SURFACE TREATMENT PRIOR TO SOLDERING

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A brief overview on the importance of the surface treatment prior to soldering has been discussed. The treatments prevents further oxidation of the surface. They should dissolve the oxide film already present on the surface and also on the solder itself. For a better solderability, the surfaces can be coated or plated. By this, rapid wetting of the surfaces by the molten solder can be achieved. Mention has been made on the unsuitability of the organic reactive fluxes and in such cases the surfaces are plated with solderable metals like gold and nickel.

Soldering is used extensively in electronic industry for joining the components, where much strength is not required. It is essential that soldered joints of high reliability can be made both economically and rapidly. It is accepted that solders are metallic materials of lower melting point than the metals they join. Even though soldering is very easily done, some precautions have to be taken before soldering with respect to surface pretreatment.

All the metals are usually covered with a non-metallic oxide layer and other physically or chemically adsorbed films. Such films form an effective insulating barrier that prevents the true metal to metal contact. In practice soldering attempts are made to remove surface oxide films and then keeping the metal surface as clear as possible and preventing further formation of such films. Cleanliness of such metal surface is achieved by polishing with abrasives of successively increasing degree of fineness, and then pickling in a suitable acid bath and washing in running water. Fluxes are usually employed to dissolve the oxide films and prevent further formation of oxide film. The flux in addition to cleaning the metallic surface, also considerably reduces the surface tension of the molten solder.

A good joint can be made, when it is properly cleaned, fluxed and heated prior to soldering. To attain such a joint, delicate electronic parts are cleaned to assure joining with the minimum exposure to corrosive environment. The metal surfaces are treated with the acidic, corrosive fluxes, active acidic fluxes which simplify cleaning and increase the joint reliability.

The surface can be cleaned by the following methods: 1) Mechanical cleaning, 2) Chemical cleaning, 3) Self cleaning flux, 4) Surface coating and plating for better solderability, and 5) Ultrasonic cleaning and vapour degreasing.

The simplest, and a non-destructive way of evaluating a clean substrate is the 'water-break' test. This may be tried on the surface to be soldered to note the ability of the metal surface to hold an un-broken film of clean water. The importance of adopting efficient rinsing during the different stages of pretreatment, after the final treatment, and finishing the substrate soon after the pretreatment need to be emphasised.

The first step of the surface treatment is by mechanical means. Here the surface films are first removed by filing, scraping and washing. Further cleanliness, is achieved by polishing with abrasives of successively increasing degree of fineness.

In the case of chemical cleaning, there are two types: 1. Alkaline degreasing. 2. Pickling.

1. **Alkaline Degreasing:** This is effected by placing the part in a bath of a weak solution of alkalies in hot water (80°C.) The alkalies of 2 to 3% strength is usually a mixture of sodium salts, which may include carbonates, hydroxides, metaphosphates and silicates. In order to get rid of the last traces of grease or oil, the part may be kept for some minutes in the bath. Cathodic degreasing is also a powerful aid for cleaning the surface. After leaving the alkaline detergent, the part should be rinsed thoroughly in soft or distilled water.

2. **Pickling:** Effective removal of rust from the degreased part is obtained by immersing in cold inhibited hydrochloric acid (one part of acid to one part of water). Time should be kept minimum to avoid pitting the surface unduly and wasting the acid.

Self cleaning flux:

To assist in the wetting of the surfaces by molten solder, a flux must be present to prevent oxidation during joint formation and to dissolve the thin oxide films already present on the surfaces of the components and on the solder itself. Metal surfaces must be prevented from oxidising while they are being

heated to soldering temperature, since they are more reactive towards oxygen at elevated temperatures. Oxidation is prevented by applying a suitable flux over the surface that is to be soldered [1].

A flux should have the following characteristics : 1. It should be a liquid, cover over the material and exclude the air ; 2. It should continue to do so up to soldering temperature ; 3. It should dissolve any oxide on the metal surface or on the solder and carry this unwanted materials away ; and 4. It should be displaced from the metal surface by the liquid solder. There are three types of fluxes based on the nature of the residues ·

1) Non-Corrosive, 2) Intermediate and 3) Corrosive.

