Making low-loss optical fiber demands a different approach
By Bill Schweber, Technical Editor

Perhaps you fooled around during breaks in chemistry lab and pulled a hair-thin fiber strand from a blob of molten glass that you had heated over a Bunsen burner. Making optical fibers in the long lengths needed for communications links should be just a matter of automating that basic and simple process, right?

Wrong. The glass optical fibers that support gigabit-per-second rates over multikilometer distances are much more complex than that basic strand (see sidebar “It’s just glass, isn’t it?”). Making optical fibers consistently, quickly, and with the extraordinary characteristics that allow them to support the data rates and distances that practical links demand mandates new thinking about how to deal with material that has been available for hundreds of years.

You can use several methods to create optical fibers, but three of these methods are dominant: inside vapor deposition, or modified chemical vapor deposition; outside vapor deposition; and vapor axial deposition. Each of these methods involves carefully and precisely building up the glass core and cladding, not just pulling a strand from molten raw material and expecting to get the desired glass fiber.

Regardless of the technique you use, the objective is to make a “preform,” which is a scaled-up version of the final fiber core and its cladding. A machine, appropriately called a “draw tower,” pulls the heated, soft preform through a furnace and out onto a take-up spool in its final form. The draw tower operates vertically, using gravity to its advantage rather than allowing gravity to make the fiber sag. The preform starts at the top and ends as a fiber on the take-up spool at the bottom. During the preform-pulling process, the system precisely monitors the fiber’s diameter. The draw tower also applies a nonoptical, protective plastic coating to the fiber before it winds the fiber onto the take-up spool. A standard 96-in.-diameter spool of single-mode fiber has 12 km (7.5 mi) of fiber, and a spool of the thicker multimode fiber has 2 to 4 km (1.25 to 2.5 mi) of fiber. (Compare those amounts with the amount of coax cable you can fit onto a spool.)

The most common technique, outside vapor deposition, deposits soot on the surface of a rotating ceramic target rod (Figure 1). The soot comprises fine particles of silica ($\text{SiO}_2$) and germania ($\text{GeO}_2$); silicon-tetrachloride ($\text{SiCl}_4$) and germanium-tetrachloride ($\text{GeCl}_4$) vapors form the soot as they react with oxygen in the flame of a burner. The vapor first
deposits the fiber’s core material, then deposits the silica cladding. By adding a dopant, such as germania, into the reaction, you can adjust the refractive index of the core during the process; other dopants control the cladding’s refractive index. You heat the coated tube and then pull out the tube. (The tube has a lower coefficient of thermal expansion, so it separates from its core and cladding coatings during the heat-induced expansion.) As the preform passes through the furnace that is part of the draw-tower pulling system, any water vapor in the deposition evaporates. The preform has a hole in its center where the ceramic rod used to be, which disappears when you draw the preform into the final fiber.

Rather than deposit the soot outside a rod, the inside-vapor-deposition process begins by forming a silicon-dioxide chemical soot inside a fused silica tube that you heat externally. This soot, which becomes the fiber’s core, condenses on the inside of the tube. The silica tube becomes the outer cladding for the fiber. You heat the tube and its internal deposit, and the tube collapses to become the preform for the fiber.

In vapor axial deposition, the vapor deposits the soot on a rod of pure silica, which serves as a seed. The machinery gradually pulls back the seed rod from one end. During this pulling back, the soot on the other end of the seed rod becomes the core, and the soot layers radiating outward become the cladding. Because the pulling back occurs during the active deposition process rather than after it, there is no hole at the fiber’s center that must collapse as the draw tower pulls the preform.

With each technique, you can create thin layers that have different and even graded refractive indices by varying the dopants that you add to the gases as they go into or onto the tube. You need these layers to create step- or graded-index fibers, which have less optical dispersion than fibers that have a single refractive-index glass core and a single refractive-index cladding separated by a sharp discontinuity.

References
2. www.siecor.com, the Web site of Siecor (a joint venture of Corning Inc and Siemens Corp).