Laser Stripping for Medical and Electronics Industry

Automated laser processes increase production efficiency, process control, and product innovation

Many wires and cables used in medical device and electronics applications require stripping outer layers of polymers from small diameter wire, and the laser is well suited for this material removal task. The laser offers tailored removal strategies for wire ends and mid wire sections and windows providing a non-contact process that is very repeatable. The easily automated laser transforms a key step in the manufacturing process providing consistent part quality.

Additional advantages of using lasers rather than chemical-based processes include: safety benefits from eliminating chemical use, reduction of chemical handling and disposal costs, and support for a company's ISO 14001 sustainability program.

LASERS FOR WIRE STRIPPING

In medical device manufacture many cardiac rhythm management, neurological, and radio frequency ablation products require material removal to expose a wire's underlying metal conductor. The diameter of wires used for these devices is constantly decreasing, making other stripping methods simply untenable. At the same time, wire stripping requirements are constantly increasing, with both end-span and mid-span parts requiring selective removal. Similarly, in electronics, size reduction of wires and increasing wire density in cables aligns well with laser wire stripping.

The laser process imparts no physical force on the wire during the process, so delicate wires with diameters as small as 50 microns can be stripped. The material is typically removed by directing a focused beam (around 25 microns in diameter) by galvanometers, which are small fully programmable x and y mirrors. This enables highly tailored removal, so parts or sections of wire insulation can be removed as needed. Changes to the size and location of the removed sections can be made on the fly by calling up pre-programmed recipes.

The material is removed by one of two methods: ablation or cut and peel. The ablation method simply removes all the material from the wire as the polymer absorbs the light energy and is vaporized – effectively ejected away from wire. The laser does not affect the wire beneath the insulation, because the power levels needed to remove the insulation are much lower than those that would damage the metal wire. This advantage can be augmented by selecting a laser wavelength that is readily absorbed by the polymers, but reflected by the wire. With the cut and peel method, a series of helical cuts in the insulation are made that mechanical free the insulation from the wire (not always possible) which is removed post process by automated or manual means – this is typically done where the cycle time is critical and post process material removal is acceptable.

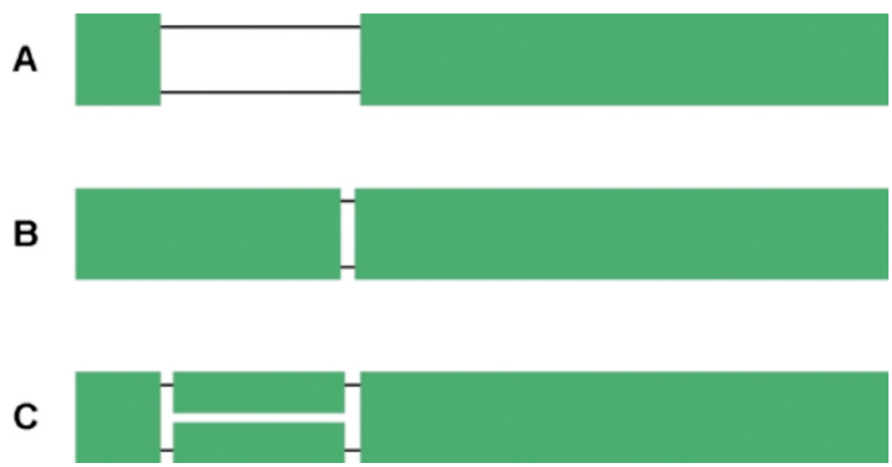

Figure 1 Methods for wire stripping a) material ablation, b) cut and peel end c) cut and peel mid section/window

LASER VS. OTHER A WIRE-STRIPPING METHODS

For wire stripping, the benefits of using the laser's highly controlled direct removal approach must be contrasted with chemical and mechanical processes currently being used.

In the medical device industry due to the relative lower volume compared to electronics, the most common process is manually based that includes dipping each wire individually into a solvent for a certain amount of time, and then manually scraping any remaining coating material deposits with a sharp knife – the X-ACTO method. Quality and repeatability is hardly assured using this process. Moving away from technicians wielding X-ACTO knives to automated pieces of equipment increases production process control, ensures quality, and increases throughput.

For example, one large medical device company recently transitioned from a manual to a laser process for producing stainless steel guidewires used in intravascular interventional devices. The wire, with a diameter similar to that of a human hair, is coated with an organic material that makes it compatible for use in humans. This organic coating material must then be stripped away from the microscopic metal core wire to enable connection to the guidewire's distal end.

