# Chemical Machining

*presented by*

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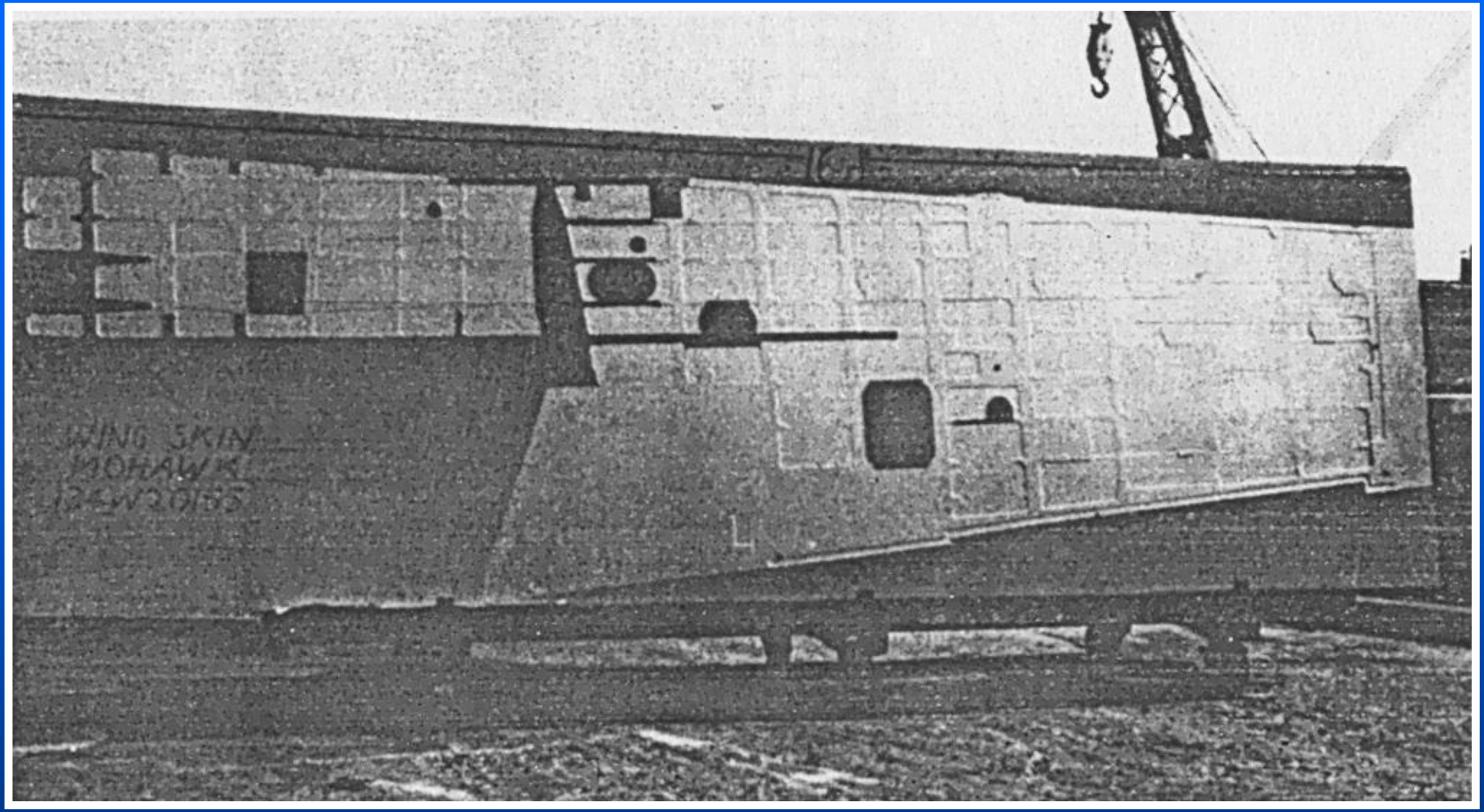
# Case Study 1

