

CHAPTER II

THEORY AND LITERATURE REVIEW

2.1 Introduction of soldering and solder paste

Soft-soldering is the joining together of two metals using a low melting temperature, tin-containing alloys as the filler metal, these alloys as the filler metal, these alloy being termed internationally “soft solders”. The melting temperature of the filler metal-the solder alloy- is usually very much lower than the melting point of the basis metal or the metal being jointed. Furthermore, in soft-soldering the filler metal wets and alloys with the basis metals and then, by capillary action is drawn into and fills the gap between them, thus forming a metallurgical bond between the components of the joint. The term “soldering” generally implies that the joining process takes place at the temperature below 450 °C (and often below 300 °C).⁴

The basis of soldering involved 4 factors

1. Solder alloy are the family of alloys almost exclusively containing tin, which are used in soft-soldering sometimes. Solder act by:
 - Wetting the basis metal surfaces forming the joint;
 - Flowing between these surfaces so as to fill completely the space between them;
 - Metallurgical bonding to the surfaces when solidified.
2. Heat activated the flux and melted the solder alloy for joined together. Form thermal point of view the soldering process must satisfy two confliction requirement;
 - The surface to be soldered must be sufficiently hot to permit wetting by the solder;
 - The components to be soldered should not be heated to a temperature at which they will be damaged.
3. Basic metal placed on PCB board must be jointed with electrical parts.
4. Fluxes have three major functions.
 - Chemical function: The main task of the flux is to remove tarnish films from surfaces and to protect the cleaned surface against re-oxidation.

- Thermal function: The flux assisting the transfer of heat from the heat source to the joint area
- Physical function: The reaction products must be removed from the surfaces to allow the solder to come into intimate contact with the base metal surfaces

These functions influence the surface tensions of the basic metal, the solder, the interfaces and hence the effect upon the wetting conditions.

Solder paste is a seemingly simple material that forms one of the foundations of the surface mount assemble operation. If the solder does not do its job correctly then first pass yield will be severely reduced.⁵

2.2 Solder paste composition (Solder Cream)

Solder paste is a suspension of solder powder particles in flux, to which special agents have been added. Its use is increasing rapidly, not only in electronics but also in many other fields of soldering.

The range of properties of currently existing solder pastes is still in sufficient to meet all the requirements for reflow soldering. Hence, the development of new pastes is desirable, for instance suitable rapid heating (as with a laser beam) and for very slow heating (as in an air furnace).

If the paste is heated above the melting temperature of solder alloy contained in it, the alloy particles will coalesce to form one volume of metal. In most cases, however, this metal contains a large number of voids or flux filled pores (see Figure 2.1)



Figure 2.1: Cross-section of a component lead, which has been reflowing soldered to an alumina substrate using a solder paste. The solder joint contains a large number of holes, which is not an exception.⁶

Most solder pastes contain 75 to 85 mass percent of solder metal, which is about 25 to 40 volume percent (see Figure 2.2). The metal particles are therefore not in manual contact when the solder paste are homogeneously distributed. Dispensing agents are added to prevent the separation of the heavy metal from the light vehicle. However, shocks during transport may impair the stability and sometimes the paste settles in which case stirring can restore uniformity of composition.

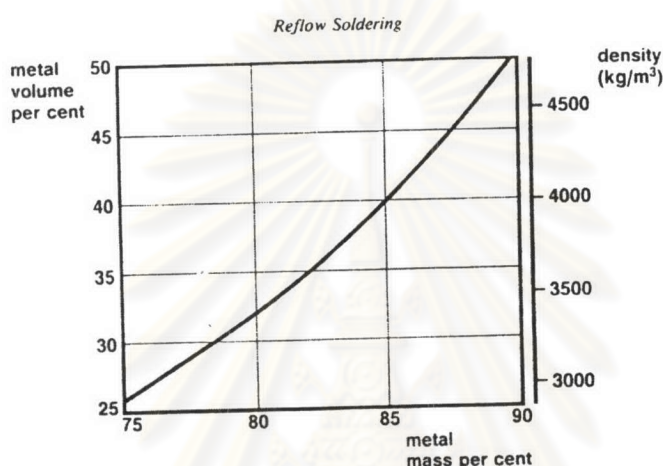


Figure 2.2: Relationship between volume percent and mass percent of solder metal in a solder paste. Density of the paste is also shown. (The curve is valid for solder tin60-lead40 and a particular resin-based vehicle) ⁵

For the application of the paste: rheological such as viscosity and thixotropy are importance. These depend on the volume fraction, the size and size distribution of metal particles, and the agent added.

2.3 Solder powder particle size and shape

Powder particle shape determines the oxide content of powder and as well as the paste's printability. Spherical powders are preferred over elliptical powders. The lower the surface area, the lower the oxidation. Hence the finer and irregularly shaped powders, with their larger surface area, have a higher metal oxide content than spherical powders.

Solder pastes containing powders of irregular shape are prone to clog screens and stencils. Figure 2.3 shows acceptable and unacceptable solder particles for use in solder paste. It should be notes that the pastes do not have to be as perfect, as shown in the picture 2.3 (a.) Some variation in particle sizes and shapes is only to be expected.

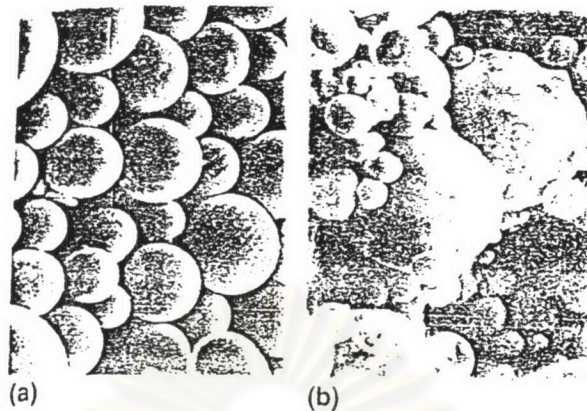


Figure 2.3: (a) Perfectly spherical and (b) unacceptable solder particles for solder paste⁶

Printing problems are encountered with solder pastes containing powder particles that are large in diameter, which readily clog screen and stencils. On the other hand, a solder paste with powder particles that are too small is prone to form solder balls during reflow.

The commonly used powder size is $-200/+325$ mesh; that is, at least 99 % by weight of powder particles will pass through a 200 (holes/square inch) mesh and less than 20% of the powder particles by weight will pass through a 325 mesh.

Criteria when selecting an alloy for solder paste.

1. Should be easily processed in to powder.
2. Must form metallurgical bond with surfaces to be jointed.
3. Alloy should be of high purity.
4. In its molten state, the alloy should have good flow properties and capillary action.
5. In most solder paste application, it should be able to wet the surfaces to be bonded by means fluxes.
6. It must not soften or re-melt at the temperature at which the device will be operating.
7. Its melting point should be compatible with board components and substrate material.
8. It should have as narrow a plastic or pasty range as possible.⁵

Table.2.1 General alloys available.⁷

Type of alloy	Melting range (°C)
60/40 Sn/Pb	183-190
63/37 Sn/Pb	183-184
62/36/2 Sn/Pb/Ag	178
96/4 Sn/Ag	221
99/1 Sn/Cu	227

2.4 Solder paste flux composition

In principle, the same fluxes are used in solder pastes as for machine soldering. Owing to the relatively large surface area of solder particles, an effective fluxing is needed and a non-activated flux may be inadequate for the complete coalescence of the particles. The fluxes in the pastes are characterized in the same way as the fluxes for cored solder wire. The colophony is either a pure colophony WW or modified type for better resistance and solubility. These materials may be referred to generically as resins and as used herein the term "resin" includes natural resins such as rosin, chemically modified rosin, and synthetic resins. To form solder paste fluxes the resins are dispersed in solvents, together with additional activators and gelling agents.

The solvent is selected regarding its ability to dissolve the colophony, its low rate of evaporation at room (but with sufficient rate at preheat temperature), its low flammability and its compatibility with the other flux components, whereas its boiling point should lie below the soldering temperature.

Activators are added to decompose and remove any oxide film existing in the portion where soldering is going to be carried out, and are usually organic compounds containing halides, typically amine hydrohalogenides, such as diethylamine hydrochloride or weak halide-free organic acids. The resin may be a weak acidic activator but it is also added to protect the metals from oxidation during solder paste reflow. The organic solvent dissolves and supplies the resin and activators to the portion to be soldered and is typically an alcohol, glycol, glycol ether, or ester.

The activator should be selected by 2 major factors

1. Flux efficacy is the ability of the flux to promote solder wetting. Efficacy is closely related to chemical activity.

2. Flux corrosive is the ability of flux residues to affect the soldered products after the soldering process.

Electronic devices all undergo continuous temperature variation except for those used under constant temperature conditions and, in extreme cases such as equipment in vehicles, the temperature variation may be as great as 80.degree. C. or more. Consequently, flux residues on printed circuit boards also undergo continual temperature fluctuations, and have therefore been subject to cracking and deterioration, which has resulted in impaired reliability.

The thickener is the thickener gives the thixotropy and has the purpose of preventing the sagging of the powder particles, and thus producing good resolution during printing or screening; its effect, however, rapidly vanishes when the temperature is increased and therefore the colophony content of the paste should be above a lower limit, depending on the metal content.

