methods have been proposed for polymer Micro lens arrays. Some examples are soft replica molding [1], electromagnetic force-assisted UV imprinting [2], Laser micromachining [3], photo resist melting [4], Gray scale mask photolithography [5], micro jet fabrication [6] and polymer electro deposition [7], reactive ion etching[8], etc.

In recent years micro lens arrays have played an important role in the field of micro-optics. Micro-lens arrays (MLAs) are basic components of many optical devices that are widely used in optical communication systems and optoelectronics. There are Extensive applications such as charge-coupled device cameras, Flat panel display, Light-emitting diode array, micro-scanning System, fibre coupling and optical communication, etc.[9-11]. Sensors, communications, metrology and medical imaging, Beam collimation and focusing, astronomy, telecommunications and optical switching, industrial manufacturing, hybrid sensors and defence and security applications are heavily reliant on optical lenses and micro lens array integrated components [12][13-23].

This research describes the new fabrication technique of fabricating Poly-dimethylsiloxane (PDMS) spherical convex array. This is basically a two-step process i.e. 1. Fabrication of micro-lens array mould cavity (master-mould) using micro-EDM and 2. Development of PDMS micro-lens array using micro-molding technique. Micro-EDM process includes fabrication of the micro-lens array mould cavity (i.e. master mould) using spark-EDM whereas micro-molding process consists of generating the micro-lens array from the above machined mould using micro-molding technique. The surface profile of generated micro-lens array is checked with the help of Scanning electron microscope (SEM).

II. FABRICATION PROCEDURE

Fabrication of micro-lens array by micro-EDM and micro-molding is not a single process but series of processes which are divided into two main parts as follows.

A. Micro-EDM Process:

In this stage, modeling of micro-lens array cavity as per our dimensions is performed on a 3D modeling software Auto-CAD. Fig. 1 shows the 2-D view of micro-lens array cavity which consists of 5 X 5 array of 25 lens profile cavity of having uniform depth of 95 μm and diameter 190 μm .

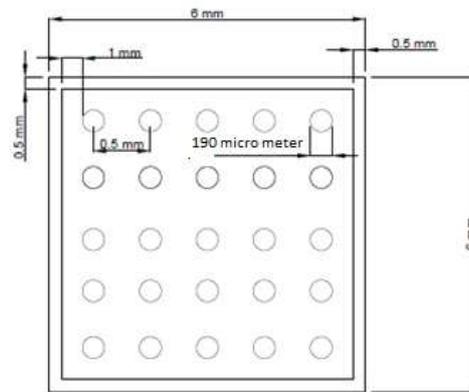
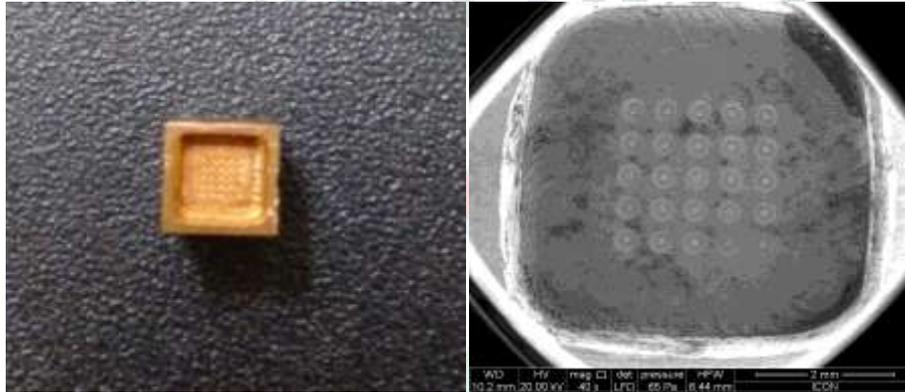


Fig. 1 2-Dimensional schematic of micro-lens array mould cavity to be fabricated using micro-EDM
(Source: Auto-CAD Drawing, D.M.C.E., Navi Mumbai).

Component was fabricated using precision Spark EDM machine. It is a conventional EDM machine in which feed can be given manually in all X, Y, and Z axes. Fig. 2 shows the micro-lens array mould cavity (i.e. master mould) machined using above Spark EDM machine and its SEM image.



i. Micro-lens array cavity in Copper ii. SEM image of the micro-lens array cavity

Fig. 2 Geometry fabricated by micro-EDM machine

B. Micro-molding Process:

Micro-molding process is a process where polymer used as a material for micro-lens array is poured in to already fabricated mould and further post treatment is carried out in order to obtain final micro-structure. The polymer used for the fabrication of micro-lens array is polydimethylsiloxane (PDMS) which is a bio-compatible material and highly viscous flowing fluid. This process involves number of processes like mixing of material, curing and peeling as described below-

1. The PDMS used in this work is Dow Corning Sylgard 184 elastomer kit, a two-part heat curable system. Curing agent and PDMS base was mixed in a clean container in 1:10 proportion with spatula.
2. As after mixing PDMS with curing agent, some bubbles were generated which need to be removed otherwise the lens array which will be fabricated will have bubbles in it. Thus, in order to remove bubbles, above mixture was filled inside the Micro-lens array cavity obtained from Micro-EDM process as in step A and the whole component was kept inside vacuum chamber for 3-5 minutes.
3. After a clear bubble free mixture was visualized through inspection glass of vacuum chamber, next step is curing inside the oven [24].
4. Curing was done by placing the component in hot air oven at 100°C around 25-30 minutes. After curing, component was allowed to cool down at room temperature outside the oven.
5. Once PDMS cooled down, steady pressure was applied in order to peel of the PDMS completely from cavity. The component was peeled off carefully from the cavity with the help of blade, needle.

