Titanium and its chemistry

(Ti)

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28th September 2022

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[1]

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- Chemistry
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TITANIUM - INTRODUCTION

Titanium - Introduction

ORIGIN OF NAME:

- The name is derived from the Titans, the sons of Uranus and Gaea in the Greek mythology.

HISTORY OF DISCOVERY:

- The first titanium mineral *menachanite* (ferriferous oxide of titanium) was discovered in 1791 in Cornwall by the Reverend William Gregor
  - These days *menachanite* is known as “ilmenite”
- In 1795, scientist Martin Heinrich Klaproth discover rutile (TiO_2)
- In 1910 M. A. Hunter, made pure titanium metal by heating titanium tetrachloride and sodium metal

[9]

ILMENITE

RUTILE

Titanium as an element

PROPERTIES: [17]

- **The melting point of Ti is 1668 °C (1941 K)**
- **Titanium has a metallic luster and is relatively ductile**
- **Titanium is about as strong as steel but it is much less dense**
  - It is an important alloying element in steel and other alloys
- **Titanium has good corrosion resistance and is not affected by the atmosphere and seawater.**
- **Titanium works as a superconductor at 0.49 K in very high (99.99 %) purity**
  - More often used as a NbTi filaments cast in a Cu wire

Titanium mining

- **Titanium can be found all over the world**
  - Titanium is the ninth most abundant element on Earth [11]
  - Earth's crust consists of 0.63% of Ti by mass
  - There are no huge deposits
  - As of 2021, China had the largest reserves of titanium minerals worldwide. [10]
- **90% of Ti can be found with Fe**
  - Ilmenite ($FeTiO_3$) [6]
  - Rutile (TiO_2)

Titanium processing

- **Titanium oxide is relatively straightforward to produce and majority of titanium is annually used in form of TiO_2**
- **Metallic titanium is much more difficult because of its high melting point and high reactivity [14]**
  - Starts to burn before reaching the melting point
  - Can react with nitrogen as well
  - This also makes recycling titanium products difficult
  - Welding of titanium is relatively straightforward when suitable tools are available

CHEMISTRY OF TITANIUM

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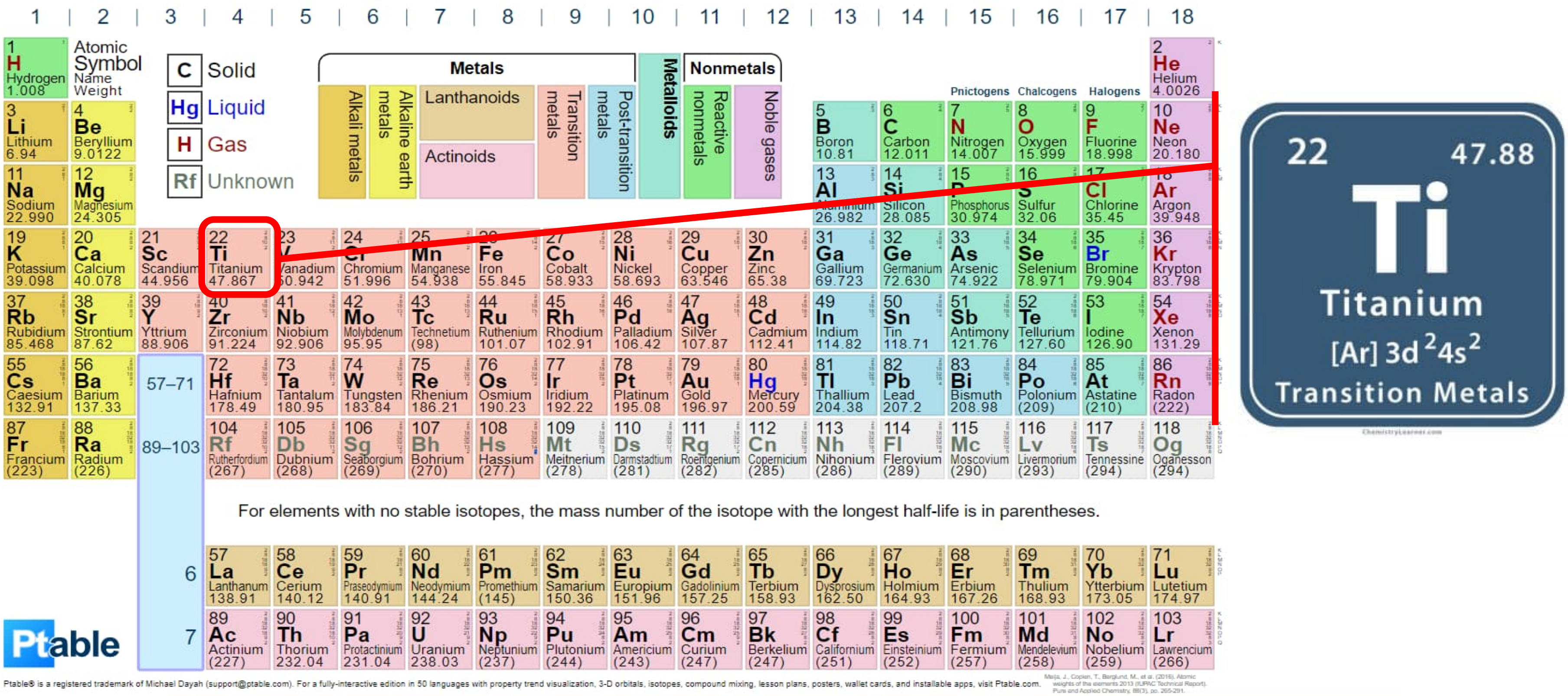
Titanium in Periodic Table[12]



