Description

Image

Caption

1. Lead-tin alloys were, until recently, the most widely used solders for electrical, plumbing and sealing of cans. Now concern for the toxicity of lead salts increasingly limits their use. © Granta Design 2. Lead used in rain gutters. © John Fernandez

The material

Lead, when pure, is very soft and, with it low melting point (327 C) it creeps, even at room temperature -- old lead pipes acquire a sag between fixing points over time. There are two broad classes of alloys base on lead. The first, typified by the lead-antimony (Pb-Sb) alloys, are designed to increase the strength and resistance to creep while retaining the excellent corrosion resistance of lead. They are used for roofing, guttering, cladding and for sound insulation of buildings. The second, typified by the lead-tin alloys (Pb-Sn) are designed as solders and have an even lower melting point than lead (as low as 183 C), a temperature easily achieved with a soldering iron or infra-red lamps. The data listed below are for lead-tin solder.

Compositional summary

Antimonial lead: Pb + 4 to 25% Sb
Lead-tin solders: Pb + 5 tp 60% Sn

General properties

Density		8.85e3	-	1.1e4	kg/m^3
Price	*	6.58	-	7.18	USD/kg
Date first used		-6500			

Mechanical properties

Young's modulus		13	-	17	GPa
Shear modulus	*	4	-	6	GPa
Bulk modulus		30	-	55	GPa
Poisson's ratio	*	0.435	-	0.445	
Yield strength (elastic limit)		9	-	36	MPa
Tensile strength		21	-	46	MPa
Compressive strength		9	-	36	MPa

Elongation	12	-	30	% strain
Hardness - Vickers	6	-	17	HV
Fatigue strength at 10^7 cycles	* 6	-	17	MPa
Fracture toughness	* 10	-	25	MPa.m^0.5
Mechanical loss coefficient (tan delta)	* 0.02	-	0.095	

Thermal properties

Melting point	183	-	312	°C
Maximum service temperature	* 70	-	120	°C
Minimum service temperature	-272	-	-271	°C
Thermal conductor or insulator?	Good conductor			
Thermal conductivity	22	-	36	W/m.°C
Specific heat capacity	125	-	215	J/kg.°C
Thermal expansion coefficient	23	-	29	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Good conductor			
Electrical resistivity	15	-	22	µohm.cm

Optical properties

Transparency	Opaque

Processability

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

Durability: water and aqueous solutions

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

Durability: acids

Acetic acid (10%)	Acceptable
Acetic acid (glacial)	Acceptable
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Limited use
Hydrochloric acid (36%)	

	Unacceptable
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	Limited use
Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Excellent
Phosphoric acid (85%)	Excellent
Sulfuric acid (10%)	Acceptable
Sulfuric acid (70%)	Acceptable

Durability: alkalis

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

Durability: fuels, oils and solvents

Amyl acetate	Acceptable
Benzene	Excellent
Carbon tetrachloride	Excellent
Chloroform	Acceptable
Crude oil	Acceptable
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	Acceptable
Acetone	Excellent
Ethyl alcohol (ethanol)	Excellent
Ethylene glycol	Excellent
Formaldehyde (40%)	Acceptable
Glycerol	Acceptable
Methyl alcohol (methanol)	Excellent

Durability: halogens and gases

Chlorine gas (dry)	Acceptable
Fluorine (gas)	Excellent

O2 (oxygen gas)	Acceptable
Sulfur dioxide (gas)	Acceptable

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)	Acceptable
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, principal component	3.9e6	tonne/yr
Reserves, principal component	7.9e7	tonne

Primary material production: energy, CO2 and water

Embodied energy, primary production	*	66.2	- 73.1		MJ/kg
CO2 footprint, primary production	*	4.15	- 4.59		kg/kg
Water usage	*	2.43e3	- 2.69e3		l/kg
Eco-indicator 95		640			millipoints/kg

Material processing: energy

Casting energy	*	5.16	- 5.7	MJ/kg
Extrusion, foil rolling energy	*	0.595	- 0.657	MJ/kg
Rough rolling, forging energy	*	0.44	- 0.486	MJ/kg
Wire drawing energy	*	1.45	- 1.6	MJ/kg
Metal powder forming energy	*	3.77	- 4.56	MJ/kg
Vaporization energy	*	1.26e3	- 1.39e3	MJ/kg
Coarse machining energy (per unit wt removed)	*	0.498	- 0.551	MJ/kg
Fine machining energy (per unit wt removed)	*	0.707	- 0.782	MJ/kg
Grinding energy (per unit wt removed)	*	0.94	- 1.04	MJ/kg
Non-conventional machining energy (per unit wt removed)		12.6	- 13.9	MJ/kg

Material processing: CO2 footprint

Casting CO2	* 0.387	-	0.427	kg/kg
Extrusion, foil rolling CO2	* 0.0446	-	0.0493	kg/kg
Rough rolling, forging CO2	* 0.033	-	0.0365	kg/kg
Wire drawing CO2	* 0.108	-	0.12	kg/kg
Metal powder forming CO2	* 0.301	-	0.365	kg/kg
Vaporization CO2	* 94.2	-	104	kg/kg
Coarse machining CO2 (per unit wt removed)	* 0.0374	-	0.0413	kg/kg
Fine machining CO2 (per unit wt removed)	* 0.053	-	0.0586	kg/kg
Grinding CO2 (per unit wt removed)	* 0.0705	-	0.0779	kg/kg
Non-conventional machining CO2 (per unit wt removed)	0.942	-	1.04	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✔			
Embodied energy, recycling	* 14.5	-	16.1	MJ/kg
CO2 footprint, recycling	* 1.14	-	1.26	kg/kg
Recycle fraction in current supply	50	-	61.5	%
Downcycle	✔			
Combust for energy recovery	✖			
Landfill	✖			
Biodegrade	✖			
Toxicity rating	Toxic			
A renewable resource?	✖			

Environmental notes

Lead is one of the "heavy metals" that include cadmium, thallium and mercury. They have a bad reputation: when ingested they accumulate in the body, causing slow poisoning. It is for this reason that lead has been eliminated as an additive to petrol and as a pigment in paint, and that alternatives are sought for lead-tin solders. Lead in decorative and architectural applications offers no threat and is easily recycled.

