

# Titanium and its chemistry

—  
(Ti)

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School of Chemical  
Engineering



# Content

- **Element**
- **Chemistry**
- **Compounds**
- **Applications**

# 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<sub>2</sub>)
- In 1910 M. A. Hunter, made pure titanium metal by heating titanium tetrachloride and sodium metal



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 <sup>[11]</sup>
  - 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. <sup>[10]</sup>
- **90% of Ti can be found with Fe**
  - Ilmenite (  $\text{FeTiO}_3$  ) <sup>[6]</sup>
  - Rutile (  $\text{TiO}_2$  )



# Titanium processing

- **Titanium oxide is relatively straightforward to produce and majority of titanium is annually used in form of  $\text{TiO}_2$**
- **Metallic titanium is much more difficult because of its high melting point and high reactivity** <sup>[14]</sup>
  - 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]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																																																									
1 <b>H</b> Hydrogen 1.008	Atomic Symbol Name Weight																2 <b>He</b> Helium 4.0026																																																									
3 <b>Li</b> Lithium 6.94	4 <b>Be</b> Beryllium 9.0122	<table border="1"> <tr> <td><b>C</b> Solid</td> <td colspan="5"><b>Metals</b></td> <td colspan="2"><b>Metalloids</b></td> <td colspan="3"><b>Nonmetals</b></td> </tr> <tr> <td><b>Hg</b> Liquid</td> <td>Alkali metals</td> <td>Alkaline earth metals</td> <td>Lanthanoids</td> <td>Actinoids</td> <td>Transition metals</td> <td>Post-transition metals</td> <td>Reactive nonmetals</td> <td colspan="3">Noble gases</td> </tr> <tr> <td><b>H</b> Gas</td> <td colspan="16"></td> </tr> <tr> <td><b>Rf</b> Unknown</td> <td colspan="16"></td> </tr> </table>																<b>C</b> Solid	<b>Metals</b>					<b>Metalloids</b>		<b>Nonmetals</b>			<b>Hg</b> Liquid	Alkali metals	Alkaline earth metals	Lanthanoids	Actinoids	Transition metals	Post-transition metals	Reactive nonmetals	Noble gases			<b>H</b> Gas																	<b>Rf</b> Unknown																	10 <b>Ne</b> Neon 20.180
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11 <b>Na</b> Sodium 22.990	12 <b>Mg</b> Magnesium 24.305																	16 <b>S</b> Sulfur 32.06																																																								
19 <b>K</b> Potassium 39.098	20 <b>Ca</b> Calcium 40.078	21 <b>Sc</b> Scandium 44.956	22 <b>Ti</b> Titanium 47.867	23 <b>V</b> Vanadium 50.942	24 <b>Cr</b> Chromium 51.996	25 <b>Mn</b> Manganese 54.938	26 <b>Fe</b> Iron 55.845	27 <b>Co</b> Cobalt 58.933	28 <b>Ni</b> Nickel 58.693	29 <b>Cu</b> Copper 63.546	30 <b>Zn</b> Zinc 65.38	31 <b>Ga</b> Gallium 69.723	32 <b>Ge</b> Germanium 72.630	33 <b>As</b> Arsenic 74.922	34 <b>Se</b> Selenium 78.971	35 <b>Br</b> Bromine 79.904	36 <b>Kr</b> Krypton 83.798																																																									
37 <b>Rb</b> Rubidium 85.468	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.906	40 <b>Zr</b> Zirconium 91.224	41 <b>Nb</b> Niobium 92.906	42 <b>Mo</b> Molybdenum 95.95	43 <b>Tc</b> Technetium (98)	44 <b>Ru</b> Ruthenium 101.07	45 <b>Rh</b> Rhodium 102.91	46 <b>Pd</b> Palladium 106.42	47 <b>Ag</b> Silver 107.87	48 <b>Cd</b> Cadmium 112.41	49 <b>In</b> Indium 114.82	50 <b>Sn</b> Tin 118.71	51 <b>Sb</b> Antimony 121.76	52 <b>Te</b> Tellurium 127.60	53 <b>I</b> Iodine 126.90	54 <b>Xe</b> Xenon 131.29																																																									
55 <b>Cs</b> Caesium 132.91	56 <b>Ba</b> Barium 137.33	57-71																86 <b>Rn</b> Radon (222)																																																								
87 <b>Fr</b> Francium (223)	88 <b>Ra</b> Radium (226)	89-103																118 <b>Og</b> Oganesson (294)																																																								

