ME306

ADVANCED MANUFACTURING TECHNOLOGY

Course Plan

Module	Contents	Hours	End Sem. Exam. Marks
I	Introduction: Need and comparison between traditional, non-traditional and micro & nano machining process.	1	15%
	Powder Metallurgy: Need of P/M - Powder Production methods:- Atomization, electrolysis, Reduction of oxides, Carbonyls (Process parameters, characteristics of powder produced in each method).	1	
	Powder characteristics: properties of fine powder, size, size distribution, shape, compressibility, purity etc.	1	
	Mixing – Compaction:- techniques, pressure distribution, HIP & CIP.	1	
	Mechanism of sintering, driving force for pore shirking, solid and liquid phase sintering - Impregnation and Infiltration Advantages, disadvantages and specific applications of P/M.	1	
	Programmable Logic Controllers (PLC): need – relays - logic ladder program –timers, simple problems only.	1	
	Point to point, straight cut and contouring positioning - incremental and absolute systems – open loop and closed loop systems - control loops in contouring systems: principle of operation.	1	

	operation.		
II	DDA integrator:-Principle of operation, exponential deceleration –liner, circular and complete interpolator.	1	15%
	NC part programming: part programming fundamentals - manual programming –	1	
	NC coordinate systems and axes — sequence number, preparatory functions, dimension words, speed word, feed world, tool world, miscellaneous functions –	1	
	Computer aided part programming:– CNC languages – APT language structure: geometry commands, motion	1	
	commands, postprocessor commands, compilation control commands	1	
	Programming exercises: simple problems on turning and drilling etc - machining centers- 5 axis machining (***At least one programming exercise must be included in the end semester University examination).***	2	
	FIRST INTERNAL EXAMINATION		

III	Electric Discharge Machining (EDM):- Mechanism of metal removal, dielectric fluid, spark generation, recast layer and attributes of process characteristics on MRR, accuracy, HAZ etc, Wire EDM, applications and accessories.	3	**15%**
	Ultrasonic Machining (USM):-mechanics of cutting, effects of parameters on amplitude, frequency of vibration, grain diameter, slurry, tool material attributes and hardness of work material, applications.	2	
	Electro chemical machining (ECM):- Mechanism of metal removal attributes of process characteristics on MRR, accuracy, surface roughness etc, application and limitations.	1	
IV	Laser Beam Machining (LBM), Electron Beam Machining (EBM), Plasma arc Machining (PAM), Ion beam Machining(IBM) - Mechanism of metal removal, attributes of process characteristics on MRR, accuracy etc and structure of HAZ compared with conventional process; application, comparative study of advantages and limitations of each process.	3	**15%**
	Abrasive Jet Machining (AJM), Abrasive Water Jet Machining **(AWJM)** - Working principle, Mechanism of metal removal, Influence of process parameters, Applications, Advantages & disadvantages.	3	

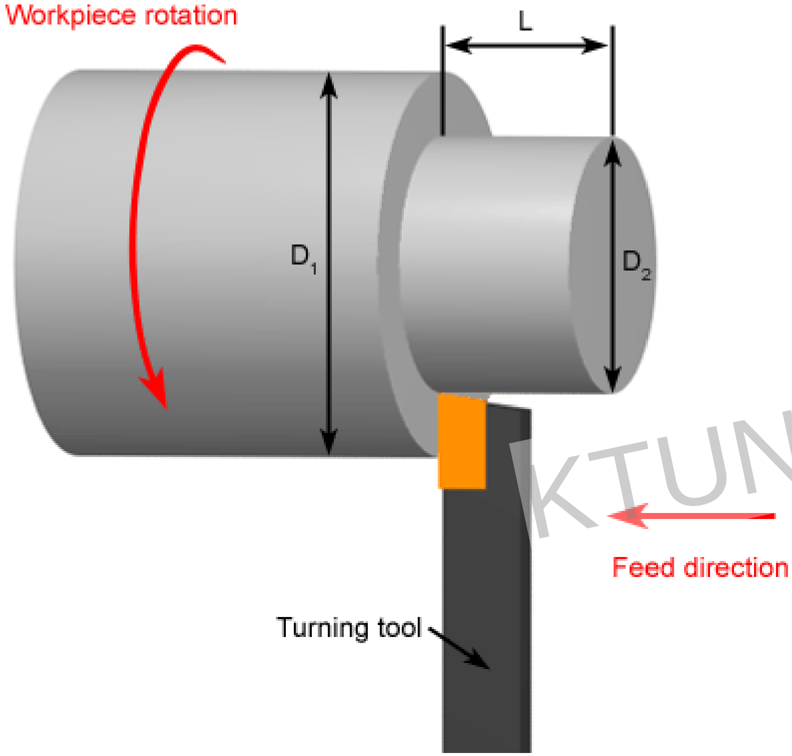
V	High velocity forming of metals:-effects of high speeds on the stress strain relationship steel, aluminum, Copper – comparison of conventional and high velocity forming methods- deformation velocity, material behavior, stain distribution.	3	**20%**
	Stress waves and deformation in solids – types of elastic body waves- relation at free boundaries- relative particle velocity.	2	
	Sheet metal forming: - explosive forming:-process variable, properties of explosively formed parts, etc.	2	
	Electro hydraulic forming: - theory, process variables, etc, comparison with explosive forming.	1	
V1	Micromachining: Diamond turn mechanism, material removal mechanism, applications.	1	**20%**
	Advanced finishing processes: - Abrasive Flow Machining, Magnetic Abrasive Finishing.	2	
	Magnetorheological Abrasive Flow Finishing, Magnetic Float Polishing, Elastic Emission Machining.	3	
	Material addition process:- stereo-lithography, selective laser sintering, 3D Printing, fused deposition modeling, laminated object manufacturing, , laser engineered net-shaping, laser welding, LIGA process.	2	

