Chimia 53 (1999) 72–74

ISSN 0009–4293

Manufacturing of Micro-Components for New Applications in Chemistry by Injection Moulding of Polymers

Tilo Callenbach*

Abstract. The *H. Weidmann AG* has set up a unique injection-moulding tool for replication of optical and non-optical microstructures down to a sub-μm scale. Our approach simplifies the initial tooling and, thus, substantially lowers the cost threshold for feasibility studies and testing of injection-moulded microstructures. Two case studies, with micro-pipettes and a micro-spectrometer, respectively, show the usefulness of this new process technology. The service for polymer-sample prototyping is available on a commercial basis at reasonable costs and turn-around times.

Introduction

Miniaturisation of devices is a promising approach to fulfil a number of requirements to overcome today's limitations of precess technology, *e.g.*, size of instrument or cost effectiveness. Current precision mechanics do not seem to be appropriate for inexpensive solutions.

Today, various micromachining technologies are known for materials such as silicon, glass or other [1][2], and it is possible to produce exciting, new devices for numerous applications [3]. However, most new microstructuring technologies are not well-suited for low-cost mass production, especially in the area of disposable devices. It has been recognised in the last few years that micromachined disposables for analytical purposes made of glass or silicon wafers are not cost-effective. Furthermore, the assembly of microstructured parts substantially contributes to the overall fabrication cost. Wafer batch-processing technologies typically do not allow to fabricate microstructured parts with a well-suited, larger-size outer shape in order to ease the functional assembly [4].

New Process Technology

Injection moulding of polymers is a well-known tool for low-cost mass production of truly three-dimensional parts for the macroscopic world. The combination of micromachining technologies for the generation of microstructures, and in-

*Correspondence: T. Callenbach
H. Weidmann AG Plastics Technology
Medical Components Department
Neue Jonastrasse 60
CH–8640 Rapperswil
Switzerland
Tel.: +41 55 221 42 68
Fax: +41 55 222 83 78
E-Mail: tilo.callenbach@HWEIDMANN.CH

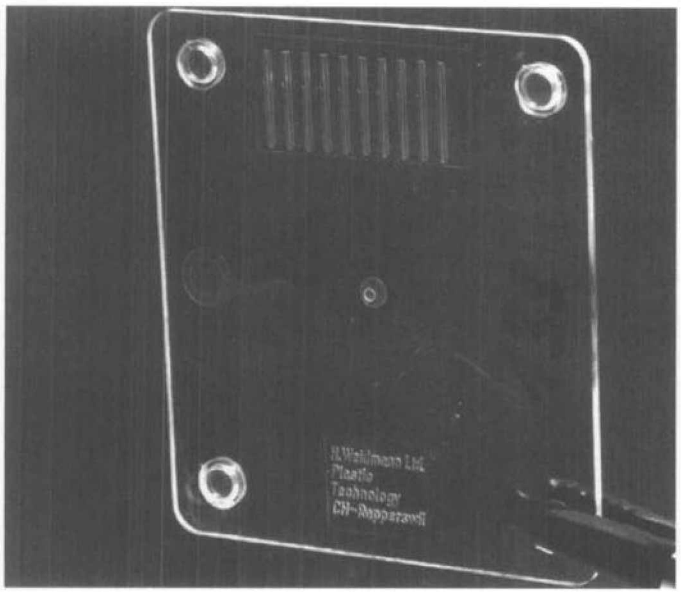

Fig. 1. *Injection-moulded microstructure with 10 micro-pipettes* (origination: NTB, Buchs)

