Utilizing 3D printing for the packaging of fiber optic sensors

K. Wiegmann, K. Bremer, B. Roth

Hannover Centre for Optical Technologies (HOT), Leibniz University Hannover, Hannover, Germany

mailto:Kevin.Wiegmann@hot.uni-hannover.de

The 3D-printing of fiber optic sensor packaging is explored. The investigation includes the evaluation of the stress-strain behavior of different filaments, the silane based bonding agent as well as the sensor performance of the printed sensor packaging.

1 Introduction

With regard to structural health monitoring (SHM) fiber optic sensors have the advantage of e.g. being small in size, resistant to corrosion, electrically passive and easy to multiplex. Consequently, in the past, fiber sensors have been used successfully for the SHM of bridges, sewerage tunnels or dams, for instance. However, when applied in SHM the development of an appropriate packaging for the fiber optic sensors is required in order to reliably monitor the parameters of interest as well as to withstand the harsh conditions of the environment. Since 3D printers allow the fabrication of tailored mechanical structures they also lend themselves for the development of low-cost and customized packaging for optic sensor systems. In this work, the packaging of fiber optic strain sensors is investigated by using a conventional 3D printer.

2 Packaging of fiber optic sensors

Printing procedure

In this work, fiber optic strain sensors have been printed using the 3D printer Makerbot Replicator 2X. In order to investigate the printing procedure a simple geometry for the sensor packaging was chosen, as shown in Fig. 1. The sensor packaging has a rectangular shape with an embedded Fiber Bragg Grating (FBG) inside.

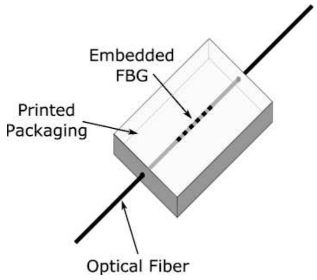


Fig. 1 *Schematic of 3D-printed sensor packaging.*

The packaging has been fabricated by first printing one half of the packaging (base plate). Then the printing procedure was interrupted and the optical fiber comprising an FBG was arranged on top of the base plate. Following this the printing procedure was continued again and the sensor packaging was finalized. A picture of the finalized sensor packaging is shown in Fig. 2.

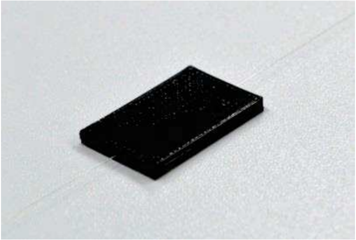


Fig. 2 *3D-printed sensor packaging comprising a FBG sensor.*

Choice of filament

The stress-strain behavior of the filament applied for the 3D-printing process is important for the sensor performance of the packaged fiber optic sensor.. Therefore the stress-strain behavior of different filaments have been investigated using a tensile testing machine. The results for ABS (Acrylonitrile butadiene styrene) and NinjaFlex^{TM} are shown in Fig. 3.

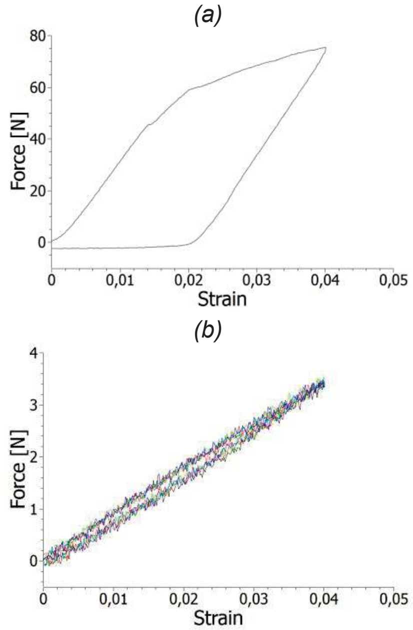
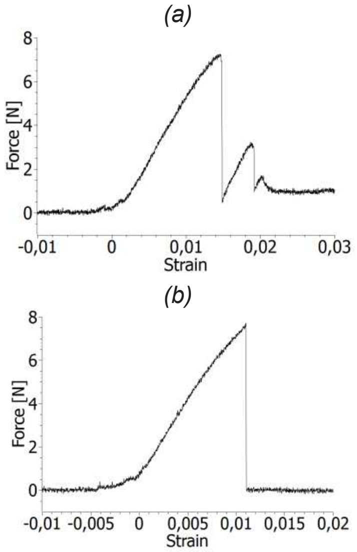


Fig. 3 *Stress-strain behavior of ABS (a) and NinjaFlex^{TM} (b).*

DGaO Proceedings 2016 - http://www.dgao-proceedings.de - ISSN: 1614-8436 - urn:nbn:de:0287-2016-B012-4
submitted: 6.Jul.2016 - published: 5.Aug.2016

According to Fig 3, the NinjaFlex^{TM} shows the best performance in terms of the hysteresis and linearity even after several cycles.

