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MatEdU / Fab Lab Instructional Module

Materials for Laser Cutter Machines

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ABSTRACT

This lesson includes activities for illustrating concepts related to materials selection for laser cutter use. Commonly used materials and their expected behaviors are discussed. We also discuss why some materials are unsafe or unsuitable for laser cutting

LEARNING OBJECTIVES

- Compare the effects of different laser cutter settings on the same material
- Produce a 3D object from a CAD model using a laser cutter
- Identify common materials suitable for laser cutting, and their chemical composition
- Compare properties that affect material behavior during laser cutting
- Generalize knowledge about given materials to predict the behavior of others

MatEdU CORE COMPETENCIES

0Cc1: Demonstrate workplace safety methods

0Dd1: Recall key job-related information (processes, references, terminology, acronyms)

1Cc1: Demonstrate familiarity with safe laboratory practice

5Aa2: Apply safely the information available in Material Safety Data Sheets

5Aa3: Apply knowledge of chemical and environmental safety including waste disposal and recycling

6Bb1: Apply concepts of heat, including temperature, thermal conductivity, specific heat, etc.

7Ii3: Explain property variations caused by annealing, heat treatment and deformation

7Kk1: Describe flammability and toxicological issues in materials

7Kk3: Describe differing thermal properties of different materials

7Kk4: Discuss optical and magnetic properties of differing classes of materials

17Aa1: Explain methods for finishing material for appearance and corrosion resistance

Key Words - Laser cutting, Wavelength, Thermal stress, Anneal, Microcrack, Vector, Raster

Type of Module - Laboratory exercise, Discussion

Time to complete - One to five 50-minute classes (depending on starting knowledge, activities chosen, and ratio of students to laser cutters)

Target Grade Levels: Secondary and postsecondary



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Level: Introductory

Prerequisite: recommend basic high school chemistry

Equipment

- Laser cutter and control system
- Computer console with chosen design software
- Appropriate ventilation system for fume removal
- Fire extinguisher and fire blanket

Instructor Notes and Curriculum Overview:

This module is intended to help students and new users consider the variety of materials that are suitable for laser cutting, find appropriate laser settings for those materials, and be prepared for challenges that may appear. Users should also be able to start from reasonable expectations when testing new materials, and be aware of all potential safety issues. This module does not cover the control software, calibration, or maintenance that the manufacturer may recommend for use with your specific laser cutter. Layout software and CAD software for drawing patterns to be used on the laser cutter are the choice of the user. Be aware that the capabilities of each laser cutter machine are different, and therefore a manufacturer's recommendations may override the information given here. Read the manual for your laser cutter before using it.

Laser cutters operate by focusing a beam of light at a material surface which absorbs some of the light. Primarily, this heats the material in a very small area at a time. The delivery of this energy can melt, burn, anneal, and/or thermally stress the area. The type of laser cutters that are available for workshop use operate in the infrared spectrum, either at 10.6 μ m wavelength for CO₂ lasers or at 1.064 μ m for solid-state lasers (such as the standard "fiber laser"). It may be interesting to know that extremely high-intensity lasers, of a level that is not generally available or practical, can blast material off of a surface by vaporizing material at a faster rate than the heat can propagate through the material. The wavelength of the laser light used is the theoretical minimum size of the cut that can be made. A shorter wavelength thus means a higher possible intensity and smaller focus of the laser spot. Cutting at a slower speed with a lower power requires more time but often improves the smoothness of the edges in the cut.

In general it is desired to burn away material using the laser without allowing the material next to the laser spot to reach a temperature near the flashpoint. This results in the removal of material without significantly altering the adjacent material. Melting a material instead of burning it with the laser means that heated liquid material remains on the surface, causing the heat to diffuse away and spread, reducing accuracy and affecting material outside of the intended toolpath. In some cases, it may be possible to mark a material accurately even if the material does not burn or vaporize. In this case, the laser is delivering heat that visibly changes something about the microstructure of the material. In these cases, the laser heat may be allowing oxidization to



occur, inducing a crystalline transformation in a metal (annealing), or microcracking the surface by inducing heat stress. It is also possible to paint a material and burn the coating, thus leaving behind a chemical marking. Similarly, if ventilation is insufficient, a material may be stained by its own chemical byproducts (soot, etc.) while it is being cut.