Non-Corrosive Flux :

Resin fluxes possess important physical and chemical properties that makes them particularly suitable for use in the electrical industry. The active constituent which is said to be abietic acid, becomes mildly active at soldering temperature and its function is largely protective. The residue after soldering is hard, non-hygroscopic, non-conducting and does not cause corrosion. The slow fluxing action of resin causes chemically clean metal surfaces. This leads to the development of activated resin fluxes. The activated fluxes with improved fluxing power usually depend on the addition of small amounts of intermediate fluxes.

Intermediate Fluxes :

The intermediate fluxes are weaker than the inorganic salt types. It consists of mild organic acids and certain of their derivatives such as hydrohalides. These fluxes are active at soldering temperatures and the activity reduces with time, because of their susceptability to oxidize. Intermediate fluxes can be washed in running water. Urea-glutamic acid hydrochloride belong to this type.

Corrosive Fluxes

Corrosive fluxes[2] consist of inorganic salts and acids. They are used when the condition of the surface is well below the ideal for rapid wetting by molten solder. Fluxes in this type can be formulated that are stable over wide temperature ranges and are more versatile in this aspect than the less corrosive types. The residue of the corrosive fluxes remains chemically active after soldering and they cause severe corrosion at the joint. For this reason corrosive fluxes are not employed in the soldering of closed circuits assembly. Acidic flux residues may be removed by washing first in weak hydrochloric acid or citric acid, which prevents the formation of insoluble oxychlorides, followed by water rinsing. Highly corrosive fluxes have a limited application in electronic industries because of the problems of residue removal. But they can give the most rapid fluxing action and hence the easiest soldering.

Removal of corrosive flux residues

After soldering it is essential to remove all the residues at the joint. The action of water on zinc chloride is to hydrolyse them, forming oxychloride of zinc which forms an insoluble coating over the residues.

$$ZnCl_2 + H_2O \longrightarrow Zn(OH)Cl + HCl$$

The hydrochloric acid dissolves in wash water but if more acid is added the action reverses and zinc chloride is formed,

$$Zn(OH)Cl + HCl \longrightarrow ZnCl_2 + H_2O$$

If sufficient acid is present[3], the zinc chloride dissolves and once a dilute solution of acidified zinc chloride is formed over the surface, they rapidly corrode. The part is then washed in hot dilute soda solutions and then in hot water to remove the salts formed by the acid products and soda. The final cleaning is done with plain water.

Reaction of flux on the surface

Thermodynamic considerations and experimental results [4,5] reveal that NH_4Cl flux is the reactive constituent in $ZnCl_2$—NH_4Cl flux. The extent to which the flux reacts with the solder or substrate metal depends on the temperature and the NH_4Cl concentration. The flux may also act as electrolyte for electrochemical deposition of solder constituents on the surface ahead of the advancing liquid drop. The chemical and electrochemical reactions occurring between the phases alter the interfacial conditions and influences the speedy cleaning action. Wetting properties and spreading characteristics mainly depend upon the metallic surface, which must be free from any tenacious oxide film or other non-metallic substances such as sulphides, carbides etc. Certain

reactive fluxes, such as those containing chloride, participate in reaction which alter the surface condition. Lewis explains the tinning action of the $ZnCl_2$—NH_4Cl flux by postulating zinc chloride in the flux, hydrolyses to hydrochloric acid which reacts with the molten solder to form stannous chloride, which could in turn be reduced to tin. He considered that ammonium chloride was added only to lower the melting point of flux.

The most usual ingrediant of corrosive fluxes[2] is zinc chloride, while the chlorides of ammonium, sodium, potassium and tin may be present to increase the activity or to lower the fusion point of mixtures. Salts such as bromides and fluoride may also be employed, since these compounds allow free halogen acids to be liberated at soldering temperature in the presence of water. Orthophosphoric acid is another corrosive flux especially useful in stainless steel soldering. Molten $ZnCl_2$ and $ZnCl_2$-NH_4Cl fluxes effectively remove the oxides from the metal surface by dissolution or chemical reaction, thus producing clean and wettable surface.

