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Micro Grinding Technique of Mutilcore Fiber Endface Using 3D Flock-structured Film

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Abstract. In order to control the 1~2-um protrusion height of mutilcore (MT) fiber endface in optic connectors, a micro grinding approach was developed using a 3D flock-structured film. The objective is to replace traditional lapping with loose-abrasive slurry. Experimental result shows that to achieve its height requirement and good quality, this approach requires 5-steps grinding processes with normal coated lapping film and three-dimensional coated flock lapping film. It is found that using 3-um-size silicon carbide flock lapping film, the grinding time and the pressure are the key factors to control he 1~2-um protrusion height of fiber endface. Moreover, the endface protrusion height of 1-um and larger can be achieved through the optimization of micro-grinding conditions.

Introduction

Fiber optic connector is the passive optical device to connect two or more fibers. Currently, the fiber optic communication technology is developing toward the direction of high-bandwidth and high speed[1]. Fiber optic connectors include different types such as SC, FC, LC, ST, MU, MT, the physical contact modes have PC, UPC, APC types and so on. The MT connector is being widely used in many areas. At present, more and more world's leading companies are speedily developing on the MT series connectors[2]. MT connector is ribbon shape plastic connector for multi-fiber, which is developed by NTT corporation, the advantages of MT connector are excellent communication capacity and low cost and so on.

The fiber height is one of key factors for connection, generally 1~3-um fiber height for MT fiber optic is requested by most customers, which has high correlation with grinding process. Traditional process is to use fiber pad and SiC slurry for grinding, the weaknesses are that it is difficult to operate and control the fiber height, the process is in a mess as well. This article will discuss the grinding process for MT fiber connectors and focus on the fiber height control and endface quality control. The optimized process, key steps and key factors are determined through DOE (Design of Experiment).

Fiber Micro-endface Quality and Light Loss

Three endface geometry parameters: apex offset, radius of curvature, and fiber height are the critical elements for achieving physical contact when two optical connectors are mated [3], as shown in Fig 1. In Samuel I-En Lin's article, he just researched normal ceramic connector and didn't mention about the lapping process for MT fiber connector. For the MT fiber optic connectors, the positive fiber height are requested, it makes the fibers fully mated so that it is able to reduce light loss when connection. Fig 2 shows a schematic diagram of ceramic fiber connection, it is critical on how to reduce insertion loss and return loss on the optical fiber connection. Insertion loss is the loss of signal power resulting from the insertion of a device in a transmission line or optical fiber and is usually expressed in decibels (dB). Return loss or reflection loss is the loss of signal power resulting from the reflection caused at a discontinuity in a transmission line or optical fiber. The fiber core diameter, refractive index, location difference, endface shape and endface quality and so on is effective on light loss when fiber optics connection. This article will focus on fiber height and endface quality on the MT fiber optic connector.

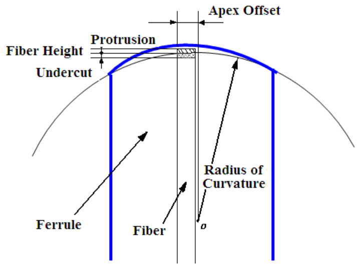

Fig 1: Fiber optic endfaces geometry parameter

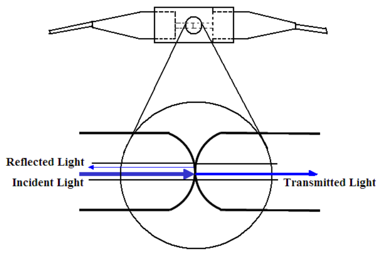

Fig 2: Schematic diagram of ceramic fiber connection

Fig 3: MT connector

Fig 4: Domaille APM HDC-4000

Experimental Material and Methods

Experimental Material. The Fiber used in the experiments is 8 cores thermoset MT fiber optic connectors as shown in Fig 3. 3M precision abrasive products 468X-15micron, 468XW-3micron, 498X-3micron, 298X-1micron and 598X-0.5micron were used in the experiment. 468X-15micron and 468XW- 3micron are standard coated lapping film with silicon carbide mineral; 498X-3micron is flock lapping film with silicon carbide mineral; 298X-1micron is flock lapping film with aluminum oxide mineral, and 598X-0.5micron is the cerium oxide flock polishing film.

Lapping Machine and Inspection Equipments. U.S Domaille lapping machine(model APM HDC-4000) is used to this experiment, the pressure and speed of the grinding machine are able to be manually adjusted[4], Fig 4 shows the machine. MT fixture and glass pad from Domaille are used as well. The endface quality inspection is to use PTISPEC magnifier; the interferometer equipment is from Norland NC-3005.

Lapping Process. The general grinding process is 468X 15micron → 468XW 3micron→ 498X 3micron→ 298X 1micron → 598X 0.5micron polishing film. Determine the process and effect of parameters by adjusting parameters. And the deionized water was used in all steps.

Result and Discussion

Design of Experiment (DOE). A four factor designed experiment (DOE) was performed using the testing, factors evaluated were applied the grinding time of 498X-3micron, 298X-1micron, and 598X-0.5micron and the pressure, see Table 1. The 468X-15micron, 468XW-3micron and rpm were fixed in the experiment per experience. A total of nine (9) design points were evaluated in this experiment. The detailed design points in the process are shown in Table 2.

