FACT SHEET

CATEGORY: 5.2	MATERIALS	TITANIUM

INTRODUCTION

The Reverend William Gregor, an English pastor, first discovered titanium in 1791. Metallic titanium was first isolated in impure form in 1887 and then with higher purity in 1910. Titanium is the ninth most abundant element in the earth's crust and is widely distributed in a variety of igneous rocks. The principal ores of titanium are rutile (TiO_2), ilmenite ($FeTiO_3$) and sphene ($CaO.TiO_2.SiO_2$).

Although titanium is the fourth most common metal after aluminium, iron and magnesium, its extraction as a pure metal has proven to be extremely difficult due to the ease at which it reacts with oxygen, nitrogen, carbon and silicon. Titanium is isolated by heating a mixture of its rutile ore and charcoal with chlorine at a temperature of 700–1000°C. The resulting titanium tetrachloride[1] is then reduced with magnesium metal.

$$2TiO_{2\,(s)} + 3C_{\,(s)} + 4Cl_{2\,(g)} \xrightarrow{700\text{-}1000^{o}C} 2TiCl_{4\,(l)} + 2CO_{(g)} + CO_{2\,(g)}$$

$$TiCl_{4\,(l)} + 2Mg_{\,(s)} \longrightarrow Ti_{\,(s)} + 2MgCl_{2\,(s)}$$

PROPERTIES OF TITANIUM

Titanium is naturally a reactive metal. A thin layer of titanium dioxide over its surface provides excellent protection from many corrosives such as natural waters, oxidising acidic brines and other caustic environments. Titanium and its alloys are usually very stable in a vast range of organic chemicals including acetic, formic, citric, tartaric, stearic and tannic acids. It is not easily corroded by seawater and can also provide benefits in equipment used to handle organic acids mixed with inorganic acids, organic solvents and salts. In most cases, alkaline environments up to pH 12 do not present any problems for this material. As with any metal, titanium is not immune to all environments and care should be taken in its application (see note).

In additional to its superior corrosion resistance, titanium has low thermal conductivity, low thermal expansion, low density and high strength. It is bio-compatible and does not react with the human body and is the only element that burns in pure nitrogen.

Property	Value
Atomic number	22
Atomic weight	47.867
Melting point	1941 K
Boiling point	3560 K
Density	4510 kg m^{-3}
Tensile strength	234 MPa
Yield strength	138 MPa

[1] Titanium Tetrachloride is very irritating to the eyes, skin, mucous membranes and lungs. Breathing in large amounts can cause serious injury to the lungs. Contact with the liquid can burn the eyes and skin.

Note: Anhydrous methanol is unique in its ability to cause stress corrosion cracking of titanium and titanium alloys. Industrial methanol normally contains sufficient water (>2%) to provide immunity to titanium and so no problems should be encountered.

TITANIUM ALLOYS

Commercially Pure Alloys

There are five grades of what is known as commercially pure or unalloyed titanium, ASTM Grades 1 through 4, and 7. Each grade has a different amount of impurity content, with Grade 1 being the most pure. Tensile strengths vary from 172 MPa for Grade 1 to 483 MPa for Grade 4.

Alpha Alloys

Titanium alpha alloys are alloys that typically contain aluminium and tin, though they can also contain molybdenum, zirconium, nitrogen, vanadium, columbium, tantalum, and silicon. Alpha alloys do not generally respond to heat treatment, but they are weldable and are commonly used for cryogenic applications, aeroplane parts, and chemical processing equipment.

Alpha-Beta Alloys

Alpha-beta alloys can be strengthened by heat treatment and ageing, and therefore can undergo manufacturing while the material is still ductile, then undergo heat treatment to strengthen the material, which is a major advantage. The alloys are used in aircraft and aircraft turbine parts, chemical processing equipment, marine hardware, and prosthetic devices.

Beta Alloys

The smallest group of titanium alloys, beta alloys have good hardenability, good cold formability when they are solution-treated, and high strength when they are aged. Beta alloys are slightly denser than other titanium alloys, having densities ranging from 4840 to 5060 kg m^{-3}. They are the least creep resistant alloys, they are weldable, and can have yield strengths up to 1345 MPa. They are used for heavier duty purposes on aircraft.

Reference: http://www.efunda.com/materials/alloys/titanium/titanium.cfm

TITANIUM DIOXIDE

More than 80% of titanium ores extracted from the earth are converted into titanium dioxide, TiO_2, one of the whitest substances on earth. Titanium dioxide reflects and scatters light extremely well and explains its use to enhance the brightness of both paints and plastics. Being non-toxic and biologically inert, titanium dioxide is also used as a brightening agent in candy, cosmetics and toothpaste. Pure titanium oxide is relatively clear and has an extremely high refractive index. It is used to make titania, an artificial gemstone.

