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GENERATION OF LIGHT EMISSION FABRIC USING PMMA/PS BASED CLAD-STRIPPED PLASTIC OPTICAL FIBER

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ABSTRACT: Plastic optical fibers (POF) have several advantages over the conventional glass optical fibers (GOF), such as flexibility and transfer of visible lights. For information delivery, various IT devices can be interconnected into or onto the fabric. For aesthetic value, fabric can be active light emission device using optical fiber. In this work, we propose a light emission fabric which contains optical fiber structure with the external clad layer removed using mechanical or chemical method. POF was embedded into plain weave structure and the light scattering phenomenon was measured quantitatively by specially designed 3D printed jig using google SketchUp software. Various light frequency including 405nm, 455nm, 530nm and 627 nm tested because visible and UV lights were of our concern. Thermal and mechanical force were used for the clad removal respectively and the removal status was measured using microscope. Light scattering was stronger in clad-removed fibers, especially 5 times in 455 nm.

Keywords: Wearable Computer, Light-Emission Fabric, Clad-Removed Optical Fiber, Plastic Optical Fiber

1. INTRODUCTION

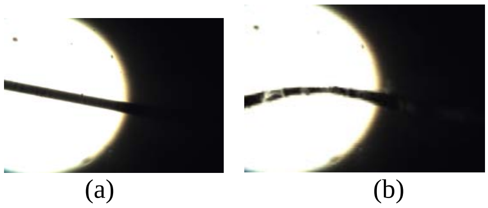
6T technologies and their fusions are gaining more interest to make a new market. Among various products, wearable computer is the typical example of textile-IT fusion. Wearable computer can deliver both information and aesthetic value through fabric structure. For information delivery, various IT devices can be interconnected into or onto the fabric. For aesthetic value, fabric can be active light emission device using optical fiber. Such light-emission fabric is already commercialized such as Lumitex® and so on. When the visible light is used, the optical fiber based fabric can be fashionable products. Otherwise UV can be delivered through optical fiber, in which can the fabric can be used for medical uses. Previous works delivered light using fiber Bragg grating (FBG) [1,2] or light-scattering materials. In this work, we propose a light emission fabric with optical fiber structure whose external clad layer has been removed using mechanical or chemical method especially. The clad-removed optical fiber was observed at its cross-section and its light-delivering property was measured. Theoretical waveguide prediction of plastic optical fiber(POF) [3] will be provided also.

The aim this paper is to develop efficient light emission POF structure that is based on cladding stripped for wearable computer. There are a few methodologies for fiber cladding stripping; h such as mechanical, chemical and thermal treatment [4,5,6]. Among them, a mechanical-emission based techniques was adopted in this work. The role of cladding is to protect total internal reflection of light inside the optical fiber waveguide. Once the cladding is removed in the middle of the fiber, the lights can be scattered out of the fiber core and this scattering can be more vigorous when the fiber is under global bending. This behavior is not favored in the communication purpose, but can be applied for other purposes also. Typical example based of emission of fiber optic sensors include sensors for liquid level measurement [7,8]. UV light, especially useful for anti-microbial treatment [9,10], as well as visible light can be used for the input light source. The goal of this paper is to provide an efficient clad removal mechanism and optimal POF based textile structure which can emit UV or visible light to the width-wise direction of the fabric.

2. EXPERIMENT

2.1 Plastic optical fiber

PRG-FB250 (a step index POF, Toray Industries) was used. It is composed of poly methyl methacrylate / fluorinated polymer as core and cladding, respectively. Refractive index was a 1.49 /1.41, and diameter was a 240 μm /250 μm . A small jig structure with heat (not shown here for patent filing) was used for the removal of cladding layer. Figure 1a shows the microscopic image of the original structure of the POF when visible light was injected. Figure 1b is the result of the clad-removed one.



(a) (b)

Fig. 1 the optical image of POF under visible light LED (a: original fiber, b: clad-removed fiber).

2.2 Light source and spectroscopy device

The light transfer efficiency was measured using a spectroscopy HL-2000 (Ocean Optics corp.) with measurement range of 190-1100 nm, 0.1 nm resolution (Figure 2). An ultraviolet radiation LED light source LLA-405, LLA-455, LLA-530 (Ocean Optics corp.) with an 18 W power was used as a light source (Figure 3).

