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Polymer microlens fabricated on fiber tip for optical interconnect

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Abstract. An optical interconnect has attracted much interest to many researchers as it seemed as a solution to meet the requirement of future demand due to the limitations of the electrical interconnect. Low power consumption, small signal variation, and wide bandwidth are the example of the advantages of the optical interconnect. Nevertheless, the optical interconnect requires a high optical coupling which is a hurdle for the optical interconnect. The implementation of the microlens in optical interconnect seems as one of the possible ways which can solve the problem. It is expected that the microlens can focus the spreading light beam and improved the optical coupling. Thus, the polymer microlens has been fabricated on two different platforms; (i) on a ferrule insert with fiber inserted and (ii) directly on the fiber end. The Far Field Pattern measurement system has been used to evaluate the light collecting for both microlens and the divergence angle was measured. The results show that the divergence angle of the microlens on fiber end is better compared to the microlens on the ferrule.

1. Introduction

The development of the information technology has lead to the demand for the high network capacity and data transfer. However, the conventional copper based electrical interconnects incapable of fulfilling the requirement due to their high propagation loss, high power consumption, and inter-channel crosstalk during high-speed data transfer [1, 2]. Thus, to satisfy the demand, the introduction of optical interconnects to the printed wiring board is seemed as a promising candidate to resolve the issues. The optical interconnects are recommended to replace electrical interconnects due to its low power consumption, wide bandwidth and high data rate density, less crosstalk, light weight and small variation in signal delay [3,4]. With these advantages, the possibility to apply the multi-layer optical interconnect for optical printed wiring board can be realized [4]. Nevertheless, to maintain high optical coupling efficiency between planar surface devices and the multichannel waveguide is quite difficult. This is because the light beam easily spreads from the devices or waveguide itself [5]. Thus, by implementing the microlens in optical interconnect, it is expected the light beam can be focused and improved the optical coupling.

In this paper, the preliminary study has been done to evaluate the possibility to apply the microlens into the optical interconnect. The microlens is fabricated in two different platforms; microlens on

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ferrule and microlens on the fiber end. The process of the fabrication is briefly explained. Some results from Far field pattern (FFP) measurement system and divergence angle are presented.

2. Fabrication and Analysis

Several fabrication technologies to fabricate the microlens for prototype or small quantities has been created and used by many researchers such as lithography, laser- and e-beam writing, deep-proton lithography, micro-jet printing, LIGA, and laser ablation [6-9]. In this paper, the syringe method is proposed to fabricated the microlens on the ferrule due to its easiness, simplicity and low fabrication cost.

2.1. Microlens on ferrule

A ferrule is a ring or cap attached to an object to protect against damage, splitting or wear. In the optical fiber, a ferrule is one of the important component to align and protect the strip end of the fiber. Ferrule can be made of plastic, metal, glass and ceramic materials. In this experiment, a ceramic ferrule is chosen as a platform to fabricate the microlens. The dimension of the ferrule is 2500µm of diameter with 1250µm of length.

At first, the bare single mode fiber (SMF) is inserted into a ferrule. Then, the Epo-Tek adhesive is applied at the end of the ferrule to ensure the bare fiber and the ferrule are attached together. After that, the UV curable resin (NP-206) with the refractive index 1.5437 (@1551nm), 1.5456 (@1305nm), and 1.5523 (@850nm) from Nissan Chemical is dropped on top of the ferrule with SMF using a syringe [10]. Subsequently, the droplet forms into partially sphere when they touch the ferrule end due to the surface tension. Later, the droplet transform into a solid microlens after being exposed to the UV light radiation with the wavelength, λ = 365nm.

Figure 1 illustrates the fabrication process of the microlens using syringe method. The dimension of the fabricated microlens is as follow; the diameter and height of the microlens are 2500µm and 992µm respectively as shown in Figure 2. Three samples of the microlens had successfully fabricated.

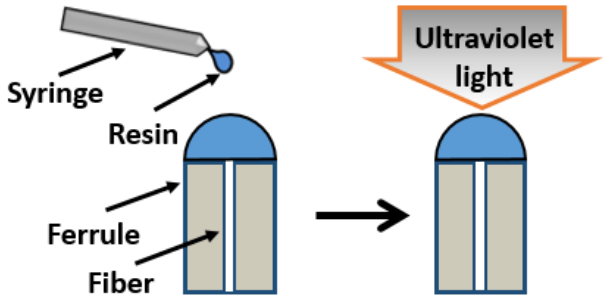


Figure 1. The fabrication process of microlens on a ferrule using a syringe.