The rheological properties of the solder paste dictate the screen print-ability of the material. Hence, in order to obtain good line definition on the PCB, the rheology of the paste must fall within a relatively narrow process window. Solder paste rheology is largely determined by those components of the solder paste which are collectively known as the vehicle. Generally, solder paste vehicles consist of solvents to dissolve the rosin fluxes or fluxing agents and the activators, and other additives to achieve the proper rheology. Currently, cyclohexanol(sorbitol) derivatives, various Cellosolve TM. mono- and dialkyl ethers of ethylene glycol and derivatives thereof are used in commercial solder pastes.¹

2.5 Solder paste flux application

Soldering will not take place without solder paste flux, which is required to improve the coalescence of the molten solder particles and the wetting of metallic substrates. In particular, solder paste flux removes oxide layers from the solder and joint surfaces, transports reaction products away from the soldering zone, and protects the clean joint surfaces from oxidation until soldering has taken place. Solder paste flux also acts as a heat transfer medium, which ensures that all parts of the joint reach a temperature above the melting point of the solder particles.

2.6 Tackiness of the solder paste

Tackiness is the ability of solder paste to hold the surface mount components in place after placement but before reflow soldering. The tackiness of a paste is an indicator of whether the working life of a paste has elapsed. If a tackiness check reveals that a paste has been pressed in to service past its working life, the paste is no longer useful to hold components in place during placement and in handling before reflow.

The tackiness of pastes depends on several factors, such as component placing pressure, pressure, pressure dwell time, contact area, speed of disrapture and paste drying time before placing of components.

2.7 Viscosity of the solder paste

Solder paste are thixotropic fluids. When deformed at a constant rate of shear stress or strain rate, the solder paste viscosity will decrease over time, thus implying that its structure breaks down progressively. Furthermore, the viscosity of the solder paste decreases as the shear stress on the solder paste increases. Explained simply, the paste is thin when a shear stress is applied (as with a squeegee), but thick when no stress is applied. This property is highly desirable for printing, as suggested by figure 2.4

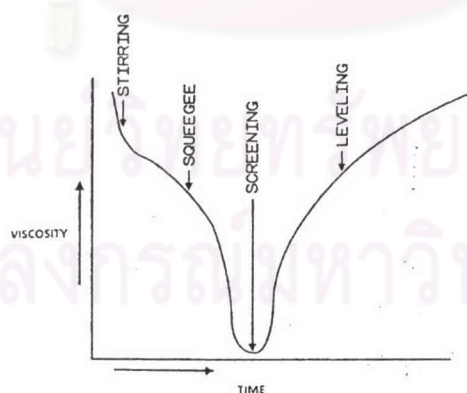


Figure 2.4: Typical solder paste viscosity change during screen printing operation⁶

The solder paste will stay on top of the open of the screen or stencil, flowing only when the squeegee induces a stress on it.

Once the paste has been deposited on the lands, the squeegee-induced shear rate is removed and the paste returns to its highly viscous form, thus staying on the lands and not

flowing onto the non-metalized surface of the board. In addition to shear force, particle size and ambient temperature have an effect on solder paste viscosity. Figure 2.5 represents the decrease in viscosity that occurs as shear force or temperature is increase or particle size is decreased (finer particle)

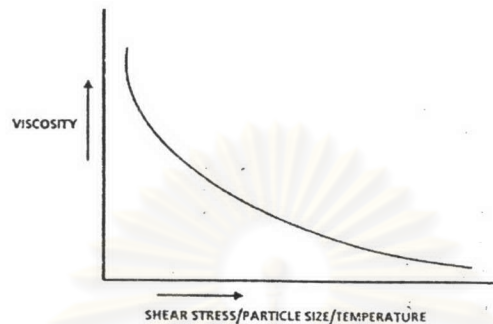


Figure 2.5: Impact of increasing shears force and temperature and decreasing particle size on solder paste viscosity with identical metal content and flux vehicle.⁶

Its should be note that Figure 2.5 is intend to show the effect on viscosity (on the Y axis) of only one variable (on the X axis) at a time. The reason for combining them is to simply illustrate a similar effect of these three variables on viscosity.

Just prior to application, the solder paste viscosity should be measured at 25 °C using a Brookfield viscometer. There are various sizes of spindles (TA, TB, TC, TD, TE, TF, etc); the TF spindle is the industry standard for solder paste viscosity measurement at 5 RPM.

The solder paste should be inspected visually for appearance: a homogeneous, light to medium gray paste is desirable. A thin layer of flux that makes the contour of solder particle still perceptible is acceptable. It should not exhibit a dry crusty appearance. To inspect for foreign substances, lumpiness, or a crusted surface, the solder paste may be stirred with a clean spatula.

2.8 Solder ball

Solder ball are small spherical particles of solder, usually 2 to 5 mils in diameter, which reside on the nonmetallic surfaces of the board. Solder balls, especially the mobile ones, are reliability hazard because potentially they can short metallic conductors at any

time during the life of substrate. There are two mechanisms by which solder ball are formed.

1. Solder Balls are caused by very fine powder particles in the solder paste. They are carried away from the main solder deposit as the flux melts and flow before solder itself melt. This happen when the paste deposited outside the land area ether by design (screen opening is larger than the land area) or by misregistration. These small powder particles then lose contact with the larger solder paste deposit and when solder melt; each particle becomes a small solder ball at the periphery of the original paste deposit. A collection of small solder ball around the main solder deposit is called a "halo".

2. Solder ball are also formed when the oxide layer on the surface of the solder particles is so thick that the rosin flux and any activator in the paste is not sufficient to remove it. Since oxides cannot melt at soldering temperatures, it is pushed aside as solder ball as solder ball by surrounding oxide free molten solder. Solder balls formed in this manner are usually larger than those formed by the first mechanism because of presence of surface oxide which is less dense than the metal.⁶

2.9 Slump

Slump is the ability of the solder to spread out after being deposit on the lands. For good soldering results, solder paste slump must be minimized. Slump also depends on the percentage of metal in the solder paste. The most reliable way to control slump is to establish bounds within which slumping is not a problem and ensure that the paste remains within those bounds. Excessive slump of a paste can cause bridging as shown in figure 2.6

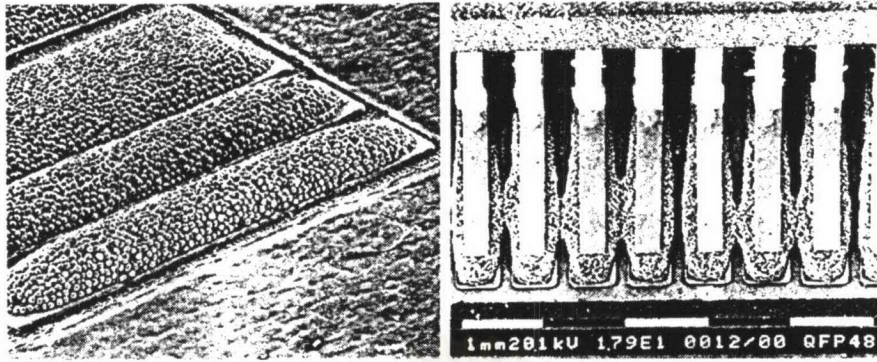


Figure 2.6: Slump of solder paste after rather rapid heating to about 100°C. Left: paste without a placed component. Right: Contract between colder pastes of adjacent solder lands by paste flow.⁸

2.10 Printability property

The printability of solder paste is reflected in the accuracy and reproducibility of the screened or stenciled solder paste pattern onto the land patterns. The printability of solder paste, which is one of the most critical tests, should be determined according to the following experiments. Dummy boards can be used for test substrates.

1. Weigh five cleaned dummy board substrates before (W_1) and after (W_2) the paste is screened or stenciled on. Use five substrates for each method of application, to get average data.
2. Determine the weight of the solder paste applied to each board by the formula $W_2 - W_1$
3. Measure and record the paste height at four predetermined points on each substrate, using a depth scope.
4. Perform steps 1 to 3 for freshly removed solder paste and for solder paste exposed to the atmosphere for 4 hours.

The acceptance criteria for use of that particular solder paste should be as follows

- The solder paste weight should not vary more than 10 % among the average measurements taken on one substrate.
- The paste height should not vary more than ± 1 mil among the average measurements taken on one substrate. The acceptable paste height range is 8-10

mils. Commonly an 8 to 10 mil paste thickness is used with stencil (4-6 mils for fine pitch packages). In addition to stencil thickness. The condition of printing equipment determines print height.

- The solder paste pattern should have uniform coverage, without stringing and without separation of flux and solder, and it should print without forming a peak.⁵

2.11 Wetting effect and de-wetting

Wetting of the basis metal surfaces by the molten solder is the primary essential for soldering to take place, since without it the solder will not spread over the surfaces and will not be drawn into joint crevices by capillary action. Moreover, this wetting action must usually occur quickly for a soldering process to be viable from the production standpoint. Nevertheless, a finite time is required for wetting to be established and for capillary penetration to occur; in the general, raising the soldering temperature gives rise to easier wetting.

The process of wetting of a metal surface by molten solder is relatively complex one. Nearly all-soldering alloys contain tin and, in the most commonly used binary tin-lead solders, tin is the active constituent, which promotes wetting while the lead is an inactive diluent's. Wetting results from mutual solubility of tin the liquid solder and the substrate, or reaction between solder and substrate which usually results in the presence, at the solder/basis metal interface, of layers of intermetallic compound, for example FeSn_2 when the substrate is the iron-based, and Cu_6Sn_5 , together perhaps with a tenuous layer of Cu_3Sn , when copper is being soldered, Figure 2.7.