Fig. 2 Spectroscopy device (HL-2000).

Fig. 3 Ultraviolet radiation LED light sources (LLA-405, 405nm)

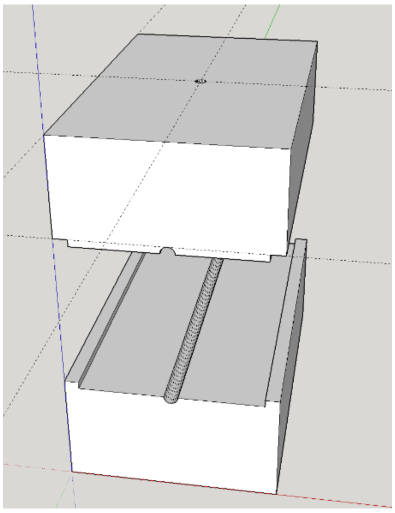
2.3 Testing of light emission of POF under textile crimp structure

The final purpose of our work is to generate a light-emitting textile weave structure using clad-removed POF's (Figure 4). The fibers in the fabric weave structure are given global bending, which is called as "crimp structure" [11,12]. The crimp gives more bended structure to the POF and the light emission becomes more efficient.

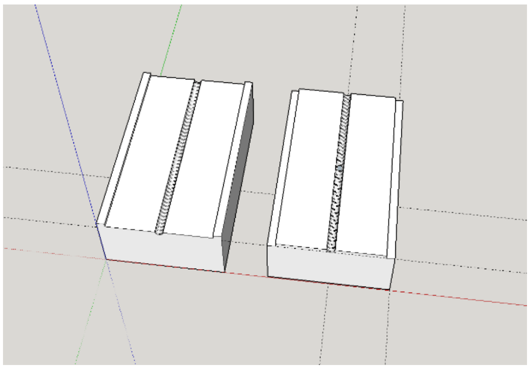
Fig. 4 Example of the proposed clad-removed POF based weave structure (plain weave)

2.4 3D printed artificial weave structure for POF light emission testing

As the fabric is very flexible in its width-direction because of low bending rigidity, light emission testing is not feasible. As an alternative method to test the light emission quantitatively, a rigid plastic structure was devised which simulates a real fabric crimp structure. As a first step, a straight fiber path was designed using Google Sketch Up Make 2016 (Figure 5). The dimension of each part is 30 (width) x 50 (length) x 20 (height) mm.



(a) perspective view



(b) side view

Fig. 5 Straight fiber path structure design

A commercial 3D printer (Cube Pro Tri by 3D systems) was used for the prototyping generation. ABS resin filament was used with blue and red colors (each correspond to bottom and upper parts of Figure 5).

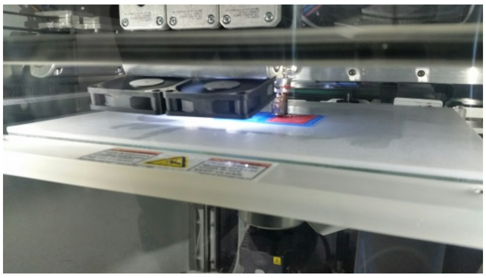
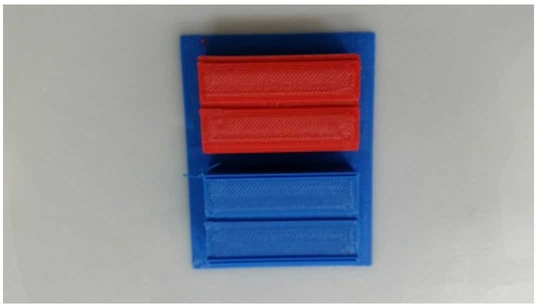
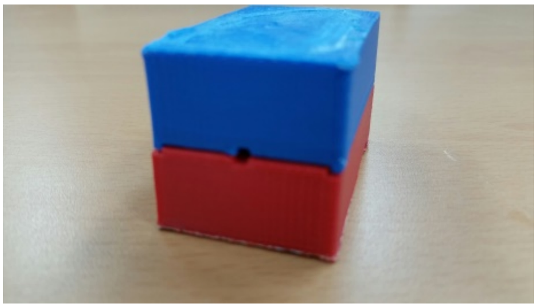


Fig.6 3D printing process of the fiber path structure

Figure 7 shows the final printing result of straight fiber path structure. The rough surface from the support structure was smoothed using an acetone steam treatment for an hour in a fume hood. The POF is inserted amidst of the two parts. Note that the upper part contains a small hall to insert the spectroscopy sensor stylus.



