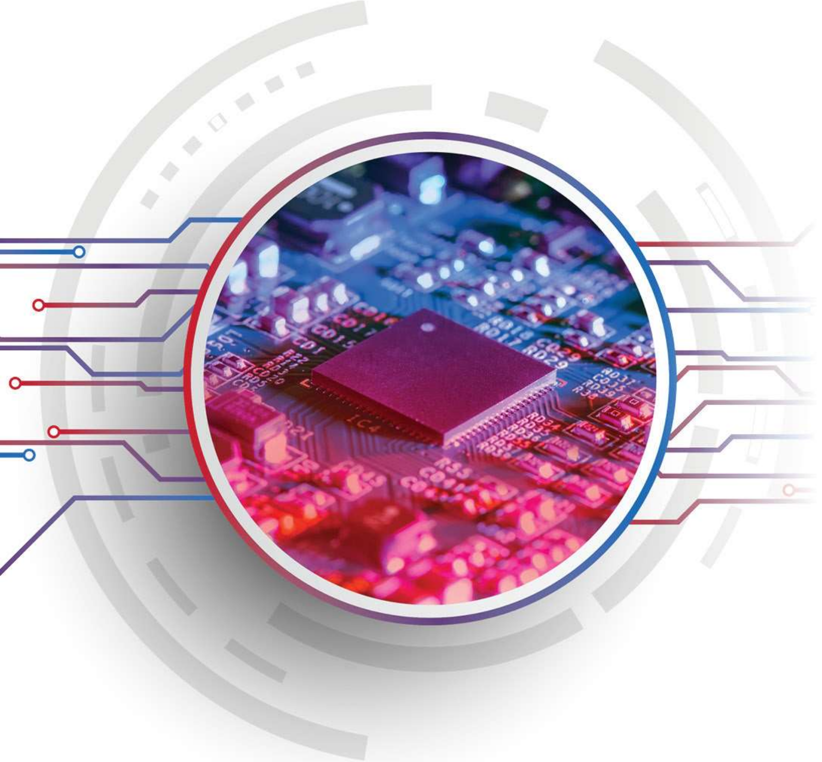

# Solder Paste Basics

## Module - 2

Nov 2022

MacDermid Alpha
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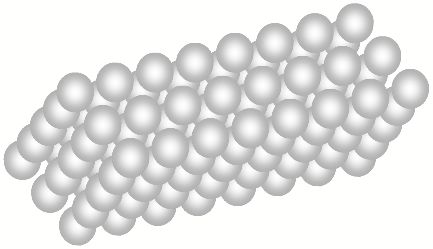
# Module 2 Solder Paste Basics

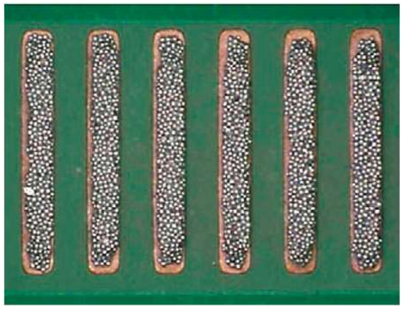
# Introduction

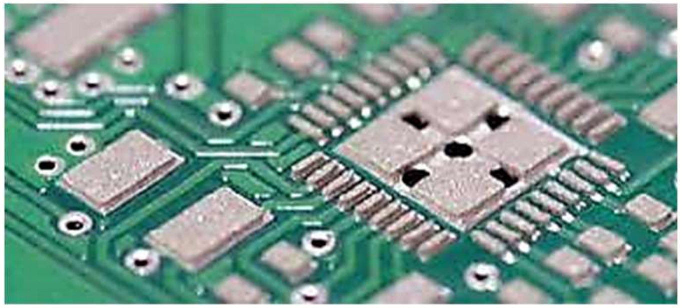
- Almost all electronics equipment contains printed circuit boards (PCBs),
- These are critically important for satisfactory functioning of the equipment.
- PCBs are also known as central nervous system of the electronic device.
- PCBs have patterns of electrically conducting copper tracks / traces.
- Electronic components are to be joined on those terminal pads of tracks / traces.
- The joints between the PCB pads and the components are made by soldering
- Generally the joints are made using material known as solder paste.

# Solder Paste – Why it is used

- Solder Paste is a consistent homogeneous mixture of solder powder (metal)
- T is in a stable viscous flux vehicle which is used to join two metal surfaces upon heating.
- 90% Metal by weight for printing applications (typical)
- 50% metal / 50% flux by volume
- 6 mil thick deposit leaves 3 mil solder after reflow.







# What is a solder paste?

- **Solder paste is a highly engineered material mixture**
  - –Solder powder (Alloys)
  - –Flux "package"
    - Activators
    - Viscosity modifiers
    - Rosin/resin ("no clean" pastes)
    - Solvents

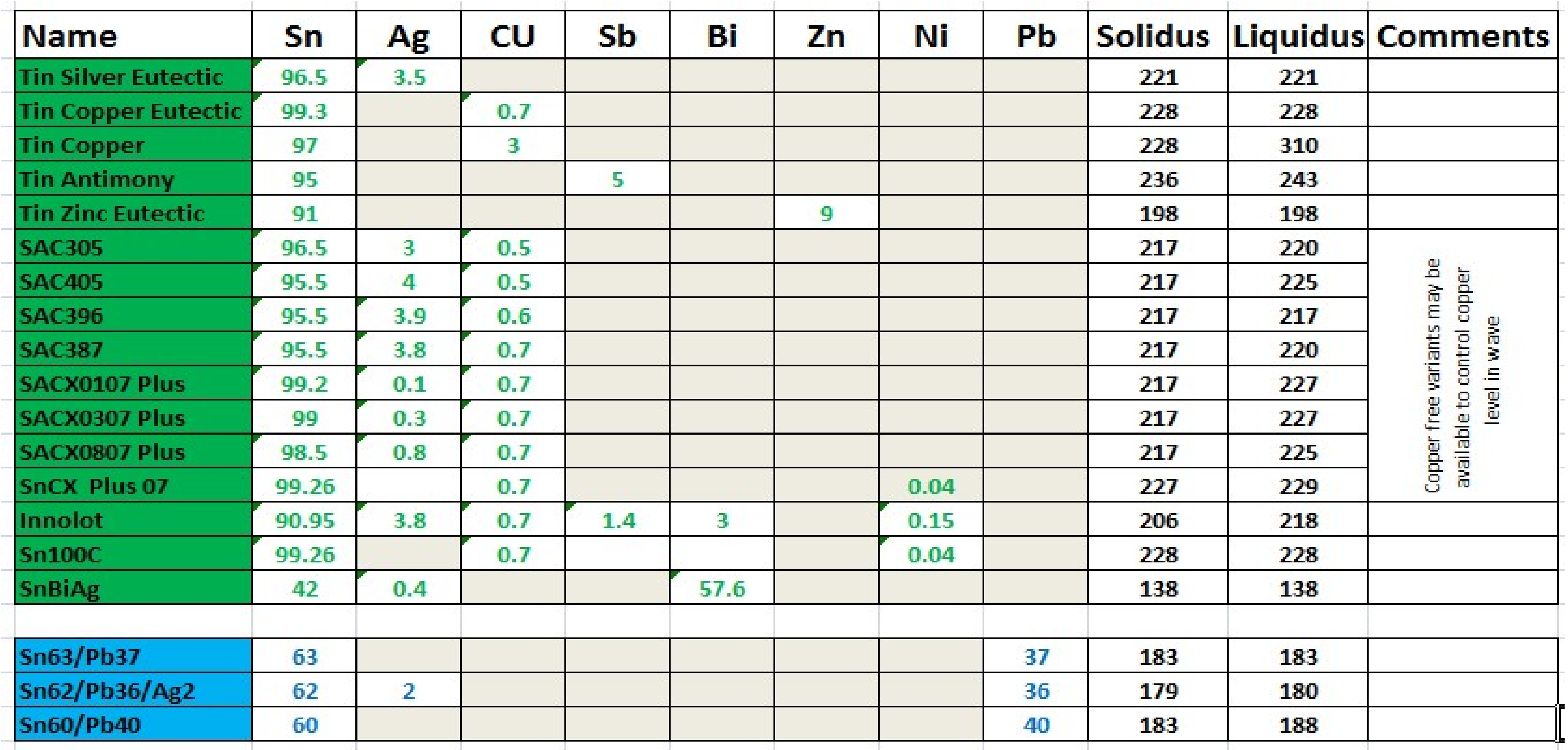
- **Some important properties of the specification of a product**
  - –Particle Size Distribution (PSD)
  - –Viscosity
  - –Tack
  - –Work life and shelf life

# How do the pieces actually ‘join’ together?

We need two things to happen:

- Wetting
  - The solder needs to spread effectively over the surfaces to be joined.
- Chemical ‘bonding’
  - Some would call this alloying of metals.
  - Process involves solid/liquid interaction, not liquid/liquid interaction.
  - This is by the formation of metal/metal compounds known as an Intermetallic Compounds or IMC’s .
  - This contributes to the bond strength of the joint.

