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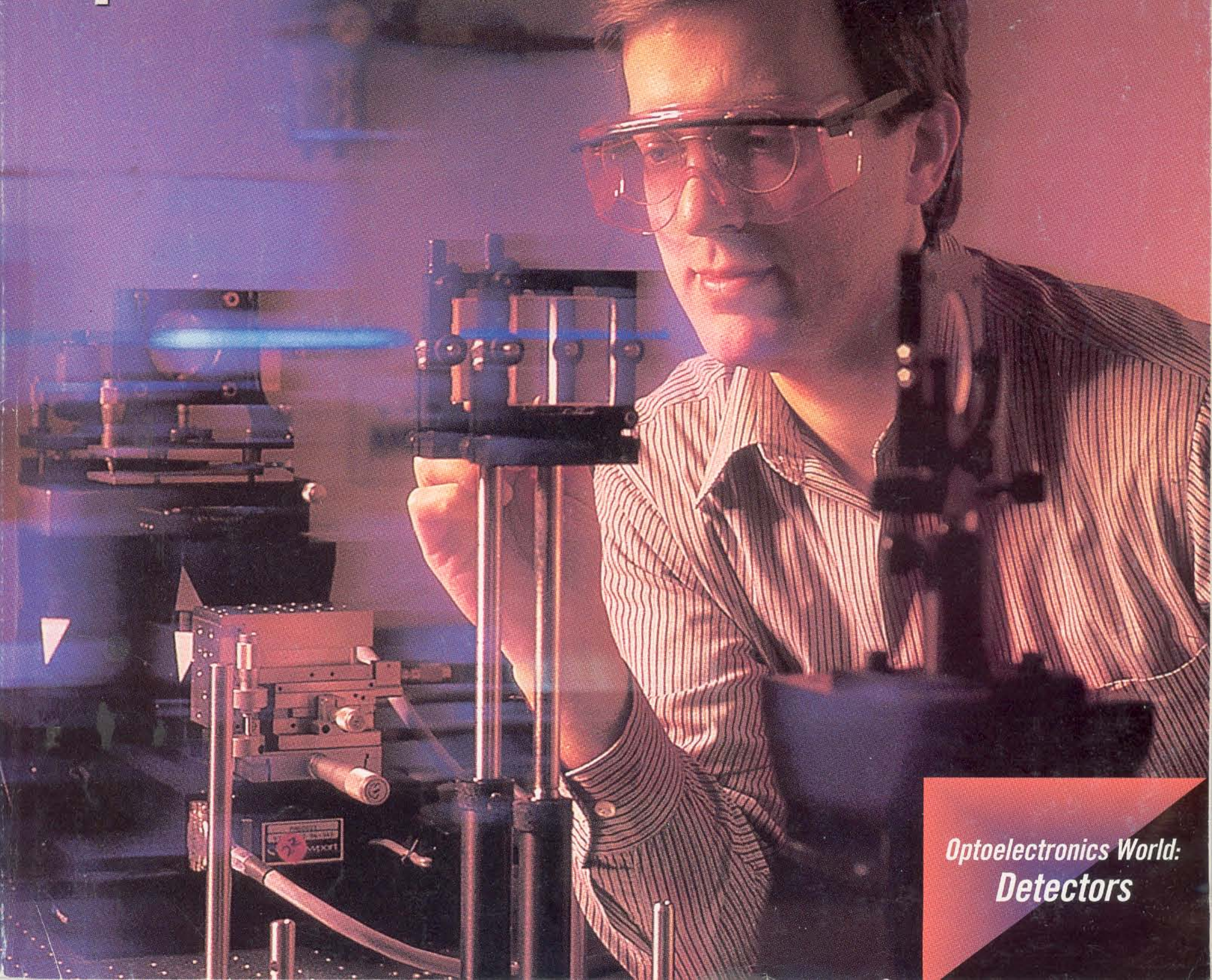

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The hard part is finding solid materials transparent at optical wavelengths that can be made into thin, uniform, durable fibers.

Meeting the manufacturing challenge of optical fiber

Jeff Hecht, Contributing Editor

The fundamental requirements for making optical fibers sound deceptively simple. All that is needed is a suitable transparent material capable of being drawn into thin, durable fibers, each with a uniform core/cladding structure along its length. However meeting these requirements is a challenge.