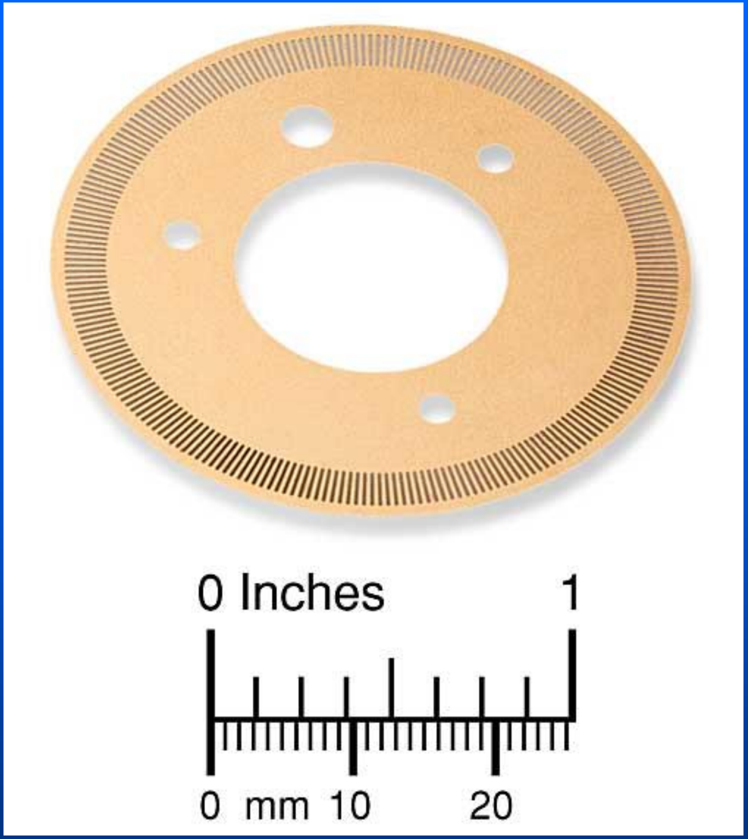



**Skin of aluminum wing of an aircraft**

**(For better strength/weight ratio → remove unnecessary metal from numerous surface pockets)**

**(source Chemcut Corporation)**

# Case Study 2




**Beryllium-copper alloy encoder disc**

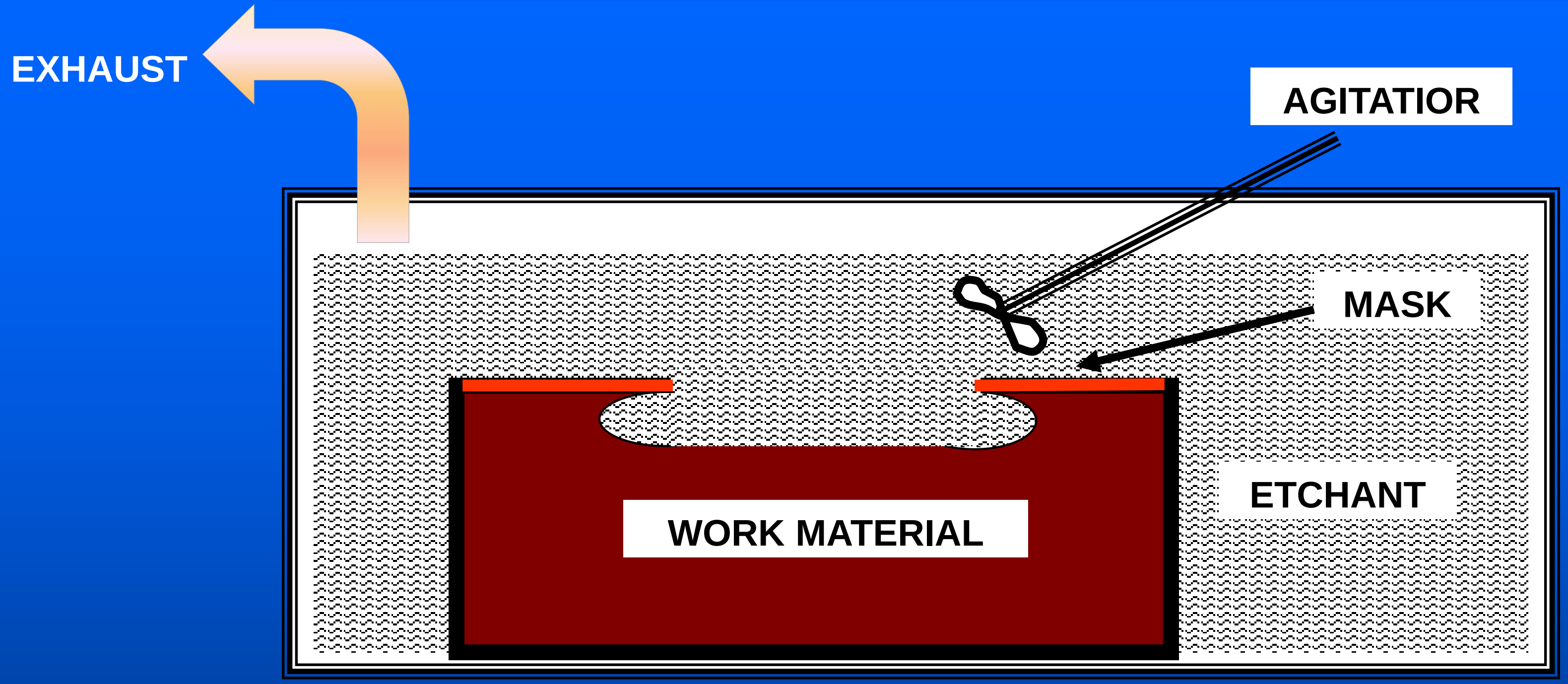
(Disc is 25 micron thick, Total 200 slits regularly spaced on disc at $1.8^0$ separation)