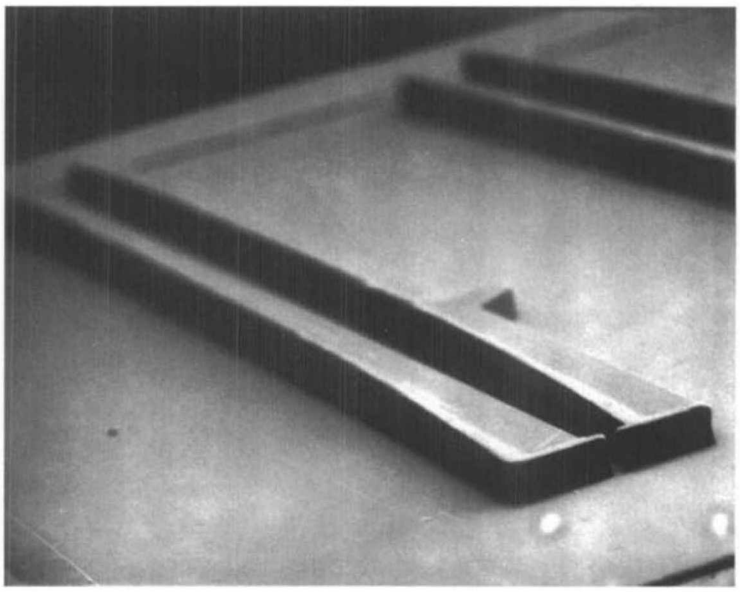

Fig. 2. *Scanning electron microscope photo of a replicated micro-pipette* (courtesy of NTB, Buchs)

jection moulding for the replication of the microstructures, is ideally suited for mass production, both with respect to technical and economical requirements. However, the step from a master structure towards injection moulding is expensive in terms of tooling investment [5]. Up to now, polymeric injection-moulded prototypes with subsequent functional testing were only available after considerable investment.

To overcome this limitation, a unique injection-moulding test tool for the replication of microstructures was developed at the *H. Weidmann AG*. The tool is used for the replication of custom microstructures as well as for in-house process development. The structures to be replicated are not limited to a certain mastering type such as LIGA [6]. Other microstructuring technologies may be more cost-effective depending on the application [7]. Advantages of our tool concept are low initial costs and a short turn-around time of approximately three months from microstructure design to polymeric test samples, which can be replicated in an industrial production process.

Technically, the replication of micro- or nano-structures requires different injection-moulding-tool set-ups and processing parameters according to the desired polymer and microstructure dimensions. With our new tool, the replica quality can easily be optimised by changing the injection-moulding processing parameters. In the case of CD-like microstructures, the following process parameters are of particular importance: melt temperature, mould temperature, injection speed, holding pressure, clamping force, and changeover point from injection to holding pressure [8].

Making use of the new tool, the customer gets immediate feed-back on the quality and the cost of a serial production of the parts long before his product development is completed. After evaluation of the prototypes fabricated with the test tool, serial-production parts with custom outer shape and geometry features can also be manufactured in-house at *H. Weidmann AG*.

