

Processing Plastics with CO₂ Lasers
Synrad Applications Lab

(Version 1.03)

Types of Laser Interactions with Plastics

There are 3 main types of material interactions when hit by the CO₂ laser beam:

- **Vaporization**

- The material vaporizes into gas residue which is blown out when cut. This is the cleanest cutting / marking process.

- **Melt Sharing**

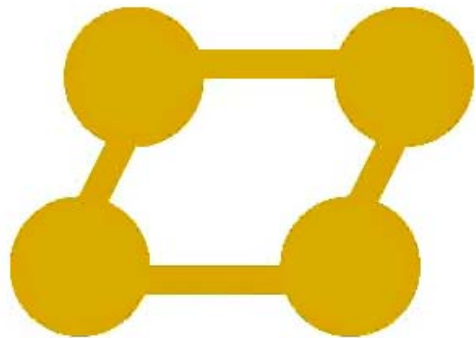
- The material melts into molten droplets which are blown out when cut. There is typically some melt-back

- **Chemical Degradation**

- The plastic material chemically degrades typically releasing carbon smoke. The material chars and has soot residue

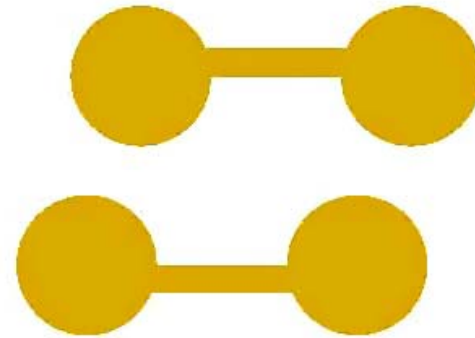
Types of Plastic

There are two main types of commonly used plastics. It is important to distinguish between these two types as they have very different cutting and marking characteristics:



THERMOSETS

&



THERMOPLASTICS

Types of Plastics - Thermosets

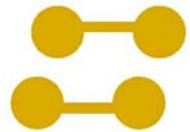


Thermosets

These plastics' polymer chains have more connections and break down easily when heated. Thus, these plastics can not be successfully melted without damaging the molecular structure and the material changing color. Laser processing is primarily accomplished by chemical degradation.

Consequently, there is discoloration and charring. These plastics typically cut and weld very poorly because of this but generally provide high contrast marks with some slight residue on the surface.

Types of Plastics - Thermoplastics



Thermoplastics

These plastics' polymer chains are simpler and have less bonding connections. Thus, the plastics can be melted easily without the polymer chains breaking down. Laser cutting is primarily accomplished by melt shearing. Marking is accomplished by melting the surface of the plastic to provide a slightly engraved mark. Since there is usually no material color change, the laser cuts are much better quality but conversely the laser marks have much lower visibility.

Types of Plastics - Examples

Common plastics of each type include:

Thermosets:

- Rubber based products
 - Polyimide
 - Epoxy Resins
 - FR2/FR4

Thermoplastics:

- Polypropylene
- Polyethylene
- Polystyrene
 - Nylon
 - ABS*
- Polycarbonate*
- PVC*

* Exhibits atypical behavior for a thermoplastic

Types of Plastic - Exceptions

The following thermoplastics experience chemical degradation as well:

- **ABS**
 - Moderate Discoloration when cut; No color changes when marked.
- **Polycarbonate**
 - Brown/Yellow charring.
- **PVC**
 - Brown/Yellow charring.
- **Plastics which are glass filled**
 - Glass-filled plastics typically will have black/brown color changes while the same unfilled plastic will not. A good example of this is Nylon.

Summary Table of Plastic Types (page 1)

