Non- traditional Manufacturing Processes (MF30604)

Lecture 1 and 2: Introduction

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Outline

- **Objective of the Course**
- **Syllabus**
- **Marking Scheme**
- **Reference Books**
- **Traditional Manufacturing Processes**
- **Need of Non-traditional Manufacturing Processes**
- **Classification of Non-traditional Manufacturing Processes**

Objectives of the course

- Learn about the basic theory, working principle, and characteristics of nontraditional manufacturing processes.
- Identify critical process variables and their effect on process performance and product quality
- Develop mathematical model relating MRR with machining parameters
- Develop understanding to properly assess the capabilities, limitations, and potentials of nontraditional manufacturing processes
- Decision for the right choice of machining process for a particular set of material and application.
- Further development of new techniques and improvement of existing methods.

Syllabus

- Introduction to Modern Manufacturing Processes/ Methods
- Electro Chemical Machining (ECM)
- Electric Discharge Machining
- Laser Beam Machining (LBM)
- Electron Beam Machining (EBM)
- Plasma Arc Machining (PAM)
- Ion-Beam Machining (IBM)
- Abrasive Jet Machining (AJM)
- Water Jet Machining (WJM)
- Abrasive Water Jet Machining (AWJM)
- Ultrasonic Machining (USM)

Marking Scheme

Total 33 marks

1) Mid Semester Exam (25 marks)
2) Assignment or Class test (8 marks)

References Books

1. Nontraditional Manufacturing Processes

   Gary F. Benedict, Marcel Dekker,Inc

2. Modern Machining Processes

   P C Pandey & H S Shan, Tata McGraw-Hill

3. Nonconventional Machining

   P K Mishra, Narosa Publishing House

4. Manufacturing Science

   Amitabha Ghosh & A K Mallik, Affiliated East-West Press

5. Laser Material Processing, by W M Steen

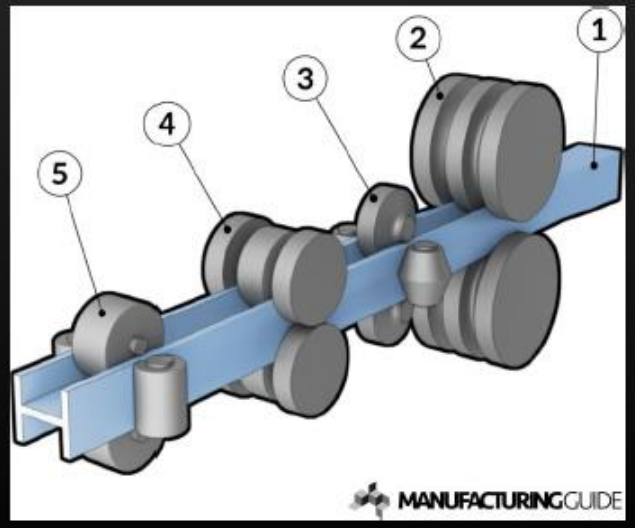
6. NPTEL Lectures, Nonconventional Machining, L35 to L40.

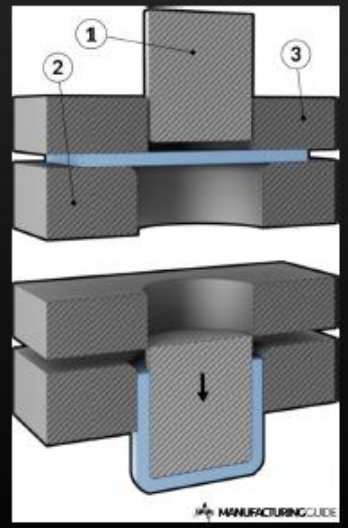
Traditional Manufacturing Processes

Machining (material removal): Turning, milling, grinding

Forming: Rolling, deep drawing,

Ref: www.manufacturing uide.com





Casting

Ref: www.machinedesign .com

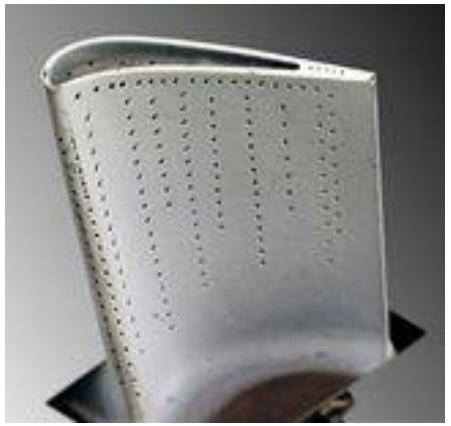
Need of Non-traditional or Modern Manufacturing

Demand of Modern Products:

A) Processing new materials : Improved mechanical, thermal, electrical, & chemical properties

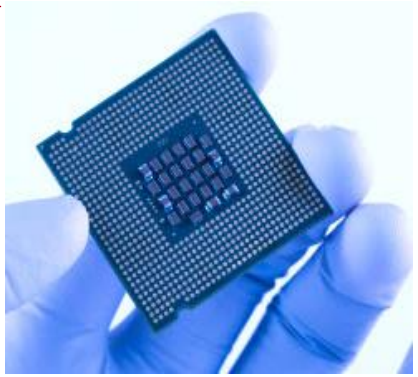
Ceramics, super alloys, composites and polymers

- Too hard / brittle to machine with traditional process
- Materials too flexible / slender to cut or clamp

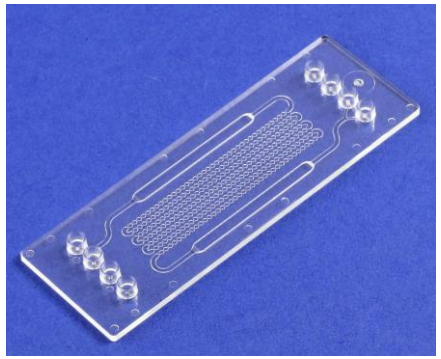


Ex: Producing holes in turbine blades
Material: Nickel-based super alloy
Operating temperature ~ 1000 to 1600°C

Ex: Electronics circuits on a polymer substrate
Material: Polymer (flexible)



Ex: Semiconductors on silicon
Material: Silicon (Brittle)

