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✓ Advanced Manufacturing Processes (AMPs)

PHOTOCHEMICAL MACHINING

by

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Chapter Description

- Aims
  - To provide and insight on advanced manufacturing processes
  - To provide details on why we need AMP and its characteristics

- Expected Outcomes
  - Learner will be able to know about AMPs
  - Learner will be able to identify role of AMPs in todays sceneries

- Other related Information
  - Student must have some basic idea of conventional manufacturing and machining
  - Student must have some fundamentals on materials

- References

Lecture Notes of Mr. Wahaizad (Lecturer, FTeK, UMP)

CHEMICAL MACHINING

CHEMICAL MILLING

✓ PHOTOCHEMICAL MACHINING

✓ CHEMICAL MACHINING

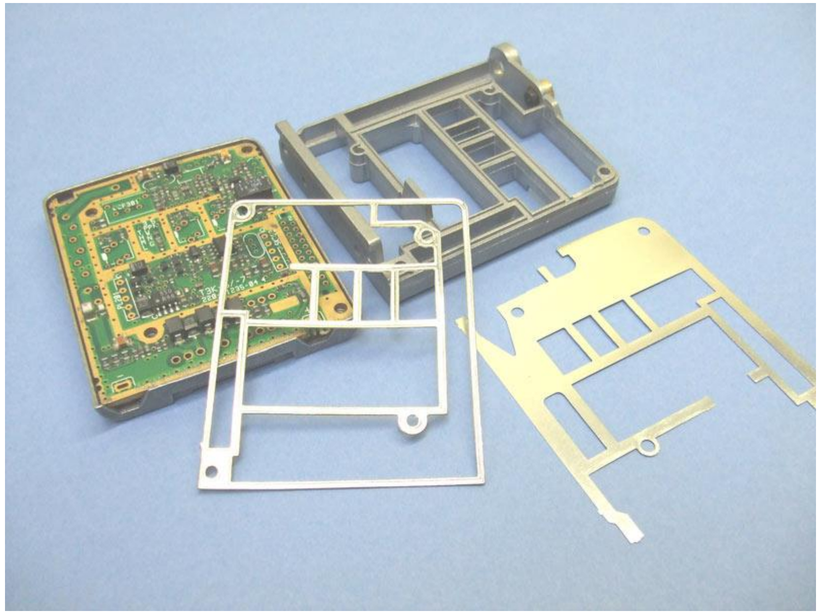
A material removal process to produce shape/ pattern on material (metal, glass, plastics, etc) by means of chemical **etching** (the etching medium is called **etchant** - acid, alkali) usually through a pattern of holes/apertures in adherent etch- resistant **stencil** (maskant/resist, photoresist).

PHOTOCHEMICAL MACHINING (PCM)

A material removal process to produce shape/ pattern on material by means of chemical **etching** through a pattern of holes/apertures in adherent etch- resistant **stencil**. The stencil is prepared using photosensitive resist (photoresist) and the phototool may be produced using microphotography.

✓ PHOTOCHEMICAL MACHINING (PCM)

- ❑ usually flat components from sheet material
- ❑ (less than 0.01 mm to greater than 1.5 mm)
- ❑ light-sensitive resist (photoresist),
- ❑ photographic technique for tool production.
- ❑ also known by different names:
    - Photoetching
    - Photochemical milling
    - Photomilling
    - Photofabrication
    - Chemical blanking
    - Chemical etching
    - Chemical fabrication
    - Chemi-cutting



✓ CHEMICAL MACHINING

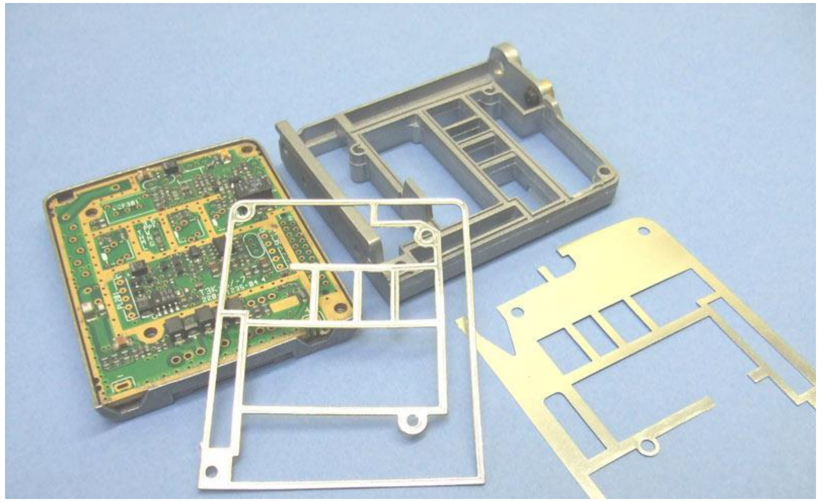
COMPARISON BETWEEN **PCM** and **CHM**

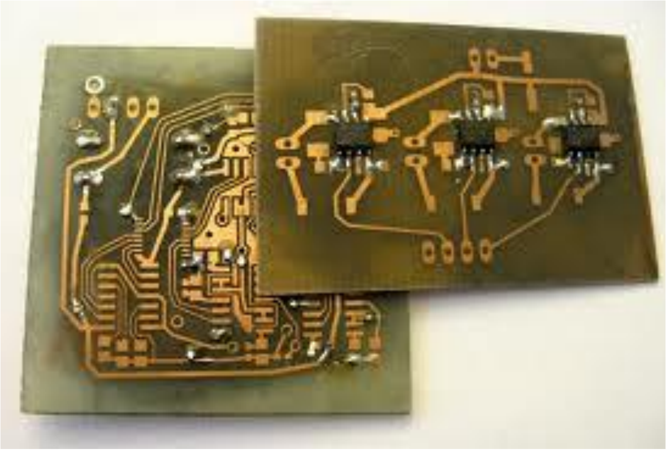
- ✓ CHM involves bulk material removal, in engineering application often involves structural components.
- ✓ PCM involves low depths of cut on flat sheet materials (either penetrating from both sides around the outline of a precision part, such as a shim; or cutting through a thin layer on to a backing board, such as copper on glass-epoxy board for a printed circuit; or etching on a surface).
- ✓ CHM employs a hard-metal template and hand scribing.
- ✓ PCM combines chemical etching with micro-photography and photosensitive maskant. PCM employs a photographically produced film transparency as a template.
- ✓ The benefits of photography and special maskant combined with low depths of cut give PCM an accuracy many orders of magnitude better than CHM.

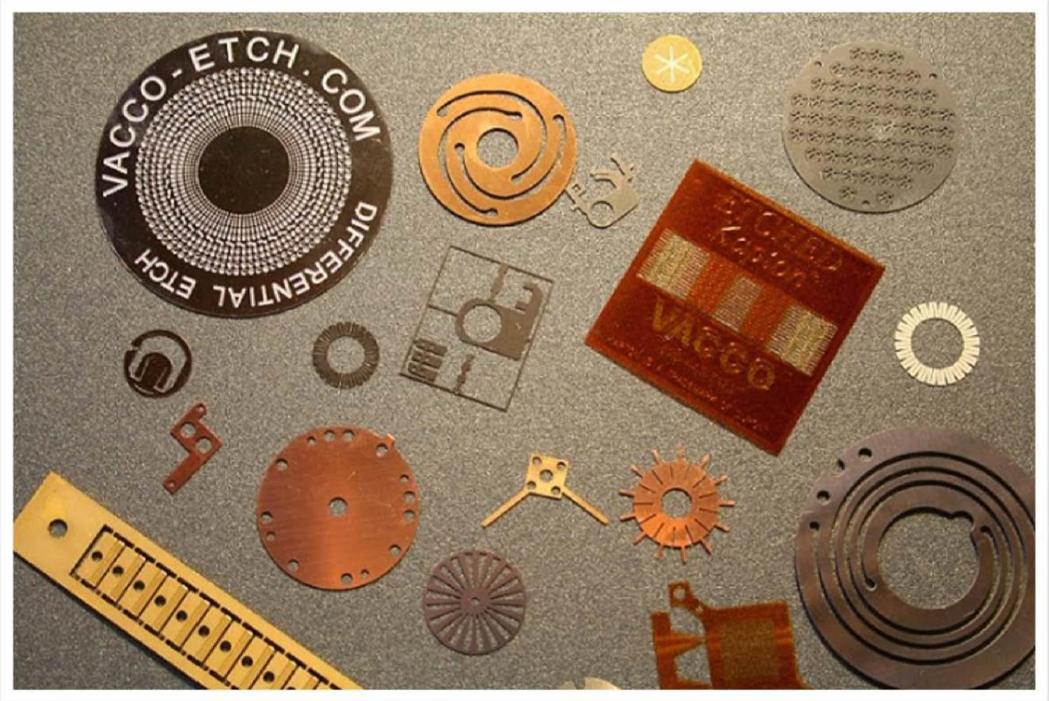
HISTORICAL DEVELOPMENT

TIME	RESIST	ETCHANT	APPLICATION/COMMENT
15 Century	Vinegar based Linseed-oil paint		Decorate *iron* plate armour
16 Century	*Wax, resin, other natural products*		*Iron or copper* plate for intaglio printing
19 Century		Hydrofluoric acid	Decorate *glassware*
1826 J. N. Niépce	Photoresist: *Bitumin of Judea asphalt*; Developer: lavender oil + turpentine		
1852 W. F. Talbot	Photoresist: *Bichromated gelatine*; Developer: water	Ferric chloride	*Copper*. Forerunner method for PCB
1888 John Baynes	Similar or dissimilar registered photoresist stencils		Perforations using two-sided etching
Early 20 Century	*Poly vinyl alcohol sensitised by bichromate salts*		Improved photoresist
Mid 1950s	Pre-sensitised *poly vinyl cinnamate* (KPR family of photoresists by Kodak)		Coincides with start of PCM industry
1960s	1. Positive working photoresist (Shipley AZ). 2. Dry film photoresist (Du Pont Riston)		

✓ PHOTOCHEMICAL MACHINING



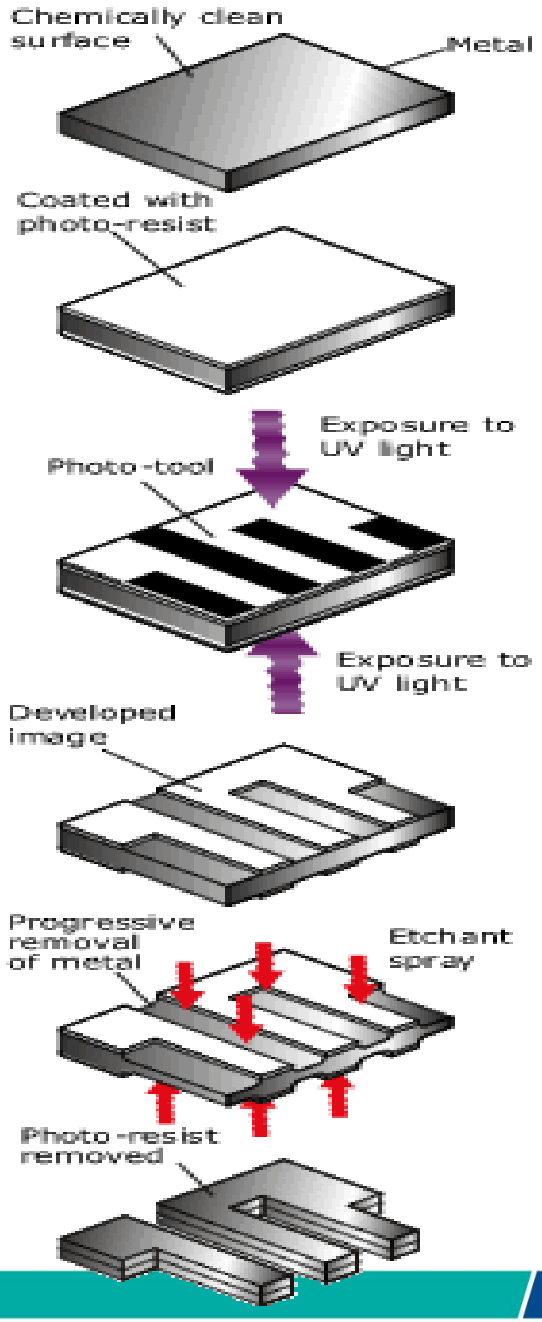




✓ PHOTOCHEMICAL MACHINING

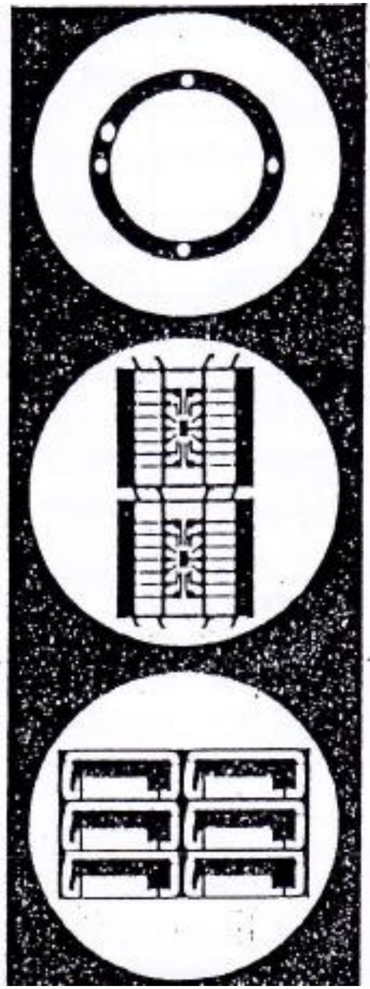
Typical applications include:

- EMI/RFI screening cans
- SMT solder stencils
- encoder disks
- springs
- connectors
- washers and gaskets
- boxes with fold lines
- contact pins
- lead frames
- actuators
- valve plates
- filter screens
- heat sinks
- perforated plates
- labels



✓ PHOTOCHEMICAL MACHINING

Absolutely burr free components



SHIMS

Absence of burrs eliminates critical spacing variations . . . . . . assembly becomes quicker and more accurate.

Delivery times reduced by up to 80%

LEAD FRAMES

Photofabrication replaces conventional tooling, resulting in reduced costs and waiting time.

