

Micro Injection-Molding of Cyclic Olefin Copolymer Using Metallic Glass Insert

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Abstract - There is shift in trend towards the use of high quality polymers as the base material in manufacturing microfluidic chips. In this paper, an amorphous metallic alloy mold insert was used in a micro injection-molding process to fabricate microfluidic features onto cyclic-olefin-copolymer (COC) material. The insert and fabricated samples were compared in terms of the geometry and surface roughness attained. Findings indicate that replication, in general, was possible but the microfeatures formed had significant flashing and tearing at the edges.

Keywords - cyclic olefin copolymer , metallic glass, micro injection-molding

I. INTRODUCTION

The use of microfluidic chips by the medical and bioengineering community is on the rise. Glass is often used as the basis for developing a series of micro-scaled fluid channels and reservoirs [1]. A typical microfluidic chip comprises of a combination of such microchannels. The exact design varies depending on the purpose of the chip [2,3].

Current trends favor the use of polymers in place of glass, in particular cyclic-olefin-copolymers (COC), due to its excellent optical properties and non-toxicity [4]. Also, of recent interest in the materials community is amorphous metallic alloy or “metallic glass”. It possess better mechanical properties, such as yield strength and elastic limit, than conventional steel [5].

Research into mold inserts that can fabricate microfluidic features has been conducted in the past. These include the use of X-ray “lithography, galvanofarming, molding” (LIGA) [6], micro-casting from molds of either ceramic [7] or silicone [8], micro-stereolithography [9], laser micromachining [10] and electrical-discharge-machining (EDM) die-sinking [11]. Each process has its merits but are not entirely suitable from a mass-production standpoint. This is due primarily to the cost, time, durability and resolution of the molds that are made.

Thus far there has been little research work done at using metallic glass as mold insert. The aim of this paper is to attempt a micro injection-molding process using metallic glass insert containing microfluidic

features, onto COC resin. The insert and the samples will be compared in terms of geometry and surface roughness attained.

II. METHODOLOGY

LM-106 amorphous metallic alloy obtained from Liquid Metal Technology was used to fabricate 25x25 mm mold inserts. This was accomplished by high-speed computer-numeric-controlled (CNC) milling. A 0.5 mm coated-carbide endmill was used at approximately 10,000 rpm. Figure 1 shows the microfluidic features to be fabricated onto the metallic alloy. All microchannels are 100 μm in width and 50 μm in height. The pitch between individual channels is 600 μm . Figure 2 shows the final insert.

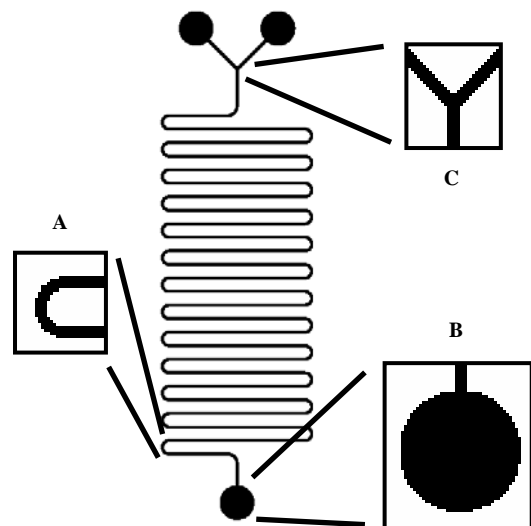


Fig. 1. Microfluidic features fabricated onto molding inserts. Labeling denotes areas of interest.

The metallic glass insert was then used in a single-cavity 75-ton injection molding machine. TKX-0001 Cyclic Olefin Copolymer resin obtained from TOPAS Advanced Polymers was used as the raw material. The resin was pre-dried and dehumidified for 12 hours at 80°C before use. The molding parameters used are shown in Table I. Figure 3 shows the COC sample that was molded. It has dimensions of 75x25x1.5 mm.