Few solids are transparent at optical wavelengths, and some, such as salt, sugar, and ice, fail the durability test. Over the years, silica-based glass and plastics have proven to be the best fiber materials, although only highly purified silica is suitable for low-loss communication fibers. These materials are most transparent at wavelengths between about 0.4 and 2 µm. Silica glass is clearest in the near-infrared, with communication windows at 1.3 and 1.55 µm. Plastic fibers are most transparent in the visible and cannot match the low loss of silica-glass fibers. Transmission at wavelengths longer than about 2 µm requires other materials.

Making the transparent fibers thin and uniform is another problem. The usual approach is to heat one end of a cylinder, or *preform,* of suitable material until it softens, then draw the softened material into a thin filament. Glass is ideal, because thick, viscous molten glass quickly solidifies into a fiber as it is stretched in air. Some plastics also work well, but many materials melt to form thin, watery liquids that won't hold together to form thin filaments even when cooled below their melting point. Water is a good example.

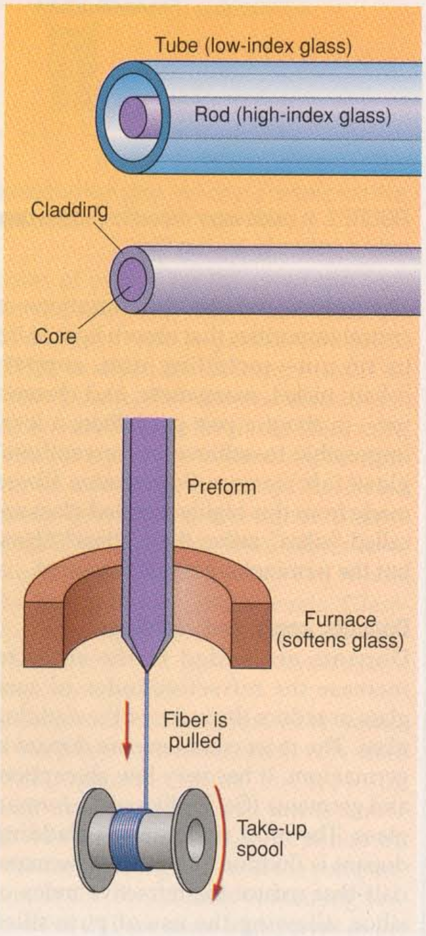

FIGURE 1. A low-index tube is collapsed onto a high-index rod to make a preform, which then is drawn into a clad fiber.

Defining glass

"Glass" is a familiar term with many meanings. From a materials-science standpoint, a glass is a noncrystalline solid with its atoms arranged randomly rather than in a crystalline lattice. A glass resembles a liquid with its atoms frozen in place. Many liquids do not form glasses because they always crystallize when cooled. Even compounds such as silica (SiO_2), which readily forms a glass, may crystallize when cooled slowly.

Most ordinary glasses are based on silica, with other materials added to modify their properties. Calcium oxide (CaO) and sodium oxide (Na_2O) reduce the melting temperature for window glass. Optical glasses contain other compounds to improve their optical uniformity and raise the refractive index above the low value of pure silica, which is 1.45 at 1.0 µm, to values as high as 1.8.

Fabrication of standard optical glasses inevitably leaves traces of impurities such as copper and iron, which absorb some visible light. This absorption raises the attenuation of fibers made from these glasses to about one decibel per meter, which is acceptable for noncommunication applications such as medical endoscopes, but not for communications. Preforms for high-loss step-index multimode fibers can be made simply by inserting a fire-polished rod of high-index core glass inside a tube of lower-index cladding glass and melting the tube so it collapses onto the rod (see Fig. 1).

Communication fibers are made differently. A process called *flame hydrolysis* burns silicon tetrachloride ($SiCl_4$) vapor in an oxy-hydrogen flame to yield extremely pure *fused silica.* Flame hydrolysis generates extremely pure material because the chlorides of troublesome impurities evaporate at temperatures far above the 58°C boiling point of $SiCl_4$ and thus remain in the liquid.