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Etched Polymer Fibre Bragg Gratings

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Abstract: Recently we initiated a new research direction for high-sensitivity and high-reflectivity Bragg grating fabrication based on etched polymer optical fibre, here we report the recent research developments on etched polymer fibre Bragg gratings.

OCIS codes: (060.2370) Fiber optic sensors; (060.3735) Fiber Bragg gratings; (060.3738) Fiber Bragg gratings, photosensitivity.

1. Introduction

Since the first demonstration of polymer optical fibre Bragg grating (POFBG) in 1999 [1], it has been used in different sensing fields due to its unique advantages compared to the silica counterparts such as low Young's modulus, large strain measurement range and high temperature sensitivity [2]. More recently the interest in polymer optical fibre (POF) has increased and these unique properties are exploited and different applications of polymer fibre Bragg grating (FBG) sensors have been reported [3]. For certain applications such as in biomedical/biomechanical sensors, high sensitivity with high reflectivity is required. Due to material advantages of polymer fibre compared to silica fibre, gratings based on polymer fibre could be a suitable alternative for these requirements.

In this paper, we present an overview on the recent progress in the development of high sensitivity and high reflectivity Bragg grating fabrication utilizing the material property changes exhibit in the polymer fibre due to etching.

2. Etched Polymer Optical Fibre

The single-mode POF sample is used had an outer diameter of$\sim$ 185 μm and a core diameter of 12 μm. To reduce the cladding of the polymer fiber, a solvent etching technique [4] with 1:1 volume of acetone and methanol is used and the etching rate is approximately 14 μm/minute. Chemical etching changes the material properties of the polymer fibre, that includes Young's modulus and thermal expansion coefficient. It is reported that, Young's modulus of the polymer fibre has significantly reduced with reduction in the fibre diameter through etching [5]. Also it is well understood that Young's modulus is inversely proportional to thermal expansion coefficient of a material, this means a decrease in Young's modulus increases their thermal expansion coefficient. Moreover, due to chemical etching, penetration of the solvent can change the properties of the core that can change the photosensitivity of the fibre. This can play a vital role to development of high sensitive and high reflective Bragg gratings.

3. High Sensitivity and High Reflectivity Bragg Gratings

To fabricate an etched polymer FBG, standard phase mask technique is used which involves a 50 mW Kimmon IK series He-Cd laser emitting light at 325 nm. The inscription facility produces 10 mm long gratings with a peak wavelength at 1530 nm. The POF containing the grating is glued to a silica single-mode fiber by using a UV curable glue to create a stable POF pigtail.

Fig. 1(a) shows the measured reflectivity pattern of polymer FBG with different diameters [6]. From the figure it is observed that, a reflectivity of 79.42 % is observed within 60 seconds of exposure for an un-etched POF with a diameter of 185 μm. Then the grating is fabricated on etched POF (140, 110 and 85 μm) under the same conditions as of the un-etched POFBG and the same experimental set-up is used. In order to study the evolution of grating, the fibre was exposed to UV light for 5 minutes and it is observed that growth pattern of all the gratings are similar but the reflectivity and the exposure times are different for the different etched polymer fibres. The highest reflectivity of 98.54 % is achieved for 85 μm diameter etched fibre within 7-seconds of exposure. This means that the reflectivity increases by 24.07 % with a reduction in diameter of 54.05 % through etching and at the same time the exposure time

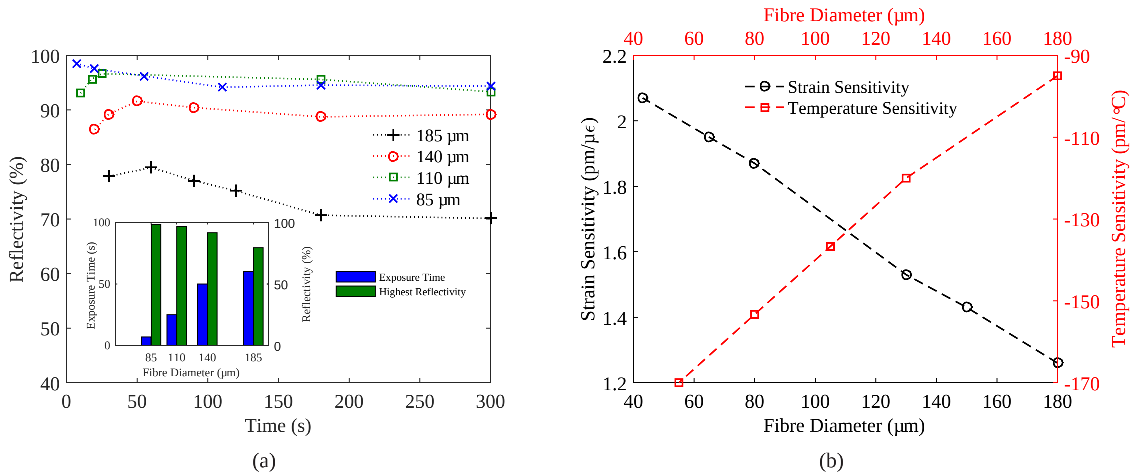

Fig. 1. (a) Measured reflectivity pattern of polymer FBG with different diameters (inset: Measured exposure time and highest reflectivity) (b) Measured strain and temperature sensitivity of polymer FBG with different fibre diameters

reduces by 88.33 %. On the other hand, the highest reflectivity achieved for other two etched fibres are 91.59 and 96.63 % for 140 and 110 μm diameters respectively. A graph comparing the highest reflectivity obtained and the required exposure time for different diameter fibres is presented in the inset Fig. 1(a).

To demonstrate the improvement in sensitivity of sensors based on etched polymer fibres, we measured the strain and temperature sensitivity of etched POFBG [5] and the results are shown in Fig. 1(b). From the figure it can be seen that the highest strain sensitivity of 2.07 pm/$\mu\varepsilon$ is observed for Bragg grating inscribed in an etched fibre of diameter 43 μm, whereas it was 1.26 pm/$\mu\varepsilon$ for an un-etched POFBG. Similarly, the improved temperature sensitivity of -170 pm/^{0}C is observed for 55 μm etched polymer FBG, whereas it was -95 pm/^{0}C for an un-etched POFBG. Thus it is evident from the figure that Bragg gratings in etched fibre exhibits considerable increase in strain and temperature sensitivity and the sensitivity increases with decrease in fibre diameter through etching. Therefore, it can be concluded that etching can improve both reflectivity and sensitivity and make it competitive to use in a range of applications where high sensitivity and reflectivity also matters.

4. Conclusion

In this paper we have demonstrated the recent updates of research on etched polymer fibre Bragg gratings. The research on etched POF Bragg grating demonstrated that etched fibres with lower diameter can exhibit high reflectivity and high sensitivity compared to un-etched ones. These results establish the prospective of etching effects on single-mode polymer fibres and can lead to further research in this area to exploit the additional benefits to develop high sensitivity and high reflectivity sensors for different high-end applications.

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