22

47.88

Ti

Titanium

[Ar] 3d<sup>2</sup>4s<sup>2</sup>

Transition Metals

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For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

57 <b>La</b> Lanthanum 138.91	58 <b>Ce</b> Cerium 140.12	59 <b>Pr</b> Praseodymium 140.91	60 <b>Nd</b> Neodymium 144.24	61 <b>Pm</b> Promethium (145)	62 <b>Sm</b> Samarium 150.36	63 <b>Eu</b> Europium 151.96	64 <b>Gd</b> Gadolinium 157.25	65 <b>Tb</b> Terbium 158.93	66 <b>Dy</b> Dysprosium 162.50	67 <b>Ho</b> Holmium 164.93	68 <b>Er</b> Erbium 167.26	69 <b>Tm</b> Thulium 168.93	70 <b>Yb</b> Ytterbium 173.05	71 <b>Lu</b> Lutetium 174.97
89 <b>Ac</b> Actinium (227)	90 <b>Th</b> Thorium 232.04	91 <b>Pa</b> Protactinium 231.04	92 <b>U</b> Uranium 238.03	93 <b>Np</b> Neptunium (237)	94 <b>Pu</b> Plutonium (244)	95 <b>Am</b> Americium (243)	96 <b>Cm</b> Curium (247)	97 <b>Bk</b> Berkelium (247)	98 <b>Cf</b> Californium (251)	99 <b>Es</b> Einsteinium (252)	100 <b>Fm</b> Fermium (257)	101 <b>Md</b> Mendelevium (258)	102 <b>No</b> Nobelium (259)	103 <b>Lr</b> Lawrencium (266)



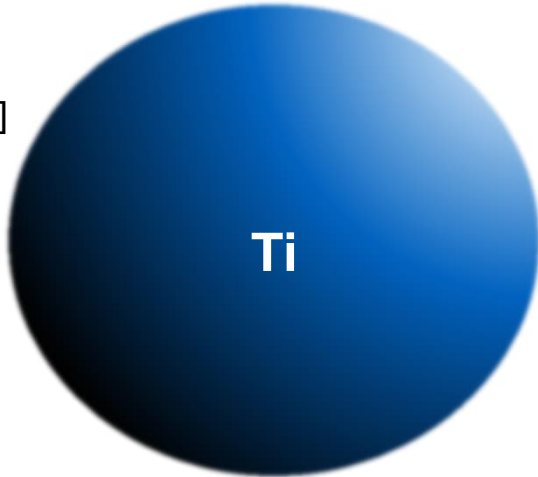
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# Chemistry:

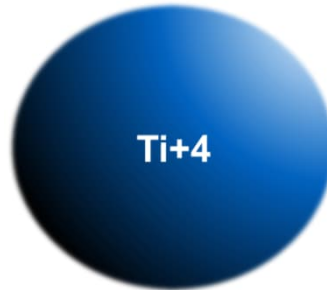
## OXIDATION STATE:

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

147 pm [22]

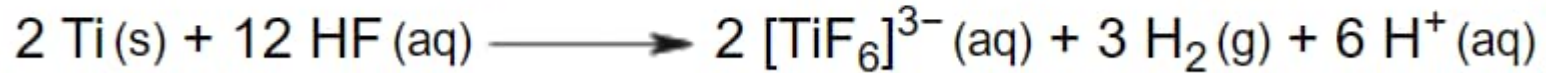


69 pm [22]

