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Development of Optical Dissolved Oxygen Sensor Element on Thin Layer Substrate for Internet of Things Platform

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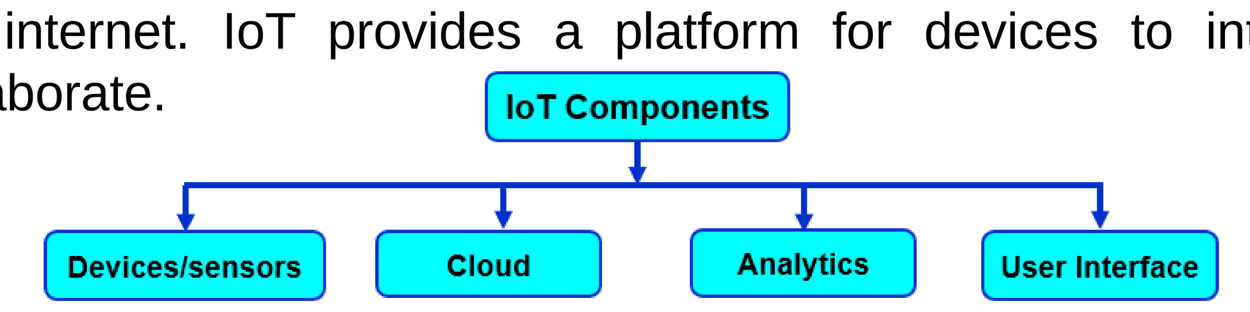
INTRODUCTION

Internet of Things (IoT) is a system of connected devices, home appliances and vehicles. They can share data with other devices over the internet. IoT provides a platform for devices to interact and collaborate.



Dissolved oxygen (DO) is the presence of free, non-compound oxygen present in water or other liquids. DO is an important parameter in assessing water quality because it has an impact on the organisms living in the water body and is related to Biochemical oxygen demand (BOD). Biochemical oxygen demand (BOD) represents the amount of oxygen consumed by bacteria and other microorganisms, and inorganic compounds while they decompose organic matter under aerobic (oxygen is present) conditions at a specified temperature. In healthy water, DO concentrations range from 6.5-8.4 mg/L and % DO saturation between about 80–120%. So it is necessary that the DO value be monitored around the clock for a healthy aquatic environment. Nowadays, optical dissolve oxygen (ODO) sensors based on the fluorescence quenching principle are widely used.

We developed an optical DO sensor element using the optical fiber method with the oxygen-sensitive dye PtOEP, which has platinum in its porphyrin structure. DO in solution, quenches the excited-state lifetime and the fluorescence intensity of PtOEP.

$$I_0 / I = \tau_0 / \tau = 1 + K_{SV}[Q]$$ The Stern-Volmer Equation

OBJECTIVES

- To develop an optical oxygen sensor element with a suitable sensitive dye element for gaseous dissolved oxygen in water as a part of the open innovation model of IoT;
- To anchor the Fluorescent dye PtOEP in an optical substrate and sensitive to the presence of DO;
- To characterize the sensor element with the following chemical (structural decay stability, hydrophobicity, acid and alkaline stability) and physical (thermal stability, porosity, photobleaching, fluorescence quenching) aspects;
- To compare the results with commercially available optical oxygen sensor devices and standard BOD methods;

METHODS

PtOEP dye films with 900 ppm and 3k3 ppm concentration with thicknesses of 160–500 um were fabricated and encapsulated in PDMS doped with Al_2O_3 at the Centre for Optics, Photonics, and Lasers (COPL) Laval University Québec, Canada.