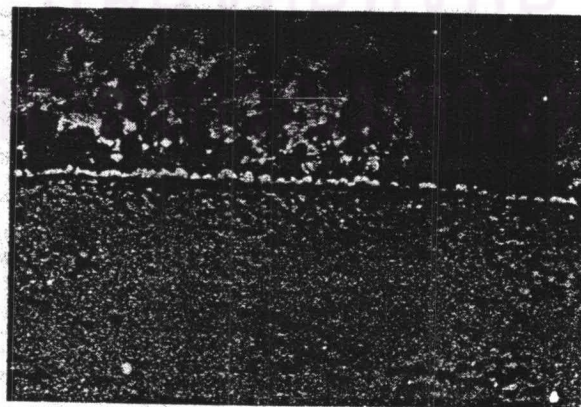


Figure 2.7: Layers of intermetallic compound formed at the interface when molten solder wets a clean copper surface; the thinner, darker layer adjacent to the basis copper is

Cu_3Sn (and is not always visible in micro sections), while the thicker layer adjacent to the solder film is Cu_6Sn_5 .⁴

To assist in the wetting of the basis metal surfaces in a joint by molten solder, a flux, which is a weak acid, must be present to dissolve the thin oxide films already present on the surfaces of the components and on the solder itself and to prevent oxidation during joint formation.

The amount of wetting and spreading of solder that occurs depends on the free energies are represented by interfacial tensions (γ) acting along the surface, the equilibrium condition for a pool of molten solder, lying under a flux on a horizontal metal surface which is heated, is denoted theoretically by the diagram seen in Figure 2.8

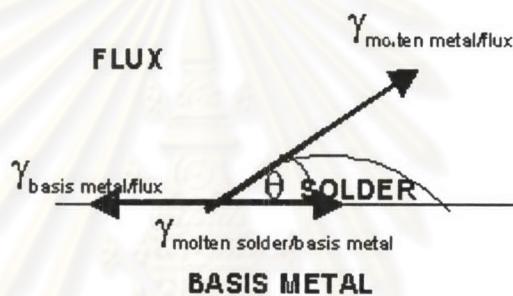


Figure 2.8: Diagram illustrating the balance of interfacial tensions occurring when a droplet of molten solder rests in equilibrium in the presence of flux on a surface it has wetted and the equation:⁴

$$\gamma_A = \gamma_B + \gamma_C \cos \theta$$

γ_A is the interfacial tension between the basis metal and the flux.

γ_B is the interfacial tension between the basis metal and the molten solder.

γ_C is the interfacial tension between the flux and molten solder.

and θ is contact angle (dihedral angle) between the basis metal and

the solder.

Thus the surface tension between flux and basis metal is balanced by the combined values at solder/basis metal interfacial tension at the solder /basis interfaces. As the interfacial tension at the solder/basis metal interface decreases, due to a metallurgical

alloying process, there will be a greater force spreading the solder over the surface, and θ will be caused to decrease in order to maintain the balance of forces. With perfect wetting, this contact angle should approach zero, Figure 2.9, corresponding to infinite spreading of solder, but in the practice other factors, such as surface roughness, have a limiting influence. The force giving rise to spreading also provide those necessary for capillary flow into a narrow joint gap, and it is generally accepted that good capillary flow is obtained when the contact angle is less than about 10° .

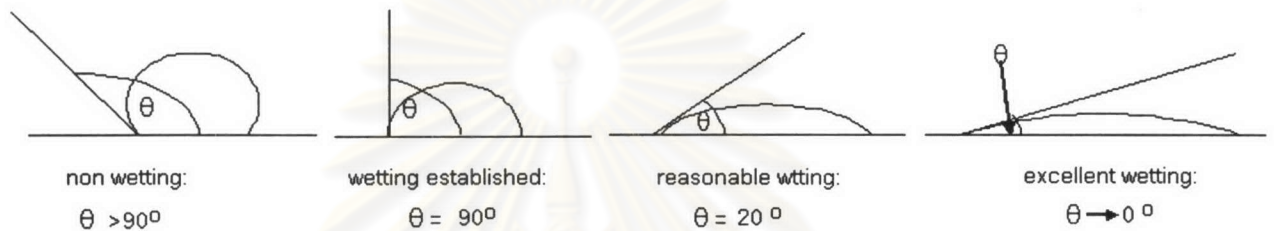


Figure 2.9: Diagram of relationship of contract angle between droplet of molten solder, and a surface on which it is lying, and degree or ease of wetting (solderability of the surface) ⁴

With certain surface conditions, after initial wetting and spreading have occurred, that is pronounced increase of contact angle so that the solder retracts in globule or dewets, leaving only an extremely thin film of solder, with a matt appearance, on the surface of which the globule rest. This dewetting is as undesirable as incomplete wetting in the first place, since it may reduce both the quantity and the continuity of the solder in the joint. Moreover, the strength of the bond between any solder remaining within the joint and an inherently dewetting surface is less than on a perfectly wetted substrate. A common cause of dewetting is the presence either on, or embedded in, the work piece surface, of an extremely thin but discontinuous, film of a material which is insoluble in flux and will not react with solder. Incomplete removal of the oxide film, or the presence of abrasive particles embedded in the surface, can give rise to dewetting, but an initially wetted surface may dewet as soldering continues or else an incompletely wetted surface may undergo a transition to a dewetted surface with longer contact times, due to the presence of a contaminant on the surface.

Dewetting is normally an indication of inadequate surface preparation and, when the whole surface is affected, re-soldering will simply alter the physical size, shape and

distribution of the solder globules, so that the overall visual appearance may change but the defect is still present. Often it is necessary to re-prepare the surface before good wetting can be achieved.⁴

2.12 Corrosive

Corrosion by flux residues is the unwanted chemical attack by these residues on the solder product during its lifetime. The residues originated from flux vapors, heated flux, and non-heated flux and their effect may range from mere discoloration to a complete destruction of the functioning of the product. Closely connect to corrosions the question of reduction of surface resistant under the influence of flux residue. A prediction of failure by corrosion or an unacceptable decrease in surface resistance is hard to give, and no generally accepted test methods are available. Difference methods are often applied in combination in order to increase the reliability of the predictions.

The testing methods can be devised into two groups:

- Test on the flux itself, neglecting the influence of the soldering operation on it;
- Test on boards after soldering, in which all-processing treatments of the product under taken into account.⁵

2.13 Electric insulation resistance

The surface resistance of a soldered board is very important because it may affect the electronic functioning of circuit on the board, especially in areas where high impedances are present. It may also give an indication of the possibility of corrosion caused by ionic transport across the surface

In a resistance measurement, use is made of a printed test pattern on a piece of board under relevant test conditions. The IEC method applies a ring and disc pattern that is submitted to a 'Damp Heat Steady State' test of 4 days' duration. The resistance measurement is taken after 1 minute at 500 volts.

2.14 Metal content

The metal content in the solder paste determines the solder fillet size. Fillet size increase with an increase in the percentage of metal, but the tendency for solder bridging

also increases with increase in metal content at a given viscosity. A higher metal content will result in higher thickness of the reflowed solder as shown in the below table

Table 2.2:The relative of metal content and thickness⁸

Metal content (%)	Thickness (inch)	
	Wet solder paste	Reflowed solder
90	0.009	0.0045
85	0.009	0.0035
80	0.009	0.0025
75	0.009	0.0020

As the above table indicates, the final thickness of reflowed solder can vary from 50% of paste thickness for 90% metal content to as low as 22 %.

2.15 Surface Mount Technology (SMT) Process

2.15.1 Solder paste printing processes

In the printing solder paste; the substrate is placed on the work holder, held firmly by vacuum or mechanically, and aligned with the aid of tooling pins. Either a screen and stencil is used to apply solder paste. Figure 2.10 and 2.11 present cross sectional and top view, respectively, which show the major difference between screens and stencils. The frame of the screens and stencils are similar; the differences lie in the construction of individual openings used for depositing the solder paste. Figure 2.11 shows schematically a screen and three different type of stencil. Figure 2.12 gives closed up photographic views corresponding to the diagram of figure 2.12 figure 2.11 show only one PLCC on a screen/stencil and figure 2.12 shows opening for only a few components, in the reality there are many components on the screens and stencils. The number of components on the screen/stencil matches the number of components on the board.

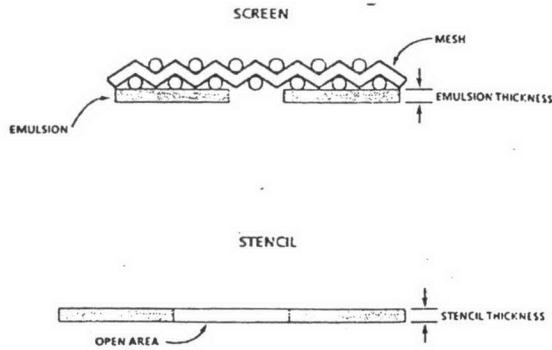


Figure 2.10: Cross-sectional views of stencils and screens for solder paste printing.⁶

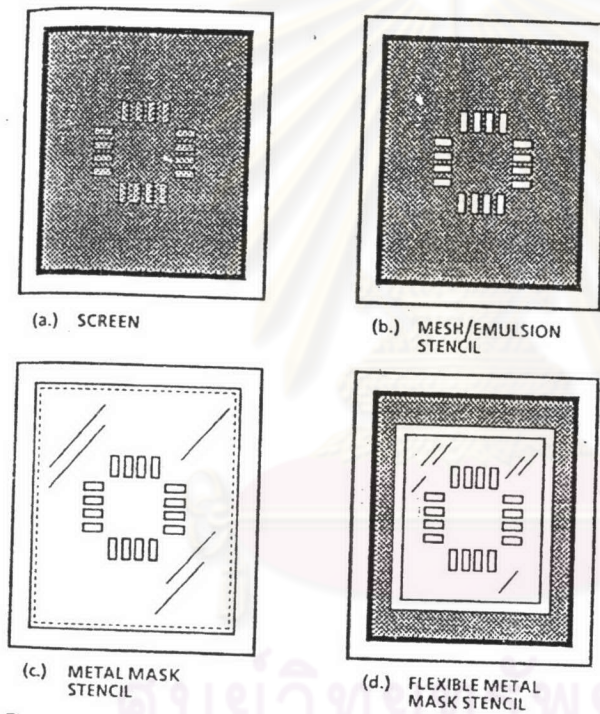


Figure 2.11: Construction of screen (a), mesh/emulsion stencil (b), all-metal mask stencil (c), and flexible metal mask (d).⁶

