Precise Machining of Micro Prisms in Large Scale Areas

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Abstract

With increasing demand for micropatterns such as V-shaped micro-prisms and the trend of larger surface areas in developing technologies, precision machining technology for micropatterns on large scale areas is expected to play an increasingly important role in today's manufacturing technology. Since the related products such as diffusion and light guide plates for large flat displays are produced by injection molding method, machining technologies for large surface flat mold are very important. In this study, we focused on developing machining technologies to fabricate large-surface micropatterns in an electroless nickel-plated workpiece with single-crystal diamond tools. The developed technologies were successfully applied to make moulds of prism-shaped patterns with tens of microns for larger televisions than 32" (675mmx450mm).

1 Introduction

Recently, there have been strong interests in fabricating micropatterns through mechanical cutting processes, i.e., ultra-precision machining. In particular, with the trend of technical development for micropatterns changing to those with large surface areas, fabricating techniques of micropatterns on large surface areas are required, and the related products can be produced using a roll mold or a flat mold. Although replication off micropattern-machined drum could be preferred in various optical films, some products such as diffusion and light guide plates are still produced by plastic injection molding. For this reason, machining technologies for large surface flat mold are very important. However, researches conducted thus far [1] have only focused on machining techniques for small surface areas of less than 10 in or of 10~20 in, and no researches have been conducted on large surface areas of over 30 in, which have generated strong interests in recent times.

In this study, we focused on developing machining technologies for the fabrication of micropatterns in an electroless nickel-plated workpiece with single-crystal diamond tools, and 32-in, 675mmx450mm, mold with prism-shaped micropatterns.

2 Machining technologies for large surface area

In the case of pattern machining for large surface areas, machining time is much longer than that in general pattern machining and it is not easy to achieve uniform machining accuracy in the entire machined areas, because of various factors such as tool wear and thermal deformation of machine tools. Z axis displacement caused by thermal expansion is one of most important errors caused by the movement of the machine tool, and this leads to a difference in cutting depths in the case of long distance cutting. In addition to this, many other error factors must be considered for ensuring uniform form accuracy in large-surface-area machining.

2.1 Improvement of tool setting accuracy

In current pattern machining, it is difficult to expect precise setting accuracy and controllable setting errors because tool setting is executed on the basis of operators' experience and ability. Moreover, since the images for setting are magnified by using a powerful microscope with a very low depth of field, it is difficult to obtain an accurate focus position, thus resulting in difficulty in acquiring accurate geometrical information from magnified images; this in turn leads to operators achieving inconsistent setting accuracy. To solve these problems, a tool-setting system based on machine vision for guaranteeing consistent setting accuracy has been developed in this study. The machine vision system used for tool setting includes image capturing, focus positioning, binarization with black-white mask, edge detection and distance measuring.

2.2 Tool path generation and machining simulation

In this paper, path generation and machining simulation software that can be applied to micropattern machining has been developed for minimizing errors that can occur in actual machining. The developed program was implemented with visual C++ in Rhino3d 3.0 as a plug-in and with the use of Boolean operation and collision detection algorithms for path generation and simulation.

2.3 Machining method and condition

The cutting conditions and method required for stable machining must be selected carefully before actual machining in order to prevent tool wear or breakage during machining. This is because several days are required for large-surface-area machining. In addition, the preheating of machine tools must be ensured to prevent thermal deflection, which is an important factor in ultra-precision machining. Z axis displacement was measured during the movement of machine tools, and micropattern machining was also carried out in sample cores with various cutting depths (1um ~ 20 um) and speeds (3000mm/min ~ 10000mm/min) to determine the cutting conditions.

2.4 Construction of OMM system

A measurement system that has a 10 nm resolution is required for precisely measuring the machined micropatterns. However, no systems are available for measuring large surface areas despite the fact that some microscopes with such a resolution are in use commercially. To fix this, we separated the head part from a Keyence 3D violet laser scanning microscope with 18000x magnification and a 0.001 μm resolution and attached the separated optical part to a machine tool by a jig that was designed and tested through various vibration analyses.

3 Experiments and results

In this study, a 32-in, 675mmx450mm mold of V- and pyramid-shaped patterns with tens of microns was manufactured by the proposed technologies. A Toshiba UMP-160160D ultra-precision machine that has been developed with a positioning resolution of 1 nm for the purpose of high-precision machining via single-crystal diamond tools was used in the experiments. Fig. 1 shows the machining conditions and results. The right half of the workpiece shows prism (V-shaped) patterns and the left half shows pyramid-shaped patterns that were obtained by crossed prism patterns. To measure the machining accuracy of the entire machined surface the nine points shown in Fig. 2 were measured using the implemented OMM system, and the difference between the designed values and the measured results was determined. From the results, it was concluded that form accuracy below average 0.2 μm can be guaranteed. Usually, since the required form accuracy of micropatterns in optical instruments is roughly 0.5 μm, it is possible to obtain precision by the application of the proposed technologies.

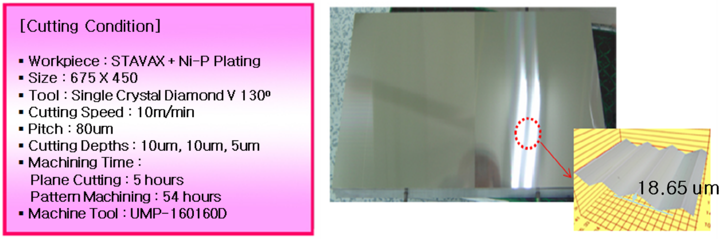
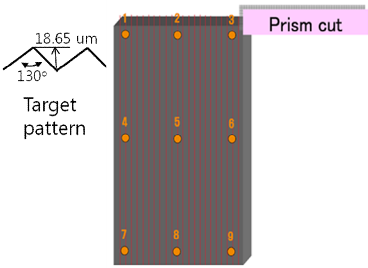


Figure 1: Machining conditions and results



Measuring Points	Target Data	Measured Date	Machining Error
1	18.65	18.86	0.21
2	18.65	18.96	0.31
3	18.65	18.71	0.06
4	18.65	18.80	0.15
5	18.65	18.71	0.06
6	18.65	18.68	0.03
7	18.65	19.01	0.36
8	18.65	18.87	0.22
9	18.65	18.67	0.02

Figure 2: Measured data

4 Conclusions

In this paper, large-surface-area machining technologies for injections molds have been proposed, and finally, a 32-in, 675mmx450mm mold was manufactured by using the proposed technologies, and it was experimentally verified that the application of the proposed technologies yields precise micropatterns.

Acknowledgments

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