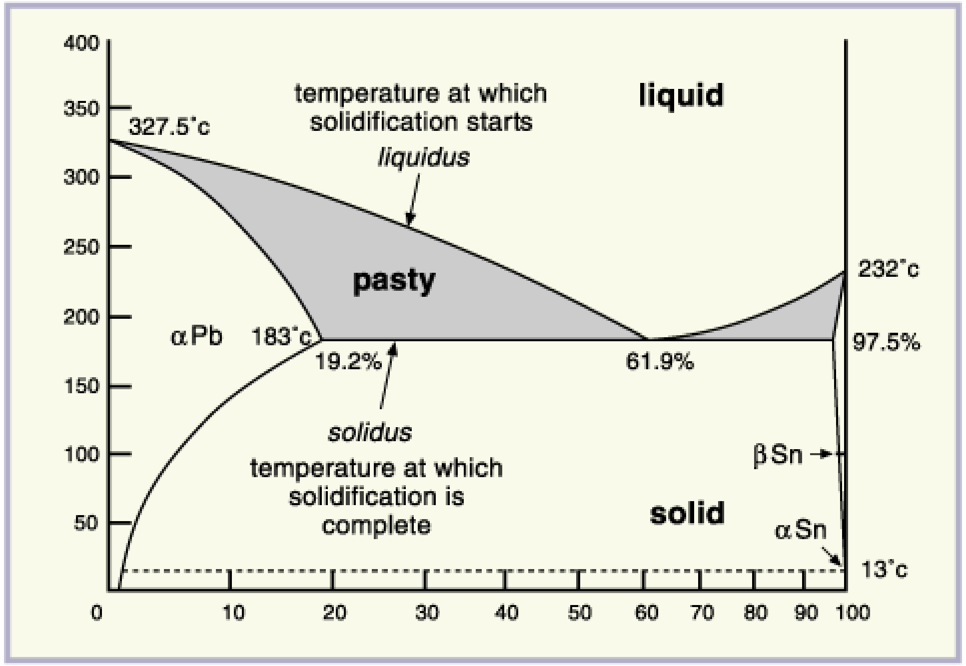
Periodic Table: Tin
At Chemical Elements.com

- ***Basic Information for Sn***
- Name: Tin
- Symbol: Sn
- Atomic Number: 50
- Atomic Mass: 118.71 amu
- Melting Point: 231.9 **°C** (505.05 K)
- Boiling Point: 2270.0 **°C** (2543.15 K)
- Number of Protons/Electrons: 50
- Number of Neutrons: 69
- Classification: Other Metals
- Crystal Structure: Tetragonal
- Density @ 293 K: 7.31 g/cm3
- Color: white

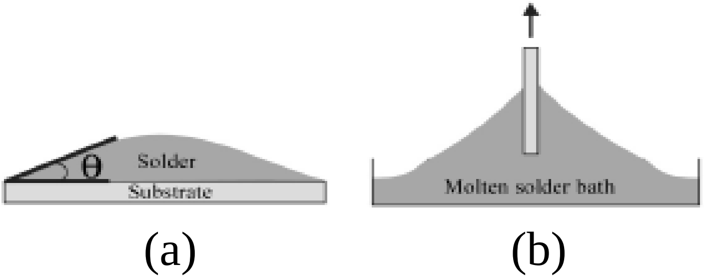
Periodic Table: Lead
At Chemical Elements.com

- ***Basic Information for Pb***
- Name: Lead
- Symbol: Pb
- Atomic Number: 82
- Atomic Mass: 207.2 amu
- Melting Point: 327.5 **°C** (600.65 K)
- Boiling Point: 1740.0 **°C** (2013.15 K)
- Number of Protons/Electrons: 82
- Number of Neutrons: 125
- Classification: Other Metals
- Crystal Structure: FCC
- Density @ 293 K: 11.34 g/cm3
- Color: bluish