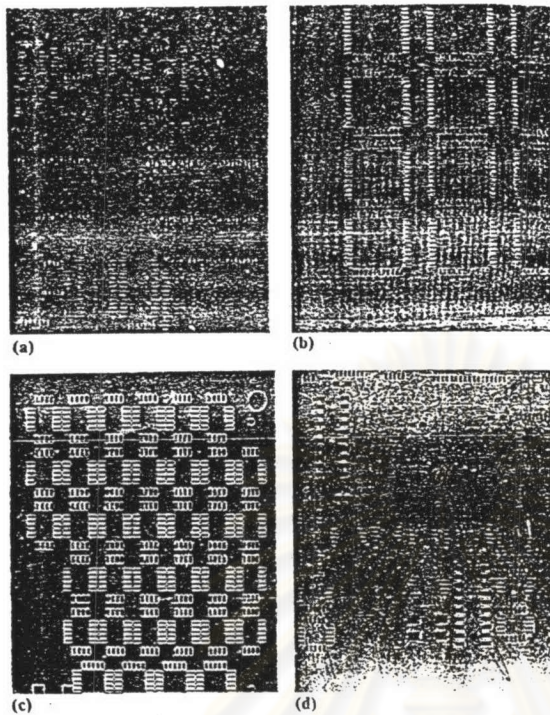


Figure 2.12 Close-up views of opening in screen (a) and three different stencil types: mesh/emulsion stencil (b), all metal mask stencil (c), and flexible metal mask (d), which correspond to the diagrams of Figure 2.11 ⁶

Figure 2.13 is a photograph of a stencil that shows the opening for all components on the board. Since each board is unique, stencils and screens are unique to particular boards and cannot be used for other. However, the flames can be used over and over for different board design to save cost.

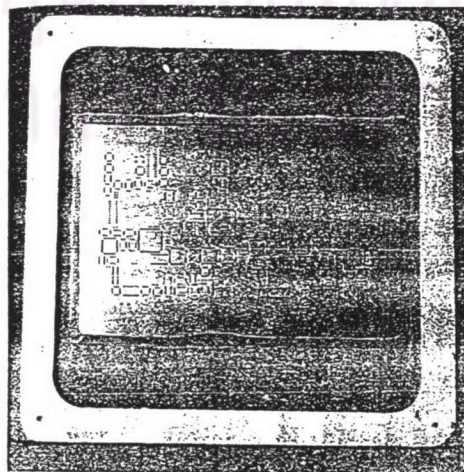


Figure 2.13: A flexible metal mask stencil. ⁶

Typically, a screen will contain open wire mesh around which solder paste must flow to reach the substrate surface. A stencil opening is fully etched and does not obstruct paste flow. The screens or stencils have etched opening to match the land patterns on the substrate, where solder paste must be deposited for the electrical interconnections.

The screen/stencil is stretched in a metallic frame and is aligned above the substrate. The distance between the top of the board and the bottom of the stencil/screen is called the snap off (see figure 2.14). This gap or snap off distance is a function of equipment design and is about 0.020-0.030 inch.

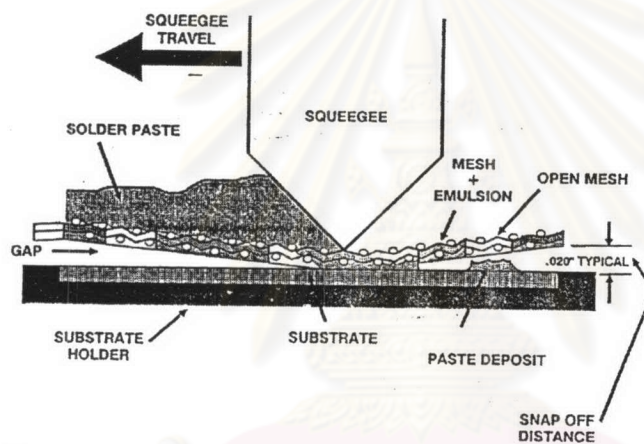


Figure 2.14: Applying solder paste on a substrate by squeegee in a screen-printing process: schematic view. ⁶

Initially, as shown in figure 2.15 the solder paste is manually placed on the stencil/screen with the print squeegee at one end of the stencil. During the printing process, the print squeegee presses down on the stencil to the extent that the bottom of the stencil touches the top surface of the board. The solder paste is printed on the land through the openings in the stencil/screen peels away or snaps off immediately behind the squeegee traverses the entire length of the image etched in the material mask. When screens are used, there is also the flood squeegee close to the print squeegee, whose function is to flood the screen with solder paste before the printing operation begins. The flood and print squeegees were discussed previously.

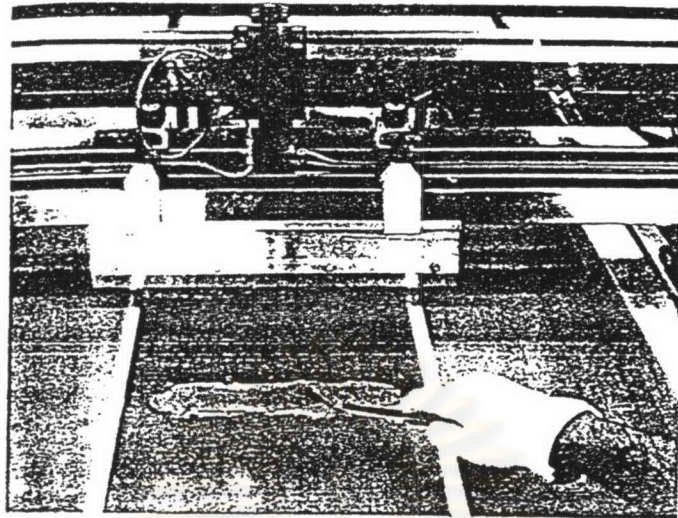


Figure 2.15: Solder paste application before printing.⁶

After paste has been deposited, the screens peel away or snap off immediately behind the squeegee and returns to its original position. (See Figure 2.14) Thus snap off distance and squeegee pressure are two importance equipment-dependent variables for good quality printing. The process sequence

1. Prepare solder paste
2. Setup and register screen/stencil
3. Print solder paste
4. Clean screen/stencil after printing

2.15.2 Placing of component

Component can be placed in their position on the substrate by hand or with automatic machines. In hand placing trivial mistakes may be made that are absent in automatic placing

The machines that place components with wire terminations into holes in the substrate (printed board) are called insertion machines or inserters: there exist inserters for radial and axial components.

Automatic insertion, particularly on single-sided boards, gives more reproducible soldering results than hand mounting. When a through hole (leaded) component is inserted into a printed board, there is an absolute go/no-go situation. Either the leads go through the holes, or they do not. With the surface mounted component, however, as the component is placed onto the substrate surface (popularly termed 'onserted'), its position

must be accurate relative to the solder lands, and placing accuracy is therefore a major item. Increased machine accuracy must be obtained by method of automatic vision and control that are being developed and introduced currently.

All machines of surface mounting, although different in detail, use the same basic steps: picking the component from the packaging medium (tape, magazine or hopper), aligning or centering the component the component and placing it on the substrate in the desired orientation with respect to the substrate, see figures 2.16 and 2.17. The exact location of each component must be programmed into the automatic placement machine; this information may be generated by the CAD system that is also used for the circuitry.

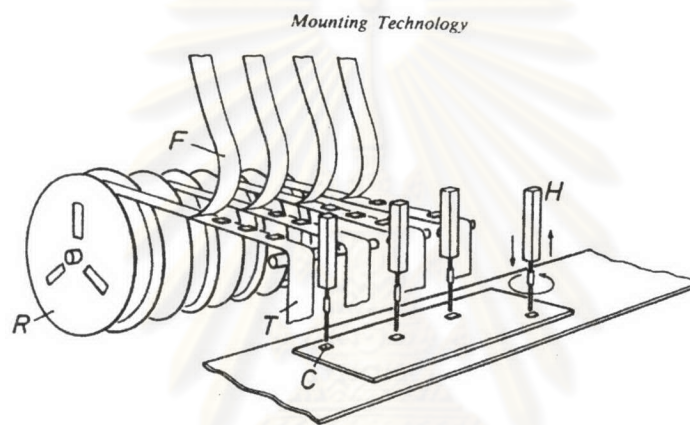


Figure 2.16: Drawing of a method for automatic placement of leadless components on a printed board. The vacuum pipettes, H, can be displaced horizontally and vertically. R is reel; T is tape with leadless components, C, which can be picked up after stripping off the plastic cover strips, F.⁹



Figure 2.17: Five stages of picking up a component from a tape, as in the Philips's MCM (modular chip mounting) machines. The component is lifted, while being held between a solid rod (below) and a vacuum pipette (above the component). Note the devices (jaws) to align the component.⁹

The selection of automatic placing machines is an issue reaching far beyond the scope of this book. However, as a guide the four placement techniques for surface mount components (SMDs) are outlined to illustrate their main characteristics (see Figure 2.18).

