Innovations in Micro Metal Injection Molding Process by Lost Form Technology

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Abstract

The production method of micro sacrificial plastic mold insert metal injection molding, namely μ-SPiMIM process has been proposed to solve specific problems involving the miniaturization of MIM. Two types of sacrificial plastic molds (SP-mold) with fine structures were used: 1) PMMA resist, 2) PMMA mold injected into Ni-electroform, which is a typical LIGA (Lithographie-Galvanoformung-Abformung) process. Stainless steel 316L feedstock was injection-molded into the SP-molds with multi-pillar structures. This study focused on the effects of metal particle size and processing conditions on the shrinkage, transcription and surface roughness of sintered parts.

Keywords :Micro metal injection molding, sacrificial plastic mold, LIGA, particle size, surface rougness

1. Introduction

The production of micro-size and micro-structured parts by metal powder injection molding (MIM) process needs more sophisticated techniques than the conventional MIM. The μ-MIM process is faced with various technical problems in each process. For example, it is difficult to fill feedstock compleletly into narrow cavity and to demold fragile green compacts out of metallic mold in injection molding process. It is also required to handle carefully them in debinding and sintering processes. The μ-MIM process using the sacrificial plastic mold (SP-mold), namely micro sacrificial plastic mold insert MIM (μ-SPiMIM) method has been developed to solve the above-mentioned problems specific to μ-MIM process. The SP-mold with multi-pillar structures was prepared by LIGA process. This study aims to demonstrate the possibility of μ-SPiMIM process for producing micro-structured parts and to investigate the effects of particle size on the transcription and surface quality of sintered parts.

2. Concept of LIGA Micro Sacrificial Plastic Mold Insert MIM (LIGA/μ-SPiMIM) Process

LIGA Process. Producing the tiny products with higher dimensional accuracy, it is required to use the molds that are more precise than conventional molds. LIGA is mainly consisted of processes; the first is irradiation process to transcript the mask shape to resin, namely resist, the second is developing process to remove unnecessary part of the resist, and to make negative structure of the desired body, the third is molding process by electro-forming metal structure in the resist. The main features of LIGA process are to create the fine profiles with dimensional accuracy in nanometer order, and micro-structures with high aspect ratio. However, the materials applicable to LIGA are limited, and the cost is comparatively high for mass-production.

Two types of LIGA/μ-SPiMIM Processes. The μ-SPiMIM inserted ultra-fine molds which were fabricated by LIGA process, namely LIGA/μ-SPiMIM process, are presented in this study. As shown in Fig.1, two types of SP-molds such as 1) PMMA resist and 2) PMMA mold injected into Ni-electroform were used for namely "One-step transcription method" and "Two-steps transcription method", respectively. In one-step transcription method, PMMA resist was used for SP-mold. This method is very

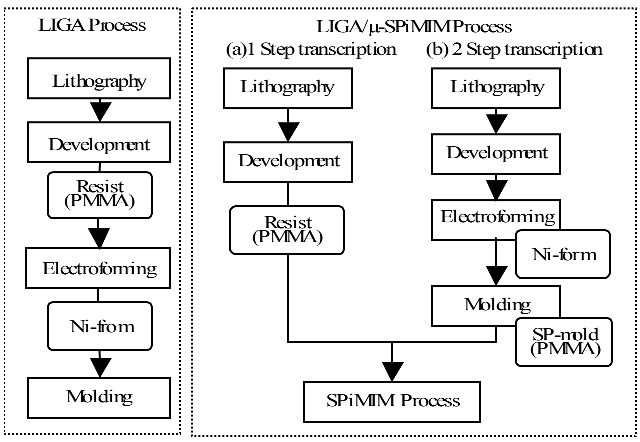

Fig. 1. Frow of two types of transcription methods in LIGA/μ-SPiMIM Process.

good for transcription because an original shaped resist is used as SP-mold. However, the cost for producing the resist is extremely high. In two-steps transcription method, on the other hand, Ni-electroform was used for injection molding of SP-mold. This method is good for mass-production with high cost efficiency, but the quality reduction of transcription due to the twice injection molding operations is a main issue.