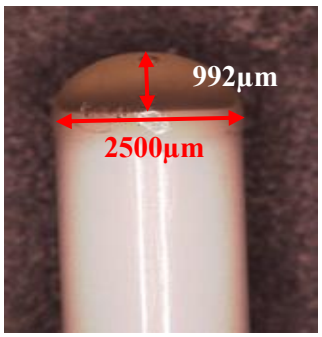
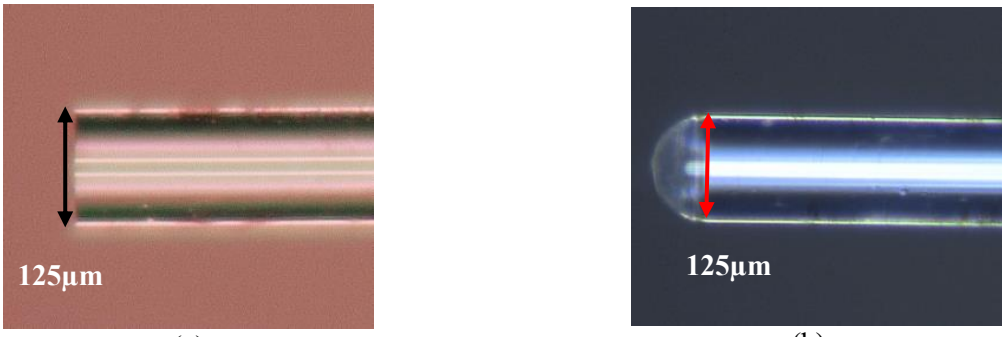


Figure 2. Example of fabricated microlens on a ferrule.

2.2. Microlens on fiber tip

The end face of the fiber tip was cut using a cleaver to obtained a perpendicular and smooth surface to avoid the diffused reflection of light emitted from the fiber before the fabrication of the microlens as shown in Figure 3 (a). The fabrication process was started with dropping a small amount of UV-curable resin onto a slide glass. Then, the resin was attached to the tip of the fiber with a sense that the tip of the fiber slightly contacted to the resin from above. After that, the resin was irradiated and cure to the ultraviolet light with the wavelength, λ = 365nm. Figure 3 (b) illustrates an example of the microlens fabricated on fiber tip. Seven samples of the microlens have been successfully fabricated.



(a) (b)

Figure 3. Example of (a) perpendicular and smooth fiber end and (b) microlens fabricated on fiber end.

2.3. Analysis

After the fabrication, both microlens were measured using Far Field Pattern (FFP) measurement method to measure the light collecting as one of the characteristics of the fabricated microlens. The 1550nm of wavelength is used in this measurement. The measurement setup is shown in Figure 4. Before start, the end of the fiber which has been fastened with SC connector is connect the laser diode (LD). Whilst, the fiber end with microlens is connect to the FFP measurement instrument. Based on the measurement result, the divergence angle of the fabricated microlens can be obtained.

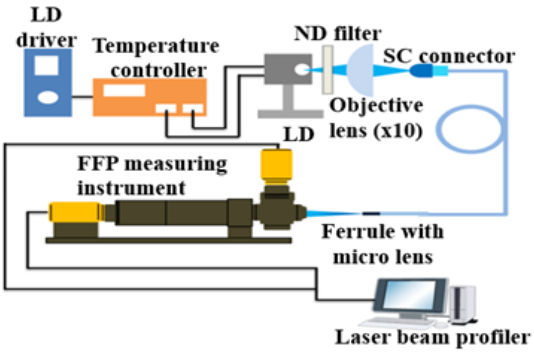
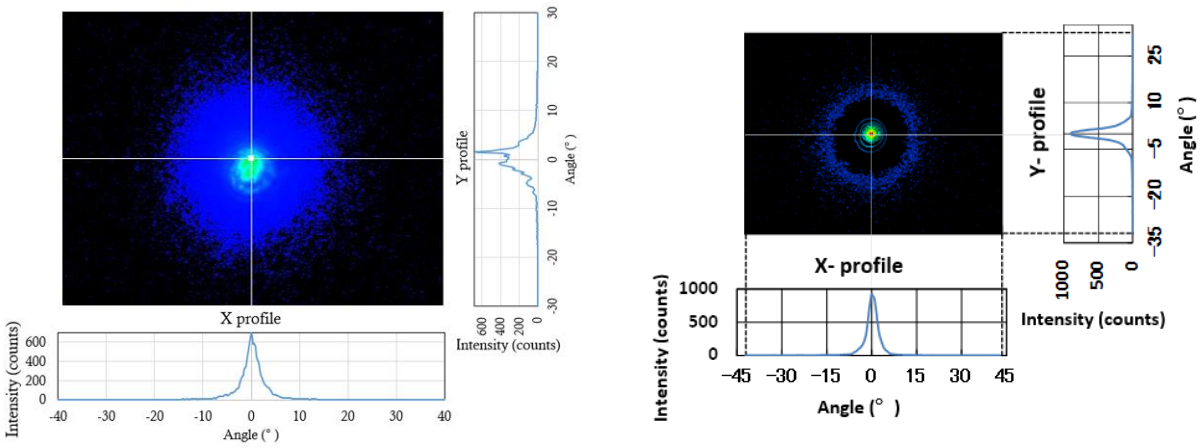


