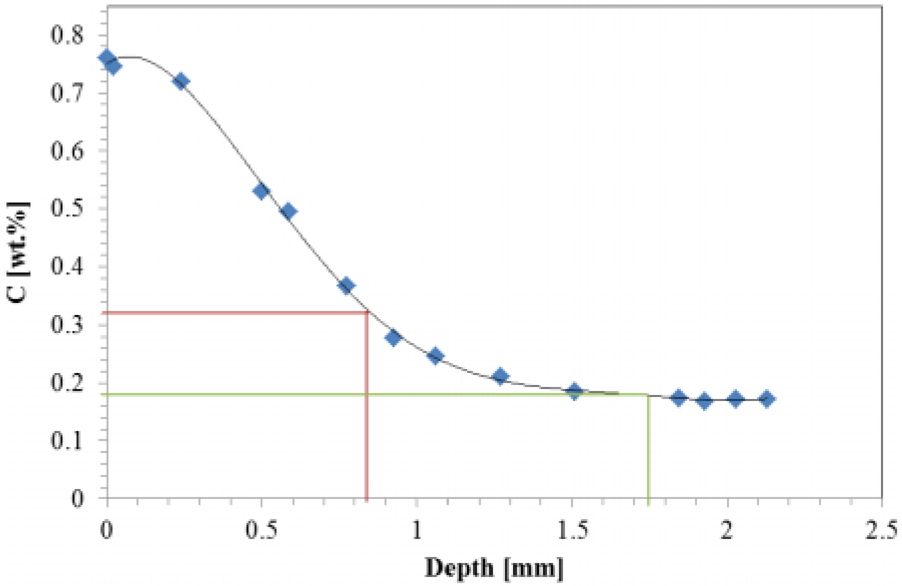
Thermochemical surface treatments

- Carburizing, decarburazing, nitriding, boriding (boronizing), chromium, vanadium and niobium addition to surface of steel.

- Purpose of process is change composition of the surface with impurity atom diffusion. It can be possible to increase corrosion, wear and fatigue resistance.

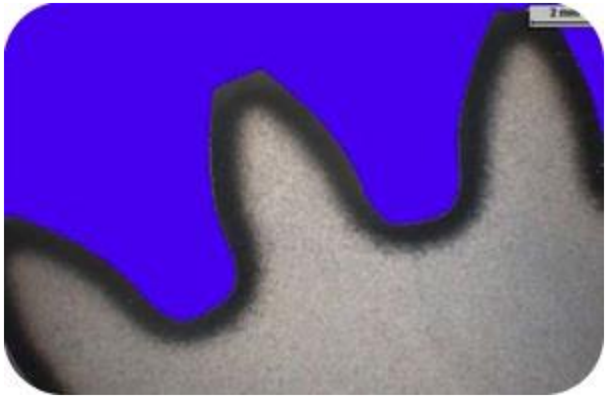
Carburizing

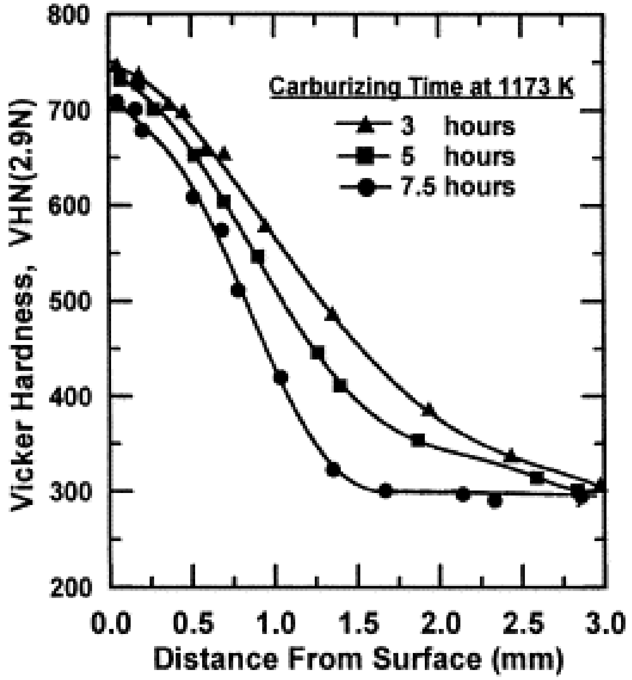
- It is a case hardening process in which carbon is dissolved in the surface layers of a low-carbon steel part at a temperature sufficient to render the steel austenitic, followed by quenching and tempering to form a martensitic microstructure.
- Absorption and diffusion of carbon into solid ferrous alloy can be carried out in contact with carbonaceous solids, liquids or gases by heating to above transformation temperature.
- **Types of carburizing:** Gas, vacuum, liquid and pack.



