

A Guide to Solder Paste



Choosing the Right Solder Paste

For many years, Nordson EFD has been formulating, manufacturing and supplying SolderPlus® solder pastes for dispense applications, SolderPlus® solder pastes for stencil printing, and FluxPlus™ flux pastes to customers worldwide. Our pastes are manufactured under highest quality standards and provide outstanding batch-to-batch consistency to provide our customers with high process efficiency.

Nordson EFD's SolderPlus® solder pastes are specifically formulated for dispensing application and provide unmatched performance. Combined with Nordson EFD dispensing systems, they ensure a high yield application process.

This document provides an introduction to the fundamentals of solder paste. While there are many possible options when formulating a solder paste, Nordson EFD's general purpose solder pastes will meet the requirements of most applications. For special requirements, Nordson EFD offers a wide range of specialized formulations. To find out which solder paste is the best solution for your application, please contact your Nordson EFD solder sales specialist for a free consultation.

1. Alloy Selection

The alloy requirements must be evaluated and an alloy identified as meeting all product requirements.



When choosing a solder alloy, there are four key considerations: lead content, melting temperature, alloy powder particle size and joint strength.

Lead content, melting temperature and strength are typically addressed at the same time. The Alloy Chart (Figure 1) lists melting and strength statistics, along with composition for 18 typical solder alloys.

At temperatures below the solidus, the alloy will be completely solid. At temperatures above the liquidus, the alloy will be completely liquid. In between, the alloy is in a plastic state and neither fully liquid nor fully solid, and strength is near zero. For best wetting, a peak temperature 15°C or more above liquidus is required. If a solder joint needs to retain physical integrity during a later operation, such as a second reflow process, the peak temperature of the later operation needs to be below the solidus temperature of the first alloy.

The solder alloy tensile strength values listed are valid at 25°C at a particular strain rate for a particular age of the alloy sample. Tensile strength drops as temperature increases. Near the solidus, tensile strength approaches zero.

When using strength values to make a decision, consider the values as a useful comparison to determine if one alloy is likely to be better than another. Include a factor of two or more as a safety margin for joint variability, and to compensate for any inaccuracy in the tensile strength value reported. Be mindful that alloys with higher solidus retain more strength at higher temperatures. Example: At 210°C Sn95 Ag5, which has a solidus of 221°C, is weaker than Sn5 Pb95, which has a solidus of 308°C, despite the higher tensile strength of Sn95 Ag5 at 25°C.

Having picked an alloy, the required particle size is the next item to identify. The Powder Size Chart (Figure 2) cross-references particle size to typical printing and dispensing requirements. The dimensions listed for gullwing, square/circle and dispense dot sizes represent the smallest feature recommended for that size powder. If the feature is smaller, the application requires the next smaller powder size.

Using too large a powder will cause printing and dispensing difficulties, compromising quality. Using a smaller powder will just cost more.

| Alloy Chart | | | | |
|--------------------|--------------|---------------|------------------------|-----------|
| Alloy: | Solidus (°C) | Liquidus (°C) | Tensile Strength (psi) | Lead-free |
| Sn42 Bi57.6 Ag0.4 | 137 | 139 | 4641 | ✓ |
| Sn42 Bi58 | 138 | | 8000 | ✓ |
| Sn43 Pb43 Bi14 | 144 | 163 | 6120 | |
| Sn62 Pb36 Ag2 | 179 | 189 | 6700 | |
| Sn63 Pb37 | 183 | | 6700 | |
| Sn60 Pb40 | 183 | 191 | 6200 | |
| Sn96.5 Ag3.0 Cu0.5 | 217 | 219 | 8900 | ✓ |
| Sn96.3 Ag3.7 | 221 | | 8900 | ✓ |
| Sn95 Ag5 | 221 | 245 | 10100 | ✓ |
| Sn100 | MP | 232 | 1800 | ✓ |
| Sn99.3 Cu0.7 | 227 | | n/a | ✓ |
| Sn95 Sb5 | 232 | 240 | 5900 | ✓ |
| Sn89 Sb10.5 Cu0.5 | 242 | 262 | 12000 | ✓ |
| Sn90 Sb10 | 250 | 257 | n/a | ✓ |
| Sn10 Pb88 Ag2 | 268 | 290 | 4900 | |
| Sn10 Pb90 | 275 | 302 | 4600 | |
| Sn5 Pb92.5 Ag2.5 | 287 | 296 | 4210 | |
| Sn5 Pb95 | 308 | 312 | 4190 | |

