# Simulation of Optical Planar Waveguide Sensor for Microplastics Detection in Water

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***Abstract*—Nowadays, microplastics pollution has become a global concern as it endangers the ecology, marine animals, and cause health threats to human beings. This paper attempted to simulate an optical planar waveguide sensor for microplastics detection in water via Wave Optics Module-COMSOL Multiphysics®. The analyte refractive index was ranged from 1.4800 to 1.5000 RIU, in reference to the microplastics refractive index. The simulation results showed significant variations in the evanescent waves of the sensor at different analyte refractive indices, thus proving that the sensor has potential for microplastics detection in water with sensitivity of 0.0040 in dimensionless unit.**

***Keywords—simulation, microplastics, optical waveguide, sensor***

## I. INTRODUCTION

Plastics have wide applications across practically all industries worldwide and are extremely useful in everyday life, for example as packaging materials, food storage, and drinking bottles. However, improper disposal of post-consumer plastics, either to be recycled or reused, may lead to environmental pollution. Plastics in water bodies such as rivers, oceans, and lakes will degrade to form microplastic fragments [1], eventually resulting in microplastic invasion of water. This consequence not only endangers aquatic animals but also risks human health.

Accordingly, several research on microplastics detection methods in water have been conducted and reported based on optical, visual, and chemical inspections such as Raman, near infrared (IR), and Fourier transform infrared (FTIR) spectroscopy [2]. Nevertheless, there were some issues that appear controversial and pose as highly disputed subjects in the microplastics detection methods in water. Among this, spectroscopic methods suffer from limitations including complicated processing steps that produce low yield with extortionate cost and are ultimately time consuming.

To overcome these limitations, an optical planar waveguide sensor for microplastics detection in water was proposed and simulated via Wave Optics Module-COMSOL Multiphysics® software. Furthermore, the electric field distribution throughout the sensor, the mode field diameter (MFD) and effective RI changes at different analyte RI mediums with its underlying physics were also studied and discussed.

## II. SIMULATION SETTINGS

The 3-dimensional representation and cross-sectional view of the newly developed single mode europium-aluminum doped polymer composite optical planar waveguide sensor are illustrated in Fig. 1. The structure consists of a core (n = 1.5100 RIU) diameter of 10 µm surrounded by cladding (n = 1.5010 RIU) with width and thickness of 80 µm and 45 µm; 617 nm was chosen as the operating wavelength where the lowest attenuation window of practical waveguide is established [3]. Due to limited information, the microplastic RI range in water were set from 1.4800 – 1.5000 RIU, with an RI step increment of 0.0050 RIU. Meanwhile, 1.4900 RIU in the middle range represents low-density polyethylene (LDPE) RI [4].

## III. RESULTS AND DISCUSSION

### *A. Electric Field Distrbution*

Fig. 2 shows the simulation output as the light wave propagates through the sensor structure. From a selective study, a colored representation of the electric field distribution when the sensor was exposed to the LDPE medium was established as shown in Fig. 2(a). The red and blue colors indicate the maximum and the minimum electric field intensity, respectively. The electric field gradually decreases when reaching the core/cladding or core/analyte boundary as the light energy attenuates when it reaches the boundary with different RI mediums. A significant evanescent wave can be seen at the core/analyte boundary

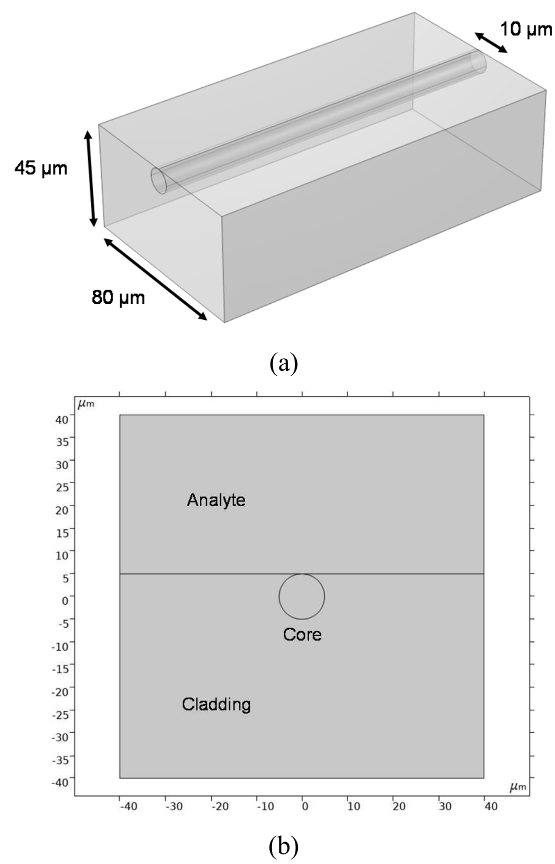


Fig. 1 The structure of Eu-Al doped polymer composite optical planar waveguide in a) 3D and b) cross section geometry for simulation purposes