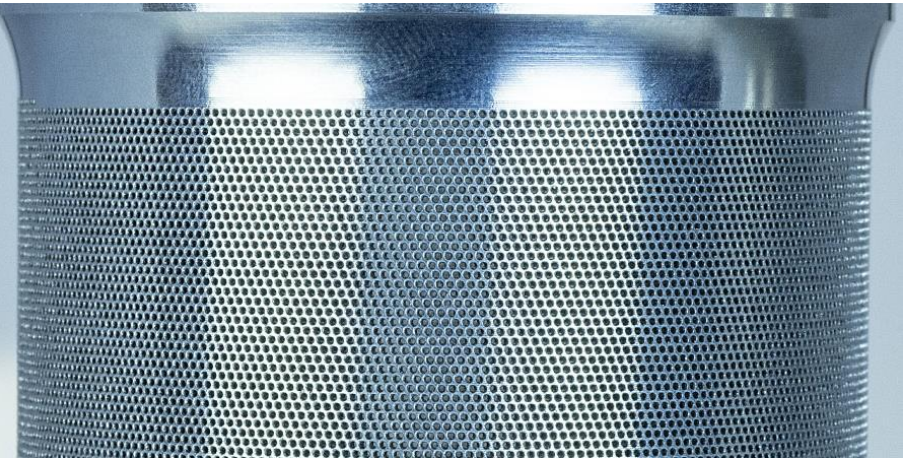


Ex: Microfluidic channels on glass substrate
Material: Glass (Brittle)

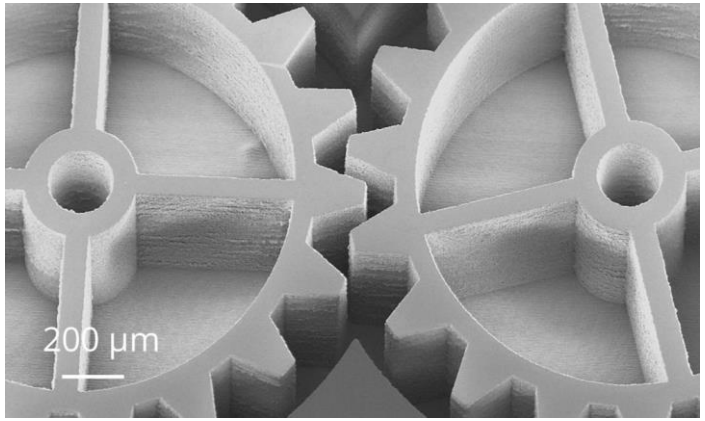
Need of Non-traditional or Modern Manufacturing

B) Dimensional and accuracy requirements

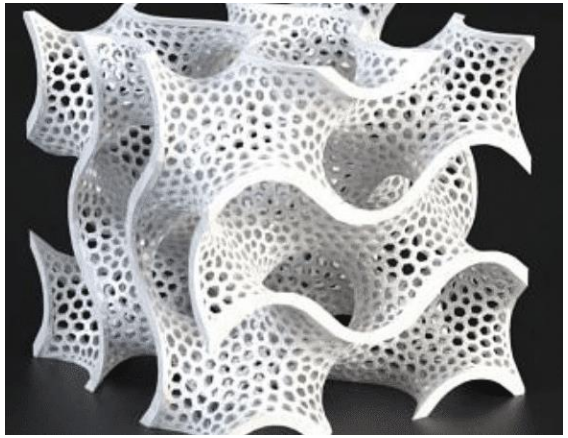
- **Complex shapes, high precision & high surface finish.**
- **High repeatability.**



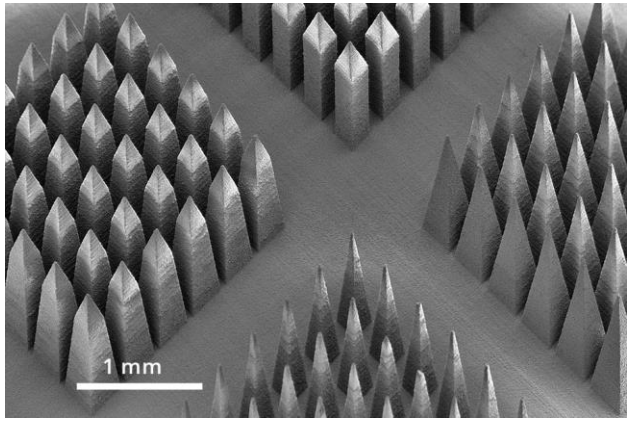
Ex: Array of micro-holes
Material: Stainless steel



Ex: Microgear
Material: Polymer

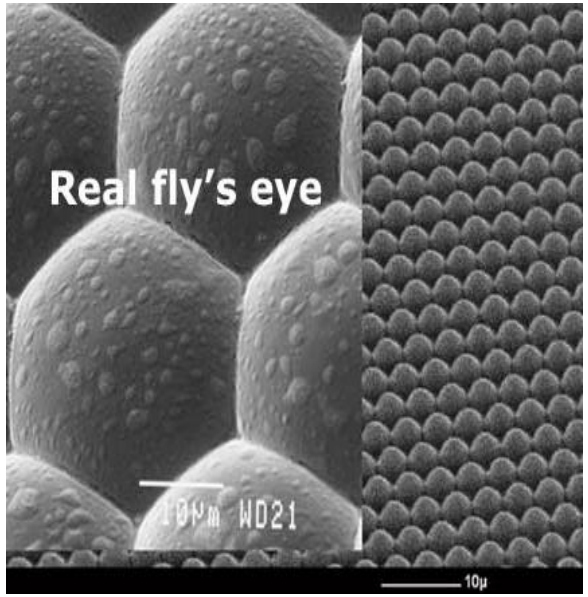


Ex: Complex shape with array of holes
Material: Polymer



Ex: Array of micropillars
Material: Polymer

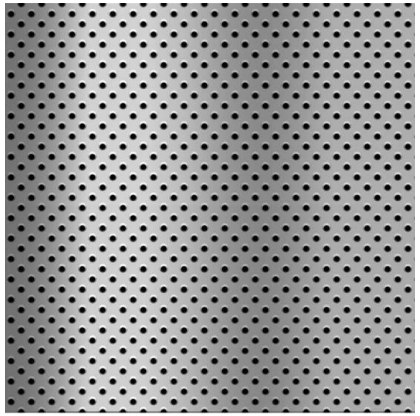
Ex: Microlense
Array of micropatterns
Material: Polymer



