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Selective Soldering: A need for Innovation and Development

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1. Introduction

Selective soldering utilises a nozzle to apply solder to components on the underside of printed circuit boards (PCBs). This nozzle can be moved to either perform dips (depositing solder to a single component) or draws (applying solder to several components in a single movement). The selective soldering methodology thereby allows the process to be tailored to specific joints and allows multiple nozzle types to be used if required on the circuit board.

Nozzles can vary by size (internal diameter) and shape (making them suitable for different process types). This is all dictated by board design and process requirements. Selection of the nozzle type is dependent upon the product to be soldered and the desired cycle time. Examples of different nozzle types are shown here.

Hand-load selective systems must be programmed with the parameters for multiple solder joints. However, many in-line systems are designed to be modular. This modularity allows for multiple solder stations with different conditions/nozzles to achieve low cycle times. Figure 1 shows the two distinct types of selective soldering systems offered by Pillarhouse International Ltd.

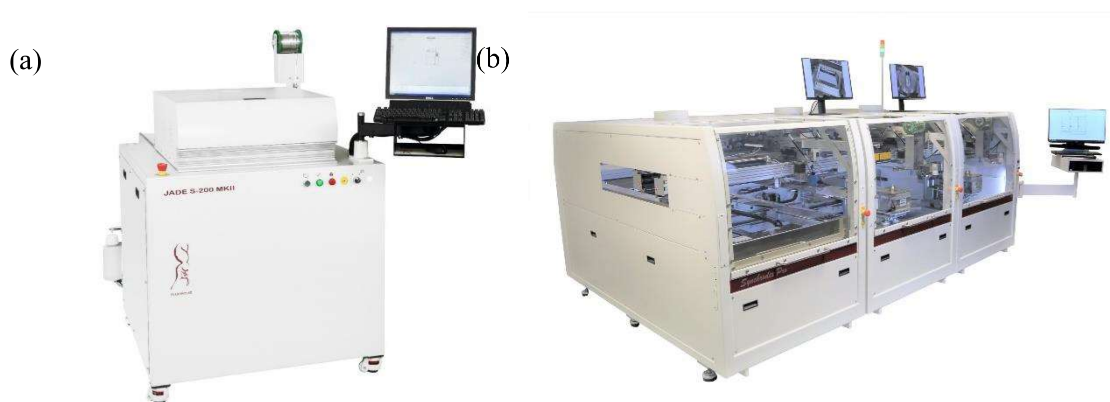

Figure 1. Examples of different Pillarhouse International selective soldering systems: (a) Jade MkII hand-load system. (b) Orissa Synchrodex Pro modular in-line system.

Selective soldering provides many other benefits compared to wave and hand soldering such as:

- Minimal thermal shock.
- Lower running costs than wave soldering.
- Operation under an inert environment to minimise soldering defects, reduce the production of dross and improve wetting performance (more details below).
- Applicability to low and high-volume production.
- Repeatability in the process and solder joints.
- Fewer operators required.

2. Key attributes of nozzles

To ensure that controlled application of the solder is maintained throughout the process, the solder must wet (adhere) to the nozzle. Wettability is the study of the adhesion of liquids to solids because of the interaction between the surface energy of the solid and the surface tension of the liquid [1,2]. Surface energy (known as surface tension when referring to liquids) is a result of the relative bond strength of the material and the level of unbalanced forces at the surface [1,2]. Multiple methods exist to characterise surface energy depending upon the components of the surface interaction that can be measured [3] however the most common is measuring the contact angle of a stationary (sessile) droplet.

When no other forces act upon a liquid droplet (i.e. no contact with other surfaces and no air resistance due to movement), it will form a sphere as its own surface tension pulls it into that shape as it is the minimum energy shape it can be. When in contact with a solid, the droplet will deform and spread out. The amount of spreading and the angle of the interface between the liquid and solid is a product of the relation between the surface tension of the liquid and the surface energy of the solid. Figure 2 demonstrates scenarios with various levels of wetting. When the surface energy of the solid is greater than the surface tension of the liquid, the droplet will spread out more and have a lower contact angle [1,3]. Figure 2(a) and (b) are an example of this.

