Six Innovative Uses for Polyimide Tubing in Medical Device Applications

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SIX UNEXPECTED USES FOR POLYIMIDE TUBING IN MEDICAL DEVICE APPLICATIONS

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Polyimide has been used in a wide range of microdiameter tubing applications for more than 30 years (see Box 1, Common Applications). However, some of the innovative ways that this exceptionally strong and durable polymer can be used—specifically in catheters and other medical devices used in minimally invasive procedures—might actually surprise medical device engineers.

This white paper will explore 6 such innovative uses for microdiameter polyimide tubing in medical devices, all of which are made possible by a film-coat manufacturing process (see sidebar, page 3).

COMMON APPLICATIONS FOR POLYIMIDE TUBING

- Retention sheath for self-expanding stents
- Inflation lumen for balloons
- Suction lumen for atherectomy devices
- Liner material for lumens containing catheter-steering wires
- Low-diameter guidewire designs or guidewire outer sheaths
- High-temperature or gamma radiation-resistant tubing applications
- Applications requiring high tensile strength, torque transmission, or column stiffness

1. AS A DISCRETE LENGTH POLYIMIDE COATING SLEEVE

For applications that require a discrete length of tubular polyimide coating, specially engineered polyimide tubing offers a possible solution. This sleeve of tubing, which is not fully polymerized, can be reduced in size with the application of heat.

For example, consider a hypotube that needs to be partially coated with polyimide. A section of thermoset polyimide tubing can be engineered to fit the portion of the hypotube that is to be coated. This heat-formable polyimide can then slide over the hypotube like a sleeve. When exposed to a variable temperature profile, the tubing will cure and shrink slightly, effectively covering that portion of the hypotube with polyimide.

Polyimide Coating Sleeve—the inner and outer diameters of which will shrink by 0.003 to 0.005 inches—is ideal for applications such as covering exposed braiding or covering a joint between two pieces. It would also be useful for adding a tip to a product that has been machined to have an inconsistent profile. It is important to note, however, that there is one key limitation: The walls must be at least 0.002 inches thick.

2. IN MICRODIAMETER HYDRAULIC FLUID OR LIQUID DELIVERY LINES

Polyimide is a thermoset polymer. This means that once it is formed, it's solid—it will not remelt or reflow when exposed to a high-temperature environment. It is also very stable, able to withstand exposure to corrosive and acidic chemicals that would typically harden or degrade other thermoplastics. In addition, polyimide tubing that is reinforced with stainless-steel braiding can resist high pressures.

These desirable qualities make polyimide tubing a suitable option for use in lines that convey hydraulic fluid or other liquids. Materials such as mineral oil, aromatic hydrocarbons, and polyalkylene glycols can be delivered safely through lines made from polyimide, which will not fail in high-heat and even nuclear environments. For example, many microrobotic medical tools rely on hydraulics.

3. AS HEAT-EXCHANGE OR COOLING SYSTEM TUBING

Thermal conductivity is paramount in materials used in tubing for heat exchange or cooling systems. As a dense material that conducts heat at a rate of .471 W/m·K, polyimide is ideal for such applications. It also is well suited for particle and fiber compositing, which means that it is possible to extend the thermal conductivity of the tubing beyond polyimide's standard capacity.

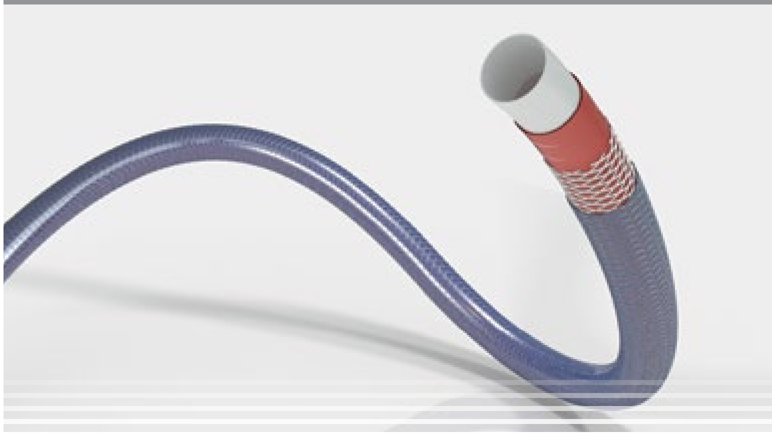
When polyimide is in its liquid, viscous state, it is easy to add particulate materials that augment functionality. In this case, a material such as ceramic or graphitic powder can be added to the polymer matrix, increasing the thermal conductivity level of the tubing by 70% to 90%.