**Solution for both the cases**

**?**

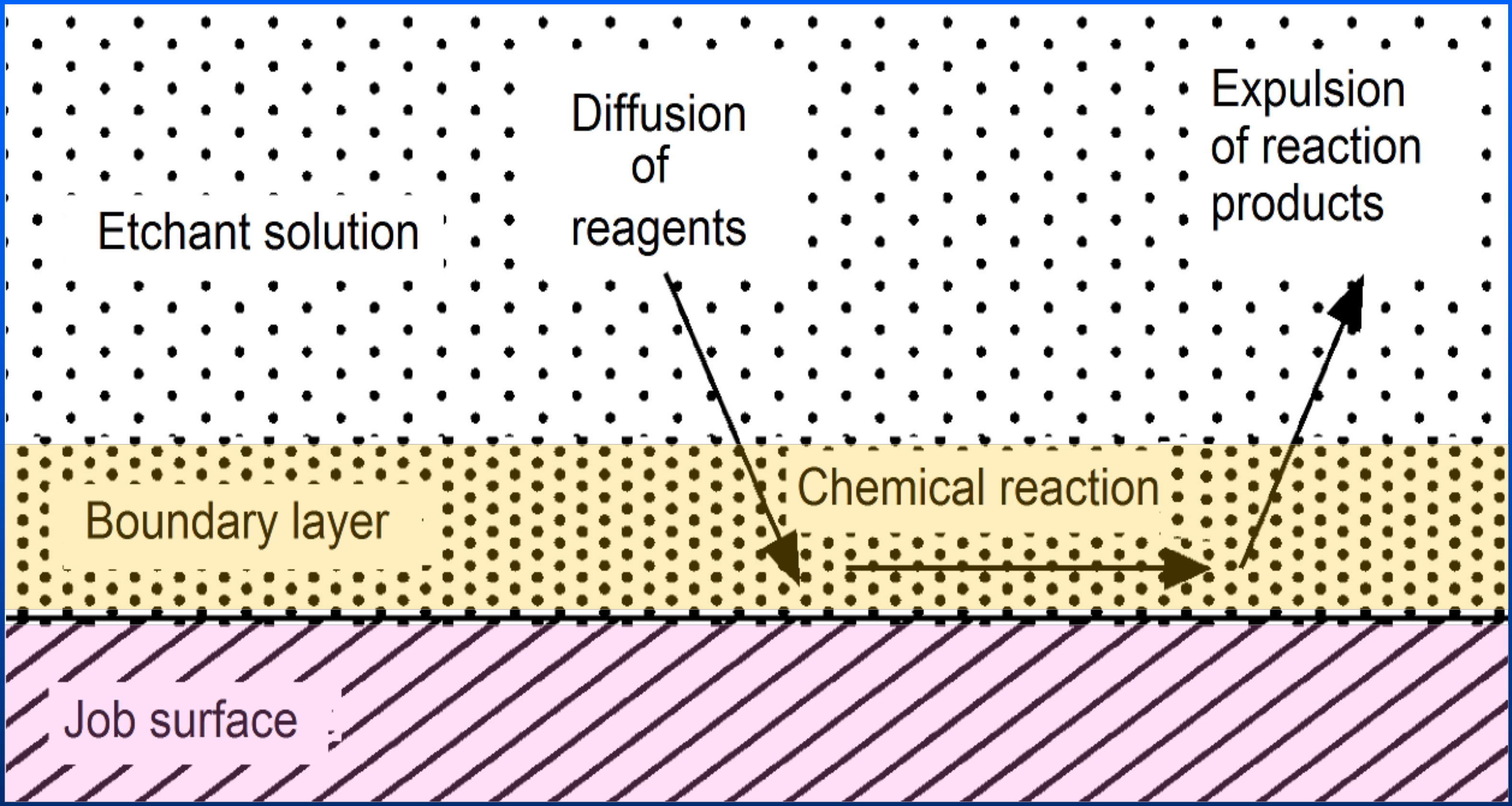
**…… Chemical Machining (CHM)**

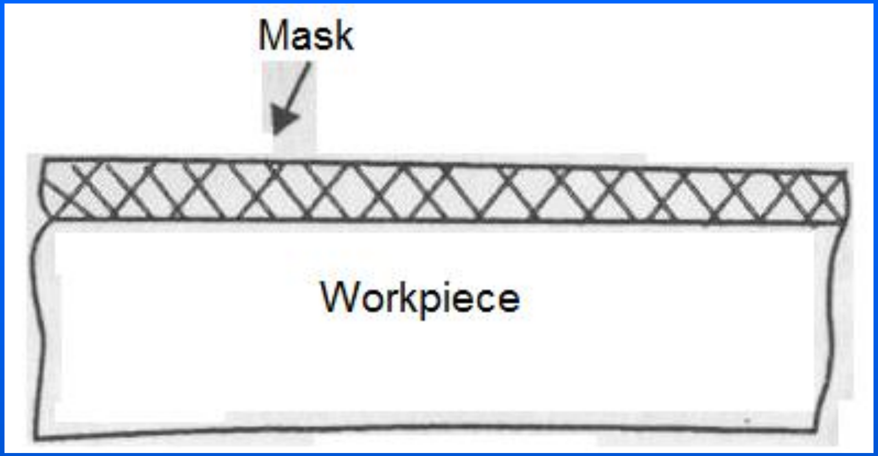
# Basic Scheme of Chemical Machining



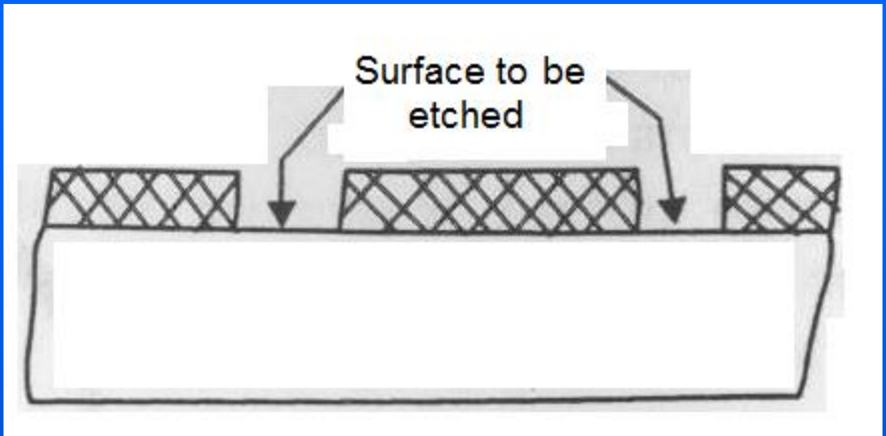

**Requirements**

- Mask
- Work piece or substrate
- Etchant (acid or alkali)
- Agitation
- Fume extraction (for reaction products)

