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Micro Injection Molding Polimeric Difracttion Grating

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Abstract
The injection molding process of diffractive micro-optical elements, inserts machined electrolytic copper with diamond tool with one edge was analyzed. The purpose of this research was to analyze the process of injection molding for replication of micro optical element polymer. In replication, fidelity was considered dimensional aspects micrometric and nanometric in relation to microstructure and finishing. Optical perfilometry and electron microscopy scanning was used to evaluate the technical machined inserts and characteristics of the replicated. The values of inserts roughness were Sa = 13.73 nm and Sq = 17.08 nm. Regarding the design micro structure height, there was a difference of 2.07 µm if compared to a maximum of 17.93 µm obtained from machining. Mold temperatures were 100, 115 and 130 °C and a constant injection pressure of 130 bar. The replicated diffraction grating presented replication levels between 98% and 99%. The experimental results showed that the injection molding process is a viable technique to replicate with high quality micro characteristics of diffraction optical elements generated by turning with single point diamond tool.

Keywords: Diffraction grating, injection moldling, plastic lenses.

1.Introduction

Optical systems are now the backbone of telecommunication networks and computers. The products used in multimedia cover a large range of equipment used for receiving (sound recorder, camera, video), analysis, manipulation and interaction (computer, software, games), storage (hard disk, compact disc, digital disc), and output (printer, projector, monitor, microphone) [1]. Diffraction grating is an optical component that contains a series of grooves, parallel and very close to each other that are the elements responsible for the diffraction. A Fresnel lens is formed by concentric saw tooth shaped structures that provide functions such as condensation and lightning dispersion, called diffraction gratings, which are diffractive optical elements, widely used because of their high efficiency. Recent advances in multi axis equipment using diamond tools combined with new techniques and materials allow great flexibility in the direct machining of diffraction gratings with varying angles and steps. Micron injection molding can be used to produce micro structured parts In large volumes and with a cost benefit ratio. Studies are being conducted on issues related to suitable material, equipment, molding technology, guidelines for micro cavity generation and process control.

2. Experimental Method

The figure 1 shows the detailed design and lens with a diameter of 8 mm.

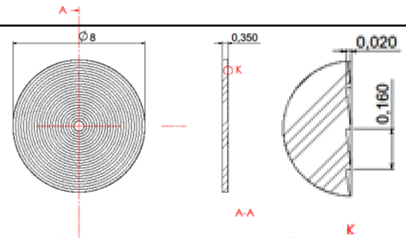


Figure 1. Diffraction grating.

The insert were made of electrolytic copper for high conductivity and used a single crystal diamond tool. The machining operation was performed in 3 steps. In step 1, the tool moves along the Z axis to generate the incidence surface. Then in step 2 the tool movement forms the outlet face of the frame, and at 3 the tool recoil. The operation was performed from the center to the periphery of the part so that it did not cause any alteration in the profile due to the effect of the contact of the half radius of the tool with the apex of the edge of the structure. Figure 2 presents schematically a generic machining model of diffraction grating profile [2].

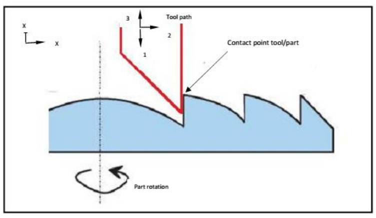


Figure 2. Cutting model with tool without tip radius.

The cutting geometry of the tool has nose radius = 0 mm and rake angle = 10 °, brand CONTOUR FINE TOOLING, model HCO 10 m LGC model,table 1.

Table 1. Tool geometry and cutting conditions.

TOOL	Rake angle γ^0	Nose radius (mm)	Spindle rotation (rpm)	Feedrate (µm/rev)	Depth of cut (µm)
HCO 10m LGC	0	0	1000	1	1

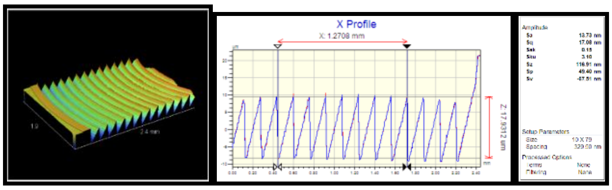
The structure of figure 1 were made of polymethylmethacrylate (PLEXIGLAS® V825) in a horizontal injection mold machine manufactured by Dr. Boy GmbH & Co. KG. To evaluate the shape and surface integrity of the mold cavities and the molded lenses was used Weeco Optical Profilometer, model NT 11000. To evaluate the relation between the molded surface and molded injection process, variations were made in mold temperature. The other parameters remained constants as shown in table 2.