Figure 1

| Powder Size Chart | | | | |
|-------------------|----------------------|--------------------------|----------------------------------|-----------------------------|
| Powder Type | Powder Size (micron) | Gullwing Lead Pitch (mm) | Square/Circle Aperture (mm)/(in) | Dispense Dot Dia. (mm)/(in) |
| II | 45-75 μ | 0.65 / 0.025 | 0.65 / 0.025 | 0.80 / 0.030 |
| III | 25-45 μ | 0.50 / 0.020 | 0.50 / 0.020 | 0.50 / 0.020 |
| IV | 20-38 μ | 0.30 / 0.012 | 0.30 / 0.012 | 0.30 / 0.012 |
| V | 15-25 μ | 0.20 / 0.008 | 0.15 / 0.006 | 0.25 / 0.010 |
| VI | 5-15 μ | 0.10 / 0.004 | 0.05 / 0.002 | 0.10 / 0.004 |

Figure 2

2. Flux Type Selection

The flux types that are valid options must be identified. This is a process of elimination, where fluxes with unacceptable criteria are removed from consideration.



Both specifications and industry usage have contributed to current naming conventions for fluxes. Industry convention includes five basic categories of fluxes to choose from: R, RMA, RA, NC and WS. The following summary is an explanation of how specifications affected the categories.

There are four categories of flux to choose from, as defined by Military Specification QQ-S-571E:

- Rosin (R)
- Rosin or Resin Mildly Activated (RMA)
- Rosin or Resin Activated (RA)
- Non-rosin or non-resin, commonly referred to in the industry as Water Soluble (WS).

Each category of flux is available with a variety of activity levels, with the limits of each defined by applicable test results.

IPC also has a flux rating system. The system uses four characters to describe any flux as published in J-STD-004. These four characters describe the product in terms of material type, including but not limited to such categories as rosin and inorganic, along with an approximation of activity level and halide content. Example: a halide-free, rosin-based solder paste with low activity is categorized as ROL0. RO stands for rosin, the L is for low activity and the number 0 is for no detectable halides.

Flux type:

- RO: Rosin
- OR: Water soluble

Activity level:

- Low: L
- Medium: M
- High: H

Halides detectable

- No: 0
- Yes: 1

In addition, the IPC standard added a category of flux called No Clean (NC). This new category of flux is defined by non-tacky residue and compliance with a Surface Insulation Resistance (SIR) test to a value of $1 \times 10^8 \Omega$.

Each of the five flux categories can be described in brief by noting their activity, the physical qualities of their residue and the cleaning methods that may be used in their removal.

Rosin (R) flux consists of rosin and solvent. Rosin flux has very low activity and is suitable only for clean and easy-to-solder surfaces. IPC classification is usually ROL0. R residue is hard, non-corrosive, non-conductive, and may be left on many types of assemblies. Residue may be removed with an appropriate solvent.

No Clean (NC) flux consists of rosin, solvent and a small amount of activator. NC flux typically has low-to-moderate activity and is suited to easily solderable surfaces. IPC classification is

usually ROL0 or ROL1. NC residue is clear, hard, non-corrosive, non-conductive, and designed to be left on many types of assemblies. Residue may be removed with an appropriate solvent. Some, but not all, NC fluxes are more difficult to remove than RMA fluxes.

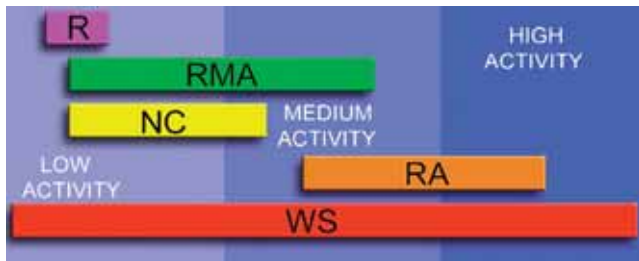
Rosin mildly activated (RMA) flux consists of rosin, solvent and a small amount of activator. Most RMA flux is fairly low in activity and best suited to easily solderable surfaces. IPC classification is usually ROL0, ROL1, ROM0 or ROM1. RMA flux residue is clear and soft. Most are non-corrosive and nonconductive. Cleaning requirements will be based on the activity of the flux and the product it is used on. Many RMA fluxes pass SIR testing as a NC flux. Residue may be removed with an appropriate solvent.