# The Most Common Soldering Alloys



| Name | Sn | Ag | CU | Sb | Bi | Zn | Ni | Pb | Solidus | Liquidus | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tin Silver Eutectic | 96.5 | 3.5 |  |  |  |  |  |  | 221 | 221 |  |
| Tin Copper Eutectic | 99.3 |  | 0.7 |  |  |  |  |  | 228 | 228 |  |
| Tin Copper | 97 |  | 3 |  |  |  |  |  | 228 | 310 |  |
| Tin Antimony | 95 |  |  | 5 |  |  |  |  | 236 | 243 |  |
| Tin Zinc Eutectic | 91 |  |  |  |  | 9 |  |  | 198 | 198 |  |
| SAC305 | 96.5 | 3 | 0.5 |  |  |  |  |  | 217 | 220 | Copper free variants may be available to control copper level in wave |
| SAC405 | 95.5 | 4 | 0.5 |  |  |  |  |  | 217 | 225 |  |
| SAC396 | 95.5 | 3.9 | 0.6 |  |  |  |  |  | 217 | 217 |  |
| SAC387 | 95.5 | 3.8 | 0.7 |  |  |  |  |  | 217 | 220 |  |
| SACX0107 Plus | 99.2 | 0.1 | 0.7 |  |  |  |  |  | 217 | 227 |  |
| SACX0307 Plus | 99 | 0.3 | 0.7 |  |  |  |  |  | 217 | 227 |  |
| SACX0807 Plus | 98.5 | 0.8 | 0.7 |  |  |  |  |  | 217 | 225 |  |
| SnCX Plus 07 | 99.26 |  | 0.7 |  |  |  | 0.04 |  | 227 | 229 |  |
| Innolot | 90.95 | 3.8 | 0.7 | 1.4 | 3 |  | 0.15 |  | 206 | 218 |  |
| Sn100C | 99.26 |  | 0.7 |  |  |  | 0.04 |  | 228 | 228 |  |
| SnBiAg | 42 | 0.4 |  |  | 57.6 |  |  |  | 138 | 138 |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
| Sn63/Pb37 | 63 |  |  |  |  |  |  | 37 | 183 | 183 |  |
| Sn62/Pb36/Ag2 | 62 | 2 |  |  |  |  |  | 36 | 179 | 180 |  |
| Sn60/Pb40 | 60 |  |  |  |  |  |  | 40 | 183 | 188 |  |

# Soldering Explained

Soldering is a process in which two or more metal items are joined together by melting and flowing a filler metal (solder) into the joint.

The Solder has a lower melting point than the adjoining metal.

In our case the Solders are primarily Tin based alloys.

Obtain metallic continuity between metals.

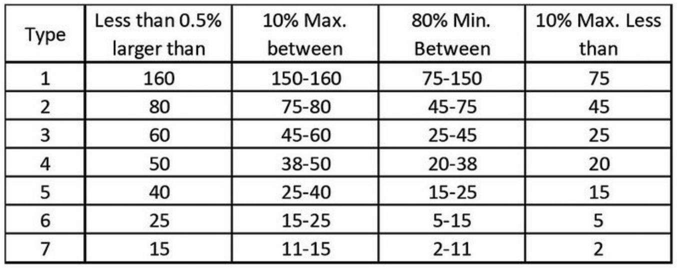
Soldering differs from welding in that soldering does not involve melting the work pieces.

Soft soldering is defined as <400°C.

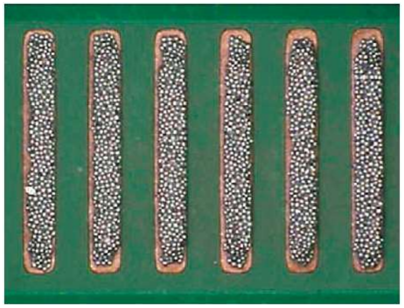
Soldering is non-destructive and can be reversed

# An Understanding on Solder Powder

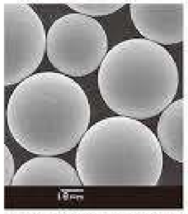
- Solder paste is comprised of powdered solder alloy suspended in flux
- There are various powder sizes based on end use requirements
- As the powder size decreases, the surface area per volume or mass of powder drastically increases
- More powder surface area means more area for the flux to react with, and more surface area for soldering to occur
- Powder surface must be free of oxides for easy wetting
- Particle shape
  Spherical shape preferred for oxidation control and optimum rheology
  Difficult to control shape with some powder manufacturing techniques



| Type | Less than 0.5% larger than | 10% Max. between | 80% Min. Between | 10% Max. Less than |
|---|---|---|---|---|
| 1 | 160 | 150-160 | 75-150 | 75 |
| 2 | 80 | 75-80 | 45-75 | 45 |
| 3 | 60 | 45-60 | 25-45 | 25 |
| 4 | 50 | 38-50 | 20-38 | 20 |
| 5 | 40 | 25-40 | 15-25 | 15 |
| 6 | 25 | 15-25 | 5-15 | 5 |
| 7 | 15 | 11-15 | 2-11 | 2 |