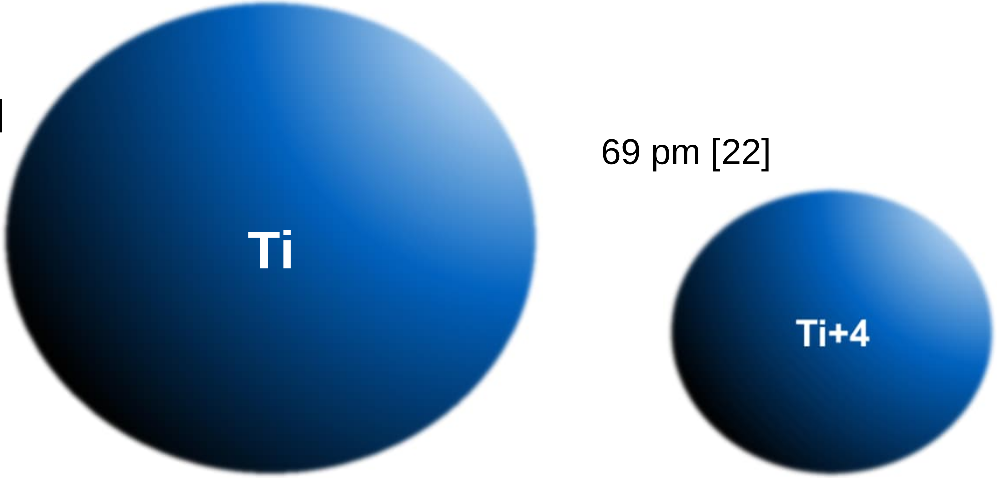
Chemistry:

OXIDATION STATE:

- Titanium shows oxidation states of +2,+3 and +4 [15]
- Most common oxidation state of titanium is +4 [14]

147 pm [22]

69 pm [22]



Reactivity of Titanium

- **Reaction with Acids:**

$$2\ Ti(s) + 12\ HCl(aq) \xrightarrow{\Delta} 2\ Ti[Cl_6]^{3-}(aq) + 3\ H_2(g) + 6\ H^+(aq)$$

$$2\ Ti(s) + 12\ HF(aq) \longrightarrow 2\ [TiF_6]^{3-}(aq) + 3\ H_2(g) + 6\ H^+(aq)$$

- **Reaction with Air:**

$$Ti(s) + O_2(g) \xrightarrow{\Delta} TiO_2(s)\ [white]$$

$$2\ Ti(s) + N_2(g) \xrightarrow{\Delta} 2\ TiN(s)$$

Reactivity of Titanium

- **Reaction with Alkalis:**

  Titanium does not appear to react wih alkalis, under normal conditions, even when heated.