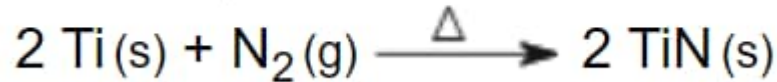
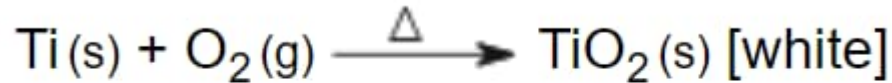


# Reactivity of Titanium

- **Reaction with Acids:**



- **Reaction with Air:**

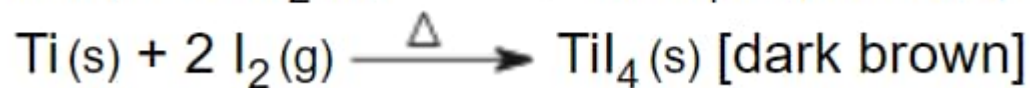
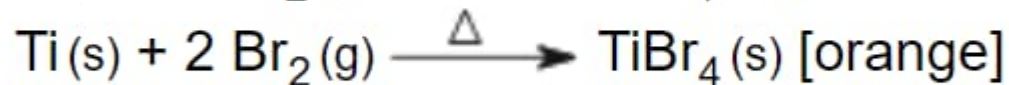


# Reactivity of Titanium

- **Reaction with Alkalis:**

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

- **Reaction with Halogens:**



# COMPOUNDS OF TITANIUM

- **TiO<sub>2</sub> is transparent**
  - Reason why titanium products are so shiny
  - White color comes through the scattering
- **TiO<sub>2</sub> is very inert**
  - Shares some similarities with Al<sub>2</sub>O<sub>3</sub>
  - This subject was touched in the Crystal field theory lecture!



# Titanium dioxide ( $\text{TiO}_2$ ) [16]

- **Act as a photocatalytic antimicrobial compound**
- **$\text{TiO}_2$  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** <sup>5</sup>
  - 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  $\rightarrow$   $\text{TiO}_2$  mixed with  $\text{Ti}_2\text{O}_3$  and  $\text{TiO}$ .
- Wide bandgap of 3.2 eV



[20]

# Limitations:

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

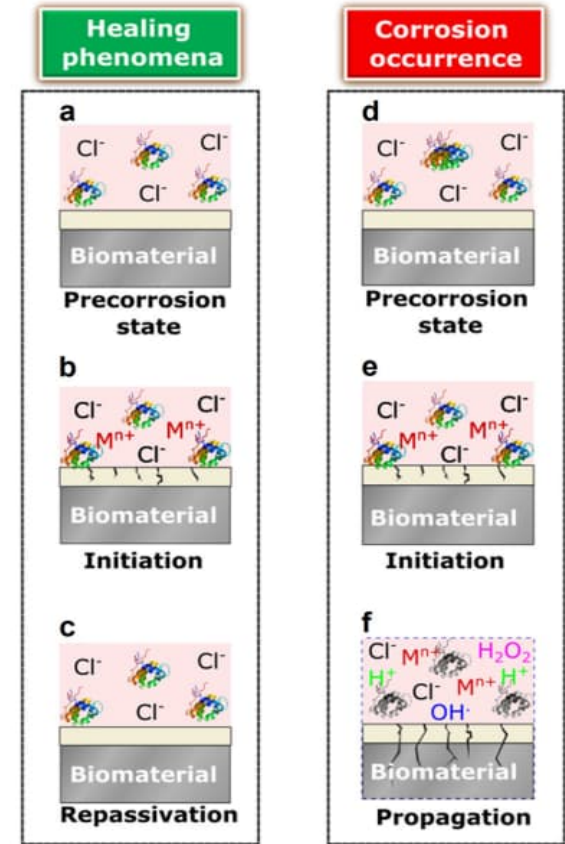


Fig. 1 Stages of corrosion and healing phenomena. Sketches a-c describe the stages of healing phenomena that occur in the materials capable of being healed, while sketches d-f describe the stages of corrosion that occur in the unhealed materials.