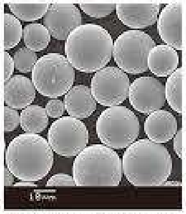


Type4



Average grain size φ 30μm

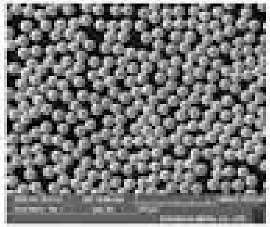
Type5



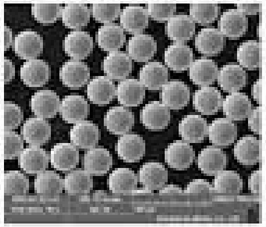
Average grain size φ 20μm

Type6

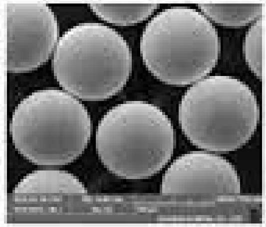
Average grain size φ 10μm



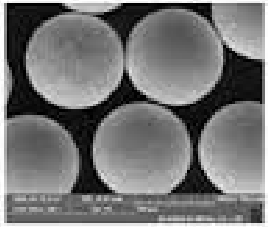
30µm



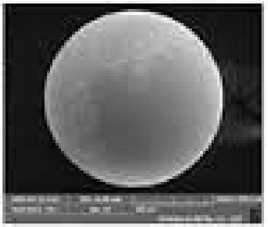
75µm



200µm

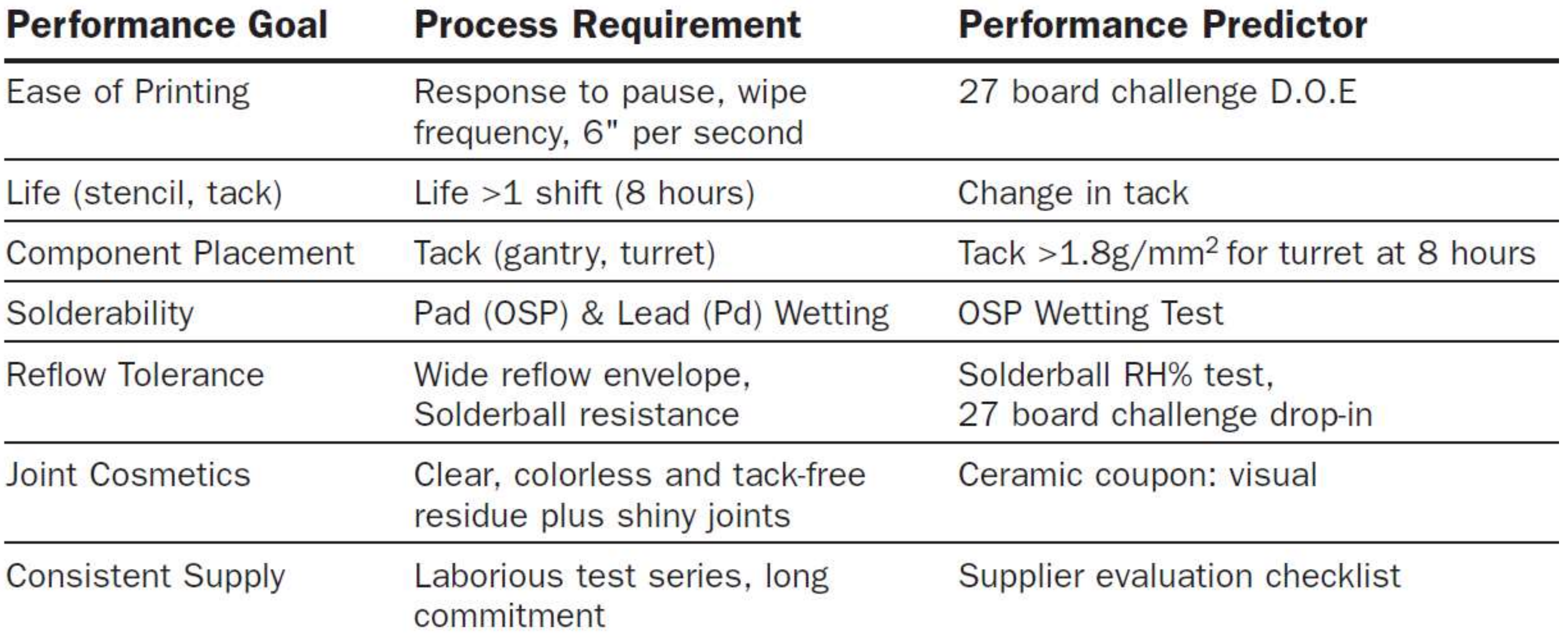


250µm



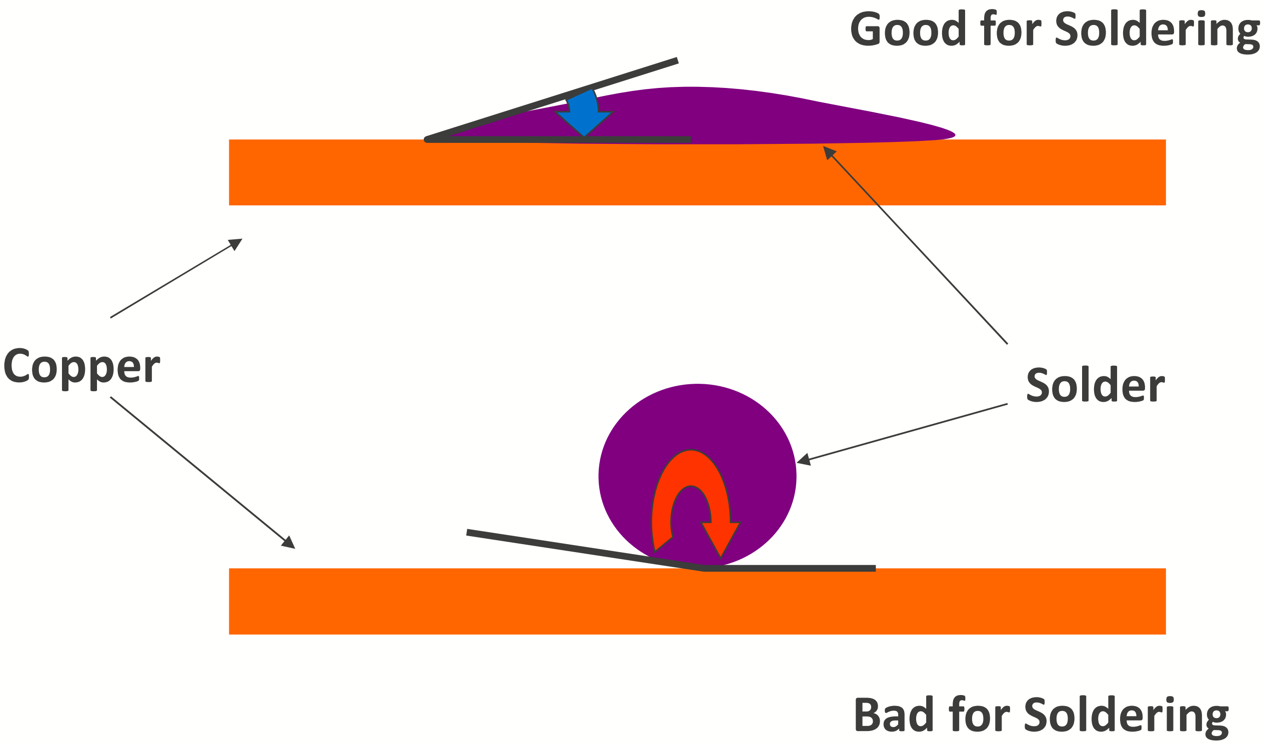
450µm

# Solder Paste Performance Standards

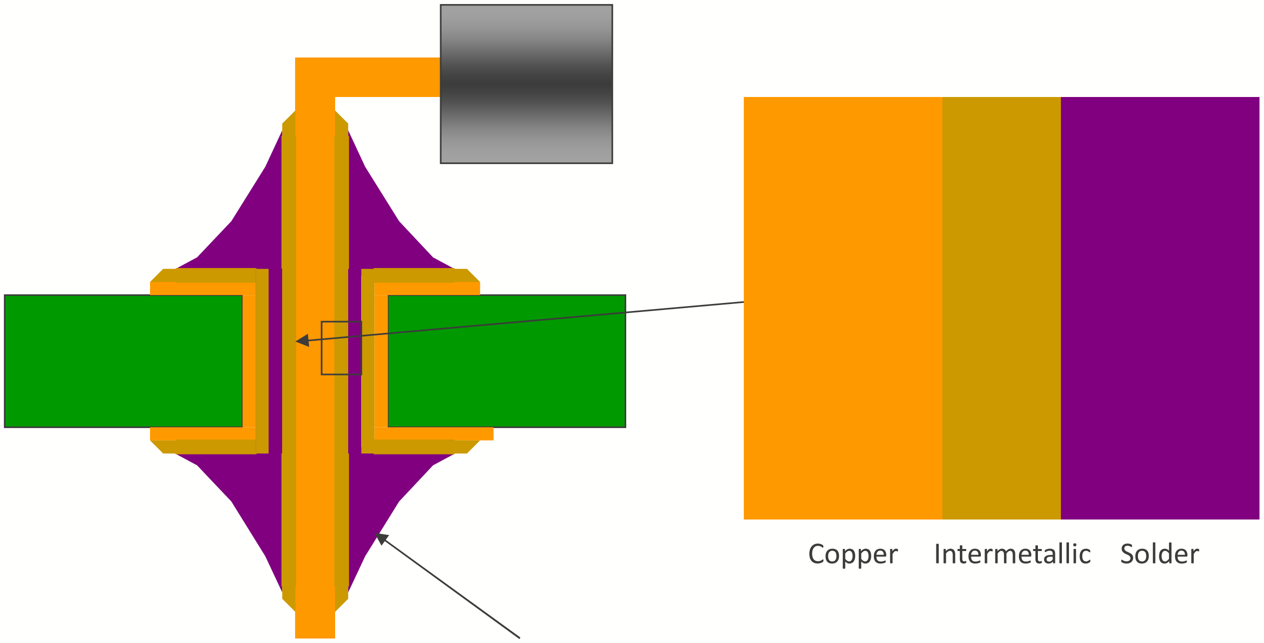


| Performance Goal | Process Requirement | Performance Predictor |
|---|---|---|
| Ease of Printing | Response to pause, wipe frequency, 6" per second | 27 board challenge D.O.E |
| Life (stencil, tack) | Life >1 shift (8 hours) | Change in tack |
| Component Placement | Tack (gantry, turret) | Tack >1.8g/mm$^2$ for turret at 8 hours |
| Solderability | Pad (OSP) & Lead (Pd) Wetting | OSP Wetting Test |
| Reflow Tolerance | Wide reflow envelope,<br>Solderball resistance | Solderball RH% test,<br>27 board challenge drop-in |
| Joint Cosmetics | Clear, colorless and tack-free residue plus shiny joints | Ceramic coupon: visual |
| Consistent Supply | Laborious test series, long commitment | Supplier evaluation checklist |