For example, such a polyimide composite would be ideal for surgical tools used for ablation procedures in which heat must be conducted away from tissue that does not need to be treated. Because polyimide can be manufactured with thin walls and small inner diameters, it also can be used to make microdiameter tubing that can be bundled together in a specialized cooling system.

4. IN ELECTROMAGNETICALLY SHIELDED COAXIAL CABLE

Catheter-based ultrasound imaging applications often rely on microdiameter coaxial cables. These cables can benefit from the use of polyimide to provide electromagnetic shielding, thanks to the ease with which polyimide can be composited.

In roughly the same way that graphite powder can be added to the polymer matrix to enhance thermal conductivity, a material that provides electromagnetic shielding, such as powdered silver or copper, can be mixed in with polyimide in its liquid, viscous state. When cured, the composited tubing will act as an electromagnetic shield for the inside conductor.



THE FILM-COAT PROCESS: WHAT MAKES IT ALL POSSIBLE

The film-coat process begins by applying a thin layer of liquid polyimide resin to a solid mandrel. The resin is cured until solid using high-temperature polymerization. The process is then repeated, adding layers of material until the desired tubing wall thickness is achieved.

This film-coat process makes it very easy to customize tubing. Different polymers, filament reinforcements, and particulate material additives can be layered onto the tubing's cross-section. The film-coat process also allows for the manufacture of tubing with much thinner walls and smaller outer diameters (OD)—walls down to 0.0003 inches and ODs down to 0.005 inches—and with more dimensional stability than tubing made via extrusion.

5. TO CREATE A MULTILUMEN SHAFT

Combining several microdiameter tubes together in one bundled, multilumen shaft can take advantage of several polyimide functionalities. For example, a multilumen shaft could include both an electromagnetically shielded tube and one that has been composited with metallic tungsten to become radiopaque, for viewing via X-ray or fluoroscopy, thus giving the shaft dual capabilities.

It is also possible to bundle together several microdiameter tubes that have been manufactured via the film-coat process to create a single shaft with several lumens. Overcoats of nylon or Pebax® can be applied to the tubes being joined; these overcoats are then fused together to bind the tubes to one another. A multilumen shaft that incorporates several polyimide tubes easily could be used in place of typical extruded multilumen shafts in many catheter applications.

6. AS A POLYMER NEEDLE OR PUNCTURE TOOL

With a tensile strength of 20 to 40 Kpsi and a modulus of elasticity ranging from 300 to 500 Kpsi, polyimide is so strong and stiff that it can actually be used to make a tube that will function as a blade-like cutting or puncture tool. A tube with a wall thickness of 0.002 to 0.004 inches could slice through different types of tissue, serving as a polymeric substitution for a conventional metallic blade.

CONCLUSION

Polyimide is a versatile polymer with a wide range of desirable properties that can be used to great effect in many different microdiameter tubing applications. Thanks to the novel film-coat tubing process, medical device engineers can take full advantage of this stable, durable polymer in ways that might not be obvious at first glance.

ABOUT VENTION MEDICAL

Vention Medical is a global integrated solutions partner with more than 30 years of experience in design, engineering, and manufacturing of complex medical devices and components. Vention Medical specializes in components and services used in interventional and minimally invasive surgical products including catheters, balloons, extrusions, polyimide and composite tubing, heat shrink tubing, braid-reinforced shafts, cleanroom injection molding, and finished device assembly and packaging. Visit Vention at ventionmedical.com.

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