

# Solder Paste Basics

## What is solder paste?

### The properties of solder paste

We talk about 'solder paste' or 'solder cream' without necessarily having a clear idea of the range of materials involved and their properties. Let's review the requirements for this material.

- The paste has to flow in order to be applied by dispensing, printing or similar methods
- Once deposited on the board, the paste must remain in place without spreading
- The paste must be sufficiently 'tacky' to enable the paste deposit to stick to components pressed into it, so that they are held in position while being transported, both during placement and on the conveyor prior to reflow
- The solder particles in the paste must fuse together when heated to form a single solder mass.

The paste must have sufficient fluxing action to enable that solder mass to wet the surfaces to be joined. This combination of properties is produced by controlling, firstly the materials from which it is made and secondly the flow properties of the paste.

### Background

The original solder paints were blown metal powder mixed with thickened zinc chloride flux base. They replaced an earlier tinning method, where

the operator applied a tinman's stick and blowtorch, then wiped the area with a moleskin to remove the surplus!

Early pastes for electronic assembly applications, intended for dispensing or screen printing, were likewise comparatively crude, but the technology has developed considerably over the past 20 years, and there is an ever-increasing rate of innovation, fuelled by the increasing importance of surface mount technology.

Changes in solder pastes have come about by progressive development and optimisation, aimed at:

- reducing activity of the flux (and the potential for harmful residues)
- improving the print characteristics
- increasing the metal content
- improving the reflow characteristics
- providing a wider process tolerance, especially for reflowing in air rather than nitrogen.

Many of these aspects are interrelated.

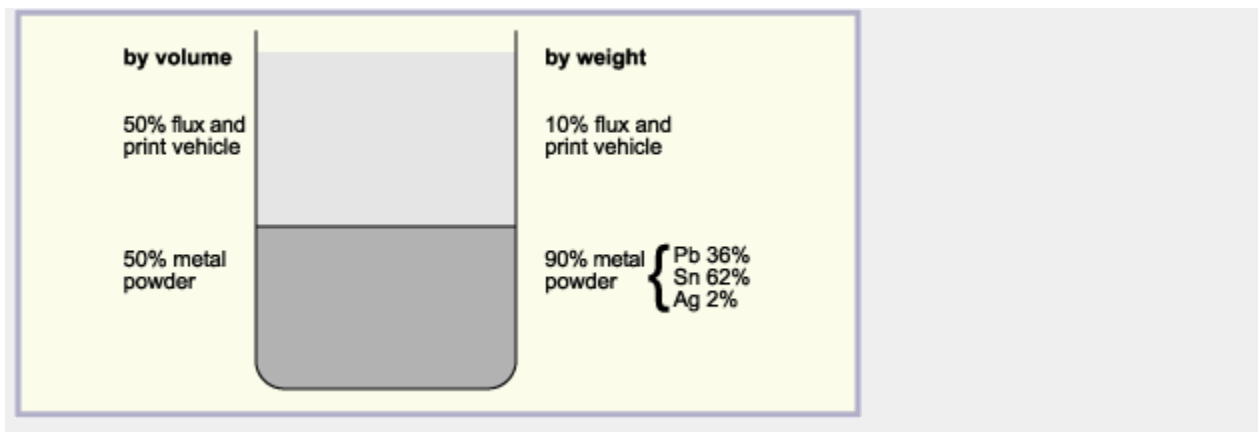
Around 1990 there were two major influences for change:

1. the take-off of **fine pitch printing** (generally defined as depositing solder for packages with 0.63mm (0.025") lead pitch or less)
2. the **CFC issue**: before 1990 'everyone washed', but environmental and cost considerations forced change, and the preferred option now reported in Europe and the US is a 'no-clean' paste system with a minimum of activators.

## Constituents of solder paste

Solder paste is a suspension of solder particles in a flux-containing printing vehicle (Figure 1), in which the shape and size of the particles and the flow properties ('rheology') of the flux vehicle are matched to the method of paste application most appropriate to the design of SM assembly.

Figure 1: Constituents of a typical solder paste



Remember that the solder alloy powder is the only permanent part of the metallurgical bond. At the end of the soldering cycle, all the printing vehicle and flux components are present only as residues, having been either volatilised during reflow, decomposed, reacted chemically, or removed during a subsequent cleaning step. However, all are crucial to forming reliable joints.

### The flux vehicle

The flux vehicle contains both flux and other substances that give the solder cream its 'pasty' nature. Its tasks are to:

- keep the solder powder evenly dispersed throughout the paste, preventing particles from precipitating

- maintain paste consistency during application so that paste is applied where it is needed, and remains there
- retain components placed on it between the placement and reflow soldering operations
- clean the surface of the alloy powder and parts to be joined, and protect them from re-oxidation during the soldering cycle, so that the solder will melt, wet and spread to give metallic continuity and a reliably strong joint.

