Nanoscale Photonic Biosensors from Biological Building Blocks

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Abstract:

In order to exploit the strong core field of an optical waveguide, we demonstrate a fully functional optical waveguide structure fabricated out of agarose hydrogel. We also show the capability of incorporating live cells within these optical waveguides and thus a new regime for optical biosensing and bio manipulation on the micro/nano scale.

Summary of Research:

In this project, we are looking to develop optical devices for biological applications using non traditional materials for fabrication. Specifically, the motivation is to use the strong optical field present in the core of an optical waveguide instead of the weak evanescent field available in traditional optical devices constructed out of semiconductor devices like silicon or glass. In order to achieve this, we use a biocompatible hydrogel, specifically agarose hydrogel, to fabricate the optical hydrogels.

Though there are other approaches to fabricating optical structures from hydrogels, they involve harsh methods like femtosecond lasers [1], which don’t allow for biological entities to be embedded inside the structure (which is necessary for exploiting the core field of the waveguides). On the other hand, fabrication process with agarose hydrogel is completely compatible for incorporating bio specimens [2].

Briefly, we use SU-8 masters fabricated in the Cornell NanoScale Facility (CNF) to mold PDMS stamps which are subsequently used to mold a molten solution of agarose (2% w/v) on an agarose hydrogel substrate (1.5% w/v), to obtain the required optical structure.

The final structure, shown in Figure 1, consists of a 1.5% w/v agarose hydrogel (index of refraction, n = 1.3342) as the substrate, a 2% w/v agarose hydrogel (n = 1.3357) as the core, and air (n = 1). A He-NE laser (633 nm, red) was subsequently used to couple to the hydrogel waveguides through an optical fibre to demonstrate a working optical waveguide, and can be seen in Figure 2. As a proof of concept experiment, cells (MDA-MB231 cancer cells) were incorporated inside the agarose waveguides, and were found to be viable using a Calcein AM live cell stain (Figure 3). In other experiments (results not shown), we also demonstrated the capability of embedding DNA inside the waveguides. We are now looking to explore the capabilities of the new platform and fabricate novel optical biosensing and bio manipulation tools which are cheap, implantable and more sensitive than other available devices.

References:

Figure 1: Agarose hydrogel waveguides with 1.5% Agarose Gel as substrate and 2% Agarose Gel as core.

Figure 2: Demonstration of a working hydrogel waveguide. A HeNe laser (red, 633 nm) was coupled into the waveguides using a multimoded fibre (from bottom right).

Figure 3: Cells inside optical waveguides: a) MDA-MB231 Cells (circled in red) stained with Calcein AM (live cell stain) embedded inside the optical waveguides. b) A cell (circled in red) interacting with a laser (488 nm) coupled into the gel waveguide.