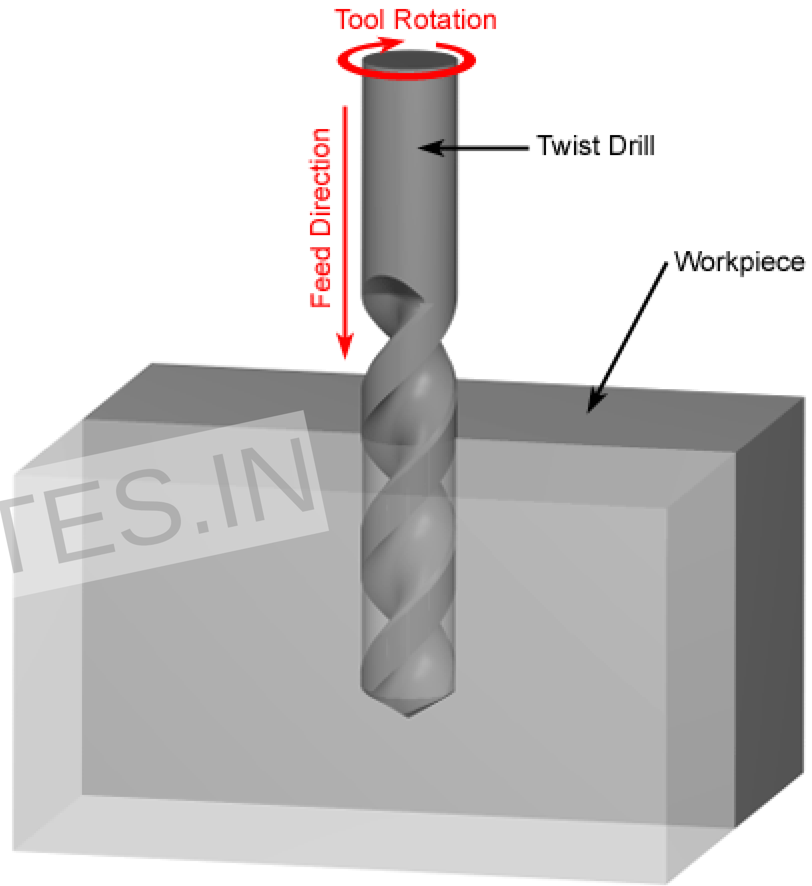
Text books/References

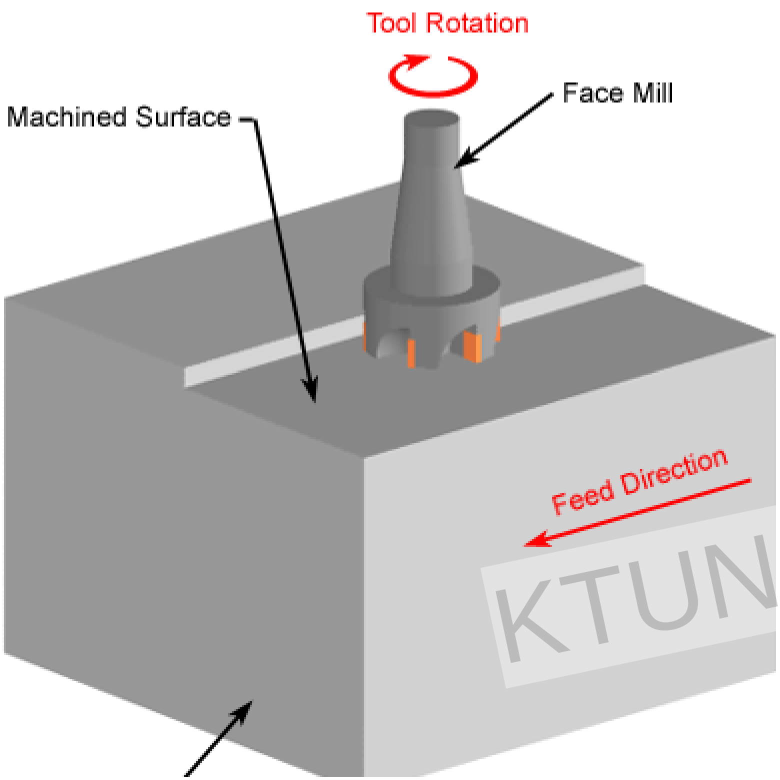
1. ASTME, High velocity forming of metals, PHI, 1968.
2. Davies K and Austin E.R, Developments in high speed metal forming, the machinery publishing Co, 1970.
3. Ibrahim Zeid, R Sivasubrahmanian CAD/CAM: Theory & Practice, McGraw Hill Education, 2009
4. Jain V.K., Introduction to Micromachining, Narosa publishers,2014
5. M.P. Groover, E.M. Zimmers, Jr. CAD/CAM; Computer Aided Design and Manufacturing, Prentice Hall of India, 1987
6. Petruzella Frank.D., Programmable logic controllers,McGraw Hill,2016
7. Yoram Koren, Computer control of manufacturing systems, TMH,2006

