Description

Image



Caption

1. Gold - Oregon Canyon Nugget (replica) © James St. John at flickr (CC BY-SA 2.0) 2. Gold ingots © AJC ajcann at flickr (CC BY-SA 2.0) 3. Gold Chains © Adam at flickr (CC BY-SA 2.0)

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	1.93e4	-	1.94e4	kg/m^3
Price	* 3.85e4	-	4.23e4	USD/kg
Date first used	-6000			

Mechanical properties

Young's modulus	77	-	81	GPa
Shear modulus	26	-	30	GPa
Bulk modulus	150	-	180	GPa
Poisson's ratio	0.415	-	0.425	
Yield strength (elastic limit)	165	-	205	MPa
Tensile strength	180	-	220	MPa
Compressive strength	165	-	205	MPa
Elongation	2	-	6	% strain

Hardness - Vickers		50	-	70	HV
Fatigue strength at 10^7 cycles	*	70	-	110	MPa
Fracture toughness	*	40	-	70	MPa.m^0.5
Mechanical loss coefficient (tan delta)	*	0.0016	-	0.0021	

Thermal properties

Melting point		1.06e3			℃
Maximum service temperature		130	-	220	℃
Minimum service temperature		-273			℃
Thermal conductor or insulator?		Good conductor			
Thermal conductivity		305	-	319	W/m.℃
Specific heat capacity		125	-	135	J/kg.℃
Thermal expansion coefficient		13.5	-	14.5	µstrain/℃

Electrical properties

Electrical conductor or insulator?		Good conductor			
Electrical resistivity		2	-	3	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%)	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, principal component	2.35e3	-	2.5e3	tonne/yr
Reserves, principal component	5e4	-	5.1e4	tonne

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 2.4e5	-	2.65e5	MJ/kg
CO2 footprint, primary production	* 2.54e4	-	2.81e4	kg/kg
Water usage	* 1.26e5	-	3.78e5	l/kg

Material processing: energy

Casting energy	* 6.02	-	6.65	MJ/kg
Extrusion, foil rolling energy	* 1.49	-	1.65	MJ/kg
Rough rolling, forging energy	* 0.887	-	0.98	MJ/kg
Wire drawing energy	* 4.8	-	5.3	MJ/kg
Metal powder forming energy	* 17.5	-	19.3	MJ/kg
Vaporization energy	* 2.59e3	-	2.86e3	MJ/kg
Coarse machining energy (per unit wt removed)	* 0.565	-	0.625	MJ/kg
Fine machining energy (per unit wt removed)	* 1.38	-	1.52	MJ/kg
Grinding energy (per unit wt removed)	* 2.28	-	2.52	MJ/kg
Non-conventional machining energy (per unit wt removed)	* 25.9	-	28.6	MJ/kg

Material processing: CO2 footprint

Casting CO2	* 0.452	-	0.499	kg/kg
Extrusion, foil rolling CO2	* 0.112	-	0.123	kg/kg
Rough rolling, forging CO2	* 0.0665	-	0.0735	kg/kg
Wire drawing CO2	* 0.36	-	0.398	kg/kg
Metal powder forming CO2				

	* 1.4	-	1.55	kg/kg
Vaporization CO2	* 194	-	214	kg/kg
Coarse machining CO2 (per unit wt removed)	* 0.0424	-	0.0469	kg/kg
Fine machining CO2 (per unit wt removed)	* 0.103	-	0.114	kg/kg
Grinding CO2 (per unit wt removed)	* 0.171	-	0.189	kg/kg
Non-conventional machining CO2 (per unit wt removed	* 1.94	-	2.14	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 7e3	-	8.5e3	MJ/kg
CO2 footprint, recycling	* 420	-	510	kg/kg
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

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