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
ABS		Thermoplastic	■ Poor-Fair: Slight discoloration of cut edge	■ Poor-Fair: Slightly engraved marks	■ No	
Acrylic (Cast)	PMMA Plexiglas	Thermoplastic	■ Excellent: Clean vaporization with fire polished edge	■ Good: Frosted white mark	■ Sometimes: Depends on background color	
Bakelite		Thermoset	■ Poor: Some Charring	■ Good: Low power: White marks; High power: Charred engraved marks	■ Sometimes: Depends on background color	
Fluoro-polymers	PTFE, Teflon, EFTE	Thermoplastic	■ Good: Some melt	■ Fair-Good: Clean engraved marks	■ No	
FR4/FR2	PCB	Thermoset	■ Poor: Brown Charring; sometimes degating is successful	■ Good: Dark marks on uncoated surface; Light marks on solder masks	■ Yes	
Nylon		Thermoplastic	■ Good: Moderate melt	■ Fair-Good: Engraved marks with some melt-back	■ No	
Nylon (Glass Filled)			■ Fair-good: Some discoloration of cut edge;	■ Good: Dark marks	■ Yes	
Polycarbonate	Lexan, Calibre, Makrolon, Panlite, Makrolife	Thermoplastic	■ Poor: Brown Charring;	■ Good: Low Power: White/Transparent Mark. High Power: Brown/Yellow marks	■ Yes	Thick smoke when cut
Polyester	Mylar, PET, PETE, PETG	Thermoplastic	■ Good: Some melt; PETG needs high assist gas pressure ~60psi	■ Fair-Good: Engraved marks with some melt-back	■ Sometimes: Depends on background color	

Summary Table of Plastic Types (page 2)

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Polyethylene	HPDE, MDPE, LDPE, UHMW	Thermoplastic	■ Fair-good: Moderate to large melt	■ Fair-good: Engraved marks with melt-back	■ No	
Polyimide	Kapton	Thermoset	■ Poor: Brown/Black Charring	■ Fair-good: Dark marks with some soot residue	■ Yes	
Polyoxymethylene	POM, Delrin, Polyacetal	Thermoplastic	■ Good: Some melt	■ Fair-good: Clean engraved marks	■ No	Formaldehyde gas
Polypropylene		Thermoplastic	■ Good: Some melt; Sometimes slight discoloration	■ Fair-good: Deep engraved marks & slight melt-back	■ Sometimes: (2D codes)	
Polystyrene		Thermoplastic	■ Fair-good: Moderate melt & residue	■ Fair-good: Engraved marks with some melt-back	■ No	
Polysulfone		Thermoplastic	■ Fair-good: Moderate melt & residue	■ Fair-good: Engraved marks with melt-back; Wet residue	■ No	
Polyurethane			■ Fair-good: Moderate melt & residue	■ Poor-Fair: Slightly engraved marks	■ No	HCN GAS
PVC	Vinyl	Thermoplastic	■ Poor: Brown/yellow charring; VERY HAZARDOUS out-gassing	■ Good: Brown/Yellow marks; Some residue	■ Yes	HCL GAS: DO NOT CUT!
Rubber		Thermoset	■ Good: Vaporizes with some residue	■ Good: Deep engraved marks with some residue	■ Sometimes: (2D codes)	Dense sooty smoke.

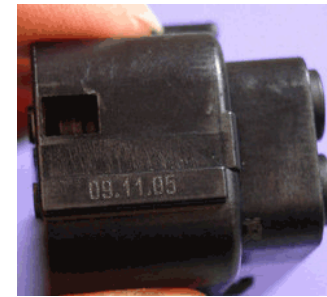
ABS

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
ABS	-	Thermoplastic	■ Poor-Fair: Slight discoloration of cut edge	■ Poor-Fair: Slightly engraved marks	■ No	-

Cutting Example



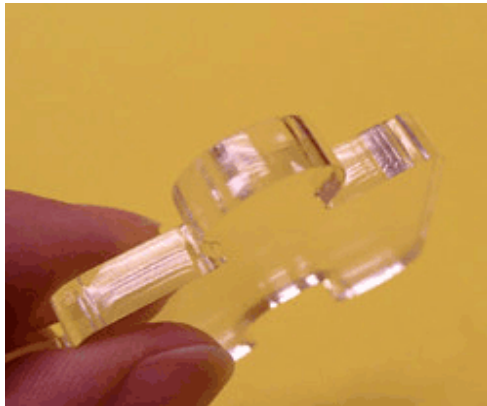
Marking Example



Acrylic

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Acrylic (Cast)	PMMA Plexiglas	Thermoplastic	■ Excellent: Clean vaporization with fire polished edge	■ Good: Frosted white mark	■ Sometimes: Depends on background color	-

