RESPONSE TO OFFICE ACTION

Dear Mr. Solite,

The Indium Corporation of America ("Applicant") herein responds to the Office Action dated June 26, 2019 with regard to Application Serial No. 88/429,449 for the mark SOLDER REDEFINED ("Applicant's Mark").

I. Disclaimer

Applicant enters the following disclaimer as requested in the Office Action:

No claim is made to the exclusive right to use "SOLDER" apart from the mark as shown.

II. Description of Services

Applicant enters the following amendment:

Class 35: Provision of technical information and advice to consumers regarding the selection of products to be purchased, said products being nano-materials, specialty alloys, solder paste, solder preforms, solder spheres, solder wire, solder tubing, solder ribbon, solder foil, solder fluxes, electrically conductive adhesives, electrically conductive underfills, electrically conductive polymers, indium containing fabrications and pure indium

Class 40: Provision of technical information and advice to consumers regarding manufacturing processing parameters for nano-materials, specialty alloys, solder paste, solder preforms, solder spheres, solder wire, solder tubing, solder ribbon, solder foil, solder fluxes, electrically conductive adhesives, electrically conductive underfills, electrically conductive polymers, indium containing fabrications and pure indium

This modification shown above is appropriate because the services in Class 40 included both services related to the selection (Class 35) and manufacture (Class 40) of the various components. The classifications themselves are appropriate as the Office Action likewise proposes selection-related services in Class 35 and manufacturing-related services in Class 40.

Because an additional class has been added, Applicant authorizes the charge of an additional filing fee.

III. No Likelihood of Confusion

First, there is a clear distinction between the goods at issue. For ease of reference, the goods and services at issue are set forth in the table below:

Application	Registered Marks
Class 35: Provision of technical information and advice to consumers regarding the selection of products to be purchased, said products being nano-materials, specialty alloys, solder paste, solder preforms, solder spheres, solder wire, solder tubing, solder ribbon, solder foil, solder fluxes, electrically conductive adhesives, electrically conductive underfills, electrically conductive polymers, indium containing fabrications and pure indium	Class 14: precious metals and alloys thereof
Class 40: Provision of technical information and advice to consumers regarding manufacturing processing parameters for nano-materials, specialty alloys, solder paste, solder preforms, solder spheres, solder wire, solder tubing, solder ribbon, solder foil, solder fluxes, electrically conductive adhesives, electrically conductive underfills, electrically conductive polymers, indium containing fabrications and pure indium	Class 40: precious metal refining and recycling services Class 42: assay services for precious metals and alloys

The goods and services associated with the registered marks all revolve around precious metals, namely the metals themselves and services related to the refining, recycling, and assaying of them. Precious metals, of course, are typically known for their use with jewelry, such as gold, silver, and platinum. Wikidpedia defines a precious metal as a "rare, naturally occurring metallic chemical element of high economic value."[1] The specimen of use submitted in connection with the registered marks confirms that the goods and services associated with the registered marks are precious metals, including for example, gold:

[1] https://en.wikipedia.org/wiki/Precious_metal (see attached).

[2]

Applicant's services, on the other hand, relate to almost the exact opposite type of metal, i.e., solder. Solder is a "fusible metal alloy used to create a permanent bond between metal workpieces."[3] The alloys that make up solder, e.g., tin, lead, copper, etc., are decidedly not precious metals nor are they of high economic value. The use of solder is also decidedly different than the prevalent uses of precious metals, i.e., solder is used in industrial applications to create permanent bonds. *Id*. In addition to the differences between solder and precious metals and the different uses for solder and precious metals, the services claimed in Applicant's mark with regard to solder further distinguish them from the goods and services claimed in the registered marks. Namely, Applicant's Mark claims the provision of technical information and advice to consumers regarding the selection and manufacturing process parameters relating to

[2] Specimen of use filed March 12, 2018 in connection with Reg. No. 5,600,043 (see attached)
[3] https://en.wikipedia.org/wiki/Solder (see attached)

various types of solder products. In other words, Applicant advises third-parties with regard to selection of various solder products and how they should be used in manufacturing processes. This is not related at all to the assay and recycling/refining services claimed in the registered marks.

Second, there are differences between the marks as well. This is not based upon a side-by-side comparison of the marks. Rather, the differences discussed below, which would be apparent to consumers upon seeing and hearing or pronouncing the marks, create a different commercial impression such that confusion as to the source of the goods offered under the respective marks is not likely to result. Even though SOLDER is disclaimed it is still the dominant portion of Applicant's Mark. "It is often the first part of a mark which is most likely to be impressed upon the mind of a purchaser." *Presto Prods., Inc. v. Nice-Pak Prods., Inc,* 9 USPQ2d 1895, 1897 (TTAB 1988); *see also Palm Bay Imps., Inc. v. Veuve Clicquot Ponsardin Maison Fondee En 1772*, 396 F.3d 1369, 1372-73, 73 USPQ2d 1689, 1692 (Fed. Cir. 2005) (affirming TTAB's holding that contemporaneous use of appellant's mark, VEUVE ROYALE, for sparkling wine, and appellee's marks, VEUVE CLICQUOT and VEUVE CLICQUOT PONSARDIN, for champagne, is likely to cause confusion, noting that the presence of the "strong distinctive term [VEUVE] as the first word in both parties' marks renders the marks similar, especially in light of the largely laudatory (and hence non-source identifying). Given that the dominant portion of Applicant's Mark, i.e., SOLDER, is completely distinct from the only portion of the registered marks, i.e., RE-DEFINED Applicant respectfully submits that there is no likelihood of confusion between the marks. This difference, given the disclaimer of SOLDER might not be sufficient on its own, but it is sufficient when considered in conjunction with the substantial differences between the goods and services discussed above.

***

Accordingly, Applicant respectfully submits that there is no likelihood of confusion with the two cited registered marks and requests that the application proceed to publication.[4]

Respectfully,

HARRIS BEACH PLLC

Dated: October 21, 2019

By: *<u>/s/ James R. Muldoon</u>*
James R. Muldoon
Attorney for Applicant

HARRIS BEACH PLLC
333 West Washington St.
Suite 200
Syracuse, NY 13202
Telephone: (315) 423-7100
Facsimile: (315) 422-9331

[4] Every attempt has been made to place the case in condition for publication. The Commissioner is hereby authorized to charge any deficiencies associated with this communication or credit any overpayment to Deposit Account 08-0865.

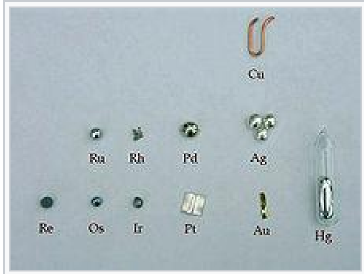
Precious metal

From Wikipedia, the free encyclopedia

This article is about valuable rare metals. For other uses, see Precious metal (disambiguation).
"Rare metal" redirects here. For other uses, see Rare metals (disambiguation).