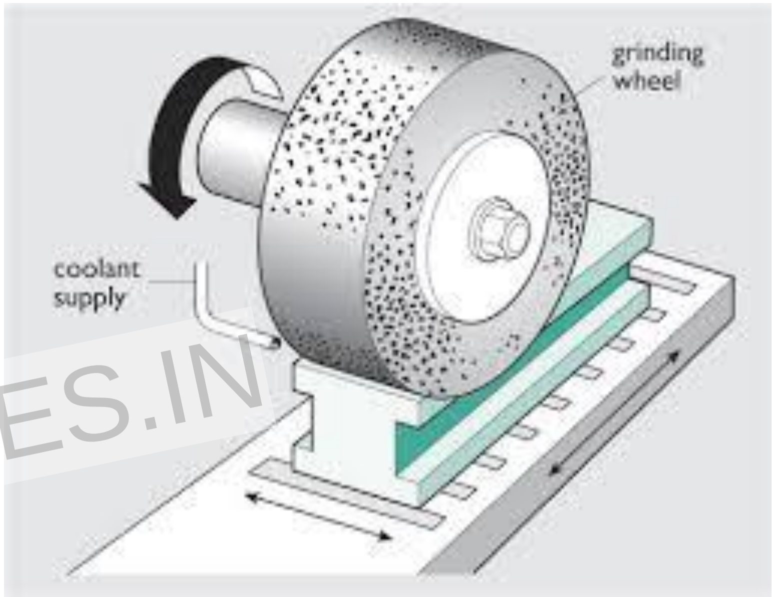
Traditional, non-traditional, micro & nano machining process

Traditional/Conventional machining



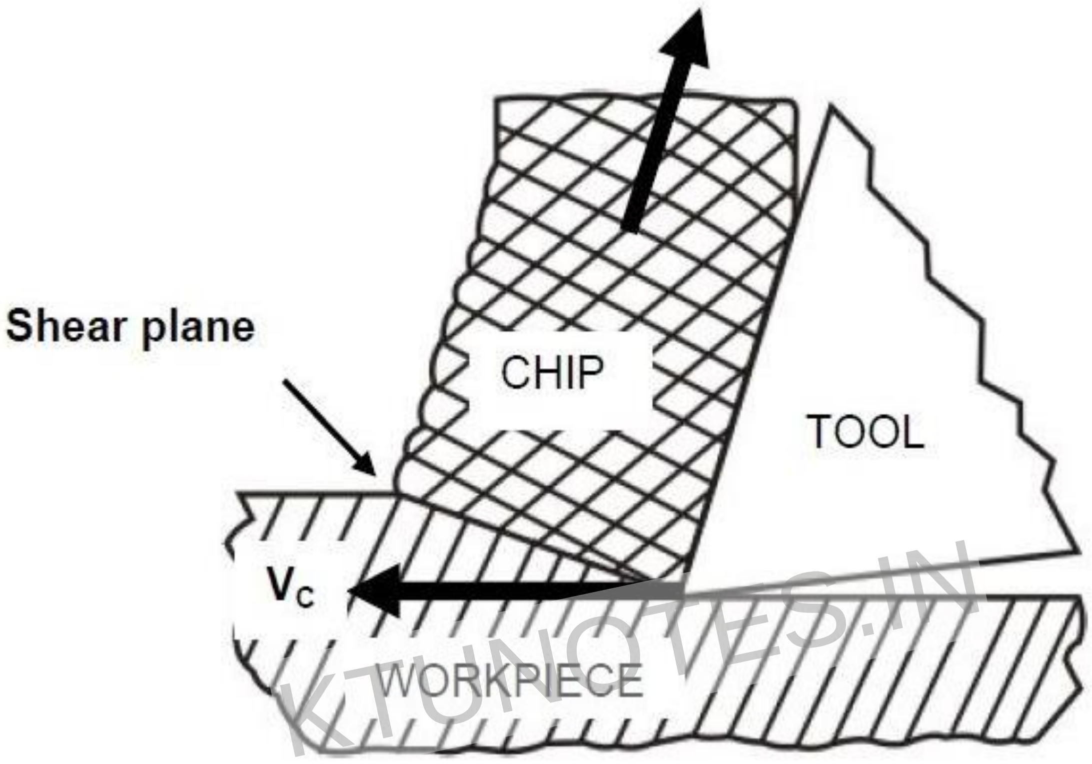






Examples of conventional machining processes are

Turning, boring, drilling, milling, shaping, broaching, slotting, grinding etc.