A comparison of the microfluidic features, such as surface roughness and geometry, between the metallic glass insert and the COC samples were made. A JEOL JSM-5600LV Scanning Electron Microscope (SEM) and a Wyko NT2000 Optical Profiler and were used to perform the analysis.

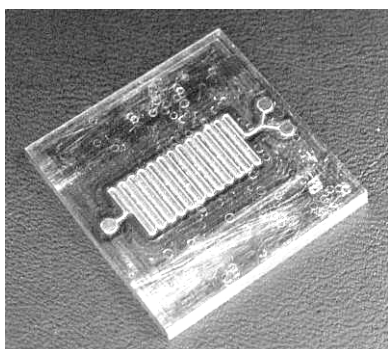


Fig. 2. Plan view of metallic glass mold insert.

Table I
Injection-molding parameters.

Parameters	Values	Units
Barrel Temperature	250/240/230	°C
Injection Speed	95	cm/s
Injection Pressure	130	MPa
Holding Pressure	65	MPa
Holding Time	10	s
Cooling Time	15	s
Mold Temperature	25	°C

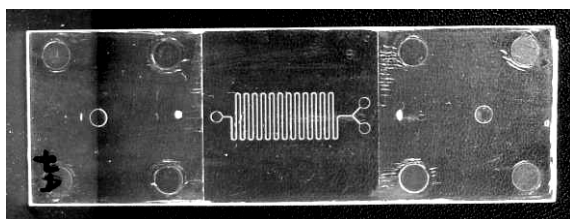


Fig. 3. COC sample injection-molded using metallic glass insert.

III. RESULTS AND DISCUSSION

Analysis was conducted at regions labeled “A”, “B” and “C” in Figure 1. In the case of measuring surface roughness the average of 3 readings was used. The results are presented in Figure 4.

The metallic glass insert showed large amounts of tool marks. The bottom edges were also not sharply defined, due to the curvature at the tip of the endmill. A series of filler-like material could also be seen on the edges of the top surfaces. The effective width of the top surface was approximately 75 μm . The height was 55 μm . The surface roughness, measured in R_A , was in the range of 180 nm to 215 nm.

On the molded COC sample, the microchannel was replicated but exhibited tearing and flashing along its edges. The bottom surface was uneven, due in a large part to the fillers that were seen from the metallic glass insert. The microchannel was approximately 70 μm in width and 50 μm in depth at the bottom. Figure 5 shows a comparison of the geometries typically seen in plan-view between microchannels. The occurrence of the tears can be clearly seen. The likely reason for this kind of effect might be due to a combination of

high molding speed and pressures, low mold temperature and poor surface quality of the insert. The poor quality of the bottom surface also prevented useful surface roughness measurements to be obtained. The R_A obtained from other regions indicated that the COC sample had a surface quality in the range of approximately 200 nm to 300 nm. Compared against the corresponding surfaces of the metallic glass insert, this represented a ‘loss’ of about 100 nm in terms of surface quality.

IV. CONCLUSION

In this paper, cyclic olefin copolymer resin was used in conjunction with a metallic glass mold insert for micro injection-molding. The process was shown to be possible but the polymer samples exhibited uneven surfaces and significant flashing and tearing in the microfeatures that were formed. This could be attributed to the surface quality of the metallic glass insert and also the molding conditions used. In terms of geometry, the microchannel was found to be approximately 7% smaller than the original dimensions. Surface quality also decreased by approximately 100nm in terms of R_A . More research regarding the interactions of insert surface finishing and molding conditions in the use of metallic glass and COC has to be done. Also, empirical studies in comparing metallic glass and COC with other kinds of insert and raw polymer material needs to be conducted.