Complete freedom from stresses

RECORDING HEAD LAMINATIONS

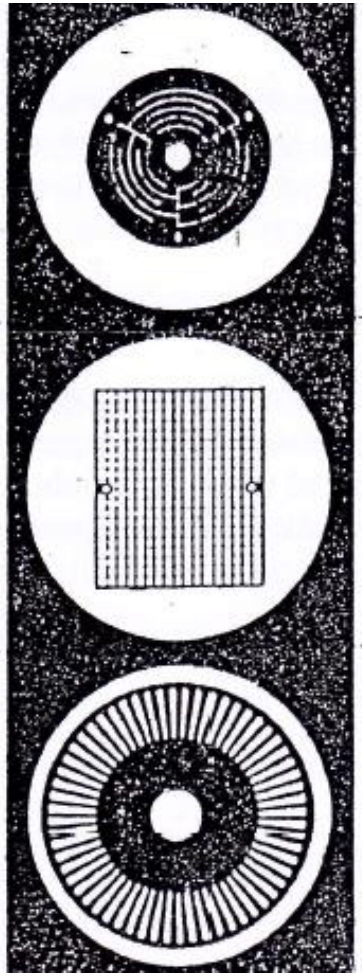
Improved recording head laminations pre-positioned and ready heat treated for fast easy assembly.

✓ PHOTOCHEMICAL MACHINING

Thick and thin shapes without distortion

Inexpensive complex shapes

Unlimited design flexibility



SPRINGS AND DIAPHRAGMS

Springs and diaphragms of any temper ...... no work hardening or conventional tool distortion.

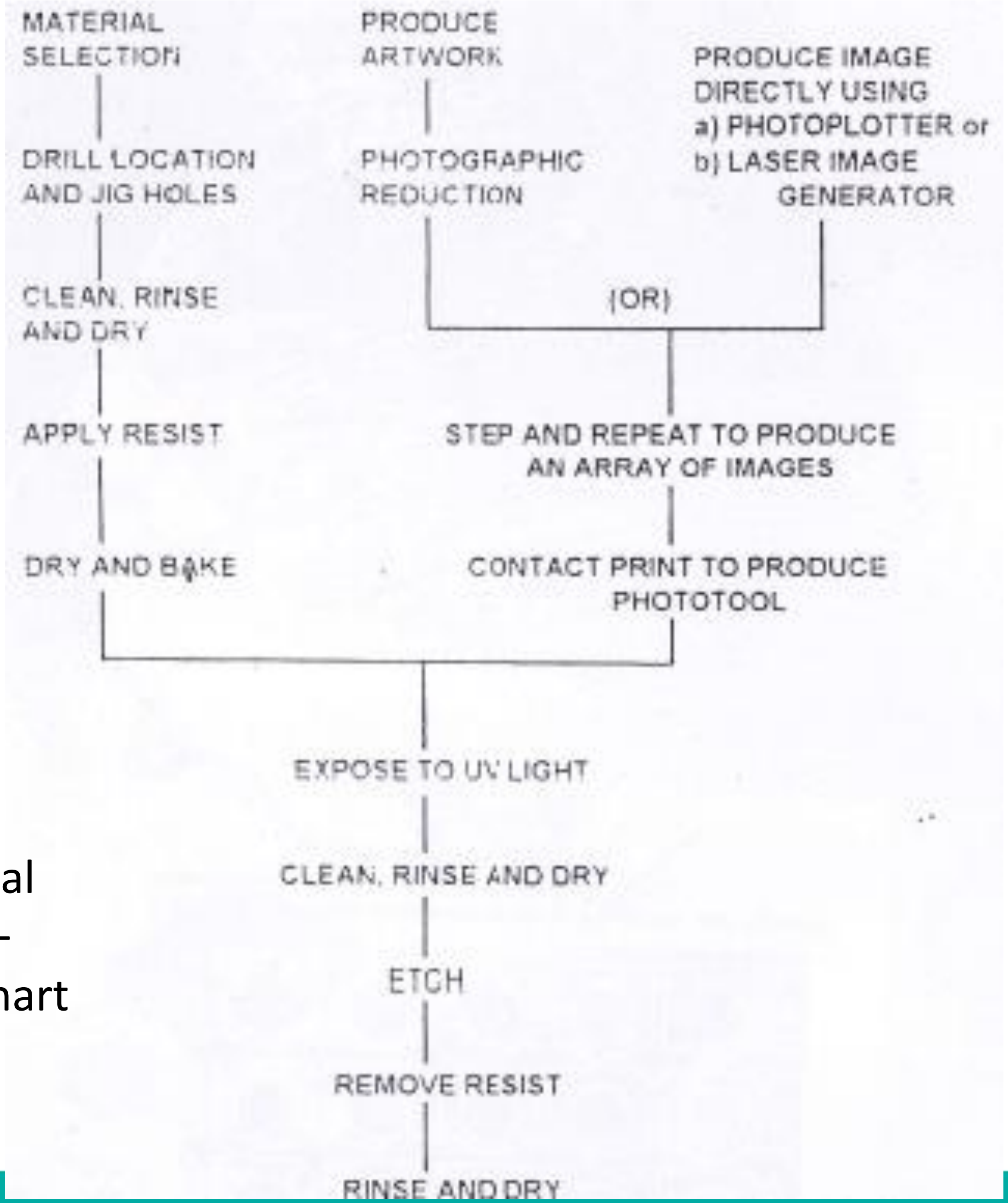
INTRICATE PROFILES

Fine detail ...... extreme complexity ...... many parts impossible to produce by other methods are "on" with Photofabrication.

ENCODER DISCS

Accurate, cheap and rapid manufacture of optical timing discs is easy with Photofabrication.

Photochemical Machining – Process flow chart



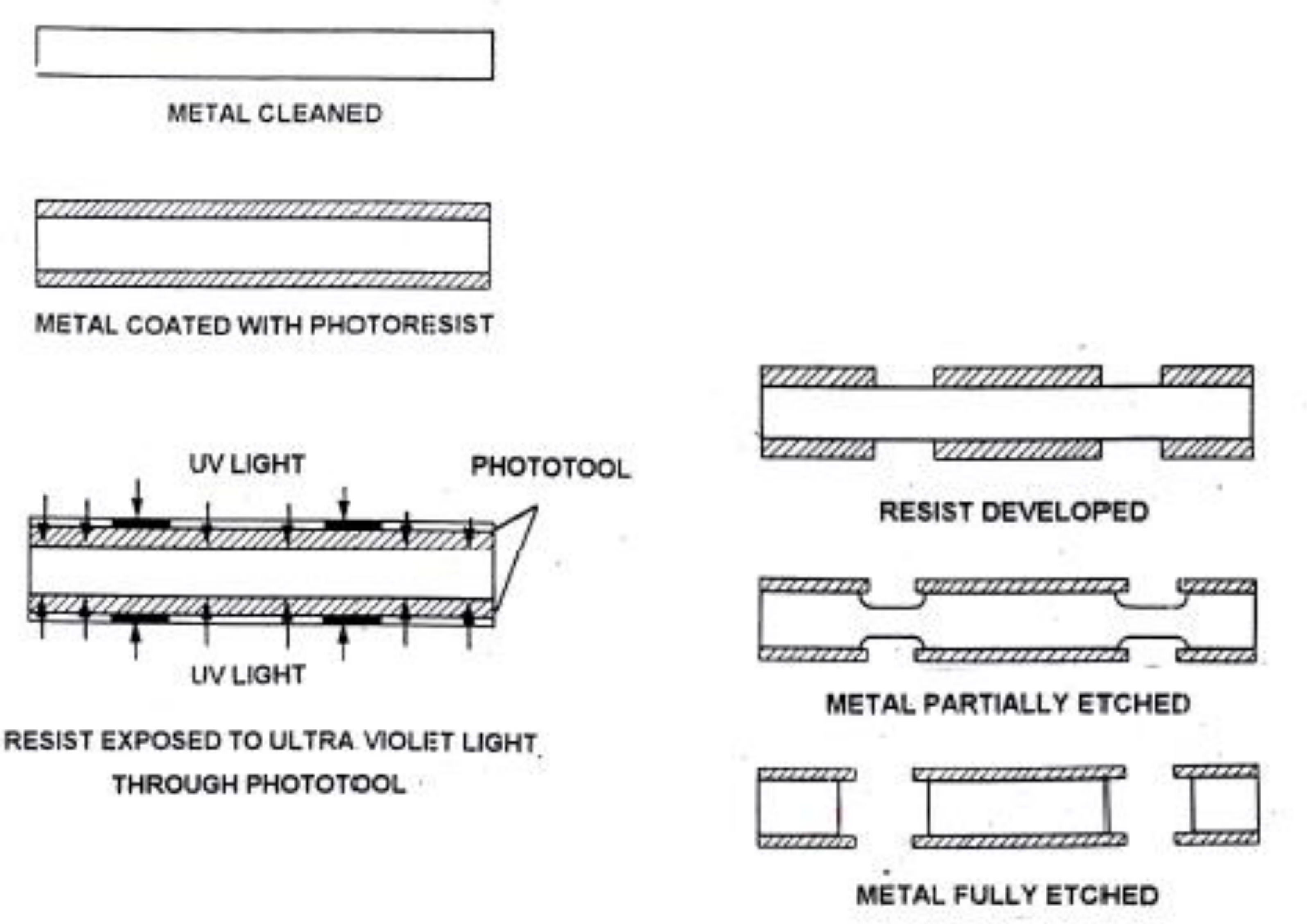


Figure: Steps in PCM

PHOTOCHEMICAL MACHINING (CHM)

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APPLICATION OF PHOTORESISTS

A. LIQUID RESIST:

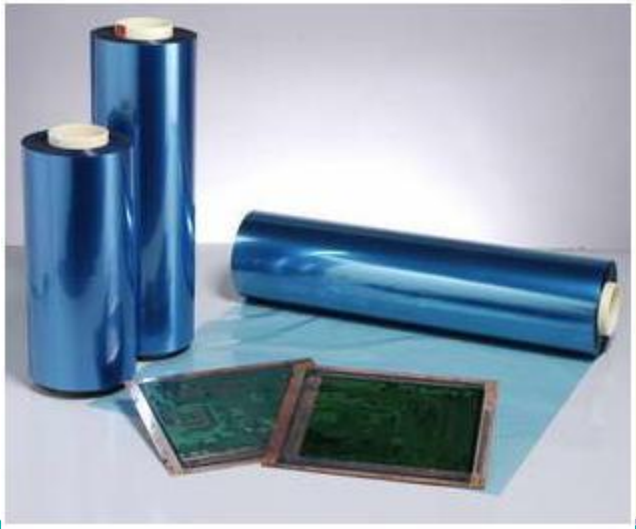
1. DIPPING – controlled withdrawal (wedging, both sides coated simultaneously).
2. FLOWING – pour resist, tilt substrate to spread and drain resist.
3. WHIRLING – pour resist, rotate at low speed (100s of RPM). Substrates can be large.
4. SPINNING – high speed whirling (1000s of RPM). For small substrates, eg. silicon slices.
5. SPRAYING – low viscosity resist, spray gun device is used.
6. ROLLER COATING – high viscosity resist, specialised machinery is needed.

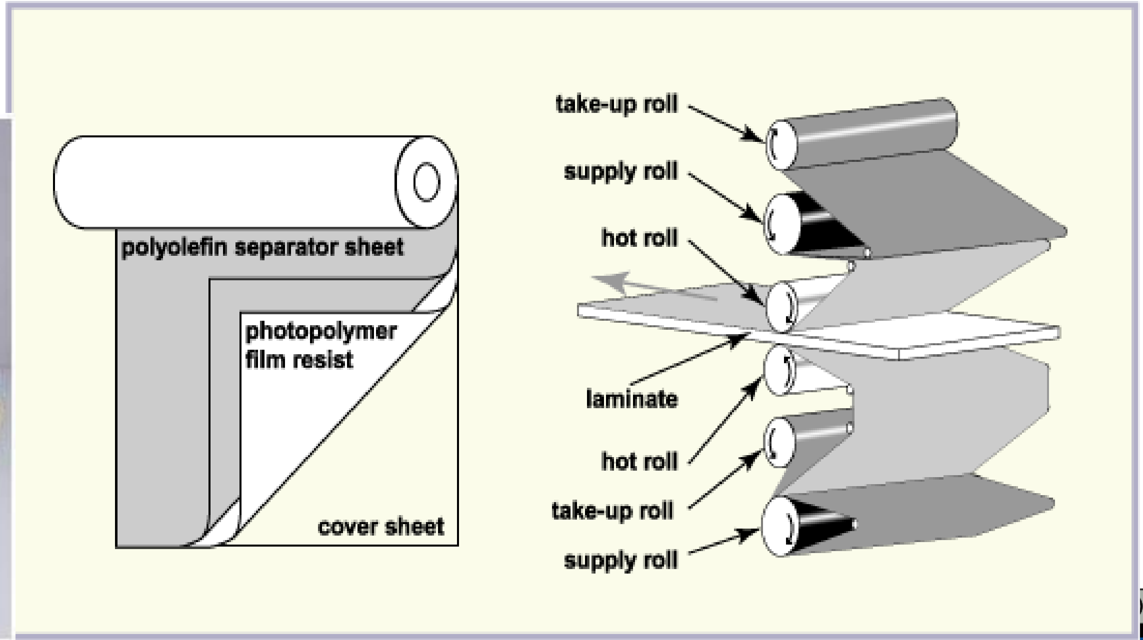
PHOTOCHEMICAL MACHINING (CHM)

APPLICATION OF PHOTORESISTS (cotd)

B. DRY-FILM RESIST (t = 15 – 100 microns):

HOT LAMINATION – remove polythene layer of the triple sandwich structure, apply resist on substrate with heat and pressure (heated roller). Both sides can be coated simultaneously using two rollers.





PHOTOCHEMICAL MACHINING (CHM)

ETCHING

Methods of etching:

- Dip etching in etching bath
- Spray etching (aqueous/liquid)
- Spray etching (gaseous)

A 3-compartment etching bath

Spray etching machine

A 5-compartment wet etching table

CHEMICAL MILLING

EXAMPLES OF ETCHANTS:

Stainless steel	Etchants based on nitric acid or hydrochloric acid or ferric chloride
Tool steel	Solution of ferric chloride and nitric acid
High tensile steel	Nitric and sulphuric acids
Aluminium	Ferric chloride, sodium or potassium hydroxide solutions (10 to 20 %)
Copper	Ferric chloride
Nickel alloy	Etchants based on nitric acid or hydrochloric acid (eg 50 % hydrochloric acid, 17 % nitric acid, 10 % sulphuric acid)
Magnesium	Etchants based on sulphuric or nitric acid
Titanium	Etchants based on hydrochloric acid, usually mixed with chromic or nitric acid.
Glass, ceramics	Etchants based on hydrofluoric acid
Plastics	Chromic-sulphuric-phosphoric acid etchant (ABS, PP), sodium-aryl solution (PTFE)
Zinc	Etchants based on nitric acid or hydrochloric acid

PHOTOCHEMICAL MACHINING (CHM)

Etching Rate

Workpiece is etched for a duration necessary to produce the required depth of etching.

