ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering, Volume VII (XVII), 2008

ABOUT FABRICATION OF MICROLENSES ARRAYS

Adrian P. POP[1], Petru UNGUR[1], Gheorghe BEJINARU MIHOC[2]
[1]University of Oradea, e-mail: adippop@yahoo.com; pungur@uoradea.ro
[2] "Transilvania" University of Brasov, e-mail: bejinaru@unitbv.ro.

KEYWORDS: array, deep lithography, micro hot intrusion, microlens.

ABSTRACT: This paper has presented some fabrication techniques of microlenses arrays, such as: technology of Deep Lithography with protons- adapted injection molding and vacuum casting, proton irradiation, micro hot intrusion process, excimer laser ablation. Also, has presented some characteristics of these fabrication techniques of microlenses.

1. INTRODUCTION

The miniaturization of components has been a common objective in all studies. Miniaturizing devices using micro-optics promises to revolutionize many electro-optical systems – from video cameras, video phones, compact disk data storage to robotics vision, optical scanners and high-definition projection displays, etc. Both higher accuracy and lower cost microlenses fabrication methods are necessary to meet the rapid demand for these commercial devices.

The microlenses represent the key elements in optical Microsystems and the majority of them are made of plastic materials, in common MEMS (Micro-Electro-Mechanical Systems) applications. MEMS technology offers a wide variety of applications for the military, industrial, and consumer markets. Large academic and research institutions have been involved in the development of MEMS technology and commercial products.

MEMS are miniaturized electronic and mechanical components. Bulk micromachining, surface micromachining, and LIGA (Lithography, Galvanoformung, Abformung) techniques are used to create these microstructures. LIGA, meaning lithography, electroplating, and molding, is a micromachining process that is capable of yielding structures with high aspect ratios. Mechanical devices such as: beams, pits, gears, membranes and even motors have been fabricated using LIGA for a variety of applications that have mainly included sensors and actuators.

MEMS devices offer the obvious advantage of miniaturization, which saves space, energy, and weight, but they also have the potential to reduce cost since thousands of these devices can be fabricated on a single wafer. The MEMS structure offers many potential advantages. For example, it's possible to construct a MEMS-tunable VCSEL or place a VCSEL onto a polysilicon-MEMS micromirror and steer the VCSEL.s beam output. VCSELs-Vertical Cavity Surface Emitting Lasers- are semiconductor lasers that emit a beam of light perpendicular to their planar surface, which are micro-optical devices.

This paper has the goal to presents certain fabrication techniques of microlenses arrays and them characteristics.

2. FABRICATION OF MICROLENSES ARRAY

The technology of Deep Lithography with Protons (DLP) is a high-precision rapid prototyping technology for the fabrication of 3D monolithic micro-optical elements and micro-mechanical structures in PMMA. With this technology, different optical components can be structured in one block to form monolithic micro-optical modules. Also, mechanical positioning and support structures can be integrated. This approach is unpractical for mass fabrication because an irradiation session, to obtain a single component, can take several hours. By using the DLP elements as a master element, it's possible to obtain replicas via different methods: with a LIGA-adapted injection molding technique and through vacuum casting.

Vacuum Cast Molding,

It's a relatively new development in polyurethane prototyping [5], uses familiar principles with new materials to further enhance, the accuracy of prototypes. The original part is embedded in a vulcanizing silicone (Fig.1-c), and placed inside a vacuum chamber (Fig.1-a) to de-aerate the silicone. This results in a very accurate replication of the part features. After curing, the mold is cut apart and the master element is removed. The master component will remain intact, which is an important advantage, and its can be reused for other replications. Then, mold is taped together and inside a vacuum chamber, a two- component resin is poured inside the prepared mold. After curing the resin it's demolded, resulting in a copy of the original part (Fig.1-d).

