

# Advanced Laser Marking

**The design potential of laser markable Celcon® acetal copolymer opens new prospects in industry**

For design engineers, decorating, labeling, marking, or coding parts molded in durable acetal resins has been a challenge. It is extremely difficult, for example, to padprint on acetal resins without surface treatments and the use of harsh chemicals. Even if the ink adheres to the plastic, the printed markings can be smudged or removed easily in use.

Laser etching of an unmodified plastic creates indelible markings, but these markings are typically only faint symbols with poor background contrast. Additives compounded into engineering resins may enhance laser markings, but at the expense of mechanical properties. To optimize laser marking of acetals, Hoechst Technical Polymers (HTP) in Summit, NJ, teamed up with laser marker manufacturer Rofin-Baasel Inc., The

Sabreen Group in Plano, Texas. Their cooperative effort integrates resins, additives, lasers, and software for better marking results while preserving all material properties. HTP has introduced two laser-markable grades of Celcon® acetal copolymer for general purpose and UV-stabilized applications, and has multiple colors under development.

This new systems approach to laser marking promises part designers indelible, high-contrast alphanumeric and graphics without sacrificing the material properties of the base resin. It can also generate significant savings per part compared with conventional printing and labeling. While brand names, logos, and functional markings can be made more visible with laser marking, the need for permanent identifying data on plastic parts is far wider than the need for decoration.

Most parts molded in acetal copolymer are in hidden applications where long-term chemical resistance, dimensional stability, and strength are important. However, global assembly and distribution make it important that such parts be identifiable and traceable.



**Figure 1. Laser-marked fuel tank and trunk release levers molded in Celcon LM90Z retain their color and strength despite long-term exposure to sunlight, and bear high-contrast markings which will not wear off despite years of use.**

## Lighting Up

While lasers have been used for decades to label metal parts, using coherent light to mark plastics is relatively new. It has attracted extra attention in the last five years as engineering resins, including acetal copolymer, replace metals in more demanding applications. Laser-marking plastics nevertheless requires different techniques than those used to mark metals. It also requires an approach tailored to the specific plastic. Because of the polymers' inherent laser absorption properties, ABS

**Figure 2. High-resolution, high-contrast markings can be etched by industrial lasers in parts molded in Celcon LM90 and LM90Z acetal copolymer.**



and polycarbonate, for example, naturally produce relatively high-contrast markings. Higher-performance engineering resins such as acetal copolymer, branched PPS, and some nylons, however, have proven more difficult to mark.

Acetal copolymer has long been the plastic of choice for moldings requiring strength, precision, and appearance. It offers designers high strength, chemical resistance, and thermal and moisture stability, and UV stability as well.

Laser-markable Celcon® LM90 and LM90Z can now give automotive designers trunk release levers or radio buttons with functional symbols unaffected by wear and sunlight. They can offer designers of business equipment gears, or other parts the capability to etch with high-density 2-D data matrix symbology, thus providing traceability of components. Laser-markable acetal copolymer enables designers to put permanent, engraved logos or functional symbols on appliances and consumer electronics. It can give industrial designers wear- and chemical-resistant parts coded with permanent identifying numbers. With carefully formulated additives, the properties of the basic polymer remain unchanged. Unlike faint laser markings on ordinary acetals, data laser-etched into the new optimized resins stands out as sharp,

white symbols on black or other dark backgrounds.

### Break From Printing

Two-shot color molding has been used historically to code or decorate plastic parts, but only at a high price. Pressure-sensitive adhesive labels can be produced efficiently but do not adhere well to plastics, especially in underhood applications. More common methods for marking plastics include ink pad and ink jet printing, ink filling, sublimation printing, embossing, and hot stamping. Printing inks can indeed produce high-quality, high-opacity characters on some plastic parts. However, all

these printing processes share shortcomings.

Codings printed on non-porous, chemically resistant engineering plastics are rarely permanent. Like stick-on decals, they have relatively poor scratch, wear, and solvent resistance. Corona discharge and flame plasma treatments are potential solutions to common ink adhesion and durability problems. Although these processes are reasonably safe and more environmentally-friendly than chemical treatments, they can be expensive to implement. Printing processes which require contact with the part's surface risk smudged or illegible markings. With printing dies or

transfer pads required for each new label or design, traditional printing techniques make changeovers for short part runs complicated and expensive. They impose continuing material costs in inks, screens, and other consumables.