Laser cutting is a form of subtractive manufacture in the most basic sense. Its greatest advantages are the simplicity of the control software, the high speed at which it can operate, and the smooth, precise cuts and markings it can make when using the proper settings. It can be very easy for a new user to turn vector graphics into finished planar designs, and more advanced users can design fitted components that assemble into 3D after being cut. Slicer software exists for taking 3D models and converting the data into layers of a given thickness for assembly in different ways, allowing laser cutters to make volumetric or enclosed objects of a variety of sizes once assembled by the user. This allows the laser cutter to be used as an additive tool in that it produces layers for assembly, even though it is directly a subtractive tool.

Safety:

Any time you are considering using a new material, do your research. Check any recommendations from the laser cutter manufacturer concerning the material, and consult the **Materials Safety Data Sheet** to see what gases and byproducts are produced when the material is burned or melted. If your material releases flammable, toxic, carcinogenic, corrosive, or teratogenic products, find another way to cut the material. If anyone in the room with a laser cutter starts to feel nauseous or dizzy, turn off the cutter, exit or ventilate the room, and double-check that the material is safe to cut. Never cut materials containing halogens such as Chlorine or Fluorine. Minimize smoke production by using strong enough ventilation to ensure that fresh oxygen is always being pulled to the laser spot, and always ensure that the cutter's exhaust is being properly filtered or evacuated.

Some hard materials like porous ceramics and stone can absorb water that can cause small explosions of hard, sharp chips when heated with a laser. Make sure to desiccate these materials before use.

Read the manual for your specific machine, regardless of the information in this module. Never operate a laser cutter with damage that may allow the laser beam to shine outside of the cutter. Never disable or circumvent the system that shuts the laser off if the machine is opened or any other safety interlock. Always keep a fire extinguisher and fire cloth nearby, as some materials can quickly catch fire. **Do not leave the laser cutter unattended while cutting.**

Please see the section on hazardous materials in the Materials Selection information at the end of this module.



Class Activities:

When operating your laser cutter, always check the materials safety data sheet (MSDS) for the material you intend to cut, and know what byproducts are created when your material is burned by the laser.

Customizing and Comparing Laser Settings

Materials needed:

- Laser cutter and interface
- Appropriate ventilation system
- Corrugated cardboard stock sheets of identical thickness
- Fire extinguisher

For a particular material, a laser cutter user may identify the optimal power and speed setting for cutting and rastering quickly and cleanly. However, varying from these settings allows the user to perform diagnostics, compensate for the condition of the laser lens and air quality, balance the needs of speed and accuracy, and intentionally create partial cuts and aesthetically different rasters. The goal of this laser cutting exercise is to test a range of machine settings and qualitatively identify the range of varyingly acceptable parameters.

Procedure:

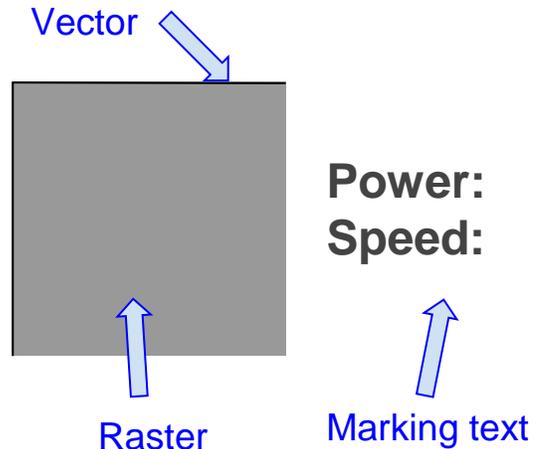
- 1) Plan a test matrix of power and speed settings for raster and vector. You will use your laser cutter to apply these to corrugated cardboard. An example is below:

	Power 5%	Power 25%	Power 50%	Power 75%	Power 100%
Speed 5%	X	X	X	X	X
Speed 25%	X	X	X	X	X
Speed 50%	X	X	X	X	X
Speed 75%	X	X	X	X	X
Speed 100%	X	X	X	X	X

If your manufacturer has recommended settings for this material, you might choose to cluster your settings near the recommended settings, rather than testing the full range on your cutter.