Major characteristics of conventional machining

- Generally macroscopic chip formation by shear deformation

- Material removal takes place due to application of cutting forces – energy domain can be classified as mechanical

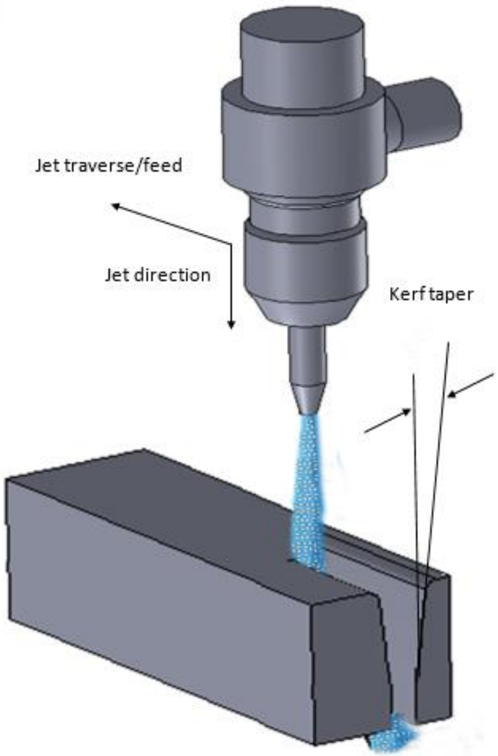
- Cutting tool is harder than work piece

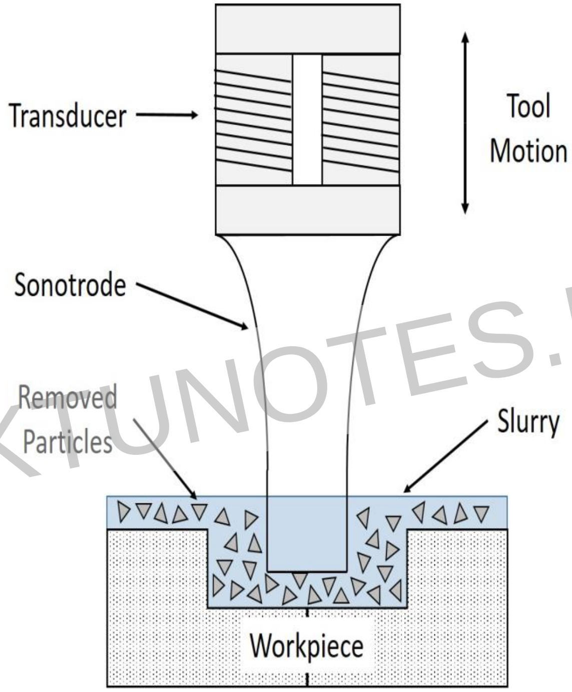
Difficulties with conventional machining processes

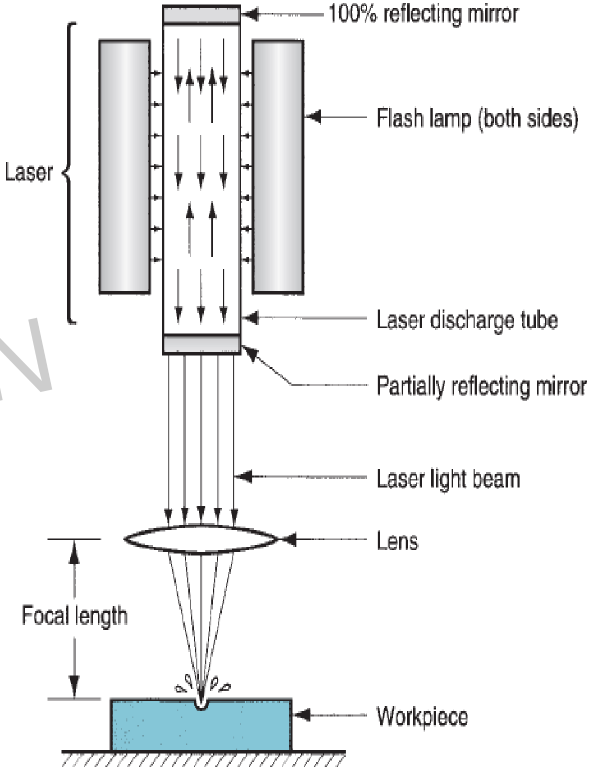
Machining processes that involve chip formation have a number of limitations

- Large amounts of energy
- Unwanted distortion
- Residual stresses
- Burrs
- Delicate or complex geometries may be difficult or impossible
- There are situations where conventional machining processes are not satisfactory, economical, or impossible for the following reasons:
  - Material is very hard and strong, or too brittle.
  - Workpiece is too flexible, delicate, or difficult to fixture.
  - Complex shapes.
  - Surface finish and dimensional accuracy requirements.
  - Temperature rise and residual stresses are not desirable.