Pb-Sn Phase Diagram



http://www.ami.ac.uk/courses/topics/0128_sm/index.html



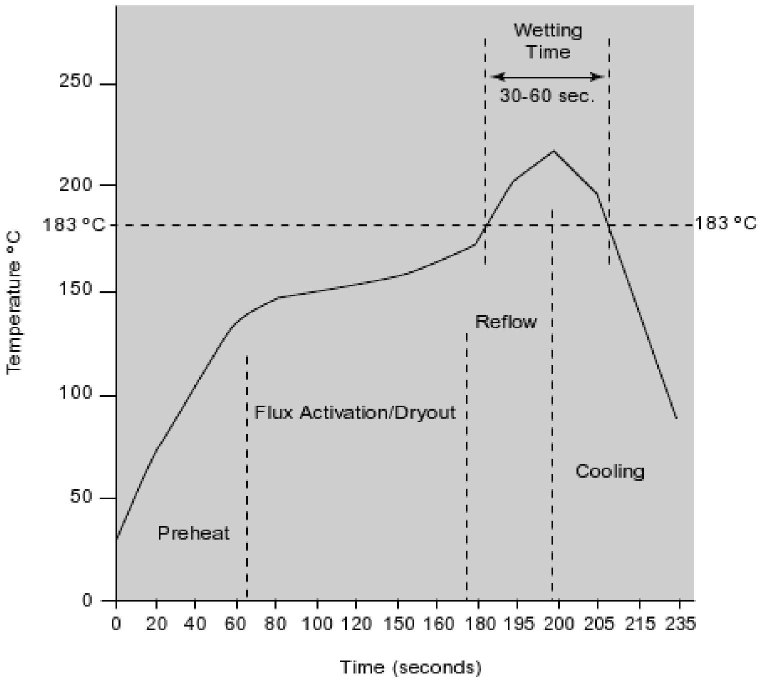
A schematic drawing for measuring the wettability of solder (a) to measure wetting angle and (b) to ensure wetting force.

www.dklmetals.co.uk/Factorfiction.pdf

Alternative basis metals to lead and their alloys

Element	Melting point (°C)	Toxic[a]	Typical composition	Melting point (°C)	Remarks	Suitable
Sn	232	No				
Pb	327	Highly	62Sn/36Pb/2Ag 63Sn/37Pb	179 183	Well-established alloys; low price	Yes
Ag	960	No	96.5Sn/3.5Ag	221	Good thermal fatigue; fast Cu dissolution	Yes
Cu	1,083	No	95.5Sn/4Ag/0.5Cu 95.5Sn/3.8Ag/0.7Cu 95Sn/4Ag/1Cu 99.3Sn/0.7Cu	216-219 217-219 216-219 227	Preliminary tests show good thermal fatigue properties at high temperatures; favourably priced	Yes
Bi	271	No	58Bi/42Sn 90Sn/2Ag//7.5Bi/0.5 91.8 Sn/3.4Ag/4.8B	138 198-212 200-216	Suitable for low temperature applications Creation of low melt. Sn/Bi phase at 138°C Fatigue at high temperature under evaluation	Yes
Sb	630	Very	95SN/5Sb 65SN/25Ag/10Sb 96.7Sn/2Ag/0.8Cu/0.5	232-240 230-235 217-220	High melting point; toxicity concern Creation of needle-shaped Ag_3Sn phases Similar properties as Sn/Ag/Cu	Yes
In	157	Very	52In/48Sn 97In/3Ag 77.2 Sn/20In/2.8Ag 86.4Sn/11In/2Ag/0.6	118 143 189	Expensive; limited availability; indium tends to corrode in combination with humidity and is very soft Creation of low-melt. In/Sn phase at 118°C	No
Zn	419	No	91Sn/9Zn	199	Problem of oxidation. Strong dross formation	No
Au	1,063	No	80Au/20Sn	280	Much too expensive	No
Cd	320	Extremely	67Sn/33Cd	170	Toxicity	No

A Zoran Miric and A Grusd: Soldering & Surface Mount Technology 10/1 [1998] 19–25



A typical reflow profile for Sn63Pb37 solder.

The reflow profile is a critical part of the solder process and must provide adequate time for flux volatilization, proper peak temperatures, and time above liquidus. A typical reflow profile is made up of four distinct zones.

1) Preheat Zone : The heating rate in the preheat zone should be 2 °C to 4 °C/second and the peak temperature in this zone should be 100-125 °C.

2) Soak Zone: The soak zone is intended to bring the temperature of the entire board up to a uniform temperature to minimizing temperature gradients. The soak zone also acts as the flux activation zone for solder paste. Soak times are usually around the range of 130 -170 °C for 60 to 90 seconds.

3) Reflow Zone : In this zone the temperature is kept above the melting point of the solder for about 30 to 60 seconds. The peak temperature in this zone should be high enough for adequate flux action and to obtain good wetting. A peak temperature range of 215 - 220 °C is generally considered acceptable.

