# *TherMark*™ *Laser Marking*

## PRODUCT IDENTIFICATION IN AUTOMATED MANUFACTURING

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**Abstract**

The primary reasons to identify manufactured parts are to track their progression through the manufacturing cycle, account for associated manufacturing costs, insure that the parts are in the proper location and to be able to provide historical documentation for quality, authenticity and traceability. These requirements are clearly defined in international government and industry regulations as well as manufacturers' marking specifications. Recent land, sea and air disasters, in addition to product recalls related to sub-standard, poorly maintained or counterfeit parts have generated considerable attention to the methodology, by which, part identification information is being applied and controlled. The greatest concerns are how to:

- Collect historical data on part history and utilization
- Develop a means to permanently mark directly on all commonly used materials with a single marking methodology
- Develop a means to automatically capture part identification information to reduce errors in the associated documentation
- Eliminate human error and insure part quality, location and integrity
- Develop a means to identify parts too small or otherwise too difficult to mark
- Reduce material integrity risks associated with direct part marking

A number of different international organizations have united to address these issues and have made significant progress. For example, a manufacturer supplying products to grocery stores is required to use UPC (*Universal Product Code*) bar code symbology. Industry groups such as the UCC (*Uniform Code Council*) and the AIAG (*Automotive Industry Action Group*) have published symbology standards and require mandatory compliance. The forces driving this phenomenon include a cycle of dropping prices, innovations in marking and reading technology and customer demand.

Today ISO9000, the international manufacturing standards, together with many leading industry groups are beginning to mandate *Direct Part Marking* (DPM). The product identification (the human-readable or machine-readable information) must be permanently marked directly on the part surface. These regulations don't say *No More Labels*, but by definition labels aren't permanent. They can get damaged - they can fall off – or worse yet, they can be put on the wrong part. Currently, the average car has more than 200 labels – in 5 years there won't be any. The problem is that companies like 3M and Avery Dennison, who supply these labels, don't know how to quickly and permanently mark directly on the part surface.

### Product Identification Symbology

Recognizing that bar codes have significant limitations in the manufacturing environment and are not always best suited for DPM applications, government and industry groups have tested, accepted and begun to standardize on some machine-readable two-dimensional symbologies. Extensive testing resulted in the selection of the Data Matrix™ symbol for use by NASA and provided proof that 2-D symbologies are reliable and can be applied to most industrial materials without impacting their structural integrity. These NASA findings spurred additional testing by the Department of Defense (DoD) and private industry that have resulted in the selection of the Data Matrix™ symbol for DPM marking by the Automated Identification Manufacturers (AIM) and the American National Standards Institute (ANSI). Additional part marking standards have quickly followed as the automotive, aircraft, electronics, pharmaceutical and semiconductor industries adopted the symbol.

*Figure 1 - The Data Matrix Symbol Can Be Scaled To Fit The Part.*

The use of bar codes and other symbologies of specifically prescribed format, such as the Data Matrix™ code are often objectionable because of their aesthetic effect and/or space requirements on the part. Furthermore, the parts may already have other existing symbologies mandated for distribution or other industry requirements. As an alternative, the use of the Xerox Data Glyph™ technology also allows for small and much less visible or even invisible machine readable code, e.g., at 600 dpi resolution a 14 character data capacity after error correction can be provided in a space only 1/8 inch square which can be merged with or superimposed onto other graphics or images. This proprietary symbology is very useful in anti-counterfeiting and other high security applications due to the fact that the code is not in the public domain and can be keyed and shaped to each individual application.


*Figure 2 - The Xerox Data Glyph Symbol Can Be Shaped To Fit Into A Graphic.*

In contrast, a typical bar code would be more than one inch long and one third inch high to provide 5 characters of data.

*Figure 3 - The Bar Code Requires Considerable Space on the Part.*

**Marking Methodology**

Government and industry have relied heavily on the use of cast, forged or molded-in product information; mechanical engraving; electric pencil; electro-chemical etch; mechanical embossing; hot stamp; rubber ink stamp; stencil and silk screen; vibration-etch, and labels or tags for part identification marking and nomenclature. These marking methods, originally designed to apply human-readable markings, do not provide the high resolution and high contrast required to successfully apply small, high-density machine-readable symbols in modern, automated manufacturing. Their manual operation also added to the large number of data transposition errors associated with paper based manufacturing and identification systems.