Gold nugget

A **precious metal** is a rare, naturally occurring metallic chemical element of high economic value. Chemically, the precious metals tend to be less reactive than most elements (see noble metal). They are usually ductile and have a high lustre. Historically, precious metals were important as currency but are now regarded mainly as investment and industrial commodities. Gold, silver, platinum, and palladium each have an ISO 4217 currency code.



Assortment of noble metals

The best known precious metals are the coinage metals, which are gold and silver. Although both have industrial uses, they are better known for their uses in art, jewelry, and coinage. Other precious metals include the platinum group metals: ruthenium, rhodium, palladium, osmium, iridium, and platinum, of which platinum is the most widely traded.[1] The demand for precious metals is driven not only by their practical use but also by their role as investments and a store of value. Historically, precious metals have commanded much higher prices than common industrial metals.

Contents [hide]

Bullion [edit]

Main article: Bullion

1,000 oz silver bar

A metal is deemed to be *precious* if it is rare. The discovery of new sources of ore or improvements in mining or refining processes may cause the value of a precious metal to diminish. The status of a "precious" metal can also be determined by high demand or market value. Precious metals in bulk form are known as **bullion** and are traded on commodity markets. Bullion metals may be cast into ingots or minted into coins. The defining attribute of bullion is that it is valued by its mass and purity rather than by a face value as money.

Purity and mass [edit]

The level of purity varies from issue to issue. "Three nines" (99.9%) purity is common. The purest mass-produced bullion coins are in the Canadian Gold Maple Leaf series, which go up to 99.999% purity. A 100% pure bullion is nearly impossible: as the percentage of impurities diminishes, it becomes progressively more difficult to purify the metal further. Historically, coins had a certain amount of weight of alloy, with the purity a local standard. The Krugerrand is the first modern example of measuring in "pure gold": it should contain at least 12/11 ounces of at least 11/12 pure gold. Other bullion coins (for example the British Sovereign) show

500 g silver bullion bar produced by Johnson Matthey

neither the purity nor the fine-gold weight on the coin but are recognized and consistent in their composition.[citation needed] Many coins historically showed a denomination in currency (example: American double eagle: $20).

Coinage [edit]

1 oz Vienna Philharmonic gold coin

Many nations mint bullion coins. Although nominally issued as legal tender, these coins' face value as currency is far below that of their value as bullion. For instance, Canada mints a gold bullion coin (the Gold Maple Leaf) at a face value of $50 containing one troy ounce (31.1035 g) of gold—as of May 2011, this coin is worth about 1,500 CAD as bullion.[2] Bullion coins' minting by national governments gives them some numismatic value in addition to their bullion value, as well as certifying their purity.

American Platinum Eagle bullion coin

One of the largest bullion coins in the world was the 10,000-dollar Australian Gold Nugget coin minted in Australia which consists of a full kilogram of 99.9% pure gold. In 2012, the Perth Mint produced a 1-tonne coin of 99.99% pure gold with a face value of $1 million AUD, making it the largest minted coin in the world with a gold value of around $50 million AUD.[3] China has produced coins in very limited quantities (less than 20 pieces minted) that exceed 8 kilograms (260 ozt) of gold.[citation needed] Austria has minted a coin containing 31 kg of gold (the Vienna Philharmonic Coin minted in 2004 with a face value of 100,000 euro). As a stunt to publicise the 99.999% pure one-ounce Canadian Gold Maple Leaf series, in 2007 the Royal Canadian Mint made a 100 kg 99.999% gold coin, with a face value of $1 million, and now manufactures them to order, but at a substantial premium over the market value of the gold.[4][5]

Economic use [edit]

1 kg gold bullion (ingots)

Gold and silver, and sometimes other precious metals, are often seen as hedges against both inflation and economic downturn. Silver coins have become popular with collectors due to their relative affordability, and, unlike most gold and platinum issues which are valued based upon the markets, silver issues are more often valued as collectibles, far higher than their actual bullion value.[6]

Aluminium [edit]

An initially precious metal that became common is aluminium. While aluminium is the third most abundant element and most abundant metal in the Earth's crust, it was at first found to be exceedingly difficult to extract the metal from its various non-metallic ores. The great expense of refining the metal made the small available quantity of pure aluminium more valuable than gold.[7] Bars of aluminium were exhibited at the Exposition Universelle of 1855,[8] and Napoleon III's most important guests were given aluminium cutlery, while those less worthy dined with mere silver.[7] In 1884, the pyramidal capstone of the Washington Monument was cast of 100 ounces of pure aluminium. By that time, aluminium was as expensive as silver.[9] The statue of Anteros atop the Shaftesbury Memorial Fountain (1885–1893) in London's Piccadilly Circus is also of cast aluminium. Over time, however, the price of the metal has dropped. The dawn of commercial electric generation in 1882 and the invention of the Hall–Héroult process in 1886 caused the price of aluminium to drop substantially over a short period of time.

Rough world market price ($/kg) [edit]

This section **needs additional citations for verification**. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.

Find sources: "Precious metal" – news · newspapers · books · scholar · JSTOR *(September 2018)*

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mass	Valuable metal price (US$/kg)

metal	abundance (ppb)[10]	10 Apr 2009 [11]	22 Jul 2009 [12]	7 Jan 2010	31 Dec 2014 [13]	16 Jul 2018 [14]
Rhodium	1	39,680	46,200	88,415	39,641	77,804[15]
Platinum	5	42,681	37,650	87,741	38,902	28,960
Gold	4	31,100	30,590	24,317	38,130	43,764
Palladium	15	8,430	8,140	13,632	25,559	32,205
Iridium	1	14,100	12,960	13,117	15,432	46,940[16]
Osmium	1.5	13,400	12,200	12,217	12,217	
Rhenium	0.7	7,400	7,000	6,250	2,425	
Ruthenium	1	2,290	2,730	5,562	1,865	8,423[17]
Germanium	1,500		1,050[18]	1038		
Beryllium	2,800		850			
Silver	75	437	439	588	441	556
Indium	50[19]		325[18]	520		
Gallium	19,000	580	425[18]	413		
Tellurium	1			158.70		
Bismuth	8.5		15.40	18.19		
Mercury	85		18.90	15.95		

See also [edit]

- Alchemy
- Gemstone
- Gold as an investment
- Hallmark
- List of bullion dealers
- Metal as money
- Metallurgical assay
- Palladium as an investment
- Platinum as an investment
- Silver as an investment
- Synthesis of precious metals (precious metal transformation)
- Taxation of precious metals
- Troy weight

References [edit]

