New Material and Processing Issues for High Quality Parts by Micro-MIM

A. Rota[1,a], Ph. Imgrund[1,b], J. Haack[1] and F. Petzoldt[1]

[1]Fraunhofer Institute of Manufacturing and Advanced Materials
Dept. Micro Engineering, Wiener Strasse 12, D-28359 Bremen, Germany
[a]rota@ifam.fraunhofer.de, [b]im@ifam.fraunhofer.de

Abstract

The development of Micro MIM as a new manufacturing process for metallic micro parts made of advanced functional materials has been the subject of considerable research over the last years. This paper addresses important quality aspects on processing of new materials by Micro-MIM. Three examples of new functional materials that can be processed are reviewed in this paper. The first example is two-component-Micro-MIM to obtain multi-functional devices. A micro positioning encoder consisting of a magnetic / non-magnetic material combination is presented. The second issue is series production of the replicate of the smallest human bone in the ear (stapes) from Titanium as an example of medical application. Quality assurance and reproducibility in terms of injection moulding paramters are addressed. In the third part, first results on the processing of the shape memory alloy NiTi by Micro-MIM are presented. Potential applications include biocompatible devices and transportation, for example automotive and aeraospace. Processing routes and initial microstrucures obtained are discussed.

Keywords: Micro MIM, multifunctional materials, titanium, shape-memory alloys

Introduction

In many applications there is a growing demand for greater precision, functionalisation and miniaturisation of components and systems leading to an increased demand for miniature and micro-sized components made of metallic materials [1]. Most current micro-production technologies, however, are not applicable for the cost effective mass production of metallic micro-parts. Therefore considerable effort was put in developing the micro metal injection moulding (μ-MIM) process for the cost effective mass production of complex micro-components and -structures during the recent years [2-4]. The suitability of the μ-MIM process for the manufacturing of micro sized components and microstructured surfaces was already demonstrated in various projects. A major advantage of this processing technology is that a wide range of metals, alloys and polymers can be processed.

In this paper, different aspects of the current developments of Fraunhofer IFAM are presented. One is μ-MIM of bimaterials by using two-component injection moulding technology. The second aspect addresses series production of titanium stapes using a special micro injection moulding device, while in the third part potential sintering routes for micro parts made of NiTi shape memory are discussed.

Two-component Micro MIM (2C-μ-MIM)

Two-component injection moulding has already been an industrially established processing route for plastics for several years. It is designed for manufacturing of multifunctional parts directly in the injection moulding process without the need of supplementary joining or assembly operations. The application range is from products for fine mechanics to very large parts, for example bumpers for automotive industry. The principle of the moulding process is schematically shown in Fig. 1.

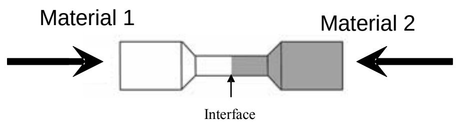

Fig. 1. Schematic of 2C-μ-MIM

The goal of the development of 2C-μ-MIM was to manufacture micro parts made of two metals with different magnetic properties in a combined shaping and joining process and subsequent co-sintering. The emphasis of the research work was to identify suitable material combinations and feedstocks for multi-functional applications in the micro range as well as the development of processing technologies for moulding, debinding and sintering. These processes were developed for the material combinations 316L / 17-4PH and 316L / Fe. The most critical issue in this development was to adapt sintering behaviour of the two parts in order to avoid stresses and cracking at the interface. To demonstrate the success of the development, a micro positioning encoder was manu-factured by this process, featuring two soft magnetic (17-4PH and Fe) endings with the joining bar made of 316L stainless steel (Fig. 2). The micrograph reveals that a crack-free interface was obtained.

