

Performance improvement of optical fibre oxygen sensor detection scheme incorporating narrow bandpass emission optical filter

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Abstract—We report performance improvement of an optical fibre oxygen sensor based on direct measurement fluorescence quenching of oxygen sensitive ruthenium complex and indirect measurement of lifetime through phase fluorometry. Comparison between detection scheme with and without emission filters using various bandpass ranges are being investigated. A 1.7 fold increase in fluorescence intensity is observed with a detection scheme employing broad (195 nm) bandpass emission filter compared to a system without emission filter. Six fold increase in fluorescence emission is detected when a narrow (25 nm) emission filter is adopted in the system. Similarly, six fold increase in phase angle value ϕ_ω is demonstrated in an in-direct O₂ sensor measurement when 25 nm bandpass emission filter is employed in such system. Improvement in O₂ sensor sensitivity and linearity are also reported with the inclusion of narrow bandpass emission filter.

I. INTRODUCTION

Fluorescence material such as Ruthenium complex can be coated at the distal end of an optical fibre (polymer or glass core material) to form optical fibre oxygen sensor based on fluorescence quenching of Ruthenium dyes. Such sensor has been reported using various optical configurations. Jorge et. al [1] for example, developed optical fibre probe which was prepared by using four different optical fibre geometries namely reflection on glass slide, at the tip of an optical fibre, unclad section of optical fibre tip and tapered shape optical fibre tip. Guillemain et. al [2] adopted a different fibre structure in which the oxygen sensitive material is mounted at the distal end of an optical fibre probe. Yan Xiong et. al [3] however uses a different approach in which the oxygen sensitive material is not located at the distal end of optical fibre but rather at the middle portion of the fibre which was achieved by removing a portion of optical fibre cladding which exposes the core of the fibre section to oxygen sensitive material. In this work, we implement coating technique of Ruthenium complex compound at distal end of plastic optical fibre (POF). POF was chosen due to its flexibility in terms of preparing the

sensor beside low in cost.

Optical oxygen sensor operation is based on direct measurement[4] of fluorescence intensity or indirect measurement[5] of lifetime using phase shift technique. In direct measurement method, quenching decreases fluorescence intensity due to collision between fluorophore and quenching agent. The quenching condition can be expressed by Stern-Volmer equations :

$$\frac{I_o}{I} = 1 + K_{sv}[Q] \quad (1)$$

$$\frac{\tau_o}{\tau} = 1 + K_{sv}[Q] \quad (2)$$

$$K_{sv} = k\tau_o \quad (3)$$

where I and τ are fluorescence intensity and excited state lifetime of fluorophore respectively. K_{sv} is the Stern Volmer constant, k is the diffusion dependent quenching constant and Q the concentration of quencher. In an ideal case, a plot of I_o/I or τ_o/τ versus $[Q]$ (known as Stern-Volmer plot) will be linear with a slope equal to K_{sv} and an intercept of unity.

In-direct measurement method involves the excitation of oxygen sensitive dye with sinusoidally modulated light. Depending on the decay time of such dye (in our case Ruthenium complex), the luminescence (emission signal) of the material have the same waveform but is phase shifted at a given frequency as shown in Figure 1. The decay time is determined by the phase shift according to Equation 4 where f is the modulation frequency of the excitation light and τ is the luminescent decay time defined as the average time the dye molecule remains in the excited state before it returns to the ground state.

$$\tau = \frac{\tan\pi}{2\pi f} \quad (4)$$

As the quenching time of fluorescence in oxygen sensitive dye is directly proportional to oxygen concentration, when the