Ink-jet printing processes produce dot matrix characters. However, ink-jet printing typically does not yield robust results on plastics such as acetals, especially with environmentally safe alcohol-based inks. Ink-jet processes also introduce variability and require significant levels of preventive maintenance. Likewise, hot stamping is not always compatible with high-temperature engineering

Table 1 — Cost Comparison of Ink Marking Versus Nd:YAG Laser Marking<sup>1</sup>

	<u>Pad Printing</u>	<u>Nd:YAG Laser Marking</u>
	<u>Direct Costs</u>	
Capital Equipment <sup>2</sup>	\$80,000	\$60,000 to \$120,000
Annual Consumables <sup>3</sup>	\$25,000 to \$45,000	\$6,500 or less
Annual Plate Costs	\$175,000 to \$250,000	\$0
Intangible Costs <sup>4</sup>		

<sup>1</sup>This comparison assumes a lot size of 50 to 100 pieces and up to 100 different setups per day.

<sup>2</sup>These costs encompass a high-end pad printer and a laser platemaker-computer combination for pad printing. They do not include ancillary equipment often needed with pad printing, such as rotary turntables. On the laser marker side, the capital cost encompasses a complete turnkey system.

<sup>3</sup>The costs for pad printing do not include electricity and water. The estimated costs of these items in a laser system is about 75 cents per hour (depending on local electricity and water rates). With three working shifts operating 365 days per year, these consumables total \$6,570.

<sup>4</sup>The user of laser systems avoids a variety of intangible costs associated with pad printing. These difficult-to-quantify intangible costs include:

- Ordering, receiving, inspecting, storing and handling ink, solvents, and other materials,
- Removing hazardous wastes,
- Setup/change-over time,
- Added assembly operation,
- Inspection of prints, and
- Scrap parts due to smudged or illegible print/decoration.

Table 2 — Properties of Celcon® LM90 and LM90Z

Properties	Test Method	Units	LM90	LM90Z
<b>Physical Properties</b>				
Specific Gravity	ISO 1183	g/cm <sup>3</sup>	1.41	1.41
Shrinkage (Flow)	ISO 294-4	mm/mm	0.022	0.022
Shrinkage (Transverse)	ISO 294-4	mm/mm	0.018	0.018
<b>Mechanical Properties</b>				
Tensile Strength	ISO 527	MPa	66	63
Flexural Modulus	ISO 178	MPa	2600	2650
Izod Impact Strength	ISO 180/1A	kJ/m <sup>2</sup> (notched)	5.7	5.9
<b>Thermal Properties</b>				
Melting Point	ISO 3146	°C	65	165
Coeff. of Linear	ISO 3167	1/°C	6	6
<b>Expansion</b>				
DTUL at 1.80 MPa	ISO 75-2/Af	°C (x10 <sup>-3</sup> )	105	98
Melt Flow Rate	ISO 1133	g/10 min	9.0	9.0

thermo-plastics and the service conditions for which those parts are intended.

In contrast to printing, laser marking produces crisp, indelible characters or graphics without contacting plastic parts and without inks or paints. It requires no pre- or post-treating of the parts and needs no solvents, inks dies, or transfer pads. The only consumables are electricity and water. Extremely sharp markings can be positioned accurately on curved or irregular surfaces, unaffected by surface moisture. In a 6-inch-diameter marking zone, repeatability is typically  $\pm 0.001$  in.

## Powerful Light

Lasers can etch parts quickly with enormous amounts of data. Nd:YAG, CO<sub>2</sub> and excimer laser markers come in a variety of configurations. The new

laser beam can be projected through a mask and/or steered by galvanometers, then focused onto the workpiece. The Nd:YAG lasers can be continuous-wave, Q-switched or pulsed. The CO<sub>2</sub> and the excimer lasers can be pulsed or modulated dot-matrixed systems. For example, Rofin-Baasel's standard StarMark® series laser marking systems can produce characters as small as 0.010" high. It can be configured with mark areas up to 6"x18" in size (Dual Head configuration) and works at speeds up to 100 linear inches/minute.

