EMBEDDING TAPERED FIBER BIOSENSORS WITHIN MICROFLUIDIC CHANNELS FOR BACTERIAL SENSING

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There is an urgent need for portable, simple, cost-effective, biosensor systems with sufficient sensitivity, specificity, and speed for rapid and timely detection and quantitation of pathogens of economic and public health significance. Current methods employed using polymerase chain reaction take as much as 8 hours to days or weeks, from sampling to result. Recent Shiga toxin producing E. coli (STEC) O157:H7, Salmonella and Listeria outbreaks resulted in thousands of illnesses and several deaths, in addition to costing millions of dollars in associated expenses. We are developing fiber optic biosensors to address this important need. Specifically we fabricate optical fiber tapers by heating and pulling standard glass optical fibers, and then immobilize antibodies on their surfaces. For bacterial sensing, the sensor can be immersed in a solution where bacteria are present. However, when there are very few (<1000 cells/mL) bacterial cells in a solution, the likelihood of capturing them on the biosensor surface is preventively small. To increase sensitivity, we aim to perform bacterial detection when the sensor is placed within microfluidic channels. Here, we present our preliminary experiments for tapered fiber biosensors embedded in various types of microchannels. We demonstrated that the sensor can endure fast liquid flow, and sensor transmission spectrum can be reliably monitored. We also show results of our tests with salt solutions with varying concentrations for sensors within a microfluidic channel.

MICROFLUIDIC CHANNELS FOR CHEMICAL AND BIOLOGICAL SENSOR APPLICATIONS

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We fabricate microfluidic channels for chemical and biological sensing applications. The channels typically have 50-400 microns height, 2-5 mm width, and 2-5 cm length, and they serve to protect the sensors and allow measurement in flow. We use three separate simple methods: 1) Double-sided tape and transparency sheets, 2) Capillary tubes, 3) Polydimethylsiloxane (PDMS)-based channels with molds created from double-sided tape and transparencies. To design the channels we use AutoCAD or equivalent software. The channels or molds for the channels are
then cut out using an Electronic Craft Cutter. We demonstrate that channels can be used to embed the sensors within for improved robustness and to allow samples flown past the sensor for biological and chemical sensing. We have developed procedures to create channels with no leakage using simple tools and supplies.

**A MORE CONVENIENT ROUTE TO ANTIBODY IMMOBILIZATION ON GLASS SURFACES**

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Unlabeled optical biosensors can give rapid response when binding occurs between the specific recognition molecules (e.g. antibodies) and the target proteins. Many optical biosensors use glass surfaces, and an important part of sensor preparation is the covalent immobilization of antibodies on the surface. This step is usually a lengthy process, and requires numerous reagents. In our experiments with tapered fiber optic biosensors, we first adopted a protocol [1] that took at least 8 hours to complete, required harsh acids, elevated temperatures, and the immobilization efficiency was sensitive to solution pH values in multiple steps. We modified these steps and used alternate reagents, which reduced the time required for the entire protocol to less than 4 hours. Moreover, the alternate protocol we tested does not require any acids, elevated temperatures, or special equipment, such as a precise pH meter. In our multiple tests using tapered fiber optic biosensors, we measured stronger response as compared to our results with the previous protocol.

**Temperature and Refractive Index Sensor based on a Simple Optical Fiber Loop**

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Optical fibers can be turned into sensors that can detect physical, chemical, and biological targets of interest. In most cases, this requires some modification of the fiber, such as tapering or etching the cladding. We have investigated fabrication of sensors by simply looping an optical fiber, keeping its protective polymer coating intact. We were able to show great temperature sensitivity, and are currently investigating refractive index sensing in a similar scheme, which might enable fabrication of chemical and biological sensors.

**Rapid Immunoassay with Tapered Fiber Optic Biosensors**

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There is an urgent need for portable, simple, cost-effective, biosensor systems with sufficient sensitivity, specificity, and speed for applications in medical diagnostics, food safety, environmental monitoring and biodefense. This study aims to demonstrate label-free real-time detection of anti-IgG using IgG (Immunoglobulin-G) immobilized on the surface of a tapered fiber-optic biosensor. We have tested our sensor against 0.5-50 µg/mL concentration of the anti-IgG, and measured concentration-dependent response. By using the rate of change of the sensor signal (i.e. peak shift) rather than the absolute change, we can determine the anti-IgG concentration within minutes. Based on our current data, we predict that the sensor platform can be used to measure < 500 ng/mL concentrations of proteins.

3D PRINTER APPLICATIONS IN SCIENTIFIC RESEARCH

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Three-dimensional (3D) desktop printer holds a promising future for science, education and sustainable development. In scientific research, 3D printing plays its role in fabrication of custom parts for experimental setups. We present some of the supporting tools that we built with a relatively inexpensive 3D printer (Cube, $1500 from 3D Systems). Specifically, we fabricated sample holders for microscopy applications, a part to reliably transport fiber optic biosensors, and cuvette and slide holders that were used during antibody immobilization on the sensors. Our research also involves creation of microfluidic channels, and the 3D printer was used to make a mold for the channel. Full prototype of cellphone-based microscope was built successfully using the 3D printer. We show how one can quickly start designing 3D parts, and summarize advantages and challenges in 3D printing.

BIOSENSOR-LIPO: INCREASING SENSITIVITY OF TAPERED FIBER SENSORS BY HYDROGEN FLUORIDE ETCHING

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We have studied the dependence of sensitivity on the thickness of the biconically tapered fiber optic sensors for the cases of homogenous and surface sensing, i.e. whether the evanescent field region is filled entirely or partially. Surface sensing is applicable to sensing proteins and toxins, while homogenous sensing is applicable for uniform chemical solutions. Our simulations show that although the sensitivity increases with thinner tapers for both homogenous and
surface sensing cases, the rate of sensitivity improvement is not sustained for the entire thickness range. For homogenous sensing the sensitivity approaches a maximum near-constant value with decrease in taper diameter. For surface sensing, on the other hand, there is an optimal thickness beyond which the sensitivity sharply decreases. To test these predictions experimentally, we fabricate fiber tapers by heating and pulling them. We further reduce the thickness by using hydrofluoric acid (HF) treatment. Our preliminary experimental results will be presented for sensitivity measurement using salt solutions. Future experiments include detection of model proteins or antibodies (e.g. Bovine serum albumin or Immunoglobulin-G) with HF-treated fiber tapers.

CELL PHONE-BASED OPTICAL MICROSCOPE FOR BRIGHT FIELD AND FLUORESCENT MICROSCOPY

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We designed and constructed a portable microscope by attaching a simple lens assembly to a smart phone. The cell phone attachment that contained an external lens and LEDs was designed in SolidWorks, created using a 3D printer, and costs less than $50. We present here the characterization of the microscope, bright field and fluorescent images. This microscope can resolve objects about 8 microns in size in a clear 5 mm x 5 mm field of view, so it can be used for monitoring biological specimens such as red blood cells in a wide field of view in especially resource-limited settings.