# 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 strength

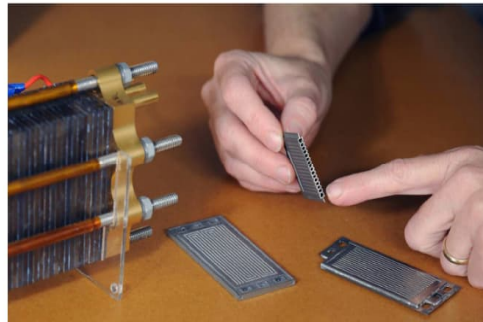


Figure 2. Photograph of titanium BPPs made by DMLS internal coolant fields (middle plate) and the stir stacks are assembled with gaskets into a stack (left).

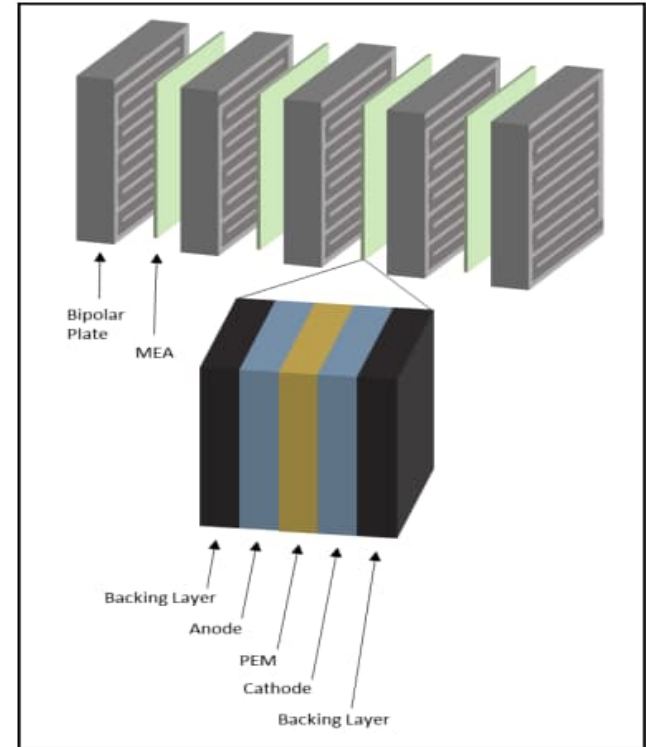
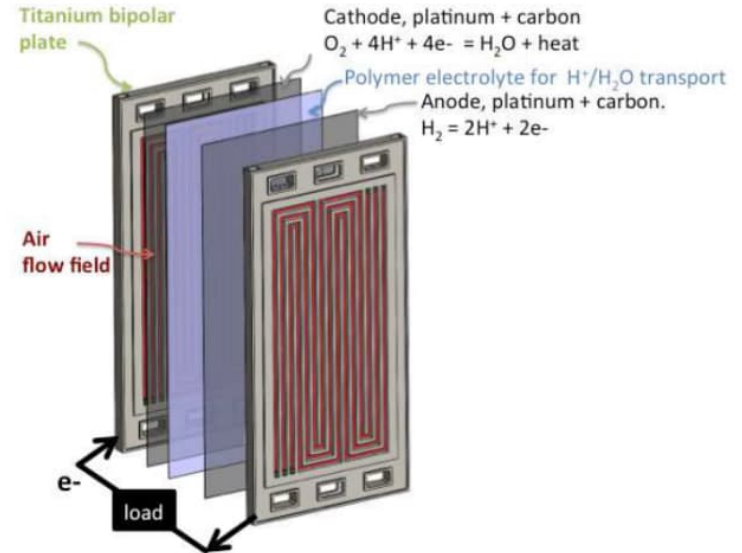


Figure 1. Bipolar plate and membrane electrode assembly combination in a fuel cell stack.

- 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.
- 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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