If depth of etch = s (μm) or (mm)
etching time = t (min)
rate of etching = E [per side]

$E = s/t$ (μm/min) or (mm/min)

Example: *If thickness of material is 3.0 mm, etching time is 10 min and thickness of material after simultaneous etching from both sides is 2.5 mm,*

$$E = \frac{3.0 - 2.5}{2 \times 10} = \frac{0.5}{20} = 0.025 \text{ mm/min or } = 25\ \mu m/\text{min}$$

PHOTOCHEMICAL MACHINING (CHM)

Etching Rate (cotd)

If milling to 1 mm depth is required,

etching time, t = 1.0/0.025 = 40 min
(assuming uniform etch rate)

Etch rate for a particular work material depends on:
- ✓ Etchant concentration
- ✓ Etching temperature
- ✓ Workpiece material type
- ✓ Heat treatment experienced by work material

PHOTOCHEMICAL MACHINING (CHM)

Etchant Concentration

Expressed in degree Baume' (°Be').

$$°Be' = 145 \times \frac{(s.g. - 1)}{s.g.}$$

Where s.g. is specific gravity, measured using a **hydrometer** of a suitable reading range or a **digital density meter**.

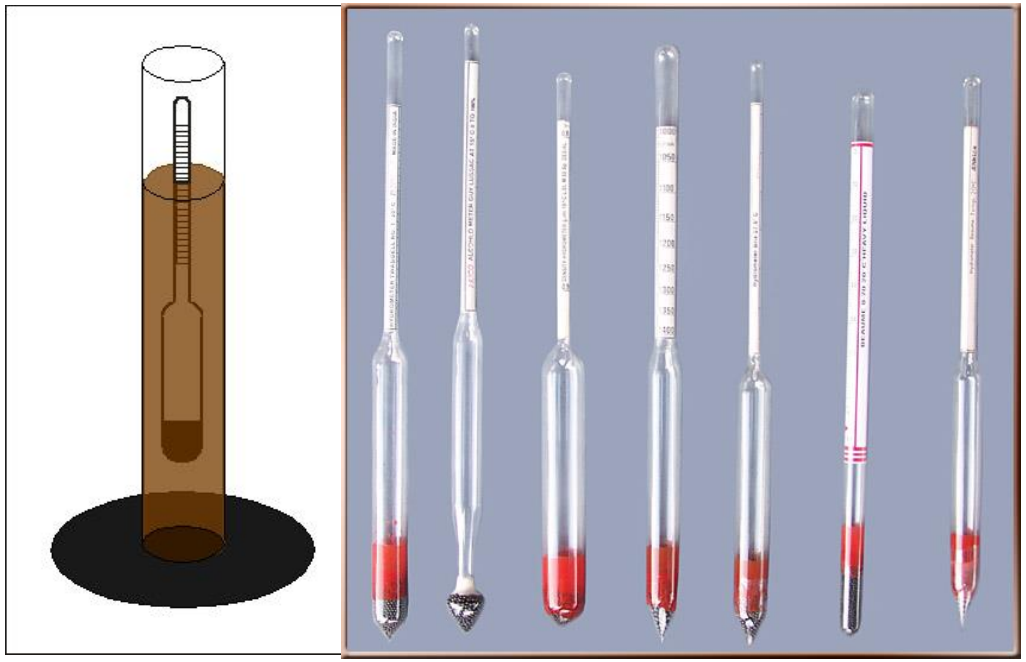
To obtain a particular concentration in °Be', the etchant is diluted to a corresponding value of specific gravity:

$$s.g. = \frac{145}{(145 - °Be')},$$

PHOTOCHEMICAL MACHINING (CHM)

Measurement of etchant concentration

digital density meter



Hydrometer

PHOTOCHEMICAL MACHINING (CHM)

Etchant Concentration (cotd).

Example: *The s.g. of a ferric chloride solution is 1.45. What is its concentration in °Be'? It needs to be diluted to 25°Be'. What should the hydrometer reading be?*

$$°Be' = 145 \times \frac{(1.45 - 1)}{1.45} = 45°Be'$$

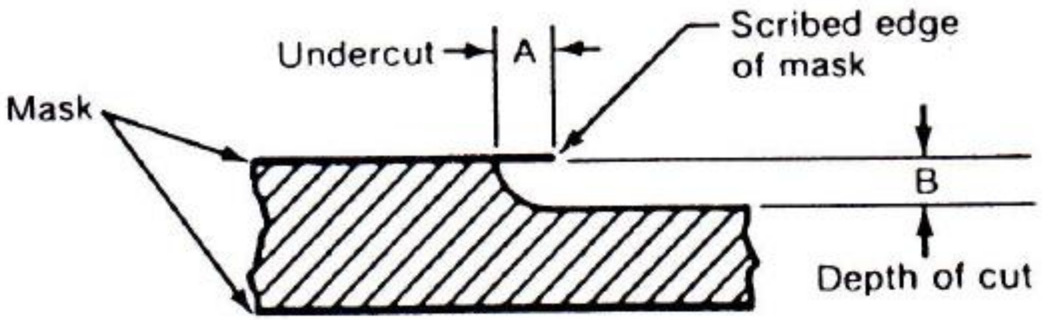
$$s.g. = \frac{145}{(145 - 25)} = 1.208$$

CHEMICAL MACHINING

Control of Dimensions

In chemical machining (CHM, PCM), two types of dimension need to be controlled:

1) **Depth** of etch (or thickness) of part after etching
2) Dimensions in **lateral** (ie horizontal) direction
   (eg hole diameter, width of pocket and land)



$$\text{Etch factor} = \frac{\text{Depth of cut}}{\text{Undercut}} = \frac{B}{A}$$

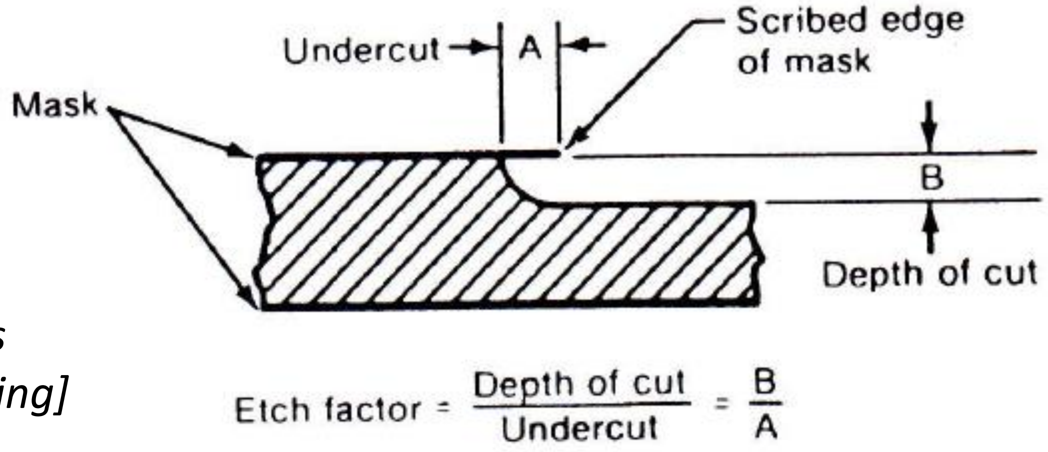
[Note: PCM does not involve scribing]

CHEMICAL MACHINING

Control of Dimensions (CHM, PCM)

Tolerance on thickness after etching is influenced by:

- ✓ Variations in **etching** operation
- ✓ Tolerance on workpiece thickness **before etching** (ie material is removed with original workpiece surface as reference)



[Note: PCM does not involve scribing]

CHEMICAL MACHINING

Control of Dimensions (cotd)

Dimensions in lateral/horizontal direction is influenced by:

- ✓ Variations in etching operation
- ✓ Side/lateral etching which needs to be compensated
- ✓ Accuracy of phototool
- ✓ Accuracy of stensil making

CHEMICAL MACHINING

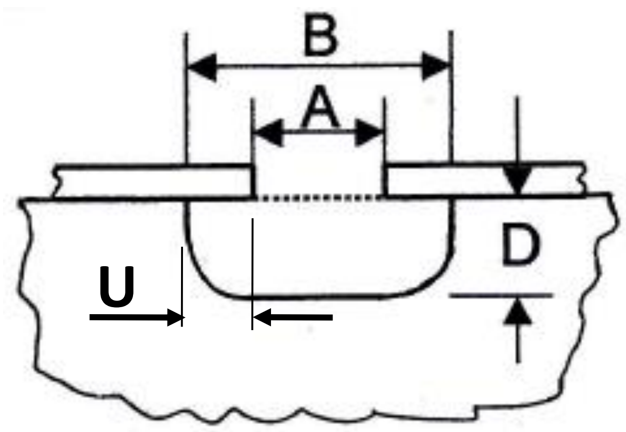
Control of Dimensions (cotd)

ETCH FACTOR

Etch factor is the ratio of inward etching to lateral etching.
It is sometimes used as a measure of etching efficiency.

side/lateral etching, $u = \frac{B - A}{2}$
(or undercut)

Etch factor, $EF = \frac{D}{u} = \frac{2D}{(B - A)}$,



ARTWORK

Enlarged artwork is produced on artwork material (such as Rubylith), a coloured (red, yellow, etc) **strippable plastic layer** coated on to dimensionally stable, clear **polyester base**.

Coordinatograph – extremely **accurate draughting machine** equipped with a marking tool (points defined as **cartesian** coordinates [x, y], and with a rotary table, the **polar** coordinates [r, θ]. Accuracy: **± 0.02 mm** (linear), **± 10”** of arc (angular).

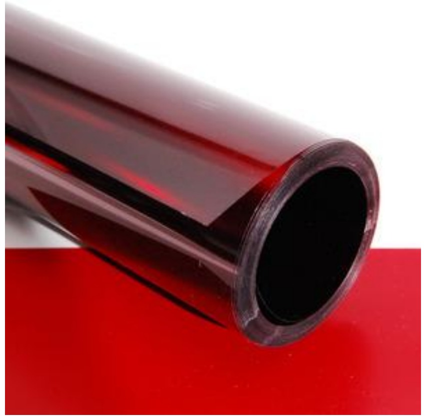
Draughting – usual method is to scribe with a **scalpel** blade into the artwork material and **peeling** the coloured layer.

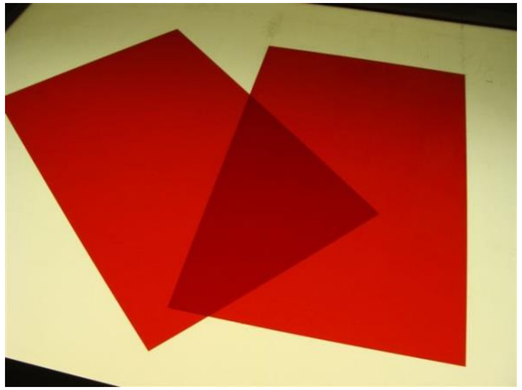
Magnification – 2 to 250 x mask size depending on tolerance required.

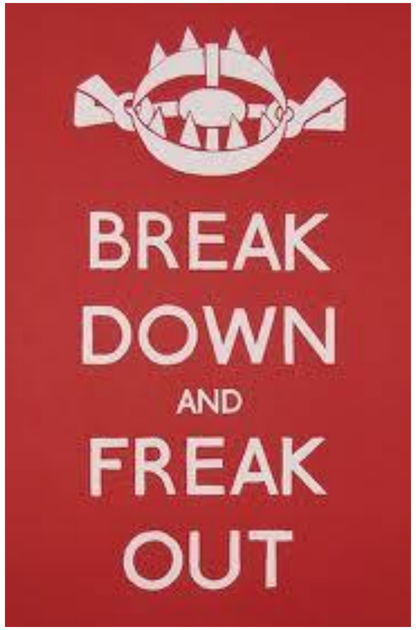
$$\text{Mask tolerance} = \frac{\text{artwork tolerance}}{\text{reduction factor}}$$

ARTWORK

Enlarged artwork is produced on artwork material (such as Rubylith)

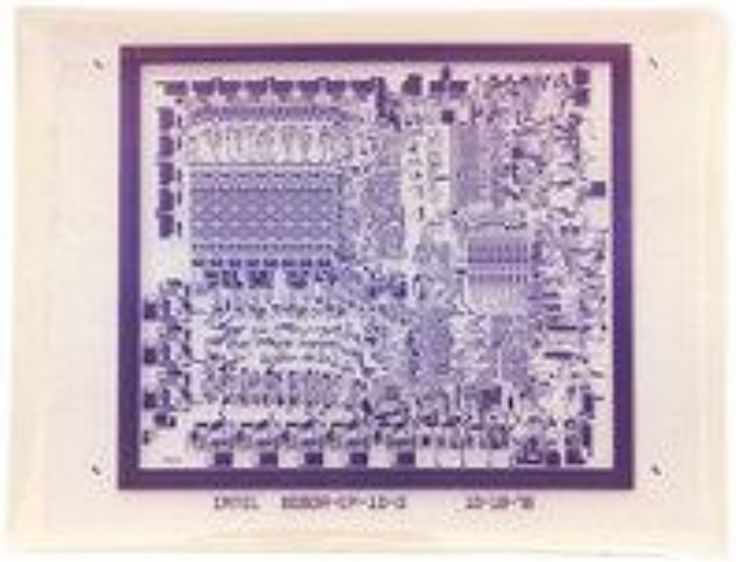






ARTWORK

Rubylith operators
Operators hand cut IC designs onto rubylith film, which is then optically reduced to create a photographic mask