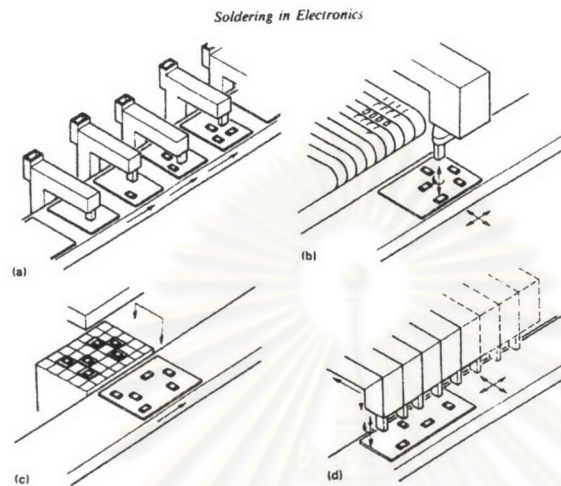


Figure 2.18: Four main techniques for placing surface mount components onto substrates:⁹

- (a) In-line placement: simple system, low cost, inflexible;
- (b) Sequential place: flexibility, higher cost;
- (c) Simultaneous placement: limited flexibility, high output;
- (d) Sequential/simultaneous placement: flexibility, high output.

In-line Placement: A simple system with a series of dedicated pick-and-place units, each of which places a single component in a pre-set position on the substrate. Generally used for hybrid circuits with few components, this type of machine has a cycle time of between two and five seconds per board.

Sequential placement: A single pick-and-place unit sequentially places the components onto the substrate. The X-Y movement can be realized either by the pick-and-place head carrying the component or by the table carrying the substrate (see Figure 2.19). As the machine is software programmable, it offers great flexibility. Cycle times around two seconds per components.

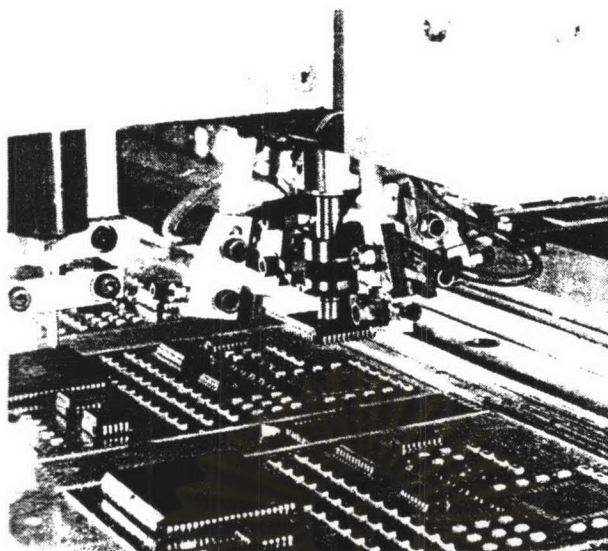


Figure 2.19: Pick-and-place head of the placing machine MPS 318, provided with a vision system. Part of the camera is visible in the top-right part of the picture. The X-movement is realized by the head and the Y-movement is realized by the table carrying the board. The machine features automatic tool interchange (not visible) to allow handling of a great variety of components. The picture shows the placing of a PLCC-44 package; note the four arms with jaws to align the package after having been poked up. The device to the left is an adhesive dispenser.⁹

Simultaneous placement: The components are placed in a single operation. A placement module (or station), containing a number of pick-and-place units, takes an array of components from the packaging medium and simultaneously places them on the substrate. The pick-and-place units are guided to the correct substrate location by a program plate (a hardware programmable machine). The machine offers a high output, but with limited flexibility. Cycle times are typically between two and ten seconds per board.

Sequential/simultaneous placement: A complete array of components is transferred in a single operation, but the pick-and-place units within each placement module can place all components simultaneously, or in sequence, allowing greater design flexibility (see Figure 2.20). Positioning of the components is controlled either by moving the substrate with an X-Y moving of the pick-and-place units (although the X movement is limited by adjacent pick-and-place units), or a combination of both.

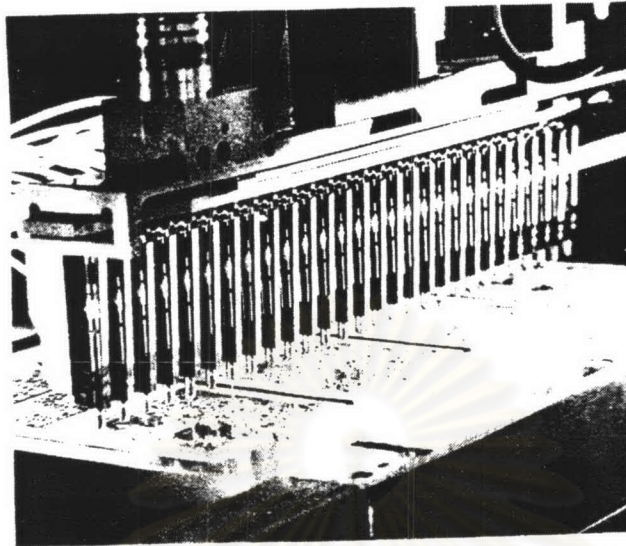


Figure 2.20: The pipette beam of a Philips's MCM VII placement system. The multiple pipettes perform the high-speed component pick-up and placing operation. The pipette beam is moved by frictionless linear motors running on air bearings, whereas the position of the beam is constantly monitored by servo systems. After components have been picked up from the tape, they are precisely centered as shown by figure 2.16. A unique acoustic monitoring system provides positive verification of successful component pick-up from the tape and subsequent placement on the printed boards.⁹

2.15.3 Paste drying

Drying the paste, *i.e.*, evaporation of the greater part of the flux solvent of the flux solvent before soldering, but after placing of components, is important, to prevent components being blown away and moved out of true position by too rapid evaporation of the solvent still present during soldering; the beneficial effect of predrying on the paste slump has been discussed earlier in this subsection. The necessary degree of predrying depends on the shape of joint and the conditions of the soldering process to reflow, such as heating rate and direction of heat input.

A distinction should be made between predrying at low and at high temperature. At low temperature, *e.g.*, at 45 °C, only the surface layer of the paste is influenced, but this is already sufficient to avoid slump. At higher temperature, the solvent from the bulk of paste is evaporated, so that the blowing away of components is avoided. On the other

hand, predrying of the paste reduces the coalescing power of the paste and gives more small solder balls on the board.

Various bake-cycles (in air) are used: 20 to 40 minutes at 70 °C, or 5 to 20 minutes at 90 °C is applied, but in the other case 10 seconds at 170 °C proves effective.

Strangely enough, it is not always recognized that the selection of the drying Conditions should also be determined by the type (boiling point) and amount of solvent presented in the paste. An impression of the effect of the drying treatment can easily be obtained by measuring the decrease of mass of the applied paste during the baking treatment (see figure 2.21). (Experimentally, measurements may be taken at short intervals, *e.g.*, of a few minutes.)

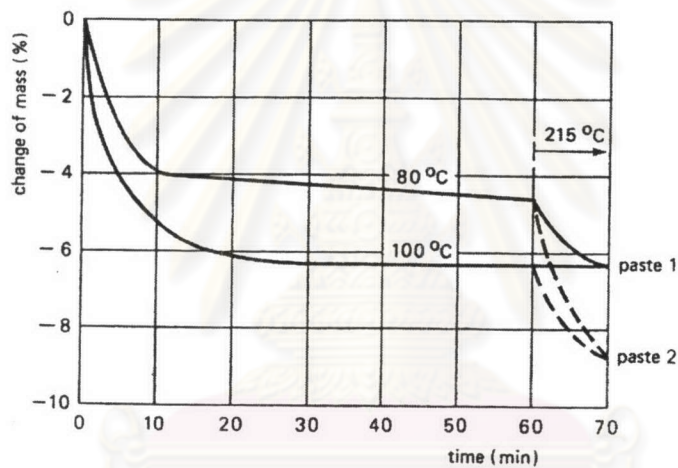


Figure 2.21: Decrease of mass of two solder pastes during preheating treatment at 80°C and 100°C for a time of 60 minutes, after which the temperature was rapidly raised to 215°C. In most case 80°C will be too low a temperature for these pastes (for pastes 2 even 100°C), and 60 minutes too long a time, to evaporate the solvents.⁸

Soldering may be carried out immediately after drying (preheating) or after a waiting time up to several days, but in this case the relative humidity in the environment must be lower than 50%. Yet, unnecessary waiting should be avoided, as the formation of satellites during soldering will become more likely.⁵⁻¹⁰

2.15.4 Reflow soldering process

Reflow soldering is the making of joints by remelting previously applied solder, without the addition of any extra solder during operation. The word “ reflow” should not be taken too literally, as reflow soldering refers nowadays to all processes in which heat and solder are applied separated.

For the various reflow soldering methods a definite minimum quantity of solder is required, depending on the design of the joints to be formed. The field of reflow soldering encompasses mass soldering methods, as well as manual operation. Many reflow methods are available as show in the figure as shown in the top.

2.15.4.1 Local heating method

1) Soldering with soldering iron

This method consists in using a soldering iron to solder the package leads and printed circuit with wire solder, etc. Determine the soldering temperature of the soldering iron to be used according to the size and shape of the location to be soldered, and the melting point of the solder. If the soldering temperature is too high, the reliability of the SMD may be degraded, and the printed circuit of the PCB may peel off.

The actual soldering temperature must be determined according to the heat resistance of the SMD. It is actually recommended that the temperature characteristics of the SMD be actually measured to determine the soldering temperature. When ever possible, use a soldering iron whose temperature can be adjusted.

