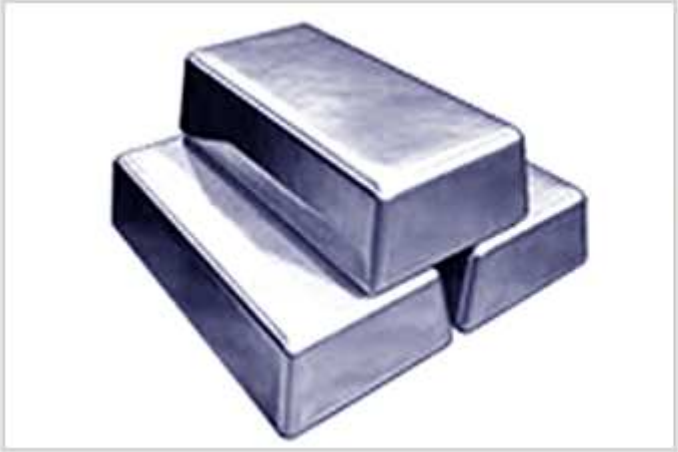
Description

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		655	-	662	lb/ft^3
Price	*	202	-	255	USD/lb
Date first used		-4000			

Mechanical properties

Young's modulus		10	-	10.6	10^6 psi
Shear modulus		3.48	-	4.06	10^6 psi
Bulk modulus		14.5	-	16.8	10^6 psi
Poisson's ratio		0.385	-	0.395	
Yield strength (elastic limit)		27.6	-	43.5	ksi
Tensile strength		37	-	49.3	ksi
Compressive strength		27.6	-	43.5	ksi
Elongation		1	-	2	% strain
Hardness - Vickers		90	-	110	HV

Fatigue strength at 10^7 cycles	*	14.5	-	24.7	ksi
Fracture toughness	*	36.4	-	54.6	ksi.in^0.5
Mechanical loss coefficient (tan delta)	*	0.001	-	0.002	

Thermal properties

Melting point		1.75e3	-	1.77e3	°F
Maximum service temperature	*	206	-	374	°F
Minimum service temperature		-459			°F
Thermal conductor or insulator?		Good conductor			
Thermal conductivity		240	-	244	BTU.ft/h.ft^2.F
Specific heat capacity		0.0549	-	0.0573	BTU/lb.°F
Thermal expansion coefficient		10.8	-	11.1	µstrain/°F

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	2.11e4	-	2.18e4	ton/yr
Reserves, principal component	4.87e5	-	5.02e5	l. ton

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 1.52e5	-	1.68e5	kcal/lb
CO2 footprint, primary production	* 95.4	-	105	lb/lb
Water usage	* 138	-	415	gal(US)/lb

Material processing: energy

Casting energy	* 738	-	816	kcal/lb
Extrusion, foil rolling energy	* 102	-	113	kcal/lb
Rough rolling, forging energy	* 66.2	-	73.2	kcal/lb
Wire drawing energy	* 296	-	327	kcal/lb
Metal powder forming energy	* 1.99e3	-	2.21e3	kcal/lb
Vaporization energy	* 4.53e5	-	5.02e5	kcal/lb
Coarse machining energy (per unit wt removed)	* 56.8	-	62.7	kcal/lb
Fine machining energy (per unit wt removed)	* 104	-	116	kcal/lb
Grinding energy (per unit wt removed)	* 157	-	174	kcal/lb
Non-conventional machining energy (per unit wt removed)	* 4.53e3	-	5.02e3	kcal/lb

Material processing: CO2 footprint

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

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

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 1.52e4	-	1.84e4	kcal/lb
CO2 footprint, recycling	* 8.4	-	10	lb/lb
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