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Tool System for UV induced micro moulding of biomedical disposables

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Abstract
A new approach for the generation of double-sided microstructured polymer films is presented based on injection-molding of urethane- and epoxy-based acrylates that are polymerized by irradiation with ultraviolet light (395 nm). Compared to hot embossing, this offers not only working under ambient conditions, but also a reduction of cycle time as well as flexibility regarding adjustment of the mechanical and/or chemical properties of the resulting polyacrylate film. A setup, consisting of the mold with the microstructured insert and two LED lamps emitting UV-light moved by a controllable stepper motor and a computer-based controller, was installed and successfully used for the fabrication of double-sided microstructured polyacrylate films.

Therefore a new and innovative tool system for 2-component UV induced micro moulding of biomedical disposables was developed. The geometrical dimensions of the microstructures (e.g. fins, channels, sharp edges and slopes) require different technologies to machine the tool inserts. Therefore micromilling and µ-laserablation technologies were used in combination attached by laser polishing operations in special areas. A highly precise, complex designed tool system with mechanically moveable areas is needed to fill the tool with the 2 various chemical compositions. The paper presents the tool concept and explains the investigated surface treatment options.

Keywords: replication, biomedical disposables, micromachining, µ-laserablation, injection moulding,

1. Introduction

The aim of the project was to develop polymer films with a microstructure on both sides and multifunctional surface properties by means of a UV injection moulding process. The background of the application is blood analysis with disposable biomedical sensors. In such microfluidic chips, areas with hydrophilic and hydrophobic properties on the inside of disposables are required. The 2-component UV-induced injection molding approach allows the control of surface characteristics by the material composition. With this in mind a special film injection molding system was developed, which allows filling with different formulations, curing by means of UV light and imaging of the necessary microstructures.

2. Design and development of tool system

The developed tool system shown in figure 1 consists essentially of base plate (1), mold (2), embedded flexible centerpiece (3), glass matrix (taken in frame, 4) and filling unit (5). This makes it possible to produce microstructured, functionalized multilayer polymer films. These are realized by sequential cycles of filling, UV-polymerisation and partial demolding of the flexible/mechanically moveable matrix-patrix system. For this purpose the tool system is closed first by lowering the glass plate and putting on the vacuum. Afterwards the filling of the mold with the first chemical composition via the injectors occurs. Besides the intake also the steady distribution of the formulation is realised by the negative pressure. Following curing with UV-light the centerpiece will be lowered by a slider element (6) that is subsequently working against spring tensions of around 150 µm up to the defined final situation. Thus the suction of the second chemical composition and subsequent the UV-curing can take place. The demolding of the composite films occurs by means of compressed air support.

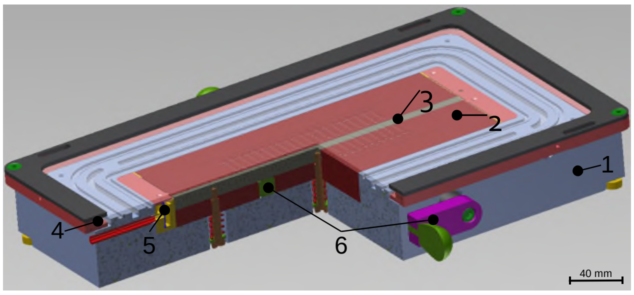

Figure 1. tool system

To prevent the adhesion of the foils in the steel patrix as well as in the glass matrix these were coated. Different surface coatings were examined and the Dursan-coating of the company SilcoTek was chosen finally because of its performance. This inert, wear- and corrosions-resistent layer has a high hydrophobicity, which is an advantage in demolding. Another advantage of this coating is the possibility to coat both, the steel and the glass components of the tool system.

Hardened hot-work steel (X 37 CrMoV 5-1) has been chosen, as it is a typical material for injection molding and hot embossing tools and has a good machinability for laser machining and milling. Soda-lime float glass was chosen for the glass plate, because the transmission measurements showed that it has a good permeability in the wavelength range of the used UV-lamps.

To ensure the functionality of the biomedical disposable sensors, among other things, the structures of the measuring chamber area and of the sample stop channel (SSC) in the mould and middle piece are to be produced. The SSC is made in the mould as a 50 µm wide and 80 µm high web. This is used later for venting the measuring chamber and stopping the sample intake, whereby this effect is to be supported by a hydrophobic material. Another challenge was the production of the ramp in the measuring chamber area. Over a length of 2,9 mm, a height difference of 25 µm has to be produced between start and end point in order to increase the later sample recording speed. In total there are 20 measuring chambers on the tool, whereby the grid dimension between the structures amounts to ca 6 mm.

