Tapered Plastic Optical Fiber Coated With HEC/PVDF for Measurement of Relative Humidity

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Abstract—A simple humidity sensor is proposed and demonstrated using a tapered plastic optical fiber (POF) as a probe. Its operation is based on intensity modulation technique using a tapered POF probe coated with a polymer blend of hydroxyethylcellulose/polyvinylidenefluoride (HEC/PVDF) composite that acts as the humidity sensitive cladding. The sensor is fabricated using an etching method and has a waist diameter of 0.45 mm and tapering length of 10 mm. As the relative humidity varies from 50% to 85%, the output voltage of the sensor increases linearly from 0.32 to 1.25 mV. The HEC/PVDF composite-coated sensor exhibits a sensitivity of 0.023 mV/% with a slope linearity of >99.65%. The sensitivity of HEC/PVDF composite-coated cladding toward humidity stems from its ability to swell as humidity increases in the atmosphere resulting in a drop in its refractive index below that of the core and thus allowing more light to be transmitted through the tapered fiber.

Index Terms—Fiber optic sensor, tapered plastic optical fiber, humidity sensor, relative humidity (RH), hydroxyethylcellulose/polyvinylidenefluoride (HEC/PVDF).

I. INTRODUCTION

Optical fibers have been used for various applications ranging from transmission medium, which covers a wide spectral range and sensors. Research in fiber sensor development is expanding and many new applications have been introduced such as in sensing and monitoring humidity, gases, vapours, chemical substances, biosignals, medical and control processes, industrial automation and others [1]–[6]. Recently, tapered optical fibers have attracted much interest especially for sensing applications [2]. An optical fiber becomes more sensitive to its surrounding when it is tapered due to the enhanced power of its evanescent wave (EW) in the cladding. Interest in tapered multimode plastic fiber has also increased because of the fiber’s superior mechanical strength and ease of manufacturing.

Recently, many EW based sensors have been proposed and demonstrated for humidity measurement. For instance, Muto et al. demonstrated humidity sensors which are based on reversible absorption of water (H₂O) from the ambient atmosphere into a porous thin-film interferometer that sits on the tapered fiber. The water absorbed changes the refractive index of the thin films and subsequently transforms the lossy fiber into a light guide. Humidity sensing was also demonstrated using a tapered fibre with agarose gel [10]. Corres et al. demonstrated a similar humidity sensor based on nanostructured films, which were deposited onto tapered fibres using the ionic self-assembled monolayer (ISAM) deposition technique [11], [12]. In another scheme, a side-polished optical fibre with a humidity sensitive overlay is used to construct a humidity sensor. Gaston et al. [13], [14] proposed a humidity sensor based on a single mode, side-polished fibre with a PVA overlay. Such a sensor was created by means of polishing the flat surface parallel to the fibre axis in order to remove the cladding. Side polishing can be realised by first immobilising the optical fibre in a rigid material, forming a rectangular block with the fibre extending out from the two end faces of the block orthogonal to the fibre axis. The advantage of this scheme is that the sensing element can be fabricated using inexpensive components and a variety of coating materials can be deposited onto the flat surface of the fibre block. However, the fabrication procedure is very time consuming, dependent upon the design of the fibre block and has limited exposed interaction length.

As mentioned earlier, tapered optical fibers have gained much popularity in various sensing applications [15]–[17] due to its high sensitivity. Compared to silica based fiber, plastic optical fibers (POFs) possess several advantages such as ease of handling, mechanical strength, disposability and easy mass production of components and system [2]. In this paper, tapered POF is coated by a polymer blend of hydroxyethylcellulose/polyvinylidenefluoride (HEC/PVDF) composite to sense the change in relative humidity. The coating of the tapered fiber changes its optical properties in response to an external stimulus. The measurement is based on intensity modulation technique where the output voltage of the transmitted light is investigated for changes in relative humidity.

II. EXPERIMENT

For the preparation of HEC/PVDF, 1 g of PVDF powder (Mw = 275,000) was dissolved in 120 ml dimethyl