Need of Non-traditional or Modern Manufacturing

C) Requirement of high production rate and economy

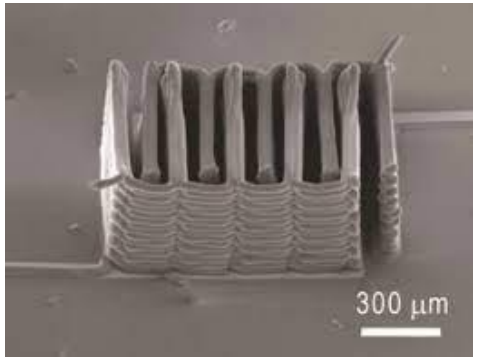
- **Less time**
- **Rapid machining**
- **Automatic processing**
- **Flexibility to change product design (Computer aided design)**



Ex: Producing holes in stainless steel sheet
In traditional machining: time/hole: 10 min
In modern machining: time/hole: 2 µs

D) Portable and miniaturized components

- **Micro/nano sized components.**



Ex: Printed supercapacitor/ battery

E) Less heat affected zone and residual stresses

Non-traditional Manufacturing Processes/ Methods

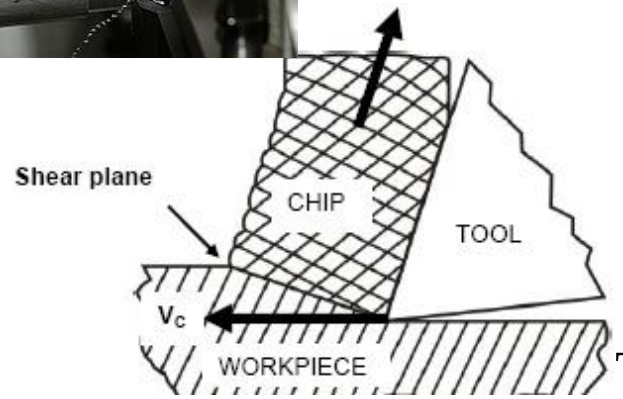
Modern Manufacturing processes employ

- New tools and New forms of energy

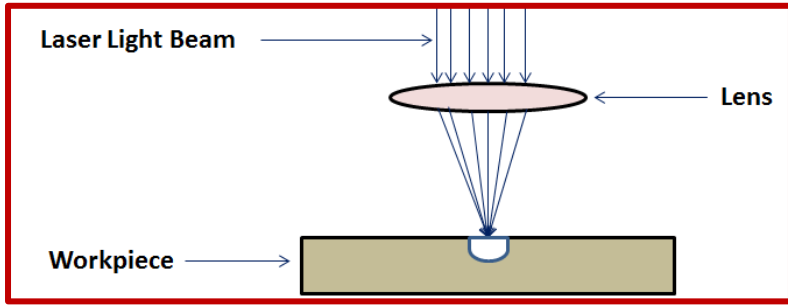
Developed as

- Efficient and economic alternatives to conventional ones.

- Often the first choice for certain technical requirements.



Traditional manufacturing process



Modern manufacturing process

Modern Manufacturing Processes differ to Traditional Mfg. Processes in following aspects ⇒

- ❖ Unconventional Energy Sources : Thermal, Chemical, Kinetic Energy ----
- ❖ Processing usually not by direct MECHANICAL contact: Nontraditional mechanism of interaction between the tool and the work piece: Evaporation, Ablation, Melt Ejection, Dissolution, Erosion----
- ❖ Nontraditional media to transfer energy from the tool to the work piece : Photons, E-beam, Dielectric media, Electrolytic media, Water, Abrasive slurry.
- ❖No tool wear.

Classification of Modern Manufacturing Processes/ Methods

Energy type	Mechanics of material removal	Energy source	Process
Mechanical	Plastic deformation/ Erosion	Mechanical motion of tool/job	Conventional machining processes
		Mechanical/fluid motion	• Abrasive jet machining (AJM) • Ultrasonic machining (USM) • Water jet machining (WJM) • Abrasive water jet machining (AWJM)
Electrochemical	Ion displacement	Electric current	Electrochemical machining (ECM)
Electrochemical and Mechanical	Plastic deformation and ion displacement	Electric current and mechanical motion	Electrochemical grinding (ECG)
Chemical	Corrosive reaction	Corrosive agent	Chemical machining (CHM)

Continued…

Classification of Modern Manufacturing Processes/ Methods

Energy type	Mechanics of Material Removal	Energy source	Process
Thermal	**Fusion and vaporization**	Electric sparks	Electric discharge machining (EDM)
		Powerful light radiation	**Laser beam machining (LBM)**
		High speed electrons	**Electron beam machining (EBM)**
		Ionized substance	**Plasma arc machining (PAM)**
Kinetic energy	**Atom by atom knocking**	**Ionized substance**	**Ion beam machining (IBM)**

