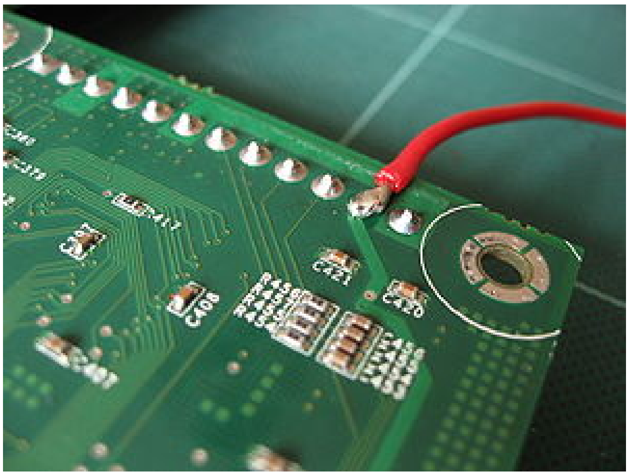
Solder



A soldered joint used to attach a wire to the pin of a component on the rear of a printed circuit board.

Solder is a fusible metal alloy with a melting point or melting range of 90 to 450 °C (200 to 840 °F), used in a process called soldering where it is melted to join metallic surfaces. It is especially useful in electronics and plumbing. Alloys that melt between 180 and 190 °C are the most commonly used.

The word solder comes from the Middle English word *soudur*, via Old French *solduree* and *soulder*, from the Latin *solidare*, meaning "to make solid". Solder can contain lead and/or flux but in many applications solder is now lead free.

Lead solder

Tin/lead solders, also called *soft solders*, are commercially available with tin concentrations between 5% and 70% by weight. The greater the tin concentration, the greater the solder's tensile and shear strengths. At the retail level, the two most common alloys are 60/40 Sn/Pb which melts at 370 °F or 188 °C and 63/37 Sn/Pb used principally in electrical work. The 63/37 ratio is notable in that it is a eutectic mixture, which means:

1. It has the lowest melting point (183 °C or 361.4 °F) of all the tin/lead alloys; and
2. The melting point is truly a *point* — not a range.

At a eutectic composition, the liquid solder solidifies at a single temperature. Tin-Lead solder solidifies to fine grains of nearly pure lead and nearly pure tin phases, there are no tin/lead intermetallics and no solubility of tin in lead or lead in tin, as can be seen from a tin/lead equilibrium diagram.[1]

In plumbing, a higher proportion of lead was used, commonly 50/50. This had the advantage of making the alloy solidify more slowly, so that it could be wiped over the joint to ensure watertightness, the pipes being physically fitted together before soldering. Although lead water pipes were displaced by copper when the significance of lead poisoning began to be fully appreciated, lead solder was still used until the 1980s because it was thought that the amount of lead that could leach into water from the solder was negligible from a properly soldered joint. The electrochemical couple of copper and lead promotes corrosion of the lead and tin, however tin is protected by insoluble oxide. Since even small amounts of lead have been found detrimental to health,[2] Lead in plumbing solder was replaced by silver (food grade applications) or antimony, with copper often added, and the proportion of tin was increased (see *Lead-free solder.)*

In electronics, the traditional use of solder was to fortify mechanically made electrical contacts, e.g. two solid copper wires twisted together. This was in part due to the higher electrical resistance of solder versus copper.[3]Printed circuit boards use solder joints to mount components and create a circuit, also replacing the use of solid solder with solder paste.

Hard solder

Hard solders are used for brazing, and melt at higher temperatures. Alloys of copper with either zinc or silver are the most common.

In silversmithing or jewelry making, special hard solders are used that will pass away assay. They contain a high proportion of the metal being soldered and lead is not used in these alloys. These solders vary in hardness, designated as "enamelling", "hard", "medium" and "easy". Enamelling solder has a high melting point, close to that of the material itself, to prevent the joint desoldering during firing in the enamelling process. The remaining solder types are used in decreasing order of hardness during the process of making an item, to prevent a previously soldered seam or joint desoldering while additional sites are soldered. Easy solder is also often used for repair work for the same reason. Flux or rouge is also used to prevent joints from desoldering.