# Wetting Angle



# Inter-metallics



Copper Intermetallic Solder

Good Wetting

# Intermetallic Growth is a Function of ...

- Temperature
- Time
- Solder type
- Base metal

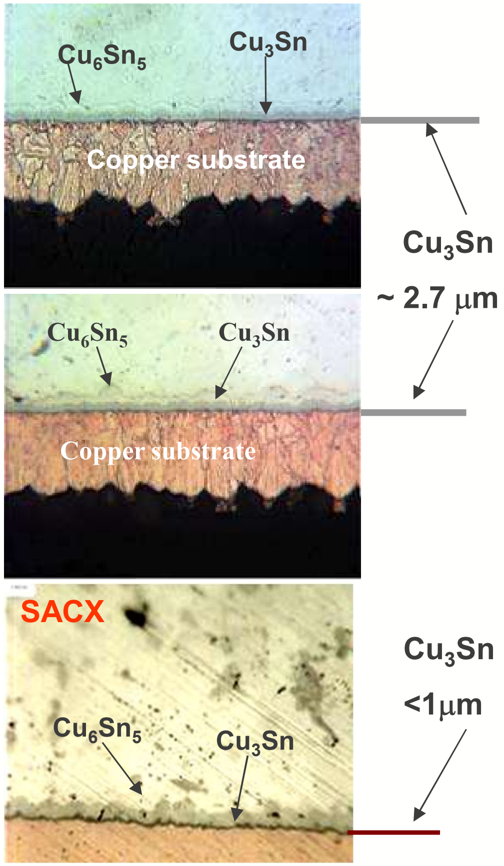
SAC Solder

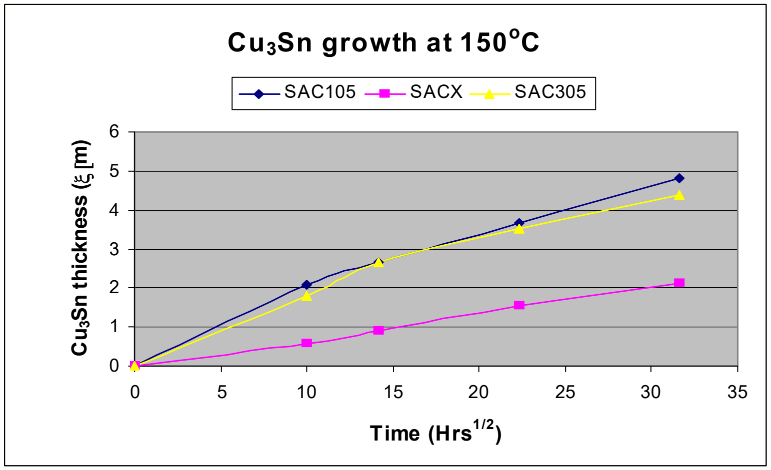
$Cu_6Sn_5$

$Cu_3Sn$

Copper

# IMC Growth on Cu Comparison of SAC305, 105 and SACX





- Reduction in growth of $Cu_3Sn$ IMC lowers probability of brittle failure.
- IMC growth is strongly correlated to tin whisker phenomenon

## Diffusion Coefficients

($D_{Cu} \rightarrow Cu_3Sn$, from IMC growth kinetics, $X \approx \sqrt{6\,Dt}$ )

| Alloy | D ($cm^2.s^{-1}$) |
|---|---|
| SAC 305 | $0.38 \times 10^{-10}$ |
| SAC105 | $0.44 \times 10^{-10}$ |
| SACX | $0.07 \times 10^{-10}$ |

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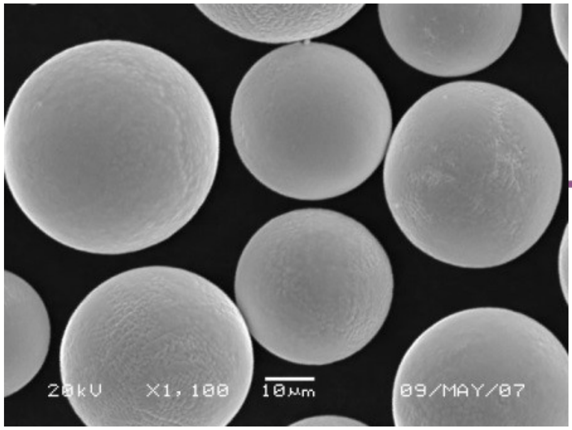
# Inter-metallics in Soldering

- Inter-metallics (IMs) are necessary for successful soldering and achieving a good mechanical bond between the component leads and the pad on a PCB.

  **However,**

- Since IMs are brittle, it is desirable to ensure that the IM layer is not thick, to avoid fracture.
- Soldering processes that have excessively high temperatures or soldering times can form thick IMs.
- Excessive rework can also cause thick IMs.

# An Understanding on Solder Powder Manufacturing



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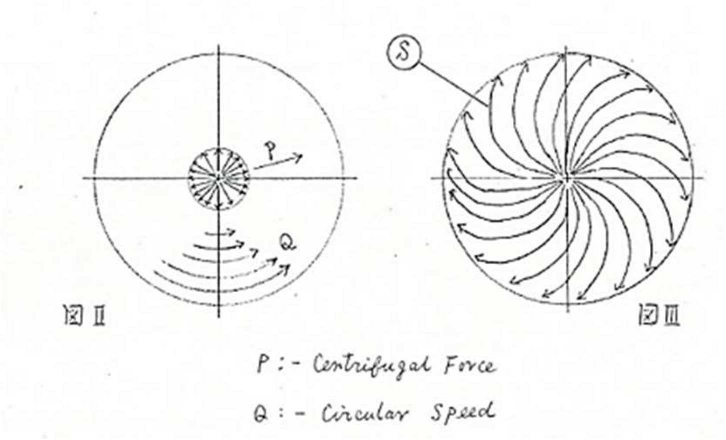
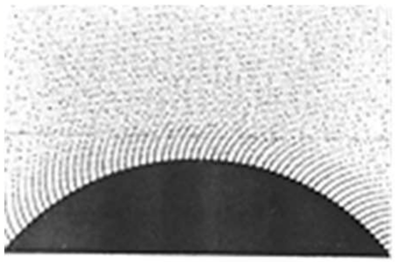
# Spinning Disc Atomization

- The method consists of rotating a circular body and pouring liquid onto the center.
- The liquid spreads out into a film as centrifugal forces urge it towards the edge of the disc
- It accelerates to ever higher speeds until it reaches close to the peripheral velocity.
- At the edge, the acceleration force due to rotation attempts to remove the liquid from the disc edge, while surface tension forces try to hold it on.