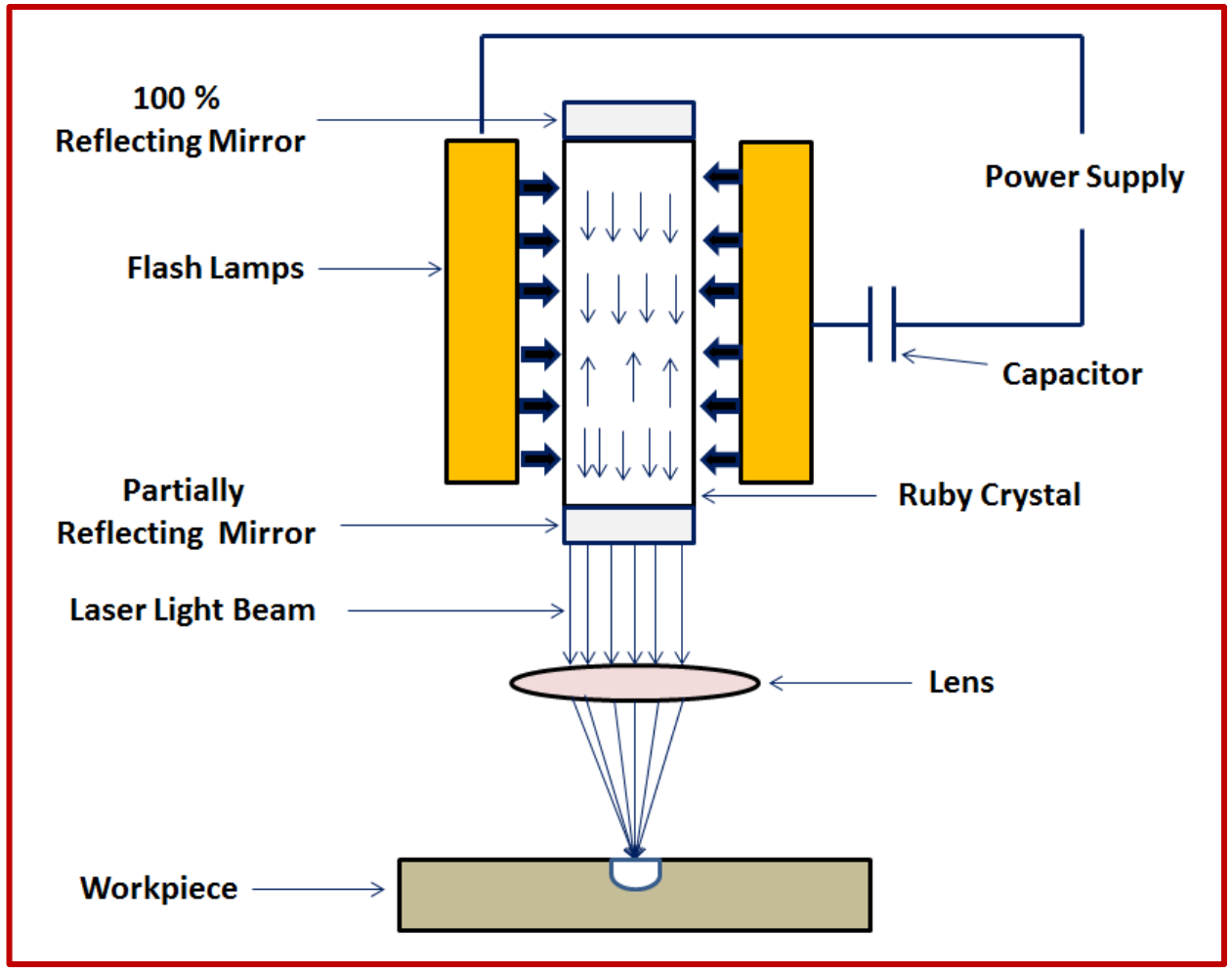
❖Hybrid modern manufacturing processes: Combination of different manufacturing techniques.

LASER Beam Machining (LBM)

Focusing Solar radiation on a paper

Intensity of sun at earth's surface = 1 kW/m^2

Focusing Light radiation on workpiece



Laser power density = 1.9x10^7 kW/m^2

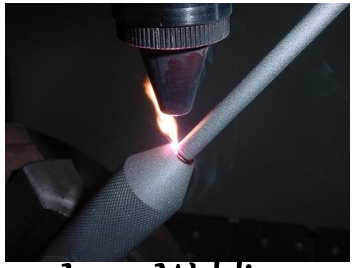
- **Can melt all the materials (including diamond)**

Applications of Laser in Manufacturing

- Laser Cutting of Metal Sheets, Glass, Wood, Plastics, Textiles, Rubber, Ceramic, Marble etc.

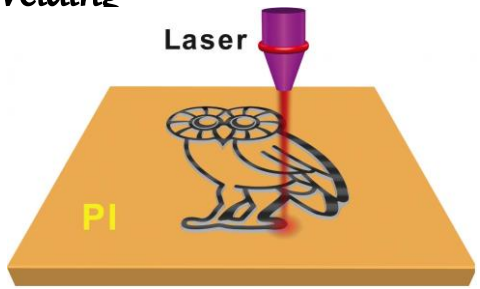
Laser Cutting

- Laser Welding of Similar & Dissimilar metals & Alloys.