1. ^ Platinum Guild: Applications Beyond Expectation Archived 2009-05-03 at the Wayback Machine
2. ^ Gold prices ran around 940 USD in July 2009 according to Kitco Historical Gold Charts and Data. The USD to CAD exchange rate averaged 1.129 in July 2009 according to OANDA Historical Exchange Rates. Although the exact moment that the $1075 figure was determined is unknown, it may be considered a reasonable value for the time.
3. ^ "1 Tonne Gold Coin". *perthmint.com.au*. Retrieved 23 July 2015.
4. ^ "the Greatest coined gold in the world". *e-allmoney.com*. Retrieved 23 July 2015.
5. ^ UKBullion (2014). "100kg Fine Gold Coin". Retrieved 2014-03-18.
6. ^ Aharon DY, and Qadan M. (2018-10-04). "What drives the demand for information in the commodity market?". *Resources Policy*. doi:10.1016/j.resourpol.2018.09.013. ISSN 0301-4207.
7. ^ *a b* Geller, Tom (2007). "Aluminum: Common Metal, Uncommon Past". *Chemical Heritage Magazine*. **27** (4). Retrieved 22 March 2018.
8. ^ Karmarsch, C. (1864). "Fernerer Beitrag zur Geschichte des Aluminiums". *Polytechnisches Journal*. **171** (1): 49.
9. ^ George J. Binczewski (1995). "The Point of a Monument: A History of the Aluminum Cap of the Washington Monument". *JOM*. **47** (11): 20–25. doi:10.1007/bf03221302.
10. ^ The abundance of the element, a measure for its rarity, is given in mass fraction as kg in the earth's crust (CRC Handbook). David R. Lide, ed. (2005). "Section 14, Geophysics, Astronomy, and Acoustics; Abundance of Elements in the Earth's Crust and in the

Sea". *CRC Handbook of Chemistry and Physics* (85 ed.). Boca Raton, Florida: CRC Press.
11. ^ Mostly taken from London Metal Exchange.
12. ^ From the *http://www.thebulliondesk.com/*
13. ^ From the *http://www.thebulliondesk.com* *and* *http://www.taxfreegold.co.uk* *(mid price quoted)*
14. ^ From the *http://www.bullionexchanges.com*
15. ^ From *http://www.infomine.com/investment/metal-prices/rhodium/1-year/*
16. ^ From *http://www.infomine.com/investment/metal-prices/iridium/1-year/*
17. ^ From *http://www.infomine.com/investment/metal-prices/ruthenium/1-year/*
18. ^ [a] [b] [c] The metal Price ($/kg)s of gallium, germanium, and indium are taken from MinorMetals.com as examples of *modern* precious metals used for investment / speculation.
19. ^ Tolcin A. (2012) U.S. Geological Survey Mineral Commodity Summaries 2012.

External links [edit]

- Precious Metals Fraud US Commodity Futures Trading Commission Precious Metals Fraud Advisory

