Lasers Focus on Tubing

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Medical device manufacturers have realized a number of benefits from the use of polyimide tubing. However, due to the obstacles in fabricating components from it, the challenge lies in successfully manipulating the tubing without negatively impacting the end product. Laser machining enables the creation of higher polyimide tubing component integrity without compromising the end product.

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Laser machining, with its ability to remove or alter material without contact, can successfully customize polyimide tubing where traditional thermal and mechanical techniques fail. Applying laser machining techniques to polyimide tubing accommodates the precise specifications of medical device engineers when they require enhanced functionality of critical tubing components.

Polyimide Tubing

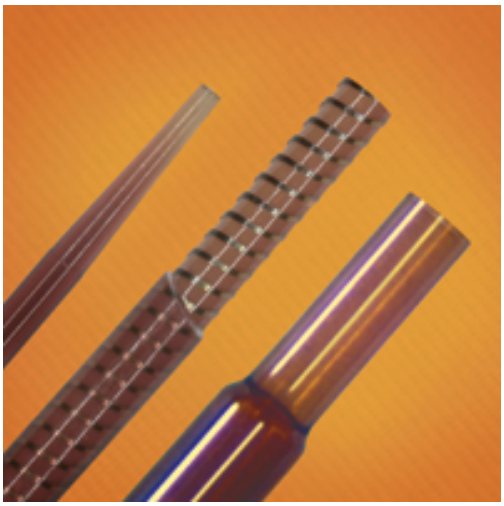
Polyimide is a thermoset polymer made stronger by the introduction of energy (typically heat) in its curing process. Cured polyimide offers very strong mechanical and dielectric properties and provides superior stability when faced with chemical exposure and high temperatures. The thermoset nature of polyimide means that once cured, the material cannot be subsequently reflowed or melted.

Polyimide tubing is constructed by molecularly bonding ultra-thin layers of cured polyimide. The ability to control the number of layers and each layer's thickness allows polyimide-tubing manufacturers to produce products with precise diameters and wall thickness. Such products offer medical device designers tight-tolerance components with superior column strength that transmit directional and torsional

forces.

The benefits of polyimide tubing can be further enhanced by customizing the component with expanded or reduced diameters, flared or tapered tips, cut holes or slots, and even marking or etching for identification. Such customized components can be inserted into smaller proximal orifices, then directed in serpentine ways to the most distal regions of the body to flush or evacuate tissue, and to deploy life-saving apparatus.

Modification Challenges



Thermoset polyimide's stability at high temperatures can challenge attempts to flare or taper the tube with traditional thermoforming techniques. Polyimide tubing also challenges traditional hole-making techniques such as mechanical punching or drilling because the stresses inherent in these methods can compromise the bonds between the tubing's layers and therefore cause delamination.

Even though laser machining polyimide delivers significant advantages, it is not without its challenges. The primary challenge lies in exposing the polyimide to the appropriate energy wavelength and intensity. Poorly executed laser machining can result in burned regions and breaches of the tube's wall.

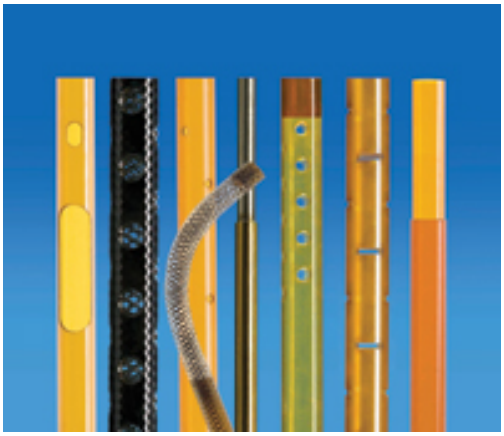
Infrared CO2 Lasers

Infrared CO2 lasers are somewhat common in the industry and are often a first stop on the path of developing processes to machine custom features in polyimide tubing. The great challenge posed by material removal with CO2 is the unwanted presentation of excess heat and energy to the polyimide. A true benefit of the CO2 laser's 9.3 or 10.6 um infrared wavelength is its ability to machine fluoropolymers and silicones as well as polyimide. This ability makes the CO2 laser an appropriate tool when customizing multi-material composite tubing. Such tubing typically has polyimide as its outer layer. When considering CO2, engineers should balance the

CO2's ability to machine all the composite's materials with the CO2's propensity to discolor, char, or melt the exterior polyimide.