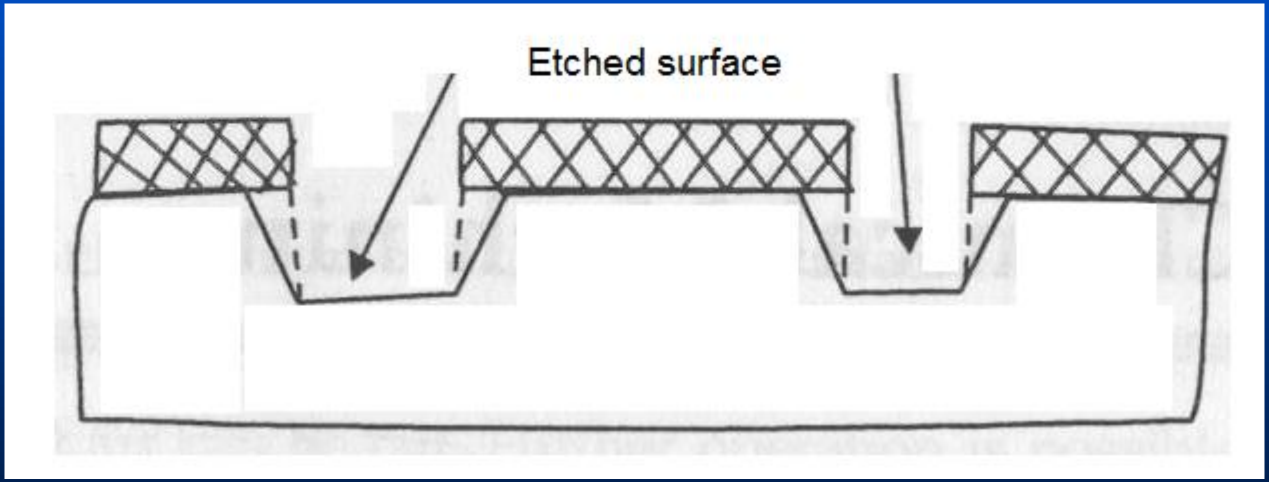

Diffusion of reagents
Expulsion of reaction products
Etchant solution
Chemical reaction
Boundary layer
Job surface




**Maskant coating**




**Development of etching surface**




**Finished part**

# CHM Classification

**Chemical Milling**
- weight reduction
- blind detailing

**Chemical Blanking**
- through detailing

**Chemical Engraving**
- detailing upto very limited depth

**Photochemical Machining**

# Classification of masks

**Cut & Peel type**

1. Vinyl, Neoprene rubber, Bee wax
2. Applied by flow, dip or spray
3. Mask thickness: 0.03-0.13 mm
4. Unnecessary portion cut & peeled

- → mask material is first applied on the entire surface of the substrate,
- → the mask is cut along a template with a sharp cutter,
- → Unwanted portion of mask is peeled off to expose the area to be milled.

# Classification of masks

**Screen print** → 1. Silk or stainless steel mesh which has a stencil placed upon the material to be machined

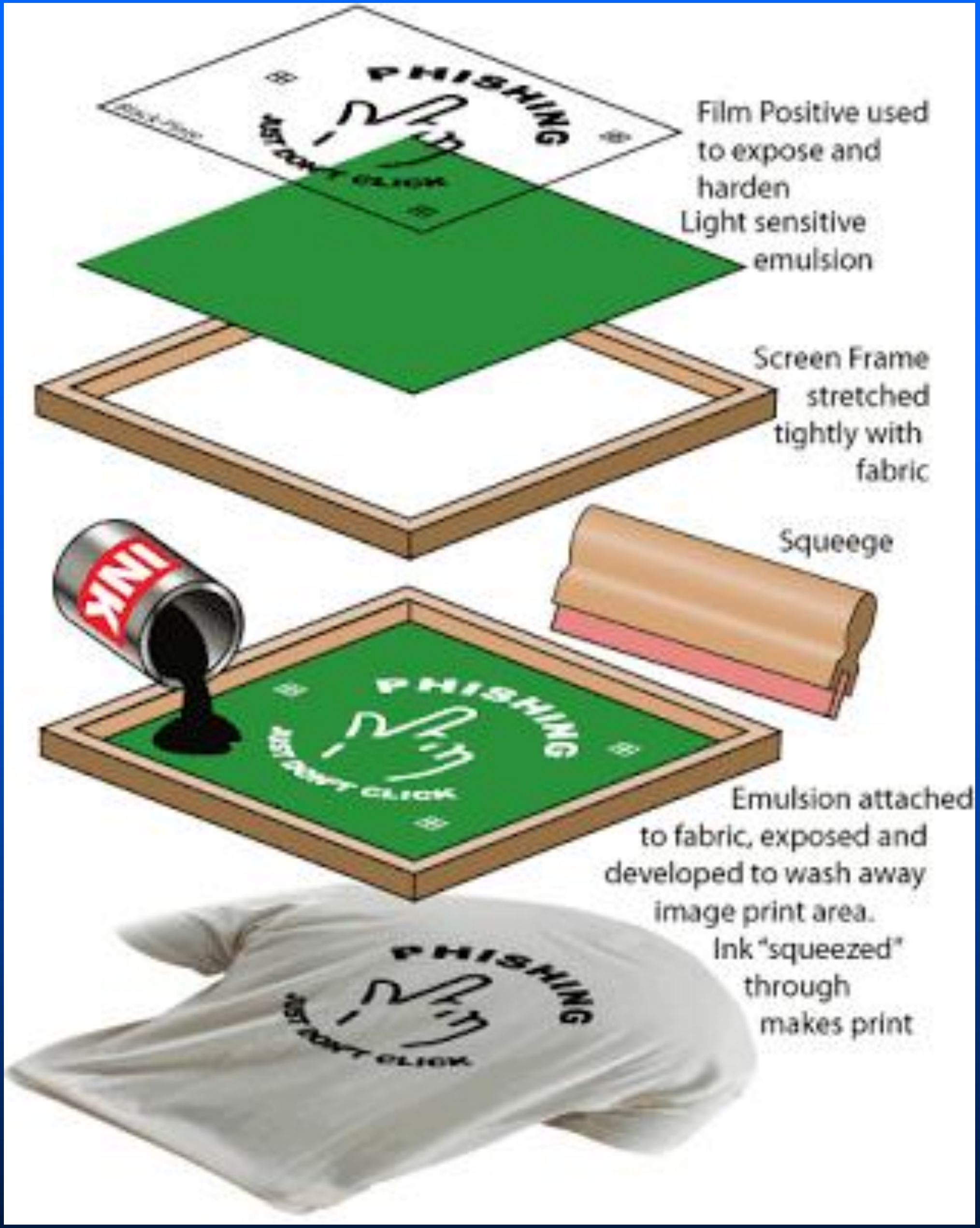
- Uses screens (mesh) made of silk, synthetic fiber such as nylon and polyester, or fine filament of stainless steel.
- Negative images of the needed patterns are created on the screen, → then resistive ink is applied by press-roller onto the substrate through the screen to create the final patterns.