Figure 4. FFP measurement system is used to evaluate the fabricated microlens.

3. Results and discussion

Figure 5 (a) and (b) display the FFP image and profile takes from the FFP measurement for both conditions. The profile image from the x- axis shows the intensity of the light along the x-axis while the image profile from the y-axis indicates the intensity the light from the source along the y-axis. The crossing point in the figure refers to the highest intensity of light that can be detected from the light. From the profile image, the divergence angle is obtained. To obtain the divergence angle, the $1/e^2$ method is used.



(a) (b)

Figure 5. An example of the FFP image and profile (a) microlens on the ferrule and (b) microlens on the fiber tip.

Table 1 and 2 below show the divergence angle of the output light without using the microlens, using the microlens with ferrule and using the microlens on fiber tip. Based on the tables, the divergence angle of the light without using the microlens is 13.9° at x-axis and 12.3° at y-axis while when using the microlens on the ferrule the divergence angle is smaller especially Sample 3 with 7.5° at x-axis and 8.4° at the y-axis. From the divergence angle, the light can focus more by using the microlens, thus it is seemed possible to use the microlens on optical interconnect to improve the coupling efficiency.

Thus, the divergence angles of the microlens on ferrule and on the fiber tip are compared to distinguish which microlens can perform better to focus the light. Based on the comparison, the divergence angle of the microlens fabricated on the fiber tip is much smaller compare to the microlens fabricated on the ferrule. The reason behind this result is due to the size of the microlens and the radius of the curvature produced. The radius of the curvature of the microlens on ferrule is approximately 1200µm while for the microlens on the fiber is about 65µm.

Table 1. Size and divergence angle of the microlens fabricated on the ferrule and the divergence angle without using the microlens.

Sample No.	Diameter (µm)	Height (µm)	Radius of curvature (µm)	Divergence angle (deg.)	
				X	Y
Without micro lens	–	–	–	13.9	12.3
Sample 1	2100	630	1190	10.8	10.9
Sample 2	2500	1000	1281.3	10.0	8.1
Sample 3	2500	992	1283.6	7.5	8.4

Table 2. Size and divergence angle of the microlens fabricated on the fiber tip.

Sample No.	Diameter (μm)	Height (μm)	Radius of curvature (μm)	Divergence angle (deg.)	
				X	Y
Sample 1	125	58.3	62.7	7.5	8.0
Sample 2	125	50.0	64.1	8.5	10.7
Sample 3	125	41.7	67.7	14.9	10.7
Sample 4	125	44.2	66.3	3.2	8.8
Sample 5	125	19.4	67.0	5.3	6.5
Sample 6	125	41.8	67.7	5.2	3.8
Sample 7	125	40.2	64.2	5.8	2.7

4. Conclusion

As a conclusion, the microlens has been successfully fabricated on two different platforms; (i) on the ferrule and (ii) directly on the fiber tip. The syringe method has been used to fabricate the microlens due to the easiness, simplicity and low cost procedures. Based on the result, by using the microlens the spreading of the light can be more focus. Thus, the microlens can help to improve the coupling efficiency on the optical interconnect. In addition, the size of the microlens and the radius of curvature produce can affect the divergence angle of the output light.

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