Rosin activated (RA) flux consists of rosin, solvent and aggressive activators. RA flux has similar and higher activity than RMA for moderately and highly oxidized surfaces. IPC classification is usually ROM0, ROM1, ROH0 or ROH1. RA flux residue is considered corrosive. Assemblies sensitive to corrosion or the possibility of electrical conduction through the residue should be cleaned as soon as possible after assembly. Residue may be removed with an appropriate solvent.

Water soluble (WS) flux consists of organic acids, thixotrope and solvent. WS flux comes in a wide range of activity levels, from no activity to extremely high activity for soldering to even the most difficult surfaces, such as stainless steel. Because WS flux covers all activity ranges, the product specification must be referenced for corrosion and electrical conductivity hazards. IPC classification normally starts with OR for organic. They come in L, M, H activity levels and halide content of 0 or 1. By definition, residue may be removed with water.

Flux Comparison Chart

The Flux Comparison Chart is a graphical representation of the typical activity range of each flux category, and the activity ranges relative to each other. Note that there is overlap of activity levels between flux groups.



| Solderability Matrix | | | | | |
|-----------------------|----------------|----|----|----|------------------|
| Finish | RMA | RA | WS | NC | High Activity WS |
| Aluminum | ✗ | ✗ | ✗ | ✗ | ✗ |
| Beryllium Copper | ✓ | ✓ | ✓ | ✓ | ✗ |
| Brass | ☎ | ✓ | ☎ | ☎ | ✓ |
| Bronze | ☎ | ✓ | ☎ | ☎ | ✓ |
| Cadmium | ✓ | ✓ | ✓ | ▲ | ✗ |
| Chromium | Non-solderable | | | | |
| Copper | ✓ | ✓ | ✓ | ✓ | ✗ |
| Galvanized Steel | ✗ | ▲ | ▲ | ✗ | ✓ |
| Gold | ✓ | ✓ | ✓ | ✓ | ✗ |
| Kovar | ▲ | ✓ | ✓ | ✗ | ✗ |
| Magnesium | Non-solderable | | | | |
| Mild Steel | ✗ | ▲ | ✗ | ✗ | ✓ |
| Monel | ✗ | ▲ | ▲ | ✗ | ✓ |
| Nichrome | ✗ | ✗ | ✗ | ✗ | ✓ |
| Nickel | ✓ | ✓ | ✓ | ▲ | ✗ |
| Nickel Iron / Alloy42 | ▲ | ✓ | ▲ | ✗ | ✓ |
| Nickel Silver | ✓ | ✓ | ✓ | ▲ | ✗ |
| Palladium | ✓ | ✓ | ✓ | ✓ | ✗ |
| Platinum | ✓ | ✓ | ✓ | ✓ | ✗ |
| Silver | ✓ | ✓ | ✓ | ✓ | ✗ |
| Solder Plated | ✓ | ✓ | ✓ | ✓ | ✗ |
| Stainless Steel | ✗ | ✗ | ✗ | ✗ | ☎ |
| Tin | ✓ | ✓ | ✓ | ✓ | ✗ |
| Titanium | Non-solderable | | | | |
| Zinc | ✗ | ▲ | ▲ | ✗ | ✓ |

Key: ✓ recommended ▲ wets clean surfaces
 ✗ not recommended ☎ alloy specific

The Solderability Matrix shows compatibility of the various flux types with common metals. For brass, bronze and stainless steel, there is enough variety in alloy composition that each must be checked against the flux type one wishes to use.

3. Special Flux Characteristics

Requirements such as difficult-to-solder surfaces, rapid reflow conditions, cleaning options and solder joint voiding concerns should be considered when choosing a paste.



The last area to consider when finalizing solder paste selection is any other special characteristics. Two flux formulas can differ greatly in performance, despite having the same QQ-S-571E and J-STD-004 classifications. Solder pastes with specific characteristics can be used to solve technical assembly problems that other forms of solder do not. The following are examples of flux characteristics that modify how a solder paste performs.

