RESEARCH BRIEF

OPTICAL FIBER BIOSENSORS

The potential

Fiber optic research has been expanding since fiber-imaging bundles were first put together in the late 1950s. While their initial use was solely as a means to transmit light over only a few tens of centimeters, fiber optics have evolved to become one of the most advanced mediums of transmission and translation available today. Today they are used in applications varying from the Internet to microscopes.

For the past decade, fiber optic biosensors have been touted as the means to revolutionize medical technology, dramatically improving patient care and cutting overall operating costs. They are immune to electromagnetic signals and are currently used in a variety of medical applications such as early cancer and AIDS detection.

The challenge

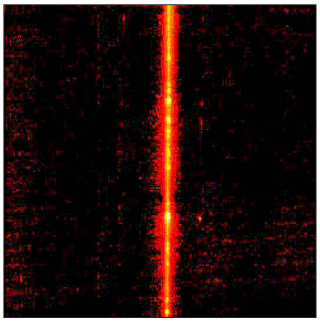
Though optical fiber biosensors have tremendous potential, their focus on microscale diagnostics requires a near-perfect margin of error. Much more sensitive sensors are needed for applications in preventative care.

For example, direct observation of viruses is a challenging task, as is analyzing DNA. Though multimode fibers are typically applied in these systems because of their larger power-transmitting capacity, they require bulky optical components which may easily become misaligned.

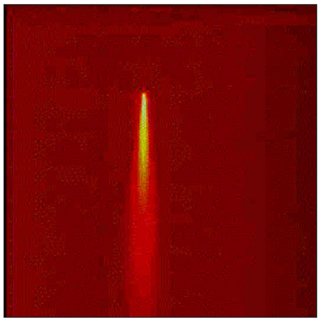
Light delivery and collection structures to be used as the transduction mechanism for measuring biochemical activity also will need to be optimized for microscale applications. In addition, modal fields must be exposed for intrinsic fiber optic sensors to interact with the surrounding environment. Without each of these factors working together, functional biosensors are not possible.

The research

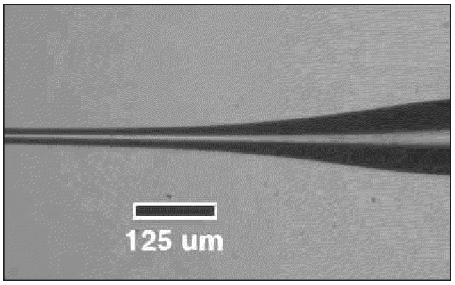
ISR researchers, led by Dr. Christopher Davis, are making the production of much more sensitive optical fiber biosensors possible, furthering their potential in preventative care.


Fluorescing optical fiber

Biosensors can detect the presence of antibodies or oligonucleotides (short DNA sequences). Already this ability has made it easier for doctors to formulate medical diagnoses and identify illness earlier and more effectively.


Untapered cleaved fiber

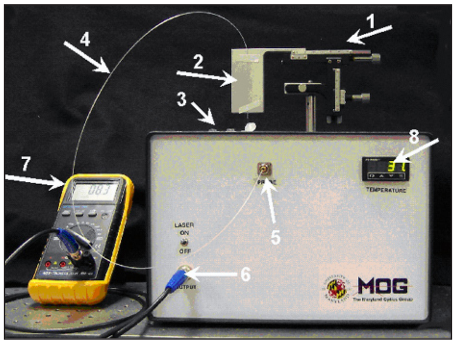
However, there is room for much improvement. DNA sensors fabricated to date are not sensitive enough to work without a preliminary chemical-amplification step. Dr. Davis and his colleagues are working to develop a more precise, optically based sensor—a challenging task.



Tapered fiber

In order for a biosensor to interact for diagnostic purposes, a transduction element must first be applied to its surface. The ISR researchers have developed one-inch long, hair-like strands of optical fiber, to which they apply fluorescent dye molecules.

To solve the problem of multimode fiber size, the researchers are developing tapered single-mode optical fiber biosensors to provide a more compact and robust sensing unit. Once the transduction mechanism has been applied, an optical fiber is tapered from its normal diameter to a smaller diameter in order to increase the electromagnetic field intensity at the surface of the fiber where the optochemical transducing layer is present. This group of fiber-optic sensors rely on the evanescent field properties of the modes propagated within the waveguide.



Biosensor prototype system with readout to an auto-ranging digital voltmeter.

1. **x-z probe positioning stage;**
2. **fiber holder;**
3. **sample holder wells (three);**
4. **probe fiber;**
5. **FC-FC fiber probe feed-through;**
6. **BNC output;**
7. **readout unit (DMM);**
8. **sample holder temperature controller**

In many sensor applications the use of multimode fiber offers some advantages, such as larger surface area and more flexibility and ease of use. Dr. Davis's team has successfully solved the problem of interfacing single and multimode fiber technology in a single sensor and have delivered to the U.S. Army a prototype fluorosensor with attomole sensitivity.

Among other advantages, the use of fiber in these applications permits the development of an easy-to-use compact system requiring no optical alignment.

Dr. Davis's team is also currently engaged in the research and development of another highly sensitive evanescent field sensor using a biconical tapered single-mode optical fiber. The biconical tapered section of the fiber is formed by heating the fiber along its length and simultaneously pulling equally in opposite longitudinal directions.

The fiber is pulled so the tapered fiber region has a waist diameter equal to or smaller than the original core diameter of the fiber. This ensures the efficient interaction of the evanescent field with the outside medium. The tapered fiber should exhibit very low loss. This can be accomplished by carefully controlling the tapering angle and symmetry of the tapered portion during pulling.

Sensors made up of such tapered fibers are highly sensitive to very small changes in refractive index, chemical concentration, pH, fluorescence, etc., making an already promising technology even more efficient.

Support

This work is currently supported by the National Science Foundation and has had previous support from the Army Research Laboratory and the Department of Energy.

Patents

US 6,633,711: Focused ion-beam fabrication of fiber probes for use in near field scanning optical microscopy

US 6,558,958: Optical fiber evanescent field excited fluorosensor

US 6,103,535: Optical fiber evanescent field excited fluorosensor and method of manufacture

US 5,990,474: Near field optical probe for simultaneous phase and enhanced amplitude contrast in reflection mode using path matched differential interferometry and method of making it

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