Replication Processes for Metal and Ceramic Micro Parts

V. Piotter, E. Honza, A. Klein, T. Mueller, K. Plewa
Karlsruhe Institute of Technology, Institute for Applied Materials, P.O. Box 3640, 76021 Karlsruhe
Corresponding author: Volker.piotter@kit.edu; Tel.: +49 0721 6082 6463

1. Introduction

Many applications in the fields of precision medical devices, micro fluidics, energy harvesting, micro-sized consumer products etc. demand for materials offering better properties than the established silicon or polymers, i.e. metal or ceramic materials have to be used. Additionally, medium or large scale series manufacturing with short process times and reduced mechanical finishing for economical production have to be built up. To comply with all these demands a row of different process technologies is currently under development or has already been established in industrial fabrication. Three examples will be described in the following sections, namely

- Micro/Nano Powder Inmould-labelling to produce parts with enhanced surface properties
- Electroforming in 2C polymer templates to produce fine-detailed metal parts
- Rolling/Calendaring as a representative for continuous processes

2. Micro/Nano Powder Inmould Labelling

This technology is based on the Micro Powder Injection Moulding process (MicroPIM) which had been under development for many years and which has already found its way into industrial application [1, 2]. The new variant (abbreviation: IML-MicroPIM) can be regarded as a combination of MicroPIM and the inmould-labelling process well-known in plastic packaging: a pre-fabricated foil or film is mounted in a tool and subsequently covered by a backwards injection-moulded layer. The foils or films are filled with metal or ceramic powders and might be manufactured by e.g. slip casting, foil casting, or rolling processes. Before inserting them into the injection moulding tool, the foils can be printed, embossed or subjected to another preliminary treatment. In this way, it is possible to generate functional patterns on the surface of the PIM body. Another benefit is obtained by the fact that submicron powders or even nanopowders can be merged into the foils thus avoiding the usually occurring massive increase in viscosity.

The major challenge associated with inmould-labelling combined with PIM is given by the development of an adequate sinter process. The demands are similar to 2-component powder injection moulding of fixed joints, i.e. sintering shrinkage and temperature shall be mostly equal. The sintering process has to allow for dense compacts of both partial volumes as well as for a tight and defect-free interface.

The process has already been investigated for macroscopic applications and trials for adaptation to micro systems technology are currently running. For example, foils filled with a fine powder fraction of particle sizes going down to the nanometer size had been backmoulded by a standard zirconia MicroPIM feedstock. Comprehensive trials followed to adjust sintering shrinkage by varying the powder contents. Finally, a tight connection between the two sections could be achieved in green state and maintained even after sintering. Present experiments deal with the optimization of foil composition and micro structuring of the foil using the injection pressure of the PIM feedstock as shape giving force.

3. Electroforming in 2C polymer templates

Besides powder-metallurgical methods, there are other special processes well-suited for manufacturing metallic micro components. Direct LIGA certainly is the best known one for obtaining high surface qualities and finest microstructures. Its disadvantage is in the relatively high systems engineering expenses for manufacturing the preforms for electroforming. Therefore, a method was developed for manufacturing the required preforms exhibiting comparatively good surface qualities. This new process conduct has been named MSG which is the German abbreviation for **M**ehrkomponenten-**S**pritzgießen + **G**alvanoformung. MSG excels by its combining mass-manufacturing injection moulding techniques and electroforming processes that have been used so far only for LIGA manufacturing of micro parts. Since the process steps involved are based on two technologies suitable for series production, low product costs per unit will be realistic. As the outstanding benefit of MSG this economic performance is combined with a technical advantage, i.e. the novel manufacturing chain provides high-quality metallic micro parts for mass use. For example, micro gear wheels with an outer diameter of approx. 580µm could be produced using a nickel sulfamate electrolyte. The high quality of the metallic micro parts was verified, among other things, by means of demonstrator surface and dimensional measurements. Compared with alternative methods like MicroPIM, significantly better or at least equal values were obtained. For example, mean surface roughnesses of 0.18-0.26 µm had been determined for the MSG samples whereas MicroPIM samples revealed values of 0.4 to 0.8 µm. Much as in LIGA, parts can be processed further after having been abraded and demoulded. To summarize, MSG does not compete with but completes LIGA in an economically reasonable way.

4. Rolling/Calendaring of metal or ceramic foils

Compared to the discontinuous process like the different variants of injection moulding continuous methods reveal larger throughput rates thus higher economic efficiency. Rolling processes, or to use the plastic engineering expression calendaring, are especially suited for planar micro- or nanostructured surfaces, however, their capability for shaping of high aspect ratio geometries is usually limited [3]. Beneath the particular challenges of procuring bended mould inserts approaches for processing polymer materials have been performed during the last years. Just at the beginning are attempts to use powder filled foils - similar to the ones applied for IML-MicroPIM - for shaping by rolling/calendaring. In this case the limited flexibility and strength of the foils provides an additional challenge. Nevertheless, first successful trials have been performed by a few members of the EU Large Integrated Project Multilayer “Rolled multimaterial layered 3D shaping technology” (FP7-NMP4-2007-214122).

References

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