Tailoring Cores of Optical Fibers by a Sol-Gel Method

Core dopants can be tailored for specific photonic applications.

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A method of tailoring the cores of optical fibers to obtain optical properties needed for specific photonic applications exploits the sol-gel process. The method is expected to open new avenues of development of fiber-optic sensors for measuring strain, temperature, intensity of ionizing radiation, concentrations of chemicals, and numerous other quantities.

Heretofore, the optically active dopants that constitute the transducer materials of fiber-optic sensors have generally been incorporated into films deposited on the exterior surfaces of optical fibers. In some cases that are particularly relevant to the present development, the exterior films have been doped sol-gels. The operation of such a sensor depends on evanescent-wave coupling of light between core of the fiber and the dopant(s) in the coating film. However, the inherent weakness and large optical loss of evanescent-wave coupling are obstacles to the attainment of adequate sensor response.

If the dopant(s) could be incorporated into the core, the optical coupling would be much stronger and the sensory light could propagate to the detection equipment with very little loss. In addition, given the limit of solubility of the dopants in the sol-gel reaction mixture and the wave-propagation geometry, the optically effective quantity of dopant that could be contained in the bulk of the core would be much greater than the optically effective quantity of dopant that can be contained in an exterior sol-gel sensory film. The net effect of incorporating the dopant into the core would be to make the sensor much more sensitive. The present method exploits this effect.

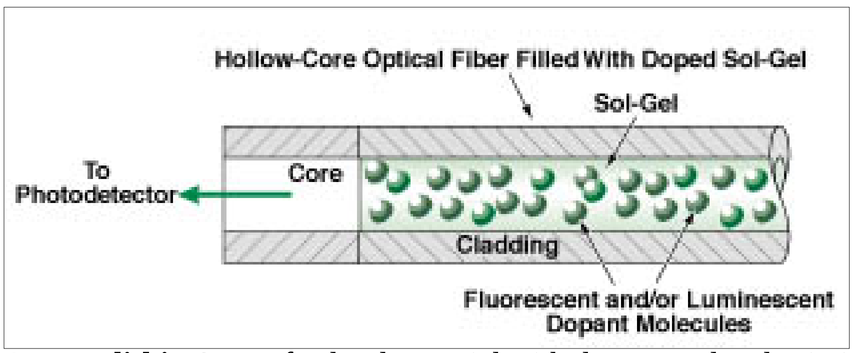
A fiber-optic sensor fabricated by this method offers an additional advantage (beyond direct vs. evanescent-wave coupling) over a comparable prior-art sensor that comprises an optical fiber coated with a doped sol-gel film. This advantage arises in connection with the fact that to prevent thermal degradation of dopants in the prior art, it is necessary to deposit the sol-gel film first, then diffuse the dopants into the pores of the film. As a result, there is a tendency for the dopants to leach out of the pores of the sol-gel film in some sensor operating environments. In the present method, there is little or no tendency for the dopants to leach out because the dopants are incorporated deep within the sol-gel core, which, in turn, is protected from the environment by the cladding layer of the fiber.

In the present method, the dopants are dissolved and incorporated as ingredients in a sol-gel reaction mixture, which is injected into an initially hollow optical fiber. The sol-gel is then polymerized, forming a monolithic solid core that comprises a porous sol-gel with the dopants occupying its pores (see figure).

One main obstacle that had to be overcome in the development of the present method was the tendency of sol-gels to shrink and crack during polymerization. In fiber-optic sensors, cracks cannot be tolerated because they cause large optical losses. Moreover, the extreme temperatures and pressures

often used for processing sol gels will cause fatigue and damage to optical fibers and preclude the use of many biochemical dopants. The success of the present method stems from the development of sol-gel formulations that can contain adequate amounts of sensory dopants and can be polymerized while managing the shrinkage in a near-room-temperature process.

The process for fabricating the tetraethyl orthosilicate (TEOS) based sol gels employs a number of agents to reduce the process problems inherent in the condensation-polymerization process. A variety of configurations of sensors is being evaluated, including sensors utilizing intrinsic and extrinsic sol-gels. Fluorescent sensing experiments with sol-gels doped with fluorescence derivatives and calcofluor derivatives are underway. Both substances have a wide variety of potential applications in biochemistry and monitoring of metabolic reactions at the cellular level.



A **Monolithic Core** of sol-gel material with dopant molecules in its pores is formed in an initially hollow optical fiber.

This work was done by Harry C. Shaw and Michele V. Manuel of **Goddard Space Flight Center** *and Melanie N. Ott of Sigma Research and Engineering. For further information, access the Technical Support Package (TSP)* **free on-line at** **www.nasatech.com** *under the* ***Materials category***.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-13913.

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