Fused Fiber Products Without a Fused Biconical Taper

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Abstract: We present a new method, thermal diffusion technolgy to make fused fiber products such as couplers/splitters, fixed attenuator, and WDMs. This new process is different from the conventional fused biconical taper (FBT) process and can make more reliable products.
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1. INTRODUCTION

Since about 1980[1], fused fiber products fabricated by tapering two single-mode fibers appropriately twisted or juxtaposed and heated have provided a practical solution to the need for a stable and low loss all-fiber products such as couplers/splitters, WDMs [2], fixed attenuators, and other special fused products. As we know, optical power coupling between fibers results from the effective fiber cores (or mode field diameter) expanded by tapering. Since fused biconical taper (FBT) process makes fiber becoming "thin" in tapering region, this could result in fiber broken inside product package, hence affects the reliability of products. To solve this problem, a few companies developed some solutions such as overclad technology [3]. We also took long time to address this issue, and finally invented a new process-thermal diffusion technology (TDT), this process can be not only easily used to build products with ultra-high reliability but also easily transferred from the current FBT process. What makes it more wonderful is that we can use traditional FBT machine to implement this process to make a serial of fused fiber products without tapering region.

2. BASIC PRINCIPLE

The method is based on the thermal-diffusion phenomenon of Ge^{2+} in original fiber cores in fusion area [4], this phenomenon induces mode-field diameter expanding and finally realizes optical power coupling between fibers. We can control diffusion time and temperature to make different products with predetermined coupling ratio/splitting ratio. According to the FBT process, after fusing two fibers together shown in Fig.1a, we have to taper (or pull) two fibers by the pulling stages which are driven by stepping motors in order to realize optical power coupling between fibers as effective mode field diameter are expanded. It is known that the diameter of fibers in tapered region for typical products is about one third to one sixth of that before tapering, this absolutely affects fused fiber products performance especially environmental stability. But in our new process (TDT), the high-temperature torch will continually heat the fibers after fusing two fibers together until the pre-determined coupling ratio/splitting ratio is reached, during the whole process of TDT, there is no tapering requirement, hence no fiber pulling stages which are driven by stepping motors. Obviously, the diameter of the fiber in diffusion area does not change after mode field diameter is expanded (see Fig.1b), this helps a lot to improve products stability.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

Using this process, we made several different fused fiber products only by heating two fibers. Generally speaking, it should take 7 to 10 minutes to make a coupler/splitter (tap) or WDM.

Here, we used two SMF28 fibers to make 3-dB coupler/splitter, and found that the diameter was about 175μm, which means no significant change of the diameter after diffusion since the theoretical result is 176.8μm if the fiber diameters are accurate before fusion. The square of transversal cross-section of 3-dB coupler/splitter made by TDT process is almost 9 times of that of 3-dB coupler/splitter made by FBT process because the diameter at tapered waist for 1550nm 3-dB Splitter made by using FBT process is about 65μm, which is only one third of that before tapering.

More interesting, we can make 40dB attenuator exactly by using this process. The pre-determined attenuation can be exactly reached by controlling the diffusion speed of fiber core and diffusion temperature. Generally speaking, it is really difficult to make such an attenuator with more than 30dB attenuation by using FBT process. In order to get a 40 dB attenuator, we have to make two 20dB attenuators, and cascade them.

It is well known know that broadband coupler/splitter can be made by pre-tapering one of two single mode fibers before fusing them together [4], which is a indispensable step in making broadband splitter/coupler [5] and currently it is a most popular method. To make broadband splitters/couplers by TDT process, we fused two different fibers together such as SMF28 and HI980, SMF28 and HI1060, or SMF28 and other special fibers, then heat them continually until the coupling ratio we want is reached. More interest is that there is still no pre-pulling step for one of two single mode fibers before fusing them together. Therefore, by using TDT process, we can easily make the broadband products by fusing two different fibers.

Of course, using this process, we can also fuse and heat multi-fiber to make 1xN splitter such as 1x3 and 1x4 splitters with symmetrical or asymmetrical splitting ratio. The heating time of making 1x3 splitter with even splitting ratio is shorter than that of making 1x2 splitter with even splitting ratio since the distance of core to core in fusion region of 1x3 splitter is more closed. Typically, the coupling region of 1x3 splitter is about 10mm that is about 70% of that of 1x2 splitter. Hence, it is confirmed that these products made of multi-fiber are more reliable because of having larger diameter of the cross-section and shorter fusion length.