Unconventional machining







Non-traditional machining (NTM) processes have several advantages

- Complex geometries are possible
- Extreme surface finish
- Tight tolerances
- Delicate components
- Little or no burring or residual stresses
- Brittle materials with high hardness can be machined
- Microelectronic or integrated circuits are possible to mass produce

The classification of NTM processes is carried out depending on the nature of energy used for material removal.

- ❑ Mechanical Processes
- ✓ Abrasive Jet Machining (AJM)
- ✓ Ultrasonic Machining (USM)
- ✓ Abrasive Water Jet Machining (AWJM)
- ❑ Electrochemical Processes
- ✓ Electrochemical Machining (ECM)
- ✓ Electro Chemical Grinding (ECG)
- ✓ Electro Jet Drilling (EJD)
- ❑ Electro-Thermal Processes
- ✓ Electro-discharge machining (EDM)
- ✓ Laser Beam Machining (LBM)
- ✓ Electron Beam Machining (EBM)
- ❑ Chemical Processes
- ✓ Chemical Milling (CHM)
- ✓ Photochemical Milling (PCM) etc.

Differences between Conventional and Non conventional machining processes.

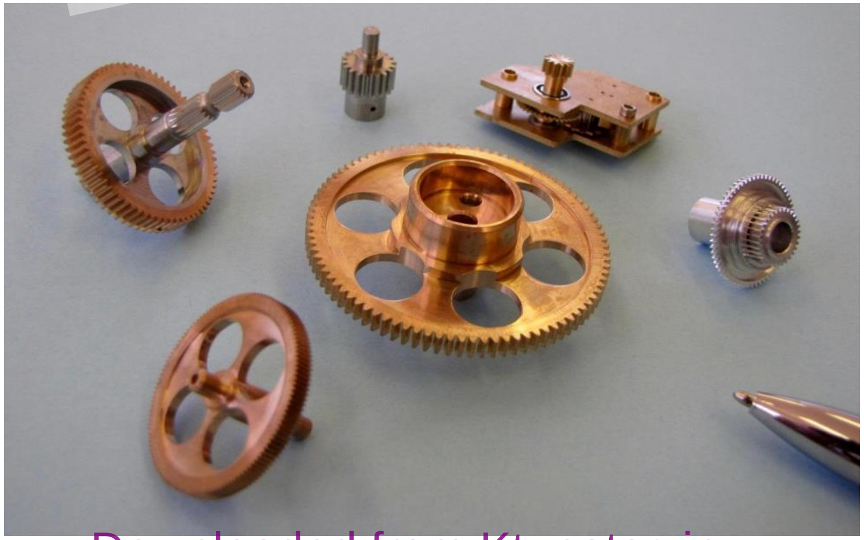
Sl. No	Conventional machining	Non-conventional machining
1	The cutting tool and work piece are always in physical contact and is in relative motion with each other, which results in friction and tool wear.	There is no physical contact between the tool and work piece. In some non -traditional process tool wear exists.
2	Material removal rate is limited by mechanical properties of work material.	NTM can machine difficult to cut and hard to cut materials like titanium, ceramics, nimonics, SST, composites, semiconducting materials .
3	Relative motion between the tool and work is typically rotary or reciprocating. Thus the shape of work is limited to circular or flat shapes. In spite of CNC systems, production of 3D surfaces is still a difficult task.	Many NTM are capable of producing complex 3D shapes and cavities

Differences between Conventional and Non conventional machining processes- cont.

Sl. No	Conventional machining	Non-conventional machining
4	Machining of small cavities, slits, and blind holes or through holes are difficult	Machining of small cavities, slits and production of non-circular, micro sized, large aspect ratio holes are easy using NTM
5	Use relative simple and inexpensive machinery and readily available cutting tools	Non traditional processes requires expensive tools and equipment as well as skilled labor, which increase the production cost significantly
6	Capital cost and maintenance cost is low.	Capital cost and maintenance cost is high
7	Traditional processes are well established and physics of process is well understood	Mechanics of Material removal of Some of the NTM process are still under research

Sl. No	Conventional machining	Non-conventional machining
8	Conventional process mostly uses mechanical energy	Most NTM uses energy in direct form. For example : laser, Electron beam in its direct forms are used in LBM and EBM respectively
9	Surface finish and tolerances are limited by machining inaccuracies	High surface finish (up to 0.1 micron) and tolerances (25 microns) can be achieved
10	High metal removal rate.	Low material removal rate.
11	Cutting tool is harder than workpiece.	There may not be a physical tool present
12	Tool life is less due to high surface contact and wear	Tool life is more
13	Noisy operation	Quiet operation mostly

Micro and Nano machining process



Micro and Nano machining processes

Why Micro Machining?