Recognizing these weaknesses, the parts identification industry began to refine existing marking methodology so it could be utilized to apply 2-D symbols. The manual metal stamp and mechanical embossing processes were replaced by automated dot peening and engraving machines. Thermal printing methods were developed to replace the electro-chemical etch process, and ink jet printers were built to replace rubber-stamping and pad-printing. While these new methods provided the means to apply variable 2-D symbols directly to products, they did not always provide the combination of permanence, high resolution and high contrast required for machine-readable micro-sized or high data density symbols.

Conventional laser marking systems were developed to satisfy these requirements, but have not been completely accepted in many major industries where surface quality and structural integrity of the part are critical. The principal factors associated with this reluctance are:

- High cost in comparison to other marking methods
- Perceived complexity of operation
- Large size and the need for special utilities and safety equipment
- Quality and structural integrity issues related to the heat affected zone (HAZ) generated in the marking area

In response to these concerns, TherMark Corporation (www.thermark.com) has developed the ***TherMark***™ process, a chemically based, thermally activated, low power laser marking technology which quickly produces permanent marks on virtually all hard surface materials without the normal surface damage associated with laser marking. It does, in fractions of a second, what normally takes minutes or hours in a conventional oven or kiln. It utilizes inexpensive, consumable laser marking materials, readily available and sold as decorative pigments and enamels. These proprietary marking materials are lead and cadmium-free, water based products, which are environmentally friendly and easy to use and clean up.

For an industrial mark to be acceptable in modern, automated, manufacturing it *must* have 4 attributes: *High Resolution* – so it can contain a lot of information. *High Contrast* – so it can easily be seen. It *must* be *Quick* – so it doesn't slow down the manufacturing process and it *must* be *Permanent* – so it will last for the lifetime of the part. At best these other processes have 2, or possibly 3 of these prerequisites. The ***TherMark***™ process is unique, it's the only marking technology that has *ALL* 4 of these attributes and at a penny or less per mark (considerably less in high volume) it is competitive with all of these other marking processes and can be used in conjunction with most existing Nd:YAG and $CO_2$ laser marking systems.

TherMark Corporation has developed the ***TherMarker***™ line of laser marking hardware, the smallest, most compact, most reliable and least expensive laser marking systems available in the industry today. They are controlled by the user-friendly, windows-based *ProLase* software package. These easy-to-use, portable laser marking systems are now being sold with prices starting at less than $40,000. TherMark Corporation and other laser marker manufacturers have incorporated test-marking programs into their software to speed the selection of optimum marking parameters that can be stored in a settings library for future selection. These actions have helped to close the gap between lasers and many of the other marking systems developed for use in industry; however, the perception still persists that laser marking may damage the part and is not safe in material critical applications.

**Quality Issues Associated With Various Laser Marking Technologies**

TherMark Corporation is addressing the quality and material science issues associated with laser marking in cooperation with its strategic partners. This group has studied laser marking with representatives from many major industries and noted a general lack of understanding of the various types laser marking processes. The group also noted a general belief by most engineers that conventional laser markings, produced by concentrating high power laser energy onto a small surface area and creating high temperatures, reduces material properties to an unacceptable level. This belief stems from observations of the heat damage

(HAZ) on the surface and material test reports that describe the propagation of cracks emanating from melted regions on the surface. While conventional lasers do mark using high power laser energy to alter or ablate the substrate surface, it is not necessary to use these high power lasers or to melt the substrate surface to produce machine-readable markings with the ***TherMark***™ process, which typically uses only 3–5 watts of continuous wave laser power. The computer software and electronic controls available today to the laser marker operator provide high quality, minimal surface damage and reproducibility in the laser marks.

The following paragraphs address the various methods used to laser mark parts and their general effects on the substrate material:

### *Laser Coloring*

Laser coloration is a process used to discolor *some* metallic substrate materials without burning, melting, or vaporizing the material. This is done by passing a relatively low power laser beam across the surface at slow speed to discolor the area of the mark. This laser marking method produces a high-quality, high-contrast marking that does not disrupt the surface. The process, however, does not work with all materials and can have an adverse affect on materials that have been previously heat-treated and can reduce the corrosion resistant properties of some stainless steel alloys. Properly applied laser coloration markings cannot be felt on a smooth surface when rubbed with the finger and appear smooth when viewed under low (10X) magnification. The laser coloring process is not recommended for parts thinner than 0.10”.