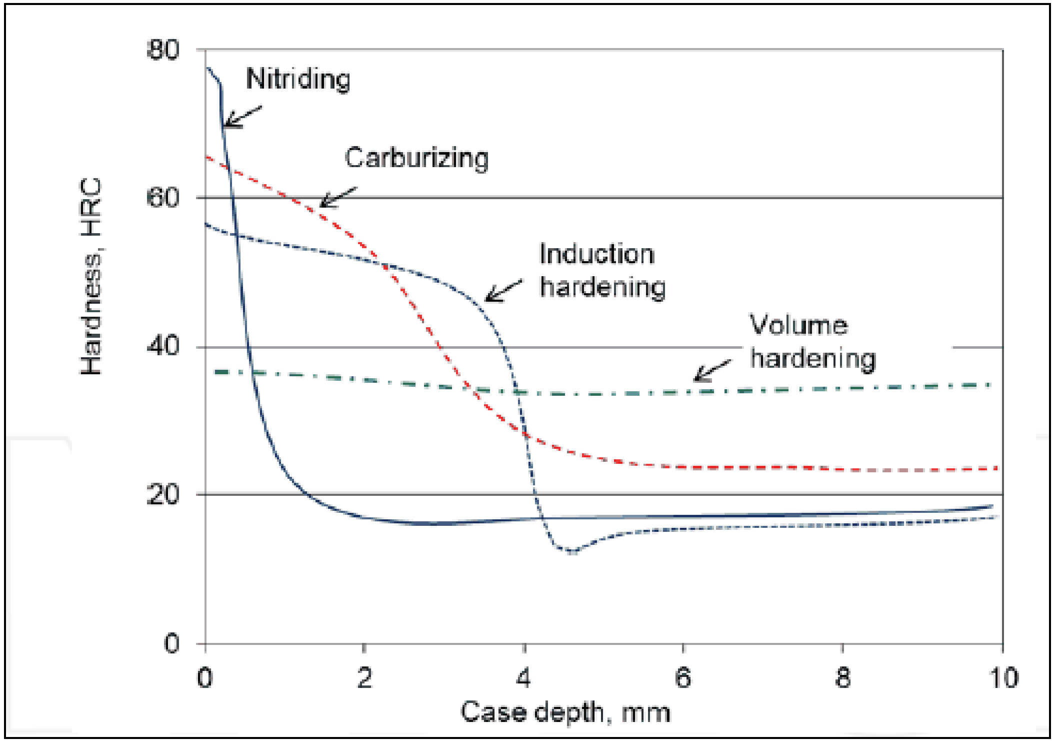
Wear resistance improves according to hardness increases in surface.

It is used for gears, shafts, pistons, chain parts, bearings, pulleys, rollers.

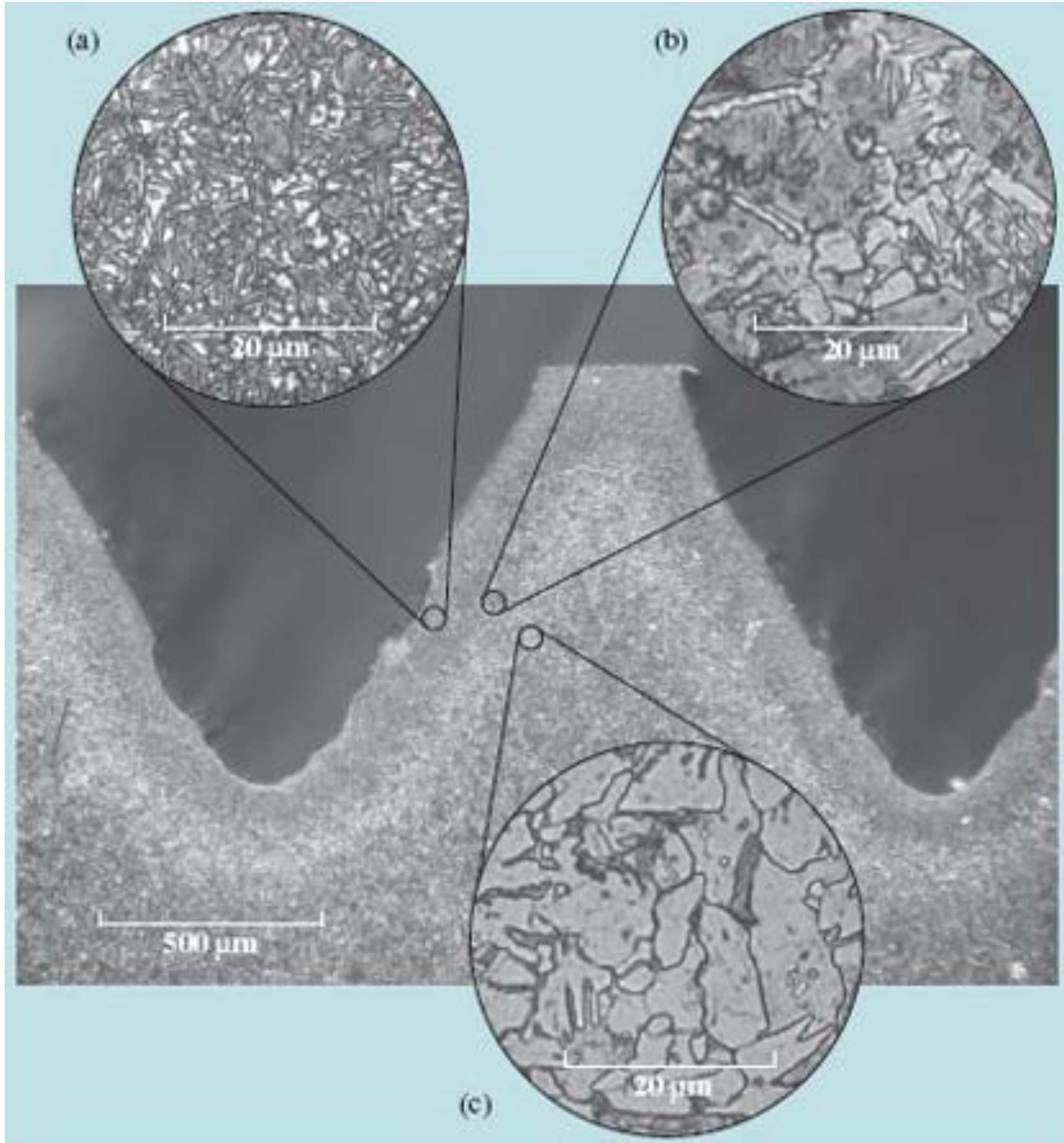




Carburizing Time at 1173 K
3 hours
5 hours
7.5 hours
Vicker Hardness, VHN(2.9N)
Distance From Surface (mm)
800
700
600
500
400
300
200
0.0
0.5
1.0
1.5
2.0
2.5
3.0