Cutting Example



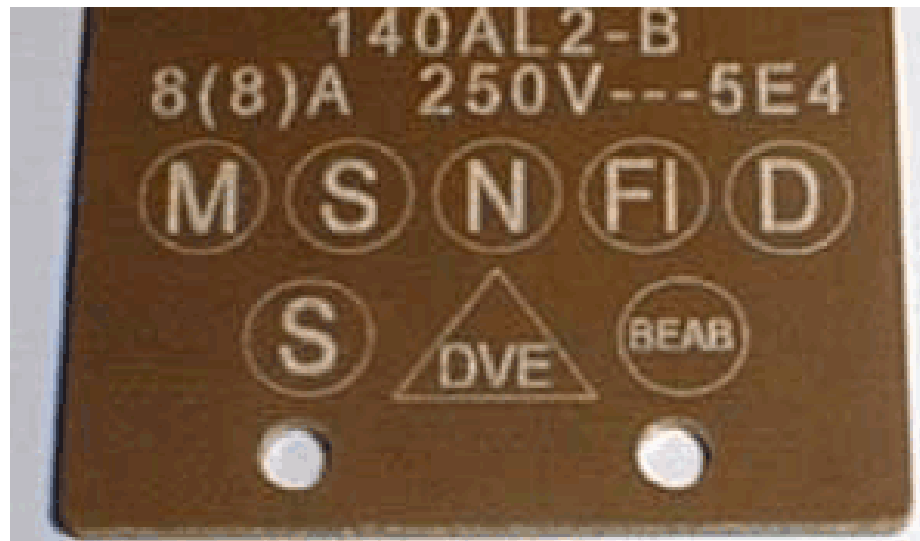
Marking Example



Bakelite

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Bakelite	-	Thermoset	■ Poor: Some Charring	■ Good: Low power: White marks; High power: Charred engraved marks	■ Sometimes: Depends on background color	-

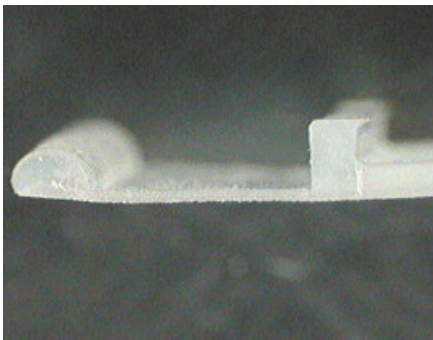
Marking Example



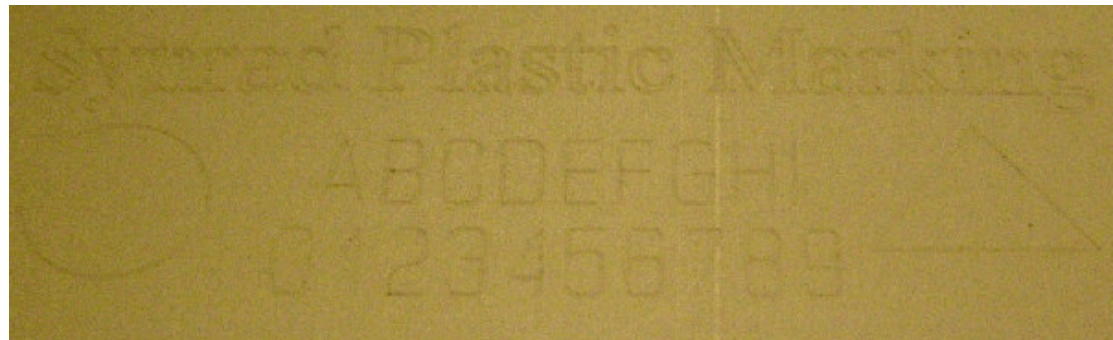
Fluoropolymers

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Fluoro-polymers	PTFE, Teflon, EFTE	Thermoplastic	■ Good: Some melt	■ Fair-Good: Clean engraved marks	■ No	-

Cutting Example
(teflon)



