

HUMIDITY MONITORING WITH POF

K. Nielsen ⁽¹⁾

1: SHUTE Sensing Solution A/S, Oldenvej 1A, Kvistgaard, Denmark.

Corresponding author: kn@shute.dk

Abstract: A fast-responding humidity sensor for operation in the c-band wavelength range is characterized. The sensor is a PMMA mPOF with an FBG sensor. The sensor response time is optimized by reducing the fiber diameter through the process of solvent etching. Resulting in a humidity sensor with a humidity sensitivity of approx. 13 %RH/nm and a response time below 10 min.

Key words: mPOF, FBG, humidity sensor.

1. Introduction

Since the emergence of the micro structured polymer optical fiber(mPOF) and the single mode operation that it offers. [1] The properties of the mPOF combined with the sensing technique of fiber Bragg grating (FBG) has offered many promising sensing applications.[2][3][4] One such promising application is the sensing of relative humidity. An mPOF made from PMMA has high sensitivity to relative humidity. [2]

2. Humidity monitoring with polymer optical fiber

For this work we want to demonstrate the high sensitivity of a PMMA mPOF operated in the C-band and demonstrate how the response delay of the sensor can be greatly reduced by reducing the diameter of the fiber.

2.1. Manufacturing the FBG sensor

To produce the sensor, we use a micro-structured PMMA fiber that has been manufactured at SHUTE. The fiber has a pitch of 5.5 μm and the holes are 2.2 μm in diameter, giving a structure that supports single mode operation. The core is approx. 9 μm in diameter. An FBG is inscribed in the mPOF using the phase mask method. Using a phase mask from Ibsen Photonics and a Kimmon He-Cd laser operating at 325 nm as the inscription light source. The resulting FBG is centered at 1565 nm, at 30°C and 40 %RH ambient conditions. The reflection spectra from the FBG is shown in fig. 1.

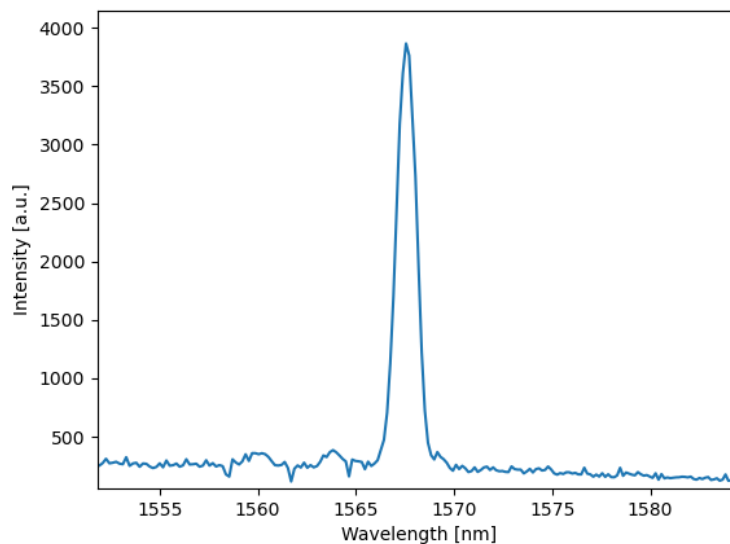


Fig. 1: The reflection spectra of the FBG sensor used in this work.

Our standard PMMA mPOF has a diameter of 130 μm and due to the thickness of the fiber the typical response time for a standard fiber with regards to changes in relative humidity is approx. 1 hour. There are many applications that require a faster response time and since the response time is given by the fiber thickness this leads to the conception of the reduced diameter fiber. The fiber diameter is reduced from 130 μm to approx. 60 μm through the process of solvent etching.[5]. There is a lower limit to the diameter reduction given by the micro-

structure of the fiber. Below 60 μm the fiber diameter is rapidly approaching the outermost holes of the micro-structure. For further reduction of the fiber diameter a different fiber design will have to be used.

