

Many established marking applications are quite cost sensitive in terms of both capital cost and the cost per mark. As a result, such applications typically make use of Q-switched, diode-pumped, solid-state (DPSS) lasers with nanosecond pulse widths, CO₂ lasers, or fibre lasers. These technologies are available at a reasonable cost and they support fast process throughput rates. Recently, a new class of so-called “high value” marking applications has emerged that require industrial picosecond lasers to provide a precision unattainable with traditional marking lasers.

Benefits of Ultrafast Processing

Laser marking involves either producing a change inside the bulk of the material, a colour change on a surface, a macroscopic change in surface relief (e.g. engraving), or a change in texture that is easily visible. Traditionally, lasers accomplish this through a photothermal process. This creates a heat affected zone (HAZ) which for most laser marked products doesn't present a problem.

However, there are some applications in which even a small HAZ can degrade product functionality or appearance, in which case there are two main routes to minimizing the HAZ: one is to use an ultraviolet laser; the other generally more effective method is to use ultrashort laser pulses of durations in the picosecond domain or shorter. Here, a combination of high peak power and tight focusing creates a very high fluence that drives multi-photon absorption. This process strips electrons from the material, which then explodes away (because of Coulomb repulsion) in a relatively cool process. The short pulse duration means that the ablated material carries away any deposited heat before it can spread. Ultrafast processing thereby delivers a smaller HAZ and greater precision. However, picosecond lasers provide lower material removal rates and are more costly than many other laser sources; they are therefore generally reserved for marking applications that demand the greatest possible precision, quality and minimum HAZ.

There are two main commercial technologies for reliable generation of ultrashort pulses. The first is the q-switched, diode-pumped, solid-state (DPSS) laser, where miniaturising the cavity length can bring pulse widths down into the sub 500 ps range.

High Value Laser Marking



Coherent Rapid series lasers offer <15 ps pulses with average powers of up to 100W. With pulse-on-demand and burst mode operation, they are suitable for processing a wide range of materials, including ceramics, sapphire and glass.

Even shorter pulses are obtained by mode locking a solid-state or fibre laser. The naturally high repetition rate (10's of MHz) is reduced by switching out most of the pulses and the remaining pulse train is sent through one or more amplifiers to reach a sufficiently high level for material removal or transformation to be achieved at a commercially viable rate.

High Value Marking Examples

Precision marking is used in the automotive industry to place bar codes on parts that are expensive and most subject to failure. The marks, which can contain serial numbers or lot numbers, allows the manufacturer to track how changes in their own production processes affect the product lifetime and reliability, therefore helping them refine their methods. In these applications, it is critical that the mark does not affect part performance in any way, and does not become illegible due to part wear in use. These requirements are an excellent match for the capabilities of picosecond laser marking, which can produce marks that involve either a color change or a slight alteration in surface relief, essentially without any HAZ and negligible surface modification.

Another example of high value marking is the production of bar codes and other marks on the sapphire wafers used as substrates in the production of high brightness LEDs. These marks are typically lot numbers and other identifying information placed on the sapphire after the LED structures have been created i.e. after a significant amount of cost has been added to the substrate. The major challenge of this application is to produce easily readable marks without adversely affecting the surrounding circuit structures, which is difficult because



Picosecond lasers can be used to mark sapphire, which is difficult to mark by other means due to its extreme hardness

sapphire is both extremely hard and also transparent at most laser wavelengths.



'Black marking' on an Apple product

Sapphire marking has been performed in the past with nanosecond lasers, but the quality achieved is less than optimal, and can lead to micro-cracks in the substrate. By contrast, the multi-photon absorption process induced by ultrafast pulses works even in materials that are nominally transparent at the laser wavelength. Therefore, a near-infrared output picosecond laser can produce marks in sapphire with excellent surface and edge quality, sharp detail in the marks, and an absence of peripheral damage and re-cast material.

One of the most commercially significant ultrafast marking applications has been so called “black marking”, a technique used to place text and serial numbers on the anodized aluminium cases of some tablet computers. Specifically, the picosecond laser is focused so that its beam waist occurs below the surface of the aluminium; only at this point of focus is the laser intensity high enough to drive multi-photon absorption. The laser creates a microstructure within the aluminium that scatters light and appears black, while the overlying aluminium oxide anodisation layer remains clear and unchanged. The result is a high contrast mark that does not wear off and which is smooth to the touch.

This mark offers two significant advantages that justify its cost. First, the mark is extremely difficult to counterfeit or alter. Second, this mark has a clear and pleasing appearance and feel, which helps the manufacturer to maintain their brand image of high quality and superior styling.

To summarise, there are a number of high-value marking applications for which conventional marking lasers cannot provide a sufficiently small HAZ. Picosecond lasers can provide far superior results that more than justify the higher cost of these lasers.

Dirk Müller and Oliver Haupt
Coherent Inc.

E: Dirk.Mueller@Coherent.com,
Oliver.Haupt@coherent.com

W: www.coherent.com