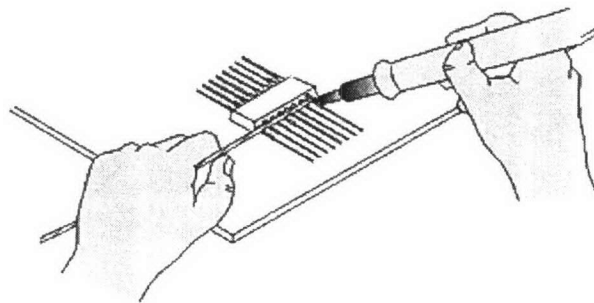


Figure 2.22: Soldering with Soldering Iron¹⁰

(2) Pulse heat soldering

This method consists in melting solder supplied in advance by using joule's heat generated by the electric resistance of an electrode or the joint on the PCB to be soldered, and soldering the SMD by applying pressure to it from a heater chip.

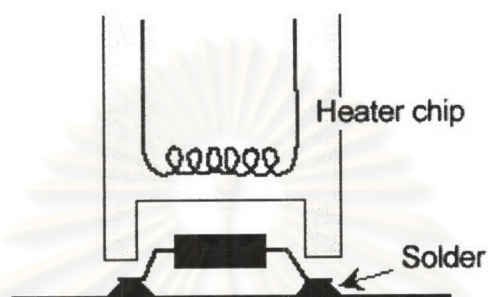


Figure 2.23: Pulse Heat Soldering¹⁰

(3) Convection reflow soldering

This method consists in soldering the SMD by heating air or N₂ gas with a heater and spraying compressed gas from a nozzle onto the joint on the PCB. The temperature is adjusted by adjusting the heat source or the flow of gas.

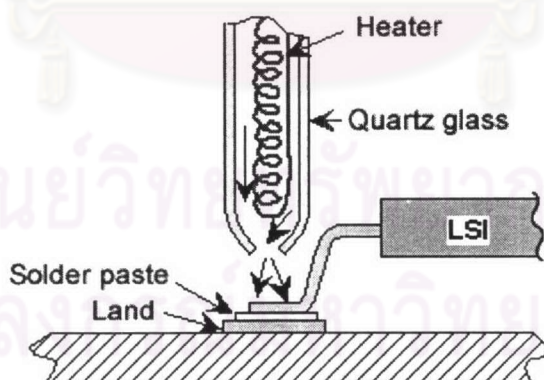


Figure 2.24: Convection Reflow Soldering¹⁰

(4) Laser Soldering

This method consists in converging a laser beam into a spot with a lens and casting the beam onto the joint. A YAG laser is used.

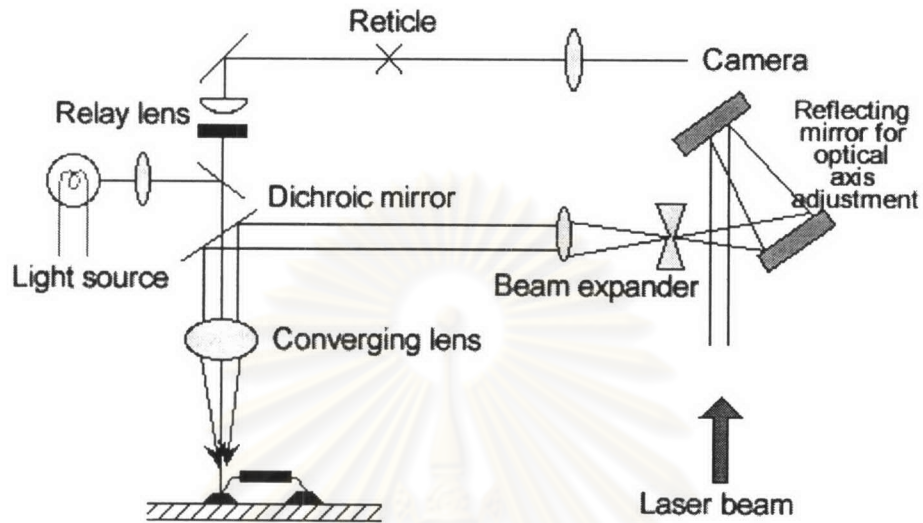


Figure 2.25: Laser Soldering ¹⁰

(5) Light beam soldering

The light emitted from a xenon lamp is cast onto an oval reflecting mirror to create a light flux that is in turn cast onto the joint for soldering.

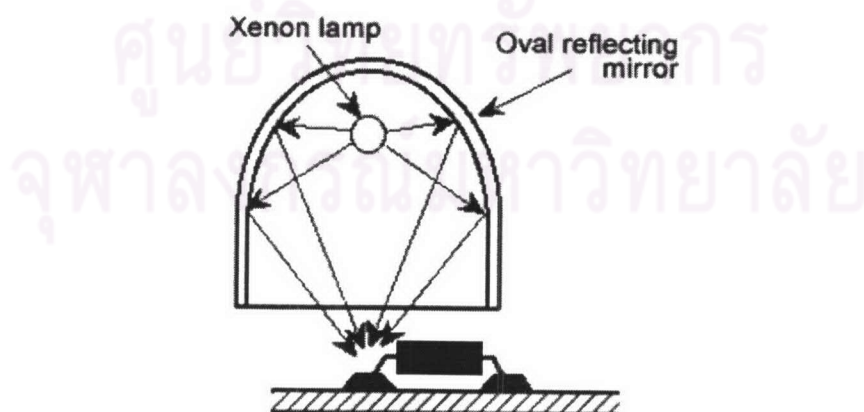


Figure 2.26: Light Beam Soldering ¹⁰

2.15.4.2 GENERAL HEATING

(1) Infrared reflow soldering

This method consists in heating the SMD with the heat generated from an infrared panel heater and soldering it onto the PWB.

The infrared ray that is emitted may be near or far infrared. The radiation efficiency of the near infrared ray varies depending on the color and shape of the SMD to be soldered. Temperature variations may occur as the result of uneven coloring on the SMD's surface. At present, far infrared radiation is mainly used. The features of the infrared reflow are described as follows.

1. Advantages

- Low running cost and excellent maintainability
- Short soldering time

2. Disadvantages

- Temperature rise on the leads greatly depends on the package size.
- Great thermal stress
- The temperature of shadowed portions may not rise because infrared radiations do not reach them.
- The infrared reflow soldering method is divided into two types, one using near infrared radiation and one using far infrared radiation.

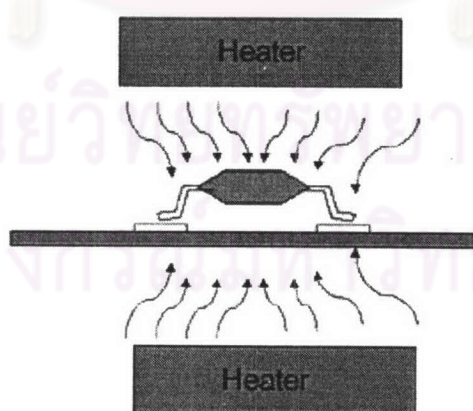


Figure 2.27: Infrared Reflow Soldering ¹⁰

(2) Convection reflow soldering

Convection reflow soldering is an improved method that solves the problems of infrared reflow soldering, i.e. the temperatures of the PWB and SMDs on it are uneven. This method also solves the problem of vapor phase soldering (VPS)-high running cost. The principle of convection reflow is to heat the SMDs by convective heat transfer, i.e., by making air heated by a heater circulate in an oven. Consequently, even if the thermal capacity of the PWB differs from that of the SMDs, the temperatures of the PWB and SMDs become uniform after the lapse of a certain time.

The features of the convection reflow soldering are described as follows.

- Excels in temperature uniformity compared to infrared reflow soldering (the temperature is little influence by the type of SMDs that are heated).

- Relatively low thermal stress

2. Disadvantages

- Slightly longer soldering time than infrared reflow.

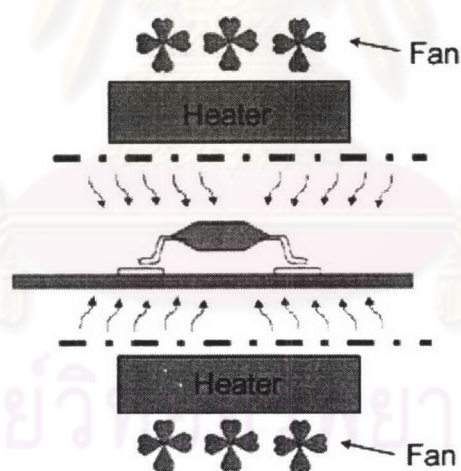


Figure 2.28: Convection Reflow Soldering ¹⁰

(3) Convection-infrared reflow soldering

This method solves the problem of the comparatively longer soldering time of the Convection reflow method by combining it with infrared reflow.

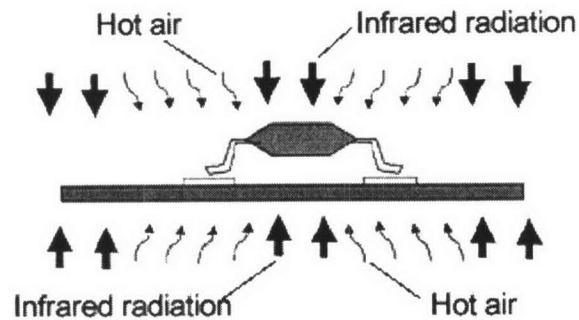


Figure 2.29: Convection-Infrared Reflow Soldering ¹⁰

(4) Vapor phase reflow soldering (VPS)

This method consists in heating to boiling temperature special inert liquid, and then subjecting the SMD to the saturated steam to achieve soldering by vaporized heat.

The features of VPS are described as follows.