# Screen print

Photo-resist is a light-sensitive emulsion that is used as a masking material.

When exposed to light, it chemically transforms, hardens and adheres to the substrate.

Upon developing unexposed portion can be removed from the work surface, exposing the desired surface on job.



# Classification of masks

**Photo resist** →

1. Naturally occurring and synthetic photosensitive resins
2. Applied by spin coater and photographic projection technique.→ so high production rate
3. Mask thickknees: extremely thin (few microns). Not used for parts more than 1.25mm thick and 1.5 m long
4. Can handle highly corrosive etchants

- The photo resist method creates very fine and accurate but thin resist patterns that provide small chemical resistances to strong alkali and acidic etchants. ← It is mostly used only for small depth applications.

# Applying photo resist by Spin Coater

Rotation (@ around 5000 rpm) is continued while the fluid spins off the edges of the substrate, until the desired thickness of the film is achieved.

The applied solvent is usually volatile, and simultaneously evaporates.

The thickness of the film also depends on the concentration of the solution and the solvent.

# Selection criteria for masks

| | |
|---|---|
| **Chemical Resistance** | → Deeper etching is possible with thicker mask |
| **Part Configuration** | → Some masks are only applicable to flat parts |
| **Quantity of parts** | → Masking process should be less labour intensive for high quantity parts |
| **Cost** | Cost affordabilty |
| **Ease of removal** | → Delicate parts require easy removal of mask |
| **Required resolution** | → Thicker masks result in less resolution |

# Uses of different masks

**Cut & Peel type**

1. Big structural parts
2. Milling of aircraft components
3. Missiles
4. Space components

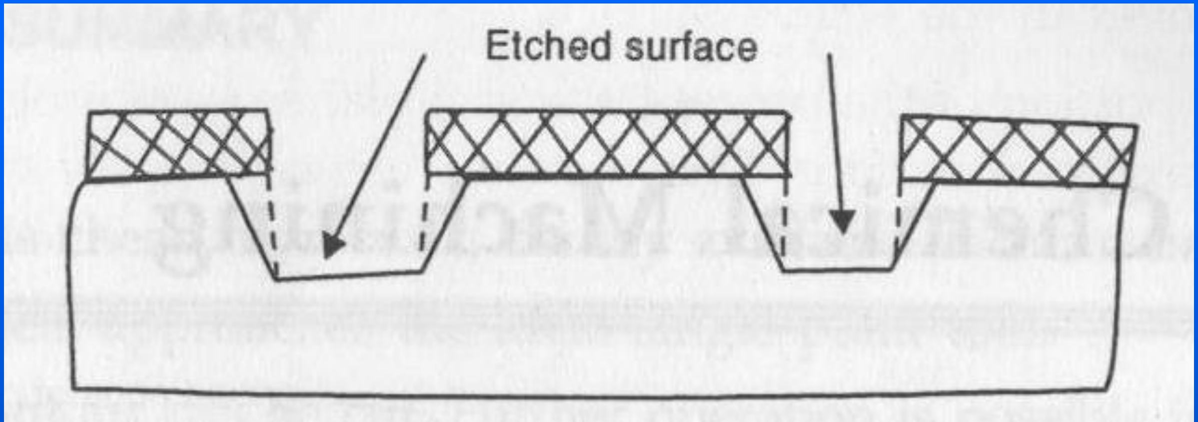
**Photo resist**

1. Small and thin components
2. Never used for big components
3. PCB
4. Watch components like gears, small spiral rings
5. Flat sheet metal components