4) Cooling Zone : The cooling rate of the solder joint after reflow is also important. The faster the cooling rate, the smaller the grain size of the solder, and hence the higher the fatigue resistance of the solder joint. Unfortunately, cooling too fast will result in residual stresses between TCE (Thermal Coefficient of Expansion) mismatched components. So the cooling rate needs to be optimized.

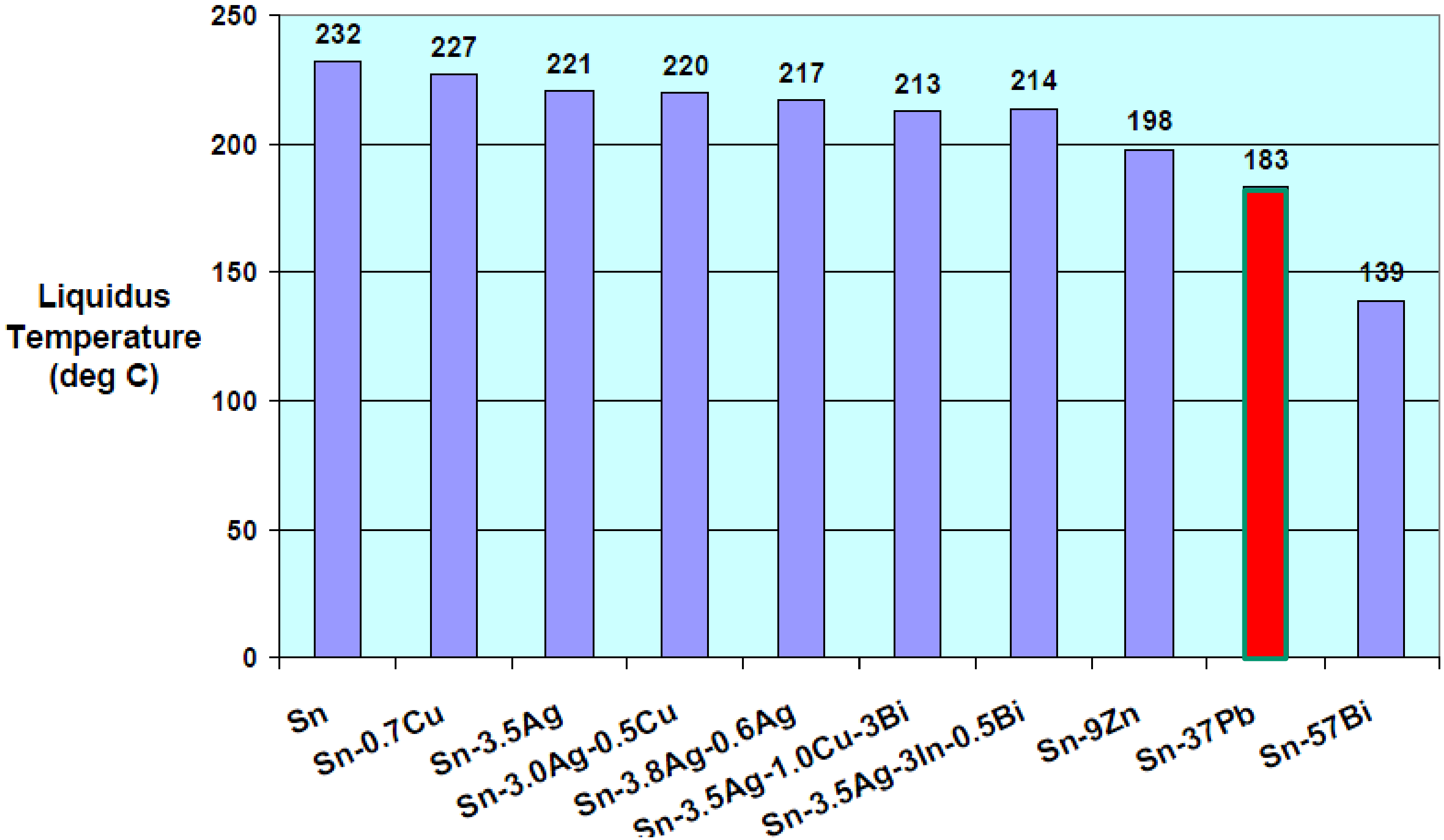
*www.anadigics.com/content/download/.../**Solder**ReflowReport.pdf*

How candidate lead-free alloys could be modified to improve their performance as solders; it is necessary to look more closely at how they differ from tin-lead solder

- A significant difference between these lead-free solders and tin-lead in that the other phases in their eutectics are intermetallic compounds rather than simple metallic solid solutions. Although the tin-rich and lead rich phases in the tin-lead eutectic are crystalline they do not grow in a form that is recognisable as crystalline.