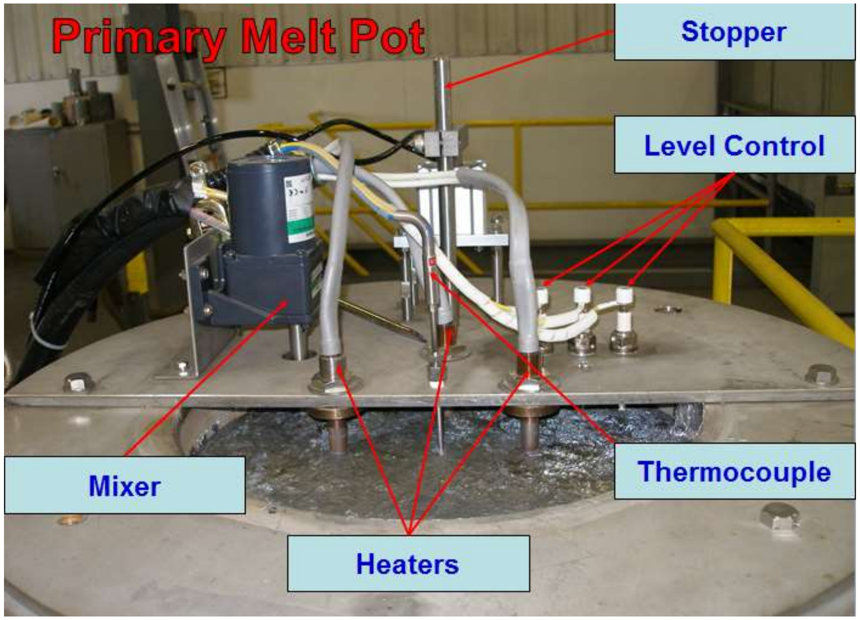


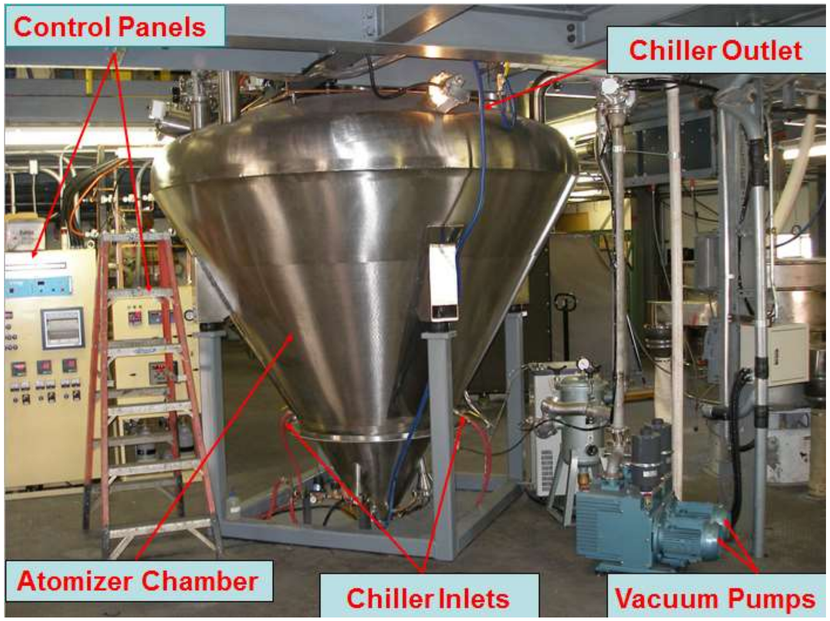


Ligament formation from a spinning disk

**For spinning disc atomization, proper wetting of the disc is required!**

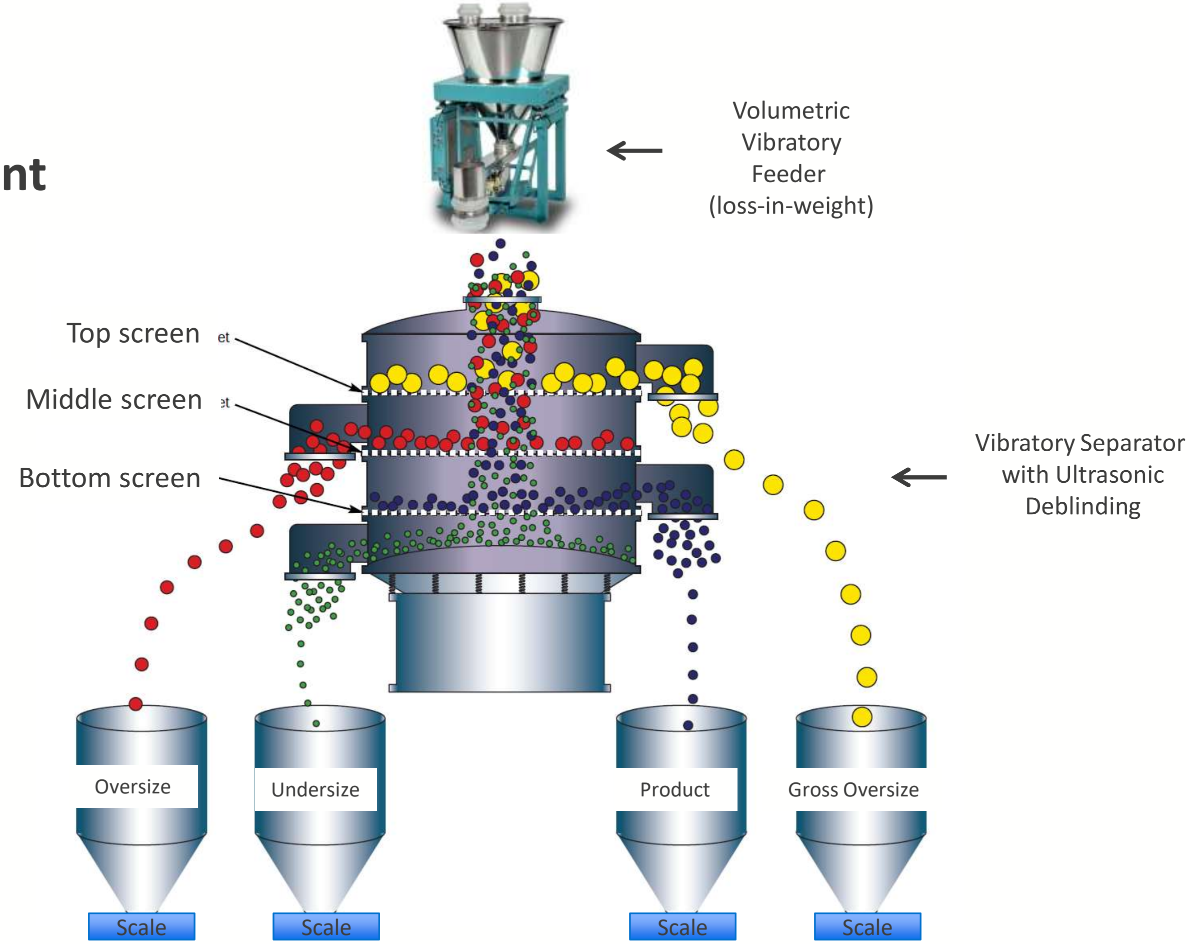
# Atomization Process



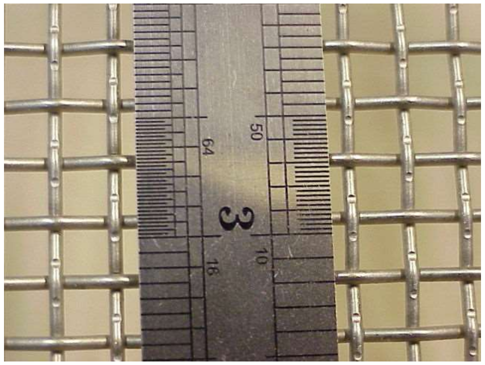


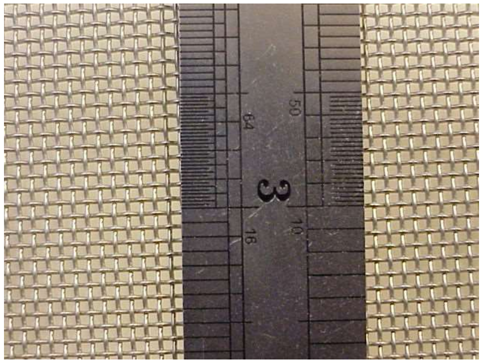
# Sieving Process

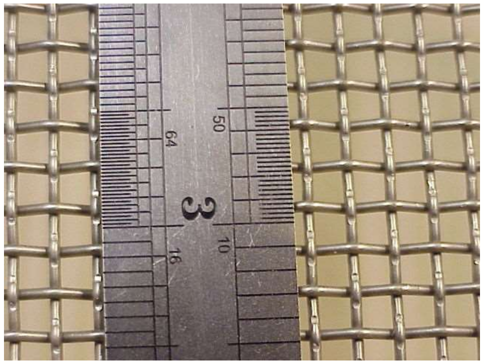
## Typical Screener Arrangement



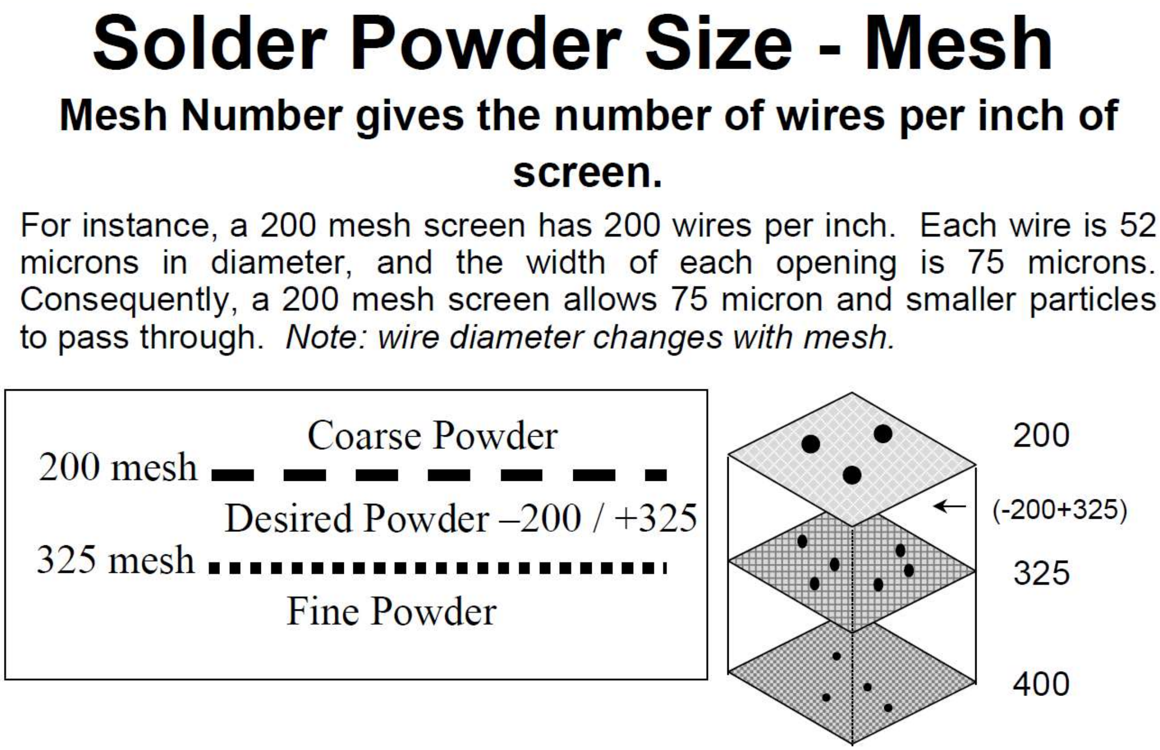
# Various Mesh Sizes







# Various Mesh Sizes



## Solder Powder Size - Mesh

**Mesh Number gives the number of wires per inch of screen.**

For instance, a 200 mesh screen has 200 wires per inch. Each wire is 52 microns in diameter, and the width of each opening is 75 microns. Consequently, a 200 mesh screen allows 75 micron and smaller particles to pass through. *Note: wire diameter changes with mesh.*

# How fine do screens get?

That depends on the wire thickness. But the supplier of screens does not offer any screens finer than 500 mesh.

If you think about it, the finer the weave, the closer the wires get together, eventually leaving no space between them at all.

So, beyond 325-400 mesh, we usually describe particle size in “microns.”

A micron is another measurement we use for measuring particle size.

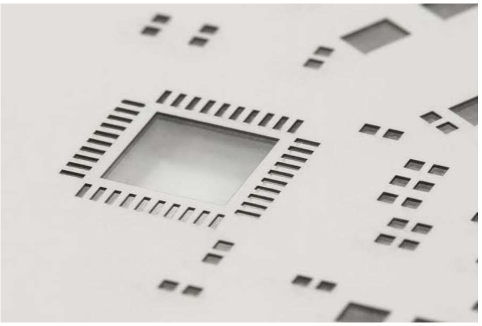
A micron is 1/1000$^{th}$ of an mm

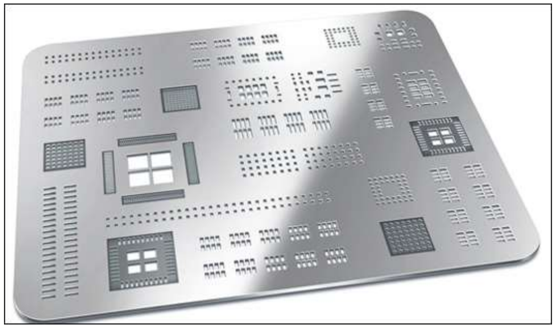
or

Simply 25.4 microns = 1 mil

# Solder Paste Powder type Selection

| Powder Type | Size | Mesh Count | Fine Pitch (mm) | Fine Pitch (in) | Circle Aperture (mm) | Circle Aperture (in) |
|---|---|---|---|---|---|---|
| II | 75-45µ | -200+325 | 0.65 | 0.025 | 0.65 | 0.025 |