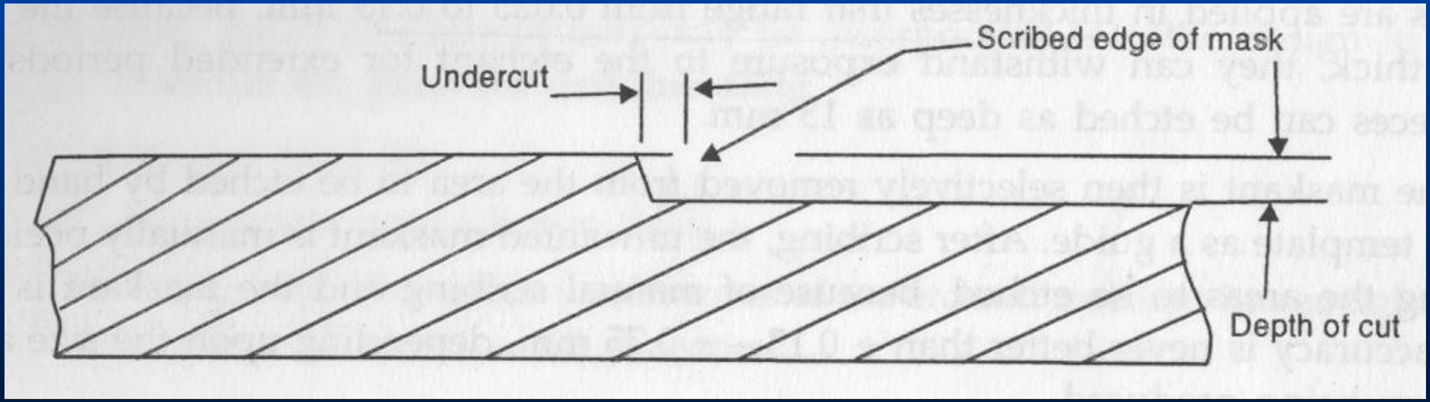
**Screen print**

1. Used for mass production
2. But less accurate as compared to photo resist technique

# Undercut and Etch factor




$$EtchFactor = \frac{Undercut}{Depth\ of\ etch}$$



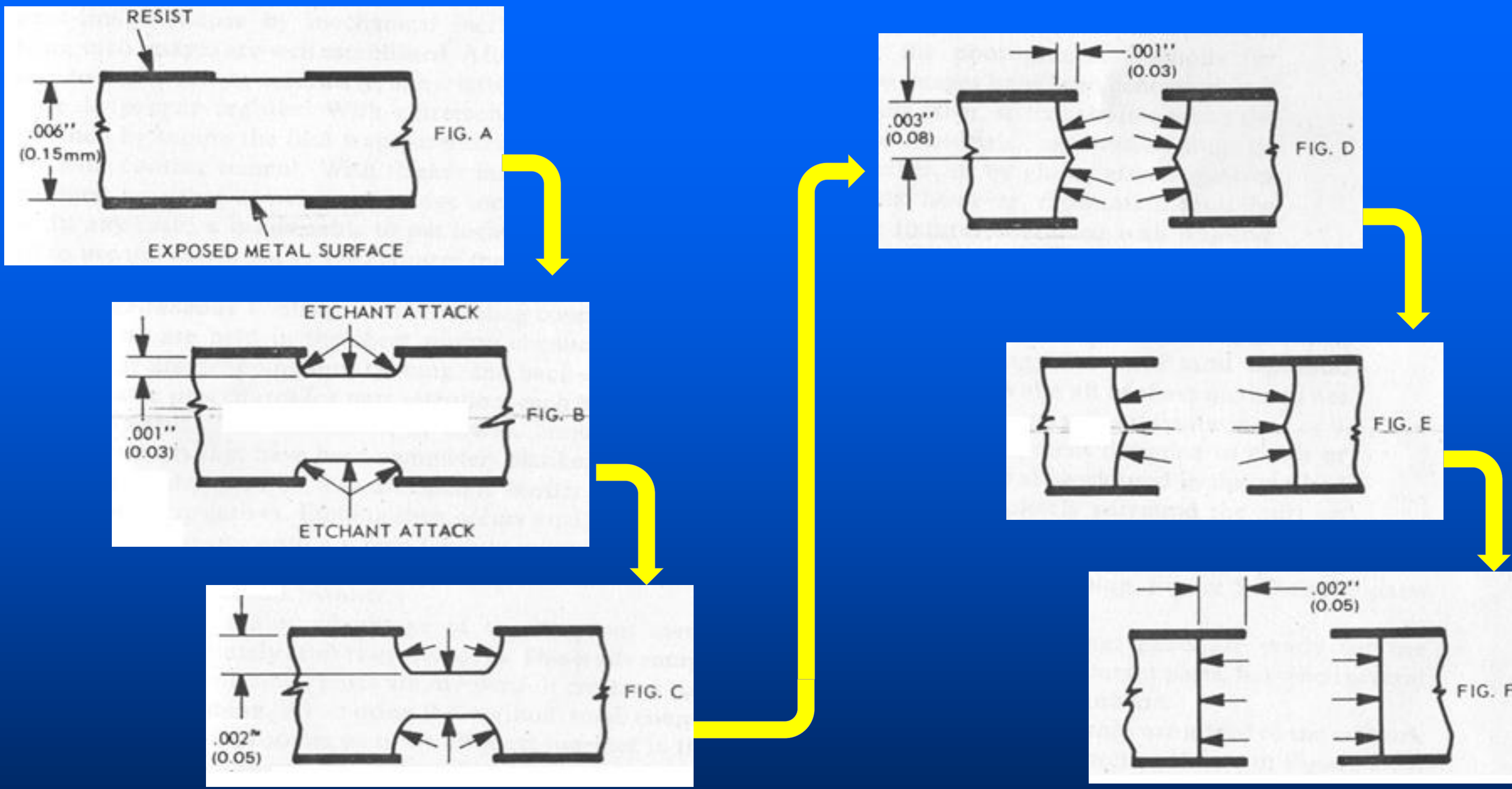
# Etchant Applications and Their Characteristics

| Metal | Preferred etchant | Etch rate (mm/min) | Etch factor |
|---|---|---|---|
| Aluminum | $FeCl_3$ | 0.025 | 1.7:1 |
| Copper | $FeCl_3$ | 0.050 | 2.7:1 |
| Nickel alloys | $FeCl_3$ | 0.018 | 2.0:1 |
| Phosphor-bronze | Chromic acid | 0.013 | 2.0:1 |
| Silver | $FeNO_3$ | 0.020 | 1.5:1 |
| Titanium | HF | 0.025 | 2.0:1 |
| Tool steel | $HNO_3$ | 0.018 | 1.5:1 |