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Forms		Anklet · Barrette · Belt buckle · Belly chain · Bindi · Bolo tie · Bracelet · Brooch · Chatelaine · Collar pin · Crown · Cufflink · Earring · Ferronnière · Lapel pin · Necklace · Pectoral · Pendant · Ring · Tiara · Tie chain · Tie clip · Tie pin · Toe ring · Watch (pocket · strap)
Making	**People**	Bench jeweler · Clockmaker · Goldsmith · Silversmith · Jewelry designer · Lapidary · Watchmaker
	Processes	Carving · Casting (centrifugal · lost-wax · vacuum) · Enameling · Engraving · Filigree · Kazaziye · Metal clay · Plating · Polishing · Repoussé and chasing · Soldering · Stonesetting · Wire sculpture · Wire wrapped jewelry
	Tools	Draw plate · File · Hammer · Mandrel · Pliers
Materials	**Precious metals**	Gold · Palladium · Platinum · Rhodium · Silver
	Precious metal alloys	Britannia silver · Colored gold · Crown gold · Electrum · Shakudō · Shibuichi · Sterling silver · Argentium sterling silver · Tumbaga
	Base metals	Brass · Bronze · Copper · Nickel silver (alpac(c)a) · Mokume-gane · Pewter · Pinchbeck · Stainless steel · Titanium · Tungsten
	Mineral gemstones	Aventurine · Agate · Amazonite · Amethyst · Beryl · Carnelian · Chrysoberyl · Chrysocolla · Diamond · Diopside · Emerald · Fluorite · Garnet · Howlite · Jade · Jasper · Kyanite · Labradorite · Lapis lazuli · Larimar · Malachite · Marcasite · Moonstone · Obsidian · Onyx · Opal · Peridot · Prasiolite · Quartz · Ruby · Sapphire · Sodalite · Spinel · Sunstone · Tanzanite · Tiger's eye · Topaz · Tourmaline · Turquoise · Variscite · Zircon
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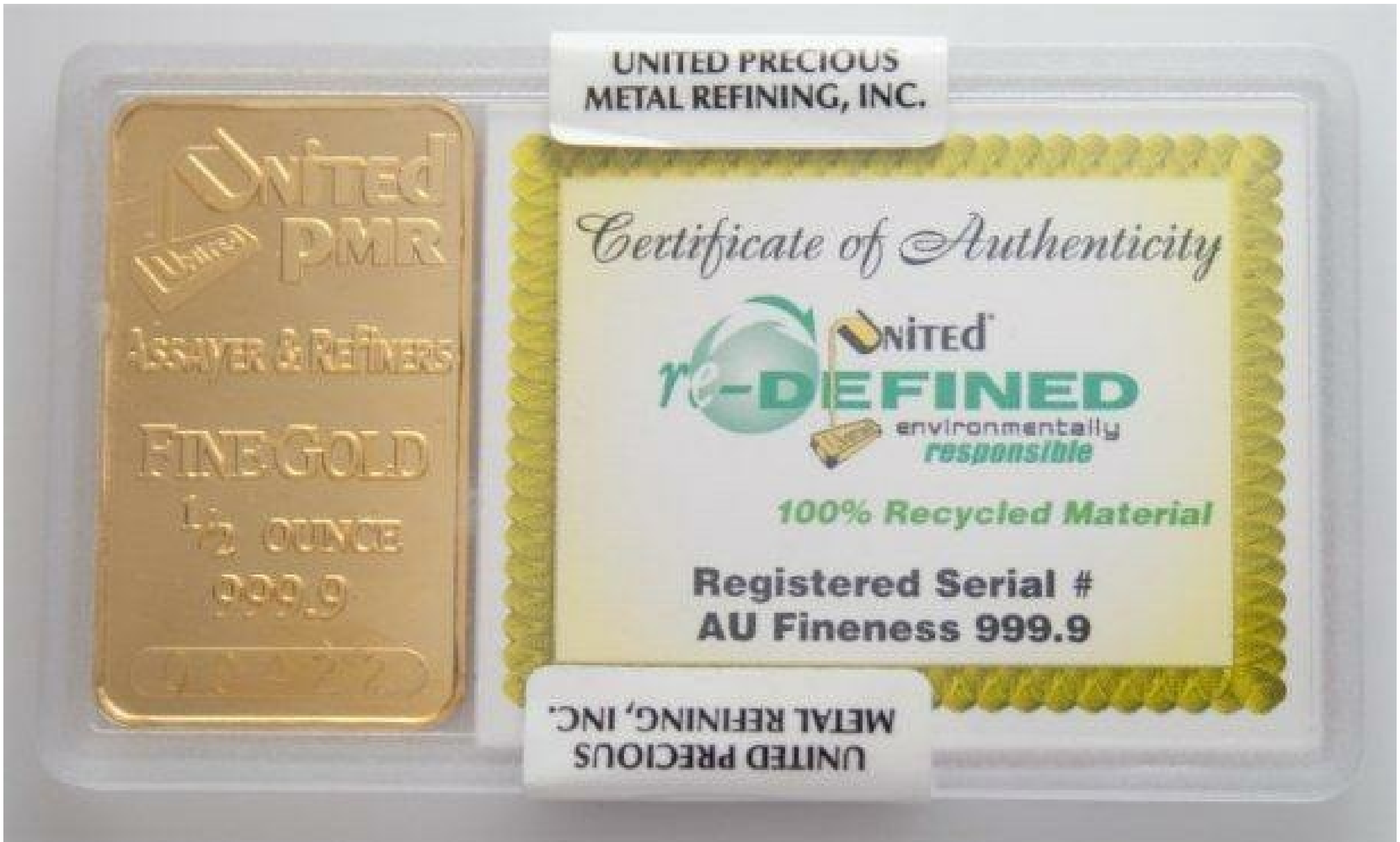
Categories: Precious metals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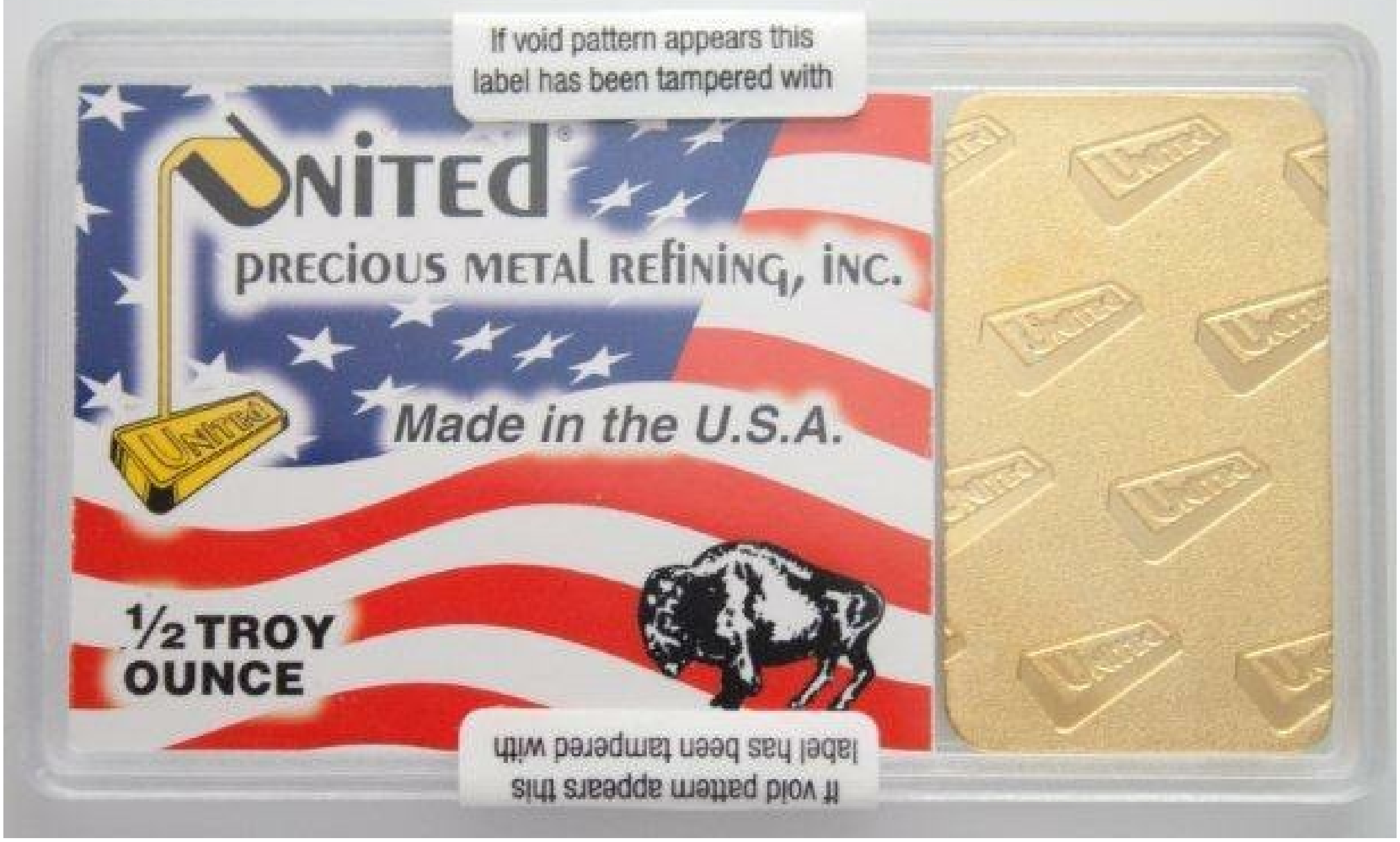
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United Precious Metal Refining, Inc. takes recycling, environmental concerns and natural resource sustainability very seriously.

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Both our facility and our fine gold and fine silver products have been certified by SCS for 100% recycled content. Earning this recognition gives us the pride to confidently tell our customers that our products and practices conform to the highest standards established by SCS and that each day we are helping to preserve both our environment and natural resources.

Environmentally Correct, Eco-Responsible, Precious Metals
Since 1988, United has provided support of environmental and social impact concerns of precious metal mining by supplying refined (re-DEFINED™) precious metals (gold and silver), sourced from industries other than mining, to the jewelry markets worldwide.

Unlike mining, where approximately 20 tons of waste is generated to

Precious Metal Spot Prices

	Bid	Change
Gold	$1,330.81	-$16.46/ -1.22%
Silver	$16.44	-$0.19/ -1.14%
Platinum	$998.00	-$7.00/ -0.69%
Palladium	$1,028.00	-$1.00/ -0.10%

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produce just one ounce of gold, refining precious metals and scrap that is sourced from other industries has virtually no waste. Think of it; for every gold ring, about 10 tons of mining waste may impact the environment and people somewhere.

As a full service refiner, providing both refining and manufacturing, United can assure our customers that when requested, their products are manufactured with 100% re-DEFINED™ Gold and Silver. If requested, United will provide a source certification document stating the materials origin. The end result of United's internal refining procedures has continually met all local, state and federal environmental regulations.