Nitriding
Carburizing
Induction hardening
Volume hardening
Hardness, HRC
Case depth, mm
80
60
40
20
0
0
2
4
6
8
10


(a)
20 µm
(b)
20 µm
500 µm
20 µm
(c)

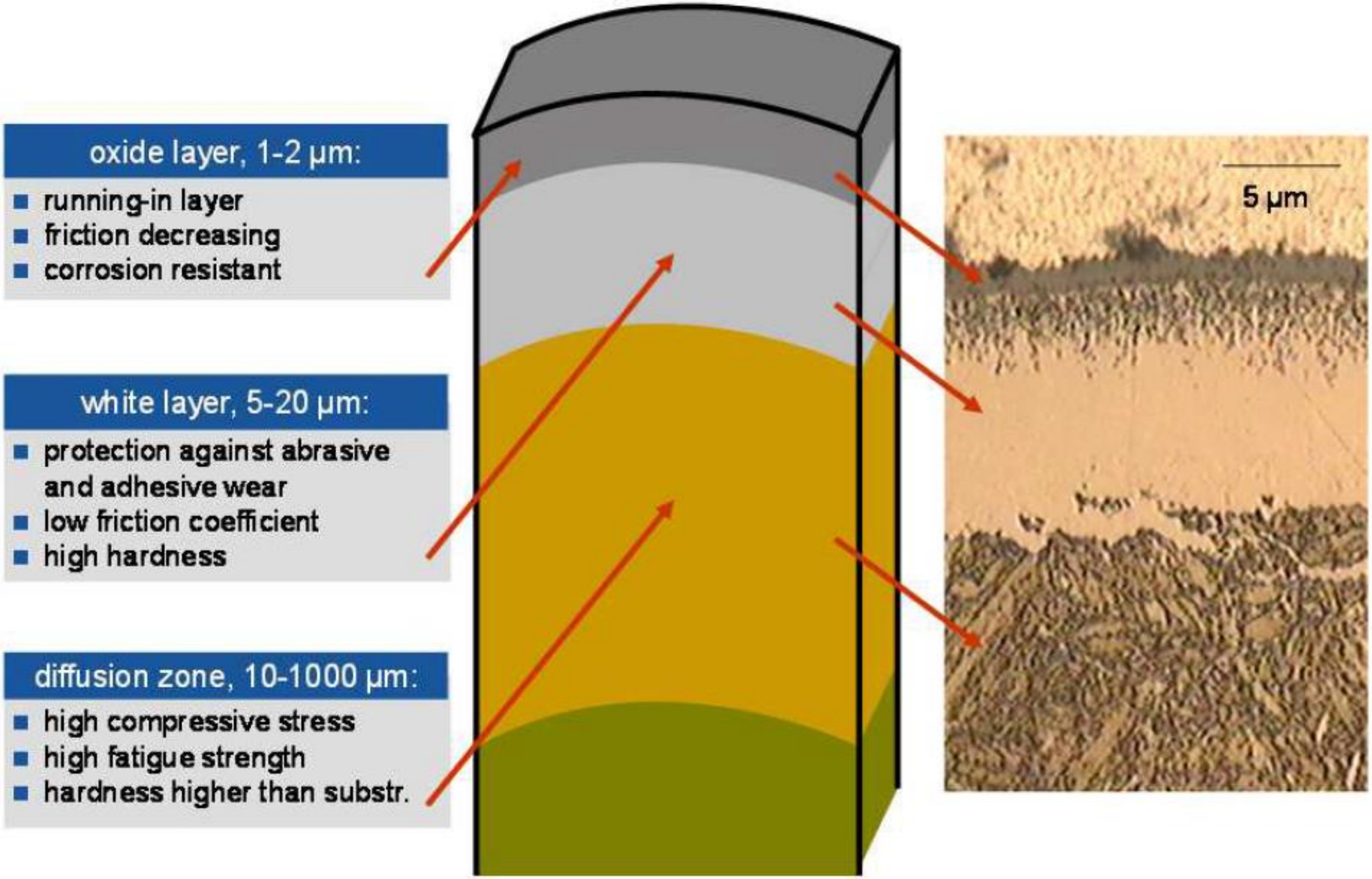
Nitriding

- Case hardening of steel by heating it in some nitrogen containing environment.
- Nitriding is applied after shaping and heat treatment of components.
- Surface hardening by diffusing N and precipitates of nitrides by soaking at below 575 °C.
- Nitride forming elements such as Cr, Al, V and Mo increases the hardness.
- Quenching is not required after nitriding. So, there is no chance of distortion or cracking.
- **Types of nitriding**

    1- Liquid or salt bath

    2- Gas

    3- Plasma (ion)


oxide layer, 1-2 µm:
running-in layer
friction decreasing
corrosion resistant
white layer, 5-20 µm:
protection against abrasive and adhesive wear
low friction coefficient
high hardness
diffusion zone, 10-1000 µm:
high compressive stress
high fatigue strength
hardness higher than substr.
5 µm

Liquid or salt bath nitriding

- Also known as soft nitriding.
- Bath is the molten mixture of <u>cyanate or carbonate.</u>
- Can be applied to all types of steels.
- Short time heat treatment process.
- Case depth consists of compound (white) layer (few microns) and diffusion zone (~0.5 mm).
- Thicker case is formed in plain carbon steels but thinner in alloy steels.
- Most economical nitriding process.
- Corrosion inhibitive ability of layer produced by nitriding can be improved by post oxidation process.