3. Experimental Procedure

Specimens. For demonstration of LIGA/μ-SPiMIM process, we tried to manufacture multi-pillar structures assuming micro-fluidic devices and micro-reactor. Each pillar is 200μm high, and has cross-section with 50μm wide. The aspect ratio is about 4. However, de-molding is not required in μ-SPiMIM process and therefore this process possesses great advantages in producing the tiny parts with micro-structures.

Materials and processing conditions. The metal powders used were austenitic stainless steel 316L (9μm and 3μm in mean diameter, Atmix Co., Ltd., PF-20J and PF-2J) produced by water-atomization method. The binder used was wax and poly-acetyl family. The material used for SP-mold was PMMA (Mitsubishi Rayon Co., Ltd., ACRYPET^{TM}, MF-001), but was extracted with acetone to prevent a significant damage for multi-pillars. The green compacts were debound at 600ºC for 2 hrs in N_2 gas atmosphere, and sintered at 1350ºC or 1150ºC for 2 hrs in Ar gas atmosphere using the vacuum debinding and sintering.

4. Results and Discussions

One-step transcription method. Fig.2 shows SEM images of the Ni-forms and micro-structured parts produced by the one-step transcription method using 3μm and 9μm 316L powder. It is obvious that fine powder provides for the better transcription than coarse ones. Also, the difference in shrinkage percentage was recognized between 9μm and 3μm powder, i.e. around 25% with 3μm powder and around 3% with 9μm powder.

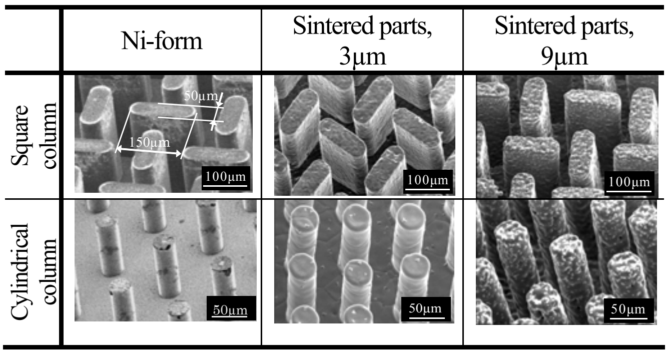

Fig. 2. Ni-forms and sintered specimens produced.

Two-steps transcription method. Fig.3 shows SEM images and profiles of Ni-form, SP-mold, 10μm and 2μm 316L sintered part with multi-pillars produced by two-steps transcription method of LIGA/μ-SPiMIM. Though the molding defects, such as weld-line and imcomplete-filling in injection molding for SP-mold develop generally, SP-mold without significant defects as shown in Fig.3(b) was obtained by optimizing molding conditions in this experiment. Also a high transcription of sintered body was obtained by injection molding of 2μm powder as shown in Fig.3(c). However, the surface roughness and shape-transcription of 10μm powder sintered part have not been achieved fully-satisficed quality as shown in Fig.3(d), because the 10μm metal powder used was too coarse compared with structural-size.

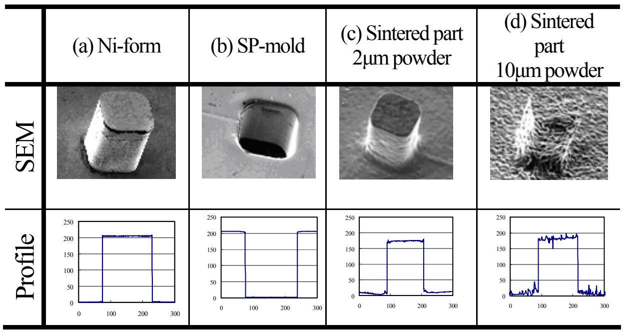

Fig. 3. SEM images of pillar in 2-step transcription.

5. Conclusions

Micro sacrificial plastic mold insert metal injection molding, namely μ-SPiMIM method was proposed to solve technical problems facing to μ-MIM process. Sacrificial plastic molds were fabricated by LIGA process. The application of μ-SPiMIM method to multi-pillar structured parts was archived by the combined processes named LIGA/μ-SPiMIM method, for two types of transcription methods. It was demonstrated that these methods actually had great potential to produce micro-structured metal components. It was also confirmed that finer metal powder was better for their transcription than coarse one. There fore, insufficient transcription and weld line in injection molding of sacrificial plastic mold, the deformation and failure in debinding have been actually overcome.