Underfill Application Guide

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About the Document

Revision History

Revision	Date	Author	Description
-	2020-11-02	Alain HUANG	Creation of the document
1.0	2020-11-07	Alain HUANG	First official release

Contents

Table Index

Figure Index

1 Introduction

Underfills are a specific class of adhesives applied between the die and substrate after the solder has been reflowed to enhance the soldering reliability against mechanical and vibrational shocks and extremely high or low temperature.

This document is a guide to underfilling Quectel modules as well as to repairing inferior components. By explicating the requirements and standards in underfill and repair processes, it helps you apply the underfill material correctly and effectively. This guide applies to all Quectel modules that require underfilling.

2 Adhesive

2.1. Package of Adhesive

Normally, adhesives applied to modules come in two packages: tube and needle tube; The latter, as is shown below, is the package of the underfill material used in this case.

Figure 1: Adhesive in Needle Tube

2.2. Type of Adhesive

- **Wrapping Adhesive (Fixing Adhesive)**

  Adhesives, such as white and red ones, used around the circuit board to wrap tiny solder pads and components in so as to prevent them from being forced to fall out.

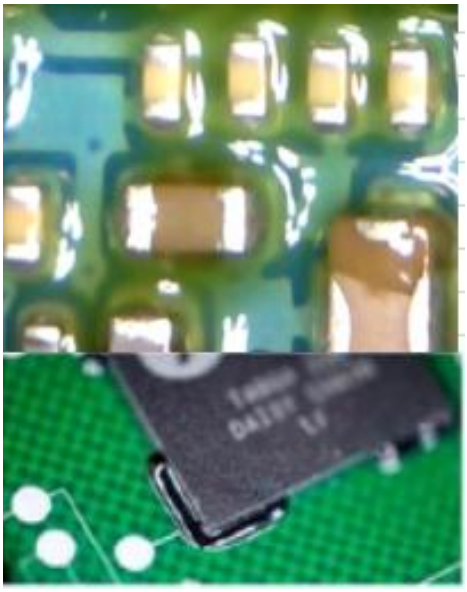

Figure 2: Wrapping Adhesive (Fixing Adhesive)

- **Underfill**

  The underfill material is usually dispensed and dragged to fill up the gap between the die and substrate by a capillary force to fully wrap in all the soldering joints.

Figure 3: Example of Underfill Application

NOTE

Underfills are the first-choice adhesives to be dispensed for Quectel modules; Their application is the focus of this document.

3 Underfill Dispenser

3.1. Type of Underfill Dispenser

There are three mainstay types of underfill dispensers as listed below:

- Automated Dispenser
- Desktop Semi-automated Dispenser
- Manual Dispenser

3.2. Dispenser Performance Requirement

The performance demands on underfill dispensers are as follows:

- Automated Dispenser: High-precision X-, Y- and Z-axis movement control, non-contact pumping, precise throughput and desirable dispensing results. The CPK for the underfill material should be higher than 1.33 ±1 mg @ 3 σ.

- Semi-automated Dispenser: Despite lower requirements for its performance than those for the performance of the automated dispenser, it is required that in the dispensing process, no components shall be contacted and that before the process, all the tools, fixtures and devices, inclusive the dispenser itself, must be checked in terms of ESD protection to ensure a safe ESD environment.

Figure 4: Automated Underfill Dispenser

Figure 5: Desktop Semi-automated Underfill Dispenser

Figure 6: Manual Underfill Dispenser

4 Underfill Process

4.1. Restore Underfill to Room Temperature

General requirements for restoring the underfill material to room temperature (RT) are as follows:

- If unpackaged, an underfill material restored to RT can be stored at RT for at most 24 hours before it should be immediately refrigerated for the earliest possible use next time. Each tube of underfill can only be restored to RT twice.
- Leftover underfill materials should be refrigerated within 12 hours and be used as soon as possible. Each tube of underfill can only be restored to RT twice, which means the underfill material can only be put back into the refrigerator once.
- Cured underfill materials are unusable and thus should be disused; Underfill materials cured upon unpackaging or too adhesive to flow should be returned to the supplier; The underfill material whose shelf life has expired should be disused.
- The underfill material whose temperature has reached RT for a longer period than allowed (e.g. having been put in RT for over 48 hours) should be disused.

