Gold

Description

Image

Caption

1. Gold bullion. 2. Gold in electronic cicuits.

The material

Gold is the king of metals. Its name has entered the language as a symbol of perfection, achievement, good fortune and security: golden ages, golden ratios, golden rules, gold standards, golden crowns, golden girl, go for gold, gilded lives. When times are bad and investments insecure, investors turn to gold. Its rich color, its malleability, its resistance to almost all corrosion and its sheer scarcity combine to make it the most desirable of metals.
Some 90% of the global production of gold gets squirreled away as bullion and jewelry. The remaining 10% plays vital roles in the electronics industry as interconnects and as surface layers on connectors. Its high electrical conductivity and resistance to attack allow extreme miniaturization. Its use in dentistry, once large, is diminishing.

Composition (summary)

>99.5%Au

General properties

Density	1.2e3	-	1.21e3	lb/ft^3
Price	* 1.84e4	-	2.02e4	USD/lb
Date first used	-6000			

Mechanical properties

Young's modulus	11.2	-	11.7	10^6 psi
Shear modulus	3.77	-	4.35	10^6 psi
Bulk modulus	21.8	-	26.1	10^6 psi
Poisson's ratio	0.415	-	0.425	
Yield strength (elastic limit)	23.9	-	29.7	ksi
Tensile strength	26.1	-	31.9	ksi
Compressive strength	23.9	-	29.7	ksi
Elongation	2	-	6	% strain
Hardness - Vickers	50	-	70	HV
Fatigue strength at 10^7 cycles	* 10.2	-	16	ksi
Fracture toughness	* 36.4	-	63.7	ksi.in^0.5
Mechanical loss coefficient (tan delta)	* 0.0016	-	0.0021	

Thermal properties

Melting point	1.94e3			°F
Maximum service temperature	266	-	428	°F
Minimum service temperature	-459			°F
Thermal conductor or insulator?	Good conductor			

Thermal conductivity	176	-	184	BTU.ft/h.ft^2.F
Specific heat capacity	0.0299	-	0.0322	BTU/lb.°F
Thermal expansion coefficient	7.5	-	8.06	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good conductor			
Electrical resistivity	2	-	3	µohm.cm

Optical properties

Transparency	Opaque

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%)	Excellent
Sulfuric acid (70%)	Excellent

Durability: alkalis

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

Durability: fuels, oils and solvents

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

Durability: built environments

Industrial atmosphere	Excellent
Rural atmosphere	Excellent
Marine atmosphere	Excellent
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	2.31e3	-	2.46e3	ton/yr
Reserves	4.92e4	-	5.02e4	l. ton

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 2.6e7	-	2.87e7	kcal/lb
CO2 footprint, primary production	* 2.54e4	-	2.81e4	lb/lb
Water usage	* 1.51e4	-	4.53e4	gal(US)/lb

Material processing: energy

Casting energy	* 652	-	720	kcal/lb
Extrusion, foil rolling energy	* 161	-	179	kcal/lb
Rough rolling, forging energy	* 96.1	-	106	kcal/lb
Wire drawing energy	* 520	-	574	kcal/lb
Metal powder forming energy	* 1.9e3	-	2.09e3	kcal/lb
Vaporization energy	* 2.81e5	-	3.1e5	kcal/lb
Coarse machining energy (per unit wt removed)	* 61.2	-	67.7	kcal/lb
Fine machining energy (per unit wt removed)	* 150	-	165	kcal/lb
Grinding energy (per unit wt removed)	* 247	-	273	kcal/lb
Non-conventional machining energy (per unit wt removed)	* 2.81e3	-	3.1e3	kcal/lb

Material processing: CO2 footprint

Casting CO2	* 0.452	-	0.499	lb/lb
Extrusion, foil rolling CO2	* 0.112	-	0.123	lb/lb
Rough rolling, forging CO2	* 0.0665	-	0.0735	lb/lb

Wire drawing CO2	* 0.36	-	0.398	lb/lb
Metal powder forming CO2	* 1.4	-	1.55	lb/lb
Vaporization CO2	* 194	-	214	lb/lb
Coarse machining CO2 (per unit wt removed)	* 0.0424	-	0.0469	lb/lb
Fine machining CO2 (per unit wt removed)	* 0.103	-	0.114	lb/lb
Grinding CO2 (per unit wt removed)	* 0.171	-	0.189	lb/lb
Non-conventional machining CO2 (per unit wt removed)	* 1.94	-	2.14	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 7.58e5	-	9.21e5	kcal/lb
CO2 footprint, recycling	* 420	-	510	lb/lb
Recycle fraction in current supply	52	-	54	%
Downcycle	✓			
Combust for energy recovery	✗			
Landfill	✓			
Biodegrade	✗			
A renewable resource?	✗			

Supporting information

Design guidelines

At today's gold price, ore grades as low as 0.5 ppm are economic. The concentration of gold in some consumer electronics is greater than this, making old mobile phones and portable computers a viable resource for the metal. Gold prices are normally quoted in US$/Troy ounce. (1 kg = 32.151 Troy oz.)

Technical notes

Gold occurs in as native metal, usually in very small particles. The metal is isolated from sand or silt by "panning" - shaking in a water-filled sieve - using its high density to separate it. It is soluble in mercury from which it is recovered by distilling off the mercury. It dissolves in alkaline cyanide solutions from which it can be recovered by precipitation. All three methods are use in its extraction and recovery from used products.

Typical uses

Jewellery; Interconnects, Printed circuit board edge connectors; Electrical contacts; Lining for chemical equipment; Coinage; Bullion; Plating for space satellites; Toning silver images in photography. Palladium, platinum, and silver may substitute for gold.

Links

Reference

ProcessUniverse

Producers