Gas nitriding

- Steel part is heated in ammonia.

  $NH_3 \rightarrow 3H + N$
- Operating temperature: 500 - 650 °C
- Operating time: 50 – 90 hours
- Case depth is between 0.2 – 0.4 mm.
- Dissociation of ammonia results in nitrogen which react with steel elements to form nitrides.
- Provides high surface hardness.
- Only special types of steels can be heat treated using this process.
- Cycle time is long and relatively expensive nitriding process.

Plasma (ion) nitriding

- Plasma nitriding, also known as ion nitriding, plasma ion nitriding or glow-discharge nitriding, is an industrial surface hardening treatment for metallic materials.
- In plasma nitriding, the reactivity of the <u>nitriding media is not due to the temperature but to the gas ionized state</u>. In this technique intense electric fields are used to generate ionized molecules of the gas around the surface to be nitrided. Such highly active gas with ionized molecules is called plasma, naming the technique. <u>The gas used for plasma nitriding is usually pure nitrogen, since no spontaneous decomposition is needed (as is the case of gas nitriding with ammonia).</u>

- There are hot plasmas typified by plasma jets used for metal cutting, welding, cladding or spraying. There are also <u>cold plasmas, usually generated inside vacuum chambers, at low pressure regimes.</u>
- Usually steels are beneficially treated with plasma nitriding. This process permits the close control of the nitrided microstructure, allowing nitriding with or without compound layer formation.
- A plasma nitrided part is usually ready for use. It calls for no machining, or polishing or any other post-nitriding operations. Thus the process is user-friendly, saves energy since it works fastest, and causes little or no distortion.

Process stages of plasma nitriding

1. **<u>Cleaning:</u>** The parts are cleaned from any grease, oils or dirt left. The pulsed plasma generator prevent the formation of arcs.
2. **<u>Heating:</u>** Nitrogen ions bombard the surface of the components and their kinetic energy turns into heat. The heating speed is easily controlled.
3. **<u>Nitriding:</u>** Nitrogen atoms diffuse in the surface of the component, forming the nitriding layer. By controlling the main process parameters: <u>temperature, pressure, gas mixture and time;</u> a nitrided layer of your specific requirements is achieved.

