

3 APPLICATIONS OF ZIRCONIUM

Zirconium and zirconium chemicals are applied in very different fields. About 95% of all the zirconium consumed is in form of zircon, zirconia and zirconium chemicals [25]. It is applied, among others, in ceramics (10%), in foundry sands (47%), as refractories (22%), in the construction of chemical plants, in electronic devices, in medicine and in nuclear reactors [13, 16].

Zirconium chemicals and zirconia in particular have recently attracted special attention as high-technology materials for multi-industrial and scientific applications because of their superior mechanical, thermal, electrical, chemical and optical properties.

3.1 Zirconium Metal

Zirconium free of hafnium (i.e. almost free) is produced for application in alloys containing low levels of tin or niobium, and used for structural parts in the core of water-moderated nuclear reactors. In this application zirconium has an amazing combination of characteristics, being ductile and having good strength up to 450 °C, which means that it can be formed and it does not deform in reactor conditions. In these alloys, it also shows very good corrosion resistance to pure hot water and steam. Another property of zirconium metal is its low thermal neutron cross-section absorption and this is the reason that it can be used in nuclear reactors as a container material for uranium oxide fuel pellets [7, 12, 13, 15].

Zirconium is also used in the construction of chemical reactors when corrosion resistance is required. Zirconium equipment can be used in hot sulphuric acid up to a concentration of 65%. It is used in the construction of hydrogen peroxide plants, in acrylic films and fibres, in methyl methacrylate, in butyl alcohol, in the production of urea, acetic and formic acids, and in nitric acid cooler-condensers [2, 12, 13].

Zirconium foil is used in ignition-flash material in photography bulbs. However, this application is falling away due to the use of electronic devices in new cameras. Zirconium powder is still in use in pyrophoric applications [12]. In combination with nickel, it is applied in pyrotechnic and ordnance areas, as a delay mixture and as igniters in squibs. Sponge zirconium finds its main use in the military industry [7].

Zirconium and its alloys with aluminium, iron, titanium or vanadium are used in vacuum tubes, in inert gas tubes and in ultra-high-purity environments in the semiconductor industry. This is possible because heated zirconium is able to absorb (reversibly) traces of hydrogen, oxygen, nitrogen, carbon monoxide and dioxide, and, irreversibly water. When these gases are adsorbed, they diffuse in the bulk of the material, leaving a fresh surface for new absorption [12].

Zirconium is used in satellites as a reflective surface agent, in superconductive magnets, in powder form (alloyed with lead) in cigarette lighter flints, and in metal-to-glass seals. It is also used in special welding fluxes due to its special properties. Furthermore, it is an ingredient in explosives mixtures [7].

Zirconium metal powders are a source of heat for squibs and ignition devices for a variety of uses, including automotive airbag inflators [7].

Zirconium has been injected intravenously as a prophylactic action to prevent the skeletal deposition of certain radioactive elements, especially plutonium [26].

Despite this long list of applications for pure zirconium metal, the consumption of zirconium ores for the production of pure zirconium metal represents only about 4% of the total use of the ores. The USA is the largest producer of zirconium metal, followed by France and the Ukraine [12].

3.2 Zirconium Chemicals in the Ceramic Industry

In this field, the most important zirconium chemicals are zircon and zirconia. Zircon is used in the production of refractory bricks and cements. Due to its high refractive index, zircon is used extensively as an opacifier in glazes and enamels. Its high refractive index gives a white, opaque appearance to the glazes and enamels. Zircon is also used in the production of alkali-resistant glass [2, 12].

Zirconia is important in the ceramic industry where it is mainly applied in the production of pigments. Zirconia and silica are fired together to produce zirconium silicate in the presence of small amounts of other elements. These elements enter the zircon lattice, forming different

colours. The pigments are used in ceramic tiles, sanitary wear and metallic dishes. Zirconia colours are suitable for this application due to their resistance to high temperatures and to attack by molten glasses in glazes and enamels [12, 15].

3.3 Zirconium Chemicals in the Glass Industry

In the glass industry, zirconium chemicals are applied to increase the refractive index in optical glasses and for glass toughening. Zirconia and zirconium hydroxide are added for these purposes. Finely divided zirconium oxide is also used for polishing glass [7, 15].

Zirconium oxide and zirconium silicate are used as zirconium-containing refractories in glass-melting furnaces. The addition of zirconium oxide in these refractories increases thermal shock resistance [26].

3.4 Zirconium Chemicals in Electronic Devices

Zirconium hydroxide, zirconium acetate and zirconium propionate are used in electro ceramics and other special ceramics. These chemicals are used as dielectrics in capacitors, sensors and piezoelectrics. Zirconia is also applied for these purposes [7, 27].

Piezoelectric devices convert mechanical energy into electricity and vice versa. In this application, zirconia is combined with lead oxide in order to form lead zirconate. Another application is in ceramic sensors where zirconia is used for sensing oxygen, due to its capacity to absorb oxygen reversibly [27].

3.5 Zirconium Chemicals in other Fields

Zirconium hydroxide, acetate, propionate, oxychloride, hydroxylchloride, nitrate, phosphate and orthosulphate, and ammonium zirconium carbonate are used in catalysis as supports and controllers. In this application, zirconium chemicals play a role mainly in four different areas [7]:

- In *autocatalysis*, zirconium chemicals are used to enable catalysts to operate at high temperatures and to displace oxygen.
- In *stationary catalysis*, zirconium chemicals enable specific reactions to occur.

- In *refinery catalysis*, they are used in refining reactions.
- In *chemical catalysis*, zirconia is applied as a precursor to other chemicals.

Examples of these applications can be found in polymer processing, where zirconium-based systems are applied in various processes of polymerisation. They are applied as homogeneous and heterogeneous catalysts for polypropylene, polyethylene and other polymers [7].

They can be used as a support for selective or complete oxidation systems of reaction, in hydrogenation as a promoter in fat/oil catalysis and as a support for nickel in general-purpose catalysts [7].

Zirconium chemicals in automotive catalysts improve the thermal properties in the wash coat. The thermal resistance of stationary catalysts is also improved if zirconium chemicals are added [7].

In the paper industry, zirconium chemicals are added to strengthen the paper and to enhance the resistance of the surface coating to water. As adhesives, zirconium chemicals promote greater adhesion of the ink to plastics and metals. Ammonium zirconium carbonate, zirconium acetate and zirconium propionate are applied for this purpose [7].

Hydroxide, acetate, propionate, phosphate and ammonium zirconium are applied in ink, pigments and paints production. [7].

Oxychloride, hydroxychloride and nitrate zirconium chemicals are also applied in the textile industry [7]. They are added to coating surfaces to give waterproof and flameproof properties to these surfaces [5, 11].

Zirconium oxychloride has been used as an antiperspirant. Zirconium carbonate and oxide are used to treat dermatitis [26].

Zirconium diboride (ZrB_2) is a potential material for high-temperature and high-wear oxidation- and corrosion-resistant applications. Some crystals are classified as gemstones and are then used in jewellery [5, 11].