Flowchart of COPL ODO Film Synthesis

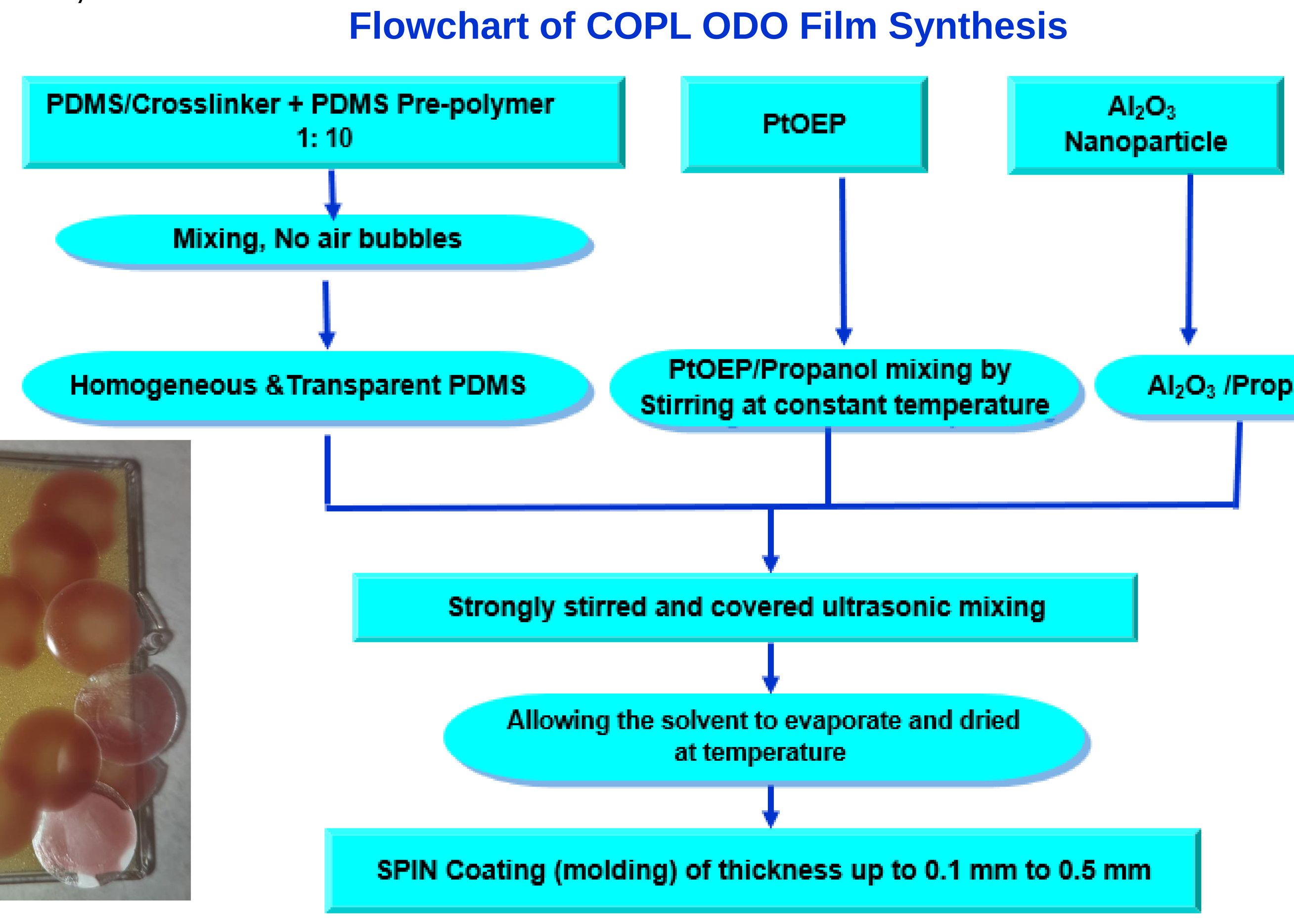


Fig 1. PtOEP ODO-COPL Sensors elements

Pumping LED was 367nm, fluorescence was detected by a PIN photodetector connected to a Lockin amplifier, data was fitted by the Stern Volmer equation. Yeast was used as oxygen quenching agent.