United Precious Metal Refining Inc. exclusively supplies the large jewelry manufacturer and the small bench jewelers with re-DEFINED™ casting grains and alloys.

For your next creation of "eco-friendly" jewelry, make sure you request re-DEFINED™ precious metals, available only from United Precious Metal Refining Inc.

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- Human Rights Statement
- Environmental Commitment
- Dodd-Frank Act

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Solder

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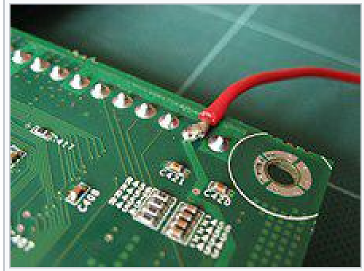
This article is about the material. For the process, see Soldering.



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

Solder (/ˈsoʊldər/,[1] /ˈsɒldər/[1] or in North America /ˈsɒdər/[2]) is a fusible metal alloy used to create a permanent bond between metal workpieces. The word solder comes from the Middle English word *soudur*, via Old French *solduree* and *soulder*, from the Latin *solidare*, meaning "to make solid".[3] In fact, solder must first be melted in order to adhere to and connect the pieces together after cooling, which requires that an alloy suitable for use as solder have a lower melting point than the pieces being joined. The solder should also be resistant to oxidative and corrosive effects that would degrade the joint over time. Solder used in making electrical connections also needs to have favorable electrical characteristics.

Soft solder typically has a melting point range of 90 to 450 °C (190 to 840 °F; 360 to 720 K),[4] and is commonly used in electronics, plumbing, and sheet metal work. Alloys that melt between 180 and 190 °C (360 and 370 °F; 450 and 460 K) are the most commonly used. Soldering performed using alloys with a melting point above 450 °C (840 °F; 720 K) is called "hard soldering", "silver soldering", or brazing.

Spool of solder, 1.6 mm diameter

In specific proportions, some alloys can become eutectic — that is, the alloy's melting point is lower than that of either component. Non-eutectic alloys have markedly different *solidus* and *liquidus* temperatures, and within that range they exist as a paste of solid particles in a melt of the lower-melting phase. In electrical work, if the joint is disturbed in the pasty state before it has solidified totally, a poor electrical connection may result; use of eutectic solder reduces this problem. The pasty state of a non-eutectic solder can be exploited in plumbing, as it allows molding of the solder during cooling, e.g. for ensuring watertight joint of pipes, resulting in a so-called "wiped joint".

For electrical and electronics work, solder wire is available in a range of thicknesses for hand-soldering (manual soldering is performed using a soldering iron or soldering gun), and with cores containing flux. It is also available as a paste, as a preformed foil shaped to match the workpiece, more suitable for mechanized mass-production, or in small "tabs" that can be wrapped around the joint and melted with a flame, for field repairs where an iron isn't usable or available. Alloys of lead and tin were commonly used in the past and are still available; they are particularly convenient for hand-soldering. Lead-free solders have been increasing in use due to regulatory requirements plus the health and environmental benefits of avoiding lead-based electronic components. They are almost exclusively used today in consumer electronics.[5]

Plumbers often use bars of solder, much thicker than the wire used for electrical applications. Jewelers often use solder in thin sheets, which they cut into snippets.

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Lead-free solder [edit]


Pure tin solder wire

The European Union Waste Electrical and Electronic Equipment Directive (WEEE) and Restriction of Hazardous Substances Directive (RoHS) were adopted in early 2003 and came into effect on July 1, 2006, restricting the inclusion of lead in most consumer electronics sold in the EU, and having a broad effect on consumer electronics sold worldwide. In the US, manufacturers 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 60/40 and 63/37 Sn-Pb solder have melting points from 50 to 200 °C higher,[6] though there are also solders with much lower melting points.


Soldering copper pipes using a propane torch and lead-free solder

It may be desirable to use minor modification of the solder pots (e.g., titanium liners or impellers) used in wave-soldering, to reduce maintenance cost due to increased tin-scavenging of high-tin solder.

Lead-free solder may be less desirable for critical applications, such as aerospace and medical projects, because its properties are less thoroughly known.

Tin-silver-copper (Sn-Ag-Cu, or "SAC") solders are used by two-thirds of Japanese manufacturers for reflow and wave soldering, and by about 75% of companies for hand soldering. The widespread use of this popular lead-free solder alloy family is based on the reduced melting point of the Sn-Ag-Cu ternary eutectic behavior (217 °C), which is below the 22/78 Sn-Ag (wt.%) eutectic of 221 °C and the 59/41 Sn-Cu eutectic of 227 °C.[7] The ternary eutectic behavior 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.

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., 18/64/14/4 tin-silver-copper-zinc (Sn-Ag-Cu-Zn) (melting range 217–220 °C) and 18/64/16/2 tin-silver-copper-manganese (Sn-Ag-Cu-Mn) (melting range of 211–215 °C).

Tin-based solders readily dissolve gold, forming brittle intermetallics; for Sn-Pb alloys the critical concentration of gold to embrittle the joint is about 4%. Indium-rich solders (usually indium-lead) are more suitable for soldering thicker gold layer as the dissolution rate of gold in indium is much slower. Tin-rich solders also readily dissolve silver; for soldering silver metallization or surfaces, alloys with addition of silvers are suitable; tin-free alloys are also a choice, though their wettability is poorer. If the soldering time is long enough to form the intermetallics, the tin surface of a joint soldered to gold is very dull.[8]

Lead solder [edit]

$Sn_{60}Pb_{40}$ solder

Tin-lead (Sn-Pb) 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. Historically, lead has been widely believed to mitigate the formation of tin whiskers,[9] though the precise mechanism for this is unknown.[10] Today, many techniques are used to mitigate the problem, including changes to the annealing process (heating and cooling), addition of elements like copper and nickel, and the inclusion of conformal coatings.[11] Alloys commonly used for electrical soldering are 60/40 Sn-Pb, which melts at 188 °C (370 °F),[12] and 63/37 Sn-Pb used principally in electrical/electronic work. This mixture is a eutectic alloy of these metals, which:

1. has the lowest melting point (183 °C or 361 °F) of all the tin-lead alloys; and
2. the melting point is truly a *point* — not a range.

In the United States, lead is prohibited in solder and flux in plumbing applications for drinking water use, per the Safe Drinking Water Act (SDWA).[13] Historically, a higher proportion of lead was used, commonly 50/50. This had the advantage of making the alloy solidify more slowly. With the pipes being physically fitted together before soldering, the solder could be wiped over the joint to ensure water tightness. 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. Tin, however, is protected by insoluble oxide. Since even small amounts of lead have been found detrimental to health,[14] 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.)