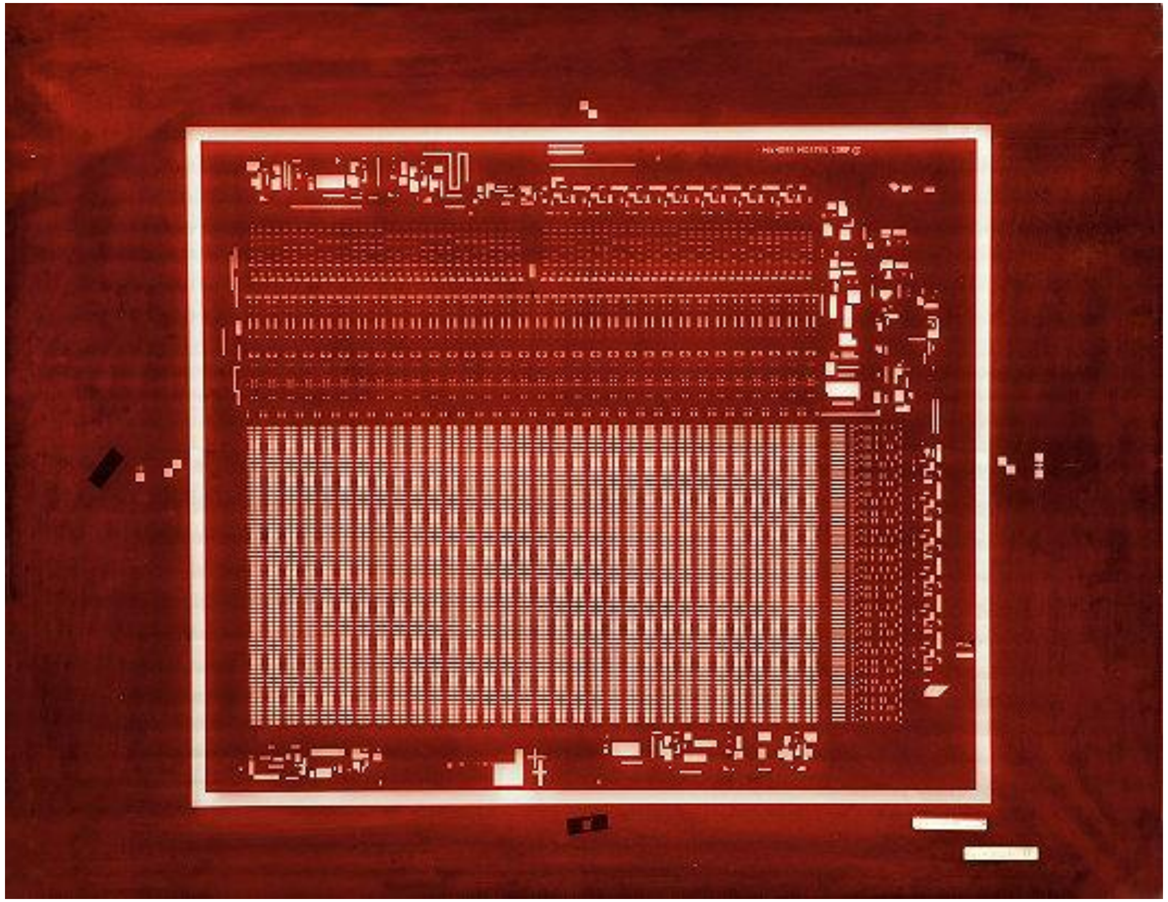


Intel 8080A microprocessor mask design transparent overlays

As ICs grew to millions of transistors, computers are used to design circuits, programming each step in high-level languages that automate the process.
The detailed chip layouts are now also generated automatically.

ARTWORK

Dimensions:
1130 mm x 1448 mm
x 6.35 mm



Mask Rubylith Layer for 4K DRAM

This mask layer for the Mostek MK4096 4K DRAM has been prepared for photographic reduction onto a glass plate. The design was transferred to the Rubylith film and selected areas cut and stripped by hand to create the pattern

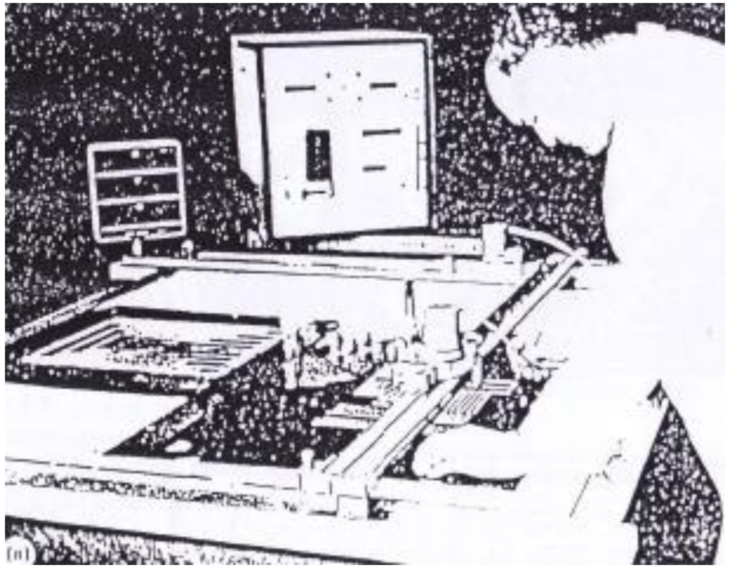
Limitation of artwork size:

1. artwork outside dimensions cannot exceed wotk area of coordinatograph (eg. a circle of 800 mm diameter for the Aristo 4438).

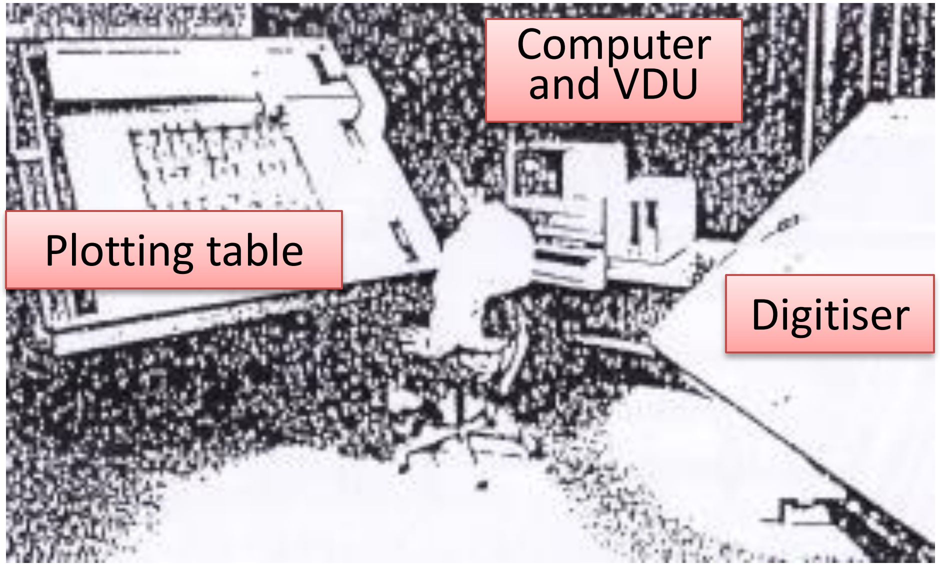
2. smallest feature on artwork is 0.4 mm wide (for ease of stripping).

3. range of reduction factors on a first reduction camera lens is limited (eg. Carl Zeiss 60 mm f/4 S-Planar Lens is only suitable for R= 13 to 30).

✓ PHOTOCHEMICAL MACHINING



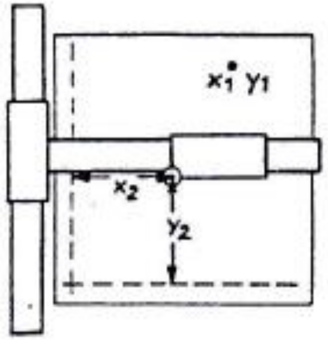
Coordinatograph machine



CADART system for CAAG (computer aided artwork generation)

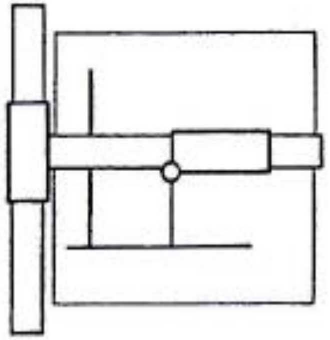
The Coordinatograph

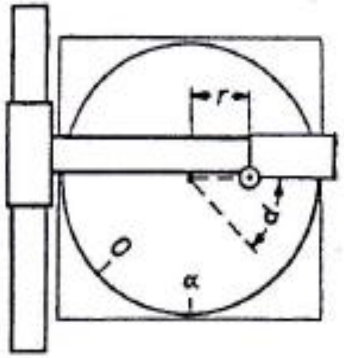
Potentialities in Principle



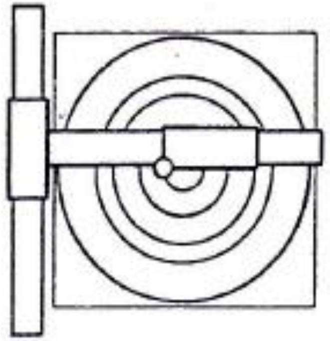
① Plotting points from rectangular coordinates

② Drafting lines parallel and perpendicular to each other



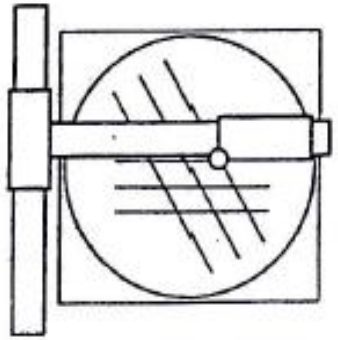


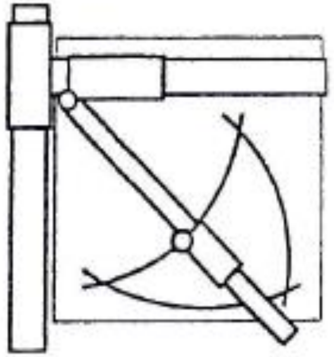
③ Plotting points from polar coordinates and constructing angles



④ Drafting concentric circles and circular arcs

⑤ Drafting sets of parallels at desired angles, one to another

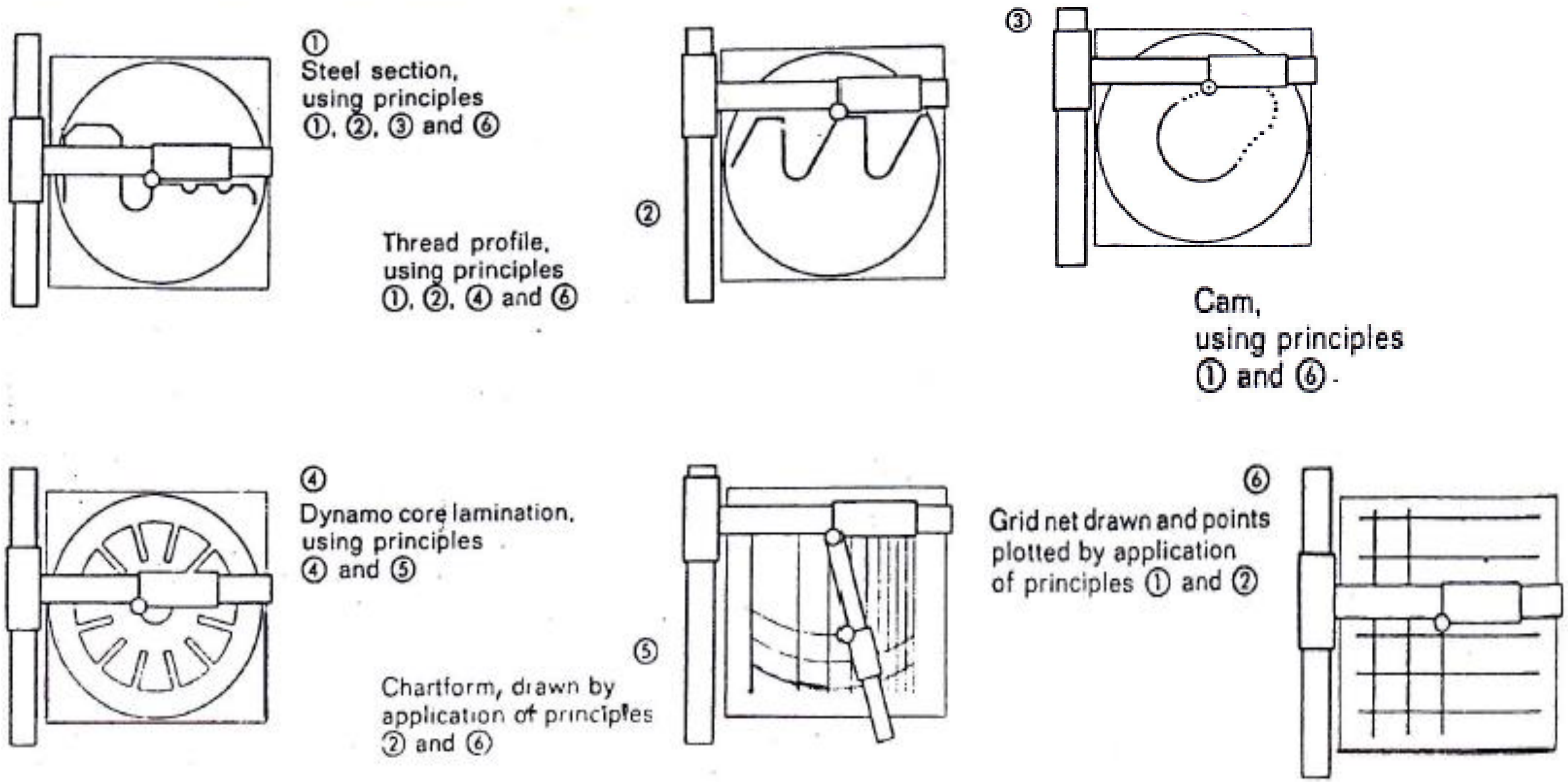




⑥ Describing circles or circular arcs, with a beam compass, about a point located by coordinates

The Coordinatograph

Examples of Practical Application



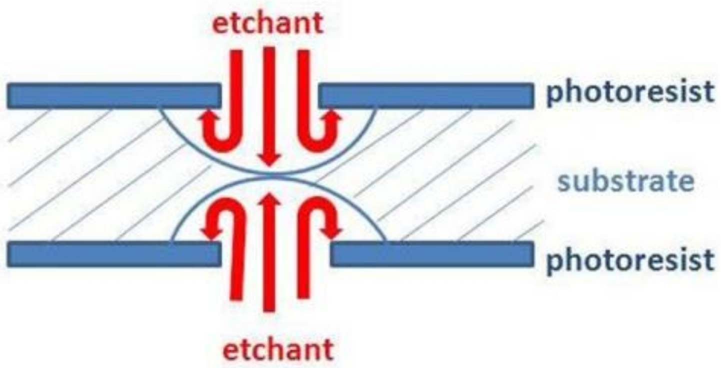


Figure: Cross section through etched profile in PCM

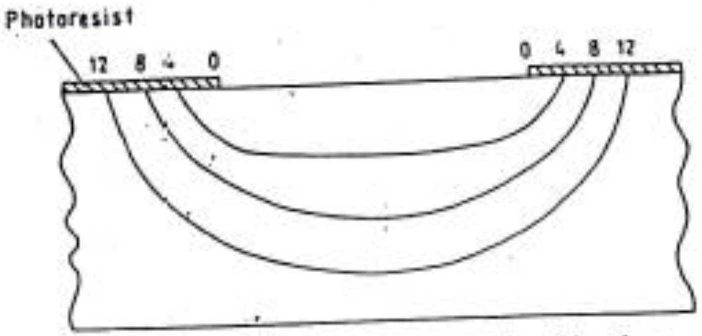


Figure 7.1 Development of profile with etching time.