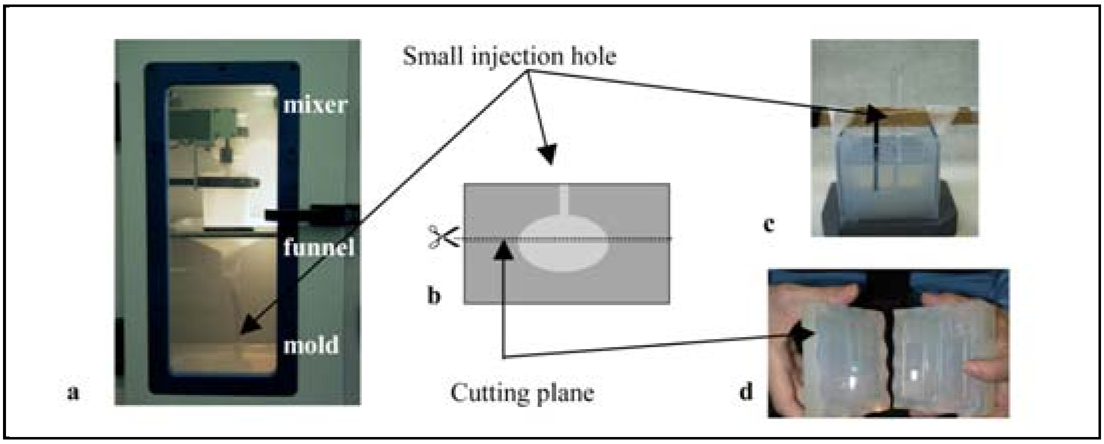

Fig.1. Vacuum casting process, where: a-Vacuum casting machine, b-Drawing of silicone mold, c-Embedding of the master component in silicone rubber, d-Opening of the mold to remove the replicated part in polyurethane.

For the replication has used polyurethane with an index of refraction n=1.515, a transmission efficiency of 93.7% and a thermal conductivity k=0.208 W/mK [5]. It's important to obtain predictable shrinkage conditions from process parameters. The results of micro-lens array made by DLP technique from micro lenses with diameter of 200 µm and different sags, were copied with the vacuum casting technique (Fig.2-a).

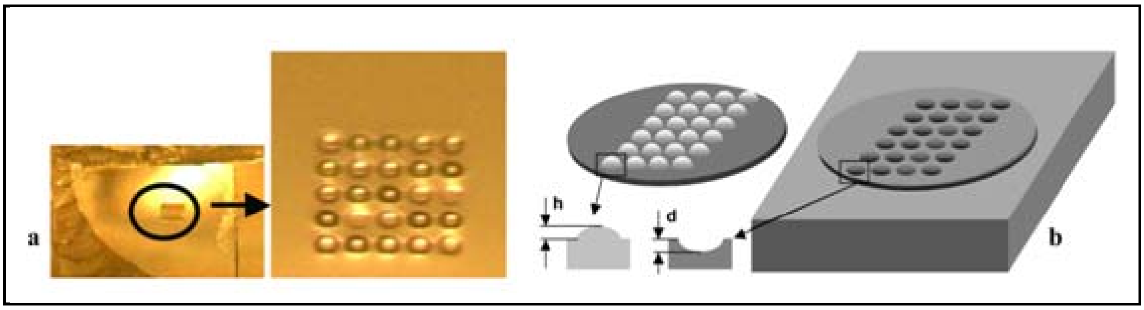

Fig.2. Vacuum casting of a DLP micro lens array, where: a-Picture of the rubber mold with a 5x5 micro lens array, b-Master of the micro lens array and the fabricated rubber mold.

From measurements has observed that the depth-d of the micro lens is 0.2% higher than the sag-h of the lenses on the master. This corresponds with the expected shrinkage of the silicone rubber. After replication, the sag of the replicated lenses is 1.25% higher than the original ones on the master, with tendency for future to reduce the difference between the original and the replicated micro lenses.

Proton Irradiation

2D arrays of spherical micro-lenses together with micro-prisms and cylindrical micro-lenses or mechanical positioning structures like 2D fibre array holders are likely to be combined with opto-electronic emitters, receivers and optical fibres to play a key-role in optical sensor arrays, in high definition display and projection systems, in biomedical and invasive medical technology and in optical interconnection and telecommunication technologies. The concept [6] of this technology is based on the proton irradiation of a sample, made of linear high molecular weight poly (methylmetacrylate) (PMMA), will result in an important reduction of the molecular weight of the material located in the irradiated zones. These irradiated zones feature a higher solubility than the bulk material and they can be selectively etched using a special solvent (Fig.3). This procedure allows the fabrication of 2D arrays of microholes, rows of smoothly curved cylindrical micro-lenses and optically flat micro-mirrors and micro-prisms. Also, alignment features and mechanical support structures can be fabricated with this procedure.

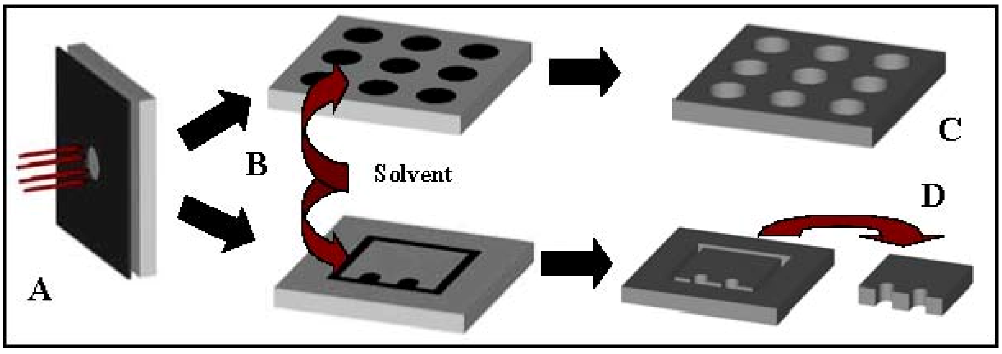

Fig.3. The basic processing steps for the fabrication of micro-hole arrays (C) and more complex 2 1/2 dimensional structures with high optical surface quality (D): Irradiating the PMMA-layer through an accurate pinhole (A) and etching the irradiated zones in a selective solvent (B), [6].

Its can swell the irradiated domains using a monomer vapor, which for circular footprints will result in hemispherical surfaces (Fig.4). This process permits the fabrication of stable spherical micro-lenses with well-defined heights.

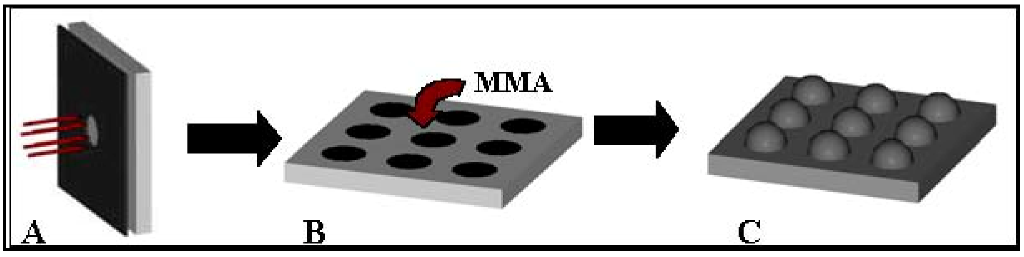

Fig.4. The basic processing steps for the fabrication of 2D arrays of stable and uniform spherical micro-lenses (C): Irradiating the PMMA-layer through an accurate pinhole (A) and applying a MMA-vapour on the surfaces of the irradiated sample (B), [6].

Micro-hot intrusion process

The process flow of the micro intrusion process has presented in Fig.5 [2]. First, a standard LIGA process is used to make the mold inserts. In the prototype demonstration, these molds are provided to make nickel mold insert with circular openings of 80 μm in diameter and of the depth of the mold insert is 200 μm. A sheet of PC (Polycarbonate) film of 500 μm in thickness is placed underneath the mold insert as shown in Fig.5-(a). They are pressed firmly at an elevated temperature that is higher than the glass transition temperature of the PC film (140^{o}C to 150^{o}C). When an adequate pressure is applied, the plastic material deforms and intrudes into the circular openings as shown in Fig.5-(b). At the end of the process, the silicon substrate that comes with the LIGA mold insert can be released by etching the seed layer on the LIGA substrate presented in Fig.5-(c) for further processing or the plastic microlenses can be demolded as shown in Fig.5-(d).

