GROUP 3

TITANIUM Alloys :TYPES, MICROSTRUCTURE, properties and applications

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Titanium And its Alloys

- Titanium is named after the Titans, the powerful sons of the earth in Greek mythology.
- Titanium is the fourth abundant metal on earth crust (~ 0.86%) after aluminium, iron and magnesium.
- Have similar strength as steel but with a weight nearly half of steel.

Titans

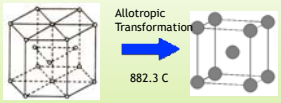
Ilmenite (FeTiO3)

Rutile (TiO2)

Types of Titanium Alloys

- •α -Titanium alloys
  - ❑Non-heat treatable and weldable
  - ❑Medium strength, good creep strength
  - ❑Good corrosion resistance
- •α + β -Titanium alloys
  - ❑Heat treatable, good forming properties
  - ❑Medium to high strength, good creep strength
- • β -Titanium alloys
  - ❑Heat treatable and readily formable
  - ❑Very high strength
  - ❑Low ductility

Alloying system of titanium alloys



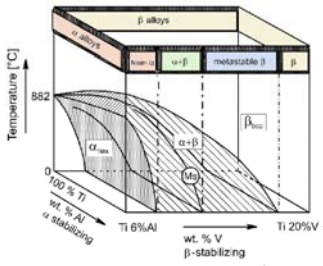
α-Phase HCP

β-Phase BCC

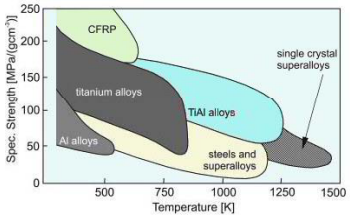
Alloying Elements

- •α- Stabilisers - Al, O, N
- •ß- Stabilisers - Mo, V, W, Fe ,Cr ,Cu
- •Neutral - Zr, Si, Sn

Basic Phase Diagrams for Ti-alloys



Relative Strength of Ti-alloys



What is a microstructure ?

- Microstructure is the small scale structure of a material, defined as the structure of a prepared surface of material as revealed by a microscope above 25X magnification.
- The microstructure of a material can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion res… av…
- Th… opl… ind…

Classification of titanium alloys

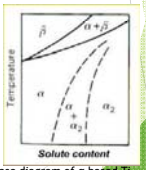
- Commercially pure (CP) titanium alpha and near alpha titanium alloys
- Alpha-beta titanium alloys
- Beta titanium alloys

Different crystal structures and properties -> allow manipulation of heat treatments to produce different types
of alloy microstructures to suit the required mechanical properties.

Commercially pure (CP) titanium and alpha/near alpha alloys

Microstructure contains HCP phase and can be divided into :

- Commercially pure titanium alloys
- Alpha titanium alloys
- Near alpha titanium alloys

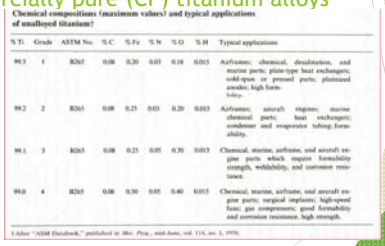


Phase diagram of α based Ti alloy

Properties of commercially pure titanium alloys

- Lower strength, depending on contents of O, N.
- Corrosion resistance to nitric acid, moist chlorine.
- 0.2% Pd addition improves corrosion resistance in HCl, H_2SO_4, H_3PO_4.
- Less expensive.

Compositions and applications of commercially pure (CP) titanium alloys



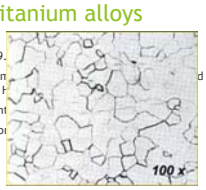
Chemical compositions (maximum values) and typical applications of unalloyed titanium†

% Ti	Grade	ASTM No.	% C	% Fe	% N	% O	% H	Typical applications
99.5	1	B265	0.08	0.20	0.03	0.18	0.015	Airframes; chemical, desalination, and marine parts; plate-type heat exchangers; cold-spun or pressed parts; platinized anodes; high form-
99.2	2	B265	0.08	0.25	0.03	0.20	0.015	Airframes; aircraft engines; marine chemical parts; heat exchangers; condenser and evaporator tubing, form-
99.1	3	B265	0.08	0.25	0.05	0.30	0.015	Chemical, marine, airframe, and aircraft engine parts which require formability strength, weldability, and corrosion resistance.
99.0	4	B265	0.08	0.30	0.05	0.40	0.015	Chemical, marine, airframe, and aircraft engine parts; surgical implants; high-speed fans; gas compressors; good formability and corrosion resistance, high strength.

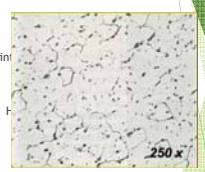
† After "ASM Databook," published in *Met. Prog.*, mid-June, vol. 114, no. 1, 1978.