2) Using your design software, design a pattern to be tested with each settings combination in your test matrix. This design will be executed by your laser cutter, and should have portions designated as cut, raster, and marking. Choose a design that shows cuts and rasters of the same speed and power next to each other, and marks the settings used next to their result. An example design is given here in greyscale, and annotated in blue. Note that your software will most likely require your vector cut lines to be true hairlines.



3) Create copies of your design, with the correct marking text, for each test matrix combination you have chosen.

4) In your cutter's control software, bring in your designs and arrange them appropriately. Space them apart sufficiently (2cm or more) that if some of them have large amounts of smoke staining, they will not occlude others.

5) Ensure that your designs are set to be cut and rastered at the power settings matching their marking text. Export your commands and run your test.

Discussion:

Examine your results qualitatively. At the given thickness of your material, what vector cut settings fully penetrated the material? Did all full cuts produce equally smooth edges? Did some cuts produce undesirable additional results? What trade-off between making a full cut and a quality cut would you choose? Are there multiple valid choices for speed/power settings?

Consider the field of raster settings you tested. Did any produce unacceptable results? How wide was the range of useful settings? For those that produced qualitatively satisfactory results, consider picking a group and running this experiment again with half the default raster density (DPI) setting, and at double the density setting.

Re-cut a new piece of cardboard with the settings which you selected as satisfactory, labeling results with laser-cut text displaying the settings used. Once you have completed this, do an initial matrix again with another material, such as MDF or PMMA, and create a sample showing the results of successful settings. Keep a stack of these marked materials as reference with your laser cutter for yourself and future users.



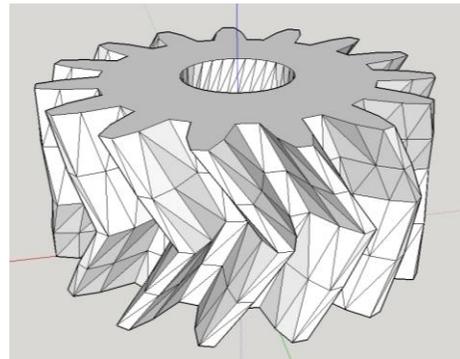
3D Rapid-Prototyping by Laser Cutter

Materials needed:

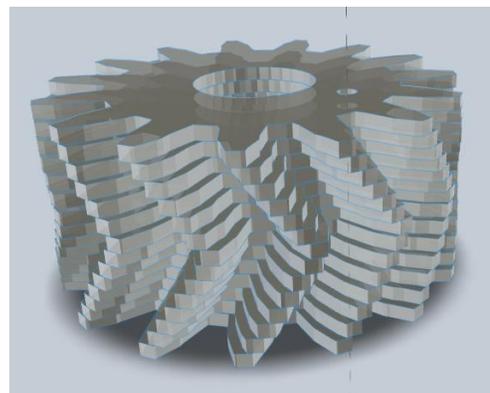
- Laser cutter and interface
- Appropriate ventilation system
- Corrugated cardboard, pine, MDF, or acrylic sheet stock. Plastic foam sheet stock (polyurethane, polyethylene) if, and only if, strong ventilation and filtration is installed.
- Fire extinguisher and fire blanket
- Computer with appropriate software platforms as described below

Laser cutting is inherently a subtractive technology, creating shapes by burning or vaporizing material. Though surface relief can be created by rastering at different power settings, laser cutting is largely unable to produce 3D net shapes, and can't make any structure with overhanging geometry without fixturing. In this exercise, we will use the laser cutter to produce these kinds of 3D shapes by adding an additive step - assembling layers.

1) Individually or in groups, generate a 3D model to STL format to use for your assembly. Models should have some degree of overhang, so that even many passes of varied rastering could not produce them. Simple but ideal designs for this exercise include helical and herringbone gears, which can be drawn in a free CAD tool like SketchUp, or generated with free parametric modelers found online at sites such as Thingiverse. Spur gears are an example of an unsuitable model, as spur gears have no overhanging geometry and can be created on a laser cutter with no need for layered assembly.