| III | 45-25µ | -325+500 | 0.5 | 0.02 | 0.5 | 0.02 |
| IV | 38-25µ | -400+500 | 0.3 | 0.012 | 0.3 | 0.012 |
| V | 25-20µ | -500+635 | 0.2 | 0.008 | 0.15 | 0.006 |
| VI | 15-5µ | NA | 0.1 | 0.004 | 0.05 | 0.002 |





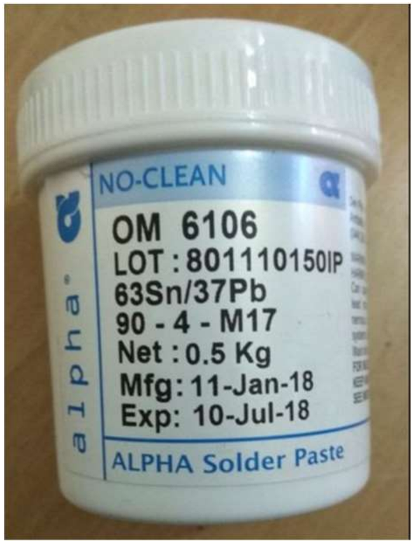
# Solder Particle Powder Size as per ANSI/J-STD-005

A solder paste can, in principle, be manufactured using any size range or combination of size ranges specified by the customer, but solder paste manufacturers have, in the main, standardized on a limited number of particle size distributions.

| DISTRIBUTION | | | | |
|---|---|---|---|---|
| **Type** | **<0.005%larger than** | **<1%larger than** | **>90%between** | **>10%smaller than** |
| 1 | 180µm | 150µm | 150-75µm | 20µm |
| 2 | 90µm | 75µm | 75-45µm | 20µm |
| 3 | 53µm | 45µm | 45-25µm | 20µm |
| 4 | 45µm | 38µm | 38-20µm | 20µm |
| 5 | 32µm | 25µm | 25-15µm | 15µm |
| 6 | 25µm | 15µm | 15-5µm | 5µm |

# Metal Content

- Solder pastes are made by mixing a metal alloy powder (around 90% by weight)
- It is blended with a cream-like material Flux made of organic chemical (~10% by weight).
- The ‘flux’ is generally a trade secret and/or covered by patents.
- The purpose of flux is to give the solder paste its cream-like texture
- Flux enables formation of metal joints by ensuring that the metal surfaces are ‘clean’
- Clean means free of oxides at the time the metal joints are formed.
- The normal loading for printable paste is 90% (by weight) of powder.
- The dispensable grade has a lower viscosity the lower metal loading - about 86%.
- Solder powder (Sn63/Pb37) takes 1/8.5th the volume the flux takes.
- **The flux is between 10-14% by weight. The volume is about half flux and half metal**.



