Micro-machining of bidirectional optical waveguide platform by ultra-fine planing technology

Eun-chae Jeon[1], Tae-Jin Je[1], Eun-Suk Park[2], Hwan-Jin Choi[2], Doo-Sun Choi[1], Myung-Yung Jeong[3]
[1]*Dept. of Nano Manufacturing Technology, Korea Institute of Machinery and Materials (KIMM), Korea*
[2]*Dept. of Nanomechatronics, University of Science and Technology, Korea*
[3]*Dept. of Cogno-Mechatronics Engineering, Pusan National University, Korea*

jeonec@kimm.re.kr

Abstract

Metal molds for a newly proposed bidirectional optical waveguide platform were machined by micro end-milling technology and ultra-fine planing technology. The platform had a Y-shape with dimensions of 100 ㎛ and 980 ㎛. The mold from the ultra-fine planing had much better surface roughness than that created by micro end-milling; therefore, the mold machined by ultra-fine planing was used to make a stamp and the platform. The platform was operated successfully at a data rate of 155Mbits/s bidirectionally.

1 Introduction

Optical communication technology using optical waveguides has been highlighted recently due to the increasing demand for high-speed networks. Generally, two optical fibers or mirrors are used for bidirectional communication which is important for the high-speed networks [1]. However, these methods require complex and expensive systems. A simple Y-junction bidirectional optical waveguide platform was suggested recently. These platforms are studied in this study to develop micro-machining technology of a mold for mass-production of the platform and to verify its characteristic when created from the machined mold.

2 Experimental procedures

A schematic diagram of the designed platform is presented in Fig. 1. The platform has a tap waveguide (100 ㎛ width) connected to a resonant cavity LED (RC LED) and a bus waveguide (980 μm width) connected to a photodiode (PD). The bus waveguide was machined by micro end-milling technology and ultra-fine planing technology in order to determine which technology is more feasible for machining the platform. The tap waveguide was then machined by the superior technology. The machining conditions of the two machining technologies are written in Table 1. A 6:4 brass (Muntz alloy) was used for the mold. A PDMS stamp was replicated from the machined mold and the bidirectional optical waveguide platform was molded from the stamp using PMMA resin. The characteristics of the molded platform were evaluated at a data rate of 155Mbits/s.

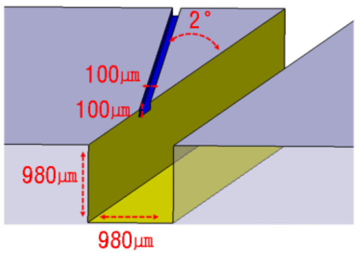


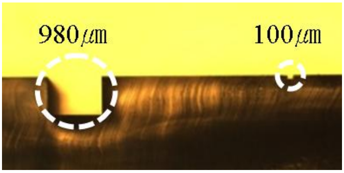
Figure 1: A schematic diagram of the bidirectional optical waveguide platform

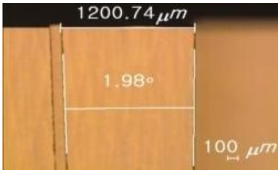
Table1: Experimental conditions for the micro end-milling and ultra-fine planing processes

Micro end-milling		Ultra-fine planing	
Cutting tool	300 μm WC flat end-mill	Cutting tool	width 980 μm diamond width 100 μm diamond
Spindle rate	50,000rpm	Cutting depth	2 μm*1 + 5 μm*195 + 3 μm*1 2 μm*1 + 5 μm*19 + 3 μm*1
Tool feed rate	10mm/min	Tool feed rate	100mm/sec

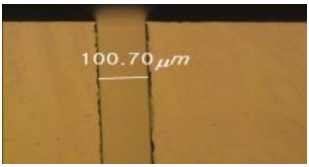
3 Results and Discussion

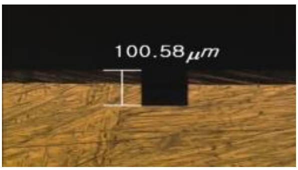
The width and depth of the bus waveguide machined by micro end-milling were exactly as designed; however, the surface roughness (R_a) of the floor was 533nm as measured by laser microscope (Keyence). The moving track of the end-mill tool created a considerable amount of roughness. The requested specification of the surface roughness of the optical waveguide was under 100nm; therefore, the micro end-milling technology was not proper. On the other hand, the surface machined by ultra-fine planing technology showed good surface roughness of 85nm. The excellent surface of the diamond cutting tools and the multi-pass machining method helped to create a good surface. Moreover, the final step of shallow depth machining was much helpful. The tab waveguide was then machined by ultra-fine planing technology, and the final machined mold is displayed in Fig. 2. The cutting force was stable during the planning process as shown in Fig. 3. The cutting force of the bus waveguide was nearly ten times the cutting force of the tab waveguide.





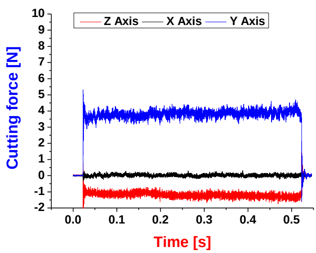
(a) (b)

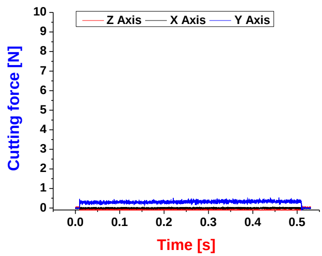




(c) (d)

Fig. 2: Two waveguides machined by ultra-fine planing: (a) side view and (b) top view, and (c) width and (d) thickness of the tab waveguide





(a) (b)

Fig. 3: Cutting force during machining (a) a bus waveguide and (b) a tab waveguide

A PDMS stamp was replicated and the PMMA bidirectional optical waveguide platform was molded. An eye diagram of the platform to which an RC LED and a PD were attached was measured under a general high-speed network condition (a data rate of 155Mbits/s). If the eye diagram shows a rectangle, the platform works normally and successfully. As shown in Fig. 4, the platform with an RC LED and a PD was operated successfully at a data rate of 155Mbits/s bidirectionally.

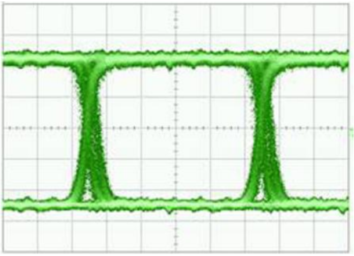


Fig. 4: Eye diagram at a data rate of 155Mbits/s measured from the molded waveguide platform [2]

4 Conclusions

We machined a mold for a newly proposed bidirectional optical waveguide platform by ultra-fine planing technology.

(1) The ultra-fine planing technology with diamond cutting tools is much better for machining a mold for optical waveguide platforms compared to the micro end-milling technology which could not meet the surface roughness specifications.

(2) The platform molded from the machined mold was operated successfully at a data rate of 155Mbit/s.

References:

[1] T. Kibler et al., “Optical Transceiver module for star networks in cars”, SPIE, pp.54, 2003.

[2] T. H. Lee et al., “Imprinted bidirectional waveguide platform for large-core optical transceiver”, Optics Letter, 36(13), pp.2324-2326, 2011.