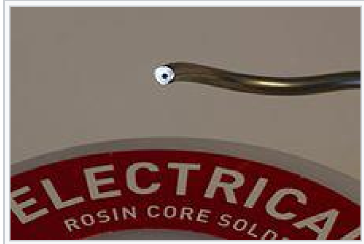
The addition of tin—more expensive than lead—improves wetting properties of the alloy; lead itself has poor wetting characteristics. High-tin tin-lead alloys have limited use as the workability range can be provided by a cheaper high-lead alloy.[15]

Lead-tin solders readily dissolve gold plating and form brittle intermetallics.[8] 60/40 Sn-Pb solder oxidizes on the surface, forming a complex 4-layer structure: tin(IV) oxide on the surface, below it a layer of tin(II) oxide with finely dispersed lead, followed by a layer of tin(II) oxide with finely dispersed tin and lead, and the solder alloy itself underneath.[16]

Lead, and to some degree tin, as used in solder contains small but significant amounts of radioisotope impurities. Radioisotopes undergoing alpha decay are a concern due to their tendency to cause soft errors. Polonium-210 is especially problematic; lead-210 beta decays to bismuth-210 which then beta decays to polonium-210, an intense emitter of alpha particles. Uranium-238 and thorium-232 are other significant contaminants of alloys of lead.[17][18]

Flux [edit]

Main article: Flux (metallurgy)



Electrical solder with an integrated resin core, visible as a dark spot in the cut end of the solder wire.

Flux is a reducing agent designed to help reduce (return oxidized metals to their metallic state) metal oxides at the points of contact to improve the electrical connection and mechanical strength. The two principal types of flux are acid flux (sometimes called "active flux"), containing strong acids, used for metal mending and plumbing, and rosin flux (sometimes called "passive flux"), used in electronics. Rosin flux comes in a variety of "activities", corresponding roughly to the speed and effectiveness of the organic acid components of the rosin in dissolving metallic surface oxides, and consequently the corrosiveness of the flux residue.

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 deionized 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, much 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 inorganic acid or rosin flux embedded lengthwise inside it. As the solder melts onto the joint, it frees the flux and releases that on it as well.

Hard solder [edit]

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 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 "enameling", "hard", "medium" and "easy". Enameling solder has a high melting point, close to that of the material itself, to prevent the joint desoldering during firing in the enameling 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 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.

Solidifying [edit]

The solidifying behavior depends on the alloy composition. Pure metals solidify at a certain temperature, forming crystals of one phase. Eutectic alloys also solidify at a single temperature, all components precipitating simultaneously in so-called coupled growth. Non-eutectic compositions on cooling start to first precipitate the non-eutectic phase; dendrites when it is a metal, large crystals when it is an intermetallic compound. Such a mixture of solid particles in a molten eutectic is referred to as a **mushy** state. Even a relatively small proportion of solids in the liquid can dramatically lower its fluidity.[19]

The temperature of total solidification is the solidus of the alloy, the temperature at which all components are molten is the liquidus.

The mushy state is desired where a degree of plasticity is beneficial for creating the joint, allowing filling larger gaps or being wiped over the joint (e.g. when soldering pipes). In hand soldering of electronics it may be detrimental as the joint may appear solidified while it is not yet. Premature handling of such joint then disrupts its internal structure and leads to compromised mechanical integrity.

Alloys [edit]

Main article: Solder alloys

Alloying element roles [edit]

Different elements serve different roles in the solder alloy:

- Antimony is added to increase strength without affecting wettability. Prevents tin pest. Should be avoided on zinc, cadmium, or galvanized metals as the resulting joint is brittle.[20]
- 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. Such joints are also prone to cracking. Alloys with more than 47% Bi expand upon cooling, which may be used to offset thermal expansion mismatch stresses. Retards growth of tin whiskers. Relatively expensive, limited availability.
- Copper 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. Copper in solders forms intermetallic compounds. Supersaturated (by about 1%) solution of copper in tin may be employed to inhibit dissolution of thin-film under-bump metallization of BGA chips, e.g. as $Sn_{94}Ag_3Cu_3$.[7][21]
- Nickel can be added to the solder alloy to form a supersaturated solution to inhibit dissolution of thin-film under-bump metallization.[21] In tin-copper alloys, small addition of Ni (<0.5 wt%) inhibits the formation of voids and interdiffusion of Cu and Sn elements.[7] Inhibits copper dissolution, even more in synergy with bismuth. Nickel presence stabilizes the copper-tin intermetallics, inhibits growth of pro-eutectic β-tin dendrites (and therefore increases fluidity near the melting point of copper-tin eutectic), promotes shiny bright surface after solidification, inhibits surface cracking at cooling; such alloys are called "nickel-modified" or "nickel-stabilized". Small amounts increase melt fluidity, most at 0.06%.[22] Suboptimal amounts may be used to avoid patent issues. Fluidity reduction increase hole filling and mitigates bridging and icicles.
- Cobalt is used instead of nickel to avoid patent issues in improving fluidity. Does not stabilize intermetallic growths in solid alloy.
- Indium lowers the melting point and improves ductility. In presence of lead it forms a ternary compound that undergoes phase change at 114 °C. Very high cost (several times of silver), low availability. Easily oxidizes, which causes problems for repairs and reworks, especially when oxide-removing flux cannot be used, e.g. during GaAs die attachment. Indium alloys are used for cryogenic applications, and for soldering gold as gold dissolves in indium much less than in tin. Indium can also solder many nonmetals (e.g. glass, mica, alumina, magnesia, titania, zirconia, porcelain, brick, concrete, and marble). Prone to diffusion into semiconductors and cause undesired doping. At elevated temperatures easily diffuses through metals. Low vapor pressure, suitable for use in vacuum systems. Forms brittle intermetallics with gold; indium-rich solders on thick gold are unreliable. Indium-based solders are prone to corrosion, especially in presence of chloride ions.[23]
- Lead is inexpensive and has suitable properties. Worse wetting than tin. Toxic, being phased out. Retards growth of tin whiskers, inhibits tin pest. Lowers solubility of copper and other metals in tin.
- Silver provides mechanical strength, but has worse ductility than lead. In absence of lead, it improves resistance to fatigue from thermal cycles. Using SnAg solders with HASL-SnPb-coated leads forms $SnPb_{36}Ag_2$ phase with melting point at 179 °C, which moves to the board-solder interface, solidifies last, and separates from the board.[6] Addition of silver to tin significantly lowers solubility of silver coatings in the tin phase. In eutectic tin-silver (3.5% Ag) alloy and similar alloys (e.g. SAC305) it tends to form platelets of Ag_3Sn, which, if formed near a high-stress spot, may serve as initiating sites for cracks and cause poor shock and drop performance; silver content needs to be kept below 3% to inhibit such problems.[21] High ion mobility, tends to migrate and form short circuits at high humidity under DC bias. Promotes corrosion of solder pots,

increases dross formation.

