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Polymer Optical Fibers as Gas Sensors

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Abstract

Gas sensors based on optical fibers are attractive alternatives to the presently available sensors. Integration of sensor fibers into protective clothing would significantly increase sensor wearability. We present a gas sensing polymer optical fiber (POF) that is flexible enough to be stitched into textiles. Also, the polymer is UV-transparent to allow for fluorescent dyes. By using a porous sol-gel matrix, response times down to 1 s were achieved.

Key words: gas sensing, optical fibers, cyclo-olefin polymer, sol-gel, ormosil, textiles

Introduction

For gas sensing, different optical systems based on the evanescent wave absorption along optical fibers have been reported [1–4]. In such a system, a dye - which responds to the presence of a target molecule - is incorporated in a polymer or sol-gel matrix.

However, glass fibers and common sol-gels are too brittle to be stitched into protective clothing. Also, UV transmission is problematic in glass fibers, which limits the use of fluorescent dyes.

Here, we present a flexible polymer optical fiber (POF) based gas sensor. The fiber is coated with a porous and flexible sol-gel for quick response times. For demonstration purposes, the sol-gel was loaded with pH-sensitive dyes. To allow the dye to be fluorescent, the polymer was selected for transparency in the near-UV range.

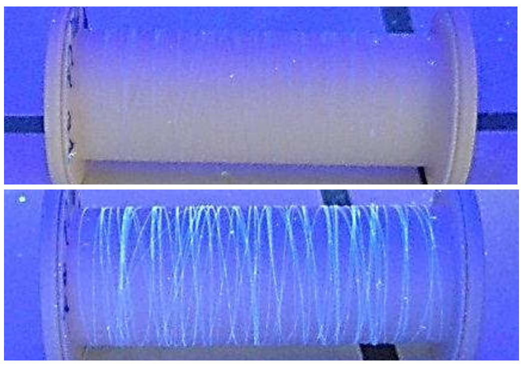
Experimental

The fiber cores were produced by melt spinning of cyclo-olefin polymer (COP) in a pilot plant. The fibers were dip-coated into sol-gel. The sol-gel was based on tetraethyl orthosilicate, which was partially replaced by organically modified silicates (ormosil). The amount and type of the latter allowed a tunable degree of flexibility to the sol-gel.

A mixture of two pH-sensitive fluorescent dyes, fluorescein and coumarin (7-diethylamino-4-methylcoumarin), was used as chemical indicator in the sol-gel matrix. Fluorescence intensities were measured using an integrating sphere connected to a photomultiplier.

Results & Discussion

The response of the flexible polymer/sol-gel system was tested towards hydrochloric acid (HCl) and ammonia (NH_3) vapors (Fig. 1). The response times were fast, typically on the order of 1 second.



a)

b)

Fig. 1. POF after exposure to HCl (a) and NH_3 (b) vapor. The bobbin was illuminated with a UV lamp (366 nm).

The reproducibility of such a sensor system was tested by alternating exposure to HCl and NH_3 vapors for 30 cycles (Fig. 2). No sensor drift was observed. However, some variability in the fluorescence intensity was seen, which may be due variations in the air flow between the liquid and the sensor. The fiber sensors were successfully stitched into textiles.

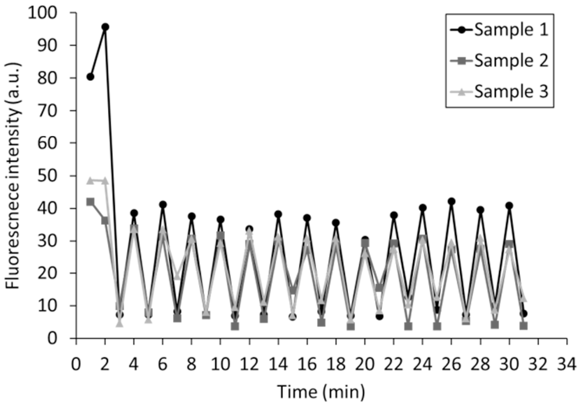


Fig. 2. Fluorescence intensity after exposure to vapors. The vapors were alternated between HCl (odd time values) and NH_3 (even time values). Each exposure lasted 1 minute. Data at time 1 min. were without exposure.

Conclusions

A flexible polymer optical fiber (POF) with sol-gel coating was developed for gas sensing. Gas detection was demonstrated using pH-sensitive fluorescent dyes vs. hydrochloric acid (HCl) and ammonia (NH_3). No degradation of the sensor was observed for at least 30 cycles.

The integration of such fibers into textiles will lead to sensors of a significantly higher wearability than was thus far possible. We foresee that this platform technology will be extended to detection of toxic industrial chemicals (TICs) and chemical warfare agents (CWAs) to protect personnel in the chemical industry and first responders.

Acknowledgements

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