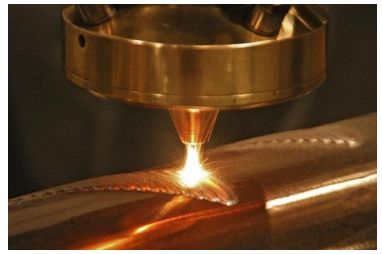
Laser Welding

- Laser Surface Hardening
- Laser scribing, marking, engraving



Laser Scribing

- Laser Surface Cladding



Laser Cladding

- Laser Rapid Manufacturing

- Laser polymerization

Laser Rapid Prototyping

- Laser Metal Forming

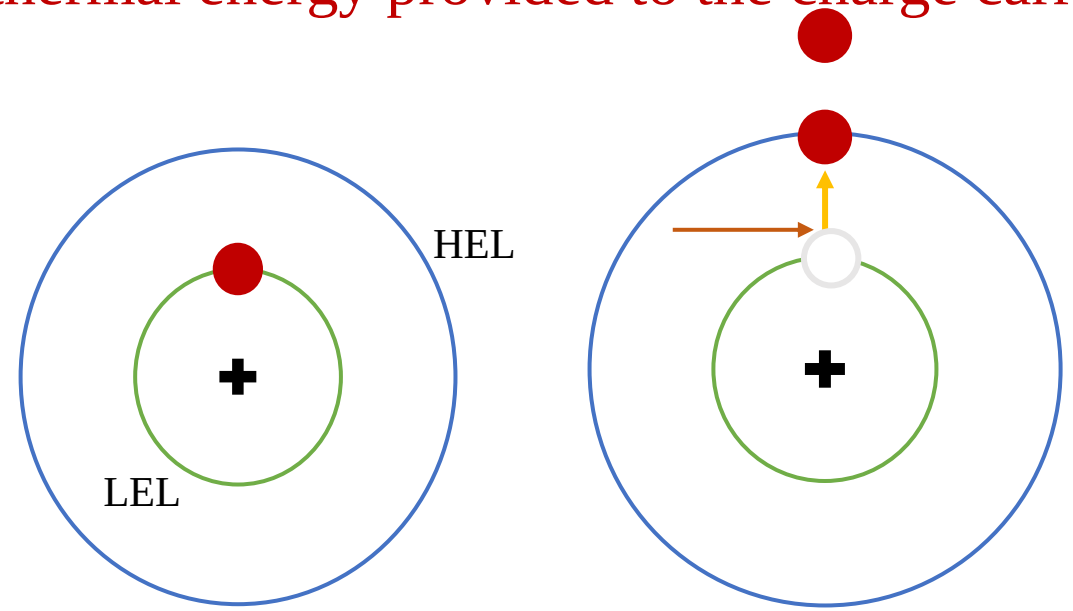
Laser Forming

- Laser Surface Alloying

Electron Beam Machining (EBM)

- Electron beam is used for machining.
- Electrons are generated by **thermionic emission from hot tungsten cathode**.
- Thermionic emission : emission of electrons from an electrode due to its temperature.

thermal energy provided to the charge carrier > work function of the material (binding potential).