1. Advantage

- Low thermal stress
- Even heating of components regardless of their shape
- Accurate temperature control through use of vaporized heat
- Extremely high heat transfer efficiency makes it possible to lower the heating temperature and shorten the soldering time.

- Little oxidation and dirt on the soldered joint because soldering is performed in inert atmosphere.

2. Disadvantages

- High running cost

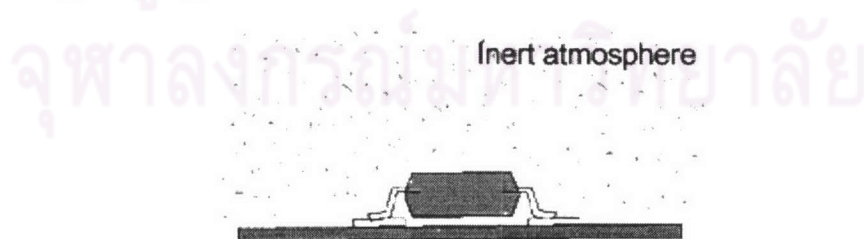


Figure 2.30: Vapor Phase Reflow Soldering ¹⁰

(5) Flow (Wave)soldering

This method consists in forcing out molten solder in a soldering bath to the component on the PWB.

The feature of this method is described as follows.

1. Advantages

- High productivity (soldering can be completed in a few seconds)

2. Disadvantages

- Difficult to solder various packages (such as fine-pitch and J-lead package)
- Self-alignment effect cannot be expected (because the components are temporarily fixed on the PWB with adhesive).



Figure 2.31: Flow (Wave) Soldering ¹⁰

(6) Thermal profile requirement (Time and temperature)

1) Preheat

- PCA from room temperature
- Solvent volatile start to volatile.
- This process prevents the component thermal shock ($\leq 2^{\circ}\text{C}-4^{\circ}\text{C}/\text{Sec}$) and avoid paste splattering.

2) Soak/Preheat

- PCA stabilize- ΔT across the PCA.
- This process is continuing volatilization of solvents-solder cream and activation of solder paste component.

- i) Chemical remove surface oxides from pad surface and component lead solder alloy particles.
 - ii) If this process is too short or too low temperature caused insufficient activation.
 - iii) If this process is too short or too low temperature caused insufficient activation.
 - iv) If this process is too long or too high or temperature caused
 - (1) The activator will be used up prior to reflow
 - (2) Solder ball is formed
 - (3) Poor soldering
- 3) Reflow
- a) This process is the temperature at which the alloy becomes liquidus.
 - b) This temperature must exceed the eutectic temperature of the metal alloy and the maximum & minimum temperature must be specified
 - c) If high temperature cause the board discoloration and if this process too long cause intermetallic growth.
- 4) Cooling
- a) This process must be occurred rapidly for promote finer-grain structure and contributes to interconnect strength
 - b) This process must caution from component standpoint.

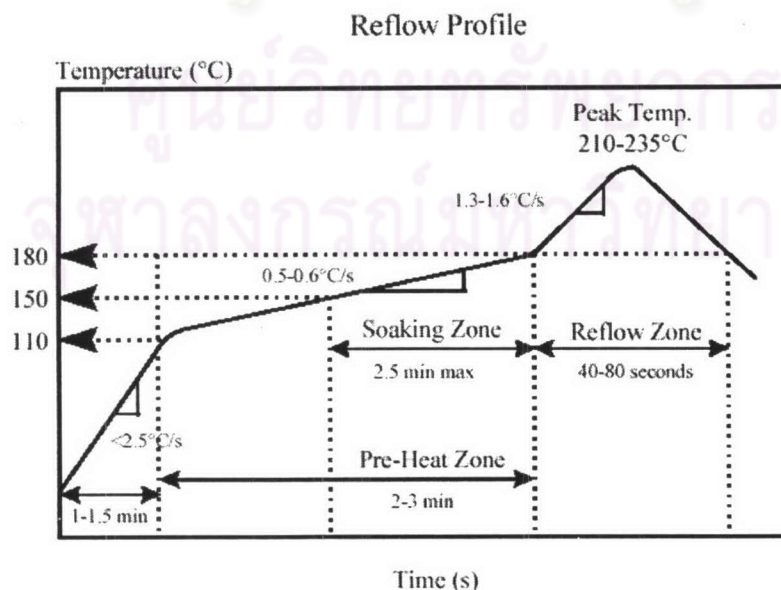


Figure 2.32 The temperature profile for the reflow soldering process

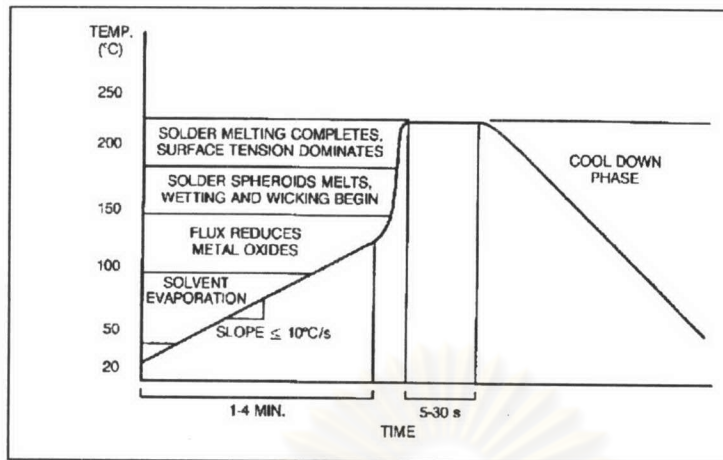


Figure 2.33 Description of the reflow temperature profile.¹⁰

2.16 Soldering paste flux preparation condition

The term "vehicle" means that composition containing a normally solid fluxing agent, optional specialized additives, and a solvent in which the fluxing agent and additives, when used in the proportions necessary for joining paste applications, are substantially soluble at an elevated temperature. Such elevated temperature is that temperature at which the second phase ingredients, including flux and specialized additives, are substantially soluble in the solvent so as to produce a clear, or substantially clear, solution. In the practice of the present invention, shock cooling is critical, and is defined as cooling from a clear or substantially clear solution, at such elevated temperature, at a sufficiently rapid rate to obtain mass nucleation or precipitation of vehicle second phase components and avoidance of significant grain growth. Preferably the paste has a maximum particle size (of second phase ingredients, primarily flux) not substantially greater than about forty (40) microns" with a majority of the particles being less than about ten (10) microns, as determined by a Fineness-Of-Grind Gage.

For most practical purposes, in accordance with the concepts of the present invention, cooling takes place at an average rate of at least 3 °F per minute.

In a preferred embodiment of the present invention, cooling is carried out in a cooling zone having indirectly cooled heat exchange surface with continuous scraping of cooled layer from said surface. However, cooling is carried out with as little mechanical agitation as possible. Following shock cooling, there is obtained a vehicle having a thick, creamy consistency, and a crystalline second stage of very fine particle size, rendering it

suitable for blending with a suspension of fine particle size metal powder. At the point of addition of the metal powder, other fine particle size additives, for instance a fine ground flux activator composition, may also be introduced into the vehicle.

The viscosity of the final paste product is that necessary for convenient dispensing in fine bore dispensing equipment. For most applications, in accordance with the concepts of the present invention, the viscosity falls within 30,000 to 500,000 centipoises, preferably 80,000 to 200,000 centipoises (as measured at 78.°F. by a Brookfield Viscometer, Model No. RVF, using a No. 7 spindle at 20 r.p.m.), depending upon the particular ingredients and proportions employed. Proportions are those necessary to achieve a viscosity within these ranges.

It was found, that by employing shock cooling, the viscosity desired remained substantially constant in storage, for a period of six months or longer, within 15% (in terms of centipoises) of that desired. In addition, it was found that the vehicle and/or paste were exceptionally stable, in that no visible phase separation occurred during a six-month storage period.

The heating temperature, to which the vehicle ingredients are heated, can also vary within a wide range, depending upon particular ingredients and proportions selected. Generally, speaking, the heating is carried out to a temperature of about 180 °F to 260 °F (about 82 °C to about 127 °C). Too low a heating temperature hampers dissolving of the flux and additive ingredients in the solvent and attainment of proper particle size on cooling. Overheating tends to cause chemical degradation, decomposition and evaporation loss.

At the completion of mixing and heating, steam valve 36 was moved to a closed position shutting off the steam flow to the vessel jacket and water valve 38 was opened introducing water [at about room temperature of about 70 °F (21 °C.)] to the jacket. Rotation of the high-speed impeller 20 was stopped, and mixing was continued with the scraper 22, still at about 27 r.p.m. Rate of cooling was maintained at about 3 °F. per minute average, until the entire mixture became opaque and vehicle temperature was about 80 °F (About 27 °C). It is understood that during cooling falling temperature periods will be interrupted by fairly constant temperature periods when precipitation of certain vehicle components takes place. The rate of cooling of at least 3 °F per minute refers to the average temperature drop in the cooling cycle. In this particular example, cooling took place in about 30 minutes. ¹¹

2.17 Literature review

Stayner, *et al.*¹² developed wax-flux compositions for use in low-temperature soldering processes comprise (A) a major amount of a wax and (B) an effective amount to cause fluxing, at or below the soldering temperature of the piece to be soldered, of a wax-soluble product obtained by first reacting an aliphatic hydrocarbon-substituted succinic acid or derivative thereof which is capable of forming carboximide bonds with an alkylene polyamine to form a carboximide and then reacting said carboximide with an alkylaryl sulfonic acid. A process for soldering electrical components to a printed circuit board comprises (A) applying a molten wax-flux composition as described above to the metal pattern side of the board, (B) allowing the wax-flux composition to solidify, (C) trimming the components leads, and (D) soldering the components to the printed circuit board.