2.2. Setup used for sensor characterization

The fiber sensor was interrogated with a Luna Innovations Hyperion SI255 interrogator, and the humidity environment was produced by a Rotronic Hygrogen2 Humidity Generator HGS2.

The fiber sensor was placed inside the HGS2 through the access ports at the front of the instrument.

Using the Rotronic HGS2 it is possible to generate required relative humidity levels and the sensor response was recorded on a laptop.

2.3. Results of the sensor characterization

The temperature was kept at a constant 30°C while the relative humidity was cycled down to 20%RH and back up to 95%RH.

In fig. 2 the recorded relative humidity level is shown together with the recorded FBG sensor response.

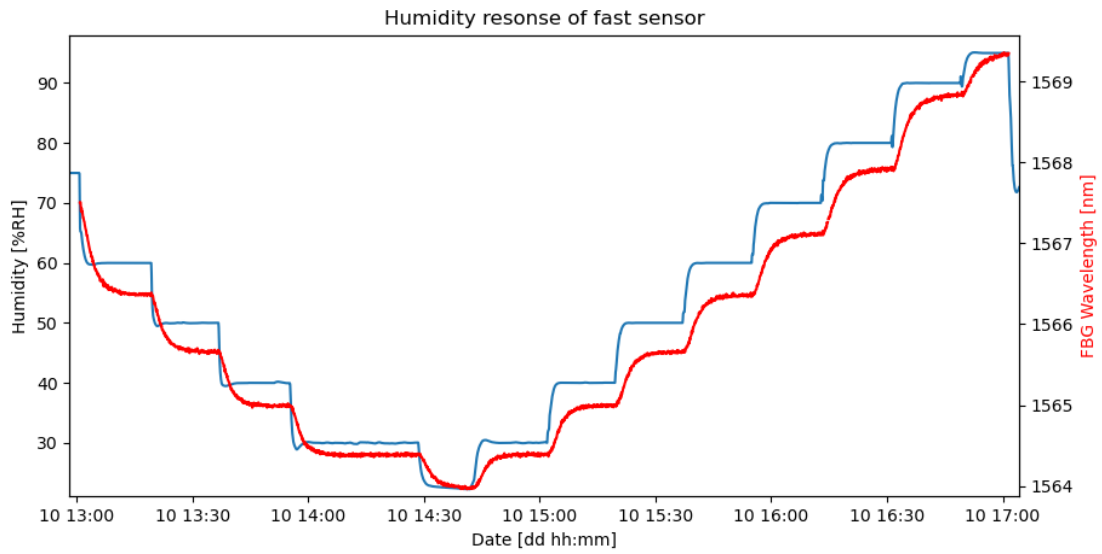


Fig. 2: Relative humidity stairs as recorded by the HGS2 instrument and the Hyperion SI255 using the mPOF FBG sensor. The temperature was a constant 30°C.

The FBG sensor follows the humidity of the HGS2 very well and very reproducibly. No apparent hysteresis was noticed during the testing. There is a clear time lag between the FBG sensor and the HGS2 reading. This was expected as the moisture needs to into the FBG sensor.

By zooming in on one of the humidity steps we can quantify the actual time lag. From the zoom shown below in fig. 3 it is apparent that the HGS2 readings take approx. 5 min to stabilize while the SHUTE sensor takes approx. 9 min to stabilize.