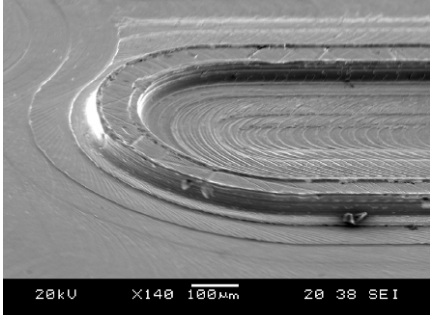
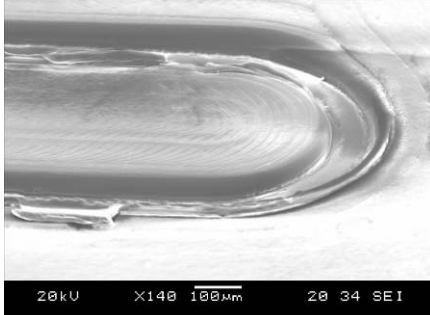
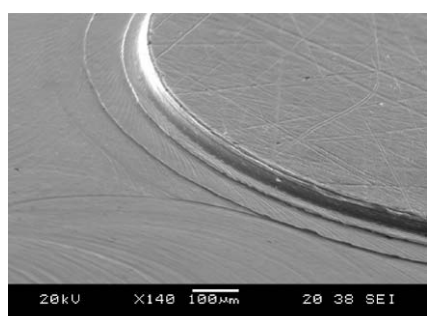
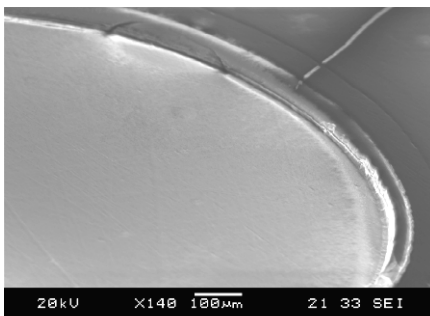
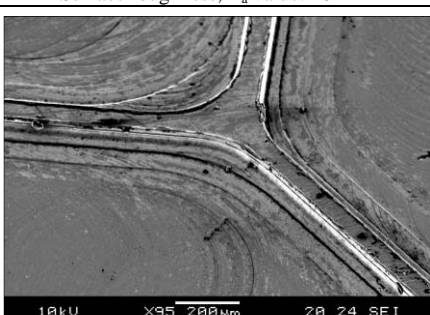
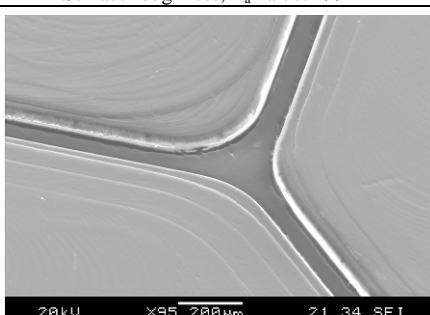
Region	Metallic Alloy	COC
A		
	Surface roughness, R_a value: 215 nm	Surface roughness, R_a value: <i>unobtainable</i>
B		
	Surface roughness, R_a value: 184 nm	Surface roughness, R_a value: 199 nm
C		
	Surface roughness, R_a value: 180 nm	Surface roughness, R_a value: 294 nm

Fig. 4. Comparison of geometry and surface roughness between metallic glass and COC.

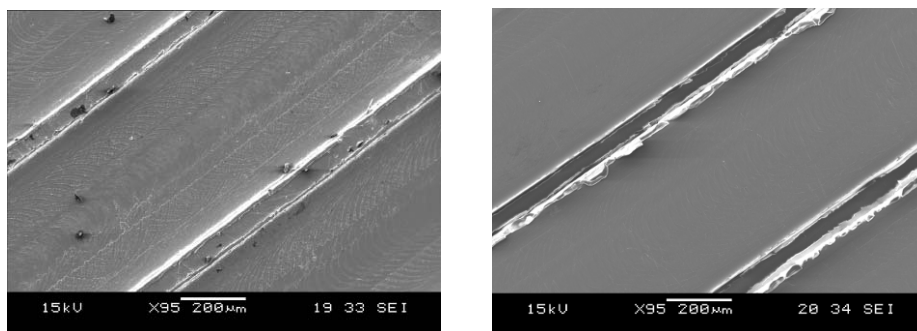


Fig. 5. Top-down view of microchannels on the metallic glass (left) and COC sample (right).

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