Observation of multimodal interference in dry-etched plastic optical fibers

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Introduction

Plastic optical fibers (POFs) have gained considerable attention for use in optical fiber sensors due to their higher flexibility and strain tolerance compared to silica glass fibers [1]. While POFs generally have higher light propagation loss than glass fibers, perfluorinated POFs (PF-POFs) exhibit lower loss in the telecommunication wavelength range [2], leading to technological advances in PF-POF-based sensing [3]. PF-POFs typically have a three-layer structure consisting of a core (50-120 μm in diameter) and cladding layer (several tens of μm thick) made of PF acrylic, covered by a protective overcladding layer (several hundred μm thick) made of polycarbonate. The characteristics of PF-POF sensors are greatly influenced by the overcladding, and previous attempts to thin or remove the overcladding have resulted in uncontrolled changes to the sensing characteristics due to precision issues with wet etching methods using chloroform and water [4,5].

In this study, we apply dry etching technology to thin the overcladding of a PF-POF to enhance sensing characteristics. The multimodal interference spectrum in this PF-POF is observed, and its strain sensing characteristics are investigated.

Experimental conditions

We utilized reactive ion etching (RIE) to achieve micro dry-etching of the overcladding of the PF-POF. The overcladding is subjected to anisotropic etching using an RIE system (RIE-4800, SAMCO Inc.) with oxygen as the reaction gas, all performed below the glass transition temperature of the cores and cladding layers.

The experimental setup shown in Fig. 1 was used to evaluate the modal interference strain sensors based on PF-POFs. Both etched and non-etched 60 cm long PF-POFs were sandwiched between two 2 m long single-mode fibers (SMFs), creating a single-mode-multimode-single-mode structure for multimodal interference [6]. The output from a super-continuum source was injected into the PF-POFs and the transmitted light was directed to an optical spectrum analyzer. Strain was applied to the entire length of the PF-POFs using movable stages.

Experimental results

Figure 2(a) illustrates the strain dependence of the transmitted optical spectrum around 1150 nm when the non-etched PF-POF was used. As the strain increased, the interference peaks clearly shifted towards longer wavelengths. The dependence was almost linear, with a strain coefficient of approximately 7.6 μm/με (see Fig. 2(b)). In contrast, Fig. 3(a) shows the spectral dependence of strain when the etched PF-POF was used. As the strain increased, the peaks also shifted to longer wavelengths, but with a higher strain coefficient of approximately 14.8 μm/με (see Fig. 3(b)). This resulted in a nearly twofold enhancement in strain sensitivity.

Conclusion

To increase the sensitivity of strain sensing using PF-POFs, we proposed and successfully demonstrated a dry etching technique for the overcladding layer. This resulted in a nearly twofold higher strain sensitivity after processing. We believe that this method has the potential to greatly improve or control the performance of PF-POF sensors.

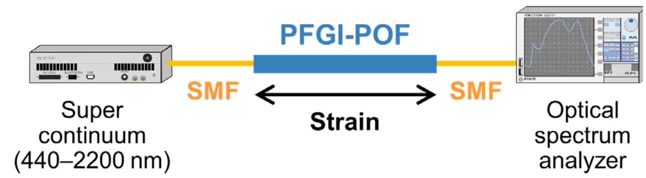
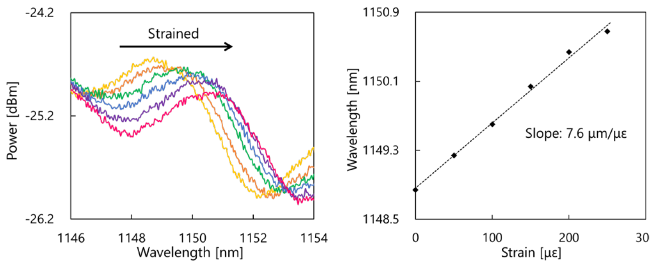
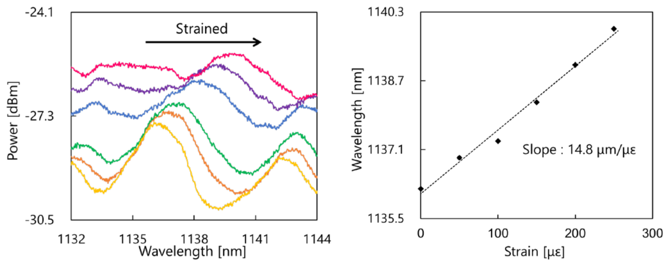


Fig. 1 Experimental setup for characterizing the PF-POF-based modal interference strain sensors. SMF: single-mode fiber.



(a) (b)

Fig. 2 Measurement results for the unprocessed PF-POF with 50 μm core. **(a)** Spectral dependence on strain, **(b)** peal wavelength versus strain.



(a) (b)

Fig. 3 Measurement results for the micro dry-etched PF-POF with 50 μm core. **(a)** Spectral dependence on strain, **(b)** peak wavelength versus strain.

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