Manufacturing of a Hybrid Piezo-actuator for a Micro-diaphragm Pump by Micro Assembly Injection Moulding

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Abstract

In preliminary investigations at IKV Aachen assemblies of hybrid microsystems have been performed using different materials. The feasibility of the integration of assembly steps into the production process has been proved using micro assembly injection moulding. To analyse the transfer of knowledge based on fundamental researches into an industrial production environment, the overmoulding of a piezo-actuator, which functions as the drive unit of a micro-diaphragm pump, has been investigated.

To be able to evaluate the possible deformations of the piezo-actuator during the overmoulding process, the filling and holding pressure periods of the injection moulding cycle are simulated to gain information of the thermal and mechanical load on the heat and pressure sensible actor-module. After designing and constructing an appropriate micro injection mould the hybrid actor-modules are produced and checked regarding their function. Moreover the bonding quality of the manufactured parts is investigated by attempting short time tensile tests.

Analysis shows that by coupling mould-fill and FEM simulation the various stresses during the overmoulding process can be simulated and thus can support the designing process of the injection mould. A production of functional hybrid actor-modules is possible. Highest pump strokes as one important quality criterion are achieved using high moulding temperatures and low injection rates.

1 Introduction

To produce structures and complex components of plastics, injection moulding is one of the most important manufacturing processes and therefore increasingly used for the production of microsystems.

The rising requirements like increasing miniaturization call for new production strategies to make the manufacture of microsystems more economical. As a result more and more procedures and methods from different micro-technologies are combined and the applicability of alternative materials is being tested [1].

2 Theoretical background and objective

Within the Collaborative Research Centre SFB 440 "Assembly of Hybrid Microsystems" useful insights regarding the fields of application for the micro injection moulding were gained by investigations at laboratory scale.

The project's aim was to test the transferability of the micro assembly injection moulding as a bonding technique in an industrial environment. Subject of the examination is the pilot production of a micro-diaphragm pump, which consists of several polymer components (Figure 1) and therefore excellently represents the typical characteristics of a highly integrated microsystem.

The conveying principle is based on a piezo-electric driven membrane in combination with passive flap valves, which are elements of the middle part. By applying a voltage on the piezo-actuator the membrane bends realising the pumping movement while the flow direction is controlled by the flap valves and the fluidic back pressure.

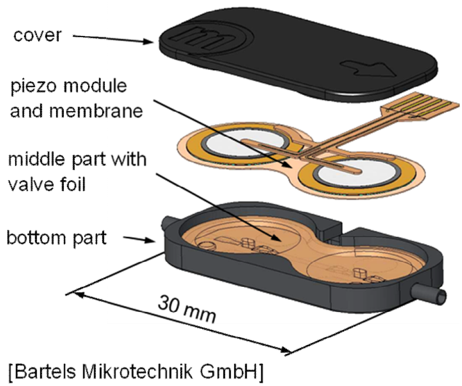

Figure 1: component parts of the micro-diaphragm pump

The production of the micro-diaphragm pump consists of many manufacturing steps. Especially the manual mounting of the piezo-actuator on the membrane extends the manufacturing time and reduces the reproducibility at the same time. Furthermore the elastic deformation of the adhesive layer during the pump process decreases the pumping efficiency.

To realise a shorter process chain and to increase the production accuracy, the manually adhered piezo-module shall be substituted by an injection moulded unit.

3 Component design and optimisation

In order to substitute the manually adhered piezo-module the piezo-actuator shall be integrated in a polymer component (*carrier*) by overmoulding. The carrier fixes the piezo-actuator within the pump and simultaneously translates the bending moment on the pump medium by a thin-walled membrane surface while meeting the geometrical requirements of the housing at the same time. The carrier's geometry is designed and optimised using the mould-fill simulation CADMOULD (Figure 2).

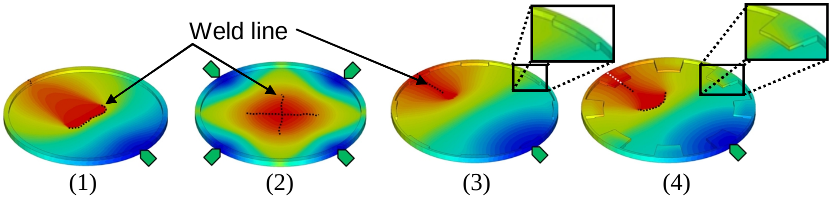

Figure 2: false-colour display of the flow front profile of different Carriers
(1): basic geometry, filled through one gate
(2): basic geometry, filled through four gates (distributed over outer ring)
(3): partial reduced wall-thickness to relocate the weld line
(4): trapezoidal brackets to improve the fixation of the piezo-actuator

In order to guarantee the functionality of the diaphragm-pump it is furthermore necessary to address the thermal and mechanical limitations of the piezo's lead-titanate-zirconate (PZT) ceramic during the overmoulding process. Longer lasting temperature loads above 150 °C (half of the Curie-Temperature of the PZT ceramic) lead to the loss of the piezo-electrical abilities of the ceramic while a mechanical load above the compressive strength (600 N/mm²) can result in breakage. Using the FEM simulation software ABAQUS the pressure and temperature during the filling and compression phase are determined. Although the critical temperature of 150 °C is exceeded during the injection phase, the rapid cooling of the cavity prevents further damage to the ceramic.

Based on the simulation results an injection mould is designed to overmould the piezo-actuators. Figure 3 shows the moving half of the constructed injection mould. The runner allows to switch between different gating systems. The parting plane between the two core shells provides a better venting of the cavity.

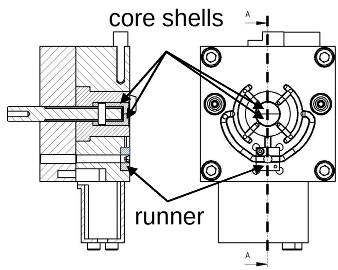

Figure 3: moving half of constructed injection mould

4 Practical investigations and results

By means of the constructed injection mould a reproducible manufacturing of functional actor-modules and therefore the functional integration in the assembly process can be demonstrated. During the manufacturing the process parameters are varied to detect the impact on the function and the optical appearance of the actor-modules (Figure 4).

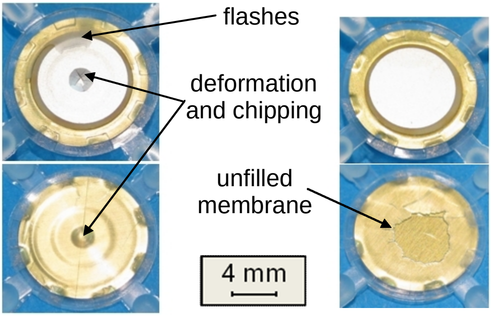

Figure 4: Impact of the injection moulding parameters on the optical appearance of overmoulded piezo-actuators

While high process temperatures and fast injection rates lead to deformations and chipping of the ceramic as well as flashes (left), low temperatures and slow injection rates result in an incomplete filling of the membran surfaces (right). Best results are archieved using moderate cavity wall temperatures of 60 °C and high melt temperatures of 265 °C as well as slow injection rates of 40 %. The thereby produced actor-modules are checked on function showing upstrokes of approx. 40 µm.

5 Conclusion and perspective

The modification of the present pump design by substituting the manually produced piezo-module with an injection moulded polymer component is possible. Optimising the component geometry and gating system is essential for good moulding quality. For a final evaluation long-term investigations have to be conducted.

Acknowledgement:

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