

## Lecture10. Non-traditional processes

This chapter describes a few of manufacturing processes that were developed relatively recently – namely in the last 50 years or so. Therefore these are sometimes called as non-traditional processes, although some of these are used much more commonly than so-called traditional processes. Most electronics manufacturing processes may also fall in this category, but we shall look at those separately. There are many non-traditional processes, we only look at the following:

- (i) Chemical machining
- (ii) Electrochemical Machining (ECM)
- (iii) Electro-discharge machining (EDM)
- (iv) Laser cutting
- (v) Ultrasonic machining (USM)
- (vi) Water-jet and Abrasive Water-jet machining

### 10.1. Chemical machining

This process is also called *etching*. The mechanism is to use chemical reaction between the material of the workpiece and some chemical reagent, so that the products of the reaction can be removed easily. thus the surface of the workpiece is etched away, exposing the lower layers, and the process is continued until the desired amount of material is removed.

#### Main uses:

- Creating shallow, wide cavities on plates, sheets, forgings and castings to reduce weight.
- Very heavily used in electronics manufacturing – as we shall see later.
- Hydrogen Flouride gas, or Hydrofloric acid is commonly used to etch fogged surface or cut-outs in glass.

#### Common application examples:

Flat springs, metal bookmarks, encoder wheels, lead frames for IC chips, sieves and filters used in medical applications, microwave oven filters, heat-sinks that are attached to printed circuit boards.

The process is carried out in the following steps:

- (1) The workpiece is cleaned
- (2) Those regions of the workpiece that must not undergo chemical milling are covered by a non-reacting material, called a **mask**. Masks are of two types: mechanical or photochemical. Mechanical masks are sheets

of inert material, usually rubber or plastic (PVC), with holes cut in areas where the CM must take place.

**Application of photomasks** takes the following steps:

- (i) *Coating*: Entire surface is covered by a photo-reactive chemical, called a **photo-resist**, or **resist**.
- (ii) *Exposure*: The chemical is exposed to a pattern of light (usually UV light); in those regions that which are exposed to the light, the resist reacts. The design of the part is a 2D drawing, called **artwork**, which is used to create a photographic negative. This negative is used for exposure.
- (iii) *Development*: Entire part is placed in a chemical bath that “fixes” the exposed layer. Usually, the parts that were exposed to the light will be washed away, while the other parts remain on the surface. These regions will be protected (masked) against chemical action of the acid.



Figure 1. (a) Sieves made by chemical milling (b) Heat-sinks made by photochemical machining

[source: [www.orbel.com](http://www.orbel.com), [www.conardcorp.com](http://www.conardcorp.com)]

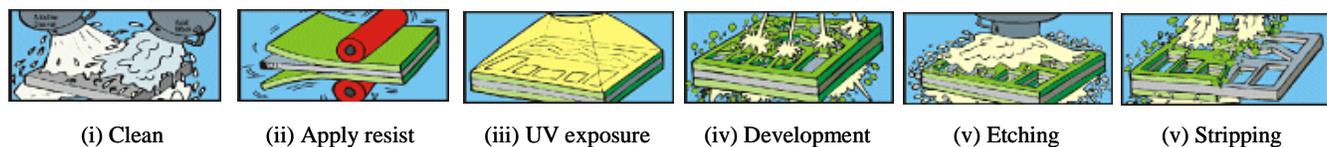


Figure 2. Photochemical milling process

## 10.2. Electrochemical Machining (ECM)

This process is the reverse action of electroplating. The workpiece is used as the anode, so the metal ions are removed from the workpiece, forming ions in the electrolyte. If the ions are allowed to deposit onto the tool (which is the cathode), then the tool shape will change and it will not be reusable. Therefore, a strong pressure is used to pump away the electrolyte and carry the metal ions away.

Common tool materials: Brass, Copper, or bronze (which are soft, ductile metals and can be easily cut into very fine shapes). Common electrolytes are Sodium Chloride, or Sodium Nitrate solutions.