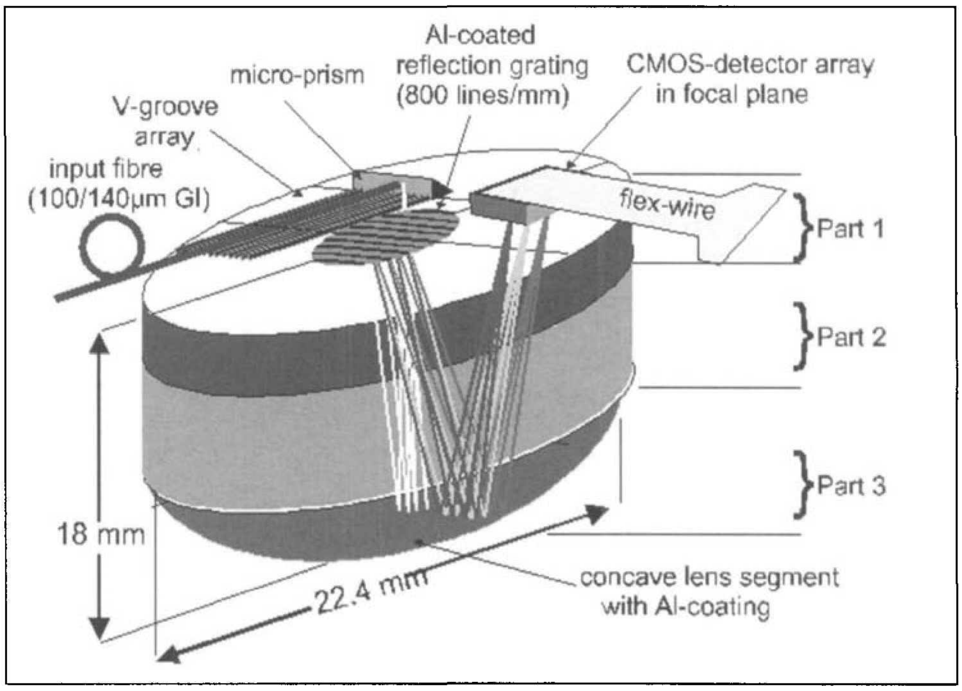

Fig. 3. *Replicated miniature-spectrometer concept developed at the CSEM, Zürich*

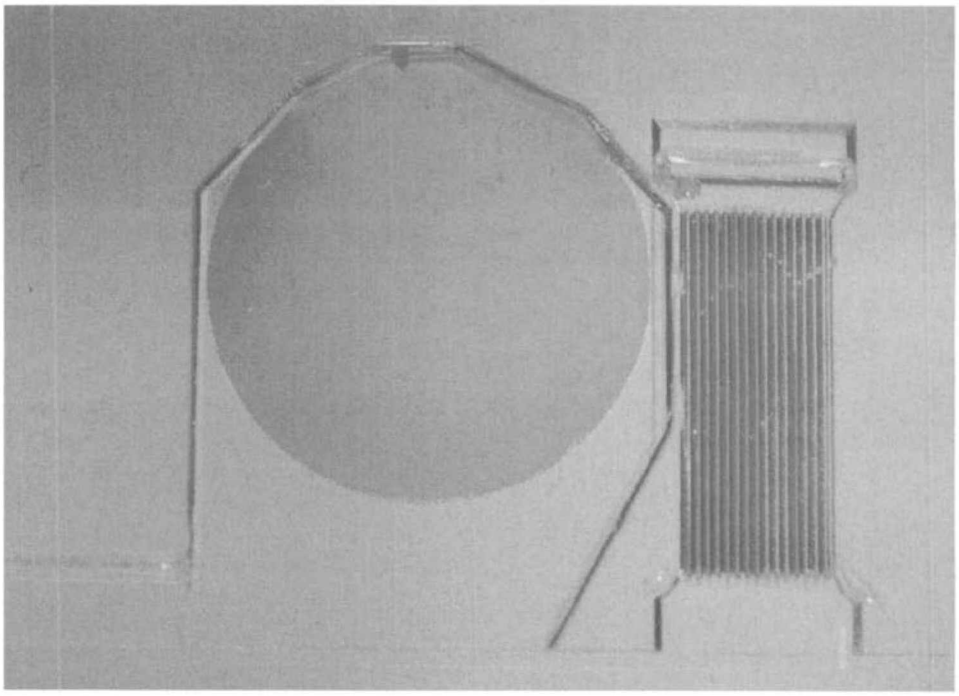

Fig. 4. *Injection-moulded component of a microspectrometer* (courtesy of CSEM Zürich)

Case Study 1: Micro-Pipettes

Micro-pipettes have been realised by injection moulding (*Fig. 1*). They represent a typical application in the area of microfluidics. The project is part of a feasibility study which was made to establish new ways for microstructure generation, to determine the quality of replication, and to learn more about necessary post processes. First tests have been accomplished, such as filling, before designs of application-specific microstructures were produced.

The pipettes work passively, *i.e.*, fluids are taken up by capillary force. At the moment, ten pipettes are produced per injection-moulding cycle. The pipettes were manufactured in polycarbonate (PC, *Bayer, Makrolon 2458*), polymethylmethacrylate (PMMA, *Röhm, Plexiglas 7N*), and PC with 10% (w/w) titanium dioxide (TiO_2). However, the replication by injection moulding is not limited to these types of polymers.