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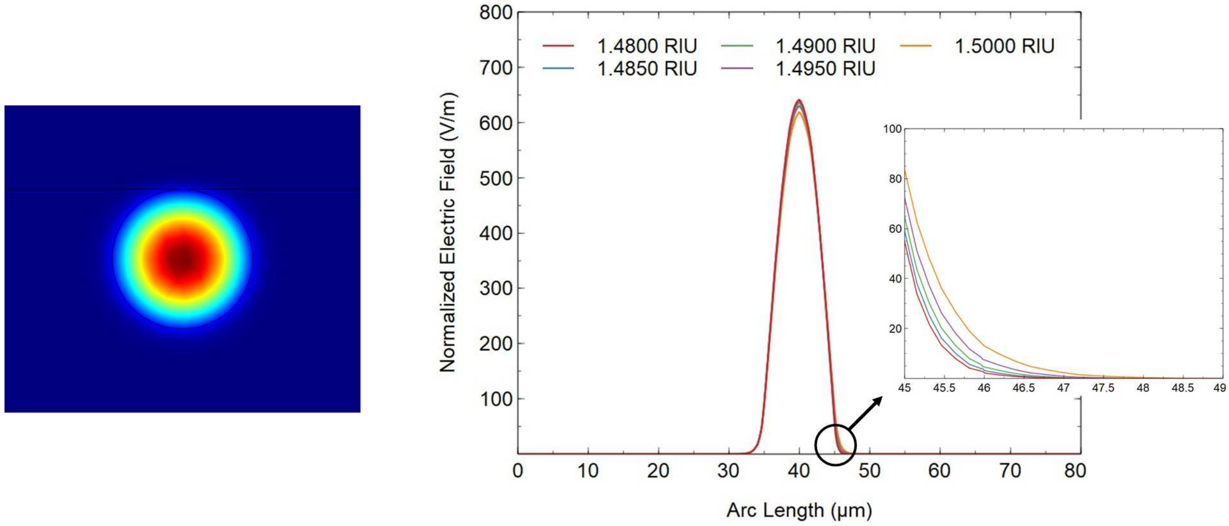


(a) (b)

Fig. 2 Colored illustration of electric field intensity around the sensor core when surrounded by (a) LDPE medium and (b) MFD of the sensor at different analyte RI.

due to lower RI contrast between the core/LDPE medium. The electric field distribution of the sensor can be analyzed by studying the MFD as depicted in Fig. 2(b). A variation of MFD can be seen by changing the analyte RI without being overlapped. Meanwhile, the inset shows the penetration depth of the evanescent wave at the core/analyte boundary. The penetration depth increases with the increase in analyte RI. The penetration depth depends on the RI difference between the core and the analyte. The lower the RI difference, the higher the penetration depth probes further into the analyte medium. This condition will lead to more energy dissipation in the analyte medium and thus increase sensor sensitivity.

### *B. Effective Mode Index and Sensor Sensitivity*

Different $n_{eff}$ can be obtained by changing the analyte RI. The $n_{eff}$ changes were plotted at different analyte RI as shown in Fig. 3. As the analyte RI increases from 1.4800 to 1.5000, the $n_{eff}$ increases nonlinearly. The non-linear change happens due to the nonlinearity of evanescent wave energy when interacting with the analyte medium [5]. However, Xiao et al. suggested an evaluation on the changes in linear fit to easily determine the sensitivity from the slope of the graph [5]. Hence, the estimated sensitivity achieved by the sensor is 0.0004 in dimensionless unit.

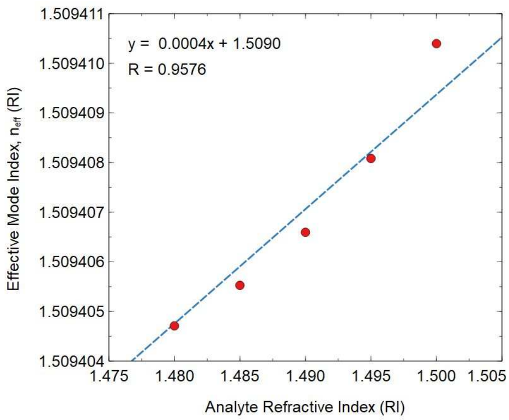


Fig. 3 The $n_{eff}$ changes of the sensor at different analyte RI

## IV. CONCLUSION

This work demonstrated the simulation of the optical planar waveguide sensor for microplastics detection in water. The sensor was simulated in different analyte RIs ranging from 1.4800 RIU to 1.5000 RIU, in reference to the microplastic RI. Different analyte RIs show different electric field distributions and evanescent fields without overlapping. The estimated sensitivity achieved by the sensor is 0.0004 in dimensionless unit. Although no optimization and comparison study with other optical sensors were involved, the simulated design pointed to a convincing sensor with potential for microplastics detection in water.

## ACKNOWLEDGMENT

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