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Fabrication and characterization of Bragg gratings in a graded-index perfluorinated polymer optical fiber

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Abstract

This work deals with the ultra violet laser based fabrication of Bragg gratings in perfluorinated polymer optical fibers and their characterization. This kind of polymer fibers shows a higher transparency than typical polymer fibers based on polymers with carbon hydrogen bonds like polymethylmethacrylate, the most used material for polymer optical fibers to date. Up to now only gratings inscribed by the phase mask technique in thin slabs of the amorphous fluoropolymer CYTOP (cyclic transparent optical polymer) made from polymer fibers were successfully detected. Infrared spectra of Bragg gratings in a perfluorinated polymer fiber are presented for the first time here.

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Keywords: Bragg grating fabrication; FBG; perfluorinated polymer optical fiber; POF; CYTOP; SHM

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1. Introduction

The first reflection spectrum of a polymer optical fiber Bragg grating (POFBG) fabricated with the phase mask method was shown by Peng et al. in 1999 [1]. The base material of the polymer fiber was methyl methacrylate [2]. Since then the generation of gratings in various kinds of polymer optical fiber (POF) was reported frequently. The material of most POF with which FBG sensors were successfully fabricated to date bases on methyl methacrylate. Exceptions are POFBG which are based on TOPAS, a cyclic olefin copolymer [3]. The mentioned fibers have the disadvantage that their usable fiber length is limited to several decimeters if typical Bragg gratings with Bragg wavelengths in the infrared (IR) region are used due to the relatively high optical attenuation of the polymer in the IR spectral range [3].

Perfluorinated POF have the advantage that their attenuation is significantly lower in the infrared spectral range which is usually used for fiber Bragg grating (FBG) applications. Perfluorinated POF allow data transmission with IR wavelengths of 1300 nm [4] and of 1500 nm [5] over a length of several 100 m. However, to date the successful fabrication of FBG with perfluorinated POF was not reported [6], [7] in spite of laboratory-confirmed photosensitivity [8], [9], [10]. In [8], [9] photosensitivity was found at the wavelength of 355 nm. It was possible to inscribe volume gratings by the phase mask technique in thin slabs of the amorphous fluoropolymer CYTOP (cyclic transparent optical polymer) made from POF [8]. The results indicate a photoinduced index modulation of the order of $3 \cdot 10^{-4}$ [9]. In [10] the photosensitivity at the wavelengths of 457.9 nm, 488.0 nm and 514.5 nm was investigated. The results showed that the photosensitivity was higher at shorter wavelengths.

In this publication the successful fabrication and characterization of FBG with perfluorinated POF are presented for the first time. The fabrication method has been described entirely in a German patent application [11]. Detailed process parameters and results of the optical functionality of such POFBG generated by the common phase mask method and a krypton fluoride excimer laser have not been published in the public technical literature so far at the best knowledge of the authors. Transmission and reflection experiments in the IR spectrum validate the successful generation of POFBG. In this work, the stability of such a Bragg grating was proved over a time period of half a year. Also results of the measurement of the glass transition temperature T_g of the POF material by differential scanning calorimetry (DSC) are shown.

Nomenclature

d	grating period of the phase mask grating
T_g	glass transition temperature
x	direction in the plane of the polymer optical fiber endface perpendicular to the y direction
y	direction in the plane of the polymer optical fiber endface perpendicular to the x direction
z	longitudinal direction of the polymer optical fiber
λ	wavelength of the laser light
CYTOP	cyclic transparent optical polymer
DSC	differential scanning calorimetry
FBG	fiber Bragg grating
GOF	glass optical fiber
GOFBG	glass optical fiber Bragg grating
IR	infrared
OSA	optical spectrum analyzer
POF	polymer optical fiber
POFBG	polymer optical fiber Bragg grating
SHM	structural health monitoring
SLED	superluminescent light emitting diode
SMF	single mode fiber
TOPAS	trade name of a cyclic olefin copolymer
UV	ultra violet