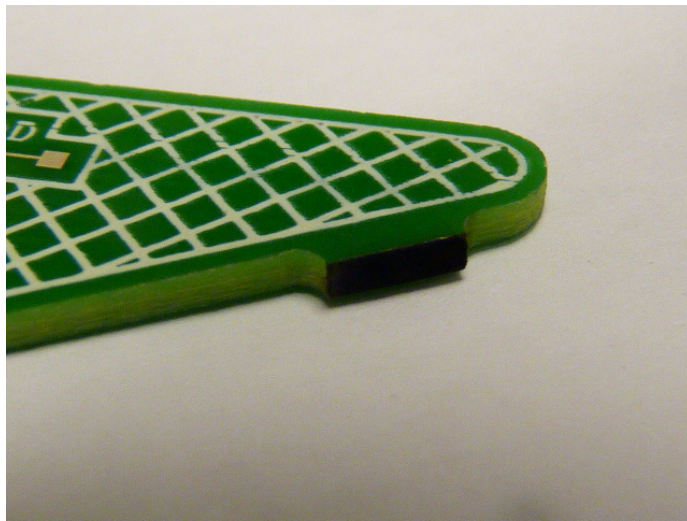
Marking Example
(teflon)



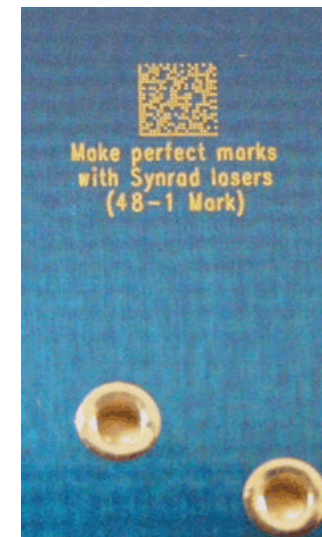
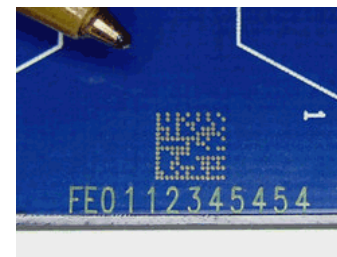
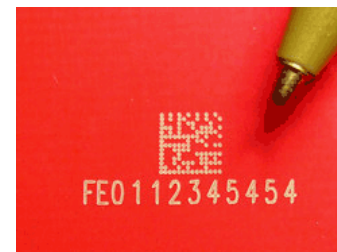
FR4/FR2

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
FR4/FR2	PCB	Thermoset	■ Poor: Brown Charring; sometimes degating is successful	■ Good: Dark marks on uncoated surface; Light marks on solder masks	■ Yes	-

Degate Example



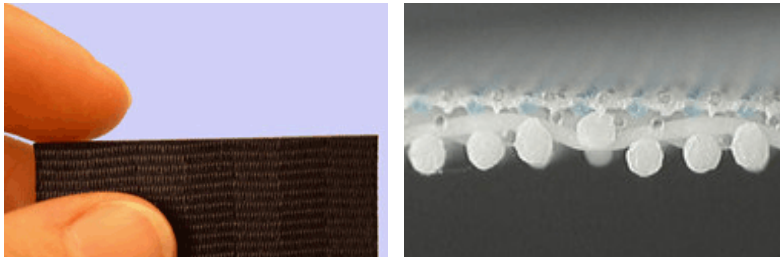
Marking Example



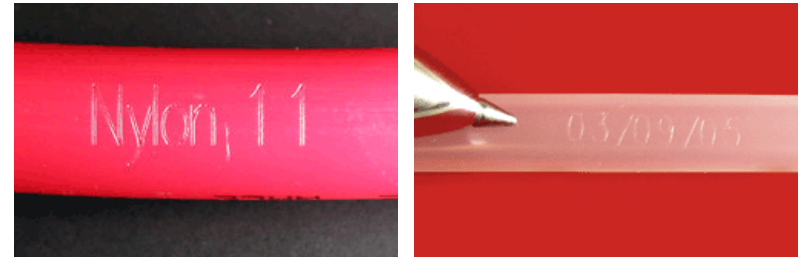
Nylon

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Nylon	-	Thermoplastic	■ Good: Moderate melt	■ Fair-Good: Engraved marks with some melt-back	■ No	-

Cutting Example
(left: fabric, right: mesh)