# Etchant selection

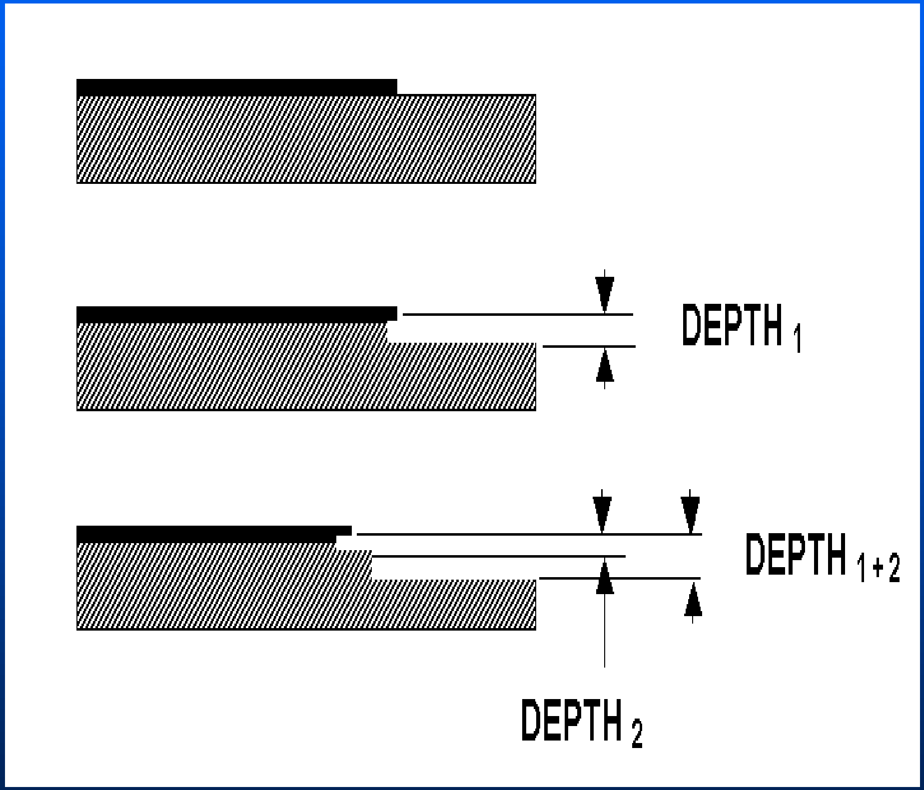
| | |
|---|---|
| **Required surface finish →** | Some combinations of material and enchant result in the formation of surface oxides, which degrades the finish |
| **Removal rate →** | Faster rate lowers the cost, but attacks the resist bond, results in poor finish, or produces high heat |
| **Material type →** | Enchant must attack the material without causing *intra granular attack* or stress corrosion cracking |
| **Etch depth →** | Some etchants produce surface finishes that worsen with increasing depth |
| **Type of resist →** | Etchant must not destroy resist during the process time |
| **Cost →** | Cost of the etchant, maintenance, and disposal |

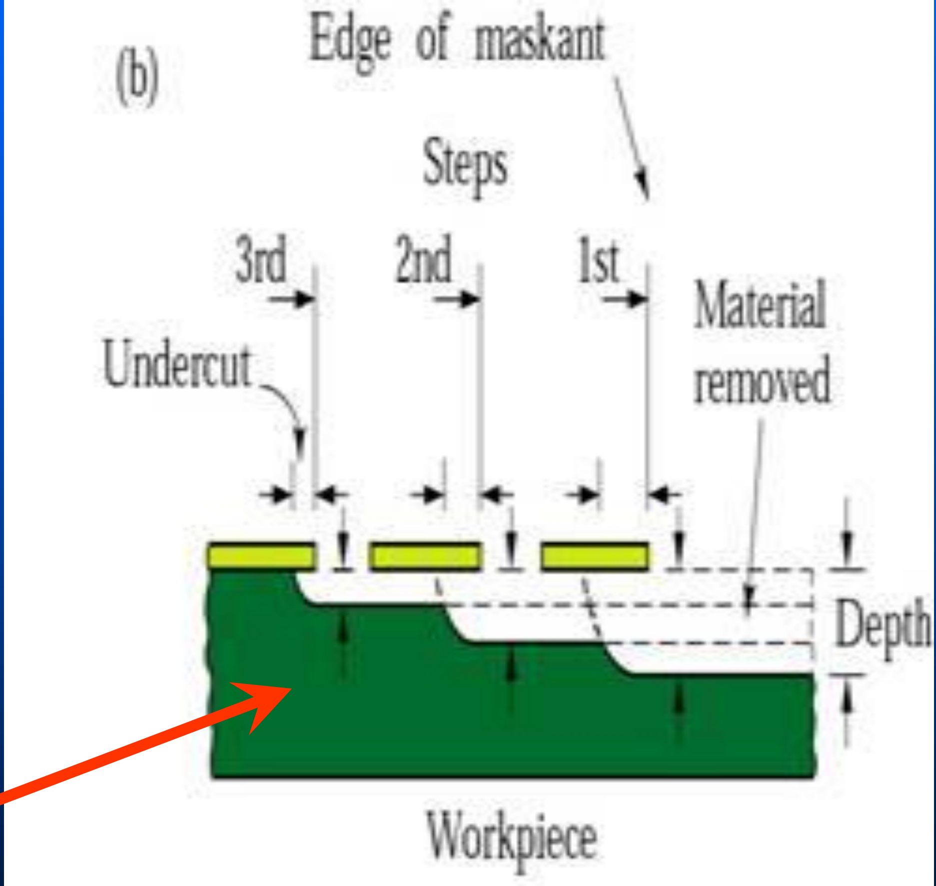
# Under cut in partially etched and fully etched parts




- Advantage of **double-sided etching**.
- Sidewise straightness (zero taper) can be achieved eventually