The new laser process consistently and precisely strips away the organic material coating from the component's metal core wire, which enables subsequent assembly operations performed to the unit in downstream processes. Far less operator-dependent than the method it replaces, the new process takes only seconds to complete, whereas the previous process took about eight minutes. Throughput rose by 250 percent, with an additional increase in yield.

In electronics, the higher volume of parts dictate automated removal techniques, however the basic premise is that same, either chemical, mechanical or a combination of both can be used. As wire diameters decrease there is less control of insulation removal of these processes with potential issues of damaging the conductor and wire deformation.

PICKING THE RIGHT LASER

A number of different lasers can be used for wire stripping, depending upon the particular wire diameter, insulation material (polyimide, Pebax®, PET (poly ethylene terephthalate), nylon, fluoropolymers, PVC), and feature requirements. **Table 1** shows the lasers most commonly used for wire stripping, listed by suggested order of consideration, from top to bottom. For each combination of material, wire diameter, and required features, there is a suitable laser that matches the desired criteria.

Laser type	Process attributes
Sealed CO_2	Absorbed well by all polymers Absorbed poorly by metals Highly thermal removal process is suited to larger wire diameters
Nanosecond Nd:YVO_4, 532 nm and 355 nm	Absorbed well by most, but not all, polymers Short pulses enable high control of removal Ablation material removal minimizes heat input Well defined edges
Picosecond and femtosecond lasers	Best quality removal and edge definition Cold processing with no heat input Can potentially remove individual layers of coextruded polymers

Table 1 – Selecting the Right Laser for Wire Stripping

The sealed CO_2 laser should always be considered first. With a wavelength of 10604 nanometers (nm), the CO_2 laser is readily absorbed by every polymer, so it will work to a certain degree no matter what insulation material is used. Also, the CO_2 laser is not readily absorbed by metals, so when all the insulation is removed and the laser impinges on the exposed wire, it has little effect for a relatively long time. This allows the completion of the process to the required tolerances on the insulation thickness and provides a large processing window. In addition, the CO_2 laser is the most cost effective in terms of dollars per watt power. **Figure 2** shows a polyimide wire that has been stripped using a CO_2 laser.

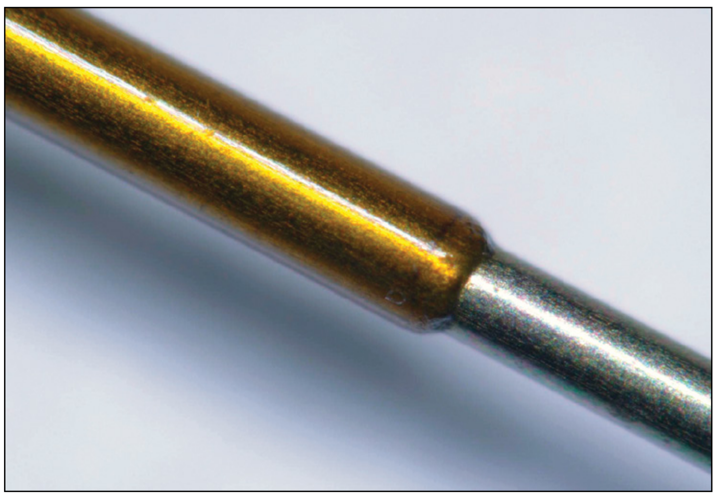

Figure 2 CO_2 laser stripping of polyimide wire insulation

The removal of the material is done more by thermal degradation, so heat input can be an issue if the wire diameter is small. This may result in wire distortion and potential cutting, or the insulation can be overheated, causing discoloration and burr formation. (A burr develops when the material bulges or is raised, and can significantly increase the overall wire outer diameter.)

If a CO_2 laser cannot be used for reasons of heat input control, the nanosecond laser should be considered next, specifically those with 532 nm and 355 nm wavelengths. Nanosecond lasers produce pulses of around 20 nanoseconds, removing wire insulation material with much less thermal interaction than that of the CO_2 laser. It can be used on smaller diameter wires, or where the removal edge must be well-defined with little or no burr. **Figure 3** shows a wire that has been stripped using a nanosecond laser with a wavelength of 355 nm.

The choice between the 532 or 355 nm is typically made based upon the insulation material, with the 355 nm being better absorbed by more polymers. If the CO_2 laser is likened to a large oxyacetylene blow torch, the nanosecond later would be analogous to a smaller, more delicate torch that might be used for finishing off a crème brûlée.

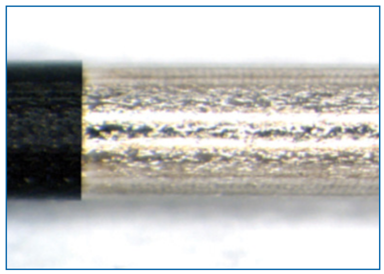

Figure 3 355 nm UV laser wire strip of small gage wire

Note the popular fiber laser operating at 1070 nm is not well absorbed by most of the typical wire insulation materials, and so is rarely used or considered.

