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# Producing Regenerated Gratings in Hydrogen-Loaded Single Mode Fiber by Heat Treatment

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**Abstract:** The fiber Bragg grating (FBG) is a passive optical fiber component with the refractive index modulated along the fiber length and has been widely applied in fiber sensing systems. High-temperature stable fiber gratings are promising for uses at high temperatures and attract extensive attention. In this paper, FBGs were inscribed in hydrogen loaded standard single mode fibers with the 248-nm excimer laser, and regenerated gratings were obtained through heat treatment. The shift of the central wavelength of the regenerated FBG had a good linearity with temperature, and the reflectivity of the regenerated FBG could almost keep unchanged at 800 ℃.

**Keywords:** Fiber Bragg grating, regenerated grating, heat treatment, single mode fiber, hydrogen loading

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## 1. Introduction

When a fiber Bragg grating (FBG) is used as a temperature sensor, it can be erased when operating for a long time at elevated temperatures. So the FBG sensors are usually applied in the environments at relatively low temperature. In order to extend FBG's sensing applications to higher temperatures, high-temperature stable fiber gratings have been studied by different workers [1–4]. One way to improve the high-temperature sustainability of FBGs is heat-treating the FBGs to obtain regenerated FBGs [5, 6]. The studies on regenerated FBGs and the regeneration mechanism are important for FBG's sensing applications and understanding the related essential issues. In this paper, FBGs were inscribed in hydrogen-loaded single mode fibers and heat treated to get regenerated FBGs. The regenerated gratings are demonstrated to be stable at temperatures around 800 ℃.

## 2. Experiment

The original FBGs were inscribed in hydrogen loaded standard single mode fibers made by Yangtze Optical Fiber and Cable Company Ltd., China. The single mode fibers were hydrogen loaded at 20 ℃ under the pressure 12 MPa for 14 days before grating writing. The gratings with a length of 8 mm were then written by using a phase mask and a 248-nm KrF excimer laser (TuiLaser, Germany), with the energy density of 220 mJ/cm$^2$ and the pulse width of 15 ns. The reflection spectra were collected

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using an optical spectrum analyzer (Yokogawa AQ6370B). Heat treatment to the FBGs was performed using a muffle furnace.

## 3. Results

After the standard single mode fibers were hydrogen loaded, the original FBGs were inscribed. The reflection spectra were recorded using an optical spectrum analyzer. The reflection strength of the original gratings was 36 dB or so, as shown in Fig. 1.

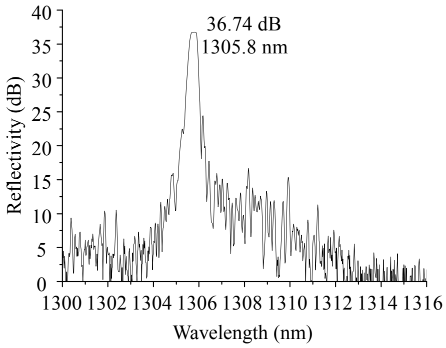


Fig. 1 Typical reflection spectrum of the original FBG fabricated in the hydrogen loaded single mode fiber.

The original FBGs were heat treated in a muffle furnace after grating writing. The heat treatment process is shown in Fig. 2. The change in the grating reflection strength during the heat treatment process is also shown in Fig. 2.

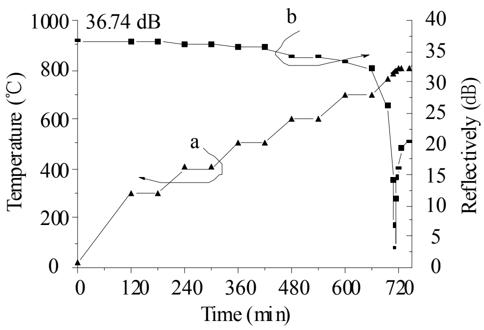


Fig. 2 Heat treatment process (a) and grating reflection strength change (b).

As it can be seen from curve (b) in Fig. 2, when the temperature reached 790 ℃, the FBG was almost erased. However, when the temperature was increased to 793 ℃, the FBG appeared again. At 793 ℃, the grating reflection strength was 11.25 dB. When the temperature was holded for 24 min at 800 ℃, the reflection intensity of the FBG reached the maximum, which was 20.42 dB, as shown in Fig. 3.

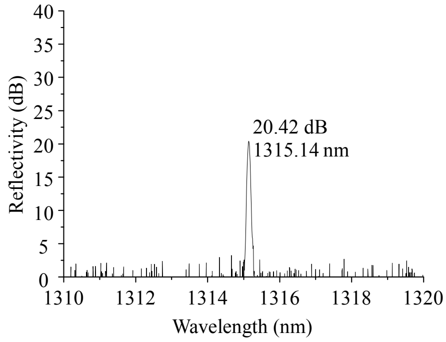


Fig. 3 Reflection spectrum of the regenerated FBG.

The temperature stability of the regenerated FBG was tested as follow. When the regenerated FBG was cooled down to the room temperature, it was put into the muffle furnace again and heated from room temperature to 800 ℃. Figure 4 shows the dependence of the peak reflectivity on time at 800 ℃. It can be seen that the reflectivity of the regenerated FBG formed in the hydrogen loaded single mode fiber almost remained unchanged at 800 ℃.

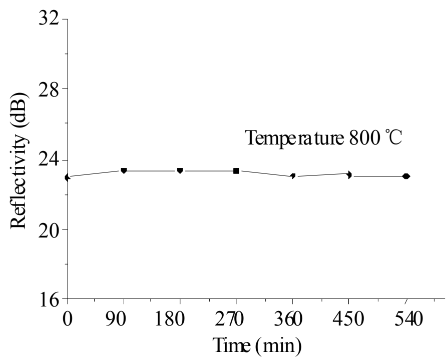


Fig. 4 Dependence of the reflectivity on time at 800 ℃.

Figure 5 shows the dependence of the Bragg wavelength of the regenerated FBG on the temperature. From Fig. 5, it can be seen that the central wavelength of the regenerated FBG increased with an increase in the temperature and showed a good linearity, the temperature sensitivity being 0.012 nm/℃ and the linearity being 0.99459. This result suggests that this heat treatment method could fabricate high-temperature stable fiber gratings for uses at temperatures around 800 ℃.

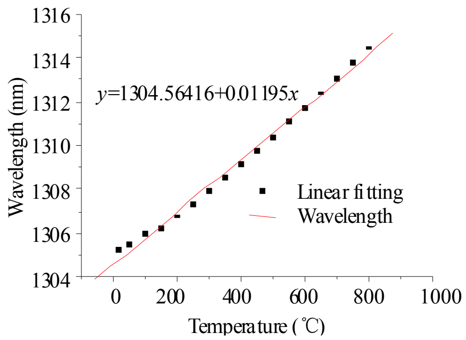


Fig. 5 Dependence of the Bragg wavelength of the regenerated FBG on the temperature.

## 4. Conclusions

The experimental results show that regenerated FBGs can be formed in hydrogen loaded single mode fibers via heat treatment. The central wavelength shift of the regenerated FBG had a good linearity with the temperature, and the reflectivity of the regenerated FBG could almost keep unchanged at 800 ℃. It is promising to fabricate high-temperature stable fiber gratings for uses at temperatures around 800 ℃.

## Acknowledgment

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