### **Types of flux**

The term 'flux' is used fairly loosely to describe a wide range of materials which have a fluxing action. These include thin, solvent-rich liquid fluxes and the highly viscous materials used in formulating pastes, as well as referring to solid flux bases such as rosin. To reduce the possibility of misunderstanding, we have tried to be consistent in using the term flux base for this last group of materials, and in referring to the mixture of flux, activators and printing vehicle used in solder paste manufacture as flux vehicle.

The flux vehicle generally has four constituents:

1. the flux base, dissolved in
2. a solvent mixture, with
3. activators, and blended with
4. thickeners and lubricants that determine the flow properties of the paste.

The flux, solvent and additives play a major role in determining the viscosity of the solder paste and the processing time prior to placement. Additives give the paste the correct flow characteristics.

Two types of chemical are involved in the fluxing function: the flux base and the activator, which enhances the fluxing ability of the system. Until recently, rosin (or colophony) has been the most widely-used and reliable flux base, presented in several standard strengths:

- rosin (R) flux – the weakest, containing only rosin without activators
- rosin mildly activated (RMA) flux – a system containing both rosin and a small quantity of activator.

Other pastes use the same range of alternative formulations (based on synthetic resins, or water-based and intended for aqueous cleaning).

Remember always that different manufacturers make totally different pastes, even with the same nominal specification, and we can never assume that claimed replacements are either exactly equivalent or even fit for purpose.

### **Solder powder**

Solder paste is a suspension of solder particles in a flux vehicle. The previous section has concentrated on performance aspects of the flux; this section deals with the metal which forms the major proportion of the paste by weight, even if only around half by volume.

Solder paste can be made from any solder alloy, but the most frequently used materials are tin-silver copper alloys, replacing the earlier tin-lead and tin-lead-silver eutectics.

Key parameters to be controlled are:

- particle shape
- size distribution
- oxide content

These are tailored to fit the needs of applications with respect to rheology and solder paste deposition and land pattern.

### **Particle shape**

In the past, some manufacturers advocated the use of non-spherical particles which could 'interlock'. There was some evidence that using spherical particles alone could induce **slump** and **outflow** of the paste as the flux melted.

**Slump** is when the particles sink just before melting occurs, leading either to solder bridging or unequal deposits (where paste on adjacent tracks was previously touching and then split unequally back onto the pads).

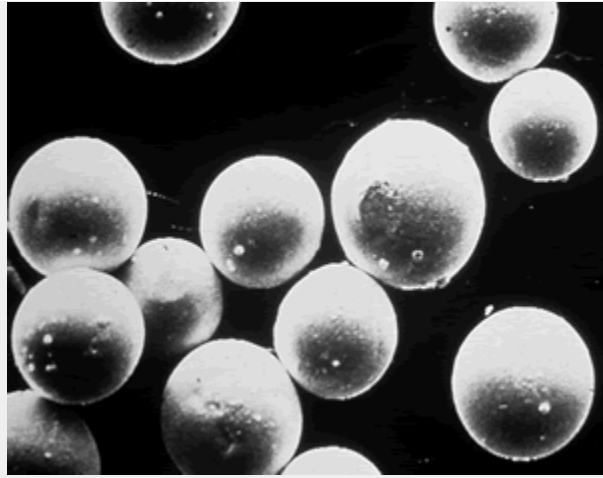
**Flow** is when particles which spread apart as the flux melts are 'stranded' at the edges of the fluxed area and remain as undesirable discrete solder balls, not drawn into the main solder fillet.

For some applications, and a small number of users, a proportion of non-spherical solder particles may still be specified, in order to retain as good a shape profile as possible throughout reflow. However, the prevailing belief in the industry is that solder particles should be as nearly spherical as possible (Figure 2), for the following reasons:

- a sphere is the physical object with the lowest surface area-to-volume ratio and hence, for a given oxide thickness, will contain the smallest amount of oxide

- non-spherical particles may jam the screen or stencil through which the paste is printed or clog the dispensing needle.

**Figure 2: Gas atomised solder powder**



Source: DEK Printing Machines

### **Powder size and size distribution**

Solder particles are sorted into various size ranges by sieving through meshes.

The relative dimensions of the meshes used are shown in Table 1.

<b>Table 1: Common mesh sizes used for sieving solder particles</b>	
<b>Mesh size</b>	<b>Particle sizes</b>
-325	less than 45µm diameter
-270	less than 55µm diameter
-200	less than 75µm diameter

-200, +325	between 45µm and 75µm diameter
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The mesh size is in units of 'lines-per-inch', with the minus sign meaning the particle fraction that has passed through the mesh is used and the plus sign meaning the fraction that has not passed through is used. The choice of particle size is a compromise between ease of application and definition of the applied paste pattern as against the problems of surface oxide and solder balling. The finer the particles:

- the easier their passage through the printing screen or syringe
- the finer the screen that can be used and the greater the definition of the print
- the greater the percentage of oxide for a given oxide layer thickness
- the higher the incidence of solder balling.

