

Flexible Sensing Foils Based on Embedded Fibre Bragg Grating Sensors

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Abstract

This work deals with the integration and testing of fibre Bragg gratings (FBGs) in bio-compatible methacrylate-based polymer sheets towards the development of flexible surfaces for pressure sensing applications.

1 Introduction

Fibre optic sensing technology has been gaining more and more attention owing to the inherent advantages of fibre optic sensors including lightweight, immunity to electromagnetic interference, environmental ruggedness and so on. Additionally, the inscribing of Bragg gratings in optical fibres significantly enhances the sensing capability of optical fibres to external perturbations, such as pressure and temperature. Consequently, innovative, highly sensitive and accurate sensors based on fibre Bragg gratings have been developed rapidly.

2 Sensing principle

A fibre Bragg grating is a periodic or quasi-periodic variation of the refractive index of the fibre core in a short segment of an optical fibre, which leads to the reflection of a narrow band of the incident optical field and the transmission of all the others. When the reflection from a crest in the index modulation is in phase with the next one, the Bragg condition is fulfilled, and the reflected wavelength λ_B , called the Bragg wavelength, is defined by the equation,

$$\lambda_B = 2n_{\text{eff}}\Lambda$$

where n_{eff} is the effective refractive index of the fibre core, and Λ is the grating spacing shown in Figure 1 (left).

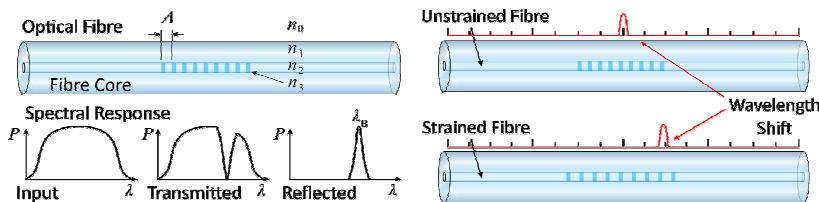


Figure 1 : Schematic of the spectral responses of a generic FBG (left); Bragg wavelength shift due to strain in the fibre (right).

An external perturbation to the FBG could affect the effective index of refraction or the periodic spacing, leading to the changing of Bragg wavelength. Therefore, FBGs can be used as sensors by monitoring the Bragg wavelength, see in Figure 1 (right).

3 Production

FBG sensors are here embedded within flexible sheets to transfer the external perturbation and realize an artificial pressure sensing skin. Providing the advantages of tuneable flexibility, biocompatibility and chemical resemblance with standard fibre coating, methacrylate monomers of methyl methacrylate (MMA), butyl methacrylate (BuMA) and 2-ethylhexyl methacrylate (EHMA) were selected for the production of (co)polymers as embedding materials. Additionally, an UV-induced moulding process was developed for the realization of the polymer sheets and the accurate positioning of fibre sensors inside. As compared to other techniques, UV polymerization and moulding are expected to provide major benefits, including large scale production capability, improved process speed and complete conversion.

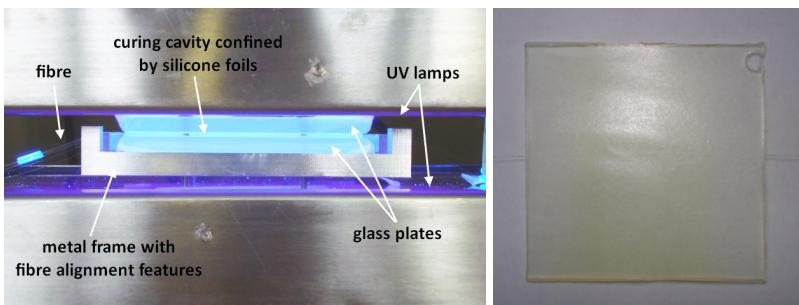


Figure 2 : Flexible foil with embedded FBG during production by UV curing (left); A straight fibre embedded in a 8×8 cm polymer foil (right).

Glass was specifically chosen due to its outstanding UV transparency and chemical inertness. Accordingly, a dedicated transparent mould consisting of glass plates, silicone spacers and metal frame was developed to embed the fibre into the polymer foil with controllable thickness and embedment depth, as shown in Figure 2.

4 Results and discussion

The monomer used for the prototype foils was a mixture of MMA/EHMA with the composition of 20/80%, and the cured polymer had a Young's modulus of 5.6 MPa. A single FBG in SMF-28 fibre with acrylate recoating was embedded in the middle layer of the 2 mm thick foil, and the grating had a length of 1 mm and a FWHM (Full width half maximum) bandwidth of about 1.31 nm, which is relatively large with respect to the commonly used longer FBGs with FWHM smaller than 0.5 nm. The FBG interrogator FBG-Scan 700 produced by company FOS&S was employed here to record the Bragg wavelength. The interrogator has a built-in broadband light source with the wavelength range of 1525 – 1565 nm and performs spectral analysis by means of an InGaAs detector array and a spectrometer platform.

A transverse load was applied upon the sensitive grating point of the fibre embedded with a rounded-end pin mounted on a custom-made leaf spring. Within the linear operational range, the leaf spring used had a stiffness of about 2.7 N/mm.

The loading and unloading process was performed by means of displacement control, with a rate of 0.5 mm/min, corresponding to a force rate of 1.35 N/min. Figure 3 shows the response of the embedded FBG sensor.

The Bragg wavelength increased along with the increased force in the loading process and recovered by the decreased force in the unloading process. A total wavelength shift of 0.57 nm was obtained over the whole force range of 0 – 3.86 N, resulting in a force sensitivity of 0.148 nm/N.

Noticeably, in Figure 3, several wavelength jumps were observed, interrupting the linear shifting of Bragg wavelength. This is believed to be a consequence of the fact that, when a transverse load is applied onto the embedded FBG with a wide FWHM, the peak shape in the reflected spectrum deforms irregularly, and the interrogator might identify one (or more) of the side lobs as an additional peak. Replacing FBGs with narrower FWHM or using an interrogator with higher resolution would solve the problem, and the investigation is undergoing.

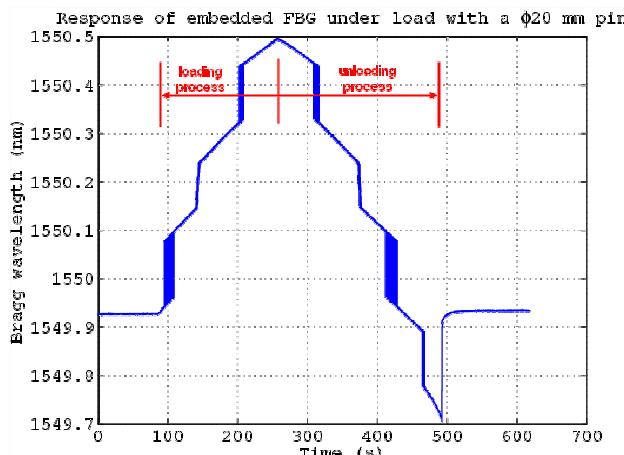


Figure 3 : Response of the embedded FBG under load with a Ø20 mm curved-end pin over the force range 0 – 3.86 N.

5 Conclusion

A prototype with fibre Bragg grating sensor embedded in flexible methacrylate-based polymer foil by means of UV induced moulding was implemented and tested. The foil response of Bragg wavelength shifting proportional to an external applied load was observed.

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