4. RELIABILITY

Actually, using this process, we have already successfully made several fused fiber product families. As all fibers are totally melt together in fusion region, and its cross-sectional shape in fusion region is very much alike a twin- core (two-core) or multiple-core fiber, so the fusion region or coupling region are very strong and have smallest twisted stress due to an almost circular cross-sectional shape. More important is that micro-cracks on the surface of the fiber can be totally eliminated during diffusion process, which greatly restricts the penetration of water in damping heat test, and prolongs the lifetime of fused fiber products made by this process. Indeed, the qualification testing results we got indicated that performance of these products is ultra-high reliable and totally exceeds the criteria of Telcordia GR-1209-CORE and GR-1221-CORE. Actually, they already passed the dumping heat of more than 5000hrs in the condition of 85°C/RH85%, shown as Fig.2, and passed drop test (impact test) of 20 times for each axis (x,y,z) on cement in the condition of the height of 1.8 m.

5. CONCLUSIONS

We have introduced a novel method to make almost all of fused fiber product families, including 1x2/2x2 narrowband and broadband splitters/couplers, 1x3, 1x4 splitters with symmetrical and asymmetrical

splitting ratio, fixed fused fiber attenuators, and wavelength division multiplexers by using thermal diffusion technology (TDT) instead of traditional FBT process. More important, these products have ultra-high reliability, and currently have huge applications in submarine systems, backbone terrestrial systems. It is certain that these products will be widely used in metropolitan networks and optical PONs in the future. And the fused fiber products machines no longer have pulling stages if using TDT process.

Reference
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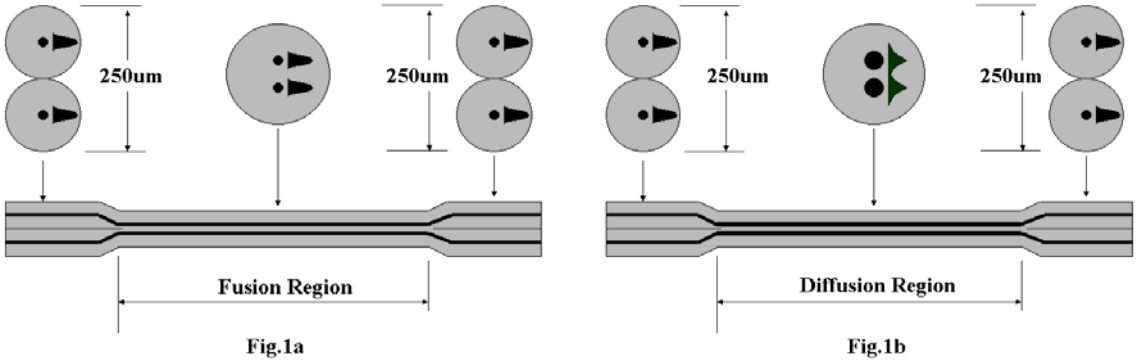

Fig.1 The comparison of mode field diameter before and after diffusion by using TDT process.

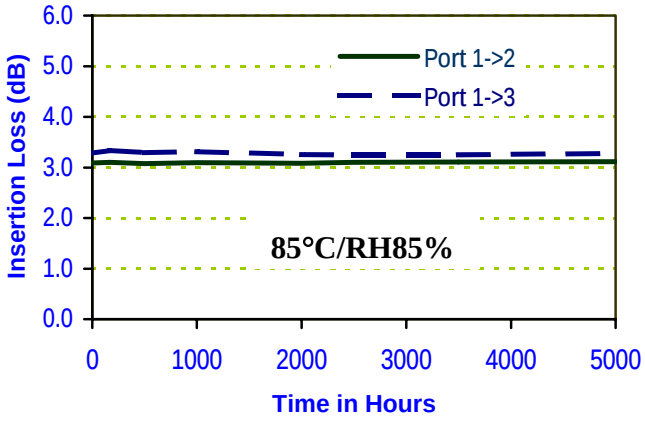

Fig.2 Damping heat test results in the condition of 85°C/RH85% for 3-dB splitter made by using TDT process.