### Common applications:

Dies and glass-making molds, turbine and compressor blades for gas-turbine engines, round or non-round holes, passages, cavities and slots in parts. ECM is also used for deburring of gears, hydraulic and fuel-system parts.

### Limitations:

The process does not yield sharp corners on the profiles it is used to produce (which is why it is good for deburring).

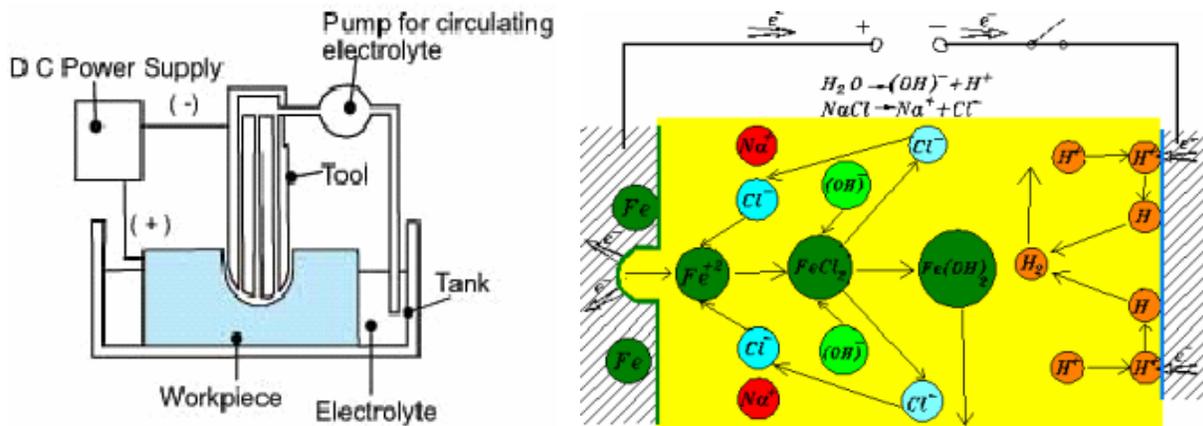


Figure 3. (a) ECM Process (b) Electrochemical action in ECM [source: www.unl.edu]

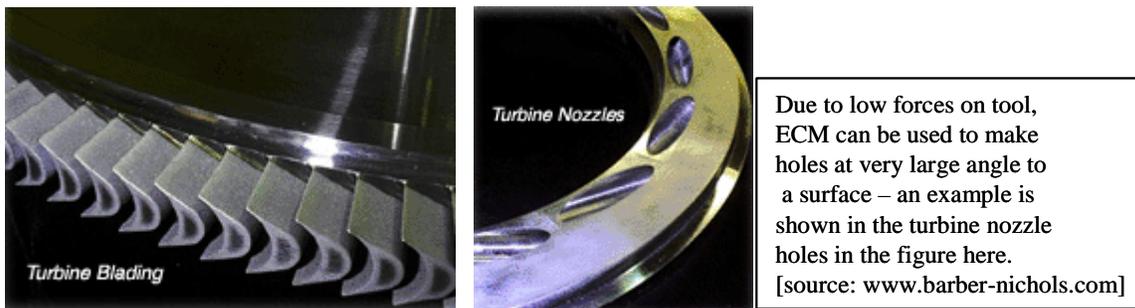


Figure 4. Examples of parts made by ECM

### 10.3. Electro-discharge machining (EDM)

EDM process is used for cutting complex and precise geometric shapes into electrically conducting metals. The metal electrode and the part are laced very close to each other, separated by a non-conducting liquid (called a dielectric) – a commonly used dielectric is kerosene. A voltage difference is then applied to the part and tool, generating a spark; the heat from the spark melts a tiny bit of metal from the part. The melted metal cools and solidifies as tiny particles in the dielectric. By pumping the dielectric to flow, the metal is carried



### Process capabilities and characteristics

EDM is a very inexpensive process (machine tool cost as well as operation costs are low). The processing rate is slow, but the machine can operate unattended: just load the part and return when it is done. Fairly complex shapes can be produced, especially mould cavities, non-circular profile holes, etc. Dimension control is good, and surface finish depends on the MRR (high MRR leads to poor surface finish).