FACT SHEET

USE OF TITANIUM

Aerospace

The aircraft industry is the single largest market for titanium products primarily due to their exceptional strength to weight ratio. The largest single use of titanium is in aero gas turbine engines: applications include compressor blades, discs and inlet guide vanes. Titanium alloys compete with aluminium, nickel and ferrous alloys in both commercial and military airframes.

Jewellery

Rings and spectacles are manufactured from titanium because of its inherent strength, resistance to dents and bending and it can be highly polished to provide a scratch free product.

Paint

Titanium paint is an excellent reflector of infrared radiation and is used extensively in solar observatories to reduce heat levels to improve viewing quality.

Cathodic Protection

A titanium anode coated with platinum provides cathodic protection from corrosion by seawater.

Medical

Replacement joints including hip ball joint.

WELDING TITANIUM

Titanium has traditionally been thought as a material that is very difficult to weld. However, this is not the case if proper procedures and equipment are used. Generally, titanium is welded with the Tungsten Inert Gas (TIG) process. When using TIG welding on titanium, Direct Current Straight Polarity (DCSP) with high frequency arc initiation is used. Scratch starting is not recommended because of the materials sensitivity to contamination.

The selection of a proper TIG torch is required for the amperage range and application. Two percent Ceriated or two percent Lanthanated tungsten electrodes are recommended for their low erosion rates, wide current range, consistent arc starts and lack of tungsten ‘spitting’.

Shielding gas is an extremely important factor for welding titanium. When titanium is heated above 400^{o}C it reacts with elements in the atmosphere including oxygen, nitrogen and carbon. It is essential that adequate inert shielding gas covers the molten weld pool and all areas above 400^{o}C to ensure a good quality weld. If these contaminants are absorbed into the molten weld puddle, the results can include poor porosity, low-notch toughness value and brittleness. Pure argon shielding gas is required for the primary gas shield and the secondary or ‘trailing’ gas shield. The argon used as the shielding gas must be of the highest purity available. A purge chamber or a trailing shield may be used for additional gas shielding requirements. It is recommended to weld small parts in a purge chamber.

It is also important to keep the base material and filler materials (if required) clean of contaminants such as oils, dirt, fingerprints and cleaning solutions. Commercial alkaline cleaners, a diluted solution of sodium hydroxide, acetone or alcohol can be used to keep the materials clean. A clean stainless steel brush should be used to brush the weld joint and immediate area. After use it should be rinsed in alcohol and stored in a sealed container.

Once welded the colour of the weld can indicate its quality.

Colour of weld	Result
Shiny silver	Absence of contaminants
Gold or straw colour	Some contamination (depending on the weld, application and code requirements, this quantity of contaminants may be acceptable.
Light blue	High level of contaminants – cannot be used for any purpose.
Dark Blue/black	High level of contaminants – cannot be used for any purpose.

FIRE PREVENTION

Storage of coarse titanium turnings and chippings from machining operations is relatively safe. However, the storage of fine titanium swarf/powder constitutes a fire/explosion hazard.

If a fire does start, its effect can be minimised by isolating the burning material from the bulk. The fire can be extinguished using either a dry powder or Class D fire extinguisher. A sodium chloride base powder can be an effective agent. Sand or salt can be used to reduce oxygen. Fires or explosions may be initiated by exposing a flammable concentration of titanium dust/swarf to spark or naked flame.

(TITANIUM) INTERNET RESOURCES

The TITANIUM INFORMATION GROUP (TIG) is an association of United Kingdom suppliers, design engineers and fabricators of titanium formed with the intention of promoting the use of titanium. http://www.titaniuminfogroup.co.uk/

The Thomas Jefferson National Laboratory presents the properties and uses of titanium. http://education.jlab.org/itselemental/ele022.html

The toxicity and related health problems associated with Titanium Tetrachloride are discussed by the Agency for Toxic Substances and Disease Registry. http://www.atsdr.cdc.gov/tfacts101.html

http://www.corrosion-doctors.org/MatSelect/corrtitanium.htm describes the corrosive effects of some chemicals with titanium.

General guidelines of welding titanium are presented at www.welding-advisors.com/welding–titanium.html

Titanium Net provides excellent information concerning the characteristics of titanium and its alloys in a wide variety of environments. http://titanium.net