Concrete requirements for restoring the underfill material to RT are stated below.

Table 1: Concrete Requirements for Restoring Underfill Material to Room Temperature

Parameter	Requirement
Time required for restoring the underfill material to RT before use	● ≥ 2.5 hours (30 ml package) ● ≥ 4 hours (250 ml package) (As the time required is decided by package volume, please refer to the guide provided by your underfill supplier.)
Time limit for the underfill material to be used after being restored to RT	24 hours (RT ≤ 26 °C)
Operational rules	● The underfill material must be retrieved from the fridge and restored to RT before use, needle side down. ● Do not hold the tube with hands while handling a room temperature underfill material. ● Do not accelerate the unfreezing process through heating lest any bubble should appear in the process.

Underfill Disuse	Underfill materials with a lot of bubbles after being restored to RT are not usable.

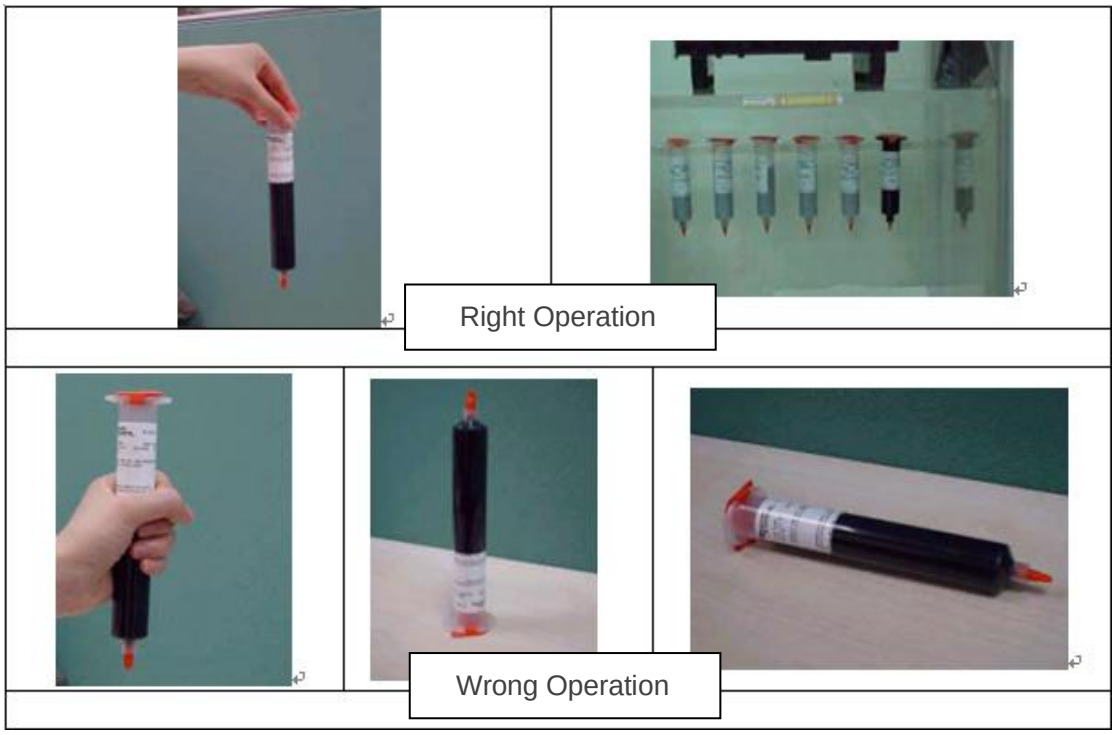

Figure 7: Demonstration of Restoring Underfill Material to Room Temperature

NOTE

Screw tight the cover/cap of the underfill tube before putting it back into the refrigerator lest the underfill material should uptake moisture via the tube mouth.

4.2. Dispense Underfill

The general technical requirements for underfill dispensing are as follows:

- Follow the guide of your underfill supplier in the storage and use of different types of underfills;
- Consult your underfill supplier as to whether a baking treatment of the substrate is required before underfill dispensing;
- Adjust needle specifications, dispensing rate and air pressure as needed to get the desirable underfill dispensing results. The needle specifications for different dispensers are listed in the table below.