Cooper, R. N.¹³ developed a water-soluble or readily water-dispersible fluxes for use in connection with soldering operations in plumbing and related or other environments, particularly for use in connection with the soldering of water lines made from copper or copper-base alloys. The said water-soluble or readily water-dispersible fluxes are produced in the form of pastes in which the paste-forming ingredients are water-soluble surfactants or mixtures of surfactants, especially those of nonionic character, with or without water, but especially where water is present in amounts of at least several percent by weight of the finished flux composition. Said paste flux compositions also contain water-soluble amine hydrochlorides, and, advantageously, ammonium chloride, with or without various supplemental ingredients which, when used, are employed in small proportions.

Snyder, *et al.*¹⁴ developed a process for making metal joining paste, particularly suitable for precision soldering and brazing, which comprises preparing a paste vehicle by mixing together, at an elevated temperature, paste ingredients including solvent, flux and specialized additives, cooling said vehicle, and blending metal powder therewith. Blending preferably is subsequent to cooling, but can be simultaneous with cooling, though without significant exposure of the metal to the vehicle at elevated temperature. Cooling of the vehicle takes place under shock cooling conditions, such as to obtain a fine particle size suspension, and is to a final temperature inhibitive of significant reaction of metal powder with vehicle acidic constituents. The present invention provides increased

viscosity control and suspension stability necessary for fine bore automatic dispensing of the paste.

Mastrangelo A.J.¹⁵ improved soldering or brazing paste compositions comprising a metal alloy powder and a vehicle therefore. The vehicle comprises hydroxypropyl cellulose blended with glycerine and/or water further blended with a mixture of polyalkoxyalkanols. Said vehicle is totally fugitive, leaving exceptionally low residue and maintains stable viscosity during extended storage.

Hasegawa, *et al.*¹⁶ developed a solder paste comprises a solder paste portion containing powdered solder and metallic spheres which are made of a material having a higher melting point than the solder paste portion and whose surface can be wet by molten solder. The metallic spheres have a diameter of 0.07-0.3 mm. The metallic spheres can comprise a single metal or two metals, one of which forms the center of the sphere and the second of which is plated on the surface of the first.

Goobich, *et al.*¹⁷ developed paste vehicle for use in a metal bearing solder paste composition having a heat-polymerizable binder. This vehicle can be non-aqueous, inorganic salt-free and dispersed in a non-aqueous, organic liquid, and may be incorporated with a flux into a solder paste composition capable of utilizing an average particle size finer than 100 mesh. This paste has excellent anti-slump properties, requires no cleanup to remove residual solder reflow, and permits smaller more controlled joints to be formed.

Davis J.L., *et al.*¹⁸ developed solder paste vehicles using blends of monofunctional and polyfunctional alcohols. The blend may have a major portion of a low viscosity, monofunctional alcohol solvent and a minor portion of a high viscosity polyfunctional alcohol thickener. The monohydric solvent has a room temperature viscosity of at least 3 centipoise and from about 3 to 18 carbon atoms and may include such materials as 2-butanol, 1-hexanol, 1-heptanol, 1-octanol, 1-nonanol, 1-dodecanol, 2-ethoxyethanol, 2-(2-ethoxyethoxy)ethanol, 2-(2-butoxyethoxy)ethanol, n-hexadecanol, n-octadecanol, benzyl alcohol and mixtures thereof. The polyalcohol has a room temperature viscosity of between about 26 to about 1500 cp and includes compounds such as 1,2-ethanediol; 1,2-propanediol; 1,3-propanediol; 1,2-butanediol; 1,3-butanediol; 1,4-butanediol; 1,2-pentanediol; 1,5-pentanediol; 2,4-pentanediol; 2,5-hexane-diol; glycerol; 1,2,4-butanetriol; 2,2'-(ethylenedioxy)diethanol; 1,12-dodecane-diol; 1,16-hexanedecanediol and mixtures thereof. These blends give improved solubility of organic

acid fluxing agents, provide relatively high viscosities of the solder paste and permit lower amounts of solvent to be used.

Degani Y.¹⁹ developed paste that is useful in applications such as surface mounting of components on printed circuit boards has been found. After soldering, the residue requires no cleaning. The achievement of these desirable properties is accomplished by employing a solder flux vehicle including a three-component residue modifier. A mixture of 4 grams sebacic acid, 23 grams propyl paraben, 4.5 grams ethyl cellulose, 3 grams dimerized rosin, 3 grams PETB and 58.5 grams of di-propylene glycol was heated in an oil bath that was kept at 130.degree. C. The mixture was mechanically stirred during the process. After 40 minutes, 4 grams of castor oil were added to the hot mixture. After 5 minutes, the mixture was removed from the hot oil bath and allowed to cool to about 70 °C. One hundred grams of the hot flux (70 °C-80 °C) were mixed with 900 grams of solder powder Sn/Pb 63/37, -325+500 mesh to yield 1 kg of solder paste.

Frazier J.D.²⁰ invented solder flux and solder paste compositions that do not require cleaning after the soldering operation. The solder flux composition of the present invention for wave solder and manual operations generally comprises about 10 to about 40% by weight of the organic quaternary ammonium salt and about 60 to about 90% by weight of the organic solvent. The solder flux composition of the present invention for use in solder paste generally comprises about 20 to about 40% by weight of the organic quaternary ammonium salt and about 3 to about 10% by weight of the thixotrope and about 50 to about 77% by weight of the organic solvent. A solder paste was then formed with 10.25 weight% of the above composition and 89.75 weight% of the solder alloy (63/37 Sn/Pb alloy). After heating to reflow, the resulting residues from the flux composition were about 1.25%.

Lutz, *et al.*²¹ developed a solder paste for membrane keyboards manufactured using screen-printable, electrically conductive pastes consisting of 40 to 75% by weight of metal powder (silver, aluminum, copper and their mixtures), 5 to 55% by weight of an organic solvent and 5-20% by weight of and synthetic resin based on a thermoplastic epoxy or phenoxy resin with an average molecular weight of 10,000 to 250,000 and an epoxide content of 0 to 1.

Gomi T., *et al.*²² developed solder paste additive contains a deactivation agent functioning at soldering temperature. This novel additive is used for fluxes and soldering pastes. In the course of soldering, the deactivation agent in the additive deactivates an

activator such as organic acids such as succinic acid contained in the flux and the soldering paste in order for removal of an oxide film from a metallic base used for electric circuit. By use of the additive, corrosion of the metallic base with the activator is prevented even though the activator remains on the base. The additive enables one to omit an unnecessary washing step from a preparation of electric circuit and rosin such as WW rosin activator such as diethylamine solvent such as isopropyl alcohol thickener agent such as hardened castor oil and tested for spread factor, corrosiveness and solder ball

Takemoto, *et al.*²³ developed soldering flux composition comprising, a flux base resin, a modified amine compound obtained by reacting (i) at least one member selected from the group consisting of vinyl group-containing compounds, carboxyl group-containing compounds and epoxy group-containing compounds (ii) with an amine compound having an active hydrogen.

Degani, *et al.*²⁴ developed a solder flux that is useful in applications such as surface mounting of components on printed circuit boards has been found. After soldering, the residue from the flux is either removable by water cleaning or requires no cleaning at all. The achievement of these desirable properties is accomplished by employing a solder flux vehicle including a removing agent, a low vapor pressure component, a high temperature component, and a rheological properties promoter.

Qiao X., *et al.*²⁵ developed solder paste for use in microelectronics packaging. Initially liquid forms with eutectic composition (i.e. 140°C), followed by rapid re-solidification and secondary melted at temperature above 180 °C. Upon reheating, processed solders do not re-melt until temperatures above 220 °C. Solder consolidation below the liquidus temperature depends critically on the amount of liquid phase formed which in turn depends on the paste ingredients. The ingredients of paste are 87% of solder powder, 6% of rosin solution 3% in IPA, 6% of DMA HCl solution 67 % in water and 1% of fish oil.

Katsuoka, *et al.*²⁶ developed a solder paste by addition of a polyamide resin, which is compatible with rosin-based resins as the main components of liquid flux and solder paste flux, which is resistant to temperature variation and provides a damp proofing effect, and particularly a polyamide resin which is obtained by polycondensation reaction of a dicarboxylic acid of 2 to 21 carbon atoms and a diamine and has a softening point of 80 °C to 150 °C, or a polyamide resin, which is obtained by polycondensation reaction of a dimer acid and a diamine and has a softening point of 80 °C to 150 °C,

highly reliable low-viscosity liquid fluxes and solder paste fluxes, with which solderability is not impaired, where the flux residues on printed circuit boards after soldering undergoes no cracking or deterioration even under temperature variation, and which prevent poor insulation and migration even under high humidity environment, are provided.

Kubota, *et al.*²⁷ disclosed a paste composition including (A) an organic binder comprising acidic functional groups; (B) an inorganic powder containing multivalent metal compounds; and (C) a mono-ol compound having a boiling point of about 178 degree. C. or more. The paste composition enables various fine patterns such as via-holes with high precision, by suppressing gelation caused by mixing an organic binder having acidic functional groups and a compound containing multivalent metals.

Currie, *et al.*²⁸ invented a lead-free solder paste comprising a solder paste flux and solder alloy particles that are substantially lead-free wherein the solder paste flux comprises resin dissolved in a solvent and also includes undissolved resin particles less than 25 μm in size homogeneously dispersed therein to provide improved solder alloy powder coalescence and substrate surface wetting while maintaining appropriate solder paste rheology for use in printed circuit board assembly processes.



ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย