

Innovative Patterning Techniques and Polymer Based Materials for Micro Optical Applications

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Micro optics technology has been shown to improve the capabilities of a wide range of applications. Development of sensors is one of the most relevant applications since optical approaches can provide lowest limit of detection (LoD). Two of the most used components for these optical devices are microlenses and waveguides. Both have been applied in research field to a variety of sensors and more complex optical devices. Nevertheless, fabrication methods to develop these structures are mainly based on micro-electronic technologies and are limited to the substrates sizes and materials that are used in that field. Moreover, usually complex technological processes are involved, resulting in high fabrication costs. This article reports about alternative patterning approaches like Direct Laser Writing (DWL) and Ink-Jet Printing (IJP) using specifically tailored polymers for the production of micro optical elements.

The ACAPOLY approach

Since the early 2000, industry has shown a considerable interest in the use of micro optical devices. The advent of cell phone cameras extensively pushed market needs for micro lenses and supported developments like the Wafer-Level-Camera Technology [1]. In the telecom/datacom sec-

tor, optical backplane concepts based on polymer waveguides have been successfully implemented using multi-mode VCSELs with a suitable micro lens system to achieve transmission rates of 10 Gbits/s [2]. Nevertheless, some applications require larger substrate size, different substrate material, topographic or curved surfaces, flexible substrate materials and/or low fabrication costs, thus limiting the use of standard patterning techniques like photolithography. Therefore, it is necessary to propose novel fabrication methods in order to solve these challenges.

Within the framework of the European project "ACAdemia and Company collaboration and technology transfer in Advanced POLYmers" (ACAPOLY, grant no. 218075, 2008-2012) the partners micro resist technology GmbH (Germany) and the Ecole Polytechnique Federale de Lausanne (Switzerland) aim to develop a new set of polymer materials for micro/nanosystems technologies that are well suited for non-conventional patterning techniques. These new polymers, based on modified epoxies and hybrid organic-inorganic materials, will be optimized for structuring using DWL and IJP techniques. Both technological processes present advantages compared to classical batch-based microelectronic tech-

nologies and allowing fast prototyping of new devices.

Ink jet printing of micro lenses

Different optical applications require different sets of materials. Moreover, the polymers have to be adapted to the patterning technique. For micro IJP, the viscosity and the surface tension of the material are important and need to be adjusted to generate stable and reproducible drops depending on the aperture size and the type of the nozzle. As inks, epoxy resin based material, diluted in appropriate solvents are used with a viscosity of less than 20 mPas, which turned out to give an excellent drop formation both in the continuous and in the Drop-On-Demand (DOD) mode. In the continuous mode, the drop ejection frequency, stage scan speed and dwell time determine the shape of the final pattern. Conversely, the DOD mode enables the fabrication of fully arbitrary patterns, because the drops can be ejected individually at arbitrary times and on the desired position. The ink-jet material itself, like epoxies [3], has a high transparency at wavelengths > 400 nm, which makes it easily applicable for integrated and refractive optics. As the jetting tool, we used a piezo-actuated ink-jet printer head (micro-

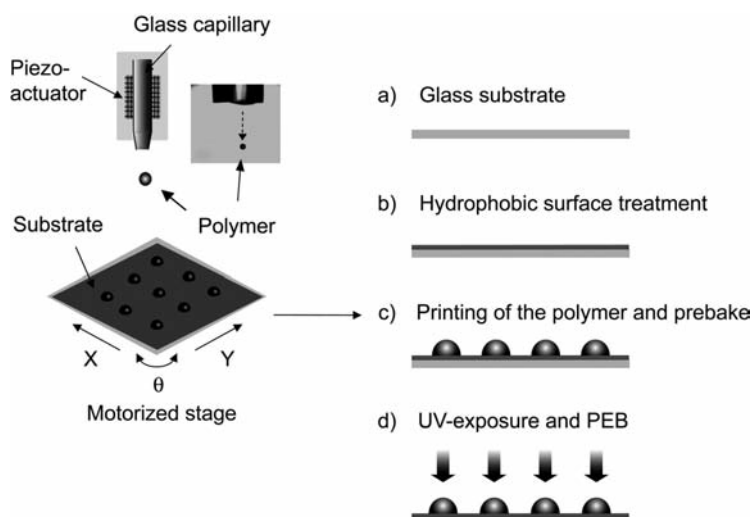


Figure 1: Schematic diagram of the DOD ink-jet printing and the process flow used to fabricate micro lenses.

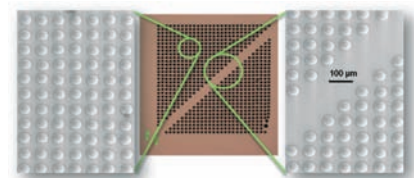


Figure 2: Images of inkjet epoxy resin based micro lenses on hydrophobic treated glass substrate. Each single lens is composed out of 1 drop of a size of 50 µm. Some jetting defects are clearly visible.

drop technologies, Germany) having a nozzle aperture of 50µm with a heated nozzle tip. The micro drops are observed via a stroboscopic camera system. After deposition, the drops are pre-baked, UV-exposed (i-line) and post exposure-baked. The process schematic is sketched in fig.1.



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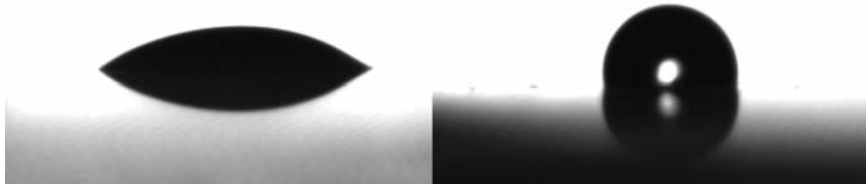


Figure 3: Side view of printed micro lenses on a pure glass surface (left) and on a hydrophobic-treated surface (right)

Figure 2 displays a regular pattern of ink-jet printed cured epoxy resin based micro lenses in the DOD mode. The influence of the substrate conditions, resulting in different wetting angles and thus in different lens geometries, is shown in figure 3. Consequently, lens dimension is tailored by surface tension of the material and the substrate condition.

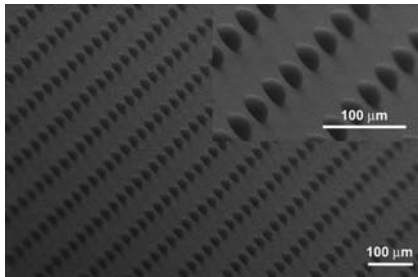


Figure 4: SEM images of ink-jet printed hybrid polymer based micro lens arrays (part of 64 x 64) on a hydrophobically treated glass substrate

Highly viscous, UV-curable, organic-inorganic hybrid polymers [4] have been targeted as jetting materials as well. Since the refractive index of these hybrid polymers can be tuned by modifying the syntheses conditions, they are of great interest for micro lens production. In figure 4, a printed micro lens array indicates the capability and the high accuracy not only of the microdrop system, but also of the reliability of the material. The diameter and the height of the microlenses are 53 μm and 12 μm , respectively. This results in a focal

length of 64 μm and a numerical aperture (NA) of 0.41.

Laser patterning experiments

Direct write patterning strategies are widely employed for photomask production, small volume customer specific wafer fabrication and template production for further replication processes. For epoxy based resists, experience of DWL exposure techniques, especially at higher wavelengths, is still rare. For the experiments, which aim for building up optical waveguides, we used the laser system DWL200 (Heidelberg Instruments GmbH) operating at 413 nm (Kr⁺-source). The issue of low absorption of available epoxy resin based resist at these energies was answered by adding specifically tailored photo sensitizer to the material. Checking the resolution and the pattern fidelity, several test patterns with a film thickness of 3 μm have been analyzed (figure 5). Although the sensitivity of the polymer still needs to be improved to achieve economic patterning conditions in terms of writing time and a mature process setup, the results already show the interesting capability of DWL for patterning negative tone resist.

Conclusion

Smart materials, based on epoxy resins or and hybrid organic-inorganic hybrid materials, offer exciting opportunities for customer demand

patterning strategies. The approach for micro lens production appears to be much more economical, since the typical manufacturing process via photoresist reflow and subsequent etch transfer into appropriate substrates is now replaced by direct lens patterning in polymers, which reduces the number of process steps significantly. Though detailed processes and synthesis parameters must to be understood more in detail, IJP and DWL techniques already show their capabilities for micro optical applications using newly developed polymer systems.

References

- [1] R. Voelkel, J. Duparre, F. Wippermann, P. Dannberg, A. Bräuer, R. Zoberbier, M. Gabriel, M. Hornung, S. Hansen, R. Suess, Technology Trends of Microlens Imprint Lithography and Wafer Level Cameras (WLC), Proc. MOC'08, Conf. On Micro-Optics, Brussels (2008)
- [2] F. Mederer, R. Michalzik, J. Guttman, H.-P. Huber, B. Luttnitz, J. Moisel, D. Wiedemann, 10Gbit/s data transmission with TO-packaged multimode GaAs VCSELs over 1m long polymer waveguides, Opt. Comm.206, pp. 309-312 (2002)
- [3] V. Fakhfour, N. Cantale, G. Merroum, J.Y. Kim, D. Boiko, E. Charbon, A. Martinoli and J. Brugger, Inkjet Printing of SU-8 for Polymer-based MEMS- a Case Study for Microlenses, Proc. 21st IEEE International Conference on Micro Electro Mechanical Systems 2008, p. 407-410
- [4] C. Sanchez, B. Julian, P. Belleville, M. Popall, Applications of hybrid organic-inorganic nanocomposites, J. Mater. Chem., 15, 3559 (2005)

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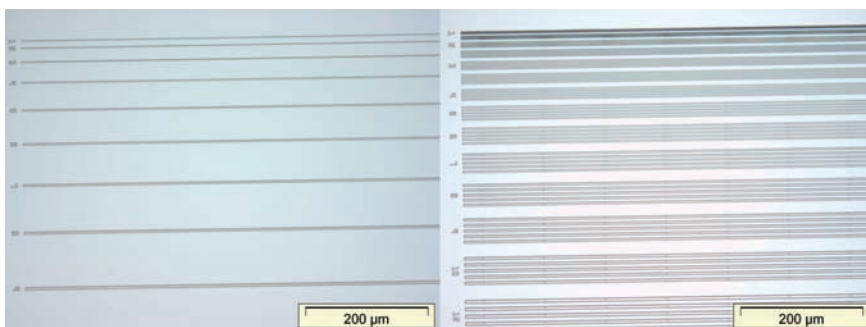


Figure 5: Test pattern of epoxy resin based material exposed with a laser power of 340 mW, dense and iso line/space structures. Isolated lines can be resolved down to 1 μm line width, where for dense line designs 2 μm equal line/space patterning seems to be the resolution limit.