LEL: Lower energy level/ Ground state, HEL: Higher energy level/ Excited state

● : electron , ⟶ : energy,

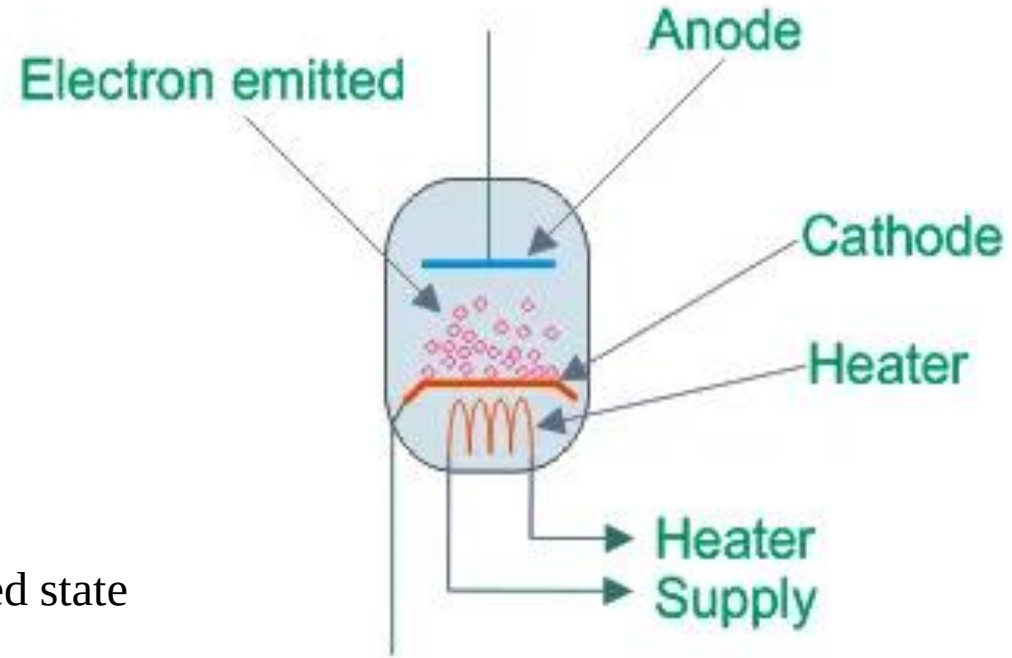


Fig. Schematic of thermionic emission process

Electron Beam Machining

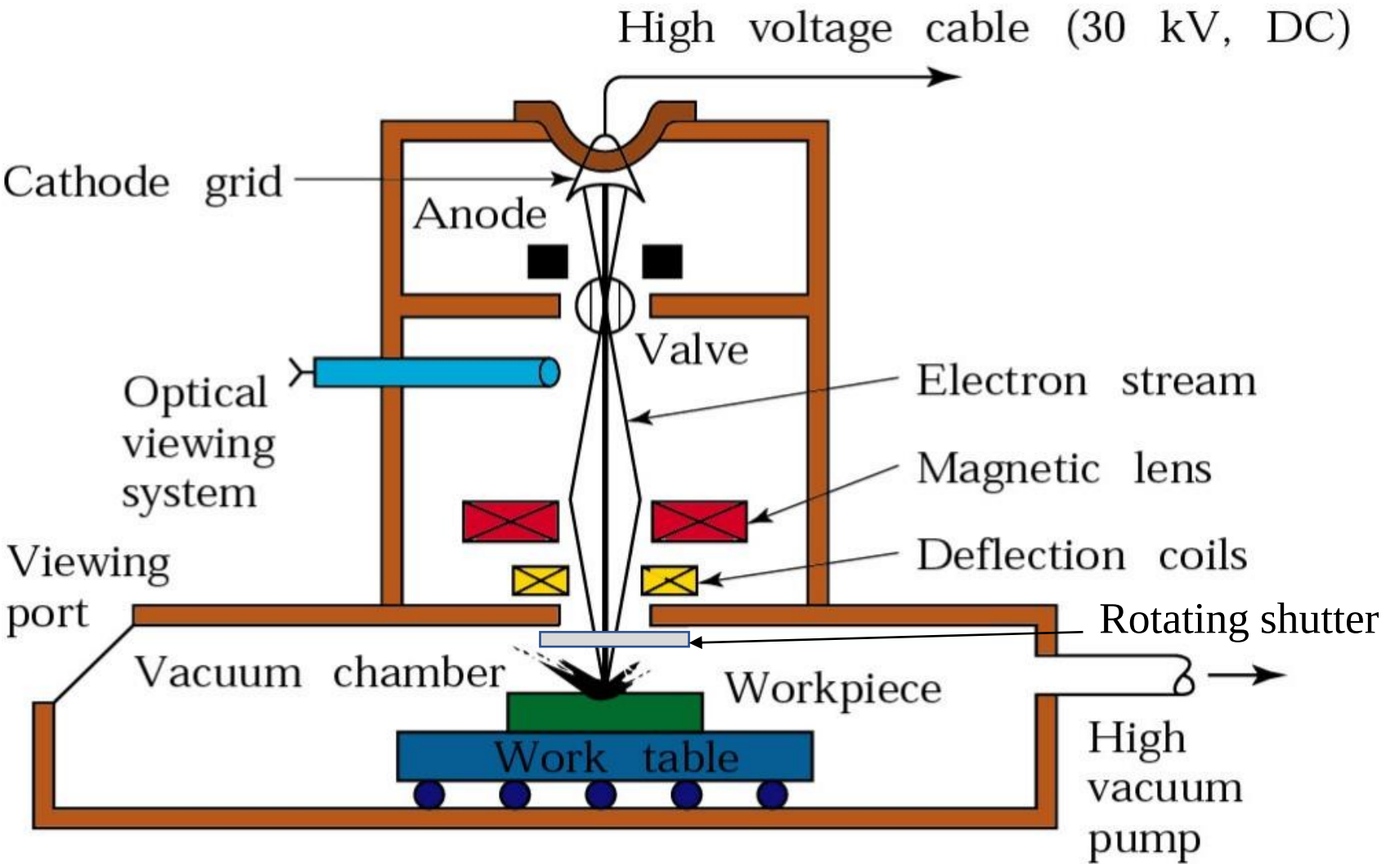
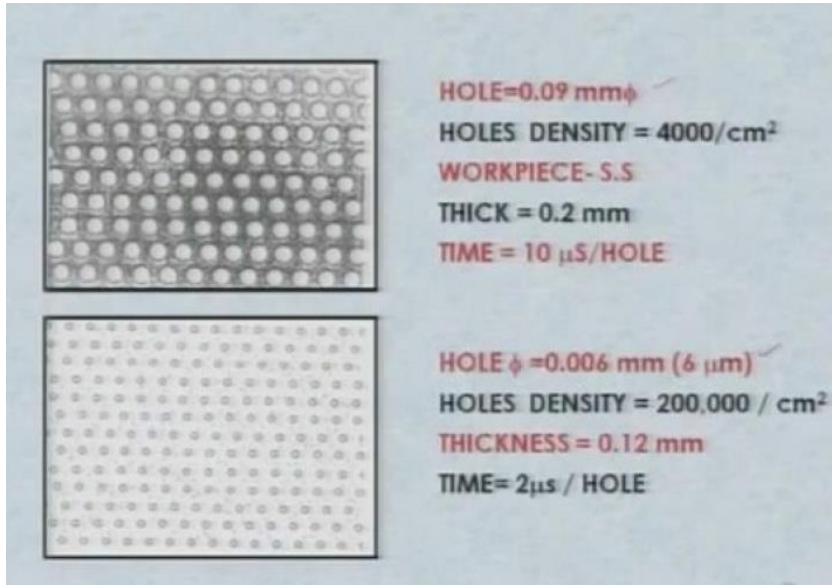


Fig. Schematic of EBM

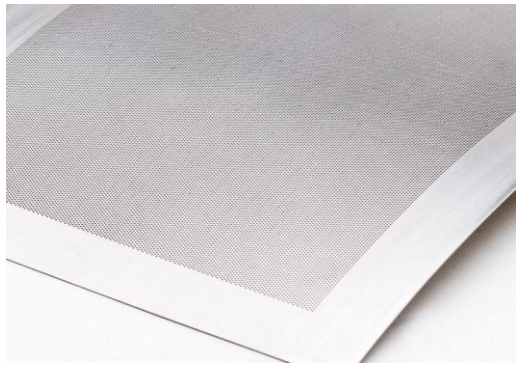
Applications of EBM

EB Drilling: Suitable where large no. of hole are needed and drilling holes with conventional process is difficult due to material hardness or hole-geometry.

- Used in aerospace, instrumentation, food , chemical & textile industries.
- Thousands of tiny holes in Turbine (steel) engine combustor.
- Cobalt alloy fiber spinning heads.
- Filters used in food processing.



Insulation
Centrifugal disc for glass wool production
12000 to 45000 holes



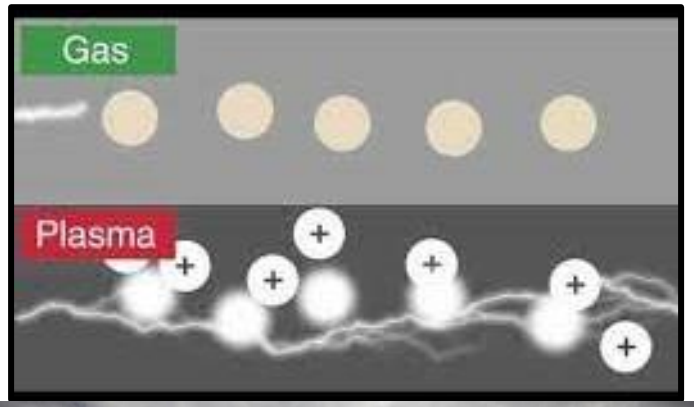
Sieves for food industry
12 million holes per square meter
1805 holes/sec

https://www.pro-beam.com/en/contractmanufacturing/mikrobohren

Plasma Arc Machining (PAM)

What is Plasma?

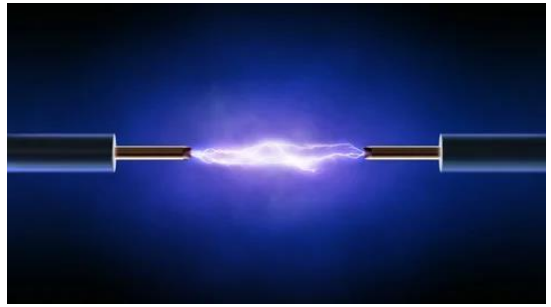
- This is the 4th state of matter –Ionized gas.
- Electrically neutral -numbers of negative charge (electron + negative ions) and positive charge equal.



What is an Arc?

Low voltage high current density gaseous discharge

- An **electric arc** is a discharge of electric current across a gap in a circuit.
- An arc discharge is characterized by a low voltage and relies on thermionic emission of electrons from the electrodes supporting the arc.