- Tin is the usual main structural metal of the alloy. It has good strength and wetting. On its own it is prone to tin pest, tin cry, and growth of tin whiskers. Readily dissolves silver, gold and to less but still significant extent many other metals, e.g. copper; this is a particular concern for tin-rich alloys with higher melting points and reflow temperatures.
- 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. Can form brittle Cu-Zn intermetallic layers in contact with copper. Readily oxidizes which impairs wetting, requires a suitable flux.
- Germanium in tin-based lead-free solders influences formation of oxides; at below 0.002% it increases formation of oxides. Optimal concentration for suppressing oxidation is at 0.005%.[24] Used in e.g. Sn100C alloy. Patented.
- Rare-earth elements, when added in small amounts, refine the matrix structure in tin-copper alloys by segregating impurities at the grain boundaries. However, excessive addition results in the formation of tin whiskers; it also results in suprious rare earth phases, which easily oxidize and deteriorate the solder properties.[7]
- Phosphorus is used as antioxidant to inhibit dross formation. Decreases fluidity of tin-copper alloys.

Impurities in solders [edit]

Impurities usually enter the solder reservoir by dissolving the metals present in the assemblies being soldered. Dissolving of process equipment is not common as the materials are usually chosen to be insoluble in solder.[25]

- Aluminium – little solubility, causes sluggishness of solder and dull gritty appearance due to formation of oxides. Addition of antimony to solders forms Al-Sb intermetallics that are segregated into dross. Promotes embrittlement.
- Antimony – added intentionally, up to 0.3% improves wetting, larger amounts slowly degrade wetting. Increases melting point.
- Arsenic – forms thin intermetallics with adverse effects on mechanical properties, causes dewetting of brass surfaces
- Cadmium – causes sluggishness of solder, forms oxides and tarnishes
- Copper – most common contaminant, forms needle-shaped intermetallics, causes sluggishness of solders, grittiness of alloys, decreased wetting
- Gold – easily dissolves, forms brittle intermetallics, contamination above 0.5% causes sluggishness and decreases wetting. Lowers melting point of tin-based solders. Higher-tin alloys can absorb more gold without embrittlement.[26]
- Iron – forms intermetallics, causes grittiness, but rate of dissolution is very low; readily dissolves in lead-tin above 427 °C.[8]
- Lead – causes RoHS compliance problems at above 0.1%.
- Nickel – causes grittiness, very little solubility in Sn-Pb
- Phosphorus – forms tin and lead phosphides, causes grittiness and dewetting, present in electroless nickel plating
- Silver – often added intentionally, in high amounts forms intermetallics that cause grittiness and formation of pimples on the solder surface, potential for embrittlement
- Sulfur – forms lead and tin sulfides, causes dewetting
- Zinc – in melt forms excessive dross, in solidified joints rapidly oxidizes on the surface; zinc oxide is insoluble in fluxes, impairing repairability; copper and nickel barrier layers may be needed when soldering brass to prevent zinc migration to the surface; potential for embrittlement

Board finishes vs wave soldering bath impurities buildup [edit]

- **HASL, lead-free** (Hot Air Level) – usually virtually pure tin. Does not contaminate high-tin baths.
- **HASL, leaded** – some lead dissolves into the bath
- **ENIG** (Electroless Nickel Immersion Gold) - typically 100-200 microinches of nickel with 3-5 microinches of gold on top. Some gold dissolves into the bath, but limits exceeding buildup is rare.
- **Immersion silver** – typically 10–15 microinches of silver. Some dissolves into the bath, limits exceeding buildup is rare.
- **Immersion tin** – does not contaminate high-tin baths.
- **OSP** (Organic solderability preservative) – usually imidazole-class compounds forming a thin layer on the copper surface. Copper readily dissolves in high-tin baths.[27]

Intermetallics in solders [edit]

Many different intermetallic compounds are formed during solidifying of solders and during their reactions with the soldered surfaces.[25]

The intermetallics form distinct phases, usually as inclusions in a ductile solid solution matrix, but also can form the matrix itself with metal inclusions or form crystalline matter with different intermetallics. Intermetallics are often hard and brittle. Finely distributed intermetallics in a ductile matrix yield a hard alloy while coarse structure gives a softer alloy. A range of intermetallics often forms between the metal and the solder, with increasing proportion of the metal; e.g. forming a structure of Cu-Cu_3Sn-Cu_6Sn_5-Sn.

Layers of intermetallics can form between the solder and the soldered material. These layers may cause mechanical reliability weakening and brittleness, increased electrical resistance, or electromigration and formation of voids. The gold-tin intermetallics layer is responsible for poor mechanical reliability of tin-soldered gold-plated surfaces where the gold plating did not completely dissolve in the solder.

Gold and palladium readily dissolve in solders. Copper and nickel tend to form intermetallic layers during normal soldering profiles. Indium forms intermetallics as well.

Indium-gold intermetallics are brittle and occupy about 4 times more volume than the original gold. Bonding wires are especially susceptible to indium attack. Such intermetallic growth, together with thermal cycling, can lead to failure of the bonding wires.[28]

Copper plated with nickel and gold is often used. The thin gold layer facilitates good solderability of nickel as it protects the nickel from oxidation; the layer has to be thin enough to rapidly and completely dissolve so bare nickel is exposed to the solder.[18]

Lead-tin solder layers on copper leads can form copper-tin intermetallic layers; the solder alloy is then locally depleted of tin and form a lead-rich layer. The Sn-Cu intermetallics then can get exposed to oxidation, resulting in impaired solderability.[29]

Two processes play a role in a solder joint formation: interaction between the substrate and molten solder, and solid-state growth of intermetallic compounds. The base metal dissolves in the molten solder in an amount depending on its solubility in the solder. The active constituent of the solder reacts with the base metal with a rate dependent on the solubility of the active constituents in the base metal. The solid-state reactions are more complex – the formation of intermetallics can be inhibited by changing the composition of the base metal or the solder alloy, or by using a suitable barrier layer to inhibit diffusion of the metals.[30]

	Tin	Lead	Indium
Copper	Cu_4Sn, $\mathbf{Cu_6Sn_5}$, $\mathbf{Cu_3Sn}$, Cu_3Sn_8[7]		Cu_3In, Cu_9In_4
Nickel	Ni_3Sn, Ni_3Sn_2, $\mathbf{Ni_3Sn_4}$ $NiSn_3$		Ni_3In, NiIn Ni_2In_3, Ni_3In_7
Iron	FeSn, $FeSn_2$		
Indium	In_3Sn, $InSn_4$	In_3Pb	–
Antimony	SbSn		
Bismuth		$BiPb_3$	
Silver	Ag_6Sn, Ag_3Sn		Ag_3In, $AgIn_2$
Gold	$\mathbf{Au_5Sn}$, **AuSn** $AuSn_2$, $\mathbf{AuSn_4}$	Au_2Pb, $AuPb_2$	AuIn, $AuIn_2$
Palladium	Pd_3Sn, Pd_2Sn, Pd_3Sn_2, PdSn, $PdSn_2$, $PdSn_4$		Pd_3In, Pd_2In, PdIn Pd_2In_3
Platinum	Pt_3Sn, Pt_2Sn, PtSn, Pt_2Sn_3, $PtSn_2$, $PtSn_4$	Pt_3Pb, PtPb $PtPb_4$	Pt_2In_3, $PtIn_2$, Pt_3In_7