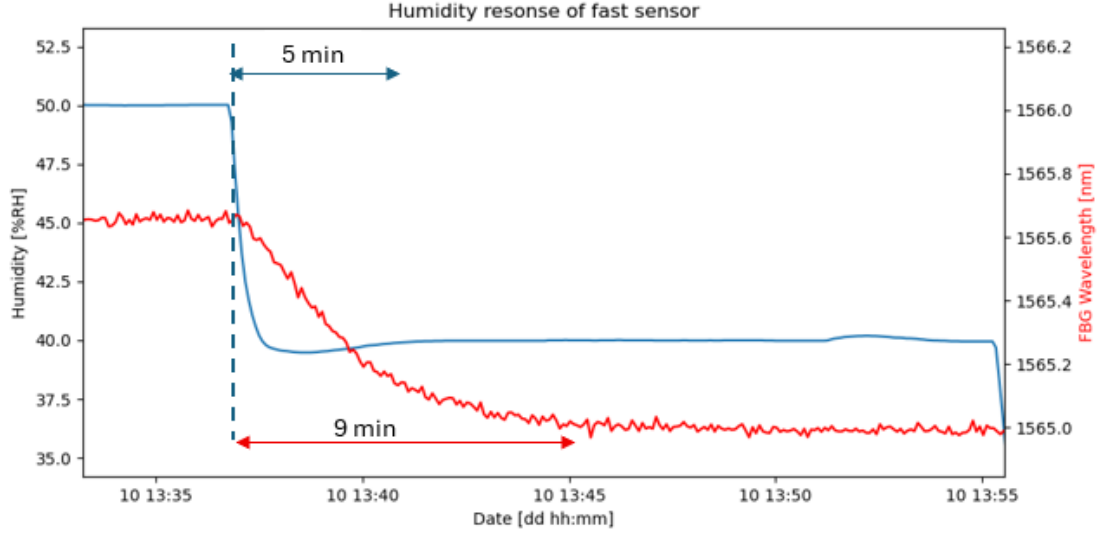


Fig. 3: A close up of a relative humidity step-down, where the relative humidity goes from 50 %RH to 40 %RH. The stabilization time of the HGS2 chamber is approximately 5 minutes while the FBG sensor needs approximately 9 minutes to stabilize.

By plotting the sensor response vs. the relative humidity, we can quantify the sensitivity of the FBG sensor. In fig. 4 the relative humidity is plotted against the FBG sensor wavelength, and a 2nd order polynomial is fitted to the data. The down cycle and the up cycle are color coded.

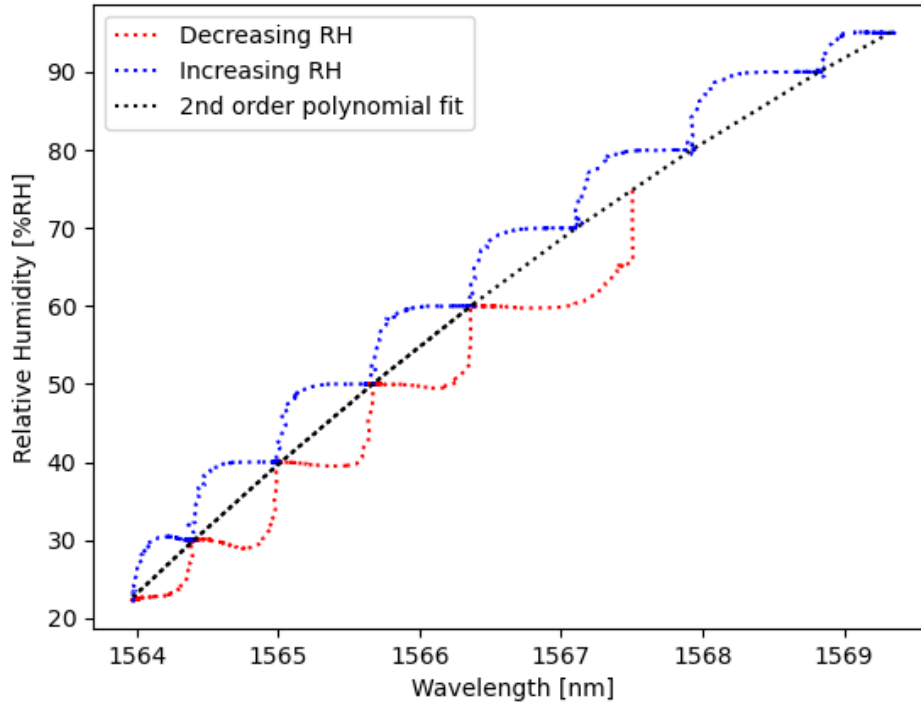


Fig. 4: The recorded humidity level plotted against the recorded FBG wavelength. There is a slight bend in the response curve, and the response is best fitted using a 2nd order polynomial.

