Polymer Coatings for Silica Optical Fiber

Introduction:
The success of large core multi-mode silica optical fibers for laser power delivery is partly attributed to availability of reliable polymer coatings that provide properties to meet customer requirements. Besides easy removal of coating and/or jacket for fiber termination, these requirements may include operating temperature, tight bending, abrasion and chemical resistance, and bio-compatibility.

Silica fiber is produced by drawing a mother preform in furnace at ~2000°C. Immediately after it is drawn, the optical fiber is coated with a polymer which prevents mechanical and chemical damage which otherwise could weaken the fiber and compromise its performance. The coating also is a major factor that limits fiber property (e.g. working temperature.) In some fiber designs, a polymer jacket is extruded over initial coating for extra protection. Table 1.0 lists major properties of fiber coated with common polymers, with a brief discussion below.

Acrylate:
Acrylate coatings are applied to large core optical fibers, though they are applied to nearly all telecom fiber for lower cost and ease to coating removal for termination. Two layers of acrylate can be made for reduced micro-bending loss. Typical acrylates have a maximum temperature rating ~80°C. Higher temperature acrylate coatings are also available for up to >150°C.

Silicone:
A silicone coating is tacky and relatively difficult to strip off cleanly. Silicone coated fiber is usually further jacketed. The silicone helps reduce micro-bending loss in cables. Silicone can be used as a cladding, which was common in early days of fibers. Though silicone withstands high temperature (~200°C), the jacket material extruded over silicone coated fiber is often the limiting factor on working temperature.

Hard Optical Polymer:
Hard optical polymer is often used as fiber cladding over silica glass core to form hard polymer clad fiber (HPCF) for low to medium power application. HPCF’s, with 0.37NA or 0.48NA, are more economical and have a larger light collection cone than the typical 0.22NA silica fibers. As each manufacturer often uses its own chemical formulation, one hard polymer clad can have higher chemical resistance than another. Silica core/silica clad fiber is sometimes coated with the hard polymer to form dual clad HPCF for high power application.

It is highly recommended that right after coating process, HPCF be jacketed to protect the thin cladding layer from scratches that damage the optical integrity. ETFE(Tefzel®), Nylon and Teflon® and are common jacket materials. The fluoropolymers are highly chemical inert. Nylon is often selected if a connector needs to be directly glued to jacket. HPCF is rated up to 125°C. It is bio-compatible and widely used in laser surgery.

Polyimide:
Polyimide coated fibers have the widest operating temperature range. They operate at cryogenic temperatures (<-65°C), as high as >=300°C (continuous) and up to 400°C (temporary excursion). Polyimide coatings are thin and epoxy friendly, making the fiber ideal for bundles. Polyimide coated fibers are fairly chemically resistant and bio-friendly. Polyimide is difficult to apply. Cure conditions (time, temperature, ambient humidity, etc) are crucial for achieving a quality coating. It is always a good practice to partner with a fiber manufacturer with extensive experience and a good reputation for polyimide, as with other relevant coatings.

Conclusion:
Polymer coatings give optical fibers mechanical and chemical protection from their surrounding environment. Some common polymers are acrylate, silicone, hard optical polymer, and polyimide. Each of them has its own characteristics and provides properties for optical fiber to meet customer requirements. In-depth coating experience in particular with polyimide is often required to achieve a functional high quality coating. Thus, it is a good idea to partner with an experienced and reputable fiber manufacturer. In addition, to save time and reduce cost in future production, it is highly recommended for system designers to consult the fiber manufacturer early in the design stage.

Table 1.0 Common Polymer Coatings for Silica Optical Fiber

<table>
<thead>
<tr>
<th>Coating Type</th>
<th>Working Temperature</th>
<th>Characteristics</th>
<th>Key Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylate</td>
<td>&lt;=80°C</td>
<td>Easy to remove, not bio-friendly</td>
<td>General use (e.g. instrumentations)</td>
</tr>
<tr>
<td></td>
<td>up to &gt;150°C (for high temp version)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silicone</td>
<td>~200°C but limited by outer jacket polymer</td>
<td>Tacky, not epoxy friendly, removable but with residue, cabled for low micro-bending loss</td>
<td>Usually jacketed for industrial</td>
</tr>
<tr>
<td>Hard Optical</td>
<td>&lt;=125°C</td>
<td>Hard, possible to remove, typically ETFE jacketed bio-friendly</td>
<td>Typically ETFE (Tefzel®) jacketed for medical and industrial</td>
</tr>
<tr>
<td>Polymer</td>
<td>-65°C to 300°C (continuous) up to 400°C (temporary excursion)</td>
<td>Thin, hard, epoxy friendly, bio-friendly</td>
<td>Fiber bundle, Medical, industrial, general use</td>
</tr>
</tbody>
</table>

1. Other common jacket materials include Teflon® and Nylon.
2. Teflon® and Tefzel® are trademarks of DuPont Corporation.