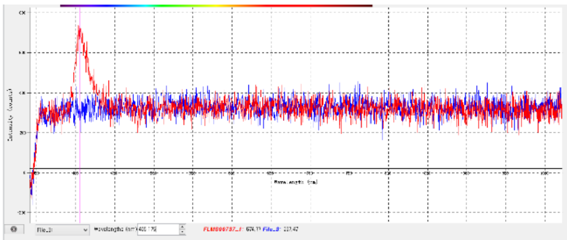
(a) 3D printing result



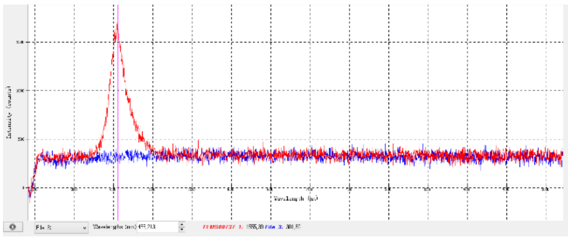
(b) combined result

Fig.7 3D printing result of the straight fiber path structure

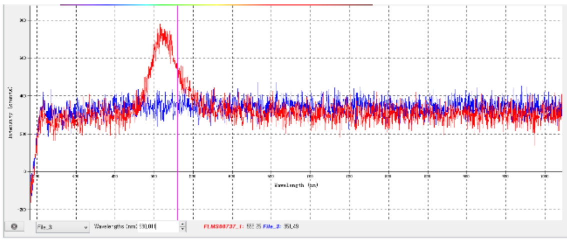
Figure 8 and Table I are the example of the spectroscopic measurement graph using the proposed POF textile structure. Blue and red curve shows the side-illumination of the original (undamaged) and clad-removed fiber respectively.



(a) at 405nm



(b) at 455nm



(C) at 530nm

Fig. 8 Example of spectroscopic measurement of original(blue)/clad-removed(red) POF using 3D printed fiber path structure at different wavelength

Table I. Measurement of side-scattered light of POF using the 3D printed structure

fiber type	ray intensity per wavelength			
	405nm	455nm	530nm	627nm
original	287.47	301.89	351.49	287.47
clad-removed	674.77	1555.39	553.25	674.77

3. RESULT AND DISCUSSION

Figure 1 shows the optical image of the original and clad-removed result of the plastic optical fiber. Note that the fibers are given visible light LED input at the one end, respectively. The original fiber (Figure 1a) does not show any light emission at the entire fiber surface, because total internal reflection occurs due to the existence of the clad. Meanwhile, the clad-removed fiber shows decreased diameter at the center and some light is shown as a white spot (Figure 1b), which shows the clad was successfully removed. The refractive index measurement of the fibers, theoretical prediction of the light transfer and results from other clad removing mechanism is on-going.

The artificial weave structure was devised to simulate the complex textile crimp structure. As a first step, the straight fiber path structure was designed and 3D printed (Figure 7). The structure gave a stable and reproducible experiment environment for POF light emission as shown in Figure 8 and Table I. Conventional devices for refractive index of POF did not work for our specimen because of the irregular surface structure and dimension. Using our method, the clad-removal can be easily detected with a simple spectroscopic device and 3D printed jig structure.

4. CONCLUSION

Thermal and mechanical force based clad removal mechanism was used for the cladding removal of plastic optical fiber. And the fiber was inserted in the fabric weave structure. The side-emission of POF fabric structure was observed quantitatively using a novel 3D printed artificial crimp structure. The 3D printed provided an efficient environment for POF light emission measurement. Only a straight fiber path was tested in this work. More general crimps from various textile weave structures will be reported in the next work with theoretical modeling.

5. ACKNOWLEDGEMENTS

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