- **Reaction with Halogens:**

$$Ti(s) + 2\,F_2(g) \xrightarrow{\Delta} TiF_4(s)\ \text{[white]}$$

$$Ti(s) + 2\,Cl_2(g) \xrightarrow{\Delta} TiCl_4(s)\ \text{[colourless]}$$

$$Ti(s) + 2\,Br_2(g) \xrightarrow{\Delta} TiBr_4(s)\ \text{[orange]}$$

$$Ti(s) + 2\,I_2(g) \xrightarrow{\Delta} TiI_4(s)\ \text{[dark brown]}$$

COMPOUNDS OF TITANIUM

- **TiO_2 is transparent**
  - Reason why titanium products are so shiny
  - White color comes through the scattering
- **TiO_2 is very inert**
  - Shares some similarities with Al_2O_3
  - This subject was touched in the Crystal field theory lecture!

Titanium dioxide (TiO_2) [16]

- **Act as a photocatalytic antimicrobial compound**
- **TiO_2 doesn't seem to be harmful for humans or the nature**
    - It is widely used as a white pigment
    - Also some sunscreen contain titanium dioxide
- **Passivation layer [5]**
    - Creates a hard surface that protects the metal underneath

TITANIUM - APPLICATIONS

1. USE OF TITANIUM IN BIOMATERIALS

Use of Titanium as Biomaterial [19]

- low elasticity modulus, high tensile strength and low density.
- exceptional osseointegration characteristics focuses on stability and inertness of titanium-based materials.
- protective oxide layer → TiO_2 mixed with Ti_2O_3 and TiO.
- Wide bandgap of 3.2 eV

[20]

Limitations:

- Damage to protective film →localized corrosion and the release of metal cations.
- passive layer is stable in a neutral simulated physiological environment
- self-healing of titanium →cytotoxity

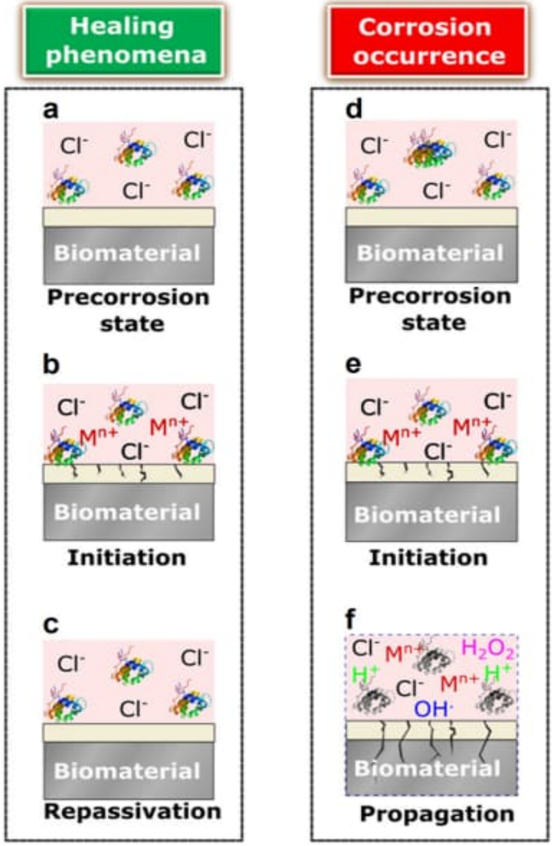


Fig. 1 Stages of corrosion and healing phenomena. Sketches **a–c** describe the stages of healing phenomena that occur in the materials capable of being healed, while sketches **d–f** describe the stages of corrosion that occur in the unhealed materials.

2. TITANIUM FOR BIPOLAR PLATE OF PEMFC

Application Of Titanium For Bipolar Plate Material Of Proton Exchange Membrane Fuel Cells [13][21][7][8]

- Recently titanium has been used as a material for bipolar plates which are the crucial component of PEMFCs.