Marking Example



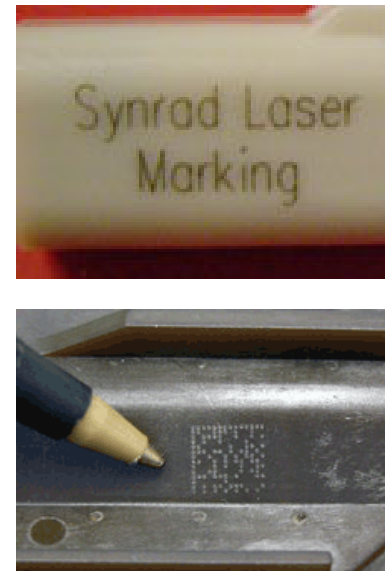
Nylon (Glass-Filled)

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Nylon (Glass Filled)	-	-	■ Fair-good: Some discoloration of cut edge;	■ Good: Dark marks	■ Yes	-

Cutting Example



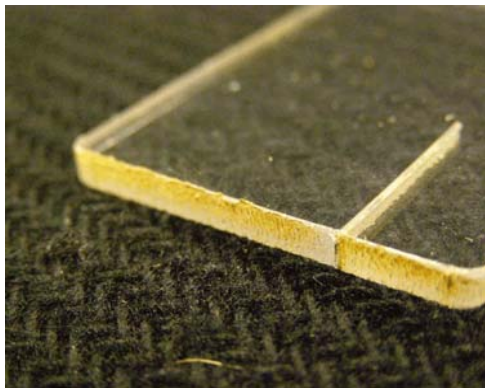
Marking Example



Polycarbonate

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Polyester	Mylar, PET, PETE, PETG	Thermoplastic	<p>■ Good: Some melt; PETG needs high assist gas pressure ~60psi</p>	<p>■ Fair-Good: Engraved marks with some melt-back</p>	<p>■ Sometimes: Depends on background color</p>	-

Cutting



High Power Marking



Low Power Marking



Polyester

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Polyethylene	HPDE, MDPE, LDPE, UHMW	Thermoplastic	■ Fair-good: Moderate to large melt	■ Fair-good: Engraved marks with melt-back	■ No	-

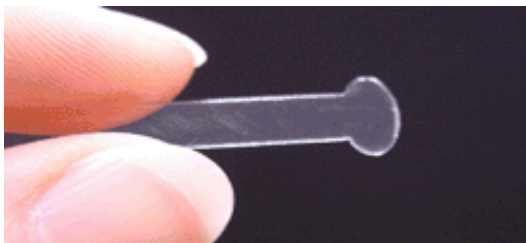
Fabric Cutting Example



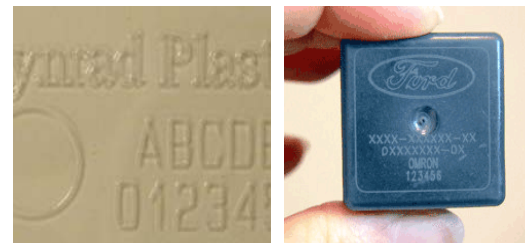
Film Cutting Example



Film Cutting Example



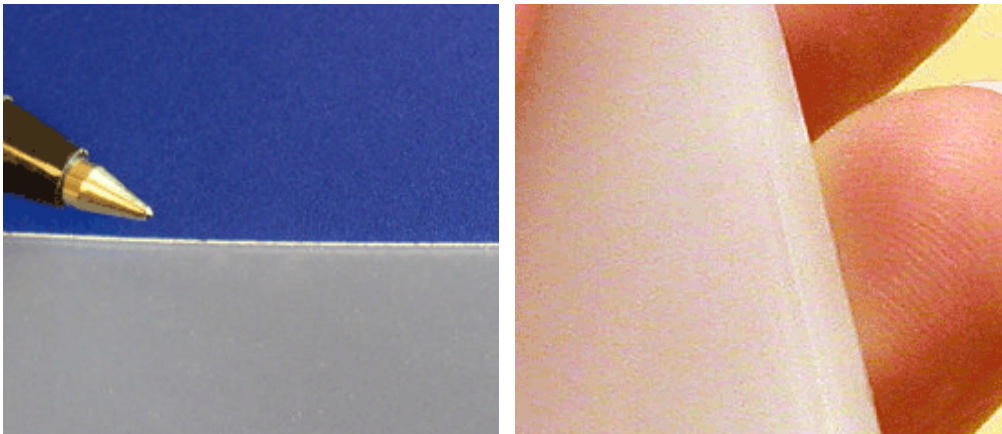
Marking Examples



Polyethylene

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Polyethylene	HPDE, MDPE, LDPE, UHMW	Thermoplastic	■ Fair-good: Moderate to large melt	■ Fair-good: Engraved marks with melt-back	■ No	-