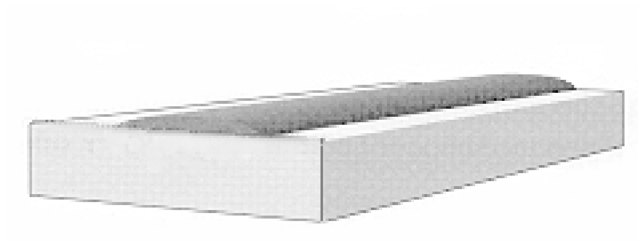

*Figure 4 – Marking Applied To A Surface Using the Laser Coloration Process*

### *Laser Etching*

Laser etching is similar to laser coloring except that the heat applied to the surface is increased to a level that causes substrate surface melting. It is only applicable to certain metals, metallic coated surfaces and some plastics. The advantage to using this technique over laser coloring is increased marking speed since the process needs less depth than is required to color metallic substrates. Excellent results can be routinely obtained at penetration depths of less than 0.001-inch. This technique, however, should not be used on some metals where material integrity is critical to the part because cracks produced in the molten metal during cooling can propagate into the underlying surface material. These cracks can expand downward if the part is stressed and/or after repeated temperature cycling. These conditions have led to metal fatigue and part failures.

Laser etched marking can generally be felt when rubbed with a finger and may have a corn row appearance when viewed under low (10X) magnification. Laser etching is not recommended for parts thinner than 0.050”.

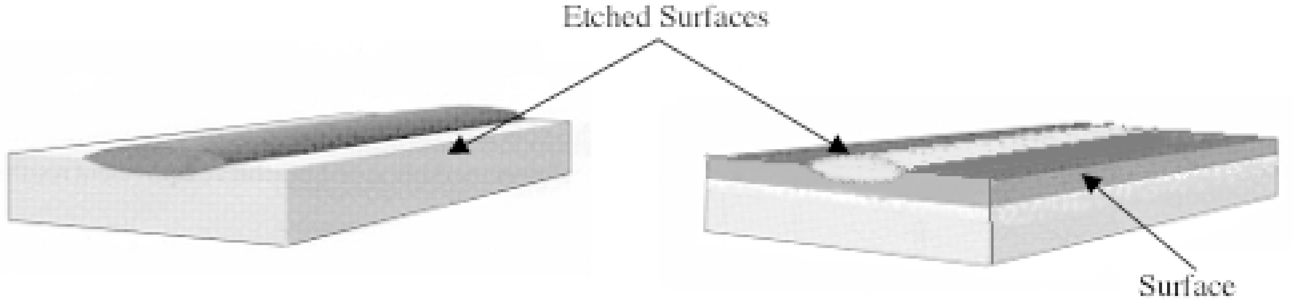


*Figure 5 – Laser Etching Applied Directly To The Surface* *Figure 6 – Laser Etching Applied To A Surface Coating*

### *Laser Engraving*

Laser engraving involves more heat than laser etching and results in the removal of substrate material through vaporization. This technique produces a deep light marking similar to a deep electro-chemical etch marking. The high contrast obtained by laser coloring or etching cannot be obtained by laser engraving because the discolored material is vaporized and ejected during the marking process. Although this method appears to be the most aggressive laser marking technique, it generally produces less damage to the substrate than laser etching; however, because most of the structural strength of materials is in the integrity of their surface and because it can produce micro cracking in some materials, its use in material critical applications should be studied by a metallurgist prior to use. Like laser etching, direct laser engraving can be easily determined by touch and low power microscope (10X) magnification. Laser engraving is not recommended for use on parts thinner than 0.10".