2) Once a candidate geometry has been chosen and made in STL format, use a slicer application to separate the model into equally-spaced Z vector cross-sections for the laser cutter. A good choice of slicer software for this specific application is 123D Make. Use a "stacked slices" approximation of your shape, such as the example shown here. With purpose built software, such as 123D Make, other slicing algorithms such as "interlocking slices" may also be suitable. Use the slice or toolpath visualization options in your chosen software to plan how you will assemble your



laser-cut layers into your final net shape. Make sure that your slicer's layer thickness matches the thickness of the stock material you will be cutting the layers from. For reference, most corrugate cardboard stock is between 4mm and 5mm thick. Cutting from a thinner material may result in needing to cut and assemble a very large number of layers to construct your object.

3) Bring your generated vectors into your laser cutter interface, and ensure that cut paths are correctly labeled as cuts and that any desired markings on the layers (such as numbers giving the orientation and order of assembly for the layers) are in place. As always, cut using a clean laser lens and proper filtration and ventilation, and remain present to deal with any fire or emergency any time the laser cutter is in operation. Cut your layers, and assemble your model.



Discussion:

In groups, consider the utility of the model(s) you have made. Why would such an object be



made in a manufacturing context? Would it be of use to artistic or engineering designers? Identify the materials and processes you would use to create a deliverable version of the object you have made by laser cutting and layer assembly.

In some cases, the object you have made from corrugate or other low-cost sheet stock may be sufficient for actual use. Objects fitting this description might be quick prototypes, artistic models intentionally using the layered appearance, lightweight home or office objects like laptop stands, or even frangibles like interestingly-shaped chewable pet toys. Other objects that are often made by sheet-stamping metals (lighting fixtures, containers, cover panels, etc) could be made with the laser cutter by cutting and fitting interlocking parts. Some designs may be completely infeasible for production on the laser cutter, such as where the final product must be made of a non-cutter-safe material, or where the desired surface resolution is ruined by layer edges, or where having assembly steps is not cost-effective.

If the process of assembling the layers that have been cut was automated, how would the decision about what can be made by this method change?

Compare and contrast the method of laser cutting layers and then assembling them with the different types of 3D printing you're aware of.



Materials Selection:

Wood and Paper-based Materials

Cardboard

Common corrugated cardboard is easily cut at very high speeds and medium power. Rastering into just the top sheet of corrugate can be done at very high speed and very low power. Because the paper-based products don't conduct heat well, melt, or deform, they have very low risk of reaching flashpoint away from the laser spot and igniting. The exception to this is, as with many materials, if the laser spot is incorrectly focused or if the air in the cutter is not correctly vented. Combustion of hydrocarbons like the cellulose and lignin in paper products ideally release only CO₂ and water vapor. If the air is not exchanged at a sufficient speed, the combustion reaction will receive insufficient oxygen and will produce increased amounts of carbon soot and smoke, instead of CO₂, clouding the laser and further overheating the area. The thicker the cardboard, the harder it will be to accurately cut both the top and bottom surfaces in a single pass, as the laser spot loses focus over higher thickness. Cardboard is easily marked without vaporizing much material. If the laser lens is dirty and scatters the beam, or if insufficient oxygen for a clean burn is present, soot may be produced and stain areas around the laser's operation.

Cork

Cork cuts and engraves well in most cases, but there may be issues depending on the thickness and quality of the cork. Thick cork or corks with significant amounts of adhesive do not cut well. By varying power/speed settings cork can create great contrast in engravings varying from light brown to black in color. Cork is also a relatively safe material to laser cut as it doesn't emit a significant amount of smoke and is not likely to catch on fire.

Woods

In general most types of wood laser cut and engrave relatively easily, but the type of wood affects the power and speed settings needed to obtain high quality results. Softer woods such as balsa require less power and can be cut at faster speeds than a hardwood. Woods that contain higher resin contents like cherry and alder tend to create deeper tones, but also have a greater potential to catch fire. To create the most contrast for engravings, woods with lighter tones and high resin content are preferable. Most woods will exhibit dark markings on the surface of cuts, but this can be limited using protective paper placing a layer of tape over the surface while cutting.