Present day high-tech industry design requirements are stringent.

– Extraordinary Properties of Materials (High strength, High heat resistant, High hardness, Corrosion resistant etc.)

– Complex 3D Components (Turbine Blades)

– Miniature Features (filters for food processing and textile industries having few tens of microns as hole diameter and thousands in number)

– Nano level surface finish on Complex geometries (thousands of tubulated cooling holes in a turbine blade)

– Making and finishing of micro fluidic channels (in electrically conducting & non conducting materials, say glass, quartz, &ceramics)

Why Micro Machining?

- Final finishing operations in manufacturing of precise parts are always of concern owing to their most critical, labor intensive and least controllable nature.

- In the era of nanotechnology, deterministic high precision finishing methods are of utmost importance and are the need of present manufacturing scenario.

- The need for high precision in manufacturing was felt by manufacturers worldwide to improve interchangeability of components, improve quality control and longer wear/fatigue life.

Micro and Nano machining processes

- Machining of micro parts is not literally correct.
- Removal of material in the form of chips or debris having the size in the range of microns.
- Creating micro features or surface characteristics (especially surface finish) in the micro/nano level.
- Definition: material removal at micro/nano level with no constraint on the size of the component being machined.

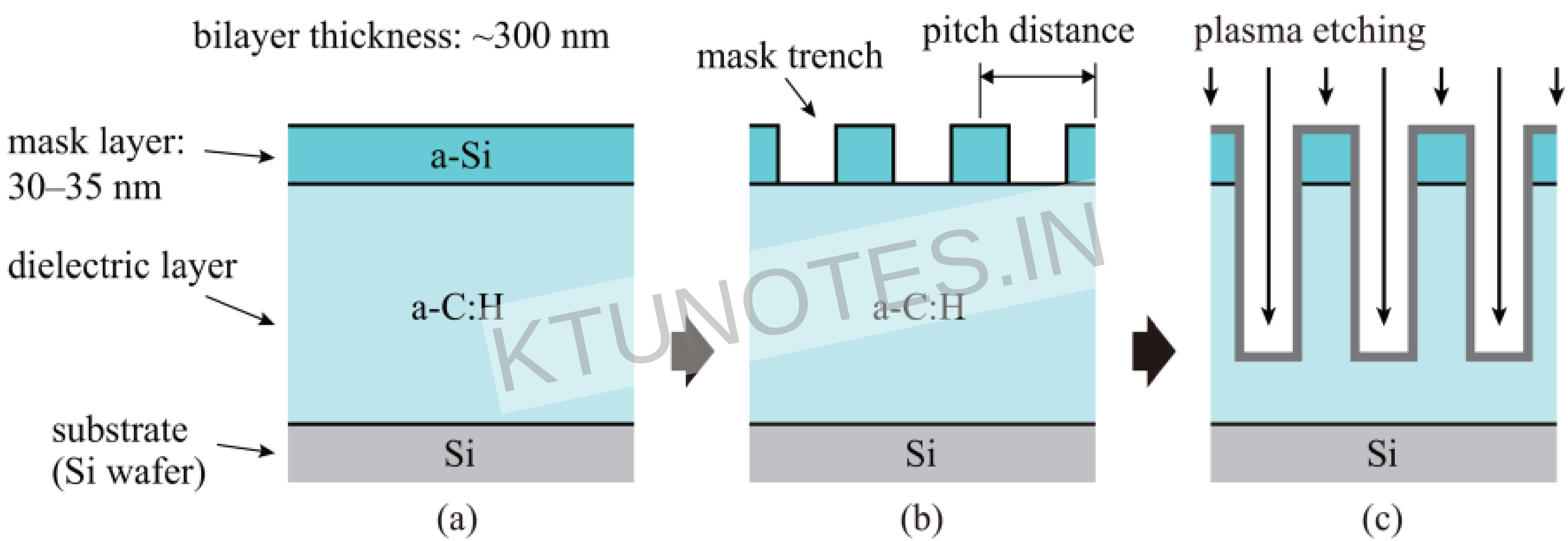
Different Micro/nano machining techniques

- Mechanical Micromachining
- Photolithography
- Etching
- Silicon Micromachining
- LIGA