Fig. 3 shows the Degasification process set up and component inside vacuum chamber.



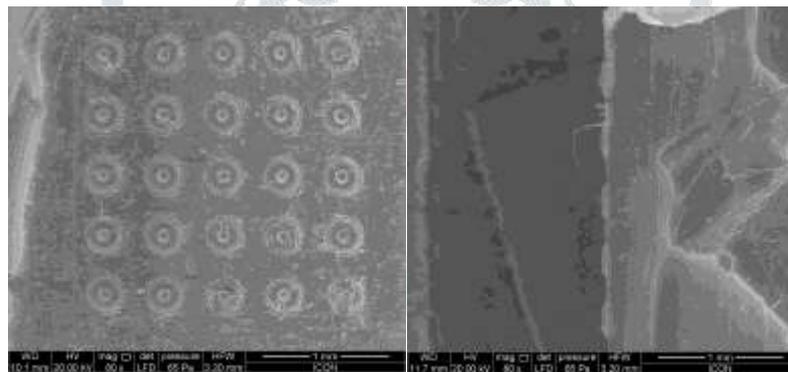
a. Degasification Set-up b. Component in vacuum chamber

Fig. 3 Degasification Process

III. RESULTS

After fabrication of micro-lens array, checking of the surface of micro-lens array was carried out. Checking was done on PDMS micro-lens array in order to ensure that the surface of the lens has good surface finish and it should not contain any air bubbles trapped inside it. Also to check the diameter of each lens is as per our requirement. For checking the surface finishing and dimensions of the machined component, SEM image of the fabricated micro-lens array was taken at ICON Analytical laboratory in Worli, Mumbai.

Fig. 4 shows the SEM images of the fabricated PDMS Micro-lens array.



a. Top view of Micro-lens array b. Side view of Micro-lens array

Fig. 4 SEM images of Micro-lens array

Observations from the Experiment:

1. While mixing PDMS base with the curing agent, one care is to be taken that they should be mixed in proper proportion otherwise the final micro-structure will not be rigid and it will be difficult to peel and curing will not be proper.
2. Proper degasification should be done otherwise the component which will be fabricated will have bubbles in it which will be considered as defect. Initially while fabricating lens array, PDMS material was poured over the cavity without removing bubbles, it resulted in the component having bubbles as shown in Fig. 6.
3. As PDMS material is highly inert so it is always beneficial to use a freshly prepared mixture.
4. Proper curing is very necessary because if PDMS is not properly cured then peeling becomes difficult and the material sticks to the equipment used to peel the PDMS.
5. Proper, clean environment is necessary for the fabrication because it may introduce dust particles to the fabricated micro-lens array.
6. Once micro-lens array is fabricated it should be preserved in a closed and clean environment.

Fig. 6 shows that the final structure will consists of bubbles if PDMS material inside the master mould is not degassed.

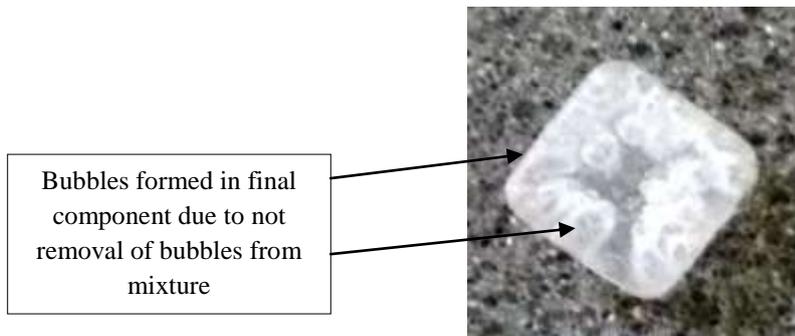


Fig. 6 Bubbles produced in component due to improper degasification of PDMS.

IV. CONCLUSION

Very simple and effective method for the fabrication of Poly(dimethylsiloxane) PDMS spherical convex micro-lens array is performed here. Basically two main processes i.e. fabrication of micro-lens array mould cavity (master-mould) using micro-EDM and development of PDMS micro-lens array using micro-molding technique are performed for the fabrication of Micro-lens array. Master mould array containing 25 concave hemispherical profiles of size $\text{\O} 190\mu\text{m}$ and depth of $95\mu\text{m}$ is fabricated using Micro-EDM process. In second stage a 5×5 array of micro-lens of PDMS material is developed using the above machined master mould by micro-molding technique. Scanning electron microscopy (SEM) images confirms that the fabricated PDMS arrays are produced without defects and good surface finish and as per required dimensions. This method of fabrication is simple, productive and cost effective with few precautions to be taken care of during the whole process. Proper mixing of PDMS base with curing agent is important so as to get the rigid component without any distortion. Degasification of the PDMS material after filling it inside the master mould should be performed compulsory in order to develop defect free component.

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