Plywood and medium density fiberboard (MDF) do not cut and engrave as easily as natural woods because they are held together by adhesives that hold them together and make them more resistant to laser cutting. In addition, some of the adhesives used in plywood and MDF



give off formaldehyde as a decomposition gas, so care must be taken to ensure proper venting of the gases produced. Comparatively, MDF is more homogeneous and tends to result in more consistent quality cuts than plywood.

One of the main issues cutting wood is that it is a naturally inhomogeneous material so results can vary even when using different pieces of the same type of wood. Two pieces of the same type of wood can have different tones, resin content, densities, grain lines and moisture content. Differences in these variables can impact the quality results when engraving. Knots in wood can create issues as well. Knots are harder to cut than the surrounding wood and can sometimes prevent the laser from completely cutting through the piece. Knots can also cause flare ups that scorch the surface and create darkened areas.

Textiles

Cloth

Most natural fiber cloth is easy to laser cut and engrave. Engraving is usually performed at high speed and low power to avoid burning through too much material. Looser fabrics such as terry cloth and plush may be difficult to engrave as they tend to burn more easily since the laser focus is less spread out amongst the fiber tows. Fleece, twill, microfiber, polyester, felt, denim and cotton, silk, and linen all cut and engrave well even if some burning may occur along the edges. Aside from polyester fibers, synthetic/plastic fibers such as nylon and spandex (polyurethane) should NOT be cut or engraved as they are potentially significant hazards. See the potentially hazardous materials section for more details.

Leather (avoid synthetic leather)

Leather is a relatively safe material to laser cut and engrave as it has low flammability. It produces a bad smelling (burning animal flesh) but nontoxic gas. Leather works well for engraving applications, but it can be more difficult to cut. Leather thicker than 1/8" to 1/4" may require multiple passes in order to fully cut. While engraving leather, levels of contrast can be created varying the power and speed settings of the laser cut. This can typically range from a medium to a dark brown or black depending on the parameters used.

Synthetic leather can also be cut and engraved, but typically doesn't yield as high quality results. Some forms of synthetic leather are made using polyvinyl chloride (PVC), polyurethane, or other plastics that create hazardous gases when laser cut (see potentially hazardous materials section) and SHOULD BE AVOIDED.

Metal (Etching only)

Laser cutting of metals is very difficult because the high reflectivity of metals requires very high powered lasers. Similarly engraving bare metals is not recommended with a CO₂ laser because the high reflectivity of the metal can reflect the laser back into the optics and damage the



machine. Typically CO₂ lasers are not capable of marking metal unless it is coated because the intensity of the beam is too low. Fiber lasers are commonly used when performing metal engraving as they have significantly higher peak intensity than a CO₂ laser.

It can also be challenging to achieve good engravings on bare metals because the high thermal conductivities reduce the ability of the laser to spot vaporize the material, potentially leading to low quality markings. Marking metals can be effective when the surface of the metal contains an oxide or has a coating that can be ablated by the laser exposing the metal underneath. This can not only provide more contrast, but can also produce higher quality marks because the oxides and coatings are not thermally conductive and thus absorb the heat more locally.

Another form of laser interaction with metals is known as laser annealing, where lower power settings for the laser are used to cause surface oxidation that will change the color of the surface. In this case, the laser does not actually remove any material. Instead it heats about 20-30 microns of the surface, causing a thin layer of oxidation that has little effect on the material below. This only works with alloys that exhibit a color change when exposed to heat and oxygen. Marks made by laser annealing are smooth to the touch since no material is actually removed from the part.

Most metals can be easily marked using a CO₂ laser with a marking compound such as Cermark^(™) which is coated onto the surface of the metal. When the material is lazed, a dark black mark is bonded strongly to the surface in the desired pattern. The markings are smooth and robust.

Brass

Bare brass cannot be engraved using a CO₂ laser due to its high reflectivity. To mark brass with a CO₂ laser a coating needs to be applied such as with painted brass. In painted brass the surface is first covered in a lacquer and then a paint coating is applied over the lacquer. The paint is then ablated away with the laser exposing the brass underneath. The lacquer prevents the brass from oxidizing and keeps it shiny for extended periods of time. Deep engraving of brass can be done with a fiber laser.

