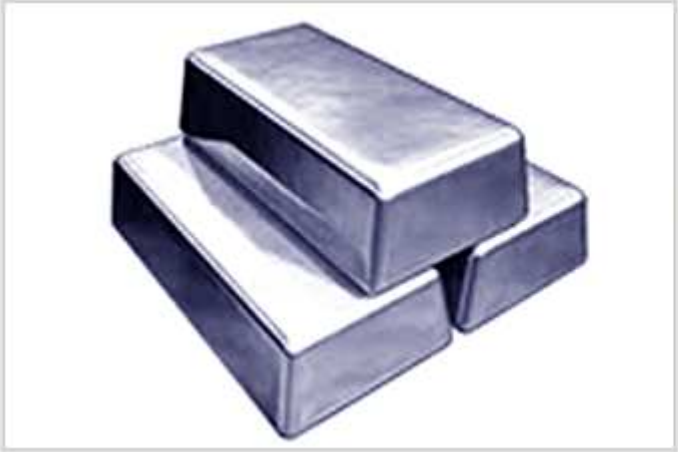
Description

Image



Caption

1. Silver bullion. 2. Solid silver conductors.

The material

If gold is the king of metals, silver is the queen. Silver is a soft, white metal with the highest electrical and thermal conductivities of any metal. It occurs as native silver but most is produced as a by-product of copper, lead and zinc refining.
Silver is valued as a precious metal, use for jewellery, tableware, musical instruments and currency. It has many industrial applications as electrical contacts and conductors, as a catalyst, in photographic film and photo-voltaics, in batteries, in pharmaceuticals, in lead-free solders and in control rods of nuclear reactors. The important industrial uses of silver compete with its desirability as a hedge against inflation, leading to volatile pricing.

Composition (summary)

>99.9Ag

General properties

Density	1.05e4	-	1.06e4	kg/m^3
Price	* 446	-	563	USD/kg
Date first used	-4000			

Mechanical properties

Young's modulus	69	-	73	GPa
Shear modulus	24	-	28	GPa
Bulk modulus	100	-	116	GPa
Poisson's ratio	0.385	-	0.395	
Yield strength (elastic limit)	190	-	300	MPa
Tensile strength	255	-	340	MPa
Compressive strength	190	-	300	MPa
Elongation	1	-	2	% strain
Hardness - Vickers	90	-	110	HV

Fatigue strength at 10^7 cycles	* 100	-	170	MPa
Fracture toughness	* 40	-	60	MPa.m^0.5
Mechanical loss coefficient (tan delta)	* 0.001	-	0.002	

Thermal properties

Melting point	957	-	967	°C
Maximum service temperature	* 96.9	-	190	°C
Minimum service temperature	-273			°C
Thermal conductor or insulator?	Good conductor			
Thermal conductivity	416	-	422	W/m.°C
Specific heat capacity	230	-	240	J/kg.°C
Thermal expansion coefficient	19.5	-	19.9	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Good conductor			
Electrical resistivity	1.67	-	1.81	µohm.cm

Optical properties

Transparency	Opaque

Critical Materials Risk

High critical material risk?	No

Durability: water and aqueous solutions

Water (fresh)	Excellent
Water (salt)	Excellent
Soils, acidic (peat)	Excellent
Soils, alkaline (clay)	Excellent
Wine	Excellent

Durability: acids

Acetic acid (10%)	Excellent
Acetic acid (glacial)	Excellent
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Excellent
Hydrofluoric acid (40%)	Excellent
Nitric acid (10%)	Excellent
Nitric acid (70%)	Excellent
Phosphoric acid (10%)	Excellent
Phosphoric acid (85%)	Excellent
Sulfuric acid (10%)	

	Unacceptable
Sulfuric acid (70%)	Unacceptable

Durability: alkalis

Sodium hydroxide (10%)	Excellent
Sodium hydroxide (60%)	Excellent

Durability: fuels, oils and solvents

Amyl acetate	Excellent
Benzene	Acceptable
Carbon tetrachloride	Excellent
Chloroform	Excellent
Crude oil	Unacceptable
Diesel oil	Unacceptable
Lubricating oil	Unacceptable
Paraffin oil (kerosene)	Unacceptable
Petrol (gasoline)	Unacceptable
Silicone fluids	Excellent
Toluene	Excellent
Turpentine	Excellent
Vegetable oils (general)	Unacceptable
White spirit	Excellent