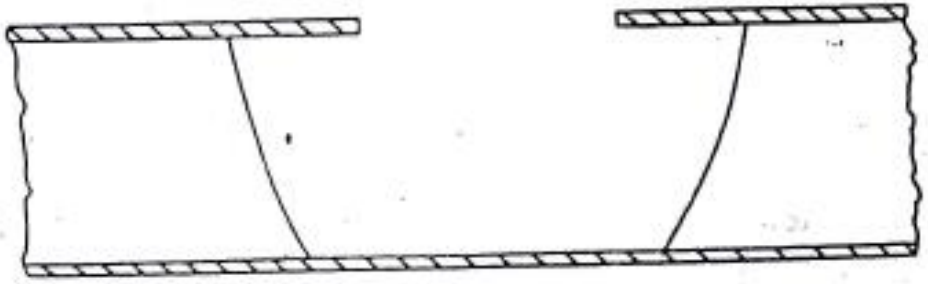


Figure 7.2 Single-sided etch profile.

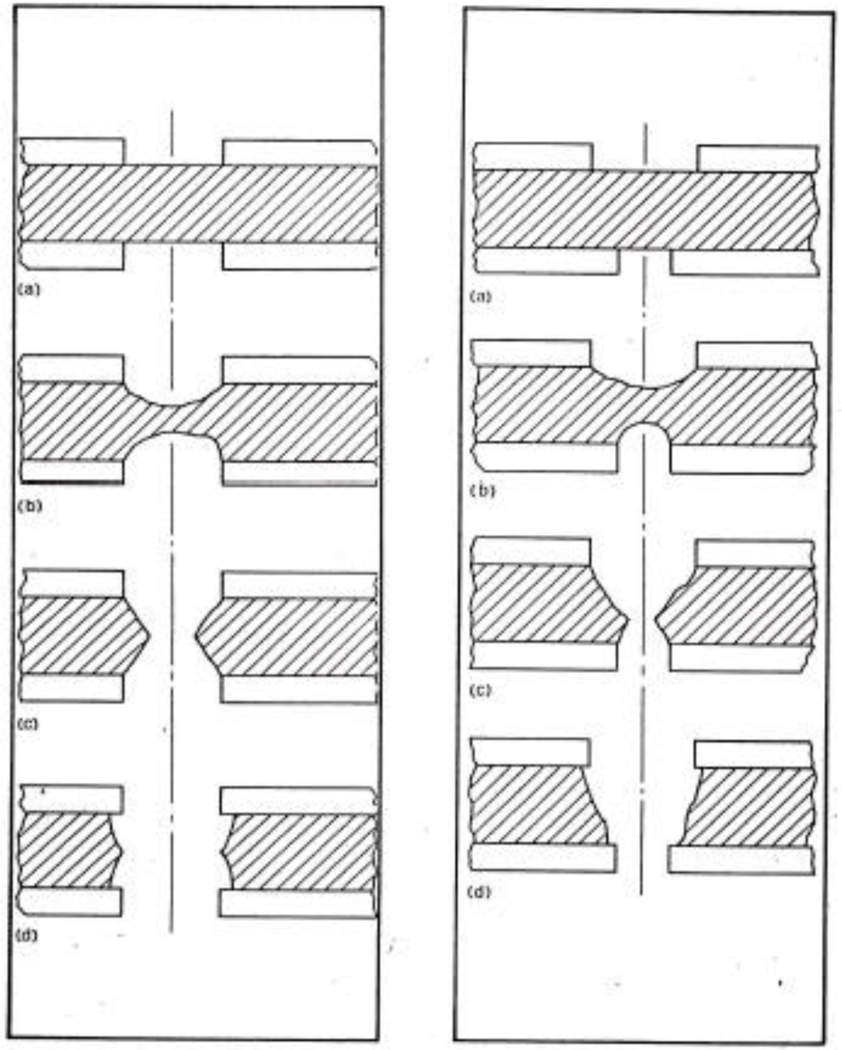
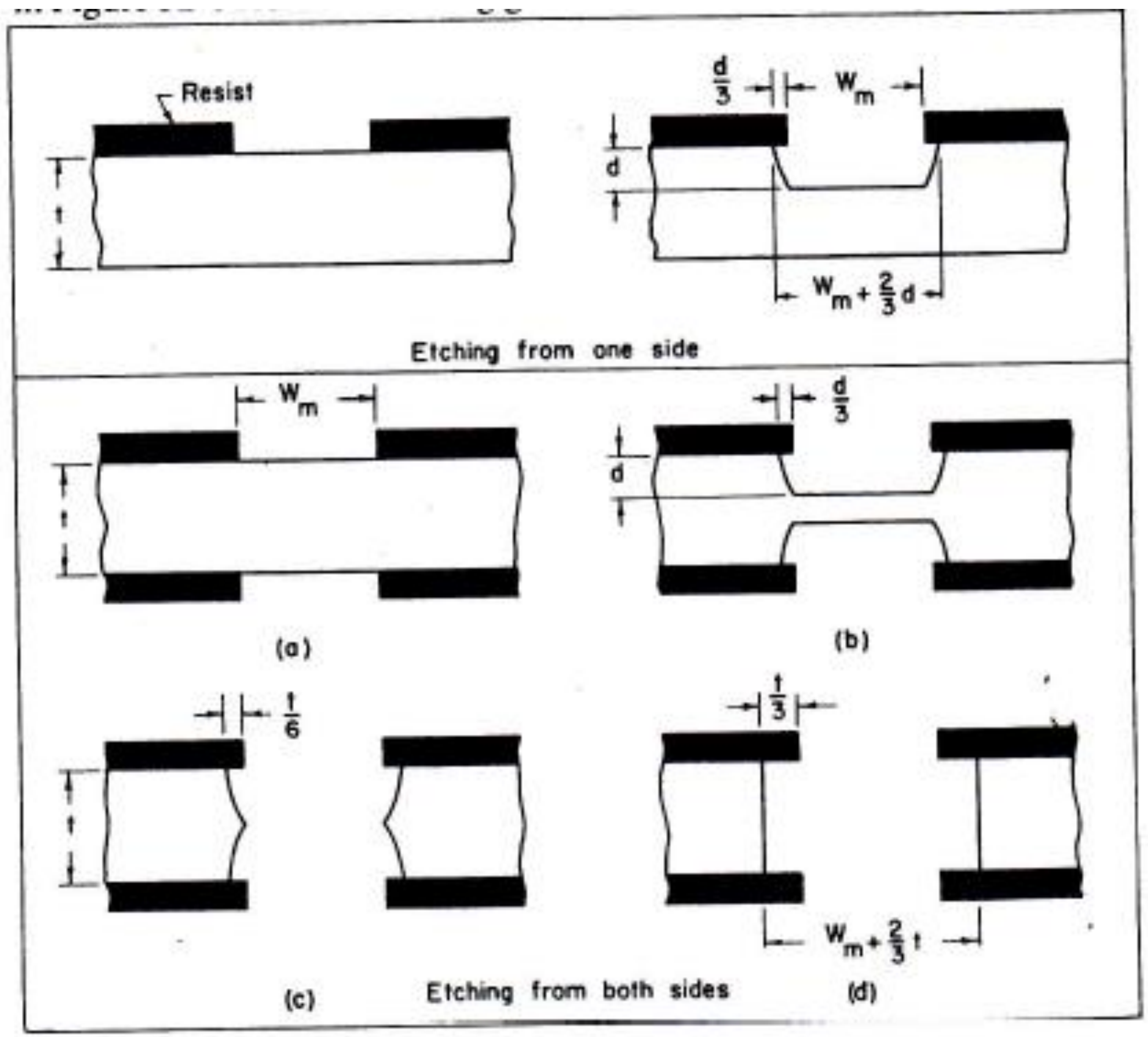


Figure: Double-sided through etching (a) 'straight hole' (b) tapered hole



Resist
d/3
W_m
d
t
$W_m + \frac{2}{3}d$
Etching from one side
W_m
d/3
d
t
(a)
(b)
t/6
t/3
$W_m + \frac{2}{3}t$
(c)
Etching from both sides
(d)

ARTWORK DESIGN

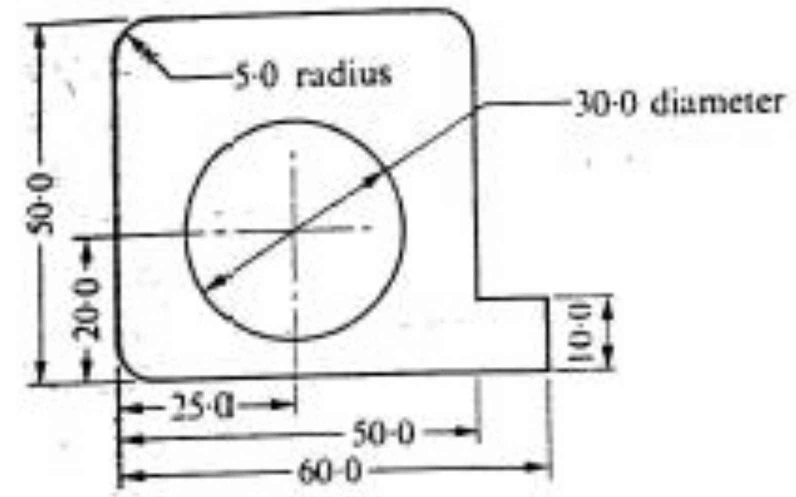
Etching allowance – the artwork dimensions are made to match those of the component <u>plus or minus</u> the etching allowance due to undercut (side etching).

Three types of dimensions:

1. Dimensions that **decrease** with etching time. Examples: outside dimension, distance between an edge and a hole centre.
2. Dimensions that **increase** with etching time. Examples: hole diameter, width of slot.
3. Dimensions that remain **constant** with etching time. Examples: angle, distance between centres.

For types 1 and 2, dimensions may decrease/increase from **one** direction or **both** or all around.

ARTWORK DESIGN



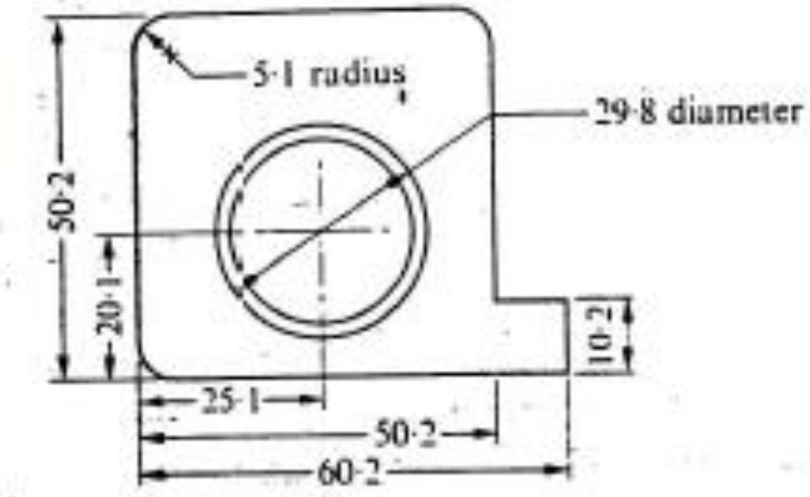
(a) Original drawing of part

Material thickness 0·2 mm
Etch factor for material 1.0,
thus etch allowance 0·1 mm
per side

For two-sided etching, t = 0.1

EF = 1 = D/u

u = D/1 = 0.1/1 = 0.1 mm



(b) Artwork dimensions

Etch band

– a line with uniform width drawn on the artwork and hence reproduced on the stencil.

Reasons for using etch band:

- ✓ To obtain **uniform profiles** on all edges. Rate of etching is dependent on stencil line width.
- ✓ To **conserve etchant**.

The width of the etch band on the mask should be equal to the width of the smallest aperture on the mask or approximately 0.8 mm if the smallest aperture is wider than 1 mm.

Etching tabs

– triangular bridges across and along the outside etch band, with apex towards the component. This apex should be etched almost to a point (0.1 mm) after processing.

Functions of tabs:

- To prevent components separating from the main sheet and lost in the etchant.
- To prevent components becoming entangled.

Verification marks

– to allow verification of reduction factor.

Registration marks

– to allow exact superimposition of dissimilar masks for:

- manufacture of part that requires use of several phototools, eg: microelectronic devices
- double-sided etching.

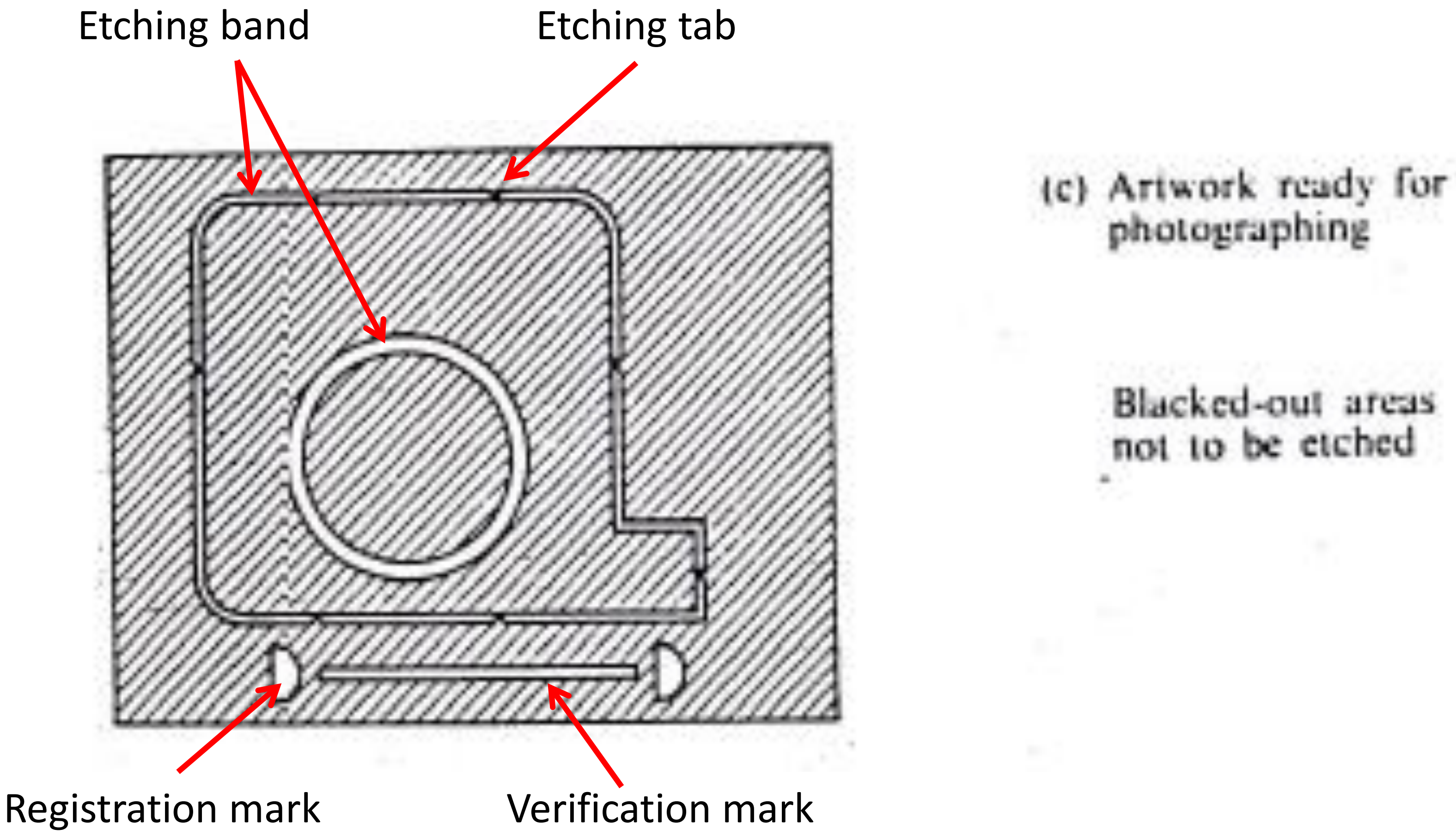
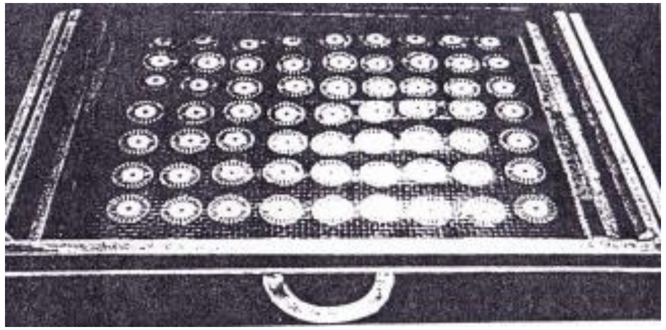