Stainless Steel

Laser engraving is not recommended on bare stainless steel surfaces due to its high reflectivity, but it can be marked using laser annealing. Laser annealing with a fiber laser is an effective method for creating high contrast markings on steel pieces. Laser annealing of stainless steel can exhibit a wide range of colors including reds, blues, greens, browns, and purples by varying the speed and power settings of the laser. The time between laser pulses (pulse width) has also been found to be a significant factor in the development of different color markings. The color variations are the result of the formation of oxides from the alloying elements and the thickness of the oxide formed, which are dependent upon the time and temperature the material was exposed to.



Anodized Aluminum

Anodized aluminum has an oxide surface layer that etches very well and results in clean, crisp markings even with a CO₂ laser. Etching of anodized aluminum does not leave any smoke or residue. However it can generate abrasive aluminum oxide particles (a common material in sandpaper) that can damage the laser cutter, so it should be cleaned after etching anodized aluminum. Bare aluminum can form transparent oxides, and is thus difficult to laser anneal.

Titanium

One of the most important properties of titanium is that it highly resists corrosion. The corrosion resistance comes from the thin oxide layers that develop on titanium. Like the oxide surface of anodized aluminum, the oxide layer of titanium can be ablated to form high quality engravings. Laser annealing is also an effective process on titanium because different oxides of Ti form at different temperatures. Titanium laser annealing can exhibit a range of color similar to that of stainless steel.

Ceramics and Stone

Glass

Glass materials can only be etched. Etching is a bit of a misnomer as most lasers will have very little direct effect on glass. Instead the heat from the laser causes trapped water and air to expand and fracture the glass on a microscopic level. Laser marking on glass typically leaves a frosted look that is the result of the formation of microcracks that reflect light, but often produces glass chips that need to be cleaned out. However, since it is difficult to actually control the cracking it is difficult to achieve high definition in a glass engraving.

Laser cutting of thin glass (< 1 mm) can be achieved with more powerful CO₂ lasers to overcome the issues with the reflectivity of glass. Cutting glass can be done with careful temperature control using the laser to heat the glass and a trailing water spray to cool the glass. The temperature gradient created by the laser heating and water cooling causes thermal stresses in the glass that result in the propagation of a very sharp crack. Laser cutting glass is becoming a preferred method in many industries for cutting, especially ones that require the use of thin glass substrates, because laser cutting results in very little chipping or microfractures compared to the mechanical cutting method. Since there are fewer defects on the edges of laser cut glass, the glass is stronger and more impact resistant than mechanical cut glass.

Ceramic Tile



For the majority of laser systems, it will not be possible to etch or cut ceramics. This classification includes clays like kaolinite and other highly stable metal oxide combinations. Sintering temperatures for these materials are frequently in excess of 1000C, and a ceramic piece will only show changes to surface texture if the laser system can achieve these temperatures and the piece has not already been well-sintered. If the ceramic is already fully sintered, or not granular in the first place, only an extremely powerful laser will be able to alter it. Consider cutting ceramics with a different method, such as water jetting.

Ceramics can be coated with glazes or paints which can be marked with the laser at extremely low risk that the ceramic itself will be damaged by the heat stresses created. For porous ceramics, like those used for garden planter pots, it is very important to fully dry the material before attempting to mark it. Water absorbed inside the material can be flashed to steam by the heat of the laser, breaking the material and causing chips to fly off at dangerous speeds.

Stone

Many kinds of stones engrave very well using a laser. The engravings produce the most contrast on polished, dark colored stones such as marble, granite, and slate. The structure and surface of a stone can also affect the quality of the engraving. Stones that have a more homogeneous and fine-grained structure produce higher quality engravings. Engravings on more polished surface also tend to produce more contrast than stones that have some texture to the surface. Quality deep engraving of stone is not possible as too much heat will cause the stone to melt and significantly reduce the contrast with the surrounding areas giving it a “washed out” look. As stone has the ability to absorb water, it is important to dry it fully before engraving. This prevents the sudden steam generated by the heat of the laser from fragmenting the surface of the stone. Fragmentation not only affects the quality of the engraving, but can be a significant safety concern as well.