For laser light to engrave plastic, energy from the beam must be absorbed to generate heat. Substrates too reflective for a given laser wavelength can sometimes be marked by adjusting the power,

pulse rate, or surface velocity of the moving beam. Nd:YAG lasers are the most common in industry and the type preferred to etch high-contrast marks in dark substrates. They operate at either the fundamental wavelength or the frequency-doubled wavelength (1064 or 532 nm, respectively). Many plastics absorb laser energy readily at 1064 nm; in other cases, the frequency-doubled wavelength is used to improve the quality of the markings. Rofin-Baasel Inc. mentioned earlier, markets a variety of marking systems under the StarMark® trade name; a 40W, air-cooled Nd:YAG system for marking, and 65, 90, 100 and 150 watt liquid-cooled systems for marking and limited thin film cutting applications.

Other industrial laser

marking systems include carbon dioxide lasers operating at 10.6  $\mu\text{m}$  and ultraviolet excimer lasers operating at several discrete wavelengths ranging from 193 to 351 nm.

## Laser Formulations

The new acetal copolymer grades formulated by HTP are intended specifically for the Nd:YAG laser, but they can be used with carbon dioxide and excimer laser equipment. The Nd:YAG laser creates a mark by melting and foaming the surface of the polymer. The thermochemical reaction leaves bright white marks etched about 40  $\mu\text{m}$  into a black substrate. By adjusting frequency and power, the amount of foaming can be controlled, so the color of the marks can be made darker. Unlike unmodified acetals, laser-markable Celcon LM90 and LM90Z were formulated to enhance contrast, with extremely white marks on a black part.

Mica and other additives are available to enhance the laser marking contrast of resins. However, they tend to detract from the long-term mechanical properties and color matches of the base resin. The laser marking additive package developed for Celcon LM90 preserves the easy molding characteristics and predictable long-term properties of general-purpose Celcon M90. Celcon LM90Z is an ultraviolet-stabilized grade



**Figure 4.** For the first time, GECOM Corp. can laser mark the symbols on trunk and fuel door release levers by virtue of the first high-performance plastic that can accept laser marking.

based on Celcon UV90Z, itself formulated to satisfy auto industry UV standards. Like Celcon UV90Z, the new laser-markable acetal copolymer is cleared to 1,240.8 kJ/m<sup>2</sup> with a DE (color change) of less than 3 CIE Lab units.

In one prototype application, laser-markable Celcon acetal copolymer gave an automotive supplier a radio faceplate with bright, white numbers and symbols engraved in black push buttons. The white characters were etched into the black surface in a single operation. Prior to the use of laser etching with laser-markable Celcon resins, white contrast color on a part was applied by hypodermic needle onto an etched surface. The part

was then wiped clean by hand. Acetal copolymer can provide a far better nonstick action for the buttons and UV resistance than that of ABS. Laser marking created significant labor savings and more durable marks. Initially, Celcon LM90 and LM90Z were formulated to produce high-contrast white marks on a black substrate. However, using a Nd:YAG laser one can now produce light blue marks on a dark blue part. Potentially, the Nd:YAG laser can mark in other similar color combinations.

### Payback Potential

Tied into a computer-integrated manufacturing system, laser marking hardware and software offer unparalleled efficiency and flexibility. Marking lasers communicate through standard serial ports. They can operate with MRPII systems which control the entire production process from order entry. Instructions can be downloaded to the laser from standard databases or computer-aided design packages. Changing an image or data takes less than a minute, which is especially important in high-volume, small-batch production with frequent code changes.

Laser marking systems provide the designer and manufacturing engineer with flexibility and economy. For example, the standard Rofin-Baasel system has a work area of 64 square inches and is compatible with a range of automated part handlers to extend its reach. Marking lasers need no drying tunnels or supplemental equipment associated with printing, and they eliminate many of the costs associated with printing processes. The differences in capital expenditures, savings in consumables, increases in productivity, and subsequent scrap reduction mean a

turnkey laser system can typically pay for itself in one year or less (see Table 1).

The savings per part naturally vary with production rates and lot sizes, but for designers, the introduction of laser-markable Celcon acetal copolymers opens new opportunities.

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**Figure 3.** Computer-programmable lasers such as the StarMark® / UW-180 laser marking system from Rofin-Baasel speed changes in and reduce the cost of marking plastic parts.

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