Surface treatment by ultrasonic cleaning and vapour degreasing

Ultrasonic sound waves occupies a major role in surface cleaning and used to clean any article made from metal, glass and ceramics. Ultrasonic energy penetrates into crevices and cavities like gear train and other mechanism, the whole unit can be cleaned without being dismantled.

Basic principles of ultrasonic cleaning

Ultrasonic cleaning provides intense mechanical agitation combined with enhanced chemical activity. The characteristic features of ultrasonic cleaning is that mechanical energy (in the form of high intensity, high frequency sound waves) is imparted to a cleaning liquid and this is nothing but a refined form of mechanical agitation. It produces in the cleaning liquid a phenomenon known as cavitation. During cleaning, the natural oxide film of the metal surfaces is eroded away by the vibrating solution, permitting the solder to wet the surface of the metal.

In ultrasonic cleaning system, transducers are attached to a tank of cleaning liquid which convert electrical energy from electrical generator into mechanical (vibrating) energy producing high intensity sound waves in the liquid and thus causing cavitation[6]. These cavities collapse violently as the pressure increases on every half-cycle. The liquid cleaning tank will always contain minute bubbles, dissolved gases, dust particles, and all these can act as cavitation nuclei.

It is estimated[6] that a pressure of more than 345 MN/cm^2 and temperature greater than 4500°C, can exist within the collapsing bubble and shockwaves exist in all directions at the instant of collapse. Cumulatively the effect is very intense on the surface of the work piece. This intense scrabbing action is characteristic of all ultrasonic cleaning. The system consists of a processing tank, a transducer and generator power supply.

In vapour degreasing, the treatment procedure is as follows:

1. Degrease the part by holding in perchloroethylene or trichloroethylene vapour until the vapour condensation action ceases.
2. Immerse in ultrasonically agitated tank of perchloroethylene or tricthloroehylene for two minutes or until all the foreign materials have been dislodged from the metal surface.
3. Drain all solvent from cavities in metal components.
4. re-vapour clean.

Once the mechanical ultrasonic energy is transmitted to the solder, cavitation action takes place in the solder which in turn goes to the surface of the metal. The cavitation corrosion process simply removes the oxide from the part immersed in the solder facilitating instantaneous wetting of the metal surface, thus producing a good joint.

Features of solder tank with ultrasonic cleaning

The small activated solder tanks have relatively low ultrasonic energy outputs[7]. In order to get higher output, larger tanks are used. Ultrasonic waves are applied at the bottom of the tank and heat is applied through the side walls Fig. 1). The major differences between the two tanks are as follows:

1. Stresses due to high ultrasonic energy inputs at elevated temperature are developed in the corner section of the flat bottom tank. These stress-points can result in the formation of cracks which

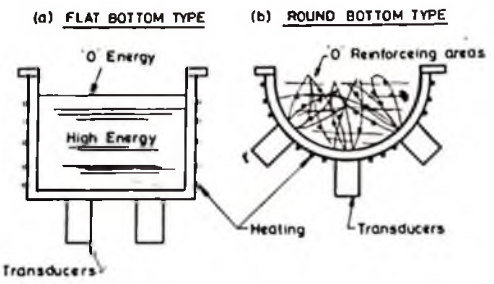


Fig. 1 (a) SOLDERING TANK WITH HIGH AND LOW ULTRASONIC ENERGY LEVELS (b) SOLDERING TANK WITH OVERLAPPING PATTERN OF ULTRASONIC ENERGY[7]

will then be propagated by the highly intense energy levels.

2. Areas of maximum ultrasonic energy follow a pattern of standing waves. The pattern is such that the lowest level of energy is always near the surface of the solder. This factor holds true regardless of solder depth.

3. Flat bottom tanks generally have low ultrasonic energy levels when compared to round bottom tanks.

Round bottom tanks

1. The basic design and layout of the transducers and heaters allows both the heat and the ultrasonic input to be distributed over a larger area.