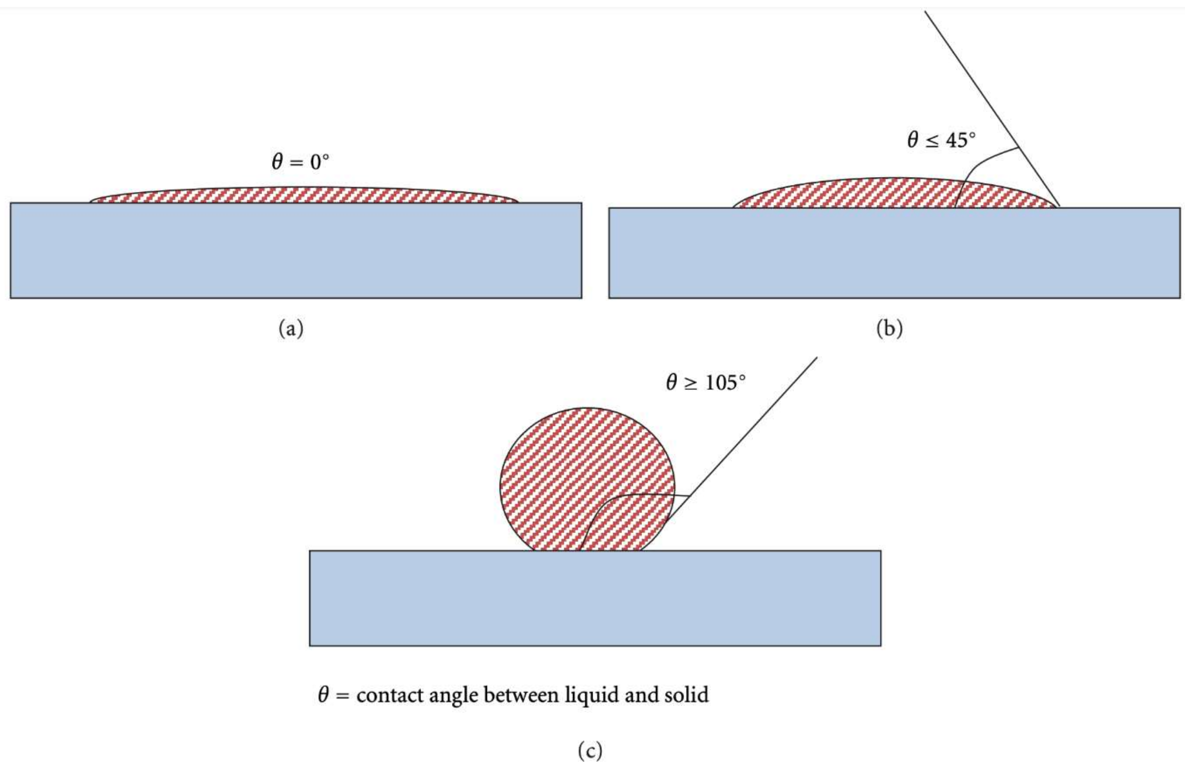

Figure 2. Examples of different contact angles between a droplet (stripped red) and solid (blue): (a) Contact angle of 0° demonstrating perfect wetting. (b) Contact angle less than 90°for a wetting surface. (c) Contact angle greater than 90° hydrophobic surface. By Idris.abk - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=97191171

Typically, a static system would be preferred for wettability studies but we are dealing with a dynamic process in the case of a nozzle. In this instance, the wetting of the solder to the tip of the nozzle maintains a stable radial wave and achieves control during the soldering process by maintaining a stable dome shape to deposit solder.

Figure 3 shows a well wetted nozzle wherein the solder is adhered to the entire outer surface of the nozzle and therefore has a stable radial wave. This allows for good control during the selective soldering process. The static wettability for this nozzle would be akin to Figure 2 (a) or (b).

Figure 3. An example of a wetted nozzle.

In the case of a material that solder does not readily wet to (non-wetting), the surface energy of the nozzle (or other material being wetted) is not enough to overcome the surface energy of the solder and therefore the solder will maintain a single stream as shown in Figure 4. The static wettability of this nozzle would produce a large contact angle such as in Figure 2 (c).

Figure 4. An example of a non-wetting nozzle.

For wetting between the liquid solder and the nozzle, there must be a clean interface with minimal surface oxides on the nozzle. The presence of oxides on the surface interferes with the wetting of the solder to the surface by acting as a barrier; additionally, the surface energy of oxides is too low for wetting to occur. Flux is used to remove oxides and generate/maintain this clean interface before and during operation. After cleaning, a chemical reaction between the solder and nozzle determines the extent of the wetting but this interaction also limits the lifetime of the nozzle. It causes wear of the nozzle and metal is leached into the solder bath. Exposure to the solder and the subsequent reaction alone does not cause significant wear. The contribution of liquid flow increases the wear in a synergistic effect which suggests that the underlying mechanism is complex corrosion-erosion.

Therefore, a good nozzle must have good wettability to solder ensuring that control can be maintained during the selective soldering process in addition to a balance between the corrosion and wetting. The composition must be chosen carefully in materials to achieve this. For example, extremely wettable materials such as copper have a high dissolution rate and will therefore be completely leached into the bath within hours demonstrating the link between the wear process and wetting.

3. The need for development

Currently, the selective soldering industry sees innovation with the production of new machines, pump types and nozzle cleaning however, there has been only minor development in the study of materials for nozzles. A new nozzle material will reduce operation and maintenance costs for manufacturers by reducing the number of nozzles required overall and reducing downtime caused by nozzle failure. Improving the wettability of nozzles will allow for more challenging joints to be tackled using the selective method. The current nozzles have a lifetime of approximately 200 hours (smaller nozzles wear faster however as they are smaller). This project has been undertaken due to customer requests to increase nozzle lifetime and reduce the maintenance required.

Kurtz Ersa [4] and SEHO [5], have developed new nozzles with similar structures based on commonly applied electroless nickel-immersion gold coatings but this approach has utilised materials that are already known to work in the industry. It is well known that the electronics industry is conservative in many regards and rightly so; "why fix what isn't broken" especially when reliability is paramount. There has been a distinct lack of research in nozzle development. Each selective soldering manufacturer is highly secretive surrounding the materials used for their nozzles but there has been some noted development in nitriding as a surface engineering technique to extend the lifespan of wave soldering apparatus [6]. Morris and O'Keefe [7,8] also produced studies on methods to extend the lifespan of soldering components, some examples being using titanium or grey cast iron as a solder resistant material, nitriding, or the application of ceramic coating (titanium nitride).

This ground-breaking research project, part funded by Innovate UK and Pillarhouse International Ltd. is partnered with Coventry University through a knowledge transfer partnership scheme. The aim is to develop a new, longer-lasting nozzle with excellent wetting properties. By applying the studies of tribology and materials science, fundamental work looking at different materials and surface engineering techniques has selected a number of potential candidates that show improved performance. Currently, prototype nozzles are being tested with key customers to generate field data and ensure compatibility with currently used fluxes. Tests have shown promising results. Watch this space for further details!

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