- The intermetallic compounds in the Sn-Cu and Sn-Ag-Cu systems, Cu_6Sn_5 and Ag_3Sn grow in a faceted manner to form structures that are distinctly crystalline in appearance, needles in the former case and plates in the latter. Probably because that faceted growth is difficult to nucleate the coupled growth that is characteristic of a eutectic does not normally occur

Liquidus temperature of some lead-free solders compared with that of Sn63Pb37



www.dklmetals.co.uk/Factorfiction.pdf

It is important that the melting point of lead-free solder be as close as possible to that of the tin-lead solder it replaces. There were ***no element in the Periodic Table*** *that would reduce the melting of tin as low as did lead, i.e. from 232 ℃ to 183 ℃.*

- Bismuth at the level of 57% could lower the melting point even further to 139°C but the resulting alloy is difficult to use.
- Zinc at the level of 9% lowers the melting point to 198°C
- Copper reduces the melting point only a few degrees to 227°C, still 44°C higher than that of tin-lead solder.
- The addition of silver to tin-copper reduces the melting point a further 10°C to 217°C . Tin-silver-copper alloy have been widely accepted as the preferred lead-free option.
- Those concerned that 217°C was still too high for a practical tin-lead replacement made further additions of elements such as bismuth and indium but these increased the cost and/or compromised other properties or the recyclability, which was one of the main reasons for elimination of lead.
- ***Practical experience has indicated however, that a melting point close to that of tin-lead was not as important as first thought***.

www.dklmetals.co.uk/Factorfiction.pdf

Sn & Sn-Alloy

- Sn coated plate
- 저융점 연질이므로 얇은 박으로 사용 – 무독성, 의약품 식품 등의 tube
- 상온가공경화가 없어 소성가공이 쉽다.(재결정온도 상온이하)
- 지금순도 99.8%

1)물리적 성질

- Sn - 백색주석(β-Sn ; bct) → 회색주석(α-Sn ; cubic)
  (변태온도가 13.2 **°C** 이나 시간적 지체 때문에 –40 **°C** 에서, 고순도 주석 -10 **°C** 부근에서 변태 됨)
- Bi, Pb, Sb 변태지연, Zn, Al, Mg, Co 변태촉진

- ***2)기계적 화학적 성질***
- 고온에서는 강도, 경도, 연신율 모두↓
- β-Sn은 금속중 Pb 다음으로 soft →쉽게 박 →굽히면 'tin cry'소리
- Sn의 내식성 – 산소의 존재에 의해 내식성↓

Sn & Sn-Alloy

- ***Soft solder (땜납)***
- Cu, brass, bronze, Fe, Zn의 접합제 - 300℃이하의 용해온도
- 주로 Sn – Pb계 → 합금조성에 따라 용해온도, 응고온도범위가 달라진다.

- 1)고온용: Sn alloy(95Sn5Ag), Cd(95Cd5Ag) or Zn(83Cd17Zn)계 alloy

- 2)저온용: Sb(β→α변태 억제) 함유 Sn alloy저온용 적합(95Sn5Sb)
  Pb의 함량이 많은 alloy 적합

- 3)기타합금
- 경석(Hard Sn) ;0.4%Cu첨가된 Sn – 의약품, 그림물감등에 대한 내식성 우수 Tube, slab으로 주조하여 냉간압연으로 plate (판) – extrusion하여 성형
- 주조용품 Sn alloy; 4~7%Sb 1~3%Cu함유 Pewter나 Britania metal장식용품에 이용

Pb & Pb-Alloy

- 역사적인 재료 (융점이 낮고 가공이 용이)
- battery 전극, Solder용, cable피복, 활자합금, bearing합금
- 밀도가 크다 (11.36g/㎤) FCC (a=4.9389)
- 연하고 ductility가 좋다.
- M.P가 낮다(327.4℃)
- 방사선 차단력이 강하다.
- 내식성 우수 – 관, 판으로 널리 이용
- 원래 반응성이 강하고 수소이온과 치환하기 쉬운 금속이나 불용해성 피복이 표면에 형성(탄산염, 규산염의 보호피막 형성 – 보통의 물)

