Metal and Ceramic Micro Components Made by Powder Injection Molding

V. Piotter, G. Finnah, B. Zeep, R. Ruprecht, J. Hausselt

Forschungszentrum Karlsruhe, Institute for Materials Research III
P.O. Box 3640, 76021 Karlsruhe, Germany
Tel.: +49 7247 82 6463, Fax: +49 7247 82 2095
E-mail: volker.piotter@imf.fzk.de

Abstract

In recent years Microsystems Technologies products steadily entered the worldwide market and it can be predicted that this growth will continue in future.
A manufacturing technology effectively supporting this trend is micro injection molding which has already reached an industrially viable status for polymeric materials. To adapt the widely used injection molding process to the microscale, however, additional devices had to be implemented. In this connection, tool evacuation and the so-called Variotherm temperature control have to be mentioned.
On the other hand, polymers do not possess the appropriate qualities for many applications in micro technology. For such cases the processing of metal and ceramic materials by the so-called MicroPIM process represents a promising solution.
Presently, the smallest dimensions achievable are 25-50µm of part thickness or minimum structural details of 5µm or even less depending on the particular powder used. The surface qualities of the sintered parts are mainly determined by the particle size of the applied powders. For example, using fine zirconia powders with a medium particle diameter of 0.4µm Rmax values of 2-3µm can be achieved, whereas surface qualities significantly decrease if rougher powders are used.
Theoretical densities of up to 97% in case of metal and 99% in case of fine ceramic powders were achieved.
The range of materials applied in micro injection molding covers typical PM steels like 17-4PH or 316L as well as hard metals like WC-Co. New developments are focused on the processing of refractory metals like tungsten or tungsten alloys.
In case of ceramic materials zirconia or alumina are mainly used but there are also certain fields for which electrically conductive ceramics like TiN are applied. Further ceramic materials are non-oxide ceramics like silicon nitride.
For both metal and ceramic powders there is an obvious demand to use finest grades. For ceramics this means the processing of nanopowders or mixtures of submicron and nanopowders for the creation of feedstocks specially tailored for micro injection molding.
One of the most interesting new approaches is the realization of functional material combinations like, for instance, magnetic/non-magnetic or conductive/non-conductive by two-component MicroPIM (2C-MicroPIM). From the economic point of view, the most important impact is to save assembly efforts which are significantly higher in micro than in macro fabrication.
For 2C-MicroPIM, machinery equipment incl. tool evacuation and variothermal temperization with the possibility to choose two different injection temperatures had to be developed at Forschungszentrum Karlsruhe. Additionally, the related tool designs had to be generated.
In case of two- or multi-component injection molding in the micrometer scale, the main technical challenges are the process parameters which have to be suitable for both materials and, at the same time, have to enable materials junction even during sintering. This can be demonstrated, for instance, by the realization of 2-component micro test specimens with 400x400 µm cross-section.
Other interesting examples are double-layer test parts to investigate deviation caused by different thermal expansion or u-shaped heater prototypes. The latter consist of a mixture ceramic containing alumina and titanium nitride. By the variation of the mixing ratio the electrical conductivity, too, can be varied. In this particular case, two-component micro injection molding is considered to be a viable process for the series production of heating elements based on multi-functional materials.
Particularly in micro technology, process simulation provides useful assistance and helps to avoid unrecoverable failures. Unfortunately, there is still a lack of micro specific software tools taking into account the special behavior of multi-phase materials.
By new approaches based on innovative material models and software tools micro- and powder-specific aspects shall be considered in the near future.