Electric arc

Ex: Ionized air (plasma)

Plasma Arc Machining

Plasma Arc

High temperature ionized gas produced by flowing gas through the arc established between cathode and work piece and/or Nozzle.

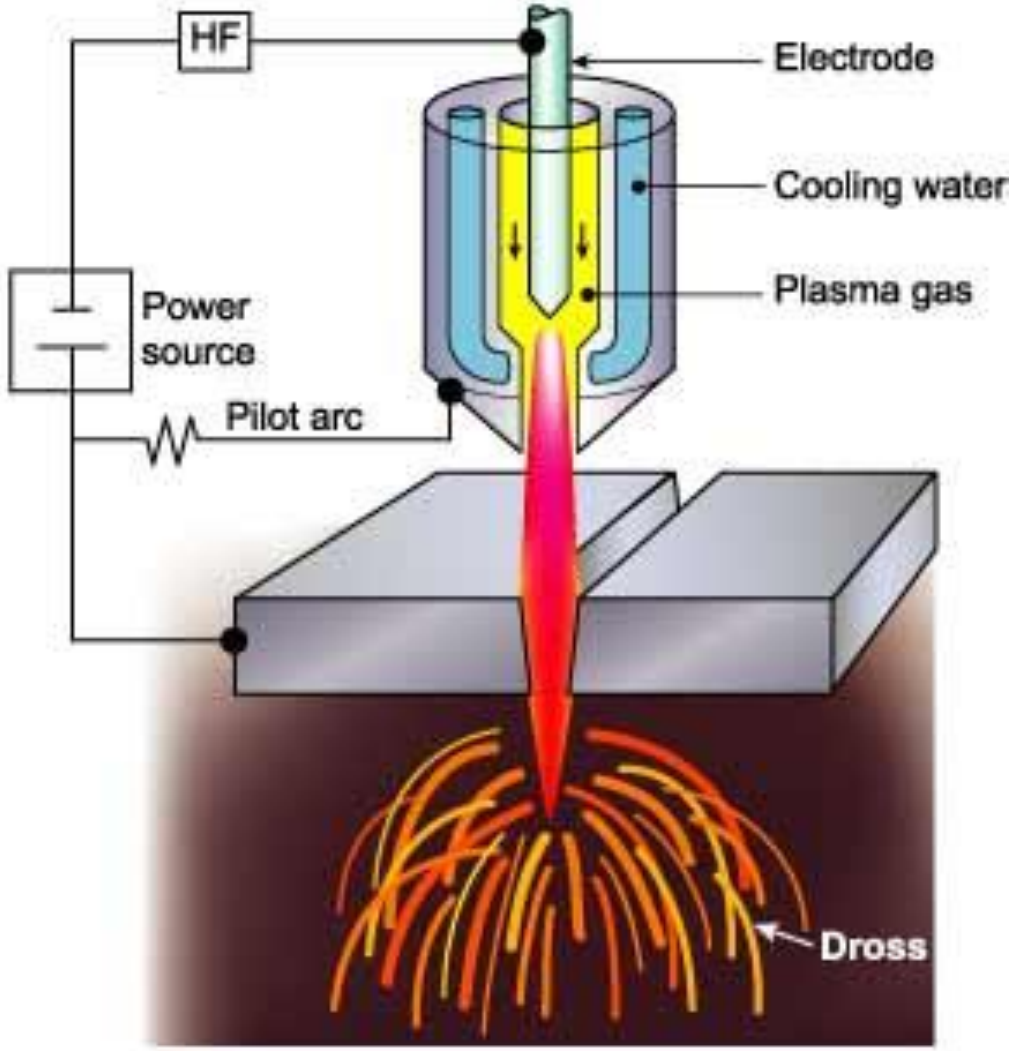


Fig. Schematic of plasma arc machining

Applications of Plasma Arc Machining

- Cutting a wide variety of conducting materials e.g. SS, Aluminum, Cr-Ni alloys, Copper, titanium, etc..
- Mostly planer cutting
- Contour cutting of complex shape integrated with CNC
- Welding of materials such as Titanium, SS etc
- Plasma arc surfacing and spraying