Ultraviolet Lasers

Ultraviolet lasers offer a more suitable machining tool for customizing polyimide tubing. Polyimide is known to absorb ultraviolet energy quite well. This absorptive characteristic can be exploited by developing a process that combines the appropriate ultraviolet laser wavelength, laser beam intensity, and scanning speed to achieve true laser ablation. The hallmark of true laser ablation is the clean vaporization of material accomplished by breaking a material's molecular bonds in a precise and controlled manner with laser energy.



Ultraviolet laser wavelengths range from the near UV 364 nm of argon gas-ion lasers to the far UV 193 nm of argon-fluorine gas-excimer lasers. Once the appropriate laser wavelength is selected, the next process task is to generate a desired laser beam. Focus and intensity are the primary attributes of a laser beam. Specific techniques used to generate a proper beam will vary depending on the laser's beam delivery system. Generally, proper focus is achieved by manipulating the beam delivery system's many optics and focal lenses vis-à-vis one another and also in relationship to any imaging mask present in the delivery system.

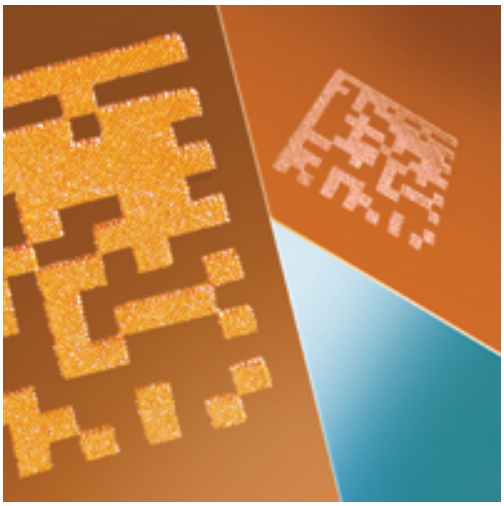
Beam intensity, in a delivery system with an imaging mask, is manipulated by the relative position of the mask and the focal lens. Greater beam intensity can be achieved by distancing the mask and focal lens. Weaker beam intensity can be achieved by bringing these two system elements into closer proximity. Beam intensity in such laser systems can also be manipulated by altering the laser's pulse rate. Lowering a laser's pulse rate will result in greater energy per pulse and greater beam intensity. Increasing a laser's pulse rate has the opposite impact on intensity.

Certain ultraviolet lasers offer what is essentially fixed beam/energy intensity. When working with such lasers, it becomes necessary to finely tune the system's scanning speed to ensure that the polyimide tubing is not exposed to excessive laser energy. These lasers are typically equipped with beam delivery systems based on galvanometer-controlled mirrors that rapidly direct the laser beam to the work site.

Proper scanning speeds are achieved through programming the galvanometer system's software.

Any discord or degradation of these critical process elements will result in polyimide machining that is less than true laser ablation. The telltale signs of such work are delaminated tube layers and rough, discolored edges, all of which can contain debris. This compromises the performance of the polyimide and negates the effort of enhancing the tube with customized features that offer greater functionality to the designers of medical devices.

Advantages of Laser Machining



There is any number of relevant advantages to laser machining polyimide tubing. They include allowing distinct customization of a tubing that is otherwise difficult to modify (in fact, laser machining may be the only solution for certain device designs); providing a flexible and amendable tooling discipline that does not require expensive hard-tooling; and accommodating rapid prototyping, design feasibility, and proof-of-concept services for design engineers. These benefits deliver a definite advantage over some of the industry's alternatives. Yet it takes a certain level of investment to achieve high-quality laser machining skills.

Conclusion

The expertise and equipment necessary to successfully laser machine and customize polyimide tubing requires the allocation of significant human and capital resources. Design engineers who seek an experienced resource that focuses on the pursuit of perfect laser machining, along with the pursuit of profound customer relationships, should be pleased to know that such enterprises do indeed exist. Both the medical device OEM and the polyimide tube component manufacturer stand to benefit by partnering with such an enterprise as a strategic initiative to achieving their goal of marketplace success.

Online

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