- **Bipolar plates Functions:**
  - corrosion resistance preventing degradation of PEMFCs, press formability for fuel gas
  - high surface conductivity to collect electric current
  - lightweight
  - high mechanical strengt

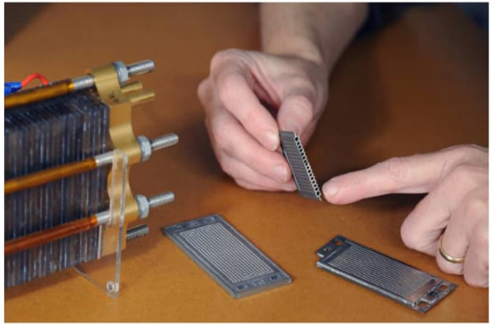


Figure 2. Photograph of titanium BPPs made by DMLS internal coolant fields (middle plate) and the str stacks are assembled with gaskets into a stack (left).

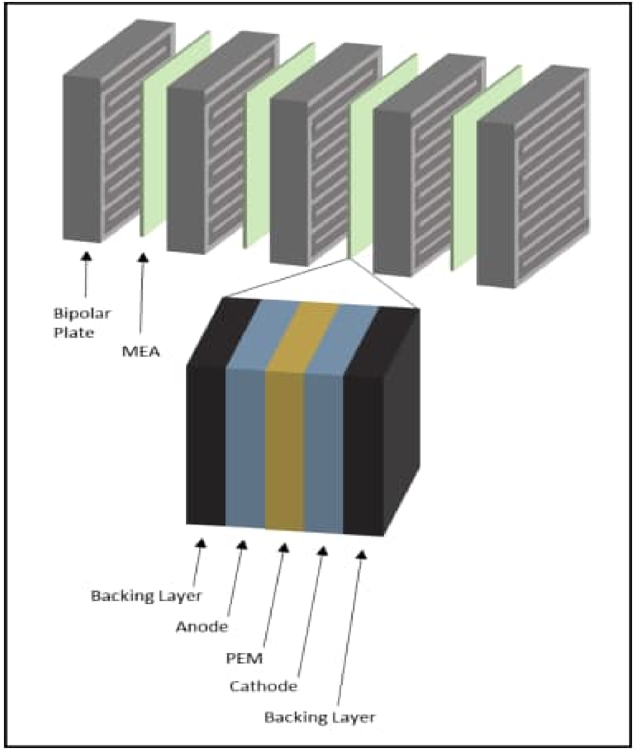
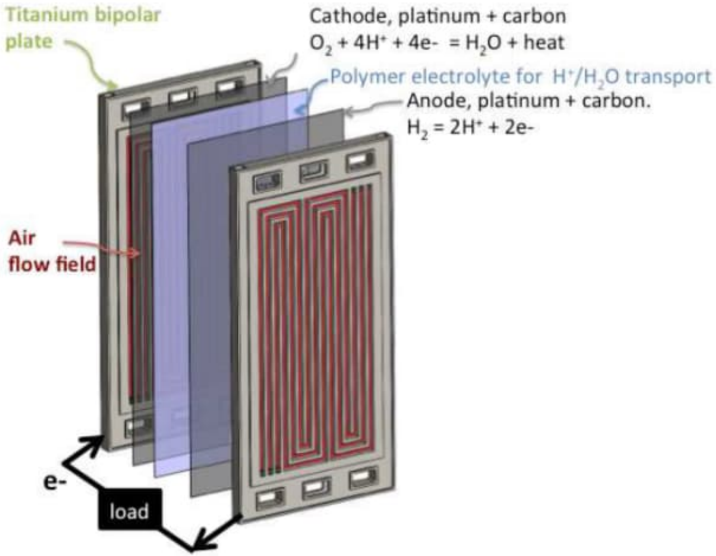


Figure 1. Bipolar plate and membrane electrode assembly combination in a fuel cell stack.

- Kobe Steel developed pre-coating type titanium coated with carbon nanoparticle composite named as ‘NC titanium’.
- NC titanium has been equipped in the fuel cell vehicle ‘MIRAI’ launched in 2020 from Toyota Motor Corporation.
- It has merits such as
  - excellent corrosion resistance,
  - lightweight
  - reduction of the manufacturing cost.

[12] TOYOTA

- The use expansion of titanium is expected as a bipolar plate material of PEMFCs for not only passenger vehicles but also commercial vehicles, railways, ships, and aircrafts in the future.



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