Microstructure of commercially pure (CP) titanium alloys

- Purity 99.…
- Main elem… d in… C, O, N, H
- O content …
- C, N, H pr… H



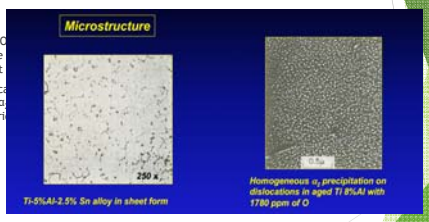
HCP α phase structure



HCP α phase structure with ß spheroidal particles due to 0.3% Fe as impurity

Alpha titanium alloy

- Al and O provide present
- 5-6%Alca phase(α deleteri



Near-alpha titanium alloys

- Small amounts of ß stabilisers (Mo,V) are added, giving a microstructure of ß phase dispersed in the α phase structure.
- Sn and Zr are added to compensate Al contents while maintaining strength and ductility.

Alpha - beta titanium alloys

- Alpha-beta titanium alloys contain both α and ß.
- A stabilisers are used to give strength with 4-6% ß stabilisers to allow the ß phase to retain at RT after quenching from ß or α+ß phase field.
- Microstructure depends on chemical composition, processing history and heat treatments, i.e., annealing, quenching and tempering.

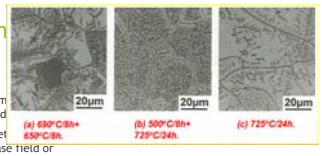
ß titanium alloys

- ß titanium alloys possess a BCC crystal structure, which is readily cold-worked (than HCP α structure) in the ß phase field.
- Microstructure after quenching contains equiaxed ß phase.
- After solution heat treating + quenching giving very high strength (up to 1300-1400 MPa).
- Metastable ß Ti alloys are hardenable while stable ß Ti alloys are non-hardenable.

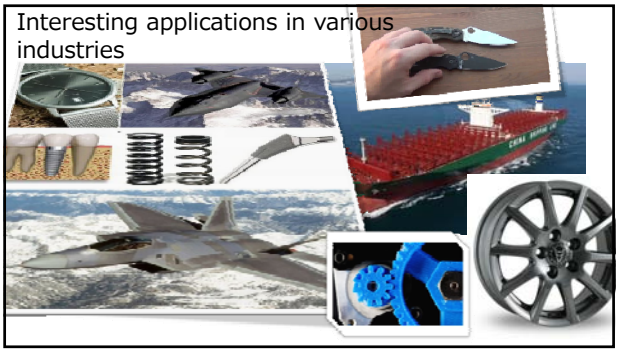
ß titanium

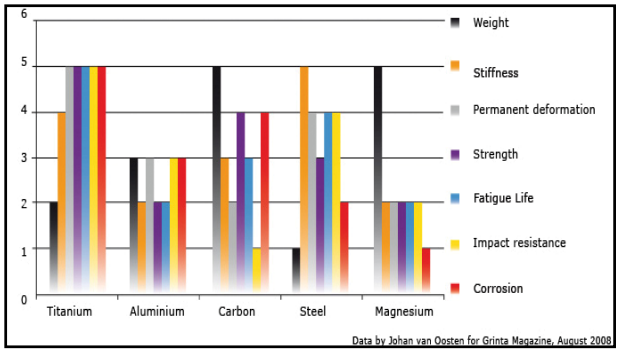
- Most ß titanium metastable and

1. coarse α platlet in the α+ß phase field or
2. α phase precipitation after long term ageing at elevated temperature.



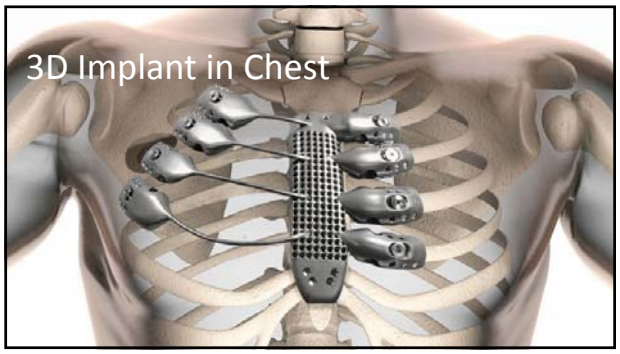
Interesting applications in various industries





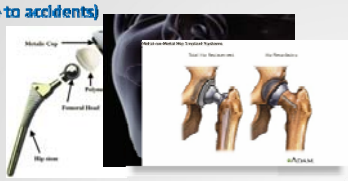
- Many Surgical instruments (Ex. In Dentistry) are nowadays made of Ti alloys.

- Ti Ceramics is an interesting field.
- Nowadays such materials are used for making implants for teeth.
- Wires of beta Titanium are used in Orthodontic operations (Highly Ductile in nature).



