# Technical and Economical Comparison of Micro Powder Injection Molding

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**Abstract**

*In recent years, micro powder injection molding (μ-PIM) is being explored as an economical fabrication method for microcomponents in microsystems technology (MST). Technical and economic comparison was performed for μ-PIM processes. Molding experiment and simulation during the filling process were performed to evaluate several different geometries and processing conditions. The influence of material parameters and process conditions on mold filling were examined as a function of features size using microchannels as an example. It was found that the heat conductivity and viscosity of feedstock, geometry and mold temperature were the most critical parameters for complete filling of micro features.*

**Keywords: micro powder injection molding (μ-PIM), microsystems technology (MST), simulation**

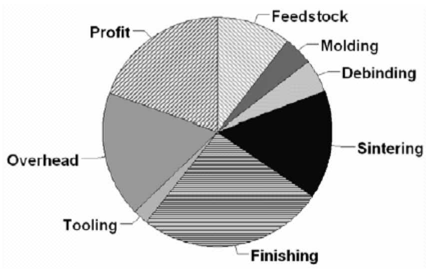
## 1. Introduction

MSTs have propelled the development of micro and multi-scale manufacturing techniques for more than a decade. Among these techniques, μ-PIM is drawing attention recently as one of the most cost-effective processes suitable for medium and mass production of micro components. While injection molding is a well established and widely used process technology for shaping polymeric materials, PIM is a relative new process for producing ceramic and metallic products [1]. In this study, technical and economic comparisons were performed for μ-PIM processes.

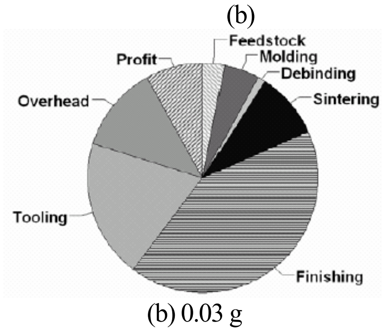
## 2. Economical Comparison

Need of μ-PIM is initiated by market of MST. Market size of MST is estimated in $68 billion with 20% growth rate in 2005 [2]. Major application fields include IT peripherals, bio-medical, automotive, house hold and telecommunication. However, cost-effective production methods such as micro injection molding are needed for further growth. Currently, polymers are the most widely used materials. However, polymers have limitations of properties such as electrical conductivity and thermal stability. Therefore, metals, ceramics and composites will be required for MST [3]. Micro parts are usually costlier than normal sized parts. We investigated the active universities, institutes, and companies in three active regions of Europe, Asia, and United States.

Fig. 1 shows price comparison between two PIM components of stainless steel. While material or feedstock portion is bigger in normal sized part (8 g), tooling cost is bigger in smaller sized part (0.03 g).




(a) 8 g
(b)




(b) 0.03 g

**Fig. 1. Price comparison for two PIM components**

## 3. Technical Comparison

Before defining what μ-PIM is, we compared the-state-of-the-art among plastic injection molding, metal injection molding, and ceramic injection molding for microparts, as shown in Table 1 [4-5].

**Table 1. Comparison of injection molding technology.**

| dimension | metals | ceramics | plastics |
|---|---|---|---|
| lateral dimensions (min, μm) | 50 | 50 | 20 |
| structural detail (min, μm) | 5 | 3 | 0.2 |
| Aspect ratio (max, height/width) | 14 | 14 | 30 |
| surface quality (Ra, μm) | 0.6 | 0.02 | 0.015 |

Based on literature survey, we can define that μ-PIM is PIM technology to make components which have features less than 1000 μm (common range ~ 100-500 μm). μ-PIM is applicable to two categories: (1) miniaturization such as micro heat exchanger, micro reactor, and micro mixer, and (2) normal sized part with micro pattern or feature such as micro channel and micro lens.

μ-PIM uses smaller particle size, micro fine powder < 5 μm for metals and ultra fine powder < 0.5 μm for ceramics. The particle size should be at least about one order of magnitude smaller than the minimum internal dimension of the micropart.

Mixing is more important as particle size decreases because specific surface area is inversely proportional to particle size. Mixing is more difficult due to fine spaces between small particles.

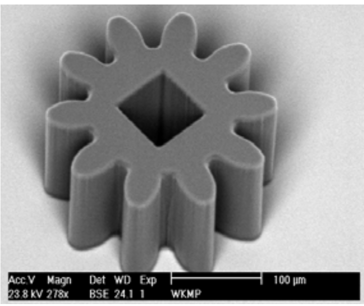



**Fig. 2. Micro gear part by LIGA tooling.**

Five tooling technologies are currently used in μ-PIM: LIGA, electroforming, laser ablation, precision machining, and rapid prototyping. Among these technologies, LIGA is most popular because of its ability of mass production and reduction of cost. Figure 3 shows one example of micro gear part by LIGA.

Two different molding technologies currently used in μ-PIM: high pressure injection molding (HPIM) and low pressure injection molding (LPIM). A micro injection molding machine, which is specially designed for μ-PIM by considering smaller shot size, accurate feedback control, and handling the ejected part, is used increasingly. The following technology issues are currently considered:

- higher mold temperature for obtaining higher aspect ratio,
- lower ejection speed during demolding,
- powder-binder separation,
- high aspect ratio, and
- gas-assisted injection molding.

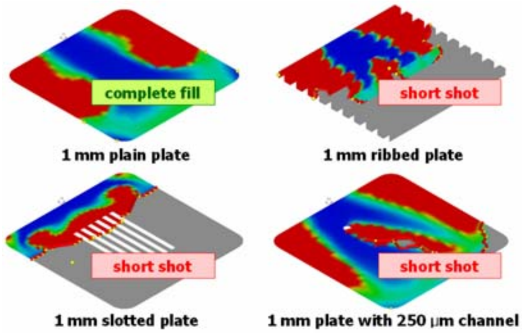



**Fig. 3. Evaluation of various μ-fluidic geometries and processing conditions.**

Fig. 3 shows filling simulation results for various micro feature on the same size of substrate [6]. It can be seen that microfeatures make a big difference in mold-filling behavior.

## 4. Summary

The fabrication of microsystems is one of the key technologies for the future. μ-PIM has the potential to become a well-established process but still has several technology barriers to overcome.

## 5. References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