### 10.4. Laser cutting

LASER (Light Amplification by Stimulated Emission of Radiation) achieves high density optical power at a small (focused) area. The power density causes localized heating, which can be used for cutting, welding, etc. The most common types of lasers used for manufacturing are CO<sub>2</sub> and Nd:YAG (Neodymium:Yttrium Aluminum Garnets) lasers – the names are based on the primary material used in the laser resonance tube.

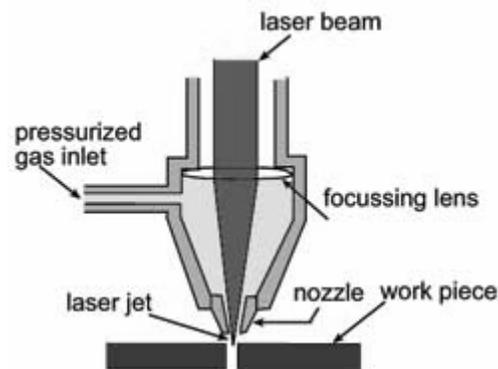


Figure 7. Schematic of laser cutting

#### Process characteristics

1. The process is more efficient if the material has low reflectivity (and therefore absorbs more light energy rather than reflecting it), and low thermal conductivity (to localize the heating).
2. Lasers can be used to cut holes with diameter as small as 0.005 mm (i.e. 5 microns), and deep holes, with L/D ratio up to 50.
3. Lasers can be used to cut up to 32 mm thick steel sheets.
4. Lasers can deliver power in continuous waves, or in a pulsed form. Usually, high precision cutting operations use pulsed lasers, in which each pulse of power lasts between a few micro-seconds ( $10^{-6}$ s) to a few femto-seconds ( $10^{-15}$ s). Usually, the lower duration of the pulse results in better accuracy or smaller feature size.
5. Complex profiles and non-circular holes can be cut into thick plates or thin sheets with very little deformation.

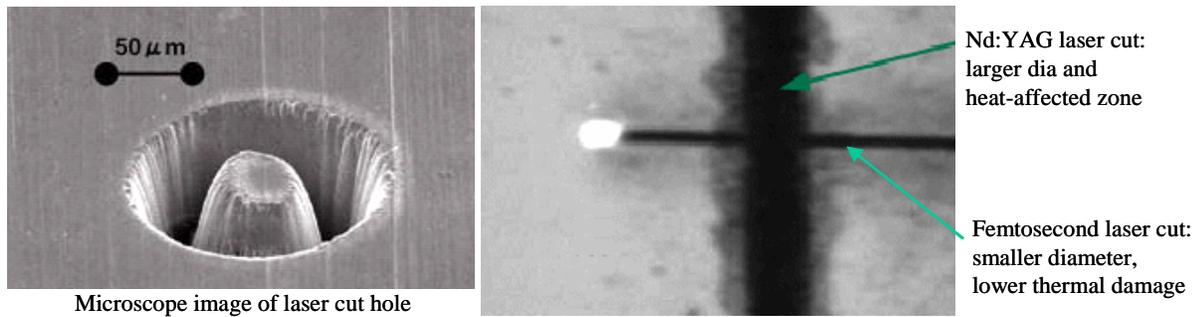


Figure 8. Examples of laser cutting of small, deep holes [source: www.cyber-laser.com]

### Most common applications

1. Making complex hole-patterns in masks for processes like chemical processing.
2. Cooling holes for first-stage vanes of Boeing 747 engine.
3. Marking of serial codes and letters on IC chip packages.
4. Deep, narrow cuts in thick sheet metal (see figure 9)
5. Cutting holes in non-metallic materials (e.g. ceramics).