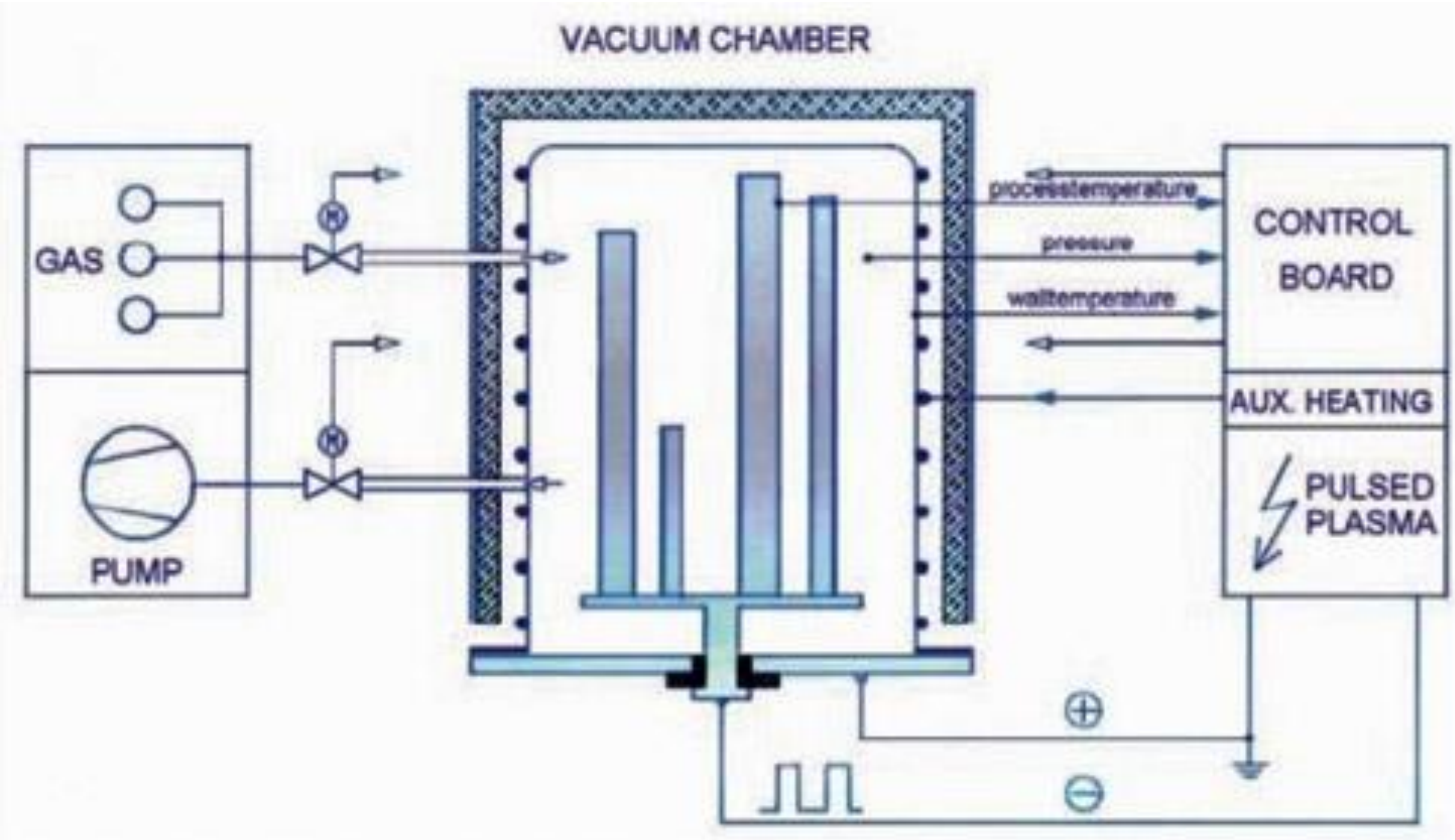
<u>Advantages of plasma nitriding:</u>

Greatly improved:

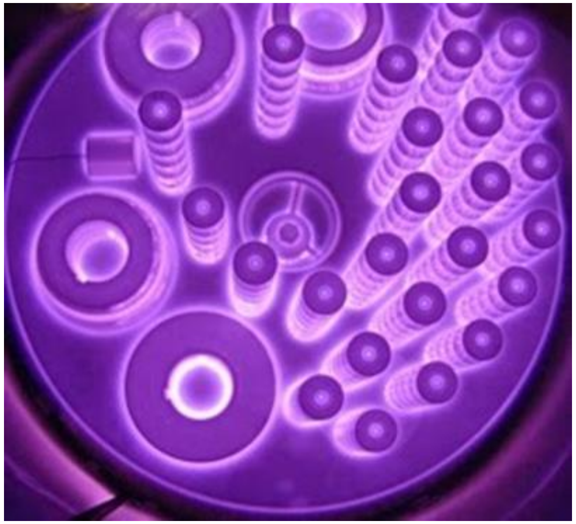
- Surface hardness.
- Wear resistance.
- Corrosion resistance.
- Fatigue resistance.
- Lower friction coefficient.

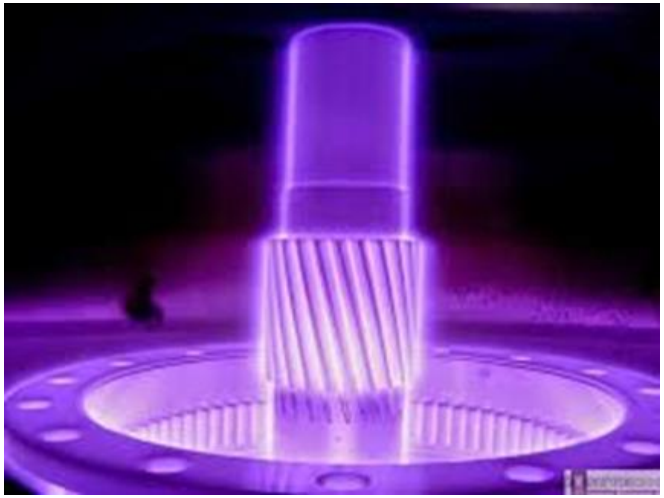
<u>Industries served:</u>

- Automotive, aerospace, energy, medical, fire arms, tooling and more.



Plasma niriding process is carried out in vacuum. High voltage is applied to the chamber which ignites the glow discharge.

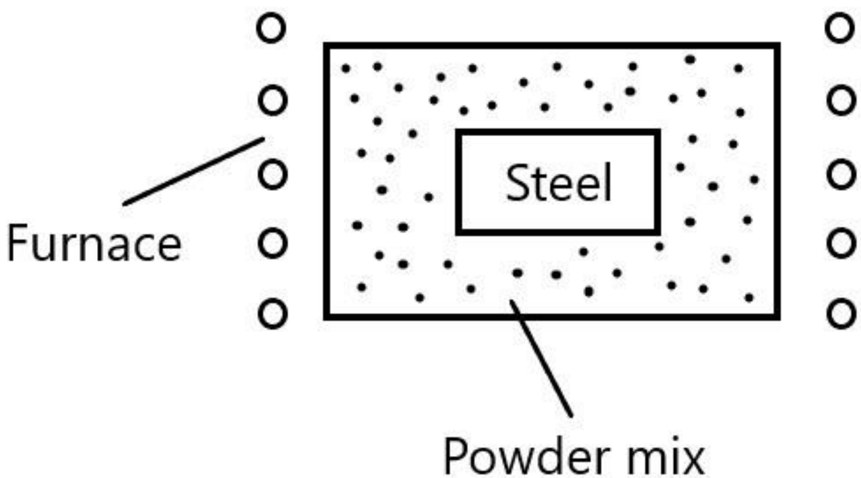




Metal diffusion

- It is a diffusion process to produce Al, Si and Cr based layers on iron, steel and super alloy surfaces.
- For improve high temperature corrosion resistance of super alloys and steels, Al is diffused to surfaces.
- Saturation of steel surfaces with Cr is gained high resistance to gaseous corrosion temperatures up to 800 °C. Also it provides anti-corrosion properties against to fresh water, sea water and nitric acid solutions.

Chromium diffusion process (Chromizing)



Heating up to 1300 °C depends on composition.