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Excellent
Acetone	Excellent
Ethyl alcohol (ethanol)	Excellent
Ethylene glycol	Excellent
Formaldehyde (40%)	Excellent
Glycerol	Excellent
Methyl alcohol (methanol)	Excellent

Durability: halogens and gases

Chlorine gas (dry)	Excellent
Fluorine (gas)	Excellent
O2 (oxygen gas)	Excellent
Sulfur dioxide (gas)	Unacceptable

Durability: built environments

Industrial atmosphere	Excellent
Rural atmosphere	Excellent

Marine atmosphere	Unacceptable
UV radiation (sunlight)	Excellent

Durability: flammability

Flammability	Non-flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Excellent
Tolerance up to 150 C (302 F)	Excellent
Tolerance up to 250 C (482 F)	Excellent
Tolerance up to 450 C (842 F)	Excellent
Tolerance up to 850 C (1562 F)	Unacceptable
Tolerance above 850 C (1562 F)	Unacceptable

Geo-economic data for principal component

Annual world production, principal component	2.14e4	-	2.22e4	tonne/yr
Reserves, principal component	4.95e5	-	5.1e5	tonne

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 1.4e3	-	1.55e3	MJ/kg
CO2 footprint, primary production	* 95.4	-	105	kg/kg
Water usage	* 1.15e3	-	3.46e3	l/kg

Material processing: energy

Casting energy	* 6.81	-	7.53	MJ/kg
Extrusion, foil rolling energy	* 0.937	-	1.04	MJ/kg
Rough rolling, forging energy	* 0.611	-	0.676	MJ/kg
Wire drawing energy	* 2.73	-	3.02	MJ/kg
Metal powder forming energy	* 18.4	-	20.4	MJ/kg
Vaporization energy	* 4.18e3	-	4.63e3	MJ/kg
Coarse machining energy (per unit wt removed)	* 0.524	-	0.579	MJ/kg
Fine machining energy (per unit wt removed)	* 0.964	-	1.07	MJ/kg
Grinding energy (per unit wt removed)	* 1.45	-	1.61	MJ/kg
Non-conventional machining energy (per unit wt removed)	* 41.8	-	46.3	MJ/kg

Material processing: CO2 footprint

Casting CO2	* 0.511	-	0.565	kg/kg
Extrusion, foil rolling CO2	* 0.0703	-	0.0777	kg/kg
Rough rolling, forging CO2	* 0.0458	-	0.0507	kg/kg
Wire drawing CO2	* 0.205	-	0.226	kg/kg
Metal powder forming CO2	* 1.47	-	1.63	kg/kg
Vaporization CO2				

	* 314	-	347	kg/kg
Coarse machining CO2 (per unit wt removed)	* 0.0393	-	0.0434	kg/kg
Fine machining CO2 (per unit wt removed)	* 0.0723	-	0.0799	kg/kg
Grinding CO2 (per unit wt removed)	* 0.109	-	0.121	kg/kg
Non-conventional machining CO2 (per unit wt removed	* 3.14	-	3.47	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 140	-	170	MJ/kg
CO2 footprint, recycling	* 8.4	-	10	kg/kg
Recycle fraction in current supply	65	-	67	%
Downcycle	✓			
Combust for energy recovery	✗			
Landfill	✓			
Biodegrade	✗			
A renewable resource?	✗			

Supporting information

Design guidelines

Silver is non-toxic and has useful anti-bacterial properties.

Technical notes

Silver is by-product of the electrolytic refining of copper and other metals, notably nickel and zinc. It is extracted from lead by mixing the molten lead with molten zinc, in which the silver preferentially dissolves. The zinc, insoluble in lead, is separated and distilled off, leaving the silver (the Parkes process).

Typical uses

Electrical contacts, linings for chemical reactor vessels, linings for heavy duty journal bearings, jewellery, table wear, photography, batteries, pharmaceuticals, lead-free solders and control rods of nuclear reactors. Aluminum and rhodium can be substituted for silver in mirrors and other reflecting surfaces. Tantalum can be used in place of silver for surgical plates, pins, and sutures. Stainless steel is an alternate material used widely in the manufacture of table flatware. Nonsilver batteries being developed may replace silver batteries in some applications. Silverless black and white film, xerography, and film with reduced silver content are alternatives to some uses of silver in photography.

Links

Reference

ProcessUniverse

Producers