A Robust pH Sensing Module Utilizing Reproducible Structural Colour Fabricated by Two-Photon Polymerisation

Jing Qian[1], *Yekaterina* Tskhe[1], *A. Louise* Bradley[2], *Larisa* Florea[1], and *Colm* Delaney[1*]

[1] School of Chemistry & AMBER, Trinity College Dublin, Dublin, D02PN40 Ireland
[2] School of Physics & AMBER, Trinity College Dublin, Dublin, D02PN40 Ireland

Abstract. Photonic structures integrated with responsive photoresists have garnered significant attention, particularly following the advancements in two photon lithography. The pH responsive photonic array presented exhibits robust structural stability and generates progressively changing structural colours in transmission across various pH buffered solutions, highlighting their strong potential for biosensing applications.

1 Introduction

Photonic structures represent a highly promising class of materials capable of manipulating light at the nanoscale, revolutionizing the field of sensing [1]. They enable highly sensitive, precise, and real-time detection of a wide range of physical, chemical, and biological parameters [2-3]. By controlling the behaviour of light - such as reflection, transmission, and scattering - photonic structures are invaluable in advancing sensing technologies across diverse applications [2-3].

In this paper, pH responsive photonic arrays are designed and fabricated. The pH-responsive properties of the material allow the size of individual units in the array to expand to varying degrees in different pH solutions, leading to a shift in transmitted colour.

2 pH responsive photonic arrays design

The optical properties of the cube array were predicted using Lumerical FDTD simulations. The 0^{th} order transmittance of the photonic structure in air (with a refractive index of 1.0) and in water (with a refractive index of 1.333) were compared to predict the spectral shift in different surrounding media.

The photonic structure, consisting of a symmetric cube array placed on a fused silica substrate, is shown in Fig. 1a. The simulated 0^{th} order transmittance of the cube array, with an xy dimension of 2.0 µm, a period of 4.0 µm, and a structure height of 6.0 µm, is depicted in Fig. 1b. The red trace demonstrates that the transmitted colour shifts toward the blue as the refractive index of the surrounding medium increases.

- * Corresponding author: cdelane5@tcd.ie

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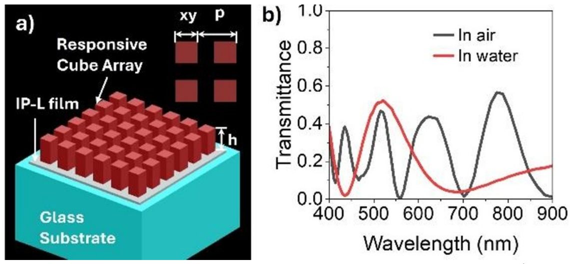

Fig. 1. a) The schematic illustrates the cube array model. b) The simulated 0^{th} order transmittance of cube array in air and water environment with xy=2.0 µm, p=4.0 µm and h=6.0 µm.

3 The fabrication of a pH responsive array

The combination of pH responsive photoresist and two photon lithography serves as the key technology for fabricating submicron pH responsive photonic structures.

To enhance the structural stability in solutions and improve the adhesion of the photonic structure to the substrate, a 0.6 µm thick IP-L (Nanoscribe GmbH) base film is printed onto a fused silica substrate. A pH-responsive film and photonic structure are then positioned on top of the IP-L film. The structural colour of the array dynamically changes in response to different pH buffer solutions, as shown in Fig. 2a. Additionally, the SEM image in Fig. 2b illustrates the uniformity of the structure.

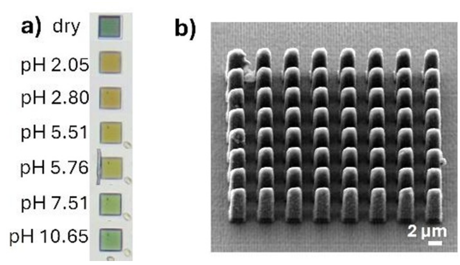

Fig. 2. a) The structural colours of the printed pH cube array, fabricated using two-photon lithography, shift in response to increasing pH in buffered solutions, with dimensions specified in Fig. 1. b) A 45° tilted SEM image of the printed sample.

4 Conclusion

pH responsive photonic structures have been successfully designed and fabricated. The experimental results have demonstrated their effectiveness in pH determination through structural colour variation in solution. The results demonstrate that this robust pH-responsive module holds significant potential for pH detection, and its sensing performance warrants further investigation.

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