## Description

**Image**

**Caption**

1. Organ pipes are made of tin or of a tin - lead alloy. 2. Close-up of the material. © Håkan Svensson (Xauxa) at en.wikipedia - (CC BY-SA 3.0)

**The material**

Tin (symbol Sn) has been know to man since at least 3500 BC. The discovery that copper alloyed with tin to give bronze, greatly improving the mechanical properties, launched the Bronze age. In 1800 Napoleon offered prize of 12,000 francs for a method for preserving food for his armies. The tin can (steel coated with tin), which revolutionise the storage and preservation of foodstuffs and liquids, was invented in 1810, ironically by an Englishman; the first commercial canning factory opened just 3 years later.

**Composition (summary)**

Tin, Sn.

## General properties

| | | | | |
|---|---|---|---|---|
| Density | 453 | - | 454 | lb/ft^3 |
| Price | * 7.71 | - | 8.16 | USD/lb |
| Date first used | -3500 | | | |

## Mechanical properties

| | | | | |
|---|---|---|---|---|
| Young's modulus | 5.95 | - | 6.53 | 10^6 psi |
| Shear modulus | 2.03 | - | 2.61 | 10^6 psi |
| Bulk modulus | 5.51 | - | 6.67 | 10^6 psi |
| Poisson's ratio | 0.325 | - | 0.335 | |
| Yield strength (elastic limit) | 1.02 | - | 2.18 | ksi |
| Tensile strength | 1.6 | - | 2.61 | ksi |
| Compressive strength | 1.02 | - | 2.18 | ksi |
| Elongation | 55 | - | 75 | % strain |
| Hardness - Vickers | 3 | - | 5 | HV |
| Fatigue strength at 10^7 cycles | * 0.58 | - | 1.31 | ksi |

| | | | | |
|---|---|---|---|---|
| Fracture toughness | * 13.7 | - | 27.3 | ksi.in^0.5 |
| Mechanical loss coefficient (tan delta) | * 0.015 | - | 0.045 | |

## Thermal properties

| | | | | |
|---|---|---|---|---|
| Melting point | 446 | - | 450 | °F |
| Maximum service temperature | * 194 | - | 212 | °F |
| Minimum service temperature | 32 | - | 55.8 | °F |
| Thermal conductor or insulator? | Good conductor | | | |
| Thermal conductivity | 34.7 | - | 35.5 | BTU.ft/h.ft^2.F |
| Specific heat capacity | 0.0516 | - | 0.0545 | BTU/lb.°F |
| Thermal expansion coefficient | 12.5 | - | 13.1 | µstrain/°F |

## Electrical properties

| | | | | |
|---|---|---|---|---|
| Electrical conductor or insulator? | Good conductor | | | |
| Electrical resistivity | 10 | - | 12 | µohm.cm |

## Optical properties

| | |
|---|---|
| Transparency | Opaque |

## Critical Materials Risk

| | |
|---|---|
| High critical material risk? | Yes |

## Processability

| | | | |
|---|---|---|---|
| Castability | 5 | | |
| Formability | 4 | - | 5 |
| Machinability | 5 | | |
| Weldability | 1 | | |
| Solder/brazability | 5 | | |

## Durability: water and aqueous solutions

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

## Durability: acids

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

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

## Durability: alkalis

| | |
|---|---|
| Sodium hydroxide (10%) | Limited use |
| Sodium hydroxide (60%) | Limited use |

## Durability: fuels, oils and solvents

| | |
|---|---|
| Amyl acetate | Excellent |
| Benzene | Excellent |
| Carbon tetrachloride | Excellent |
| Chloroform | Excellent |
| Crude oil | Limited use |
| 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%) | Excellent |
| Glycerol | Excellent |
| Methyl alcohol (methanol) | Excellent |

## Durability: halogens and gases

| | |
|---|---|
| Chlorine gas (dry) | Unacceptable |
| Fluorine (gas) | Unacceptable |
| O2 (oxygen gas) | Limited use |

| | | | | |
|---|---|---|---|---|
| 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 | Unacceptable | | | |
| 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 | 3.02e5 | | | ton/yr |
| Reserves, principal component | 5.51e6 | | | I. ton |