Titanium RibCage

- Ti alloys used in making various implants:
  - Orthopaedic implants
  - Bone Screws
  - Trauma Plates (Fractures due to accidents)
  - Dental Fixtures
  - Surgical instruments
  - Joint Replacement



- Innovation:
  - SR-71 (also known as ***BlackBird*** or ***Lockheed***) is made by US Aircraft agencies.
  - One of the most famous in its time.
  - Its ridiculously FAST !!!
  - Its Top speed is around..
  - ***3540 km/hr or 983 metres/sec***
  - Cost around **33M US$**
  - Retired in 1999.
  - Still the fastest manned jet-powered aircraft in History.
  - Mostly made of ***Beta Ti alloys*** (Around 85%).

Ti 6-4 or Ti6Al4V

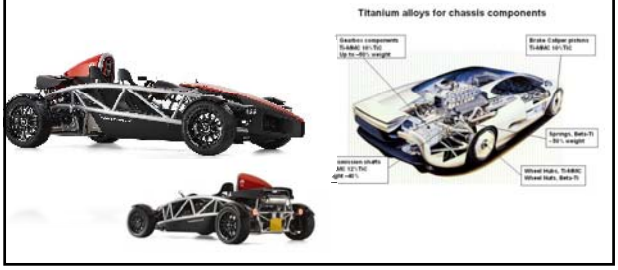
- Most extensively used alloy of Ti for various purpos
- Used as spring hard
- Machine Parts.
- In Engines
- Propellers.
- Making of Gears.

- Causes of using Ti alloys in automobiles

✓Weight Reduction (= Fuel Consumption Reduction)
✓1% decrease in weight = 0.7% reduction in fuel consumption.
✓Weight reduction in moving parts saves more fuel.
✓Ti alloys have density around 60% that of steel.
✓Elastic Modulus half that of Steel.
✓Ideal for use in making Springs with high stiffness.
✓Resistance to Corrosion.
✓Strength.

- Wheel Rims

- Strengthens Chassis of automobiles

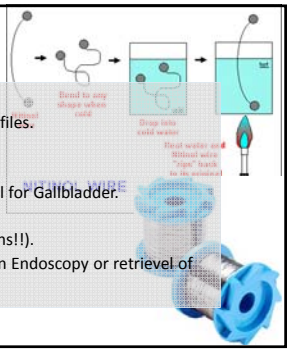


- DTBs and MTBs (Ti alloy frame) and motor bike bodies

Innovative:

- Inspired from Fastest Aircraft SR-71
- World's First Titanium Car!!
- Launched in Shanghai Auto Show 2013
- A Superecar Known as Icona Vulcano (Titanium Version)
- Body made of Hand Crafted Ti and Carbon Fibre
- Took over more than 10,000 hrs to complete!!
- Machining Ti alloy is difficult and thus requires more time
- Price around 5M $ (Main cause -> Extensive use of Ti).

Nitinol: NiTi



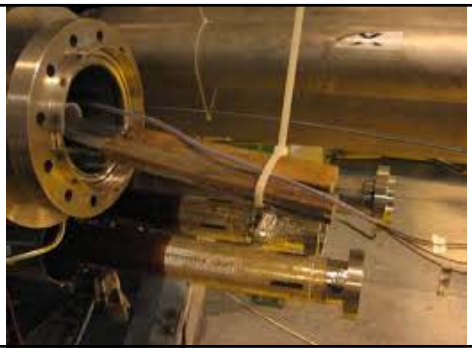
- Its wires are extensively used.
- Used in guidewires, stylets, orthodontic files.
- Shape memory alloy, super elasticity.
- Difficult to prepare this alloy.
- Nitinol Basket instrument is highly useful for Gallbladder.
- Used in heat engines.
- Used in magic shows (self bending spoons!!).
- Nitinol basket due to its flexibility used in Endoscopy or retrievel of kidney and uretric stones.

Nitinol Basket

Ti in making Rings

Nobium Titanium Alloys: NbTi

- **Niobium-titanium** (**NbTi**) is an alloy of niobium and titanium, used industrially as a type II superconductor wire for superconducting magnets, normally as Nb-Ti fibres in an aluminium or copper matrix.
- **Used as Superconducting Cable**
- Nobium Titanium coming out of an LHC dipole magnet.



Military Operations..

Use of Titanium alloys:

- Ti Grade1 used in choppers of a Helicopter
- Ti coated Fire arms.
- Ti manufactured watches.

& many other uses:

- TiN (Titanium Nitride) used in coating and produces lustrous Gold like paint on the materials.
- Used in Making Ship Hull (Very effective)

3D printing

- 3D printed Skull.
- Ti & its alloys because of its various uses and properties, also called as..
- "*Metal of the Future*".