# Role of Flux in a Solder Paste

**What is flux?**

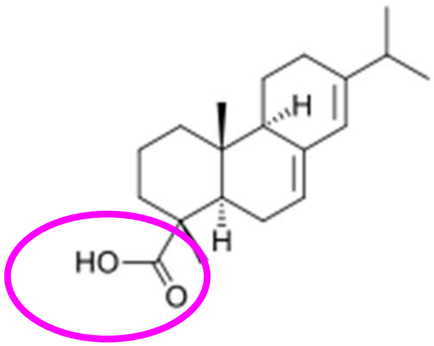
⇒ Chemicals based on rosin (resin) as a main component.

Rosin contains abietic acid (a kind of organic acid) that helps in soldering.

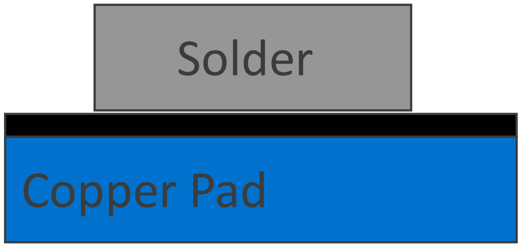
**Flux Plays the following key roles**

- Clean base metal/powder surface (Removal of Oxide Film)
- Promotes wettability of solder (Reduced surface tension)
- Coat base metal and molten solder (Re-oxidation prevention)
- Tool for rheology control

Abietic acid



The oxide (CuO) on the surface of the copper is removed.



←An oxide layer (usually 2-10nm)

Why use water-soluble flux
2.21 Why use no-clean flux
2.22 What does the solvent in solder paste do
2.23 What is slump
2.24 In what containers do you buy solder paste
2.25 Should solder paste be stored in a refrigerator
2.26 What should be done when solder paste is removed from a refrigerator
2.27 How much moisture in solder paste can be tolerated
2.28 What happens if jars are left open
2.29 Should old paste be put into jars
2.30 What is preheating
2.31 What is dwell or soak time
2.32 What is the peak temperature
2.33 What does a supplier's reflow profile look like
2.34 What is lead free solder

# Assembly Complexity

***IPC Joint Industry Standards classify assemblies by their performance environments***:

- ***Class 1 -General Electronic Products***

  Includes products suitable for applications where the major requirement is function of the completed assembly. (Home consumer electronic products, appliances, toys)

- ***Class 2 -Dedicated Service Electronic Products***

  This includes products where continued performance and extended life is required, and for which uninterrupted service is desired, but not critical.

  Typically the end-use environment would not cause failures.

  Included here would typically be computers, industrial and telecommunications equipment, and automotive electronics (except for engine management, drive-train and safety-related components)

- ***Class 3 -High Performance Electronic Products***

  This encompasses products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must function when required.

  This would typically include military weapon and defense systems, aerospace, life support systems and under-the-hood automotive electronics.

# Why use Water-Soluble (WS) flux

- Post soldering assemblies are CLEANED using DI water
- The flux system used in this type of paste is water washable
- WS Flux contains more active chemistry for formation of reliable joints – compared to No-clean
- Intention is not to restrict chemistry activity to form reliable joints
- Hence boards assembled with WS Flux must be cleaned with water to eliminate flux chemistry
- Cleaned Assemblies are a pre-requisite for Class-3 Products
- Boards cleaned, are free of residues and are expected to perform well in harsh environments
- Cleaning is an additional process – involves cost by equipment, real estate & disposal of spent chemistry
- Ionic contamination test is performed to measure the degree of cleanliness

# No-Clean Flux

- Eliminates cleaning operation
- Widely used flux in the PCB Assemblies across globally
- Adopted due to restrictions on the world production of CFCs imposed by the Montreal protocol
- Came into effect from 1st January 1989, directly affect the usage of CFCs in electronic cleaning
- No-Clean fluxes are also known as low solid or low residue fluxes
- The solids content are generally 2-5% by weight respectively
- Residues are tolerated and left on the board – post soldering
- If well processed generally do not pose any post soldering reliability concerns
- Widely used for Class 1 & 2 end products

# Handling of Solder Paste

**STORAGE**

- Long term storage of solder paste is best achieved by refrigeration 0-8°C (32-46°F).
- The material should be stored immediately upon receipt.
- Typical shelf life is 6 months.
- For WS Paste the shelf life is lower (4 months)
- Solder paste should never be stored at room temperature 19-25°C (66-77°F).
- Room temperature stability is intended to provide manufacturing flexibility

# Handling of Solder Paste

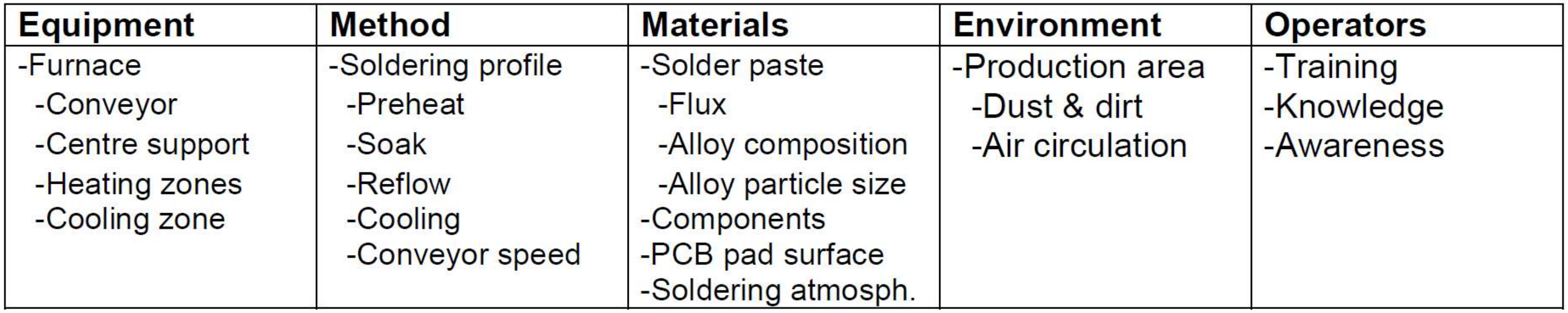
**USAGE**

- Paste should always be used on a First In First Out (FIFO) basis.
- Paste should not be stored outside the refrigerator any longer than necessary (never more than four (4) days).
- Solder paste should be allowed to reach room temperature, 19-25°C (66-77°F)
- No forced heating but conditioned to 3-4 hours out of refrigeration to reach RT before the paste is used.
- Used paste from stencil cannot be mixed with unused paste in jar.
- This will alter the rheology of the unused paste and, potentially, negatively affect paste performance.
- Safe disposal of solder paste residues in accordance with local environmental legislation - MUST.

# Reflow – Factors to Consider

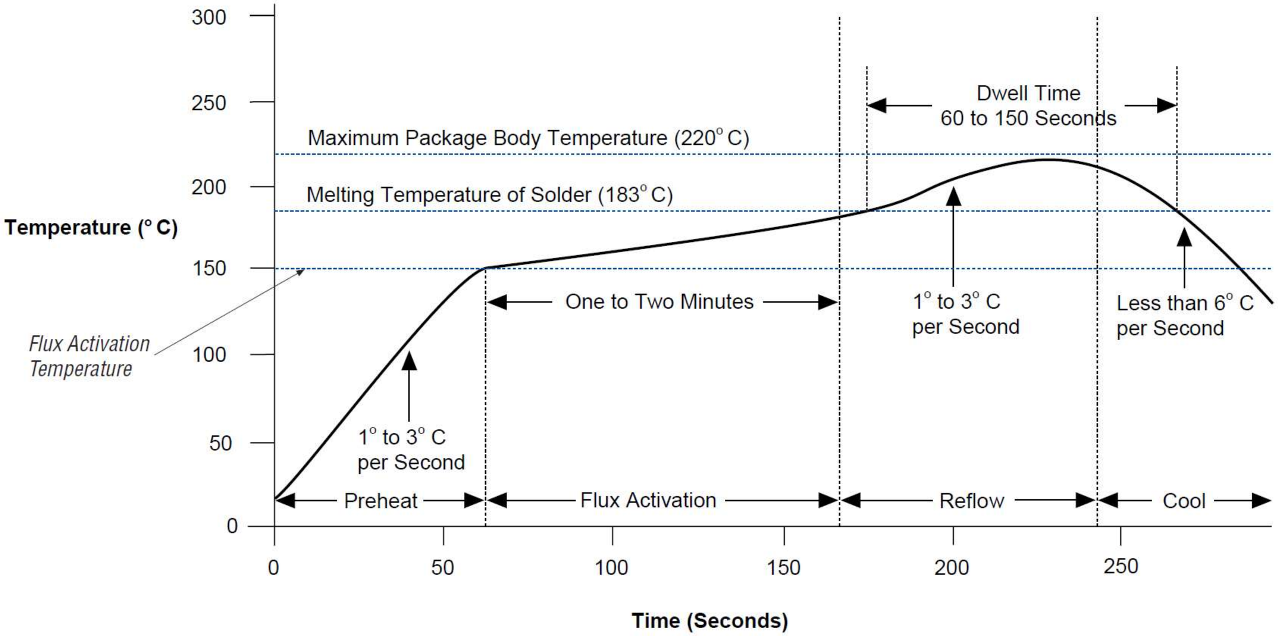
In the reflow soldering process, solder paste printed onto PCBs re-melts and forms the solder joints.