Cutting Example



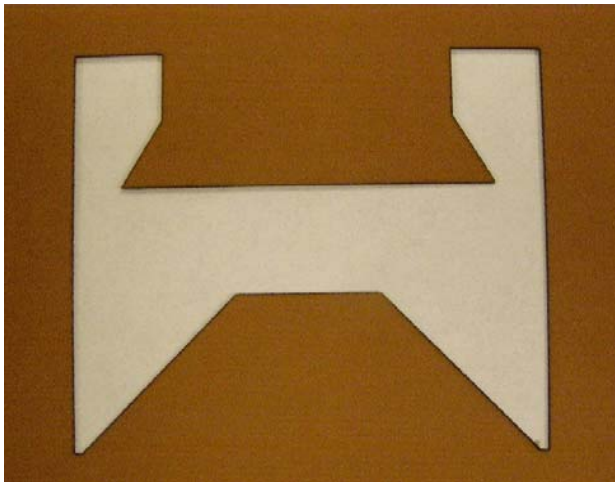
Marking Example



Polyimide

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Polyimide	Kapton	Thermoset	■ Poor: Brown/Black Charring	■ Fair-good: Dark marks with some soot residue	■ Yes	-

Cutting Example



Marking Examples



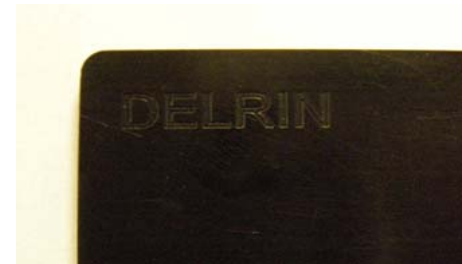
Polyoxymethylene

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Polyoxymethylene	POM, Delrin, Polyacetal	Thermoplastic	■ Good: Some melt	■ Fair-good: Clean engraved marks	■ No	Formaldehyde gas

Cutting Example



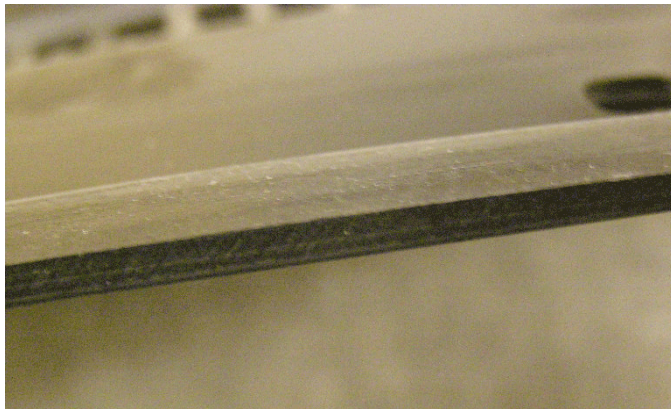
Marking Example



Polypropylene

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Polypropylene	-	Thermoplastic	<ul style="list-style-type: none"> ■ Good: Some melt; Sometimes slight discoloration 	<ul style="list-style-type: none"> ■ Fair-good: Deep engraved marks & slight melt-back 	<ul style="list-style-type: none"> ■ Sometimes: (2D codes) 	-