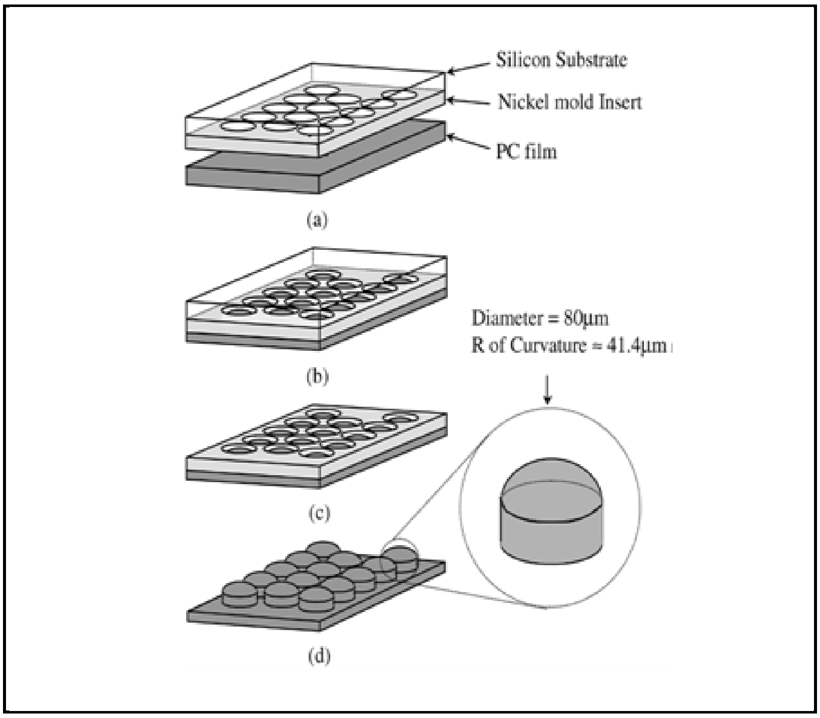

Fig.5. Fabrication sequences of the micro-hot intrusion process, where: (a)-Mold insert and polycarbonate film, (b)-Micro-hot intrusion under elevated temperature and pressure, (c)-Release of the silicon substrate if an LIGA mold insert is used, and (d)-Release of plastic lenses, [2].

Excimer Laser Ablation

The working parameters of excimer laser included laser energy, shot number, scanning velocity and pulse repetition rate [7]. The relationship between these parameters can be expressed as

$$H = \frac{SV}{f} \qquad (1)$$

, where: f-is laser frequency, S- laser shot number, H-height of mask pattern in scanning direction, V-scanning velocity. When a larger H is exposed to the laser beam energy, deeper workpiece ablation thickness will be the result. Based on the above, mentioned facts, different mask patterns can be designed to obtain patterns with various H-dimensions

The laser energy profile in the mask pattern in terms of the laser shot number can be calculated, with which the 3-D microstucture can be analogously predicted.

$$D \propto S \tag{2}$$

, where: D-is ablation depth. The depth is a function of S and K. K can be treated as a calibration number. It's a function of the material thermal and photochemical properties. The relationship can be expressed as follows:

$$D \propto KS \tag{3}$$

, where: K-is thermal and photochemical properties. Based on Eqs. (2) and (3), as long as the mask pattern is defined, the 3-D microstructure produced using laser ablation can be predicted.