Supporting information

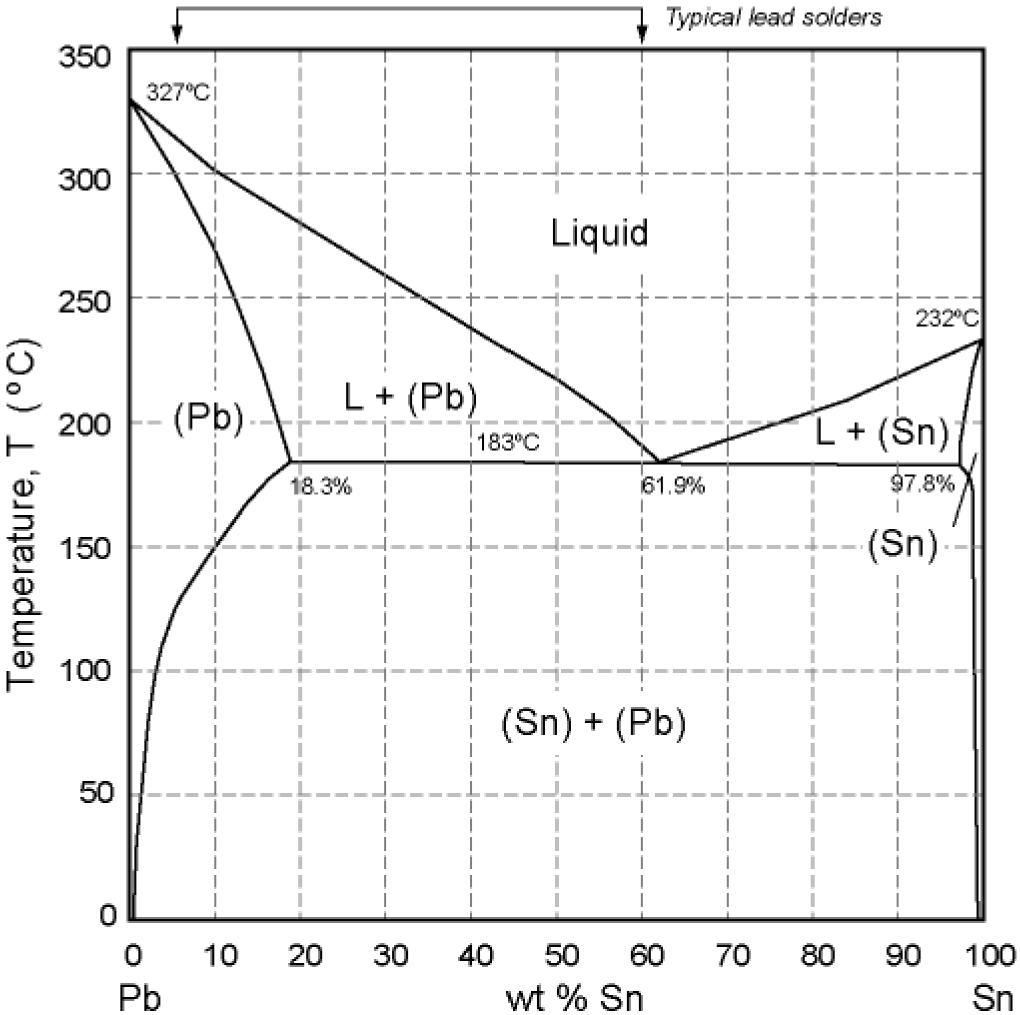
Design guidelines

Lead and its alloys are easy to shape because it melts at a low temperature (327 C) and is soft and ductile. They are exceptionally corrosion resistant, weathers to an attractive patina, and have good sound-insulating properties. They are readily cast to complex shapes in cheap molds, can be cut, soldered or welded with ease, require no special finishing or protective coating and are easy to recycle.

Technical notes

Lead, with an atomic weight of 207, is one of the heaviest of elements. For this reason it is used for flywheels, counter weights, projectiles (bullets) and X-ray shielding. It alloys readily with tin (Sn) to give pewter (typically 10%Pb 90% Sn) and solder (typically 40%Pb 60% Sn, melting at 200C) and with antimony (Sb) to give type metal, (70%Pb 30%Sb). Its chemical properties are exploited in lead-acid storage batteries.

Phase diagram



Phase diagram description

Lead solders are alloys of lead (Pb) with 5 to 60% tin (Sn), for which this is the phase

Typical uses

Roofs, wall cladding, pipe work, window seals, and flooring in buildings; sculpture and table wear as pewter; solder for electrical circuits and for mechanical joining, bearings, printing type ("Type metal"), ammunition, pigments, X-ray shielding, corrosion resistant material in the chemical industry and electrodes for lead acid batteries.

Links

Reference

ProcessUniverse

Producers