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, standardised on a limited number of particle size distributions. As shown in Table 2 below, the American ANSI/J-STD-005 standard, which has superseded IPC specification IPC-SF-819, defines six sizes of ball.

Table 2: Solder particle powder size designation in ANSI/J-STD-005				
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

- Size 1 was a component of solder paint, but is now obsolete
- Size 2 was the commonest material up to 1990, and is still in use for packages with greater than 0.76mm (0.030") pitch. If you try hard, then this can be used to print designs down to 0.63mm (0.025") pitch
- Sizes 3 and 4 are the current main runners: size 3 works to 0.38mm (0.015") pitch, and size 4 will print down to 0.20mm (0.008") pitch
- There is a move towards finer ball sizes, and some produce sizes 5 and 6, which have even smaller particles, and are intended for extreme fine pitch work.

'Dust', and the similarly-sized 'satellites' which sometimes accompany solder balls, are avoided because of their high oxide content. It is also important to avoid either over-size balls or aggregates of balls which will not pass through the stencil apertures. Both these requirements can be seen in the ANSI/J-STD-005 specification, which includes a specific test for maximum particle size.

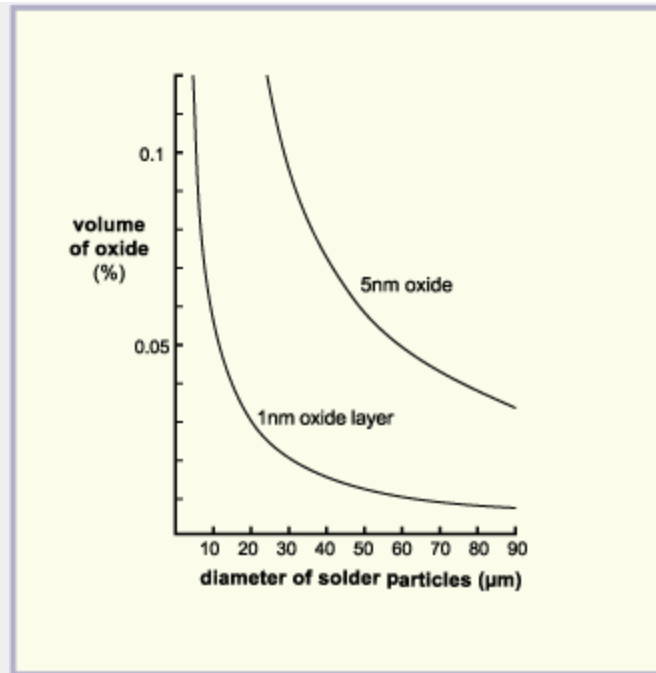
There is obviously a distribution of particle shape and size, depending on the method of manufacture, and yields frequently do not exceed 50% – the smaller the ball and the tighter the distribution, the lower the yield, which explains why fine pitch pastes are more expensive. To produce good quality powders with a reasonable yield has been the major thrust of work in recent years, and making powder to very accurate size distributions is 'the trade secret'.

### **Oxide content**

The oxide thickness on solder will depend on its exposure to the air, but some permanent oxide film will be established on a clean surface unless the oxide level is below 15ppm. Powder will start growing an oxide film immediately after manufacture, although the rate will depend on such factors as temperature and the presence of flux.

Unfortunately, the ratio of surface area to volume of a sphere increases as the particle size reduces and so, for a given oxide thickness, more oxide will be present in the paste. The degree to which this happens is shown in Figure 3.

**Figure 3: Relative volume of oxide as a function of particle size**



after Lea 1988

Truly oxide free powder is hardly attainable, and although excessive oxide content is detrimental to solderability and can cause solder balling, powder containing oxygen in the range 50–200ppm is generally considered satisfactory.