- Cu_6Sn_5 – common on solder-copper interface, forms preferentially when excess of tin is available; in presence of nickel, $(Cu,Ni)_6Sn_5$ compound can be formed[7][9]
- Cu_3Sn – common on solder-copper interface, forms preferentially when excess of copper is available, more thermally stable than Cu_6Sn_5, often present when higher-temperature soldering occurred[7][9]
- Ni_3Sn_4 – common on solder-nickel interface[7][9]
- $FeSn_2$ – very slow formation
- Ag_3Sn - at higher concentration of silver (over 3%) in tin forms platelets that can serve as crack initiation sites.
- $AuSn_4$ – β-phase – brittle, forms at excess of tin. Detrimental to properties of tin-based solders to gold-plated layers.
- $AuIn_2$ – forms on the boundary between gold and indium-lead solder, acts as a barrier against further dissolution of gold

Glass solder [edit]

Glass solders are used to join glasses to other glasses, ceramics, metals, semiconductors, mica, and other materials, in a process called glass frit bonding. The glass solder has to flow and wet the soldered surfaces well below the temperature where deformation or degradation of either of the joined materials or nearby structures (e.g., metallization layers on chips or ceramic substrates) occurs. The usual temperature of achieving flowing and wetting is between 450 and 550 °C (840 and 1,020 °F).

Two types of glass solders are used: vitreous, and devitrifying. Vitreous solders retain their amorphous structure during remelting, can be reworked repeatedly, and are relatively transparent. Devitrifying solders undergo partial crystallization during solidifying, forming a glass-ceramic, a composite of glassy and crystalline phases. Devitrifying solders usually create a stronger mechanical bond, but are more temperature-sensitive and the seal is more likely to be leaky; due to their polycrystalline structure they tend to be translucent or opaque.[31] Devitrifying solders are frequently "thermosetting", as their melting temperature after recrystallization becomes significantly higher; this allows soldering the parts together at lower temperature than the subsequent bake-out without remelting the joint afterwards. Devitrifying solders frequently contain up to 25% zinc oxide. In production of cathode ray tubes, devitrifying solders based on $PbO-B_2O_3-ZnO$ are used.

Very low temperature melting glasses, fluid at 200–400 °C (390–750 °F), were developed for sealing applications for electronics. They can consist of binary or ternary mixtures of thallium, arsenic and sulfur.[32] Zinc-silicoborate glasses can also be used for passivation of electronics; their coefficient of thermal expansion must match silicon (or the other semiconductors used) and they must not contain alkaline metals as those would migrate to the semiconductor and cause failures.[33]

The bonding between the glass or ceramics and the glass solder can be either covalent, or, more often, van der Waals.[34] The seal can be leak-tight; glass soldering is frequently used in vacuum technology. Glass solders can be also used as sealants; a vitreous enamel coating on iron lowered its permeability to hydrogen 10 times.[35] Glass solders are frequently used for glass-to-metal seals and glass-ceramic-to-metal seals.

Glass solders are available as frit powder with grain size below 60 micrometers. They can be mixed with water or alcohol to form a paste for easy application, or with dissolved nitrocellulose or other suitable binder for adhering to the surfaces until being melted.[36] The eventual binder has to be burned off before melting proceeds, requiring careful firing regime. The solder glass can be also applied from molten state to the area of the future joint during manufacture of the part. Due to their low viscosity in molten state, lead glasses with high PbO content (often 70–85%) are frequently used. The most common compositions are based on lead borates (leaded borate glass or borosilicate glass). Smaller amount of zinc oxide or aluminium oxide can be added for increasing chemical stability. Phosphate glasses can be also employed. Zinc oxide, bismuth trioxide, and copper(II) oxide can be added for influencing the thermal expansion; unlike the alkali oxides, these lower the softening point without increasing of thermal expansion.

Glass solders are frequently used in electronic packaging. CERDIP packagings are an example. Outgassing of water from the glass solder during encapsulation was a cause of high failure rates of early CERDIP integrated circuits. Removal of glass-soldered ceramic covers, e.g., for gaining access to the chip for failure analysis or reverse engineering, is best done by shearing; if this is too risky, the cover is polished away instead.[37]

As the seals can be performed at much lower temperature than with direct joining of glass parts and without use of flame (using a temperature-controlled kiln or oven), glass solders are useful in applications like subminiature vacuum tubes or for joining mica windows to vacuum tubes and instruments (e.g., Geiger tube). Thermal expansion coefficient has to be matched to the materials being joined and often is chosen in between the coefficients of expansion of the materials. In case of having to compromise, subjecting the joint to compression stresses is more desirable than to tensile stresses. The expansion matching is not critical in applications where thin layers are used on small areas, e.g., fireable inks, or where the joint will be subjected to a permanent compression (e.g., by an external steel shell) offsetting the thermally introduced tensile stresses.[32]

Glass solder can be used as an intermediate layer when joining materials (glasses, ceramics) with significantly different coefficient of thermal expansion; such materials cannot be directly joined by diffusion welding.[38] Evacuated glazing windows are made of glass panels soldered together.[39]

A glass solder is used, e.g., for joining together parts of cathode ray tubes and plasma display panels. Newer compositions lowered the usage temperature from 450 to 390 °C (840 to 730 °F) by reducing the lead(II) oxide content down from 70%, increasing the zinc oxide content, adding titanium dioxide and bismuth(III) oxide and some other components. The high thermal expansion of such glass can be reduced by a suitable ceramic filler. Lead-free solder glasses with soldering temperature of 450 °C (842 °F) were also developed.

Phosphate glasses with low melting temperature were developed. One of such compositions is phosphorus pentoxide, lead(II) oxide, and zinc oxide, with addition of lithium and some other oxides.[40]

Conductive glass solders can be also prepared.

Preform [edit]

A preform is a pre-made shape of solder specially designed for the application where it is to be used. Many methods are used to manufacture the solder preform, stamping being the most common. The solder preform may include the solder flux needed for the soldering process. This can be an internal flux, inside the solder preform, or external, with the solder preform coated.

See also [edit]

- Body solder
- RoHS
- Solderability
- Solder mask
- Solder fatigue

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- "Solder". *Encyclopædia Britannica*. **25** (11th ed.). 1911. p. 374.
- Phase diagrams of different types of solder alloys

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