Plastic Materials

There are many types of plastics and the result from cutting each type of plastics can be drastically different. Some plastics like acrylic can be cut with very few problems, while others such as polyvinyl chloride (PVC) should never be cut because they release toxic and/or corrosive gases. Other polymers can be significant fire hazards and must be closely monitored. Many polymers are listed in the potentially hazardous material section of this module due to these issues. In general, one should be cautious before cutting a plastic material. ***If it is not possible to identify the plastic, don't cut it.***

Acrylic (PMMA)

Acrylic (poly(methyl methacrylate)) produces high quality cuts and smooth polished edges. Acrylic comes in cast and extruded forms. For cutting, extruded acrylic tends to work better than cast acrylic because it produces a more highly polished clear surface. When engraving, cast acrylic tends to appear “frosted”. Acrylic can be a potential fire hazard so it needs to be monitored while cutting.



Polypropylene

Laser cutting polypropylene (PP) at a high laser pulse frequency can result in relatively smooth edge although upon closer inspection the edge will contain striations caused by PP melting in the vicinity of the laser pulse. PP does not typically produce high quality engravings as it often melts more than it ablates. PP has a low melting point and readily absorbs heat which can result in warping of thin pieces. Cutting polypropylene foam is a significant fire hazard and should be avoided.

Corrugated plastic

Corrugated plastic (coroplast) is made out of polypropylene and for the most part behaves similarly to regular polypropylene. However, the corrugated structure makes it more difficult to cut than sheets of PP because it takes more power to fully cut through the fluted sections than it does the face sheets. This can make it difficult to find speed and power settings that will cut both well. Coroplast also has more surface area exposed to air than PP sheet and is a potential fire hazard.

Delrin

Delrin® is a brand name for acetal (a.k.a. polyoxymethylene). Delrin can be laser cut with very sharp, clean edges and tends to engrave nicely too, although often there is not a lot of contrast in engravings. Extruded Delrin often contains residual stresses that can be released during laser cutting and result in warping of the part, especially with thinner samples. Delrin can be a safety hazard as it releases formaldehyde as a decomposition gas.

Polyimide

Often seen under the trade name Kapton®, polyimide does not cut well with CO₂ lasers, as it significantly burns and chars. It can be reasonable for engraving however, as the black soot marks provide good contrast. Polyimide cuts very cleanly when using a UV laser with a wavelength of 355 nm.

Rubber

Rubber is commonly used to refer to a class of material that exhibits significant amounts of elastic and anelastic deformation. A more accurate term for these materials are elastomers as rubber refers to the specific material made from rubber trees. Natural rubber is a thermoset polymer so material is removed by ablation and produces high quality cuts and engraving, albeit with some residue that needs to be cleaned off. It can also produce a significant amount of smoke.



Silicone elastomer is another common material that also laser cuts and engraves very well. The most significant issue with silicone is the amount of residue and dust produced during the cutting.

Do not cut neoprene rubber - it contains chlorine and is a significant safety hazard. ***If you are unsure of what type of rubber you have, do not cut it.***

Potentially Hazardous Materials

Many materials can potentially be significant hazards to laser cut as they can damage the laser cutter, catch fire, or emit toxic gases. *In some cases if the laser cutter has the proper ventilation equipment these materials can be cut safely*, but it is necessary to verify that the laser cutter is properly outfitted to handle the material. Below is a list of materials that can be dangerous to laser cut.

Materials containing halogens (chlorine, fluorine, etc.) such as PVC, Neoprene, and Teflon

Burning halogen-containing materials releases **toxic and corrosive gases**. Halogen gases such as chlorine can quickly cause severe damage to lungs and the rest of the respiratory system. HCl gas can also quickly corrode the laser cutter machinery and the laser's sapphire lens, sometimes even if the gas is ventilated by a fume hood. Teflon cuts well, but needs to have the proper ventilation system for removing the gaseous byproducts. PVC should never be used in the laser cutter.