Table 2. Injection parameters.

Test N°	Inj.temp. (°C)	Inj. speed (mm/sec)	Inj.time (sec)	Inj.pres. (bar)	Moldtemp. (°C)
1	210	115.5	0.8	130	100
2	210	115.5	0.8	130	115
3	210	115.5	0.8	130	130

3. Experimetal results

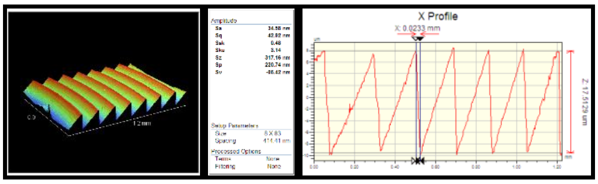
Figure 3(a) shows the profilometry of 3D insert diffraction grating structure machined monocrystalline diamond tool. (b) shows the profile accuracy. In A it can be seen that at the bottom of mold the grooves are sharp and well formed resulting from the use of tool has tip radius = 0. The value obtained in machining operation 17.93 µm results in a decrease of 2.07 µm if compared to design height (c) The roughness values Sa = 13.73 nm and Sq = 17.08 nm are shown in (d).



(a) (b) (c)

Figure 3. (a) 3D mold. (b) Profile structure. (c) Values of the roughness.

Mold temperature was varied at 100, 115 and 130 °C. The injection pressure was keep constant at 130 bar. Figure 4 (a) optical profilometry of the lens molded at 100 ^{0}C. In (b) the roughness Sq = 42.92 nm compared to roughness of insert Sq = 17.08 nm, shown in figure 3 (d), resulted in an increase of the lens roughness. The height 17.51 µm of the replica is shown in (c). Compared with the height 17.93 µm of insert obtained from profilometry of figure 3 (b), resulted in a decrease of 0.42 µm which is not significant for the process.



(a) (b) (c)

Figure 4. Optical profilometry of diffraction grating injected with mold temperature at 100 ^{0}C. (a) Three-dimensional profile of lens. (b) Roughness (c) Profile structure.

Analysis related to the degree of replication of microstructures can be seen in the chart where the replication rate was calculated from equation, Hr/Hi x 100 (%), suggested by [3], were: Hr=height of the replicate structure and Hi =height of the insert.

The replication rate is dependent on the process variables, and the mold temperature and the injection pressure were studied. In figure 5 the graph with the injection pressure constant and was varied the mold temperatures above the Tg of material, the replication rates remained practically constant. The replication rate was between 98 and 99%, meaning that the parameters involved in the molding process provided a good degree of replication.

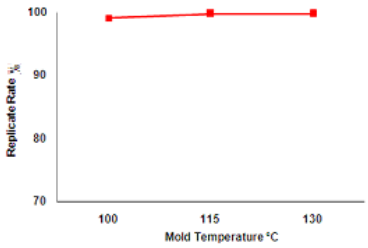


Figure 5. Replication rate of the diffraction grating height with respecto to: (a) Injection pressure (b) mold temperature.

4.Conclusions

The main objective of this research was to analyze the process of injection molding for replication of micro optical element polymer. This research includes learning about the process of micro injection molding, its ability to reproduce the characteristics of small lenses and their limitations. Factors such as mold temperature and injection pressure were studied. As the concepts applied in this study are different from those used widely in conventional injection molding, due to little information nationally, both in industry and in academia, the results of the experiments can be considered satisfactory and show that it is possible to obtain polymeric microelements injection molded, high quality and precision optics, using molds machined monocrystalline diamond tool, where the reduction of cost of production for the manufacture of molds and molding the lens is very important factor. The process is capable of replicating micro-optical components in high volume production with low cycle times of injection. The lenses of this research were molded with injection time of 0.8 second and constant injection speed of 115 mm / sec. Although the values of the roughness of the insert and the replicated lenses have been higher than expected for optical surfaces, where it is recommended to be in the range 5-10 nm, the experiments showed good fidelity replication. Although the tests performed has been observed that the temperature of the mold together with the injection pressure influence the quality of the molded surface, it can be considered that condition alone, whereas other parameters, such as clamping force, injection time and injection speed can also affect the results. The degree of replication of the molded lens indicates that the process conditions were appropriate.

5. References

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