When extreme quality or minimal heat input is needed, the options to consider are the ultra-short pulse picosecond and femtosecond lasers. These two laser families produce pulse widths that are extremely short – picoseconds is 10-12 seconds (s) and femtosecond is 10-15 s. The pulses are so short that the material does not have time to conduct any heat from the process area into the surrounding material.

This so-called "cold processing" enables the best quality results, but such a high quality level comes at a steep price. Ultra short pulse lasers cost about 25 times more than CO_2 lasers, and about 5 times that of a 532/355 nm laser. They may be appropriate for very high value products or for those with extremely small wires (50 microns diameter) where very fine control is needed.

LASER WIRE STRIPPING SYSTEMS

In medical device manufacturing, the wires are typically part of a production line. They are not usually processed in reel to reel machines; rather, they are processed in either a manual or automated load machine that handles the wire pieces one at a time at the required length.

Essentially the wire stripper can either rotate the wire or use multiple heads to remove the insulation from the stationary wire. Sometimes the process, rather than the manufacturing environment, dictates which of these techniques is used. As always, the best solution is based on a clear understanding of both the application and production needs.

Figure 4 shows a laser ablation system recently developed by AMADA WELD TECH, which includes high speed galvo beam steering and a custom wire feed and rotating mechanism that achieves accurate and repeatable wire positioning. Also included are several proprietary features needed to manage heat balance in the part during the ablation process; the features facilitate clean removal of the insulation material, while fully protecting the delicate metal wire substrate.

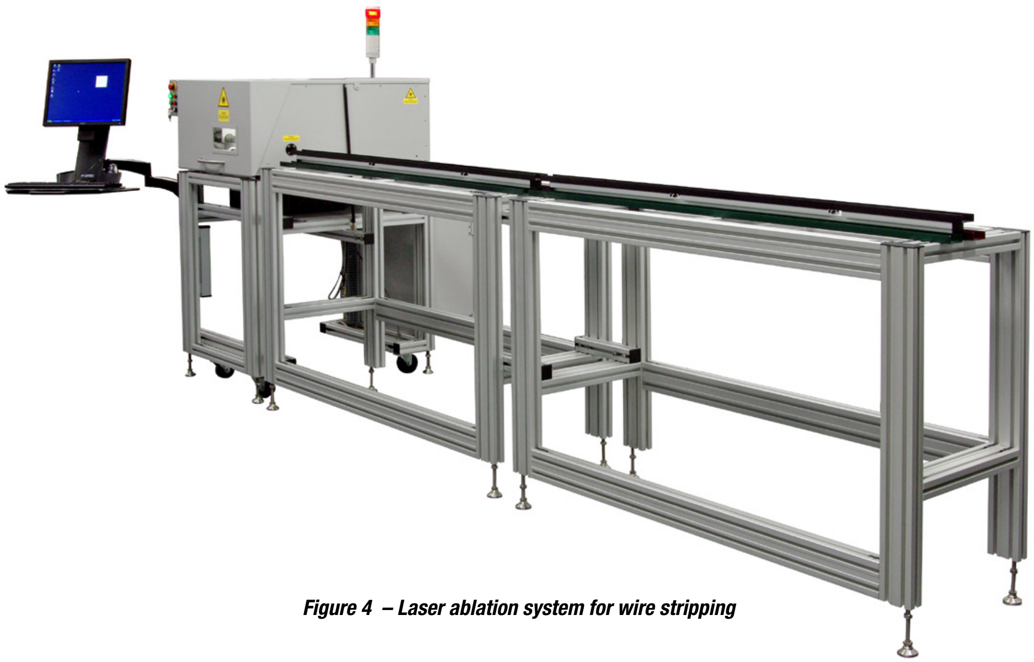

Figure 4 – Laser ablation system for wire stripping

This approach also includes a self-cleaning mechanism that removes sticky debris from the ablation process area that might have contaminated tooling. In effect, the system has a dual cleaning process: the vacuum on the laser itself, along with a high-tech “toothbrush” that mechanically cleans the tooling after every operation. This self-cleaning feature allows tens of thousands of wires to be run with minimal scheduled maintenance.

Use of lasers for wire stripping transforms a key step in the process to a lean operation. The key to the success of wire stripping processes is the development of the process itself. To make the right decision on which laser source and removal methodology works best, it is absolutely essential to test possible options in an application laboratory with a range of lasers. The resulting system solution will then be optimal in both process and implementation.