CHAPTER

6

OPTICAL PROPERTIES AND SENSITIVITY OF FIBRE OPTIC EVANESCENT WAVE SENSOR

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6.1 INTRODUCTION

Optical chemical sensors are widely applied, and they use methods of optical transduction to yield information from analytes. Techniques that are commonly used in optical sensors are absorption, fluorescence, and refractometric. Optical sensors dependent on absorption can be colorimetric or spectroscopic in nature. The colorimetric sensors are based on detecting an analyte-induced colour shift in the analyte. In contrast, sensors based on spectroscopic absorption depend on the analyte's detection by checking its intrinsic absorption of molecules (McDonagh et al., 2008). One of the sensors using the absorption technique is Fibre Optic Evanescent Wave (FOEW) sensor.

In the life sciences, environmental research, and chemistry industry, FOEW sensors are widely applied due to the high sensitivity and results provided at high speed during real-time monitoring. There are two FOEW sensors: FOEW sensors based on Structured Optical Fibres (SOFs) and FOEW sensors based on Fibre Gradings (FGs). FOEW sensors based on SOFs can be classified into unclad, D-shaped, U-shaped, and tapered sensors according to the form of optical fibre structure in the sensing area. A fibre system that operates with a change of fibre periodically RI in a fibre core can be classified as FOEW sensors based on FGs. FGs have two types which are short-duration FGs (grading period less than 1 mm) and LPFGs (the grating period between tens and hundreds of micrometres) (Jiao et al., 2020).

FOEW is a type of fibre optic sensor that operates based on Evanescent Waves (EWs). Light will travel through the fibre core when the Refractive Index (RI) is higher than the RI of the cladding in a fibre structure. A total internal reflection would be generated when light travels through the fibre. The point of reflection will cause an evanescent wave to be created at the interface of the fibre-analyte. In FOEW sensors, the EWs penetration depth varies from 10 nm to 100 nm (Jiao et al., 2020). Therefore, the bulk solutions would not affect the sensor's results, which provide better performance than fibre-reflective and transmissive sensors.

The EW's attenuation on the unclad fibre surface directly affects the sensitivity of its sensing region. The etched fibre core's surface roughness significantly affects the sensors' transmission properties and sensitivity (Machavaram et al., 2007). To fabricate a high-quality evanescent-field fibre, chemical etching technology has been investigated and tested (Qiu et al., 2011). However, the etching products will be adsorbed on the surface and unevenly distributed during the etching process. Therefore, chemical etching cannot be used to obtain a smooth surface on the etched optical fibre without agitation (Herrera et al., 2011). Ultrasonic waves are widely used to improve the surface roughness of silica optical fibres (Chen et al., 2002). To fabricate an etched fibre core with smooth and different surface roughness, a simple etching approach that combines ultrasonic agitation with the use of Buffered Hydrofluoric Acid (BHFA) solution and Hydrofluoric Acid (HFA) solution etchant is used (Zhong et al., 2013). The optical reflectivity of the interface between the fibre and the surrounding environment will be affected by the surface roughness of the unclad fibres; this is very important for constructing high-sensitivity sensors (Machavaram et al., 2007).

6.2 FIBRE OPTIC EVANESCENT WAVE SENSOR

In general, optical chemical sensors are divided into two types which are fibre optic chemical sensors and planar waveguide chemical sensors. Fibre optic chemical sensor is a type of sensor using fibre optic as a light ray's propagation medium and sensing region, while a planar waveguide chemical sensor employs a planar substrate to form the bare sensor chips to guide the light in only one dimension (McDonagh et al., 2008). Fibre optic chemical sensors are divided into three transduction mechanisms: fluorescence-based, absorption-based, and refractometric. Absorption-based optical chemical sensors employ an absorption fluid to replace a portion of fibre cladding as a sensing region. Absorption-based sensors are divided into two types which are colorimetric and spectroscopic. Colorimetric is used in the analyte colour change detection in the sensing region, while spectroscopic is used in the detection of probing the intrinsic molecular absorption (McDonagh et al., 2008).

The fibre optical chemical sensor which employs the interaction between evanescent wave fields with the analyte sensing region can be classified as a fibre optic evanescent wave sensor. For example, FOEW sensor for absorption for monitoring the amount of the ion present in water has been developed. This sensor measured the absorption of the evanescent wave in the sensing region (Lee et al., 2003). Apart from that, fibre optic pH sensor based on evanescent wave absorption has been widely used by industry to monitor pH in certain mediums. In this type of sensor, a fibre cladding portion being removed and replaced by an absorbing fluid and the fractional power changing at the end of the fibre are being measured (Gupta & Sharma, 1997).

Fibre optic sensors based on evanescent wave absorption have the advantage of small size, flexibility, and the possibility of distributed sensing, providing fast results and low cost. However, FOEW sensors have been reported to face challenges such as limited sensitivity, selectivity, response, and recovery times (Jiao et al., 2020). Fibre optic evanescent wave sensor based on unclad fibres is the sensor developed by using an unclad fibre as a sensing region, the evanescent wave will