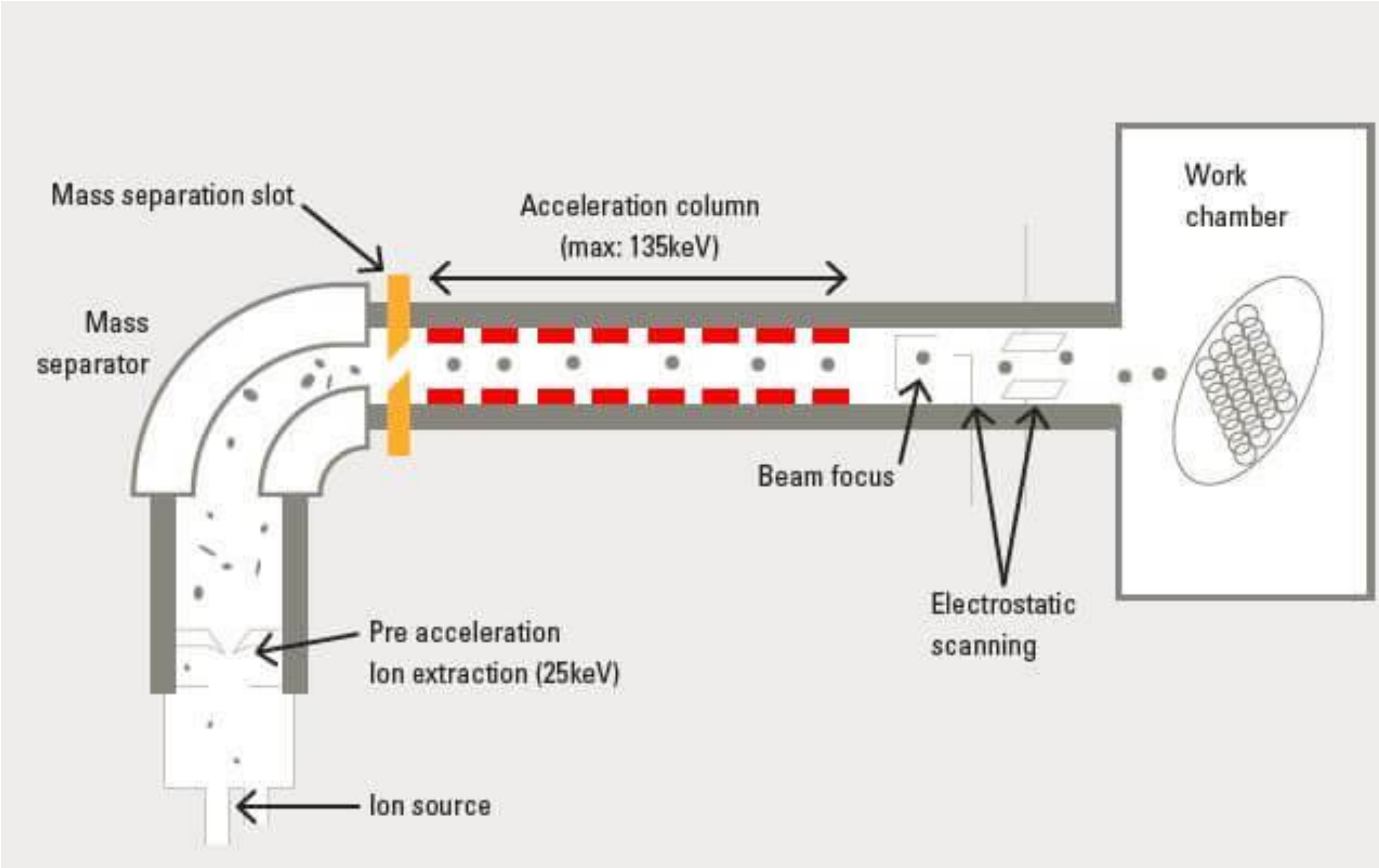
Powder mix: Pure Cr or FeCr (Cr source) + Al_2O_3 (filler) + NH_4Cl, NH_4I (halide activator)

In low carbon steels (~0.1 C) solid solution forms in ferrite (soft chromising). Surface hardness = 250-300 HV

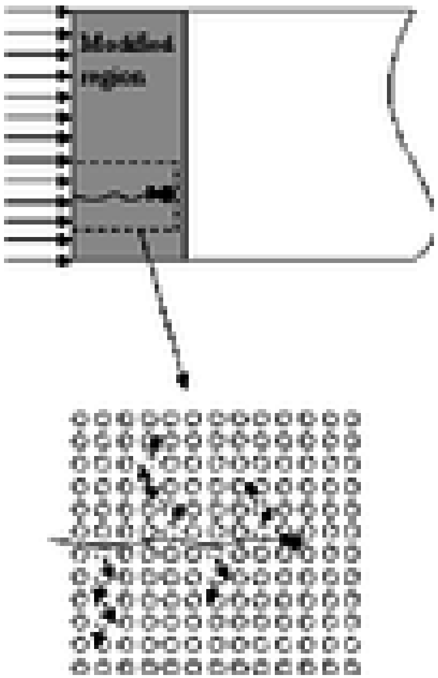
In high carbon steels (min 0.35 C) $(Fe,Cr)_7C_3$ carbide layer forms (hard chromising). Surface hardness = 1300-1600 HV