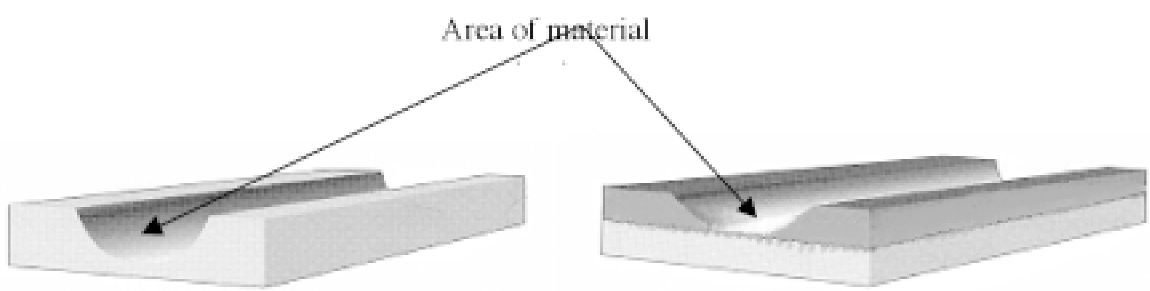


*Figure 7 – Laser Engraving Applied Directly* *Figure 8 – Laser Engraving Applied To Coating*

### *Laser Bonding – TherMark™ Process*

Laser bonding is an additive process that involves the bonding of proprietary laser marking materials to the substrate surface using the heat generated by Nd:YAG, $YVO_4$, $CO_2$ or fiber lasers. These proprietary laser marking materials generally consist of glass frit powders or metal oxides, nitrites or carbonates mixed with inorganic pigments and a liquid carrier (usually water based) similar to the materials used to porcelainize pots, pans and cast iron sinks. These materials can be painted or sprayed directly onto the surface to be marked, or applied via pad or ink jet printer. Self-adhesive tapes and labels may also be used in a dry transfer version of the marking process. Laser bonding is accomplished using relatively low laser power levels that have no measurable detrimental effect on metal or glass substrates and are safe for use in material critical applications.

The ***TherMark***™ process is capable of quickly producing high resolution, high contrast, permanent marks on virtually all hard surface materials without destroying the protective characteristics of surface coatings such as anodize, chromate and plating. The ***TherMark***™ process can be used with any thickness material and will not create any HAZ or cause the surface or structural damage usually associated with conventional laser marking. The marks produced using the ***TherMark***™ process are resistant to high temperature, are unaffected by salt spray and are extremely resistant to both mechanical wear and chemical abrasion.

The ***TherMark***™ process fuses proprietary, enhanced contrast and/or colored laser marking materials to the surface of various glass, ceramic, porcelain, metal and plastic substrates using Nd:YAG, $YVO_4$, $CO_2$ or fiber lasers. The wavelength ($\lambda$) and output power (joules/cm2) of the laser source are determined by the combination of the composition of the substrate material and the specific marking material to be applied. These marking materials make it possible to produce images with varying optical properties including, but not limited to, contrast, color, reflectance, diffraction; and varying physical properties including, but not limited to, thickness, durability, structural shape and electrical conductivity. Like laser etching and engraving, the ***TherMark***™ process can be easily determined by touch and low power microscope (10X) magnification.

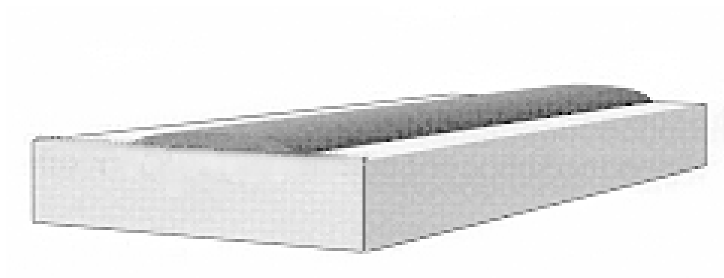

*Figure 9 – TherMark™ Laser Marking Material Bonded To The Surface*

**Summary**

The ***TherMark***™ process of permanently marking materials will be especially useful in marking glass, ceramic, porcelain and other brittle materials whose surface structure can not withstand the thermal shock of conventional laser marking methods and for very hard metal surfaces that resist other marking techniques. On all substrate materials, the resulting image has enhanced contrast and/or color, which produces a symbol or mark more easily viewed and imaged by the human eye and/or machine vision equipment.

*Direct Part Marking* (DPM) is used when a part must be marked permanently. Labels can be damaged or removed; by contrast, DPM makes the symbol or mark a permanent "*part of the part*", allowing reliable tracking all the way from manufacture to retirement.