Silver solder is also used in manufacturing to join metal parts that cannot be welded. The alloys used for these purposes contain a high proportion of silver (up to 40%), and may also contain cadmium.

Flux-core solder

A tube of multicore electronics solder used for manual soldering - the flux is contained in five cores within the solder itself

Flux is a reducing agent designed to help remove impurities (specifically oxidised metals) from the points of contact to improve the electrical connection and mechanical strength. The two principal types of flux are acid flux, used for metal mending and plumbing, and rosin flux, used in electronics, where the corrosiveness of acid flux and vapours released when solder is heated would risk damaging delicate circuitry.

Due to concerns over atmospheric pollution and hazardous waste disposal, the electronics industry has been gradually shifting from rosin flux to water-soluble flux, which can be removed with deionised water and detergent, instead of hydrocarbon solvents.

In contrast to using traditional bars or coiled wires of all-metal solder and manually applying flux to the parts being joined, some light hand soldering since the mid-20th century has used flux-core solder. This is manufactured as a coiled wire of solder, with one or more continuous bodies of non-acid flux embedded lengthwise inside it. As the solder melts onto the joint, it frees the flux and releases that on it as well.

Lead-free solder

A coil of lead-free solder wire

On July 1, 2006 the European Union Waste Electrical and Electronic Equipment Directive (WEEE) and Restriction of Hazardous Substances Directive (RoHS) came into effect prohibiting the intentional addition of lead to most consumer electronics produced in the EU. California recently adopted a RoHS law[4] and China has a version as well. Manufacturers in the U.S. may receive tax benefits by reducing the use of lead-based solder. Lead-free solders in commercial use may contain tin, copper, silver, bismuth, indium, zinc, antimony, and traces of other metals. Most lead-free replacements for conventional Sn60/Pb40 and Sn63/Pb37 solder have melting points from 5–20 °C higher, though solders with much lower melting points are available.

Drop-in replacements for silkscreen with solder paste soldering operations are available. Minor modification to the solder pots (e.g. titanium liners and/or impellers) used in wave-soldering operations may be desired to reduce maintenance costs associated with the increased tin-scavenging effects of high tin solders. Since the properties of lead-free solders are not as thoroughly known, they may therefore be considered less desirable for critical applications, like certain aerospace or medical projects. "Tin whiskers" were a problem with early electronic solders, and lead was initially added to the alloy in part to eliminate them.

- Sn-Ag-Cu solders are used by two thirds of Japanese manufacturers for reflow and wave soldering, and by about ¾ companies for hand soldering. The widespread use of this popular Pb-free solder alloy family is based on the reduced melting point of the Sn-Ag-Cu ternary eutectic reaction (217˚C), which is below the Sn-3.5Ag (wt.%) eutectic of 221˚C and the Sn-0.7Cu eutectic of 227˚C (recently revised by P. Snugovsky to Sn-0.9Cu). The ternary eutectic reaction of Sn-Ag-Cu and its application for electronics assembly was discovered (and patented) by a team of researchers from Ames Laboratory, Iowa State University, and from Sandia National Laboratories-Albuquerque.
    - $SnAg_{3.0}Cu_{0.5}$, tin with 3% silver and 0.5% copper, has a melting point of 217 to 220 °C and is predominantly used in Japan. It is the JEITA recommended alloy for wave and reflow soldering, with alternatives SnCu for wave and SnAg and SnZnBi for reflow soldering.
    - $SnAg_{3.5}Cu_{0.7}$ is another commonly used alloy, with melting point of 217-218 °C.