When reflow soldering a PCB printed with solder paste, there are a lot of factors to consider.



| Equipment | Method | Materials | Environment | Operators |
|---|---|---|---|---|
| -Furnace<br>-Conveyor<br>-Centre support<br>-Heating zones<br>-Cooling zone | -Soldering profile<br>-Preheat<br>-Soak<br>-Reflow<br>-Cooling<br>-Conveyor speed | -Solder paste<br>-Flux<br>-Alloy composition<br>-Alloy particle size<br>-Components<br>-PCB pad surface<br>-Soldering atmosph. | -Production area<br>-Dust & dirt<br>-Air circulation | -Training<br>-Knowledge<br>-Awareness |

# A Typical Reflow Profile

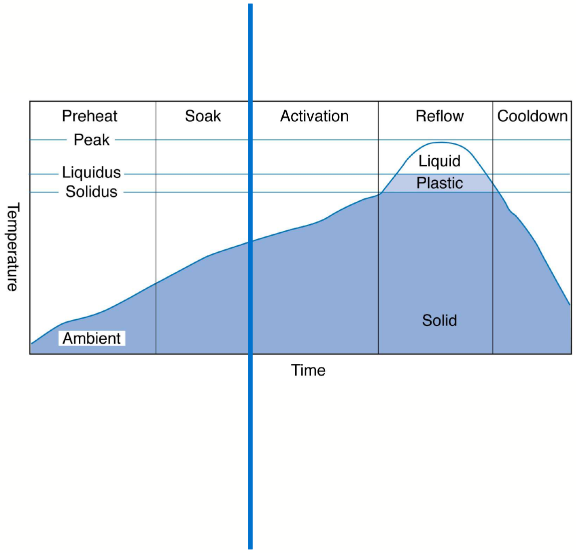


A good profile will meet or exceed the minimum times at the coolest spot on the product while not exceeding the maximum times at the hottest point on the product.

# Reflow Profile

**Preheating Zone:**

- Components are heating up (gradually without thermally shocking them).
- Duration: 45 to 90 seconds
- Solvent evaporation (starts). Rate of increase in temp 2-3 Deg C / Sec
- The activation system is starting to clean the powder surfaces and pads.



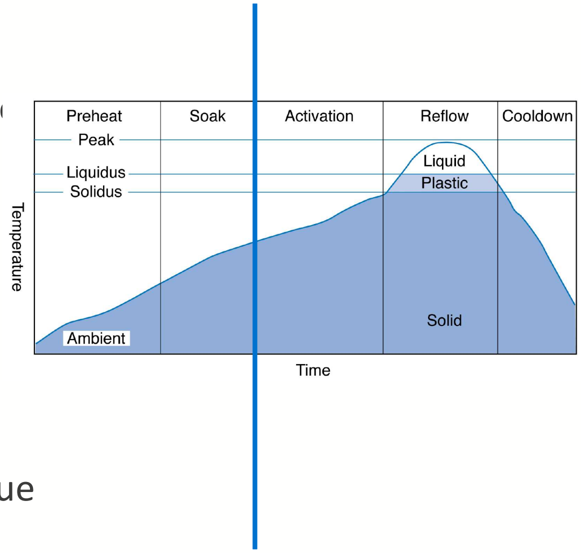
**Soak Zone:**

- Temperature of the entire assembly to equilibrium before reaching the reflow.
- 20 to 90 seconds
- Solvent continue to evaporate.
- Temperature range at which the flux begins to remove oxides.

# Reflow Profile

**Activation:**

- The flux transitions from a gel state to a fluid state,then cleans the surfaces to be soldered
- Duration: 10 to 90 seconds for alloys with solidus under 250°C.
- Excessive time in the activation range will use up available flux activity
- This may result in non-wetting, de-wetting, and related solder defects.
- Temperature ramps up from 140°C to the alloy solidus at between ½° and 3°C/S



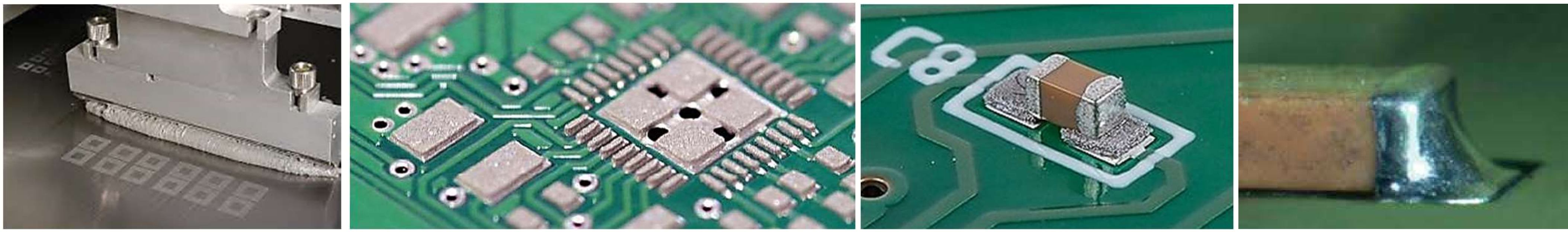
**Reflow Zone:**

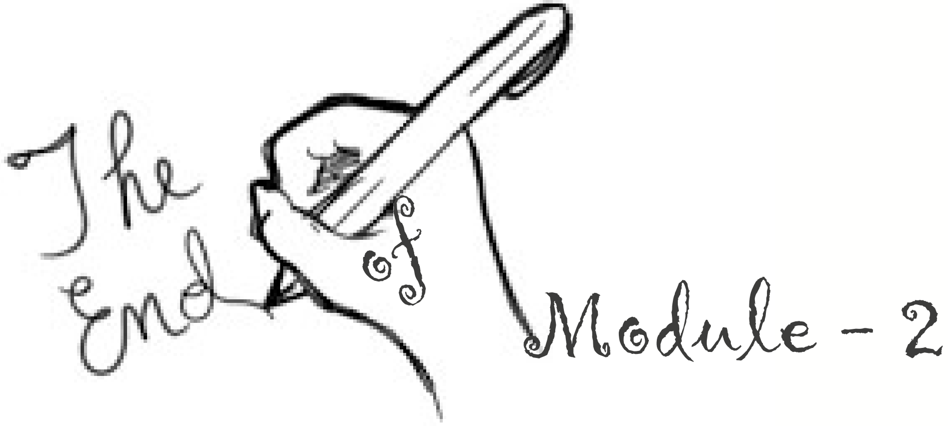
- Alloy melts and allow solder to wet and form the proper fillet.
- Temperature attains Peak

**Cooling Zone:**

- Solidification of the solder joint
- Cooling of the assembly (faster cooling will result in finer grain and higher fatigue resistance).
- Cooling rate will affect Joint strength and appearance.

# Assembly Equipment / Process





ANY QUESTIONS?

# Back up Slides

# Equipment Used in Powder Production (back up slide 1)

# The Finished Paste Product (back up slide 1)