Pb & Pb-Alloy

1) Pb-As (cable 피복용, Arsenical lead)

- 0.12 ~ 0.2%As, 0.08~0.012%Sn, 0.05~0.15%Bi
- 강도, 내creep성질이 Pb보다 우수
- 고온에서 extrusion가공 – water quenching강도가 증가
- creep rate – 25 **°C** 0.21kg/㎟의 T.S에서 0.13%year

2) Pb – Sb alloy

- Sb의 고용도 – 온도에 따라 크게 변화
- 주물 후 or 열간압출가공 후 시효경화한다.
- Sb의 첨가 – 강도증가
- Cu, Te첨가 – 결정립 미세화, g.b석출에 의한 피로강도의 저하 억제
- 1% Sb (antimonial lead) – cable 피복용
- 4~8%Sb (경석, hard lead) – Sb%가 낮은 alloy 관, 판 가공용
Sb%가 높은 alloy 주물용
- 9%Sb – 축전지 전극 격자용

Two small vials of liquid metal.
The vial on the right contains *gallium*, an element that melts at 29.76°C.
The vial on the left is an alloy that contains gallium, indium, and tin, and melts at -20°C.

http://sci-toys.com/scitoys/scitoys/thermo/thermo4.html

Pb & Pb-Alloy

https://www.inventables.com/technologies/low-temp-fusible-alloy

- ***3) Fusible alloy (저융점 합금)***
- 250℃이하 m.p. – Pb, Bi, Sn, Cd, In등의 alloy
- 비교적 m.p.가 낮은 alloy (Bi를 많이 함유)
  - 공정조성 합금(Eutectic alloy)이 이용
  - 비공정조성합금(non-eutectic alloy) :
    응고 온도 범위가 넓어서 실용상 고체로서의 강도가 거의 소멸하는 온도→항복온도(yield temperature)
- 용도 : 화재통보기, 압축공기용 탱크 안전밸브, 방화문체결구, 광휘소둔로의 액체 seal, 저온 땜납

FUSIBLE ALLOYS

AIM is a leading supplier of fusible alloys for a broad range of Tool & Die applications.

AIM fusible alloys are low melting temperature alloys that contain bismuth, lead, tin, cadmium or indium. AIM's fusible alloys are utilized in a broad variety of tool & die applications, including casting, tube bending, machining parts for soft metal dies, fixturing, anchoring parts, toggle dies and supporting castings and interrupted cuts.

These silvery white alloys expand only ~3.3% of their volume when changing from liquid to solid form, which makes these alloys ideal for many industrial applications. AIM fusible alloys are rarely consumed in an operation and therefore can be remelted and used multiple times.

These alloys are normally used in gravity casting but also can be used in other casting methods.

Specifications & Applications Information On Commonly Used AIM Fusible Alloys

AIM Fusible Alloy	47	58	70
Composition %			
Bismuth	44.7	49	50
Lead	22.6	18	26.7
Tin	8.3	12	13.3
Cadmium	5.3		10
Indium	19.1	21	
Melting Temp. (ºC)	47	58	158
Density lb/in^3	.32	.31	.339
Brinell Hardness Number	12	14	9.2
Tensile Strength lb/in^2	5400	6300	5990
% Elongation	1.5	50	200
Conductivity (% of IACS)	4.50%	2.43%	4.00%
CTE In/In PPM/ºC	25	23	22
Liquid Specific Heat	.035	.032	.040
Solid Specific Heat	.035	.032	.040
Latent Heat of Fusion BTU/lb	6	8	14
Growth-Shrinkage Time After Casting			
2 Minutes	+.0005	+.0003	+.0025
6 Minutes	+.0002	+.0002	+.0027
30 Minutes	.0000	+.0001	+.0045
1 Hour	.0001	.0000	+.0051
5 Hours	-.0002	-.0002	+.0051
24 Hours	-.0002	-.0002	+.0051
500 Hours	-.0002	-.0002	+.0057

For additional information please contact AIM at
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1 401 463-5605
1 401 463-0203 Fax
or visit us on the web at
www.aimsolder.com