Every pipette consists of two rips, each having a length of 10 mm, a width of 300 µm, and a height of 160 µm. The capillary duct is made of a 160 µm-gap. The pipettes have to be separated and sealed. The resulting volume per pipette is 0.256 µl. They allow to take up a well-defined, reproducible volume of a sample fluid or an analyte. *Fig. 2* shows a scanning electron microscopy picture of a capillary break at the end of one pipette before sealing.

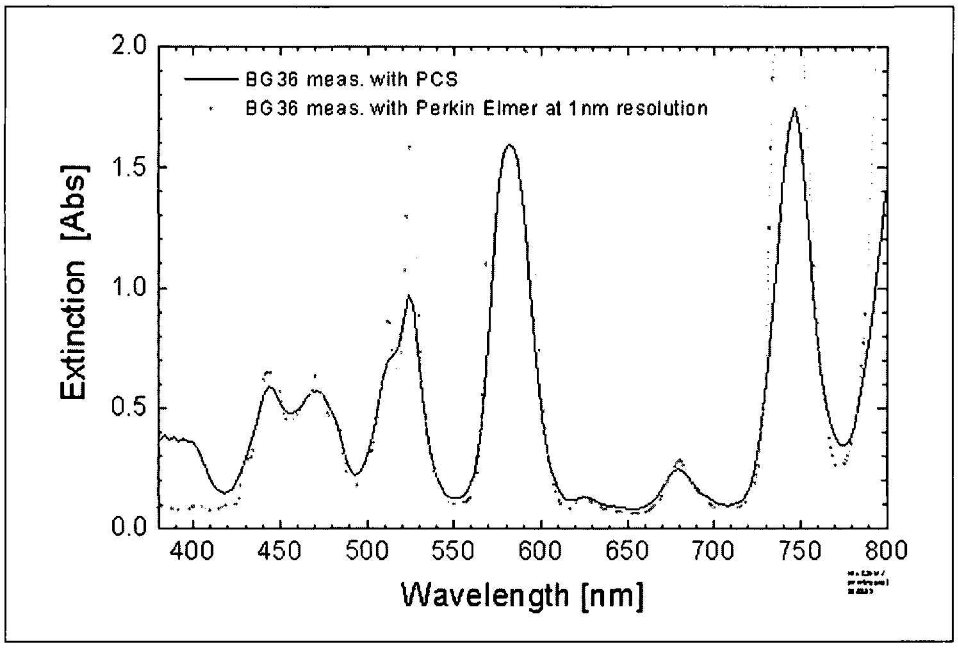

Fig. 5. *Example of an absorption measurement* (courtesy of CSEM Zürich)

Table. *Performance of the Replicated Miniature Spectrometer*

Accessible wavelength range	405–780 nm
Linear dispersion	2.8 nm / pixel (pixel pitch = 25 μm)
Resolution	10 nm FWHM with a 100/140 μm GI fibre input
Transmission	max., 15%
Stray-light suppression	22 dB cross talk from red light to blue pixel

The results of this case study show that an industrial process technology for the manufacturing of new, minaturized microchannel systems, *e.g.*, incorporated into disposable sensor cartridges, is available. The uptake of analytes with plastic chips, which is driven by capillary force, greatly reduces the complexity and size of the instruments. Portable instruments and easy-to-use disposable sensor chips for various applications are thus feasible. Furthermore, the waste of sample fluid and disposables can be greatly reduced due to the use of microfluidic devices.

Case Study 2: A Replicated Minature Spectrometer for the Visible Region

Miniature spectrometers with fibre pigtails are versatile sensors for, *e.g.*, chemical process control and biochemical diagnostics. Industrial replication is a key fabrication technology for the low-cost production of optical microsystems. In a case study on replicated miniature spectrometers, micro-optical parts for a miniature spectrometer were produced, using the replication-process technology as developed by *H. Weidmann AG,* in close collaboration with the Centre Suisse d'Electronique et de Microtecnique (CSEM) in Zürich.