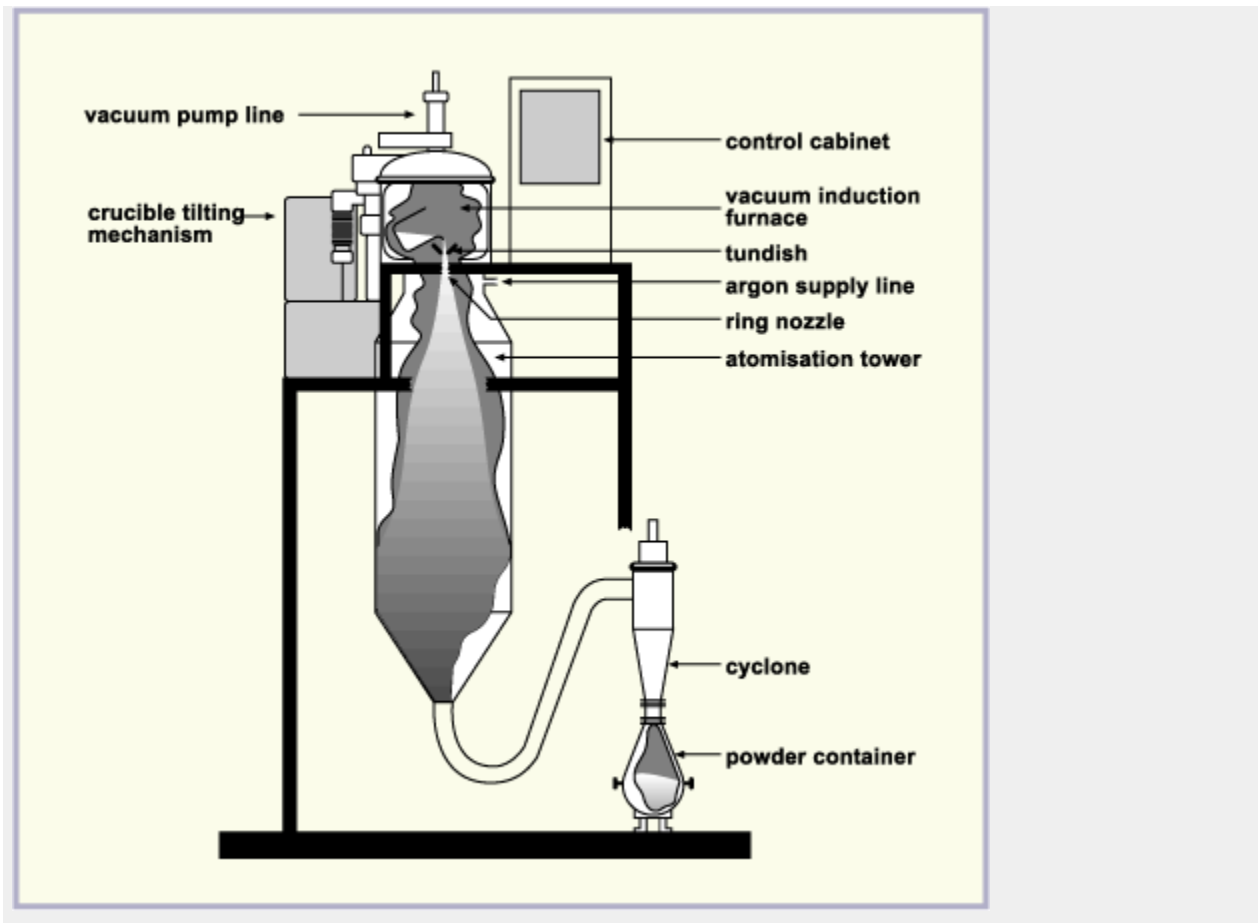
### Methods of manufacture

A **shot tower method** (as for lead shot) is still in use, but only for the large balls used for ball grid arrays (BGAs). Solder powders are produced by a variety of **atomisation processes**, where molten alloy is broken into particles using a jet of gas, a spinning disc, or an 'ultrasonic horn'. The powders produced have relatively high density, a good flow rate, and are spherical in shape.

Figure 4 is a schematic of an inert gas atomisation system, consisting of a vacuum induction furnace, tundish, ring nozzle, atomisation tower, cyclone, and powder collection container. The solder is melted under inert

gas to avoid evaporating the alloy components, and then dosed into the atomisation tower where the melt is disintegrated into powder by an energy-rich stream of inert gas. The process is carried out under inert gas at atmospheric pressure, and is able to produce high-quality powder.

**Figure 4: Schematic of tilting crucible inert gas atomisation system**



The shape of solder particles depends critically on the powder production process. Non-spherical particles and agglomerated clumps must be eliminated at atomisation, since this cannot be done during the next stage of sieving in nitrogen. Whilst this process will separate powders of

different sizes, irregularly shaped particles can pass a sieve with one dimension much longer than the mesh size.

For reasons associated with the nature of the process of blowing powder, its conversion into paste is often carried out at a different location. Care has to be taken during transit and storage to avoid both contamination by chemicals or foreign bodies and oxidation. Powder is stored in nitrogen, and there is a valid argument for enclosing the entire process, or using clean rooms, to ensure suitable conditions for manufacture

Source : [http://www.ami.ac.uk/courses/topics/0245\\_spb/index.html](http://www.ami.ac.uk/courses/topics/0245_spb/index.html)