Cutting Example



Marking Example



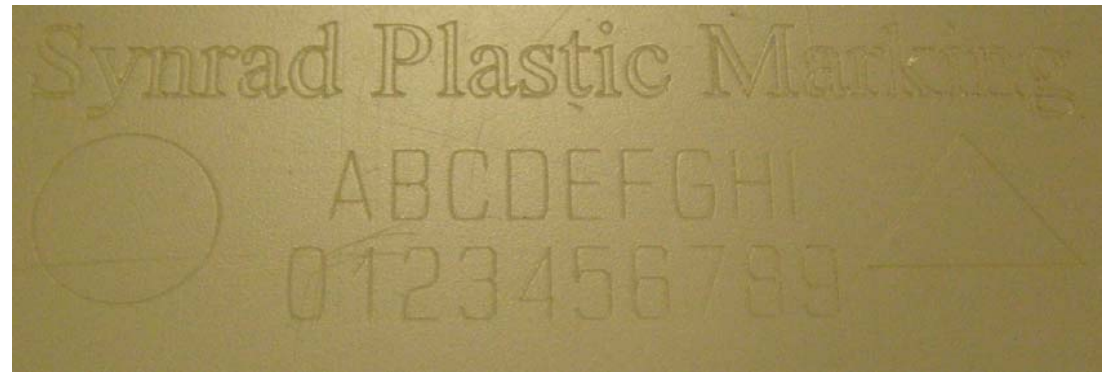
Polystyrene

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Polystyrene	-	Thermoplastic	■ Fair-good: Moderate melt & residue	■ Fair-good: Engraved marks with some melt-back	■ No	-

Cutting Example



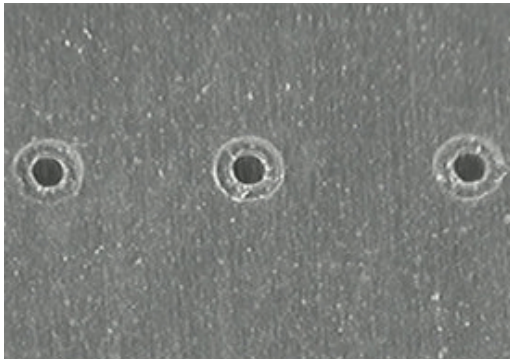
Marking Example



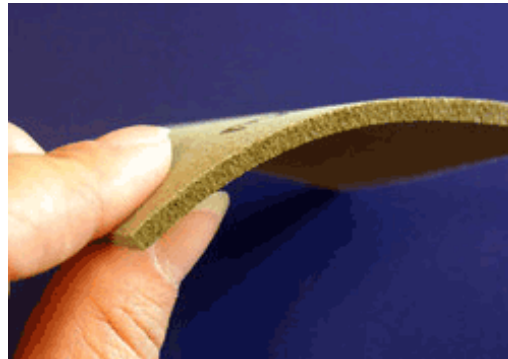
Polyurethane

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Polyurethane	-	-	■ Fair-good: Moderate melt & residue	■ Poor-Fair: Slightly engraved marks	■ No	HCN GAS

Film Drilling Example



Foam Cutting Example



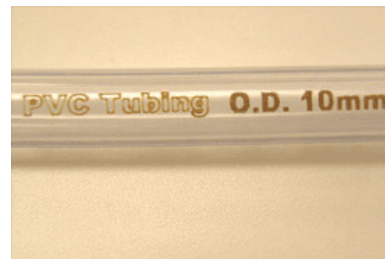
Marking Example



PVC

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
PVC	Vinyl	Thermoplastic	<ul style="list-style-type: none"> ■ Poor: Brown/yellow charring; VERY HAZARDOUS out-gassing 	<ul style="list-style-type: none"> ■ Good: Brown/Yellow marks; Some residue 	<ul style="list-style-type: none"> ■ Yes 	HCL GAS: DO NOT CUT!

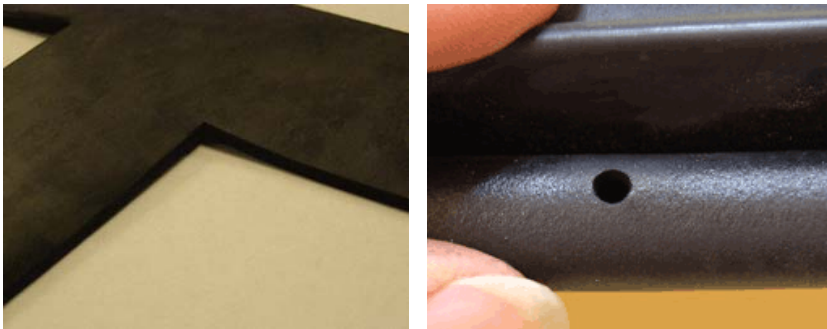
Marking Example



Rubber

Name	Also Known As	Type	General Cut Quality	General Mark Quality	Barcode Mark Successful	Safety
Rubber	-	Thermoset	■ Good: Vaporizes with some residue	■ Good: Deep engraved marks with some residue	■ Sometimes: (2D codes)	Dense sooty smoke.

Cutting Example



Marking Example



SYNRAD

Thank you!