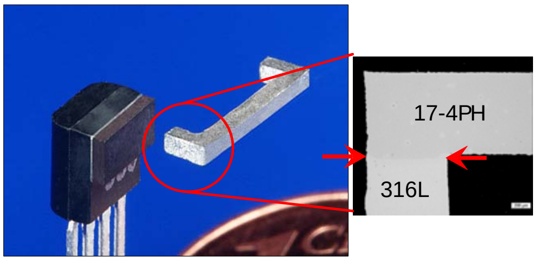

Fig. 2. Magnetic positioning encoder; micrograph of the interface

Series production of Ti stapes

Due to the high requirements on precision and reproducibility of μ-MIM if series production is attempted, careful control of the production parameters of injection moulded micro-components, the precision in dosage and injection of extremely small feedstock quantities need to be investigated. Therefore in collaboration with Krämer Engineering, Rendsburg, a mould replicating the smallest bone in human body, stapes in the ear, was designed and manufactured. In the case presented here, the stapes were made of Titanium and the relevant data from the injection moulding process was recorded using a micro injection moulding machine (Battenfeld Microsystem 50). Fig. 3 depicts some stapes as obtained after sintering.

Fig. 3. Series production of stapes

In the investigations, there was a very good reproducibility of feedstock volume which is injected into the mould (107.19 mm³ +/- 0.09 % for a series of 208 parts). Still, considerable deviations in the pressure inside the mould were visible as the minimum pressure was recorded to be less than 100 bar and the maximum over 800. The average value was 343 bar with a standard deviation of 29 %. To determine the influence of these quite large deviations on part quality, 100 of the Ti stapes were weighted as green parts and sintered parts. For both the injection moulded and sintered parts, only very slight deviations in the weight was recorded. So, the average weight of the moulded parts was 6.01 mg +/- 1.17%. In the sintered parts, deviation was comparable with the weight being 5.4 mg +/ 1.51 %. Thus it can be concluded that the pressure inside the mould is less an issue concerning part reproducibility, if it is assured that the volume of injected feedstock is well constant.

Processing of NiTi

Recently some efforts on processing shape memory alloys by Metal Injection Moulding in order to obtain net-shape products were reported in literature [5]. To broaden the application possibilities (actuators and medical parts) the processing of pre-alloyed NiTi powders by μ-MIM is currently evaluated. As initial samples micro tensile test specimens with a cross-section of 1 mm² were injection moulded and sintered using various processing parameters, as the variation of sintering atmosphere between Argon and high vacuum. The first goal of the work was to optimise density and to minimise the occurrence of impurities and formation of undesirable phases such as Ni_3Ti or $NiTi_2$. Fig. 4 presents a typical microstructure obtained after sintering.

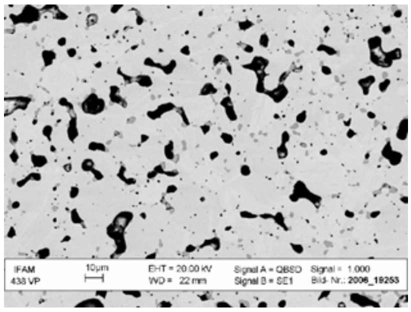

Fig. 4. Microstructure of μ-MIM NiTi, sintered under Argon atmosphere

The picture reveals a multiphase microstructure with some porosity. The density was determined to be about 90-92 %. By means of EDX, the dark grey phase was determined to be Ti rich (possibly Titanium carbide) the grey phase $NiTi_2$ and the predominant light phase NiTi. Based on this encouraging result further process optimisation is under way including DSC measurements for determination of the transformation temperatures for the shape memory effect.

References

1. J. Hesselbach, A. Ratz: Investigations on the current state of micro production technology; IWF, TU Braunschweig, 2002
2. A. C. Rota, New Features in Material Issues for Metallic Micro Components by MIM, Proceedings of PM2TEC 2002, Orlando, Florida, USA, pp 10-49 – 10-57
3. V. Piotter et al., PIM Enters Microsystems Technology, PM Science & Technology Briefs, Vol. 4, No.1, 2002, pp 5-8
4. A. Rota, P. Imgrund, F. Petzoldt, Micro MIM – a production process for micro components with enhanced material properties, Proceedings of Powder Metallurgy World Congress, Vienna, 2004, Vol. 1, 467-472
5. M. Bram et al., Powder metallurgical fabrication processes for NiTi shape memory alloy parts, Materials Science and Engineering A337 (2002) p. 254-263