3. Manufacturing of tool system

3.1. Production of steel patrix

The geometrical dimensions of the microstructures on the one side and the fact that the required molds have to achieve special demands regarding the surface quality and the accuracy of the micro structures on the other side, cause the established manufacturing processes to reach their limits [1]. Therefore different technologies to machine the tool inserts were used, especially micromilling and µ-laserablation technologies were used in combination attached by laser polishing operations in special areas.

The chosen structuring variant was to first produce a large part of the actual geometry by micro milling. Subsequently the very fine microstructures, the bevel and the sample stop channels were created by laser mircostructuring. In this process variant it is decisive to exactly position the individual areas of laser and milling to each other. At structural dimensions < 20 µm the accuracy requirements are often below +/- 1 µm for the positioning of the areas to each other [1, 2]. The workpiece clamping was realized on both machining systems by a highest precision zero-point clamping system EROWA-FTS, which was developed especially for micro manufacturing. The position alignment of milling and laser machining fields to each other was supported by external optical measuring equipment.

Due to the type of process different surface characteristics result in the structuring processes of removal and machining [1, 2]. To achieve defined surface properties and to obtain a defined roughness profile laser polishing was used. In particular for the ramps in the measuring chamber area laser polishing was required in order to achieve high sample recording speeds.

3.2. Production of glass matrix

The textured glass plate, which is picked up in the frame, covers the tool system and closes it, when the vacuum is applied. In addition the glass plate allows curing of the polymer with a UV light source. The microstructuring of the glass plate enables the production of double-sided, microstructured polymer films. On the other hand, this ensures that the glass plate does not rest on the form elements of the steel patrix.

With regard to the structuring of the tool side made of glass, various investigations were carried out with respect to the structuring of glass with ultrashort pulse laser. The corresponding parameter tests had to be carried out in order to realize a process-reliable, efficient and contiguous structuring.

However, the reached surface roughness of the generated strucutres of approximately R_z = 2-4 µm was too large and led to great adhesion problems during demolding. To improve the surface quality and to achieve a targeted smoothing of the surface, the structured areas were laser polished with an CO2-laser.

4. Results

The laser polishing of the measuring chamber area significantly improved the surface quality as shown in figure 2.

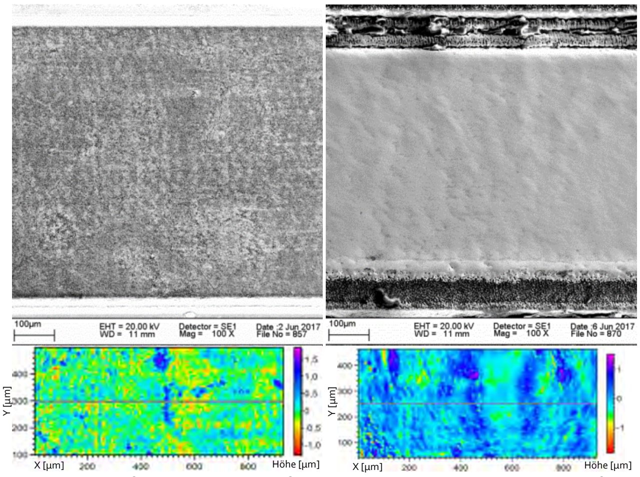

Figure 2. Surface roughness of the measuring chamber area before (left) and after (right) laser polishing

As a result of laser polishing, the surface roughness could be reduced by approximately 44 % to S_a = 0,127 µm. Furthermore, the verification of the manufacturing accuracy showed that the required tolerances could be maintained. Table 1 summarizes the achieved accuracies of the most important geometry features.

Table 1 manufacturing accuracy

Structure	Setpoint [mm]	Result [mm]
SSC	0,050	0,052
grid dimension	5,988	5,987
total grid dimension	113,76 ± 0,03	113,755

Based on the comparison of the two tested coatings (Dursan and Sipolox) the Dursan-coating was chosen. On the one hand, the SEM images of the produced polymer films and of the coated tools showed a significantly more homogeneous and smoother surface. On the other hand, better results could be achieved with the water contact angle measurements compared to the Sipolox coating.

5. Conclusion

In summary, it should be noted that it is possible to produce double-sided microstructured polymer films with multifunctional surface properties by the developed tool system. So the functionality of the tool system could already be proven in the first moulding experiments. The results will be presented in the publication „Microstructured multi-functional polymer chips by UV induced injection molding", which will also be published at the same conference [3].

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