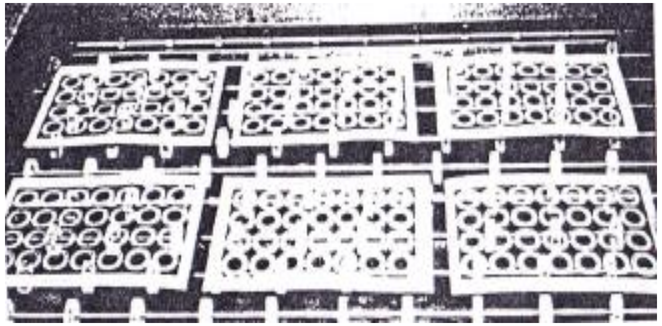
Figure: Artwork showing etching band, etching tabs (or tie-ins), registration mark and verification mark

Methods of holding workpieces

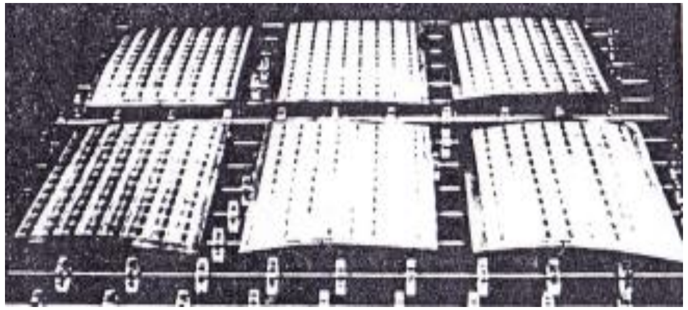
1. "Drop-out etching"



2. Tabbing



3. Back-coating



4. Racking

PHOTOTOOL MANUFACTURE

Microphotography – the making of small photographic precision images by reduction techniques.

Photographic materials – light sensitive materials used for phototool manufacture. They can be line films, lith films or HR (high resolution) films and plates.

A **photographic material** consists of two layers, the light sensitive emulsion and the support.

The **emulsion** consists silver halide (chloride, bromide, iodide) grains in a gelatine matrix.

The **support** may be (in increasing order of dimensional stability) **cellulose acetate**, **polyester** (films) or **glass** (plate).

PHOTOTOOL MANUFACTURE (cotd)

Extreme Resolution Photography (ERP) – an extended microphotography used in making the finest line images.

ERP requires:

- HR emulsions (resolution – 2000 lines/mm)
- a perfect (aberration-free) diffraction-limited lens
- a precision focusing system.

PHOTOTOOL MANUFACTURE (cotd)

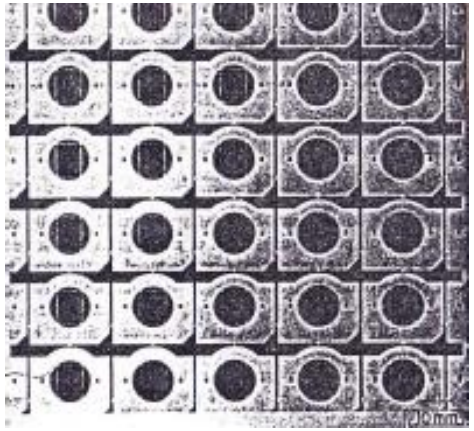
Exposure – the exposure that the emulsion receives is the product of the light intensity and the duration that the shutter remains open. Exposure produces a silver atom as a speck (but invincible/ latent) on the silver hallide grain.

Development – the bathing of the latent image in a chemical formulation (developer) to amplify the image and render it visible. The silver halide grains that contain the silver specks are converted to silver grains whilst unexposed grains remain unaffected. Development is done under appropriate darkroom conditions.

Fixing – washing away of remaining silver halide grains from the gelatine by dissolving them in sodium (or ammonium) thiosulphate solution (known as hypo or fixer).

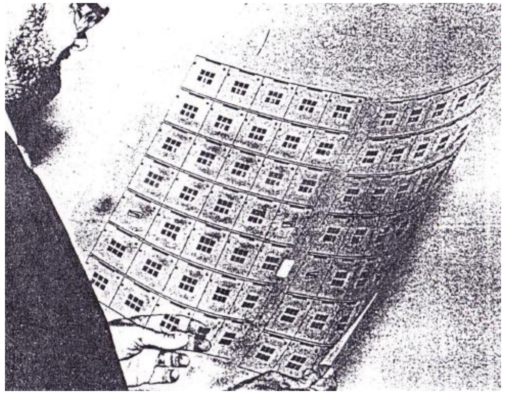
PHOTOTOOL MANUFACTURE (cotd)

Phototool



A typical phototool consisting of **stepped and repeated** images

Photomaster



A pair of mirror image photomasters which are used to print the pattern of the part on to the photoresist

Tolerance in PCM

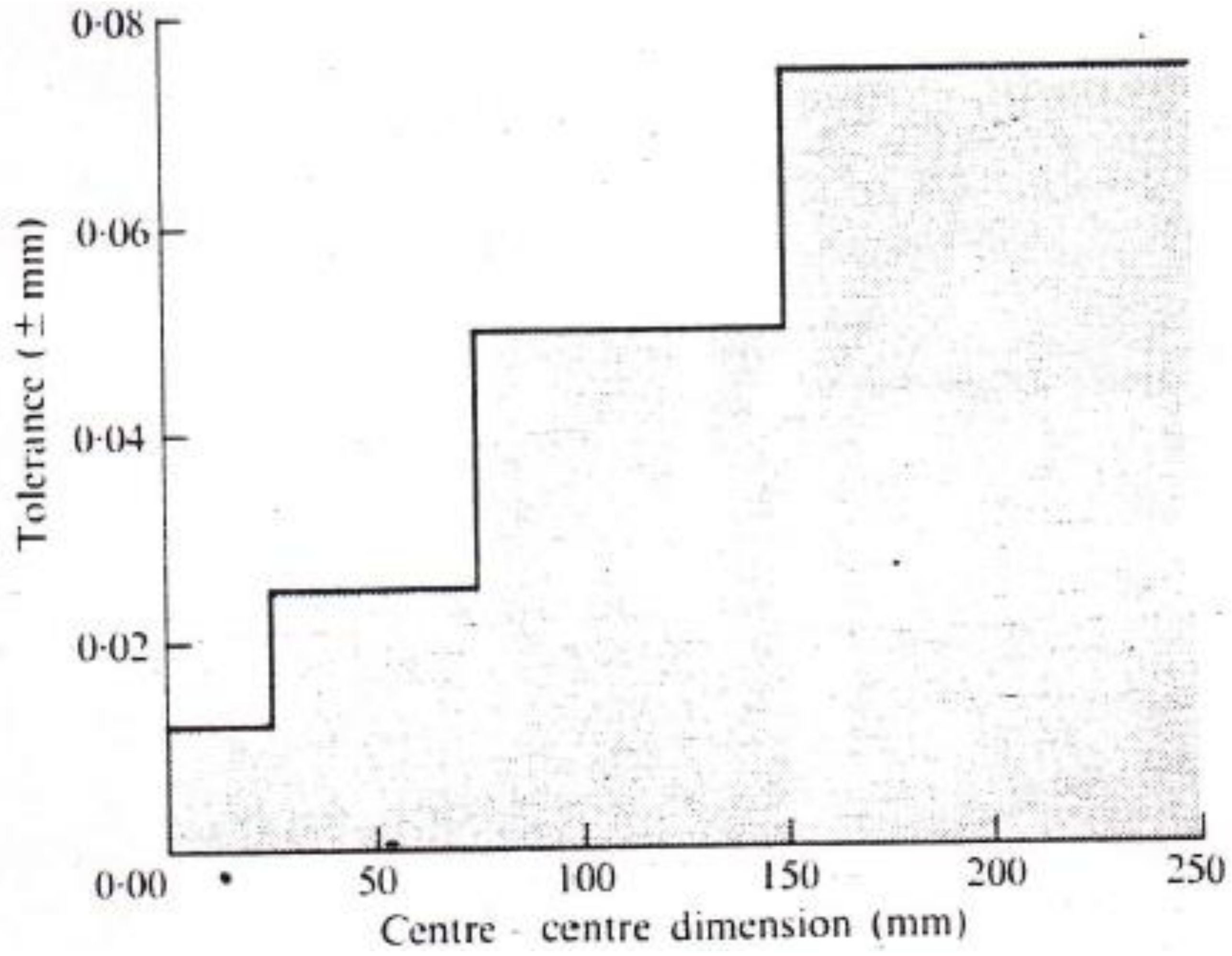


Figure: Practical tolerance on centre-to-centre dimensions in PCM

Tolerance in PCM

Table V-3
Standard PCM Tolerances for Common Materials

Workpiece Material	Tolerance, mm — Workpiece Thickness, mm: 0.025	0.050	0.013	0.25	0.38	0.50
Copper, copper alloys and glass sealing alloys (Nicoseal*)	±0.005	±0.013	±0.025	±0.038	±0.063	±0.089
Nickel-silver	±0.013	±0.025	±0.025	±0.038	±0.063	±0.089
Magnetic Ni-Fe alloys (HyMu 80*)	±0.013	±0.025	±0.025	±0.038	±0.063	±0.089
Steel	±0.013	±0.025	±0.038	±0.038	—	—
Nickel and stainless steel	±0.013	±0.025	±0.038	±0.050	±0.076	—

Table V-3 (continued)
Standard PCM Tolerances for Common Materials

Workpiece Material	Tolerance, mm — Workpiece Thickness, mm: 0.025	0.050	0.013	0.25	0.38	0.50
Aluminum and magnesium	±0.025	±0.038	±0.063	—	—	—
Plastics (Mylar⁺, Kapton⁺)	±0.025	±0.038	±0.063	±0.13	—	—
Molybdenum, titanium and exotics	±0.013	±0.025	±0.050	—	—	—

Tolerance in PCM

Table V-4
Practical Tolerances Attainable for Prototype and Short PCM Runs

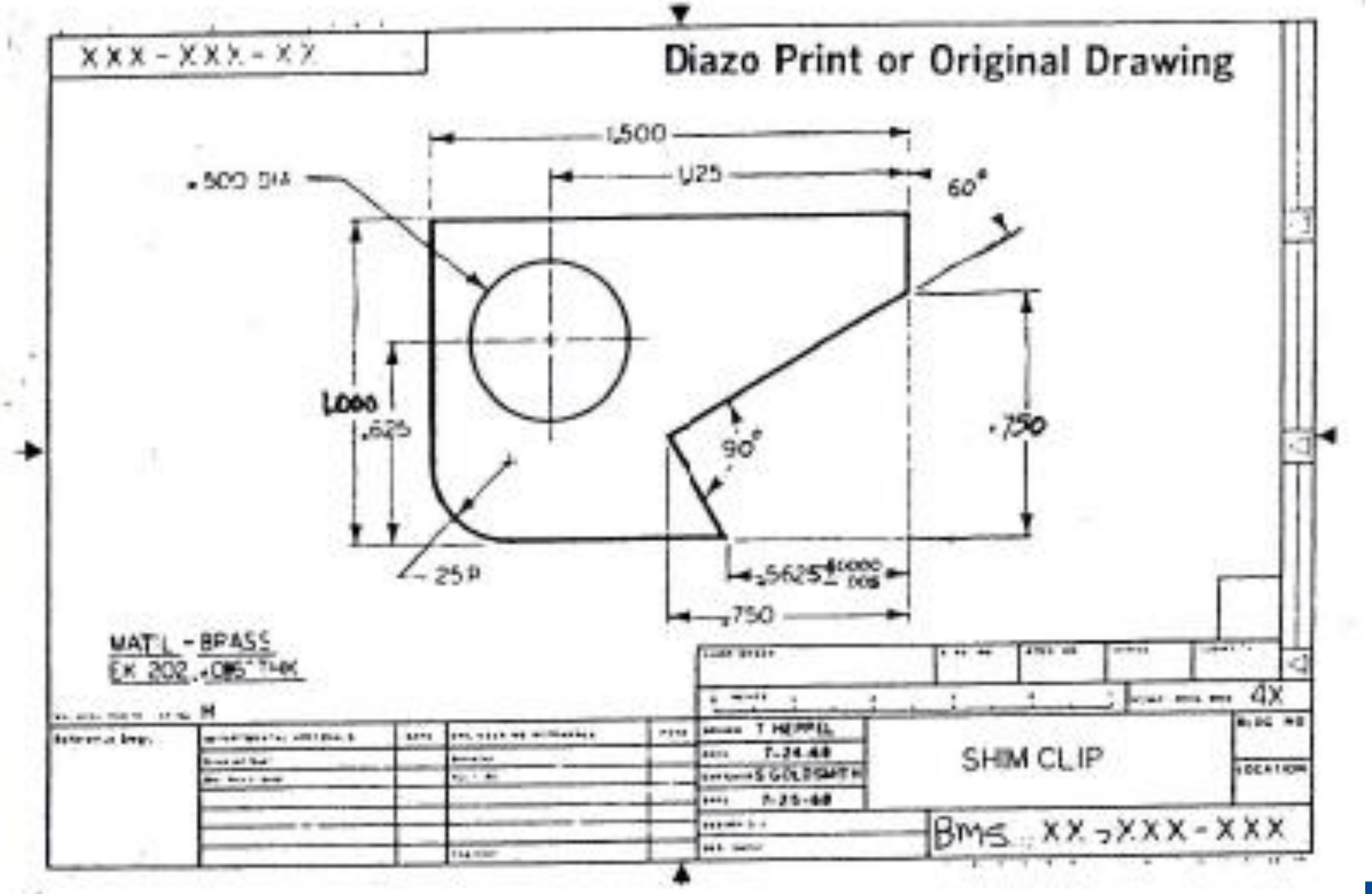
Approximate flat size mm	Tolerance, mm — Thickness, mm						
	0.025	0.050	0.13	0.25	0.38	0.50	1.0
50 x 50	Empirical	±0.013	±0.018	±0.025	±0.038	±0.051	±0.10
200 x 250	Empirical	±0.018	±0.025	±0.038	±0.050	±0.076	±0.13
300 x 450	Empirical	±0.025	±0.038	±0.050	±0.076	±0.10	±0.15