Table 2: Needle Specifications for Different Dispensers

Parameter	Automated Dispenser	Semi-automated/Manual Dispenser
Suitable Needles	21–23#	18–23#
Recommended Needle	22#	20#
Needle Material	Stainless steel	Stainless steel

- Ensure that the PCB is placed level while dispensing underfill on it;
- Ensure that the distance between the needle's periphery and the component is kept at 4–6 mil as is shown below:

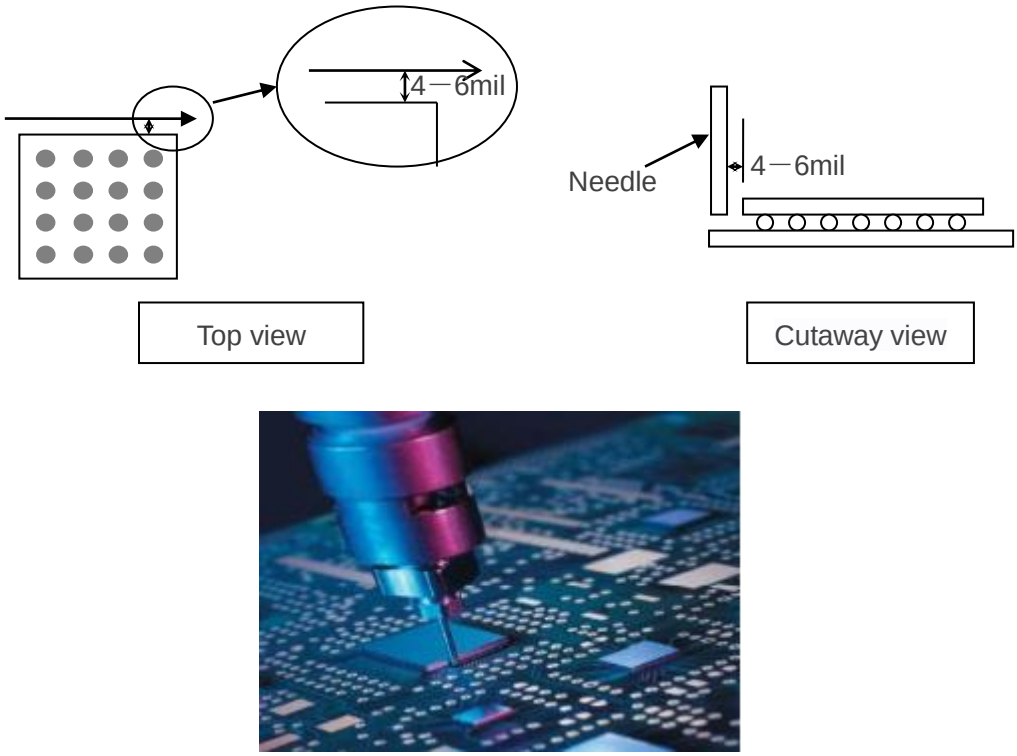

Figure 8: Dispensing Needle Kept at 4–6 mil away from Component

- The pattern for dispensing the material is recommended to be the "L" pattern. The "L" starts on the longest side of the module and turns the corner to the shorter side.
- Use the electric scale to check whether the throughput of underfill is as required; The accuracy of the scale must be at least 0.001 g (1 mg).

4.3. Underfill Curing

The underfill material can cure in a reflow or drying oven; the substrate should be placed level.

Table 3: Curing Parameters

Parameter	Requirement
Curing Temperature	Depends on the type of the underfill
Curing Time	Depends on the type of the underfill

The following curing temperature setting is for your reference:

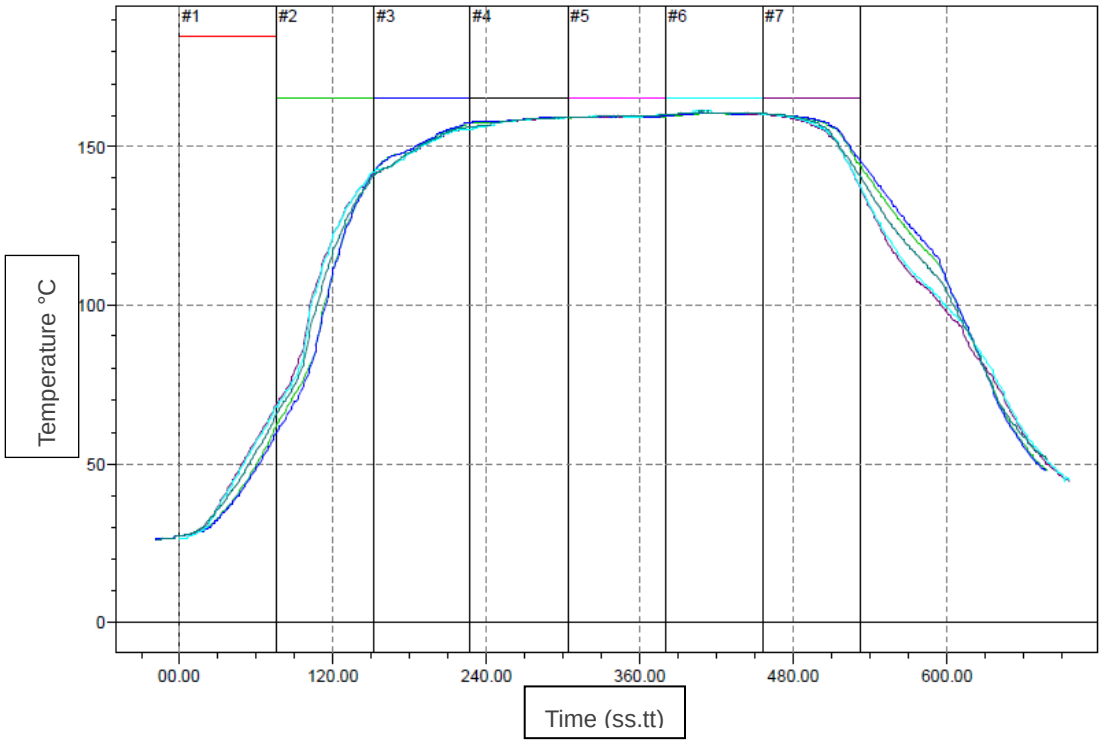

Figure 9: Curing Temperature Profile

NOTES

1. Curing time refers to the time it takes for the underfill material to be cured at the curing temperature; It does not include the time for the underfill to reach its curing temperature.
2. It is recommended to set the curing temperature and time according to the specific parameters of underfills. For underfills with different specifications, proper curing temperature profile and curing process should be determined after consulting the supplier.

3. Inappropriate dispensing process may cause bubbles to appear; The expansion of air during heat-up curing may cause unwanted underfill ejection, which contaminates and thus invalidates the solder joints. A countermeasure is to extend the heating up process during underfill curing.
4. The underfill process can only be applied to quality PCBs having passed all the tests, since a second reflow after the underfill process is inadvisable.

5 Industrial Standard

5.1. Technical Standard

The technical standards specified in *IPC J-STD-030A* regarding adhesive application are as follows:

- No voids;
- No exposed component periphery or solder joints;
- Adhesive fully cured;
- No flux residues