Bonding agent
In addition to the stress-strain behavior of the filament also a strong bonding between the optical glass fiber and the packaging is important for sensor application. Since the filament applied is an organic polymer that is in contact with an inorganic glass interface silane has been applied as a bonding agent. To evaluate the bonding behavior between the polymer filament and the optical glass fibre with and without bonding agent the tensile testing machine was applied again and the obtained results are shown in Fig. 4.


(a)

(b)

Fig. 4 *Evaluating bonding behavior between polymer filament and glass fiber without (a) and with (b) bonding agent.*

From Fig. 4 it is obvious that silane enhances the bonding between the polymer filament and the optical glass fiber

3 Evaluating sensor performance

The sensor performance was explored by compressing the printer packaging with an integrated FBG. Furthermore, the behavior of the FBG was interrogated by using a broadband light source (Opto-Link C-Band ASE light source) and an Optical Spectrum Analyzer (OSA), as shown in Fig. 5.

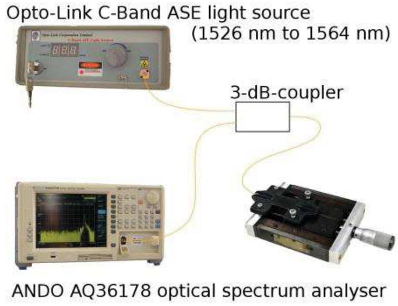
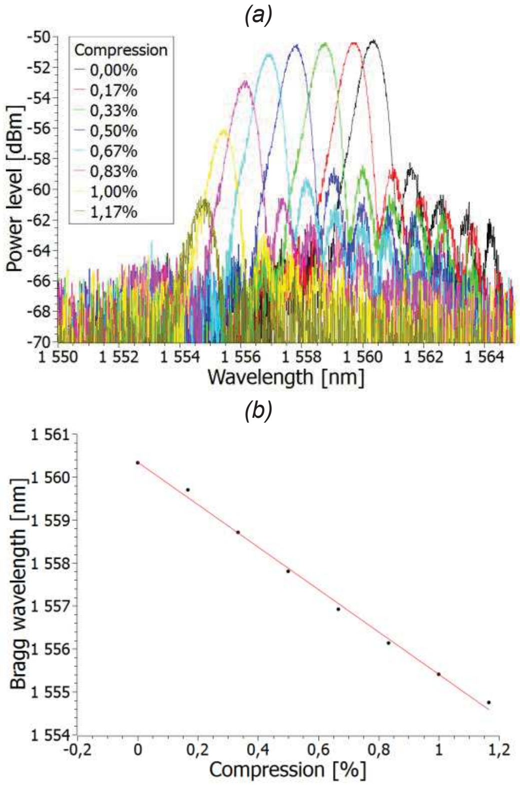


Fig. 5 *Set-up evaluating sensor performance.*

The measured sensor spectrum and the obtained shift of the reflected Bragg-wavelength depending on the compression applied is shown in Fig. 6.


(a)

(b)

Fig. 6 *Measured sensor spectrum (a) and the obtained shift of the reflected Bragg-wavelength (b) depending on the compression applied.*

From Fig. 6b it follows, that the measured shift of the Bragg-wavelength depends linearly on applied compression with a strain sensitivity of 0.5 pm/με. Furthermore, the measured reflected sensor spectrum shows a constant spectral width (full width half maximum, FWHM) of the reflected Bragg-wavelength but an increasing light attenuation for increasing compression rates. The increased attenuation might be addressed by introducing micro- and macro-bends into the optical glass fiber at increasing compression rates.

4 Summary

A customized packaging with an embedded FBG was realized and the resulting optical and mechanical properties were characterized. A linear sensor response was obtained with a sensitivity of 0.5 pm/με to applied strain. Furthermore, a constant spectral width of the reflected Bragg-wavelength but an increased light attenuation was measured for increasing compression rates. Therefore, the results verify that depending on the design, the filament as well as the bonding agent applied a packaging for a fiber optic strain sensor can be developed which meets the requirements for future SHM applications.