Reduced Slump: The reduction of solder paste spread after deposition, to minimize definition loss. This feature is important when pads are close together and bridging is a risk.

Restricted Residue: The flux residue remains either on or very close to the fillet after reflow. This feature is most important with NC formulations where the joint is visible or the spread of flux to surrounding areas can cause a problem.

Halide-free: Halide-free solder pastes have an IPC J-STD-004A rating of 0 for the fourth character. Example: ROL0. Halides may be found in some flux activators. They assist in oxide removal due to their high energy state. Halides are materials that contain a halogen: Chloride, Bromide, Fluoride or Iodide.

Low Residue: The quantity of flux residue left after reflow is less than with normal solder pastes. Either there is less flux to begin with, or a larger percentage evaporates as part of the reflow process.

Difficult to Solder Surfaces: Difficult-to-wet metals and highly oxidized surfaces can both require flux with higher activity or different activators that work better with the metal involved. Aged components, lead finishes such as Alloy42 and the like are a special consideration for flux selection alternatives.

Gap Filling and/or Vertical Surfaces: The flux is designed to hold the alloy in place until liquidus is reached. These formulas are suited to bridging gaps, filling holes and soldering joints on vertical surfaces.

Note: They are not normally successful in forcing a bridge between two adjacent pads on a circuit board in place of a zero ohm resistor.

Rapid Reflow: A term used to describe the heating of solder paste in under 5 seconds. A rapid reflow solder paste will not spatter when heated as quickly as 0.25 second. Typical reflow methods that achieve rapid reflow include laser, solder iron, hot bar and induction.

Pin Transfer or Dipping: An application technique where the solder is applied by dipping a component or pin into the solder paste. A thin, consistent layer of solder paste sticks to the component. This technique is useful in applying solder to products that do not lend themselves to printing or dispensing, such as pin arrays.

24-hour: The working life of printing paste. It is designed to be used for up to 24 hours before print defects due to drying out begin.

