

A Study on the Machining Technology for Micro Prism Structure Array by Using Shaper Cutting Process

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Abstract

The precision mold machining technology for manufacturing micro prism structure array was developed using ultra-precision shaping machine and single point diamond cutting tool in this study. The size of pattern is 10 μ m length, 6 μ m width 1.3 μ m and 2.2 μ m height. The length of pitch is 314 μ m and 191 μ m, respectively. This study deals with how to machine the micro structure, characteristic of the ultra-precision shaping machine, design and making of cutting tools, how to align cutting tools, feasibility test, analysis of machining process, final mold machining and measuring results.

1 Introduction

The display industry needs large-area optical components having micro patterns or micro structure arrays (sometimes mixed on the same component) such as lenticular shape, prism, pyramid, lens, channel and thin wall (barrier rib) more and more for increasing optical efficacy recently [1]. Some researchers are developing metal cutting, laser machining and etching technique for meeting the demand of the ultra-fine structure, and some technologies are applied to mass production. Ultra-fine machining technology for flat mold was developed to make micro prism structure array efficiently using ultra-precision shaping machine and single crystal natural diamond cutting tool in this study. The technology can be applied to make highly efficient optical components used in LCD BLU [2].

2 Experiments

The mold size and the details of micro prism structure arrays are displayed in Fig. 1. The size of micro structure were $10\mu\text{m}$, $6\mu\text{m}$, $1.3\mu\text{m}$ and $2.2\mu\text{m}$ (length, width, height 1 and height 2, respectively), and the pitches among the structures were $314\mu\text{m}$ and $191\mu\text{m}$. The size of the mold was $45\times 55\text{mm}^2$ and the mold was made of electroless plating nickel. The two kinds of single crystal diamond cutting tools were designed and manufactured for the two kinds of pitches ($314\mu\text{m}$ and $191\mu\text{m}$). The micro prism structure array was made by cross-machining with the two kinds of diamond tools attached to ultra-precision shaping machine. The first tool moved to transversal direction and after finishing transversal machining the second tool moved to vertical direction which was rotated 100° from the first direction. The machining speed was $1,200\text{mm}/\text{min}$ and the machining depth was $2.2\mu\text{m}$ and $1.3\mu\text{m}$. Machining of each pattern was finished by moving of the tool once.

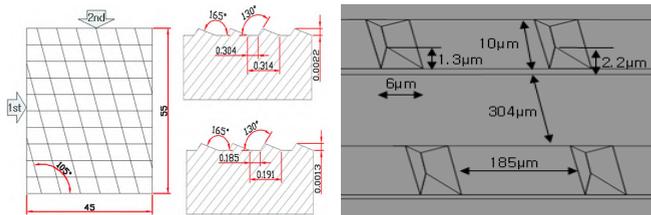


Figure 1: The details of mold and micro prism structure array

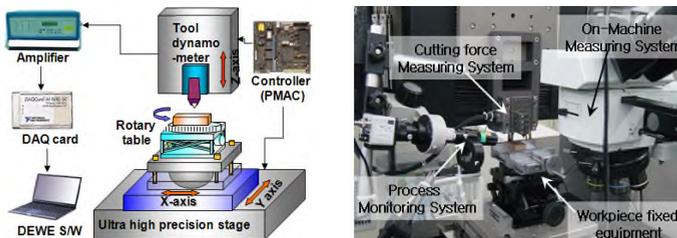


Figure 2: Schematic diagram of experimental set up of the ultra-precision shaping machine

The schematic diagram and the photo of the ultra-precision shaping machine are shown in Fig. 2. The shaping machine consists of three-axis (X-Y-Z) stage and rotary table module. The machined mold is located on X-Y stage combined with the rotary table. The X-Y stage, the rotary table and Z stage (attached the tool) are controlled under 5nm, 0.01° and 40nm, respectively. There was a tool dynamometer (Kistler, MiniDyn 9256A2) beneath the mold, which measures cutting force and machining state during machining in real time.

3 Results and Discussion

3.1 Pre-test of prism pattern machining

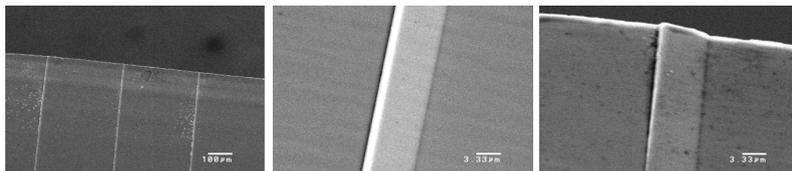
Figure 3 shows machining result of 314 μm pitch after machining for flatness. A little deviation of inclination was observed in Fig. 3(a), and there was a little deviation of height at the point of intersection when rotating the mold 100° and machining. The deviation of inclination was under 3 μm . It was necessary to recalibrate inclination precisely after rotating the mold. The machining results of prism pattern using 304 μm width diamond tool at entrance surface, middle surface and exit surface are presented in Fig. 4. There is little burr at the exit surface, however, they are well-machined overall.



(a) 1st machining error

(b) 2nd machining error

Figure 3: Machining troubles caused by rotation error of mold



(a) Entrance surface

(b) Middle surface

(c) Exit surface

Figure 4: Comparison of machined surfaces

3.2 Machining and analysis of prism structure array

Figure 5 presents the machined mold and the magnified photo of prism structure array, and figure 6 shows the measured size and accuracy of machined patterns. There were 41,000 micro prism patterns without errors of shape, roughness and burr on the area $45 \times 55 \text{ mm}$ of the machined mold. It was observed that the pitch and angle of the arrays were matched to the designed values.

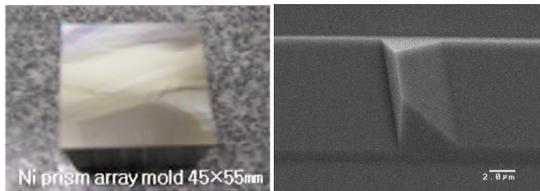
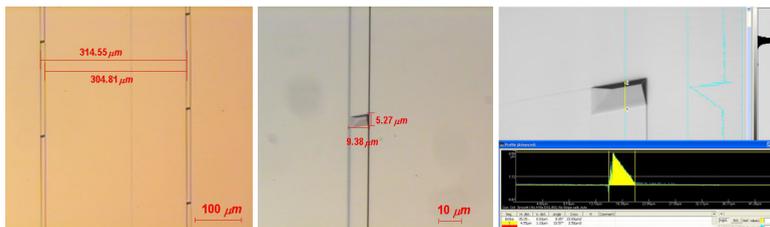


Figure 5: Machined mold and micro prism structure



(a) pattern pitch (b) pattern size (c) pattern angle (165° , 130°)

Figure 6: Measurement and analysis of the micro prism structure array

4 Conclusion

It was developed to manufacture a mold having micro prism structure array using shaper machining technology in this study. The micro prism structure array was obtained by cross-machining with two kinds of fine diamond tools having different angle and width. This technology can be used to manufacture complex light guide plate and film mold having high optical efficacy which are much useful in display industry.

References:

- [1] Y. E. Yoo., S. M. Hong., T. J. Je., D. S. Choi., "Mechanical machining of prism pattern", Transactions of Materials Processing, Vol. 15, No. 1, pp. 71~75, 2006.
- [2] T.J. Je, B.D. Kim, E.C. Jeon, J.S. Yoon, Y.E. Yoo, D.S. Choi, E.S. Lee, "Machining technology of micro prism array using planner cutting process", Proceedings of the KSMPE spring conference, pp.191~194, 2009