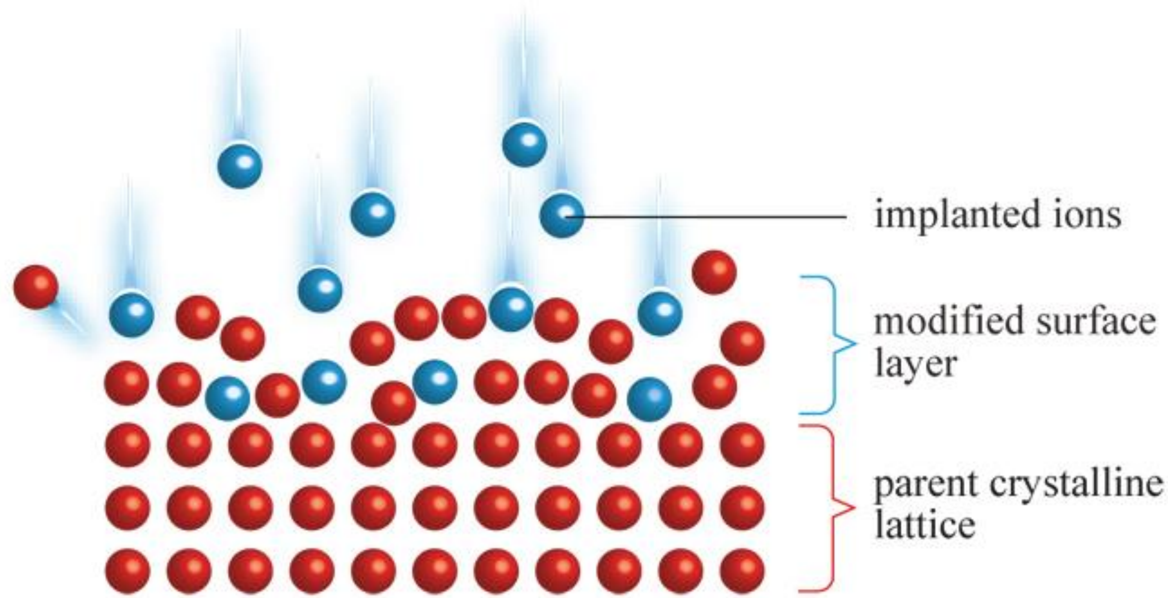
Ion implantation

- It is a controlled ion penetration process into material surfaces using with high energy ion beams (10, 20 keV – 100, 200 keV).
- It is carried out in a vacuum chamber at ultra low pressures (10^{-4} – 10^{-5} torr).
- Numerous ions (10^{16} – 10^{17} ions/cm^2) bomb surface and diffuse through subsurface layers and interacts with base material atom.



Mass separation slot
Acceleration column
(max: 135keV)
Work
chamber
Mass
separator
Beam focus
Electrostatic
scanning
Pre acceleration
Ion extraction (25keV)
Ion source





<u>**Ion implantation parameters**</u>

- Ion energy
- Ion impact angle
- Ion flow density
- Implantation time
- Type of ion
- Implantation temperature
- Nature of base material

Advantages of ion implantation

- Almost every element in the periodic table can be implanted.
- Because of being a low temperature process, it does not effect former processes.
- Two different material can produce compound like MoS_2 on steel surface.
- Metastable, amorphous glassy phases can be obtained on surfaces.
- There is not a certain interface.

Disadvantages of ion implantation

- If implanted atoms have mobility, inclusions or precipitates can be formed.
- High energy ions cause many crystal defects on material surface.
- Shallow surface layer. Thus, implantation into deep regions are difficult.
- Base material heats up because of ion bombing.
- Devices are expensive.

Basic industrial applications of ion implantation

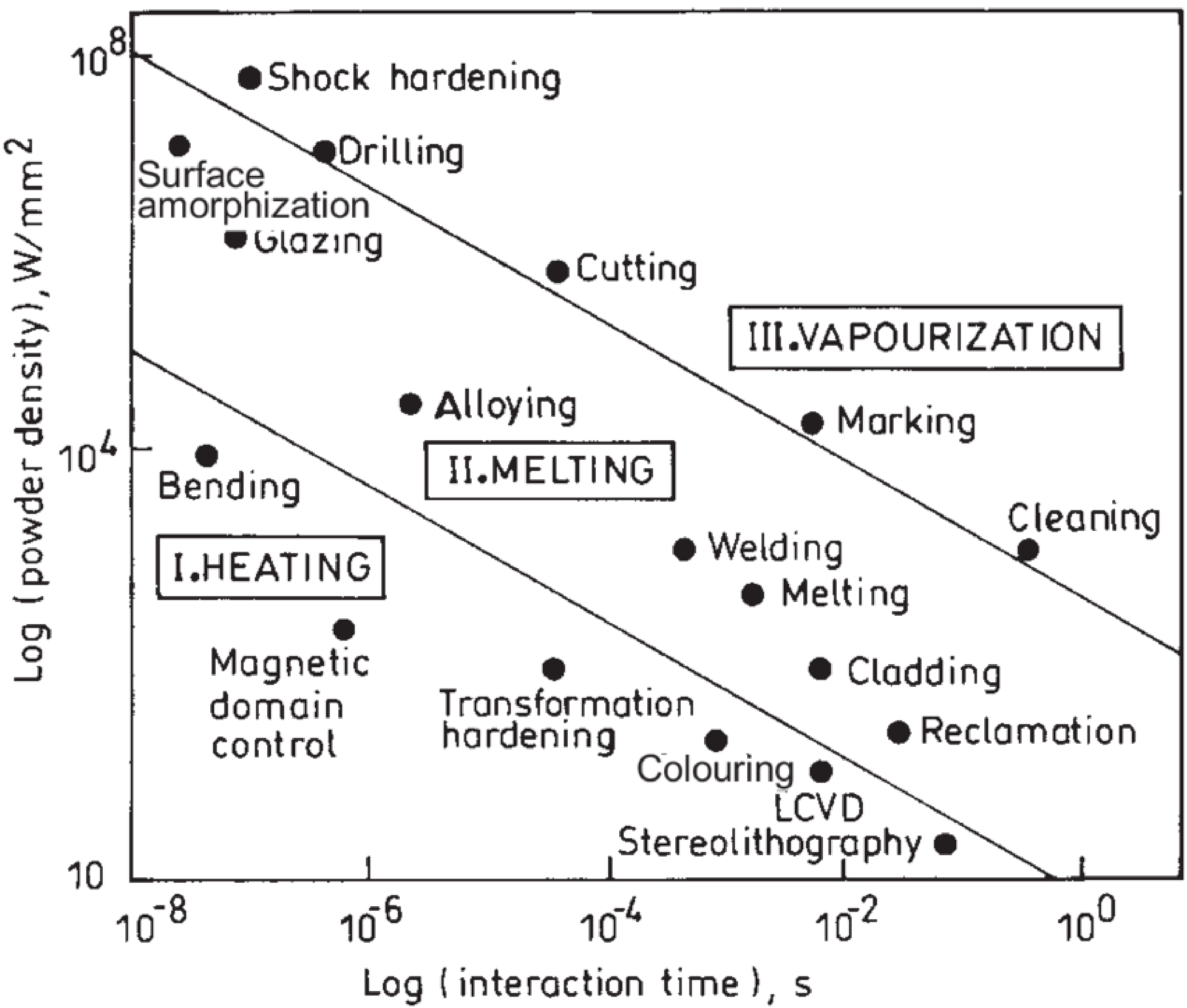
- **Semi conductor industry:** It is developed for implantation of semi conductive elements of integrated circuits.
- **Metal tools:** Properties improved and life time increased. Steel forming tools in automotive industry and plastic extrusion dies surfaces are implanted with nitrogen. So wear and friction resistances improve.
- To improve wear properties of ceramics. Stabilize conductive polymers.
- **Biomedical applications:** To improve wear properties of Ti based implants. Bearing surfaces of knee and hip implants are implanted with nitrogen ions.