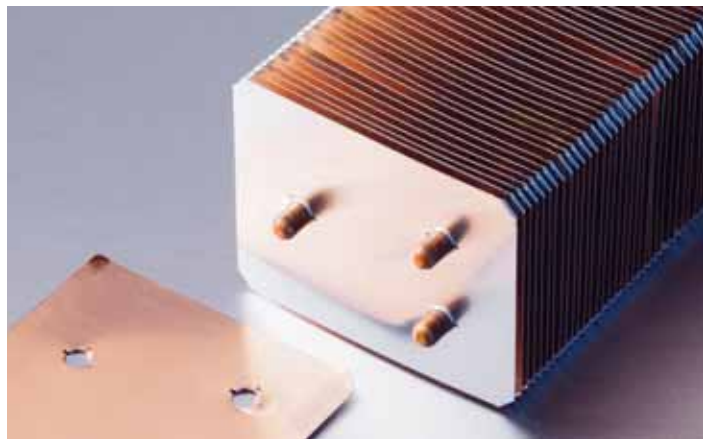
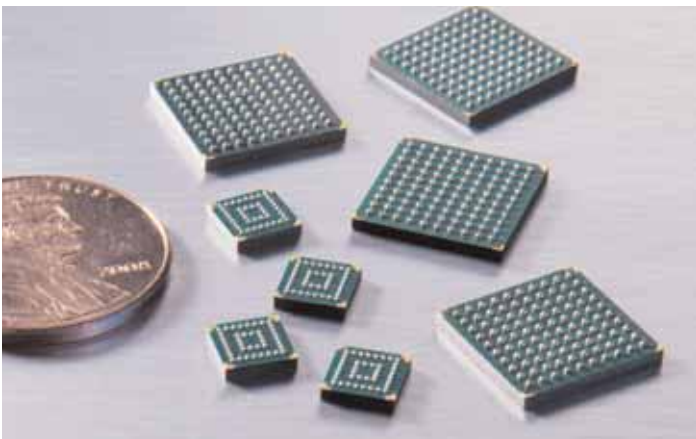
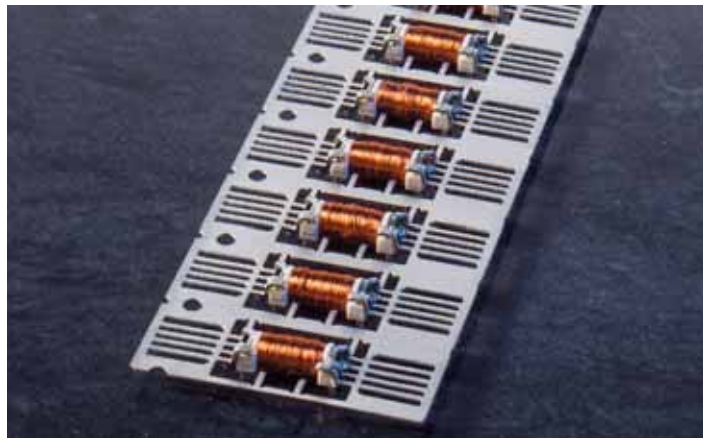
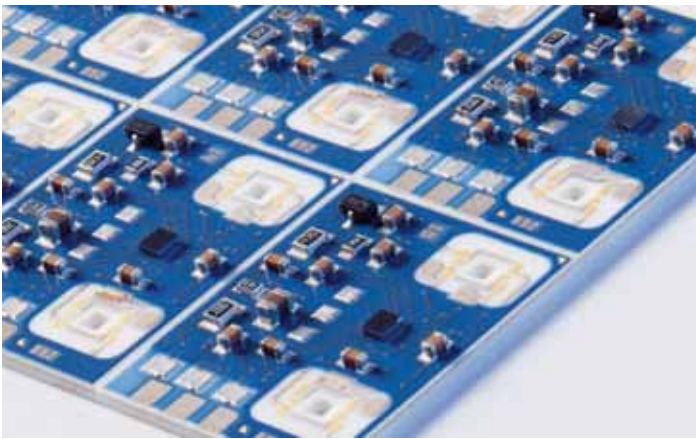
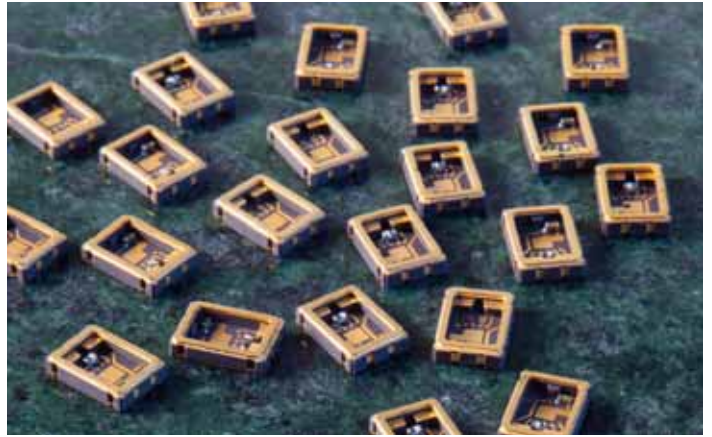
Low Void: IPC-7097A is the Specification for the Design and Assembly Process Implementation for BGAs. The inspection criteria for Ball Grid Array (BGA) and MicroBGA often call for voiding under 20%. A low void solder paste is required to meet the very low voiding limits for Class 3 assemblies.

Conclusion

This guide covers the most significant steps in selecting a solder paste. There are additional details of alloy and flux performance not covered here that can be very important in the solder paste selection process. It is always worth a call to your Nordson EFD solder sales specialist to review your requirements to ensure you are using the best solder paste for the job.

The goal of any assembly operation is to maximize quality and throughput. Quality is maximized by choosing a flux that offers the best performance with the materials, geometry and heating processes used to manufacture a product. Throughput is maximized by picking a solder product that allows for the most rapid processing possible. It is the job of the solder paste formulator to produce a product that gives the best combination of both.

There are more details of alloy and flux selection than those covered in this guide. There are differences in wetting characteristics, plastic deformation characteristics and the effects of alloy contamination during the soldering process that can all play significant roles in solder paste selection. Above all, not all solder pastes are created equal, even if they seem to be. With decades of experience in precision fluid dispensing as well as solder paste formulation, Nordson EFD offers a wide range of solder products with exceptional batch-to-batch consistency, including some of the highest-performing dispensing pastes in the industry.



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