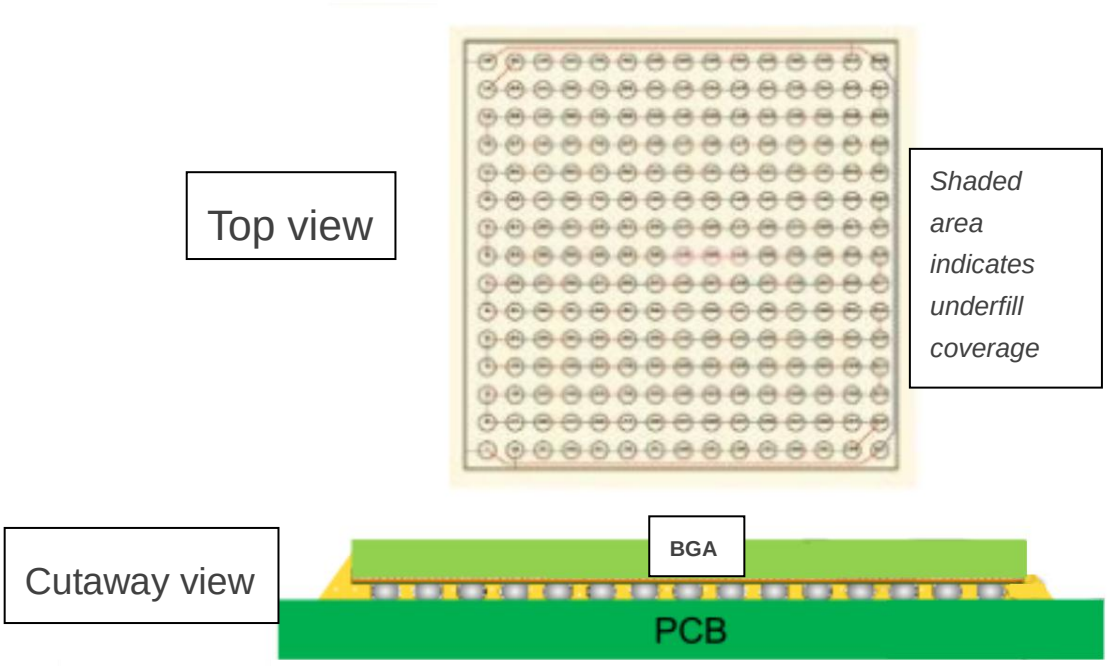

Figure 10: Underfill Technique Illustration

5.2. Acceptance Standard

For the underfill result to pass quality inspection, the following prerequisites must be met:

- The underfill material is sufficient to form four filleted corners and underfill bands at the four sides of the device;
- The fillet height is over 25% of the height of the device, and the top of the device is not covered;
- No pins or solder joints are exposed;
- An obvious contact angle is formed between the cured underfill and the bottom periphery of the device.

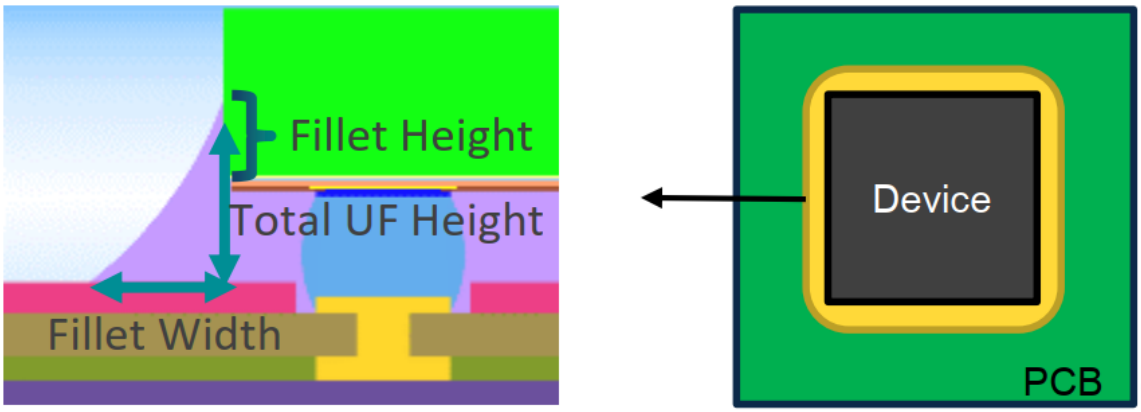

Figure 11: Acceptable Underfill Dispensing Result

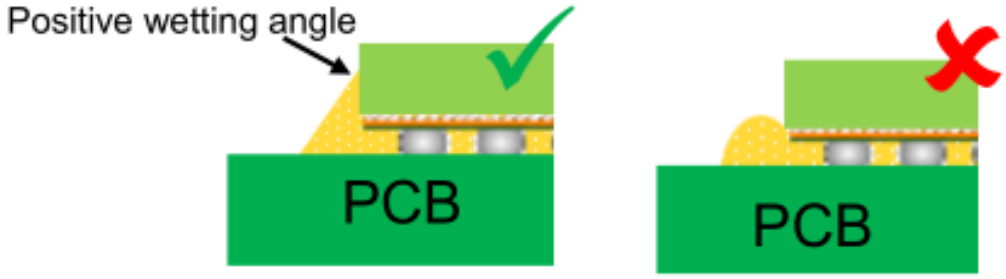

Figure 12: Quality Product VS Inferior Product

5.3. Defect Judgement

The existence of bubbles and voids after the underfill process is a defect. Nonstandard curing temperature and underfill process will cause higher investment cost and, in severe cases, unacceptable product quality. Standard underfill dispensing can prevent the solder joints from cracking or being

inactivated. Therefore, it is critical to discern bad underfill dispensing.