Table V-5
Practical Tolerances Attainable for PCM Production Runs

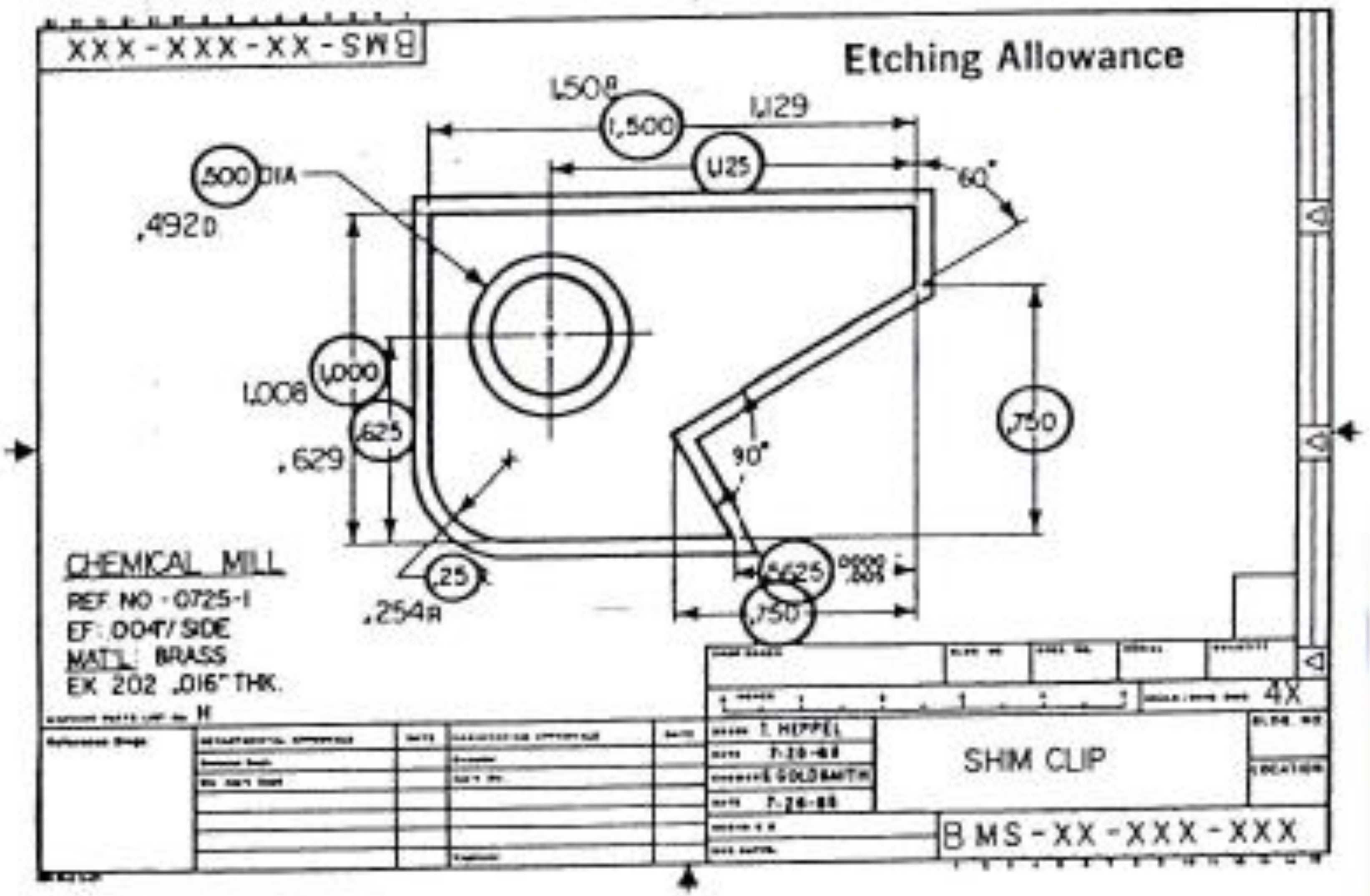
Approximate flat size mm	Tolerance, mm — Thickness, mm						
	0.025	0.050	0.13	0.25	0.38	0.50	1.0
50 x 50	Empirical	±0.025	±0.025	±0.038	±0.050	±0.076	±0.13
200 x 250	Empirical	±0.025	±0.038	±0.050	±0.063	±0.10	±0.15
300 x 450	Empirical	±0.038	±0.050	±0.063	±0.089	±0.11	±0.18

Example of Artwork

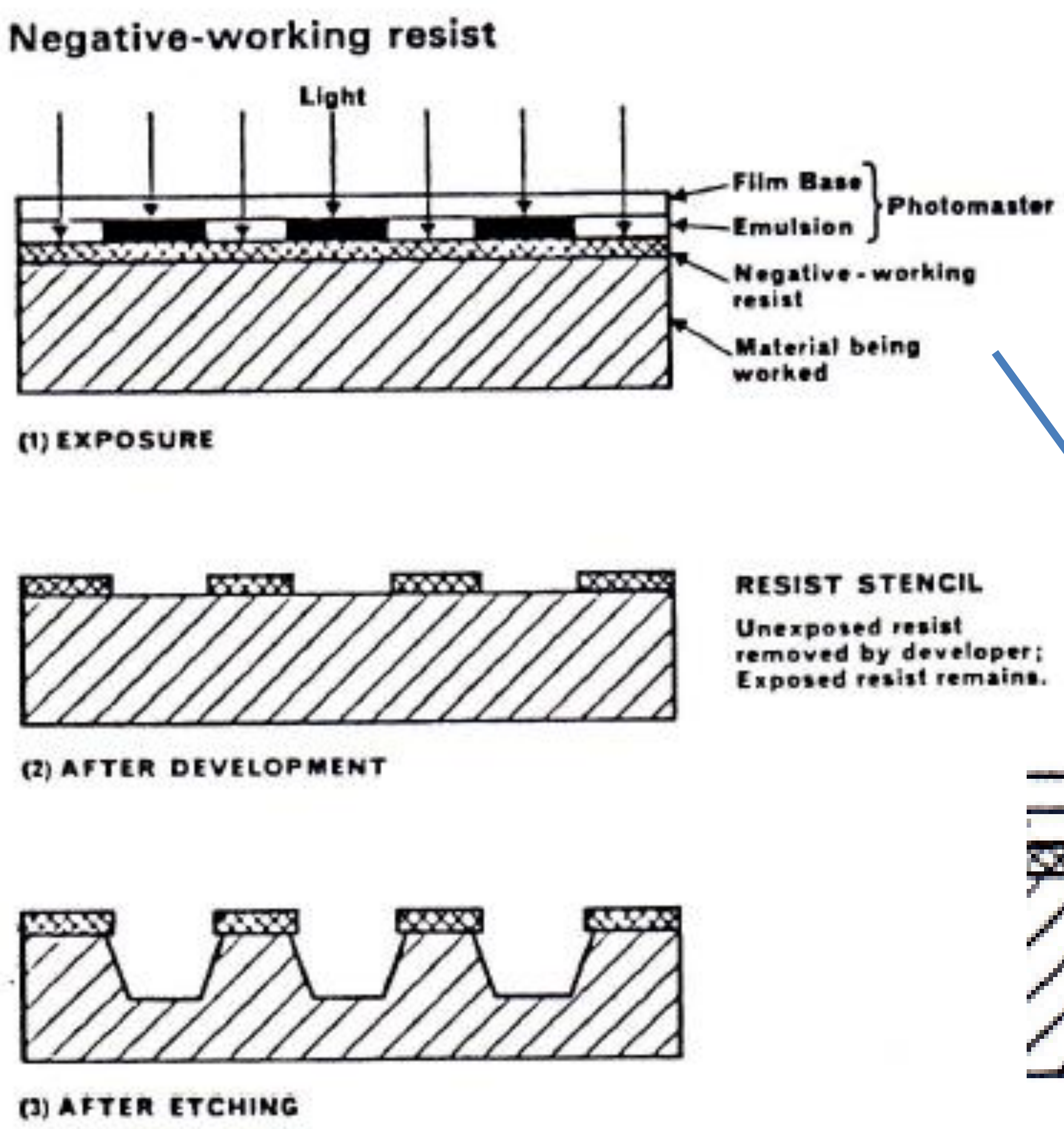
Component drawing of finished part



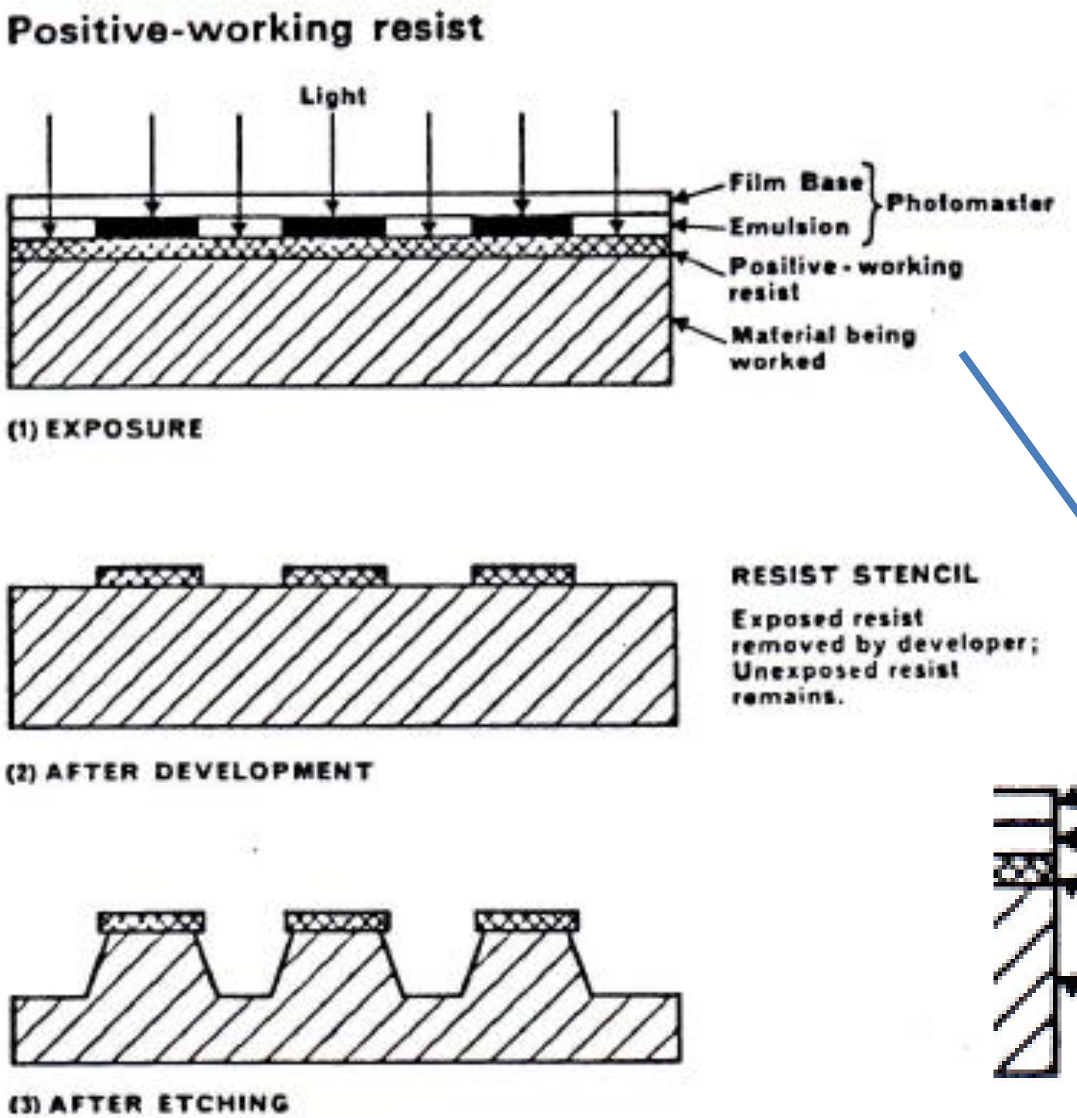
Example of Artwork (cotd)