Polycarbonate (PC)

There are several issues with cutting PC. The first is that it tends to result in low quality cuts and discoloring of the edges due to chemical degradation. **PC easily overheats** because it absorbs the infrared light of the laser more strongly than most other materials. As a result it is a significant fire hazard and must be watched closely. PC can be cut, but it is recommended only for very thin sheets (< 1 mm thick) so that heat buildup in the material is limited. It also does not engrave well compared to other materials.

Materials containing styrene such as polystyrene, styrofoam, thermoset polyester, and ABS

Any time styrene (or benzene) gas can be released by the laser cutter, the user must make certain that no one is exposed to the gas. Styrene gas causes damage to the central nervous system over time, and causes immediate damage to the respiratory system and skin. Symptoms of styrene exposure are dizziness and rash. **Styrofoam should never be used in the laser cutter**, as it easily bursts into flame, creating both a large fire hazard and much more styrene gas than a single cut would make. Solid sheets of non-foam styrene can be laser cut as long as the proper precautions are taken.

Plastic Foams



Foamed plastics are an **increased risk for flammability** because they have large amounts of surface area exposed to oxygen. Some plastics that can be cut safely in sheet form, such as polypropylene, will easily catch fire when in foam form. Any time you are considering cutting foam, check to make sure it is sufficiently flame retardant first. Styrofoam in particular is very flammable, and toxic when burning, and should never be used in the laser cutter.

Stone, ceramic, or other porous, hard materials

Any time you are cutting a hard material that has the ability to absorb moisture or any chemical that could be trapped inside the material and then vaporize, ensure that it is completely dry before cutting. Using a laser on a stone or porous tile that has absorbed water will result in small or large **steam explosions** that blast hard, sharp chips off of the surface. Drying a finely porous material once it has been in water may take multiple days or even weeks in a desiccating atmosphere.

Materials containing Nitrogen bound to Carbon (a CN bond) such as nylon, ABS plastic, polyurethane and some acrylics

Organics containing a CN bond will create **hydrogen cyanide gas (HCN)** when burned, an extremely toxic gas absorbed through the skin and lungs that kills humans by preventing oxygen from getting to organs. These materials should never be used in the laser cutter unless sufficient chemical filters are paired with strong ventilation. HCN is a weak acid that generally will not damage the machine or laser lens. Some acrylics, especially rubbery acrylics, may contain the acrylonitrile group that also produces HCN. Read the MSDS for all materials you intend to cut with the laser.

Fiberglass composites

Fiberglass composites consist of fiberglass embedded in a polymer matrix, which is typically a thermoset polyester or an epoxy. Both polyester and epoxy matrices can give off **toxic gases** when they thermally decompose. Styrene monomers are used as a crosslinking agent in thermoset polyesters and styrene and benzene gas can be released. Epoxies can give off HCN gas.

Even if toxic gases were not released, composites are difficult to obtain high quality cuts or etch due to the inhomogeneous nature of the material and the significantly different melting points between the fiberglass and polymer matrix composite materials. As a result it is difficult to find a power setting that will work consistently cutting both types of materials.

Carbon fiber composites

Carbon fiber composites have similar issues with laser cutting and etching as fiberglass composites. The matrix for carbon fiber composites is typically an epoxy that will emit **toxic**



gases upon decomposition. Dry carbon fiber (without resin) can be laser cut at very slow speeds. When cutting carbon fiber cloth, the laser can sinter the edges of the fabric making it less likely that individual tows of the fabric will pull out although there may be some fraying.



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Sources

Refer to Material Safety Data Sheets for the combustion products released when materials are cut in your laser cutter: <http://www.msdsonline.com>

Basic laser cutter safety: <http://www.ulsinc.com/resources/laser-safety>

After consideration of materials by their decomposition in combustion, we ensured that our conclusions matched the general maker community consensus:

http://atxhackerspace.org/wiki/Laser_Cutter_Materials

http://fablabdevon.org/wp-content/uploads/2014/08/Laser_Safe_Materials1.pdf

<https://www.pololu.com/docs/0J24/3>

https://dallasmakerspace.org/wiki/Laser_Cutter_Materials