  - $SnAg_{3.5}Cu_{0.9}$, with melting point of 217 °C, is determined by NIST to be truly eutectic.
  - $SnAg_{3.8}Cu_{0.7}$, with melting point 217-218 °C, is preferred by the European IDEALS consortium for reflow soldering.
  - $SnAg_{3.8}Cu_{0.7}Sb_{0.25}$ is preferred by the European IDEALS consortium for wave soldering.
  - $SnAg_{3.9}Cu_{0.6}$, with melting point 217-223 °C, is recommended by the US NEMI consortium for reflow soldering.
  - Much recent research has focused on selection of 4th element additions to Sn-Ag-Cu to provide compatibility for the reduced cooling rate of solder sphere reflow for assembly of ball grid arrays, e.g., Sn-3.5Ag-0.74Cu-0.21Zn (melting range of 217-220˚C and Sn-3.5Ag-0.85Cu-0.10Mn (melting range of 211-215˚C).
- $SnCu_{0.7}$, with melting point of 227 °C, is a cheap alternative for wave soldering, recommended by the US NEMI consortium.
- $SnZn_9$, with melting point of 199 °C, is a cheaper alloy but is prone to corrosion and oxidation.
- $SnZn_8Bi_3$, with melting point of 191-198 °C, is also prone to corrosion and oxidation due to its zinc content.
- $SnSb_5$, tin with 5% of antimony, is the US plumbing industry standard. Its melting point is 232-240 °C. It displays good resistance to thermal fatigue and good shear strength.
- $SnAg_{2.5}Cu_{0.8}Sb_{0.5}$ melts at 217-225 °C and is patented by AIM alliance.
- $SnIn_{8.0}Ag_{3.5}Bi_{0.5}$ melts at 197 to 208 °C and is patented by Matsushita/Panasonic.
- $SnBi_{57}Ag_1$ melts at 137-139 °C and is patented by Motorola.
- $SnBi_{58}$ melts at 138 °C.
- $SnIn_{52}$ melts at 118 °C and is suitable for the cases where low-temperature soldering is needed.

Different elements serve different roles in the solder alloy:

- Silver provides mechanical strength, but has worse ductility than lead. In absence of lead, it improves resistance to fatigue from thermal cycles.
- Copper lowers the melting point, improves resistance to thermal cycle fatigue, and improves wetting properties of the molten solder. It also slows down the rate of dissolution of copper from the board and part leads in the liquid solder.
- Bismuth significantly lowers the melting point and improves wettability. In presence of sufficient lead and tin, bismuth forms crystals of $Sn_{16}Pb_{32}Bi_{52}$ with melting point of only 95 °C, which diffuses along the grain boundaries and may cause a joint failure at relatively low temperatures. A high-power part pre-tinned with an alloy of lead can therefore desolder under load when soldered with a bismuth-containing solder.
- Indium lowers the melting point and improves ductility. In presence of lead it forms a ternary compound that undergoes phase change at 114 °C.
- Zinc lowers the melting point and is low-cost. However it is highly susceptible to corrosion and oxidation in air, therefore zinc-containing alloys are unsuitable for some purposes, e.g. wave soldering, and zinc-containing solder pastes have shorter shelf life than zinc-free.
- Antimony is added to increase strength without affecting wettability.

See also

- Helping hand (tool)
- Body solder
- Soldering
- Solder paste
- Solder sucker
- Solder wick
- Solderability
- Soldering gun
- Soldering iron
- Welding
- Brazing
- Field’s metal
- Rose’s metal
- Wood’s metal

References

[1] "Internet Microscope for Schools : Micrographs : Lead". Pwatlas.mt.umist.ac.uk. http://pwatlas.mt.umist.ac.uk/internetmicroscope/micrographs/microstructures/more-metals/lead.html. Retrieved 2008-09-22.

[2] N Engl J Med. 1990 Jan 11;322 (2):83-8 PMID 2294437 (P,S,G,E,B) The long-term effects of exposure to low doses of lead in childhood. An 11-year follow-up report.

[3] Principles of soldering By Giles Humpston, David M. Jacobson (Google Books result)

[4] http://www.dtsc.ca.gov/HazardousWaste/EWaste

External links

- SolderingGuide.com
- Solder Paste Selector Guide
- Physical Properties Table: Specialty Alloys and Solders
- Lead-free solder alloys
- Common Solder alloys and their melting ranges
- Phase Diagrams of different types of solder alloys

- Solder Fumes Dangers by Sentry Air Systems
- Phase diagrams for lead free solders

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