Mechanical Micromachining

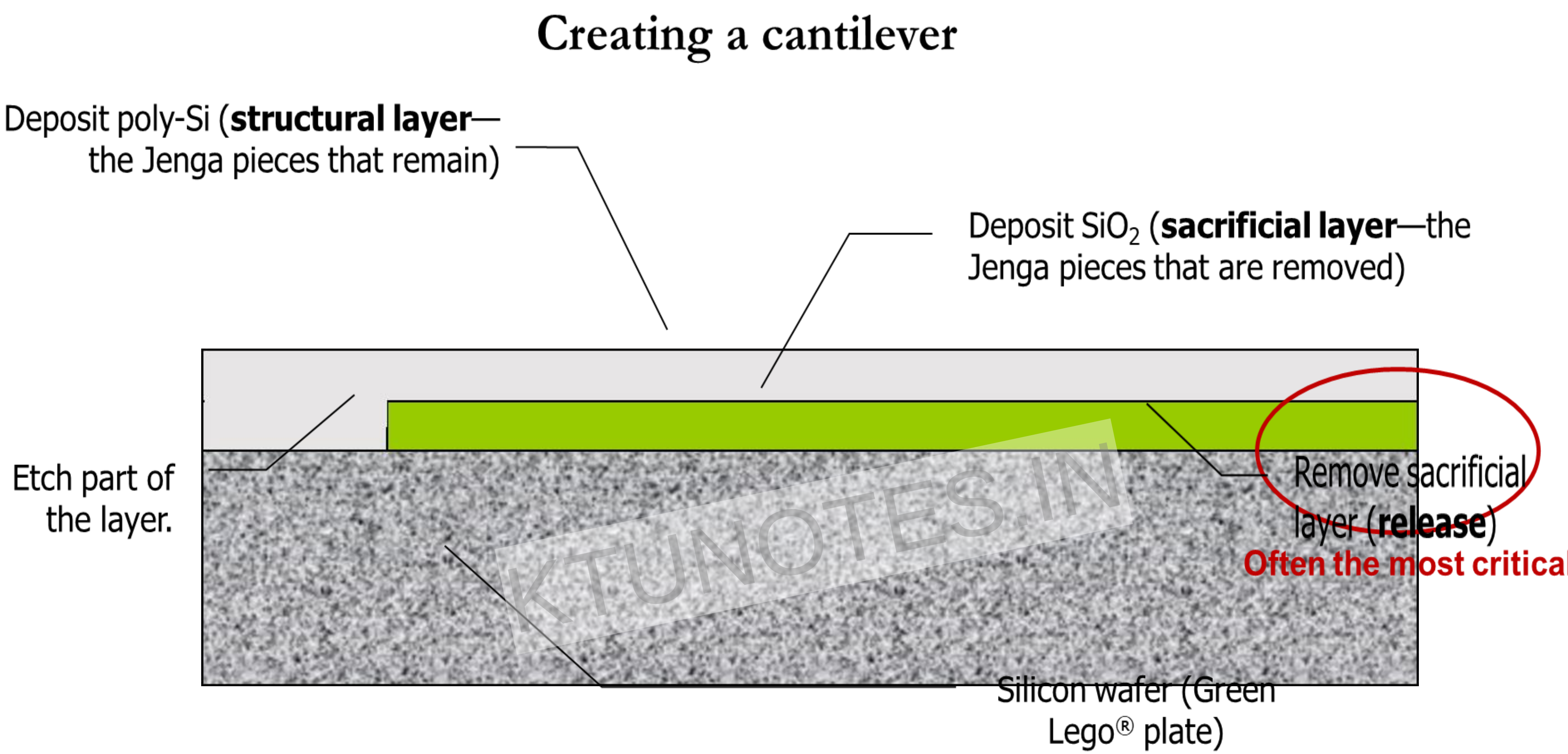
- Photolithography

- Etching



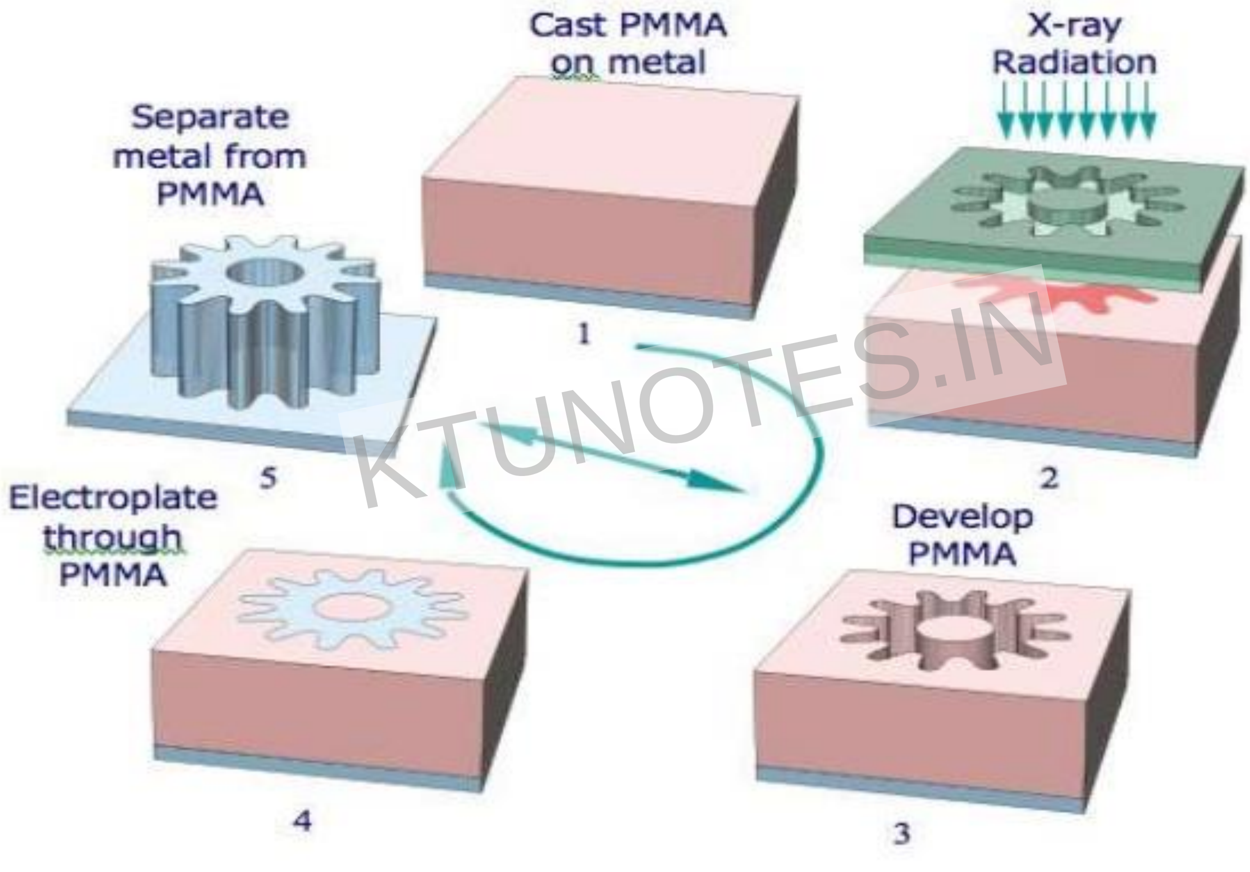
bilayer thickness: ~300 nm
mask layer:
30–35 nm
dielectric layer
substrate
(Si wafer)
a-Si
a-C:H
Si
(a)
mask trench
pitch distance
a-C:H
Si
(b)
plasma etching
Si
(c)

Silicon micromachining/ Surface micromachining



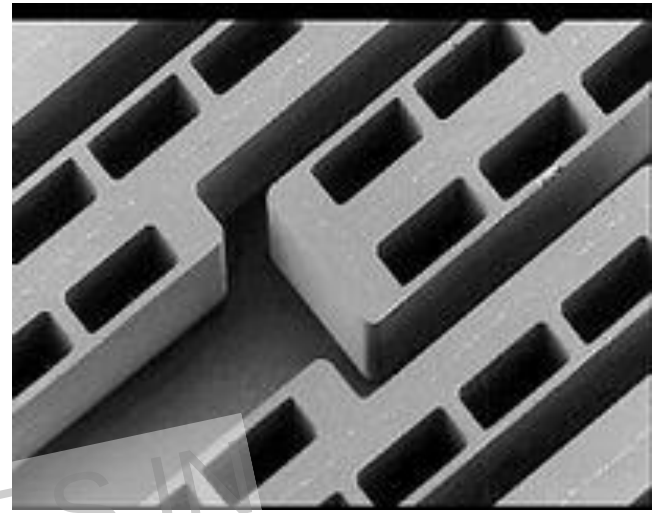
- Surface micromachining builds microstructures by deposition and etching of different structural layers on top of the substrate.
- Polysilicon is commonly used as one of the layers and silicon dioxide is used as a sacrificial layer which is removed or etched out to create the necessary void in the thickness direction.
- Added layers are generally very thin with their size varying from 2-5 Micro metres

LIGA- Lithographie, Galvanoformung, Abformung
(Lithography, Electroplating, and Molding)



LIGA Processess

SEM picture of an ant carrying a LIGA micro gear



SEM picture of a polymer LIGA structure made by moulding. Smallest polymer width is 6 µm; polymer height is 120 µm, the aspect ratio is, therefore, 20.

- Used to create high-aspect-ratio microstructures.

- There are two main LIGA-fabrication technologies, **X-Ray LIGA**, which uses X-rays produced by a synchrotron to create high-aspect ratio structures**, and UV LIGA**, a more accessible method which uses ultraviolet light to create structures with relatively low aspect ratios.

The notable characteristics of X-ray LIGA-fabricated structures include:

- high aspect ratios on the order of 100:1
- parallel side walls with a flank angle on the order of 89.95°
- smooth side walls with $R_a = 10$ nm, suitable for optical mirrors
- structural heights from tens of micrometers to several millimeters
- structural details on the order of micrometers over distances of centimeters