Surface alloying (Laser cladding)

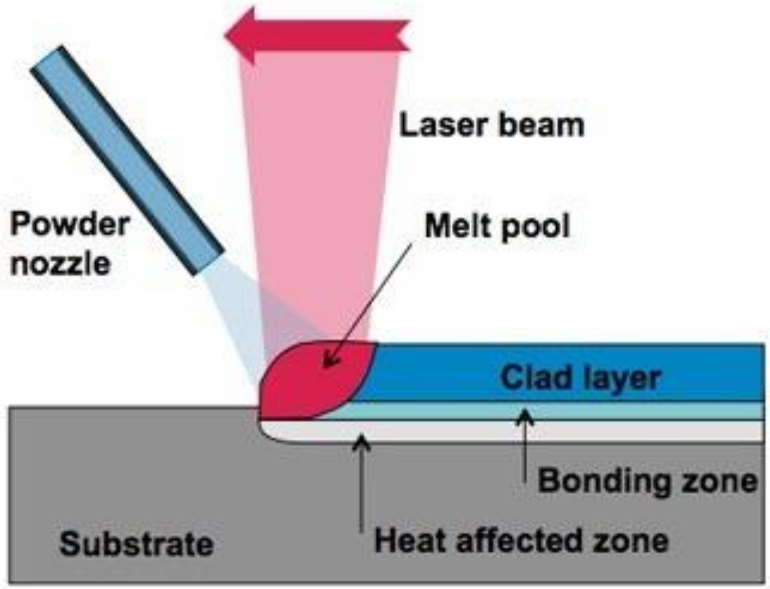
- First, melting of the surface in desired layer than controlled addition of alloying material.
- Especially laser is used for this process.
- Additive material can be in solid, liquid or gaseous phase.
- Alloy depth is controlled with laser power and process time
- A layer in different composition on the surface can be produced. It has higher resistance to corrosion, erosion, wear and oxidation.

Laser surface alloying examples

- If N_2 shielding gas is used during Ti melting, TiN forms.
- TiC can be made with C injection in Ti melting also carbonitrides can be produced with N_2 gas.
- Elemental Cr can be alloyed to 1018 steel. Fe-Cr alloy forms on surface.
- Intermetallic phases like Al_3Fe, $TiAl_3$, Al_3Ni and $AlNi_2$ can be formed on the surface of aluminium to increase hardness.
- Particle reinforced composites can be produced with dissolving particle injection. SiC and WC are suitable particles for this process.



Shock hardening
Drilling
Surface amorphization
Glazing
Cutting
III.VAPOURIZATION
Alloying
Marking
II.MELTING
Bending
Cleaning
I.HEATING
Welding
Melting
Magnetic domain control
Transformation hardening
Cladding
Reclamation
Colouring
LCVD
Stereolithography
10^8
10^4
10
10^{-8}
10^{-6}
10^{-4}
10^{-2}
10^0
Log (powder density), W/mm^2
Log (interaction time), s



LASER SURFACE ALLOYING

Video links

- https://www.youtube.com/watch?v=0BaUFmDPp44
- https://www.youtube.com/watch?v=pYQuqNFG2ro
- https://www.youtube.com/watch?v=FwlDKV3GR8M
- https://www.youtube.com/watch?v=BSpoNNVZc58
- https://www.youtube.com/watch?v=XAGsZetnupw
- https://www.youtube.com/watch?v=C0GINDPG8Ns
- https://www.youtube.com/watch?v=8_jt93zrT20
- https://www.youtube.com/watch?v=IWLlBXYOaIU
- https://www.youtube.com/watch?v=X3dom58qD9Y
- https://www.youtube.com/watch?v=BdCW9pVu1qU