## Primary material production: energy, CO2 and water

| | | | | |
|---|---|---|---|---|
| Embodied energy, primary production | * 2.34e4 | - | 2.58e4 | kcal/lb |
| CO2 footprint, primary production | * 12.5 | - | 13.8 | lb/lb |
| Water usage | * 1.25e3 | - | 1.38e3 | gal(US)/lb |

## Material processing: energy

| | | | | |
|---|---|---|---|---|
| Casting energy | * 587 | - | 649 | kcal/lb |
| Extrusion, foil rolling energy | * 50.2 | - | 55.5 | kcal/lb |
| Rough rolling, forging energy | * 40.5 | - | 44.7 | kcal/lb |
| Wire drawing energy | * 103 | - | 114 | kcal/lb |
| Metal powder forming energy | * 447 | - | 492 | kcal/lb |
| Vaporization energy | * 2.59e5 | - | 2.86e5 | kcal/lb |
| Coarse machining energy (per unit wt removed) | * 52.9 | - | 58.5 | kcal/lb |
| Fine machining energy (per unit wt removed) | * 65.9 | - | 72.8 | kcal/lb |
| Grinding energy (per unit wt removed) | * 80.4 | - | 88.8 | kcal/lb |
| Non-conventional machining energy (per unit wt removed) | 2.59e3 | - | 2.86e3 | kcal/lb |

## Material processing: CO2 footprint

| | | | | |
|---|---|---|---|---|
| Casting CO2 | * 0.407 | - | 0.45 | lb/lb |

| | | | | |
|---|---|---|---|---|
| Extrusion, foil rolling CO2 | * 0.0347 | - | 0.0384 | lb/lb |
| Rough rolling, forging CO2 | * 0.028 | - | 0.031 | lb/lb |
| Wire drawing CO2 | * 0.0714 | - | 0.0789 | lb/lb |
| Metal powder forming CO2 | * 0.33 | - | 0.364 | lb/lb |
| Vaporization CO2 | * 179 | - | 198 | lb/lb |
| Coarse machining CO2 (per unit wt removed) | * 0.0366 | - | 0.0405 | lb/lb |
| Fine machining CO2 (per unit wt removed) | * 0.0456 | - | 0.0504 | lb/lb |
| Grinding CO2 (per unit wt removed) | * 0.0556 | - | 0.0615 | lb/lb |
| Non-conventional machining CO2 (per unit wt removed | 1.79 | - | 1.98 | lb/lb |

## Material recycling: energy, CO2 and recycle fraction

| | | | | |
|---|---|---|---|---|
| Recycle | ✔ | | | |
| Embodied energy, recycling | * 3.87e3 | - | 4.27e3 | kcal/lb |
| CO2 footprint, recycling | * 2.8 | - | 3.1 | lb/lb |
| Recycle fraction in current supply | 5.5 | - | 6.5 | % |
| Downcycle | ✔ | | | |
| Combust for energy recovery | ✖ | | | |
| Landfill | ✔ | | | |
| Biodegrade | ✖ | | | |
| Toxicity rating | Non-toxic | | | |
| A renewable resource? | ✖ | | | |

**Environmental notes**

Tin(II) salts can be poisonous by ingestion and other routes, and there is evidence that tin can have experimental carcinogenic and human mutagenic effects. Some organo-tin compounds are very toxic.

## Supporting information

**Technical notes**

Tin is extracted by the reduction of cassiterite, SnO2, with carbon. At normal temperatures tin is metallic ("white" tin), but below 13.2 C it transforms (slowly) to non-metallic gray tin -- a problem known as "tin pest" when tin is used at low temperatures.

**Typical uses**

Tin is used in pure form in storage tanks for pharmaceutical chemical solutions, as electrodes of capacitors, and fuse wire and as organ pipes (though usually alloyed with some lead). Its most important applications, however, are as a coating on steel sheet ("tin plate") and as an alloying element in bronze, pewter and solder. Its salts are used as polymer additives, for antifouling paints, and to produce a transparent, conducting coating on glass.

**Further reading**

Eco data from Hammond, G. and Jones, C. (2006) "Inventory of carbon and energy (ICE), Dept. of Mechanical Engineering, University of Bath, UK

## Links

Reference

ProcessUniverse

Producers