Description

Image



Caption

1. Copper electrical wires. © Chris Lefteri 2. Kettle pot. © Granta Design 3. Close-up of a copper cladded building. © John Fernandez

The material

In Victorian times you washed your clothes in a 'copper' - a vat or tank of beaten copper sheet, heated over a fire; the device exploited both the high ductility and the thermal conductivity of the material. Copper has a distinguished place in the history of civilization: it enabled the technology of the Bronze age (3000 BC - 1000 BC). It is used in many forms: as pure copper, as copper-zinc alloys (brasses), as copper-tin alloys (bronzes), and as copper-nickel and copper-beryllium. The designation of 'copper' is used when the percentage of copper is more than 99.3%. It is heavy and soft, not what you want for good mechanical performance. It is in its thermal, electrical, environmental and aesthetic qualities that copper excels. Its thermal and electrical conductivities are greater than those of any other metal except silver, and it is 50 times more expensive. It is exceptionally durable -- copper artifacts 2500 years old survive today; it is one of the reasons that it is used for coinage. And it is visually attractive: copper objects are prized, and prestige buildings are clad with it.

Composition (summary)

Cu

General properties

Density	557	-	558	lb/ft^3
Price	* 3.21	-	3.53	USD/lb
Date first used	-8000			

Mechanical properties

Young's modulus	16.2	-	21.5	10^6 psi
Shear modulus	6.53	-	7.54	10^6 psi
Bulk modulus	17.4	-	22.5	10^6 psi
Poisson's ratio	0.34	-	0.35	
Yield strength (elastic limit)	4.35	-	50.8	ksi
Tensile strength	14.5	-	58	ksi
Compressive strength	4.35	-	50.8	ksi
Elongation	3	-	50	% strain
Hardness - Vickers	44	-	180	HV
Fatigue strength at 10^7 cycles	10.2	-	18.9	ksi
Fracture toughness	27.3	-	81.9	ksi.in^0.5
Mechanical loss coefficient (tan delta)	3.5e-4	-	0.005	

Thermal properties

Melting point	1.8e3	-	1.98e3	°F
Maximum service temperature	356	-	572	°F
Minimum service temperature	-459			°F
Thermal conductor or insulator?	Good conductor			
Thermal conductivity	92.4	-	225	BTU.ft/h.ft^2.F
Specific heat capacity	0.0889	-	0.0927	BTU/lb.°F
Thermal expansion coefficient	9.39	-	10	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good conductor			
Electrical resistivity	1.74	-	5.01	µohm.cm

Optical properties

Transparency	Opaque

Processability

Castability	3	-	5
Formability	4	-	5
Machinability	4	-	5
Weldability	3		
Solder/brazability	5		

Durability: water and aqueous solutions

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

Durability: acids

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

Durability: alkalis

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

Durability: fuels, oils and solvents

Amyl acetate	Excellent
Benzene	Excellent
Carbon tetrachloride	Excellent
Chloroform	Excellent
Crude oil	Acceptable
Diesel oil	Excellent

Lubricating oil	Excellent
Paraffin oil (kerosene)	Excellent
Petrol (gasoline)	Excellent
Silicone fluids	Limited use
Toluene	Excellent
Turpentine	Excellent
Vegetable oils (general)	Excellent
White spirit	Excellent

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Limited use
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)	Acceptable
O2 (oxygen gas)	Limited use
Sulfur dioxide (gas)	Limited use

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)	Unacceptable
Tolerance up to 450 C (842 F)	Unacceptable
Tolerance up to 850 C (1562 F)	Unacceptable
Tolerance above 850 C (1562 F)	Unacceptable

Geo-economic data for principal component

Annual world production	1.56e7	ton/yr
Reserves	5.31e8	l. ton

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 6.15e3	-	6.8e3	kcal/lb
CO2 footprint, primary production	* 3.52	-	3.9	lb/lb
Water usage	* 35.1	-	38.8	gal(US)/lb
Eco-indicator 95	1.4e3			millipoints/kg
Eco-indicator 99	2.17e3			millipoints/kg

Material processing: energy

Casting energy	* 935	-	1.03e3	kcal/lb
Extrusion, foil rolling energy	* 431	-	477	kcal/lb

Rough rolling, forging energy	* 231	-	256	kcal/lb
Wire drawing energy	* 1.53e3	-	1.69e3	kcal/lb
Metal powder forming energy	* 2.55e3	-	2.87e3	kcal/lb
Vaporization energy	* 8.82e5	-	9.74e5	kcal/lb
Coarse machining energy (per unit wt removed)	* 81.5	-	90	kcal/lb
Fine machining energy (per unit wt removed)	* 352	-	389	kcal/lb
Grinding energy (per unit wt removed)	* 652	-	720	kcal/lb
Non-conventional machining energy (per unit wt removed)	8.82e3	-	9.74e3	kcal/lb

Material processing: CO2 footprint

Casting CO2	* 0.647	-	0.715	lb/lb
Extrusion, foil rolling CO2	* 0.298	-	0.33	lb/lb
Rough rolling, forging CO2	* 0.16	-	0.177	lb/lb
Wire drawing CO2	* 1.06	-	1.17	lb/lb
Metal powder forming CO2	* 1.88	-	2.12	lb/lb
Vaporization CO2	* 610	-	675	lb/lb
Coarse machining CO2 (per unit wt removed)	* 0.0564	-	0.0623	lb/lb
Fine machining CO2 (per unit wt removed)	* 0.243	-	0.269	lb/lb
Grinding CO2 (per unit wt removed)	* 0.451	-	0.499	lb/lb
Non-conventional machining CO2 (per unit wt removed)	6.1	-	6.75	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 1.4e3	-	1.55e3	kcal/lb
CO2 footprint, recycling	* 1.02	-	1.12	lb/lb
Recycle fraction in current supply	40	-	46	%
Downcycle	✓			
Combust for energy recovery	✗			
Landfill	✓			
Biodegrade	✗			
Toxicity rating	Non-toxic			
A renewable resource?	✗			

Environmental notes

Copper and its alloys are particularly easy to recycle - in many countries the recycle fraction approaches 90%.

Supporting information

Design guidelines

Copper and its alloys are easy to cast, to roll to sheet, to draw to wire, and to shape in other ways. They resist corrosion in the atmosphere, acquiring an attractive green patina (copper carbonate) in clean air, and a black one (copper sulfide) in one that is not - copper roofs in cities are usually black. The patina of bronze is a rich warm brown, much loved by sculptors. Pure copper has excellent electrical and thermal conductivity, is easy to fabricate and join, has good corrosion resistance and reasonable strength. Where high conductivity is necessary, oxygen-free high-conductivity (OFHC) copper is used. In its annealed form it is soft and ductile; with work-hardening the material becomes harder but less ductile.

Technical notes

There is now a UNS designation system for copper and its alloys: the letter C (for 'copper') followed by a 5-digit number. Only the first digit means anything: C1**** designates almost pure copper, the C2, C3 and C4 series are brasses with increasing zinc content, the C5s are bronzes based on copper and tin, the C6s are other bronzes containing aluminum instead of tin, and the C7s are copper-nickel alloys. More information on designations and equivalent grades can be found on the Granta Design website at www.grantadesign.com/designations

Typical uses

Electrical wiring, electrical conductors, cables, busbars, high strength, high conductivity wires and sections, overheads lines, contact wires, resistance-welding electrodes, terminals, high conductivity items for use at raised temperatures, heat exchangers, heat sinks, coinage, pans, kettles and boilers, plates for etching and engraving, roofing and architecture, boilers and pressure vessels.

Links

Reference

ProcessUniverse

Producers