2. Two radially mounted transducers provide an overlapping pattern of ultrasonic energy within the solder. This results in a very uniform cavitation pattern.

3. The ultrasonic standing waves in the solder intersect the top surface of the solder at the shallow angle resulting in a relatively high level of cavitation close to the solder surface.

Surface coating and plating for better solderability

Rapid wetting of the surfaces by the molten solder is achieved only if the surfaces are in a suitably clean condition to allow surface reaction to occur easily. Freshly cleaned metal surface will oxidize, however, and it is usual to protect them with an organic or metallic coating. If these coatings are completely dissolved away in the molten solder, interface reaction takes place with the underlying metal and it is therefore important to get absolute surface cleanliness before coating the substrate.

Even though copper has good solderability, its surface becomes stained on exposure to air. This problem is solved by coating with a metal that retains better solderability. The solderability of a surface is enhanced by the application of a preservative metal surface and surfaces are tinned to wet subsequent soldering. This is done by cleaning, fluxing and hot dipping or flow tinning the surface.

Hot dip coating[3] must be considered as the prime candidate for a solderable coating. It is used extensively for tinning of leads and surfaces of reactive metals, whose corrosion is very high even at room temperature, when one surface is to be wetted to another. The pretinned parts are pressed together under heat using an interference joint configuration. This pretinning and joining are both accomplished without the flux, this process is most used in ultrasonic fluxless soldering.

Electro-tin coating is essential since loosely adherent coatings are immediately dissolved off without the base metal being wetted by the solder. This deposits solder quite well for a few days, but, after some weeks, the adhesion is uncertain due to diffusion of the tin into the metal and also due to oxidation. This can be avoided by coating adequate thickness of tin.

Electro-tinning[8] does not guarantee, that surface will be solderable. This is because, after tinning, the solders will fuse with the subsequent solders and expose the substrate, if the surface is contaminated.

Metallic coating

In some cases where the organic reactive flux is not suitable, the parts are plated with solderable metal having high resistance to corrosion, wear resistance and better wetting properties. Usually nickel and gold are plated and it is reported that the solderability is extremely good. It is found that hot dip coating on brass parts[9] suffer loss of solderability than the electrodeposited coating of similar thickness. The use of a nickel undercoat is recommended[2]. This should be thick enough($\sim 5\mu m$) not to be dissolved away during hot dipping and the barrier layer serves to prevent diffusion during storage.

Gold forms protective coating since there is no oxide formation[10]. The majority of the soldering defects when base metals are gold plated are due to the residues on the surface. Usually the plating

thickness will be approximately 2.5 to 5μm, as the soldering will dissolve up to about 1.5μm. The solderability of most gold deposits is good though it depends upon the type of plating bath and the alloying additions[11]. Since gold dissolves rapidly in molten solder and easily forms intermetallic compounds with tin and lead, thick coatings ($\sim$5 μm) are liable to cause embrittlement of the solder in the joint. As the thickness of the gold decreases, so the risk of embrittlement is lessened and joint strength is raised[12]. The following properties makes the gold a worth while material in electronic industry for plating prior to soldering. 1. Higher chemical stability ; 2. Low electrical resistivity ; 3. Low contact resistance ; 4. Easy soldering with other materials. Palladium coatings appear to exhibit rapid alloying with solder similar to gold, but to a slightly reduced extent. Silver also rapidly forms intermetallic compound layers with tin, but it does not produce embrittling effect[11].

Organic coating

In the case of printed circuit boards, where it is not possible to finish with a metallic coating, a temporary protection may be given with varnish or lacquer. This lacquer is the water displacing variety. A simple resin/alcohol (dilute flux) may also be applied after cleaning and drying the board.

Conclusion

To get a good joint, surface treatment prior to soldering is very important. This can be achieved by using different cleaning processes. Most of the fluxes are corrosive at the melting point of solder which is not desirable in electronic industry. So fluxless soldering can be used by employing ultrasonic cleaning and soldering system. Where better corrosion and wear resistance is necessary, plating prior to soldering can be used.

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