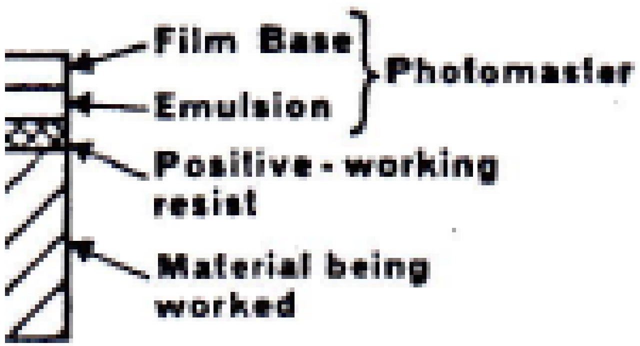


Photoresist type

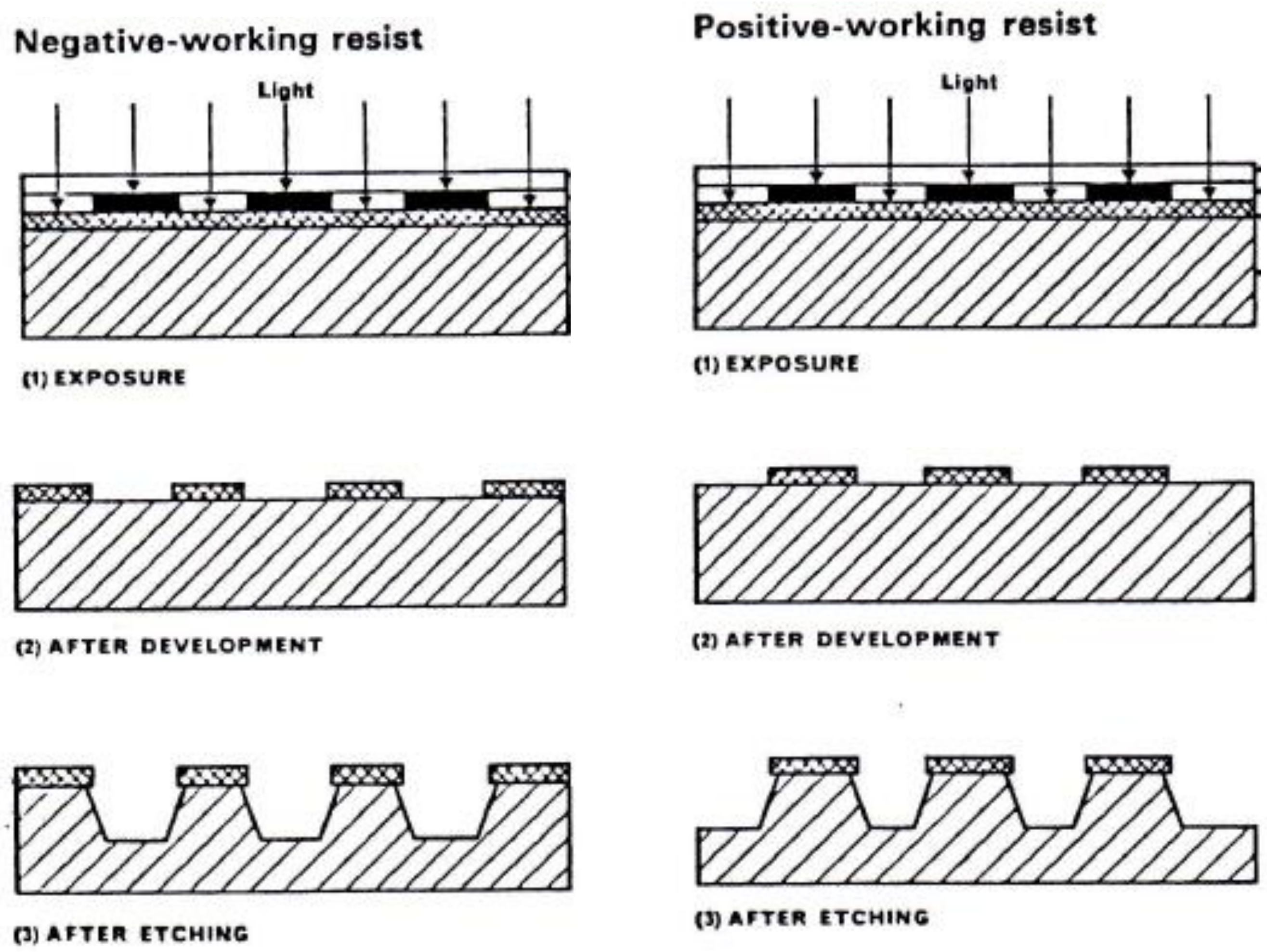


Photoresist type (cotd)





Photoresist type (cotd)



Photoresist type (cotd)

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Summary of solubility changes

1. Negative-working systems.

   (a) organic solvent soluble polymer $\xrightarrow{h\nu}$ insoluble, cross-linked polymer (polyvinylcinnamates, allyl ester resins, cyclised rubbers and some dry films).

   (b) organic solvent soluble monomer $\xrightarrow{h\nu}$ insoluble polymer (some dry films)

   (c) aqueous soluble hydrophilic polymer + monomers $\xrightarrow{h\nu}$ insoluble hydrophobic higher molecular weight polymer (aqueous and semi-aqueous developable dry films)

2. Positive working systems rely on alkali insoluble material $\xrightarrow{h\nu}$ alkali soluble material.

Comparison of PCM with Stamping

When both PCM and stamping are a possible alternative, the economic factor due to order quantity is the decisive factor.

The relative costs of the 'tools' are important factors:

- Phototool is relatively cheap to produce (photographic process)
- Stamping tool is more expensive (machining, heat treatment, finishing, etc, and higher material cost)

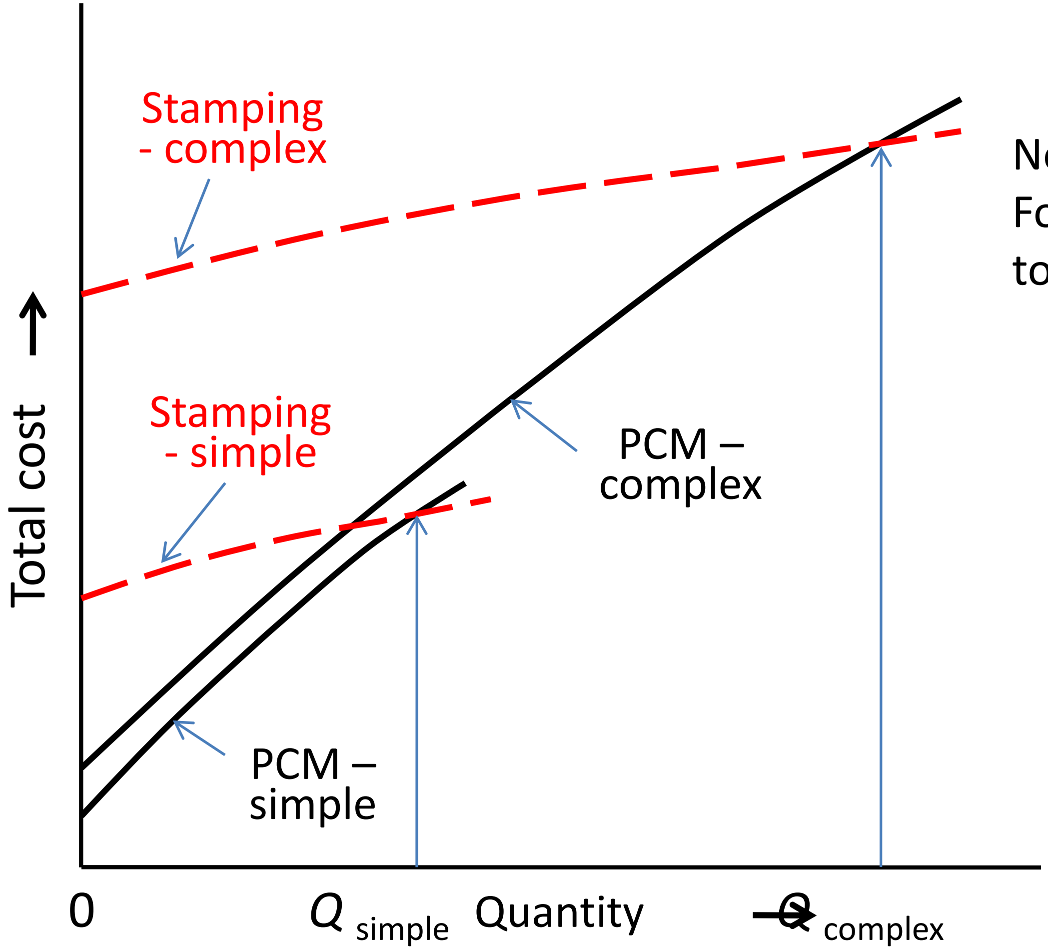
However the running costs of PCM are more expensive than those of stamping.

Breakeven quantity of parts between PCM and stamping:

$$Q = \frac{D - A}{P_E - P_S}$$

where:
Q = break even quantity
D = cost of punch and die; A = cost of artwork and phototool
P_E = part processing cost by etching
P_S = part processing cost by stamping

Comparison of PCM with Stamping



Note:
For both stamping and PCM:
total cost = fixed cost + variable cost

$$Q = \frac{D - A}{P_E - P_S}$$

Q = break even quantity
D = cost of punch and die;
A = cost of phototool
P_E = processing cost by etching;
P_S = processing cost by stamping

The graph illustrates that:

1. Stamping becomes economically viable when Q is high
2. PCM remains competitive at even higher Q when product is more complex

Comparison of **Different Etching Technologies** and **Products**

Fabrication method ***or End product***	**Typical material etched**	**Thickness of material etched**	**Underlying material or support**
Photochemical machining (PCM)	Metals, glasses or ceramics	From < 0.1 to 2 mm (typical maximum)	Not applicable
Printed circuit boards (PCBs)	Electroformed copper foil (a conductor)	17.5 µm (typical)	Rigid epoxy fibre glass or other insulator such as flexible polyimide
Integrated circuits (ICs)	Silicon dioxide or silicon nitride	0.01-0.1 µm (typical)	Silicon
Chemical milling (CHM)	Aluminium, titanium and aerospace alloys	0.1-10 mm (typical)	Not applicable

http://www.pandct.com/media/shownews.asp?ID=21523

CASE STUDY: Investing in the future of Photochemical machining Precision Micro adopts Laser Direct Imaging (LDI) technology

24 June 2009

Precision Micro, a specialist Photochemical machining company has installed **Laser Direct Imaging** (LDI) in its quest for Continuous Process Improvement.

Photochemical machining (PCM) is the process of manufacturing sheet metal components using a photo resist and etchants to selectively remove the unwanted material. PCM can accurately produce highly complex parts, with very fine detail and can provide an economical and technically superior alternative to stamping, punching, laser or water jet cutting, or wire electrical discharge machining (EDM) for thin gauge precision parts.

CASE STUDY: Investing in the future of Photochemical machining Precision Micro adopts Laser Direct Imaging (LDI) technology (cotd)

”Next generation” LDI is used extensively in the manufacture of **minute advanced electronics components** and it is this very technology in which Precision Micro has made its significant investment. LDI is said to have already provided great benefit to customers, allowing them to develop designs that were previously prohibitive on either technical or economic grounds.

“LDI has enabled us to deliver rapid prototyping even quicker and tool modifications can be carried out in a matter of minutes. **Dimensional and positional accuracy** across large formats are at new levels with a four fold improvement in pitch accuracy across an 800mm x 600mm sheet. We have also noted the improved capability has lead to substantial **yield improvements**.”

Investing in the future of Photochemical machining Precision Micro adopts Laser Direct Imaging (LDI) technology (cotd)

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The new LDI system is reported to have created an increase in **demand for tight tolerance** components, as a result of the machine's ability to image ultra fine, 15-micron features. Its CCD cameras and image recognition system also provide exceptionally precise front to back feature **alignment**.

Precision Micro is believed to be the first specialist etching operation to utilise the LDI process. Its philosophy of investing into what is undoubtedly the most advanced etching plant in Europe is reported to be paying dividend in a difficult economic climate.

"Our enhanced technical capabilities have enabled us to tackle with success projects that many of our competitors struggle to carry out. By investing in LDI, we are reaffirming our commitment to our customers by providing a better, more efficient and more cost effective service"

PCM

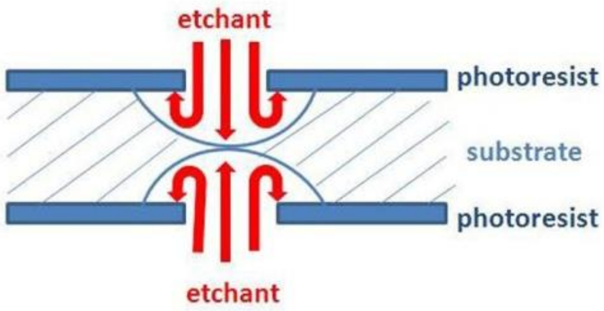

Figure: Cross section through etched profile in PCM

Figure: UV exposure unit

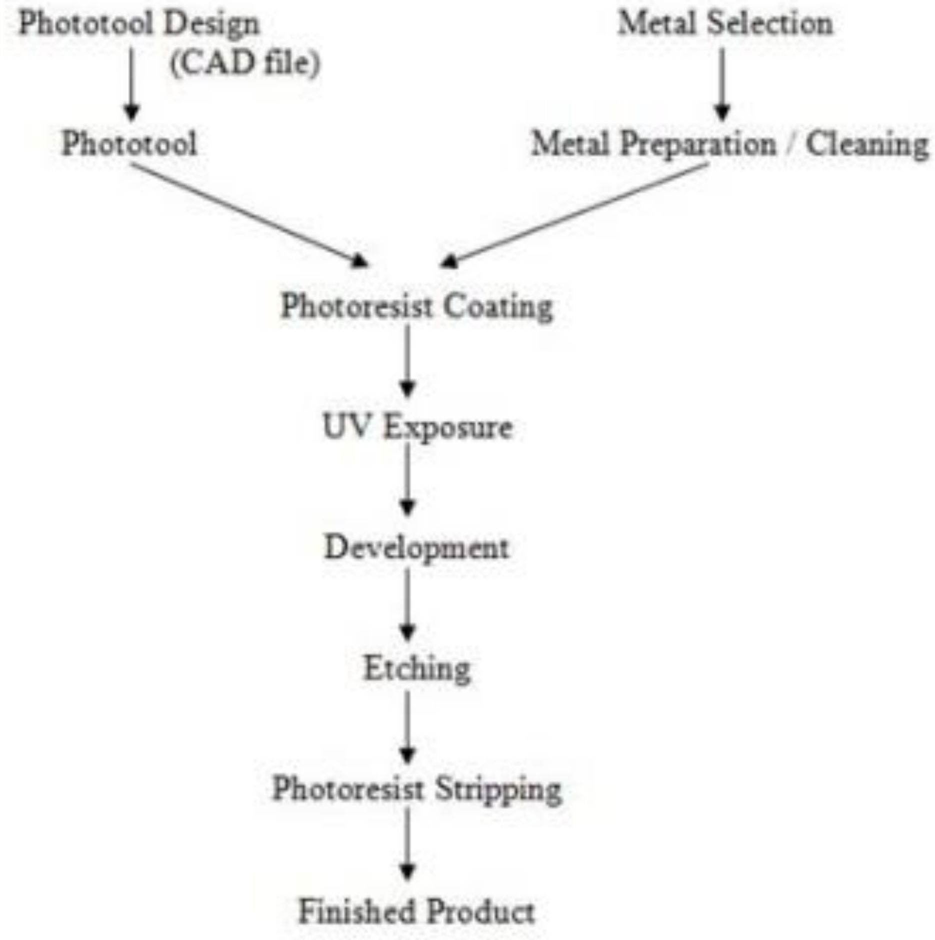

Figure: The stages of the PCM process

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