

Cadmium

Pure cadmium is a white, shiny metal with a bluish tinge. While soft, ductile and flexible at room temperature, it becomes brittle if heated to around 80°C. The metal takes its name from a Greek word, 'kadmeia', for the zinc ores with which it is commonly associated, and the Latin word 'cadmia'.

Cadmium was used as a sulphide pigment in artists' paints in the mid-1800s, but the metal only started to find significant industrial applications when new zinc electrowinning plants started to come on stream in the mid-1920s to 1930s, which recovered cadmium cements as a by-product of the process. Cadmium's chemical properties are similar to zinc's, and it was as a corrosion-resistant coating for steel that it saw its greatest initial industrial use.

Occurring in compounds rather than as a metal in nature, cadmium's abundance is relatively small, but it is present in almost all zinc minerals. Cadmium sulphide, a yellow substance, appears with some varieties of zinc sulphide, while otavite comprises cadmium carbonate. Most primary cadmium recovered is associated with ores of sphalerite (zinc sulphide). Zinc blende typically contains 0.5% cadmium and the zinc industry is still the major producer of the metal.

Cements from the solution purification stage of zinc production are treated with dilute sulphuric acid, which dissolves both zinc and cadmium, leaving copper and lead in the residue. An enriched cement containing zinc and cadmium is formed before further treatment with sulphuric acid. Cadmium is recovered from a purified solution by electro-winning to produce 99.99% pure cadmium cathode. Even higher-purity cadmium can be obtained through distillation.

Increasing efforts are being made to recycle cadmium, notably from spent nickel-cadmium batteries – not least for environmental reasons, of which more later. Other sources of the secondary metal include copper-cadmium and other alloy scrap, plus dust generated by steel-industry EAFs.

APPLICATIONS

By far the greatest use for cadmium is in negative electrodes for rechargeable alkaline batteries – the complementary positive electrodes being made from trivalent nickel oxide.

The energy density of a typical cell is 55 Wh/kg. Nickel-cadmium batteries are widely used for portable electronic devices, in some electric vehicles and as a source of emergency power.

Other cadmium applications include anti-corrosion coating for small metallic parts, on which cadmium is easily electrodeposited, and in pigments, where it can be used as a sulphide and selenide to provide a range of colours from



yellow and orange to red in plastics, glass and ceramics.

Using cadmium as an alloy, at 0.05-1.3% with copper, for example, increases the recrystallisation temperature and mechanical properties of the metal. Bismuth-based low-melting-point alloys used in products like sprinklers include some cadmium, as do AgInCd alloys used to make neutron control bars for nuclear reactors.

OUTLOOK

Cadmium's toxicity has become a significant brake on its use. According to the US Geological Survey (USGS), US domestic consumption of cadmium metal declined by about 35% in response to environmental concerns between 2001 and 2005. Batteries amounted to 81% of estimated apparent consumption of 430 tonnes, with the balance used in pigments (10%), coatings and plating (7%), stabilisers for plastics such as PVC (1.5%), and non-ferrous alloys and other applications. Amidst tightening supply, cadmium prices have been rising. As of mid-February, *Metal Bulletin's* free market price for min. 99.99% cadmium is 130-145 cents/lb in warehouse.

The USGS points out that during the past decade, increased environmental awareness has resulted in regulatory pressure to reduce or even eliminate the use of cadmium in many developed countries. In the USA, the US Environmental Protection Agency (EPA) describes cadmium as a persistent and bioaccumulative toxic pollutant.

In the EU, The Restriction of the Use of Hazardous Substances (RoHS) legislation prohibits the incorporation of cadmium and other heavy metals in most electrical and

Key numbers

Atomic number	48
Melting point (deg C)	321.07
Boiling point (deg C)	767
Density	8,650 kg/m ³
Presence in Earth's crust	0.1-0.5 ppm

Sources: Umicore; International Cadmium Association



Saft

Built for the Golden Valley Electric Association (GVEA) in Fairbanks, Alaska, this US\$30m battery energy storage system (Bess), developed by Saft, is designed to provide a guaranteed 27 MW for a minimum of 15 minutes in order to stabilise the local power grid and reduce its vulnerability to unexpected outages. In tests during commissioning, it delivered 46 MW for five minutes – a new world record for such an installation.

Saft won the contract to design and build the battery, which comprises 13,760 rechargeable nickel-cadmium cells in four parallel strings, as part of a consortium led by ABB, which provided the system concept and the DC-to-AC power converter system. In the event of a power outage, the system maintains power supply long enough for back-up generators to start up. Saft is providing a 'cradle to grave' service by taking responsibility for the recycling of each cell.

The system provides a nominal voltage of 5,000 V and a storage capacity of 3,680 Ah. The entire battery weighs around 1,300 tonnes and occupies a space of 940 sq metres. It has a distributed filling system to ensure that the cells can be easily filled with the correct level of electrolyte, together with an electronic battery monitoring system.

Although the Bess is initially configured with four battery strings, it can readily be expanded to six to provide a full 40 MW for 15 minutes. It could ultimately accommodate up to eight battery strings, giving considerable flexibility to boost output or prolong the useful life of the system beyond the planned operation of 20 years.

electronic equipment sold in the region after 1 July this year, but cadmium plating of electronic components is exempt.

In 2005, the Environment Council of the European Union adopted a directive that bans the sale of certain types of portable nickel-cadmium batteries, restricting their use to a range of essential equipment for which there is currently no economically viable alternative, such as alarm and emergency systems, cordless power tools and medical equipment.

Looking further ahead, nickel-cadmium batteries

Estimated world refinery production and reserves (tonnes)

	Refinery production 2005	Reserves
USA	550	90,000
Australia	460	110,000
Belgium	120	—
Canada	1,400	55,000
China	3,000	90,000
Germany	420	6,000
India	500	3,000
Japan	2,400	10,000
Kazakhstan	2,300	50,000
South Korea	2,200	—
Mexico	1,600	35,000
Peru	600	12,000
Russia	1,050	16,000
Other countries	1,410	120,000
World total (rounded)	18,000	600,000

Source: USGS

containing more than 0.002% cadmium may be banned for all but a limited range of essential applications in the EU from 1 January 2008. Rather than a ban, the battery industry is promoting greater collection of spent industrial and portable rechargeable batteries, from which it says it can recycle 99% of the materials in a safe closed loop. The cadmium industry as a whole argues that the health issues linked with the metal's use are well understood, that its applications as a compound in many of its uses are inherently safe, and that its properly monitored usage and recycling are the way forward.

The USGS points out that the steadily declining production of cadmium metal in older industrialised nations is actually being offset by increased production in China and other developing countries, where manufacturing of nickel-cadmium batteries is growing.

While the bulk of cadmium usage will continue to be in batteries, recently developed ultrathin photovoltaic films comprising cadmium selenide (CdSe) and cadmium telluride (CdTe) nanocrystals are one new potential area of application, of possible use in future solar cells. Some designs of solar cell already contain cadmium telluride and cadmium sulphide.

Nickel-cadmium faces some competition from lithium-ion and nickel-metal hydride batteries, but their higher cost currently limits their use.

In applications other than those where cadmium is used as a coating for safety-critical components, zinc or vapour-deposited aluminium can be substituted for cadmium in many plating applications. Cerium sulphide can replace cadmium in pigments for some plastics.

While the fundamental properties of cadmium in its well established applications are long-proven, to a great extent its ultimate long-term usage rests on the zeal with which environmental legislators continue to further restrict or ban its use.