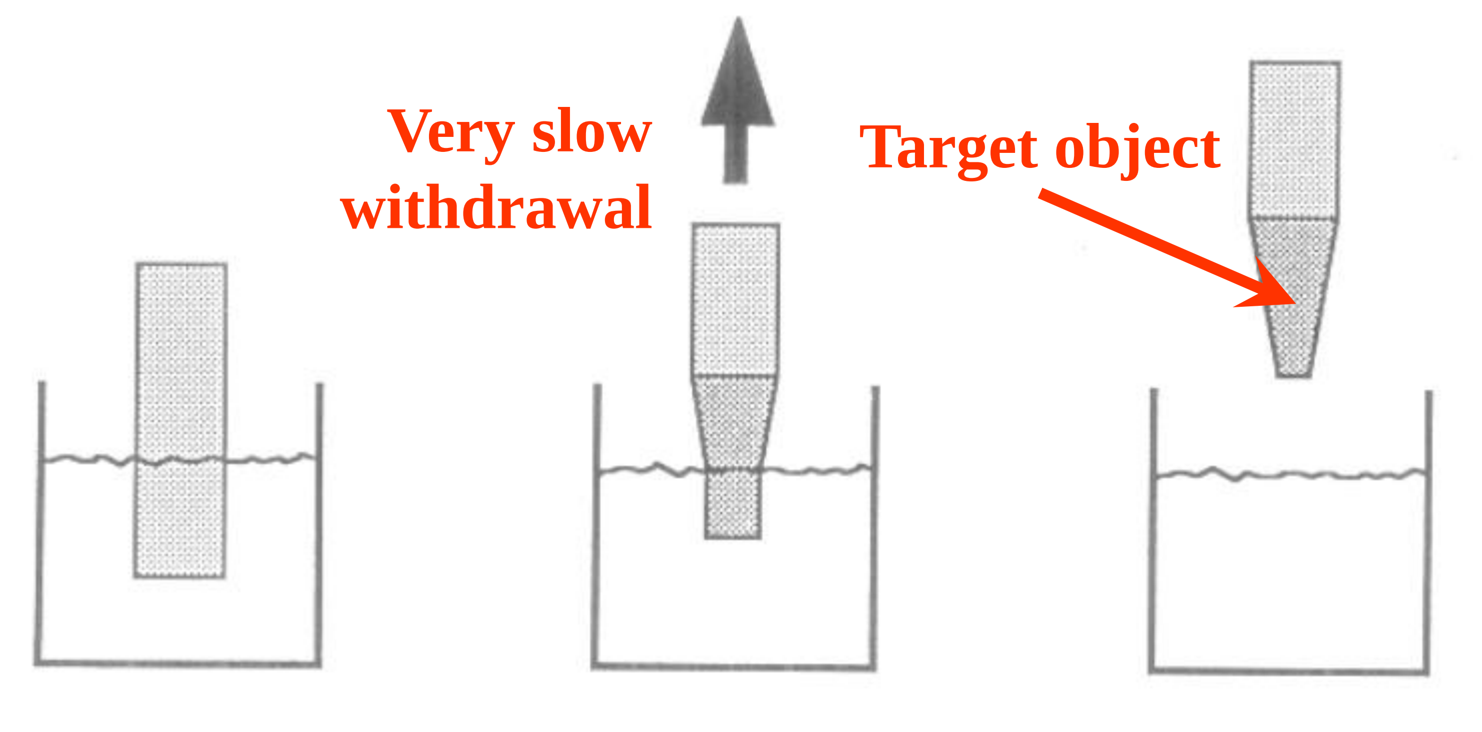
# Process Sequence in Stepped Etching



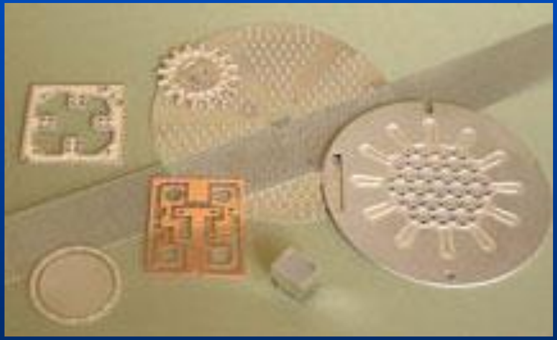

Target object

# Taper achieved in CHM through controlled volume withdrawal



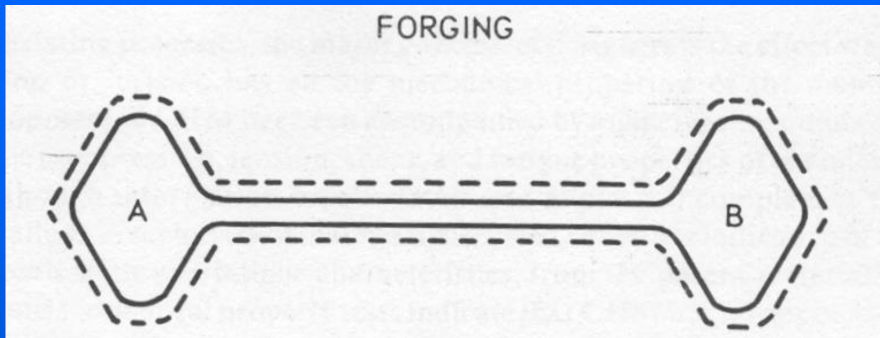
# Advantages of CHM

- No conventional tools & dies (as required in stamping process)
- Dimensional repeatability
- Design flexibility (from prototype to mass production)
- Low cost
- Metal properties remain unchanged
- Burr free, crack & stress free parts
- Well-suited for too complex, too thin as well as too small parts

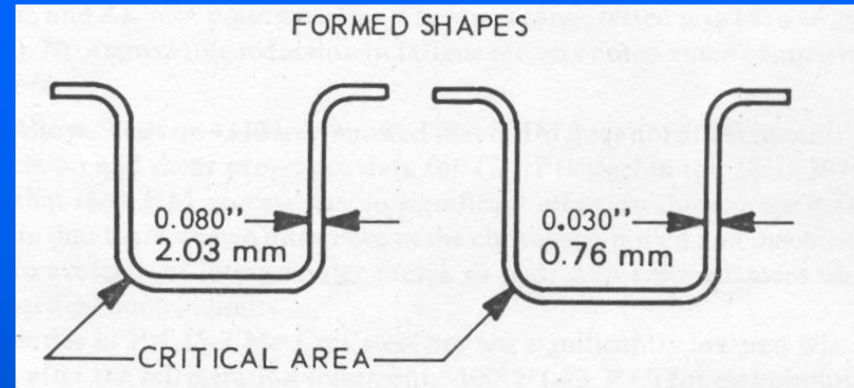


# Applications of Chemical Machining

# Finishing applications on forged/ formed/ machined parts




**Heavier ends A & B can be formed to desired thickness by forging, the thin central portion cannot**




**Properly formed hat section**


**This part was first machined oversize to provide vertical webs, then reduced overall by CHM to provide web sections thinner than conventional methods**