RESULTS AND DISCUSSIONS

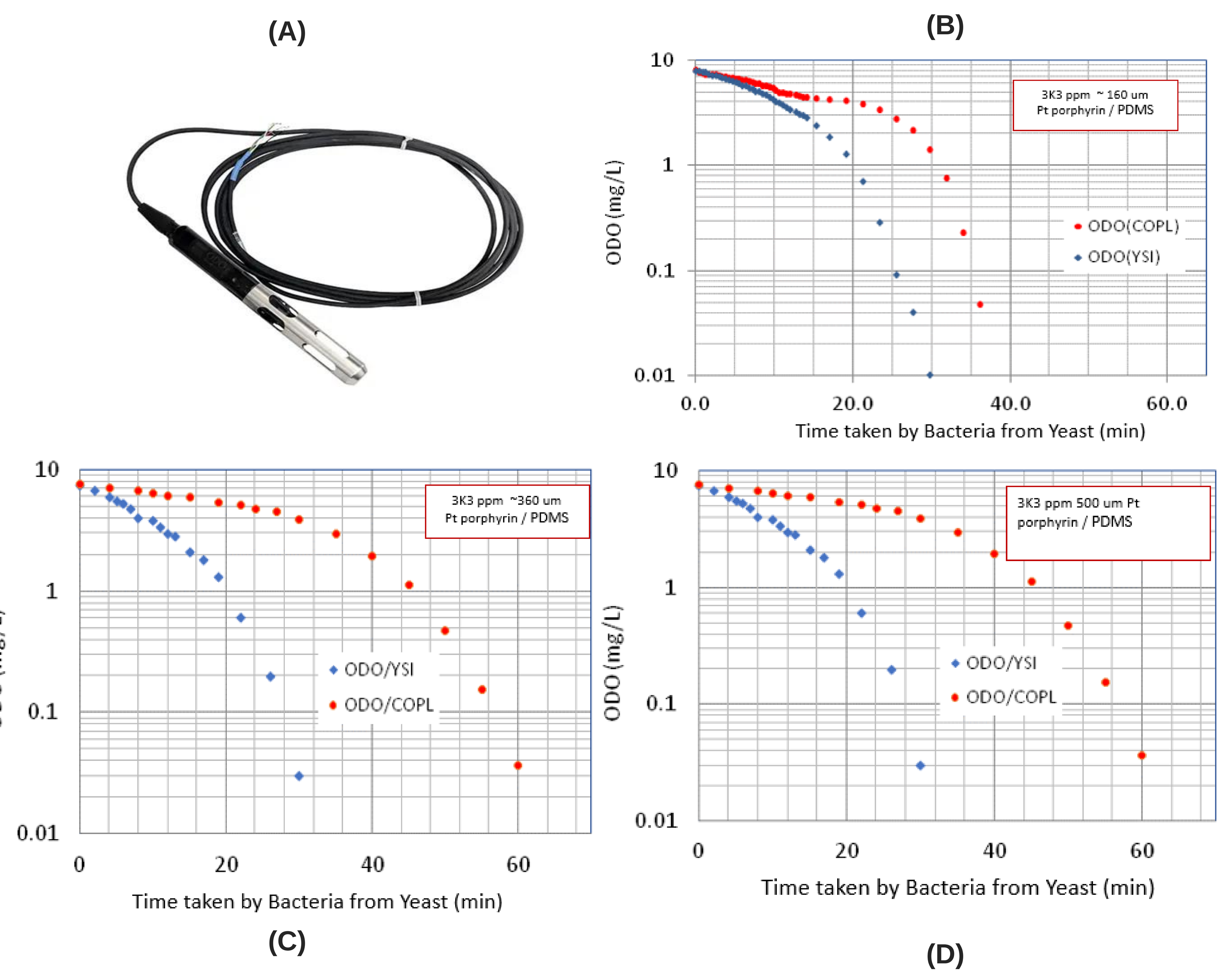


Fig 2. (A) YSI ODO RTU sensor. ODO vs time for different film thicknesses: (B) 160um; (C) 360um; (D) 500um

- The DO values of ODO-COPL samples of three different thicknesses (160 um, 360 um, and 500 um) at the same dye PtOEP concentration were compared with commercial YSI ODO-RTU;
- The sensor was tested in DI H_2O at 20 ºC and 760 mm Hg, with 200 mg of yeast, achieving a DO measurement range of 0.01–9 mg/L;
- The result shows a thin layer of ODO-COPL sensor of 160 um in Fig 2. (B) gives a similar pattern, followed by YSI ODO-RTU, as it shows a 0.1 mg/L DO value in 25 minutes, and ODO-COPL gives the same value in 32 minutes.
- The time taken by the thickest layer, i.e., the 500-um ODO-COPL sensor, to reach 0.1 mg/L of DO takes 55 minutes. It is possible that excitation light cannot reach the dye and similarly less diffusion of oxygen molecules is present for fluorescent quenching.

CONCLUSIONS

- The thinner the thickness, the more feasible is the excitation of the PtOEP dye followed by more diffusion of DO molecules, which quenches the fluorescence intensity of PtOEP dye dispersed in the sensor element;
- It is suggested to develop more ODO sensor elements at thinner thickness to increase O_2 diffusion for shorter fluorescence response time;
- There is need for more samples and experiments to detect possible causes of this weakness of quenching in longer time to better understand its physiochemical properties;

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