The CSEM has developed a miniature optical-spectrometer design [9] (see *Fig. 3*) which consists of a plano-convex body similar to a *Ebert-Fastie* monochromator. The convex lens-segment collimates the light coming from the input fibre onto the grating. The light diffracted by the grating is focused onto a photodiode array by a second reflection at the convex segment. The spectrometer was finally constructed with two injection-moulded parts (parts 1 and 3 in *Fig. 3*) and a planar spacer (part 2). The fabrication of part 1,which forms the planar side, is very challenging as several deep and shallow optical micro-relief structures are combined (*Fig. 4*). This part contains V-groove structures for fibre attachment and a 350 μm high optical micro-prism as well as a shallow sub-μm grating. Amorphous materials, such as PC (*Bayer, Makrolon 2458*) or PMMA (*Röhm, Plexiglas 7N*) were used to produce parts by injection moulding.

Spectrophotometric measurements are used to determine solute concentrations and to identify solutes through their characteristic absorption spectra. *Fig. 5* gives an example of an absorption measurement performed using blue/green *Schott* colour glass (BG36). The micro-spectrometer (PCS) is compared to a commercial spectrometer (*Perkin Elmer, Lambda 9*). Other applications may include portable colour measurement systems. The serial production of micro-spectrometers is expected to start in 1999.

The performance of the spectrometer is summarised in the *Table*. The performance data are close to data obtained by ray-tracing simulations; this proves the high precision and optical quality of the replicated parts. In *Fig. 5*, a transmission spectrum of a blue-green BG36 *Schott* colourglass taken with the low-cost replicated spectrometer is shown and a measurement with a commercial bench-top spectrometer at 1-nm resolution. The accessible wavelength range is limited by the use of the commercial polymeric spacer material which contains UV-absorbers for environmental stability. In summary, this case study has shown that it is possible to realise optical microsystems such as miniature spectrometers with parts fabricated by the new, high-precision injection-moulding process technology described in the paragraphs above.

The author would like to thank *H. Teichmann*, CSEM Zürich, Switzerland, and *R. Bischofberger*, NTB, Buchs, Switzerland.

Received: November 20, 1998

[1] T. Schaller, W. Bier, G. Linder, K. Schubert, *Feinwerktechnik & Messtechnik*. **1994**, *102*, 5.
[2] R. Schaefer, *Medical Plastics and Biomaterials* **1996**, *3*, 32.
[3] S. Büttgenbach, in 'Mikromechanik', Teubner, Stuttgart, 1994. chapt. 6, p. 162.
[4] D. Jaeggi, B.L. Gray, N.J. Mourlas, B.P. van Drieënhuizen, K.R. Williams, N.I. Maluf, G.T. Kovacs, in 'Proceedings of the Solid State Sensor and Actuator Workshop', Hilton Head, South Carolina, June 8–11, 1998, p. 112.
[5] M.T. Gale, in 'Micro-Optics'. Ed. H.P. Herzig, Taylor & Francis, London, 1997, chapt. 6, p. 153–177.
[6] R. Ruprecht, T. Hanemann, V. Piotter, J. Hausselt, *Swiss Plastics* **1997**, *19*, 5.
[7] R. Bischofberger, M. Cucinelli, *Kunststoffe-Synthetics* **1998**, *9*, 34.
[8] Bayer Plastics Business Group. Optical storage media in Makrolon, CD 2005/MAS130. Application Technology Information ATI 871.
[9] H. Teichmann, M.T. Gale, J.M. Raynor, P. Seitz, H. Schütz, R. Stutz, J. Pedersen, S. Westenhöfer, in 'EOS Topical Meetings Digest Series of European Optical Society' Topical Meeting, Engelberg, 6–8 April, **1998**, *16*, 51.