The relation between relative humidity and the FBG sensor is best described using a 2nd order polynomial. A polynomial is fitted using least square method and the polynomial that best describes the relation is:

$$\%RH = -0.71186 \times \lambda_n^2 + 13.02239 \times \lambda_n + 68.608$$

Where λ_n is the FBG wavelength subtracted by 1567 nm.

Using the polynomial fit the recorded FBG response can be converted to relative humidity and compared to the recorded relative humidity from the HGS2. The comparison is shown in fig. 5.

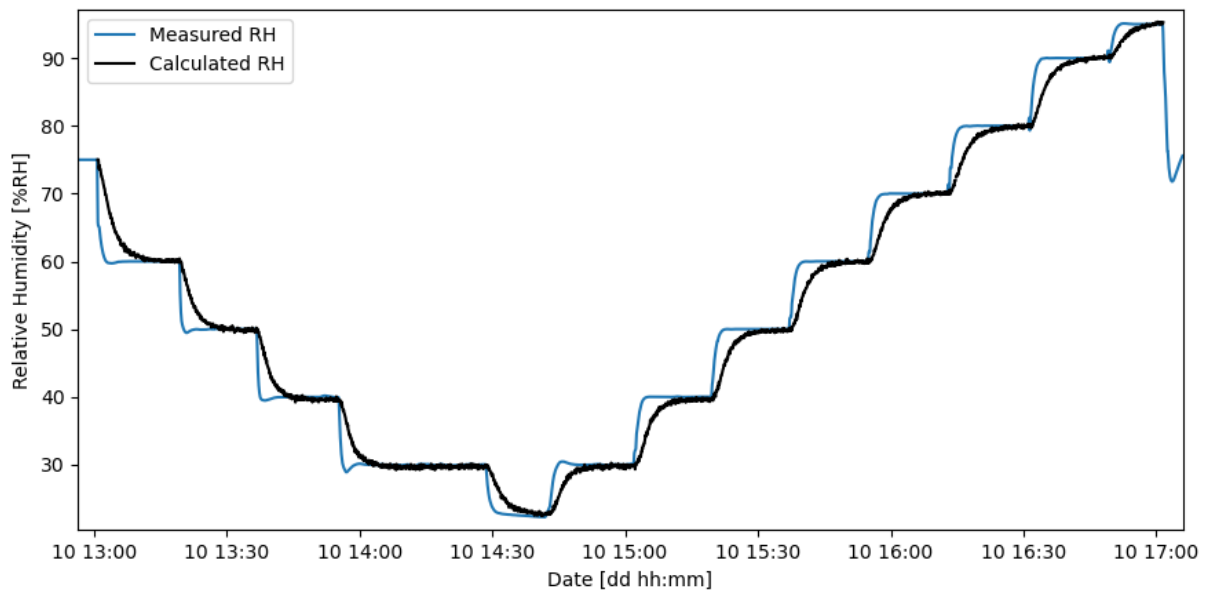


Fig. 5: The calculated humidity level plotted together with the recorded humidity level. The correlation between the calculated humidity level and the recorded humidity level is good for the whole range due to the 2nd order polynomial.

4. Conclusions

Polymer optical fibers are well suited for relative humidity sensing. The results demonstrate that the response rate of the fibers can be greatly increased by reducing the diameter of the fibers. We demonstrate a response time of less than 10 min for a POF with a reduced diameter of approx. 60 μm .

Acknowledgements

The author would like to thank Dr. Ing. Carlos Miguel-Giraldo from NDT Production & Structural Health Monitoring Material, Processes & Tests at AIRBUS Operations, S.L for his assistance in making the measurements used in this work.

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