Table 1:

Factors / Level	498X 3mic	298X 1mic	598X 0.5mic	Pressure
	second	second	second	lb
1	90	90	90	3.2
2	120	120	120	4
3	150	150	150	4.8

Table 2: $L_9(3^4)$

Factors / Testing#	498X 3mic	298X 1mic	598X 0.5mic	Pressure	Result
	second	second	second	lb	Fiber Height>1000nm
1	1(90)	1(90)	1(90)	1(3.2)	0%
2	1(90)	2(120)	2(120)	2(4.0)	13%
3	1(90)	3(150)	3(150)	3(4.8)	50%
4	2(120)	1(90)	2(120)	3(4.8)	63%
5	2(120)	2(120)	3(150)	1(3.2)	38%
6	2(120)	3(150)	1(90)	2(4.0)	55%
7	3(150)	1(90)	3(150)	2(4.0)	73%
8	3(150)	2(120)	1(90)	3(4.8)	80% (the best)
9	3(150)	3(150)	2(120)	1(3.2)	50%
K1	63	136	135	88	
K2	156	131	126	141	
K3	203	155	161	193	
R	140	24	35	105	

Remark: 498X 3mic: K1=0+13+50=63; K2=63+38+55=156; K3=73+80+50=203; R=203-63=140

Result and Analysis. The fiber height are inspected by Norland NC-3005 after each design points finish and figure out the percentage of good connectors (>1000nm), the result is shown in Table 2 as well. The analysis shows the grinding time of 498X-3micron flock film is the key points, the pressure is also key points. The grinding time of both 298X-1micron and 598X-0.5micron flock lapping films are not the key points for fiber height control. The optimized process is determined on 150s grinding time of 498X-3micron, 4.8lb pressure(8cores) is recommended. 90s-120s grinding time of 298X-1micron and 598X-0.5micron are enough considering the efficiency.

Verification. The process of Testing-1 is shown in the Table 3. The result shows that no scratching is found by magnifier(X400), and the interferometer inspection shows parts of fiber height are less than 1000nm. Fig 5 shows the fiber surface; Fig 6 shows the interferometer result.

Table 3:

Verification Testing							Testing-1	Testing -2	Testing-3
Step	Grade	Mineral	Model	Pressure(lb)	Speed (rpm)	Pad	Time(s)	Time(s)	Time(s)
1	15mic	SiC	468X	3.2	140	Glass	15	15	15
2	3mic	SiC	468XW	3.2	140	Glass	60	60	90
3	3mic	SiC (Flock)	498X	4.8	175	Glass	90	180	0
4	1mic	Al_2O_3 (Flock)	298X	4.8	175	Glass	90	90	120
5	0.5mic	CeO (Flock)	598X	4.8	175	Glass	120	120	120

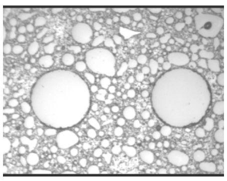

Fig 5: Fiber surface of testing-1

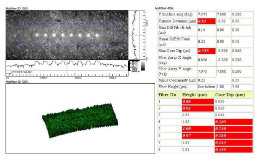

Fig 6: Testing-1 interferometer result

The process of Testing-2 is shown in Table 3. The fiber height meet 1000nm by interferometer inspection and no scratching is found by magnifier after grinding. Fig 7 shows the interferometer result.

To further verify the result of testing-2, the step 3 is removed. Meanwhile, increasing the lapping time of 468XW-3micron and 298X-1micron in Testing-3. The testing result shows the fiber height is less than 1000nm. Fig 8 shows the interferometer result.

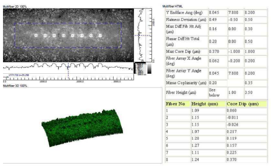

Fig 7: Testing-2 interferometer result

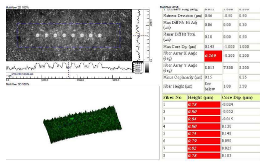

Fig 8: Testing-3 interferometer result

Discussion. The testing-3 further proves that the third 498X-3micron flock lapping film is the key step for fiber height control. Increasing the grinding time of this step can improve the fiber height. The grinding process is not a simple two-dimensional grinding, but a complex three-dimensional grinding with flock film, as shown in Fig 9, the fiber grinding is shown in Fig 10. The fiber material is composed of SiO_2, so the removal of fiber material is less than plastic material, the result is the fiber height is increased by flock silicon carbide lapping film.

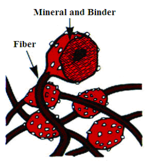

Fig 9: Three-dimensional structure of flock film

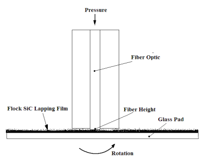

Fig 10: Flock lapping

Summary

Grinding process is an alternative approach for MT fiber endface with 1-2-μm height. Experiment result shows that the flock lapping films is feasible for a micro-grinding of mutilcore fiber connect, and the 3micron SiC flock lapping film is the key step for micro fiber height control. Moreover, 3-μm-size SiC Flock lapping film has good performance in removal rate and roughness, properly increasing lapping time will help the fiber protrusion; the pressure is also key point, properly increasing the pressure of 498X flock can increase the fiber height. The grinding conditions with 180s Lapping time, pressure 0.6 Lb/connector and 175rpm can achieve the fiber height greater than 1 μm. The optimized process was determined through DOE as well.

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