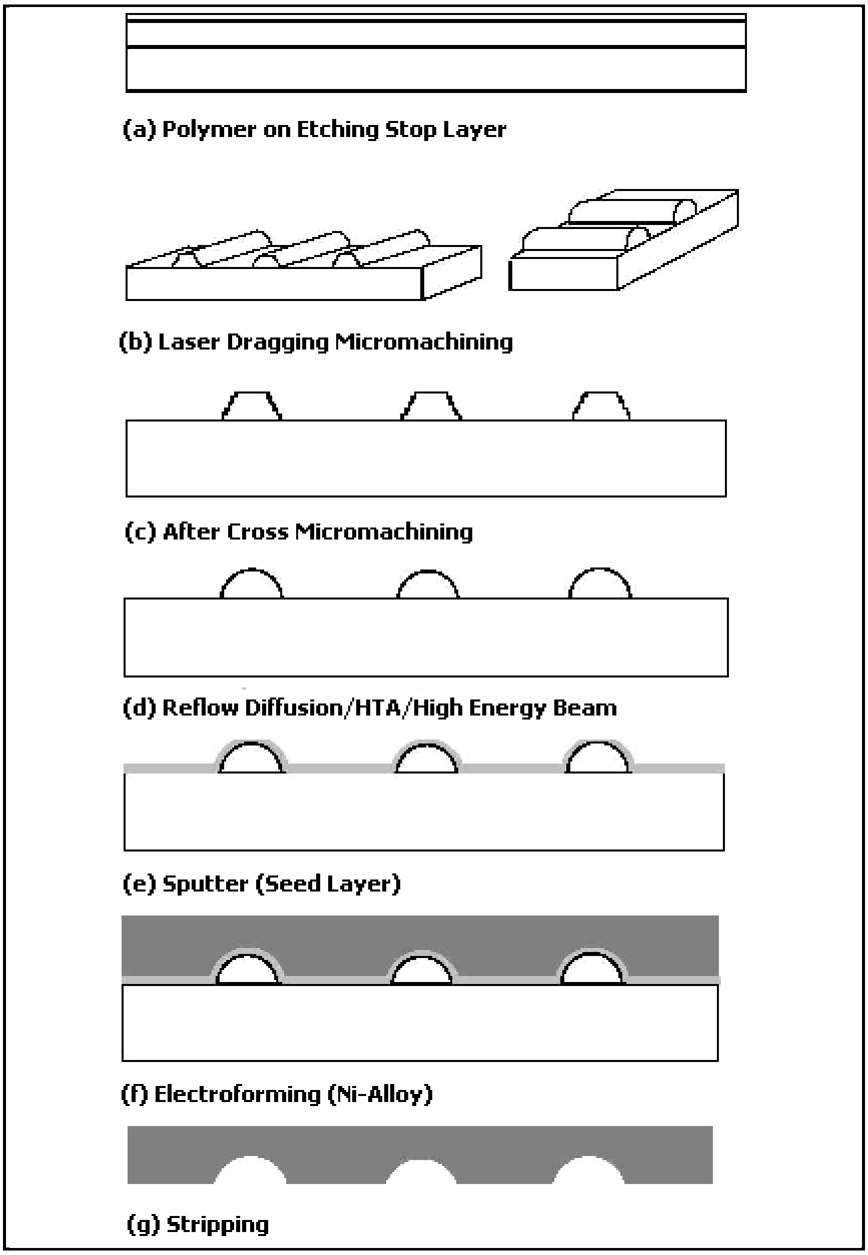

Fig.6. Schematic drawing of the laser ablation fabrication process [2].

In laser ablation processing: the liquid PI is spun on 100 mm wafers at different rotational rates resulting in controllable PI thin film thickness [2]. Then, the curing process is followed by the spin process, due to obtain concrete films. The laser dragging method with various laser energy, repetition rate, and shot numbers are applied to form the 3-D microstructures via laser ablation. To enhance the surface smoothness, a thermal reflow process is then properly applied.

3. CONCLUSIONS

This paper has presented certain fabrication techniques of microlenses arrays. A main role in microlens array has got by its radius of curvature, which must be controlled for assured quality image and preventing loss signal.

From fabrication techniques of microlenses arrays, the most accuracy and quality process has represented by excimenter laser ablation.

4. REFERENCES

[1] LUCA-MOTOC, D., BEJINARU-MIHOC, GH., POP, P.A., NOVAC, M.N.: “Materiale si Semifabricate Optice”.Vol.I-Sticla Optica, Transilvania University of Brasov Editor, ISBN 973-635-515-2, Brasov, 2005.
[2] PAN, L.W, et al.: “Microplastic Lens Array Fabricated by a Hot Intrusion Process”, Journal of Microelectromechanical Systems, Vol. 13, No. 6, December 2004, pp.1063-1071, 2004.
[3] POP, P.A.: “Optica Tehnica”, University of Oradea Editor, ISBN 973-673-590-X, Oradea, 2004.
[4] Royall, C.W., et al.: “Microjet Printing of Micro-optical Interconnects and Sensors”, SPIE Phot. West Proc., V. 3852, p.400-407, 2000.
[5] TUTELEERS, P., el al.: “Investigation of the replication quality of plastic micro-optical interconnection components”, s01p073.pdf., pp.1-4, 2001.
[6] VYNCK, P., et al.: “Beam Monitoring Enhances Deep Proton Lithography: Towards High-Quality Micro-Optical Components”, paper LEOS 9dec2002 P_Vynck.pdf., pp.1-4, 2004.
[7] YANG, H., PAN, C.P.: “Analogous Micro-optical Components Fabricated Using Excimer Laser Ablation”, Tamkang Journal of Science and Engineering, Vol. 6, No. 3, pp. 145-150, 2003.