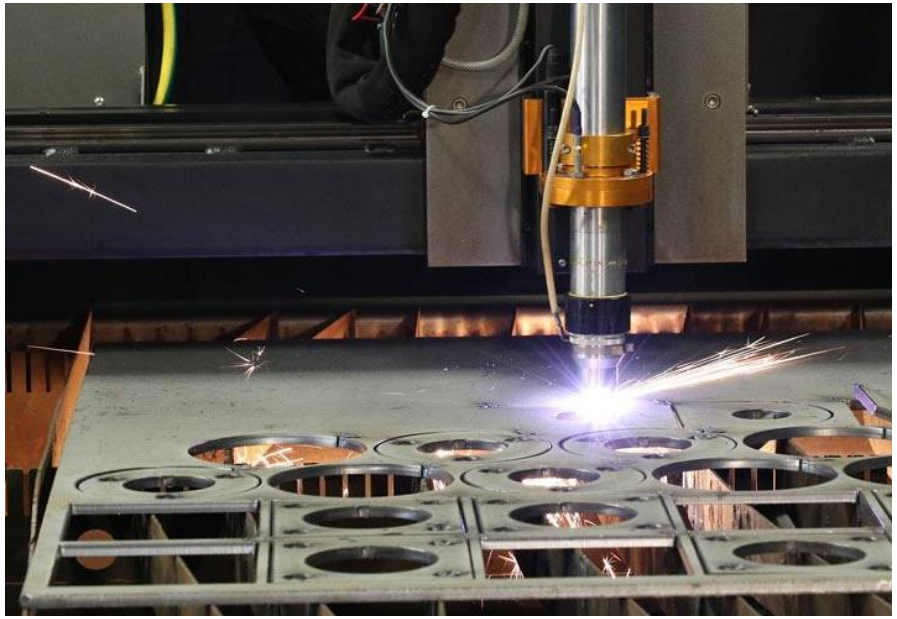


Fig. Cutting an alloy sheet using plasma arc cutting

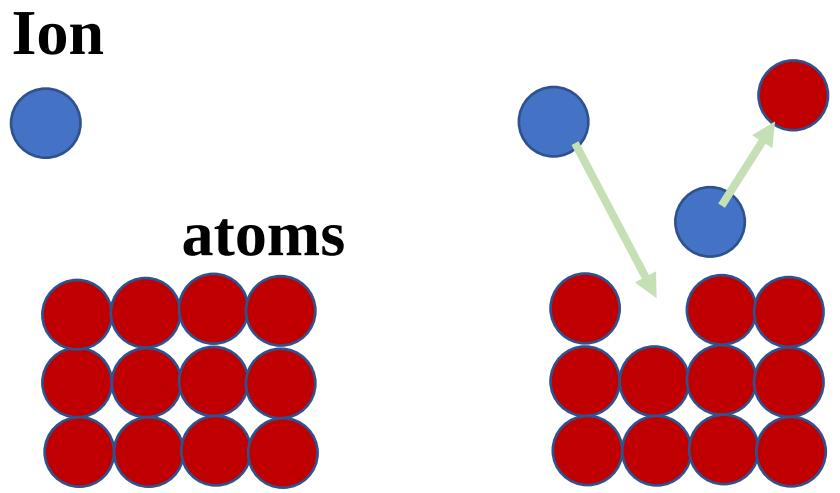
Ion Beam Machining (IBM)

- **A** type of particle beam consisting of ionized atoms i.e. ions.

Sputtering:

- A stream of ions of an inert gas, such as argon or metal such as gallium is accelerated in a vacuum by high energies and directed toward a solid workpiece.

- Ion beam knocks off atoms from workpiece by transferring kinetic energy and momentum to atoms on the targeted surface.



Kinetic Energy> Binding Energy

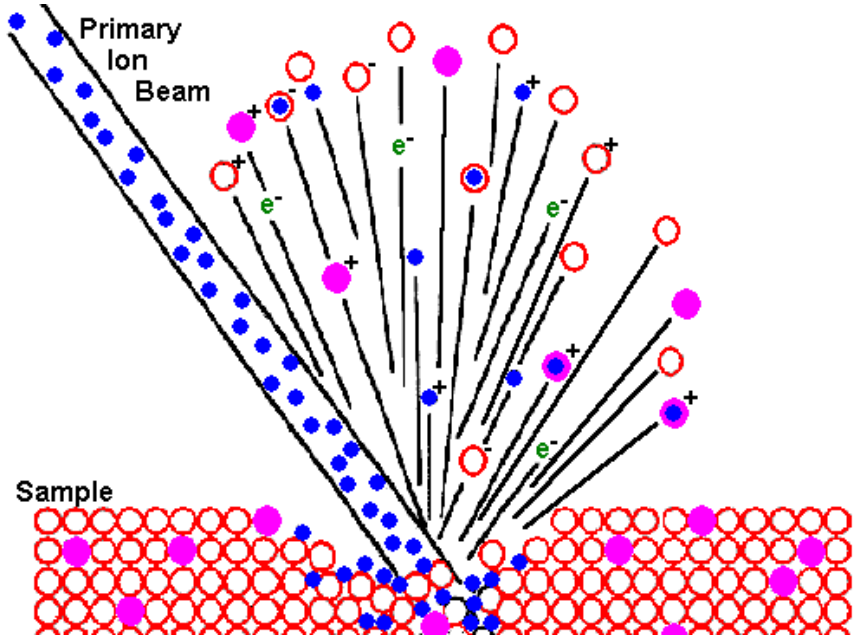
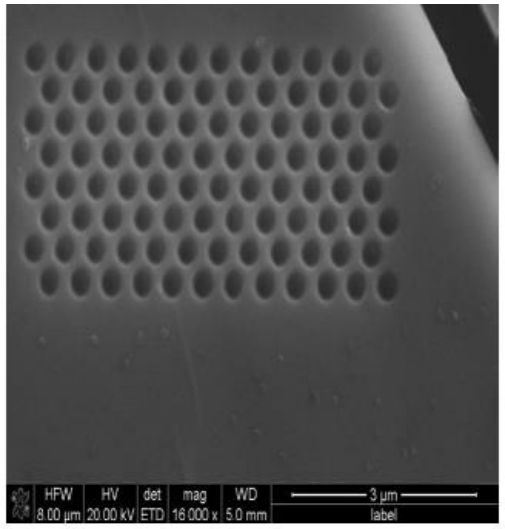


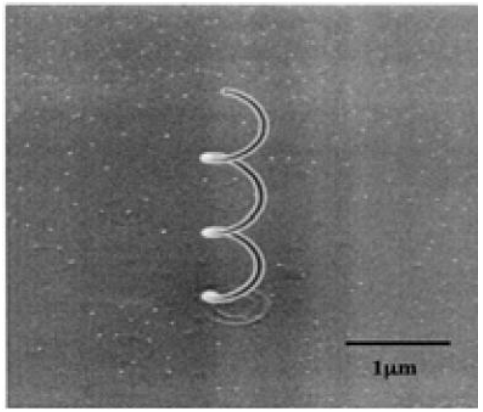
Fig. Schematic of sputtering process

Applications of Ion Beam Machining

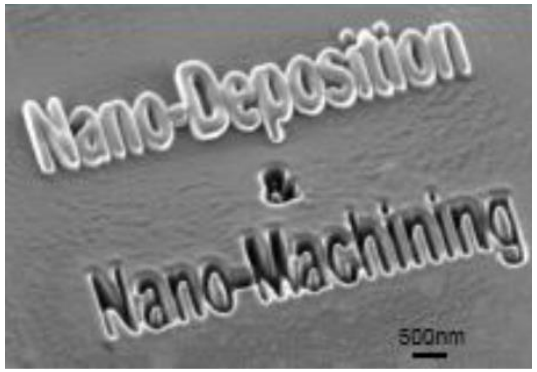
- **Etching / Milling** of all material, reactive etching, substrate cleaning,
- **Deposition:** Sputter deposition,
- **Ion- beam lithography**
- **Ion-beam implantation**



50 nm size holes patterned on a thin film using IBM



Coil 700 nm pitch, 80 nm line width, diamond like amorphous carbon, Fabricated by FIB induced deposition



Deposition and machining using FIB

THANK YOU!