Figure 9. Thick steel sheet cutting using laser

### 10.5. Ultrasonic machining (USM)

The most common use of ultrasonic machining is in welding operations, especially in welding of plastics, with application in package sealing, etc. However, Ultrasonic machines can also be used for material removal. Such USM's are actually a type of grinding operation. The figure below shows a schematic of ultrasonic

grinding used to cut holes/slots. The vibration of the transducer (usually a piezo-electric material) is high frequency and low amplitude. The tool is a specially designed shape which tapers down so as to amplify the vibration amplitude (typical tip vibration is at 20KHz, and 0.0125 mm~0.075mm amplitude).

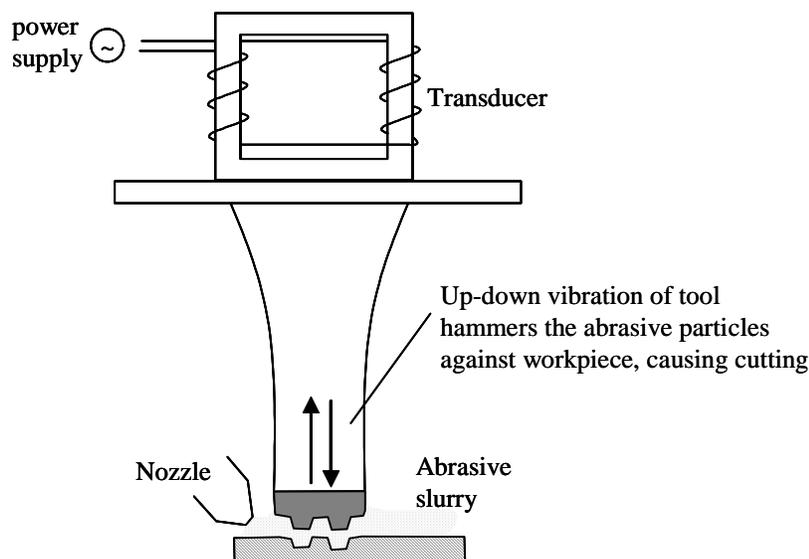


Figure 10. Schematic of USM

#### Common applications:

1. Machining of shallow slots and holes in brittle materials, e.g. ceramics, glass, diamond, tool steel etc.

#### 10.6. Water-jet and Abrasive Water-jet machining

Water jet machining uses a high pressure (~400 MPa) jet of water to blast against the workpiece, causing it to break at the point of impact of the stream. The nozzle diameter ranges from 0.05mm~1mm, which means that the jet is very narrow. In some cases, abrasive particles (e.g. silicon carbide, aluminum oxide) are mixed with the water, giving a faster machining action; if abrasives are added, the process is called Abrasive water-jet machining. AWJM machines are fitted with special system to collect, filter, and clean the used water and to capture the abrasive particles which will otherwise cause pollution.

#### Process characteristics

1. No heat is generated, therefore there is no thermal stress, thermal distortion, or thermal damage.
2. The operation does not leave any burrs, so no secondary smoothing operation is required.
3. Fast and precise cutting of fabrics is an important application for the textile industry.

4. Environmentally friendly process (almost no pollution)

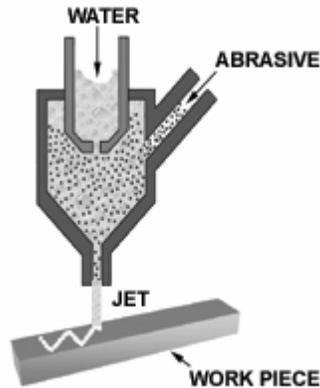


Figure 11. Schematic of AWJM process

**Common applications:**

1. Vinyl, foam coverings of car dashboard panels; plastic and composite body panels used in the interior of cars
2. Cutting complex shaped patterns in cloth (for manufacture of textiles)
3. Cutting glass and ceramic tiles.



Figure 12. An example of historic use of water for machining granite (rock)