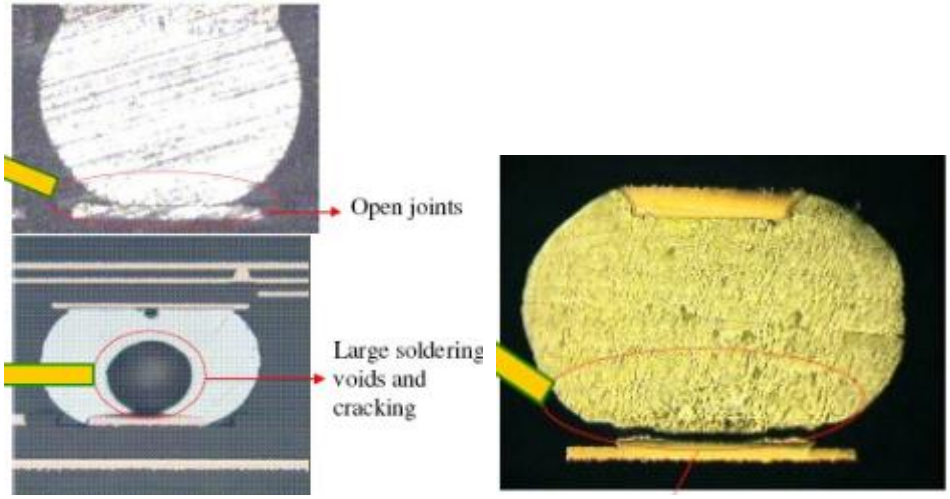

Figure 13: Solder Joints Cracking

The following two measures can be taken to judge whether the underfill result is acceptable:

1. Cross-section Slice Analysis

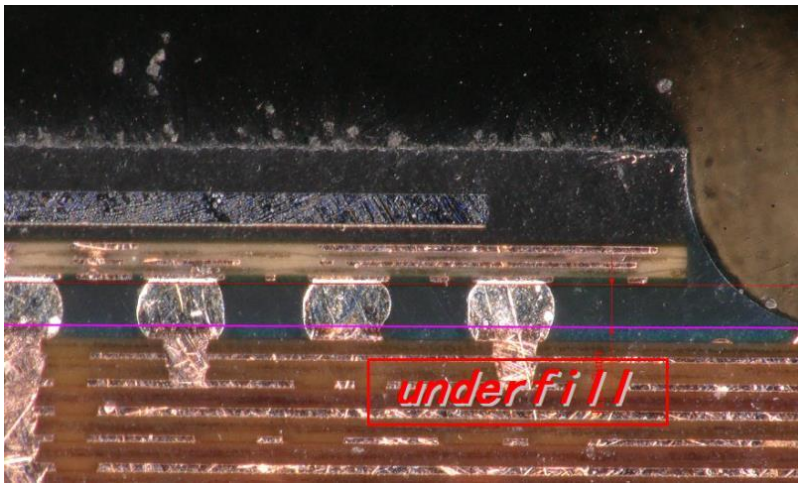

Figure 14: Cross-section Slice

2. The scanning acoustic tomography (SAT) can be used to detect delamination, cracks, voids and other defects after underfilling to help judge the process quality.

6 Repair of BGA-encapsulated Components

This chapter illustrates the procedure for repairing inferior components encapsulated in BGA.

If there is an inferior component with BGA encapsulation, the first thing to do is to separate the PCB from BGA and clean the solder joints/balls on them. The tools and materials needed for this procedure is listed below.

- Thermostatic electric soldering iron
- Welding and repairing fixtures
- Heating gun
- Tweezers
- Eco-friendly flux
- Vacuum sucking pen
- Solder wick/braid
- Bottom heating platform
- IPA cleaning solvent

The repair procedure is illustrated in the chart below:

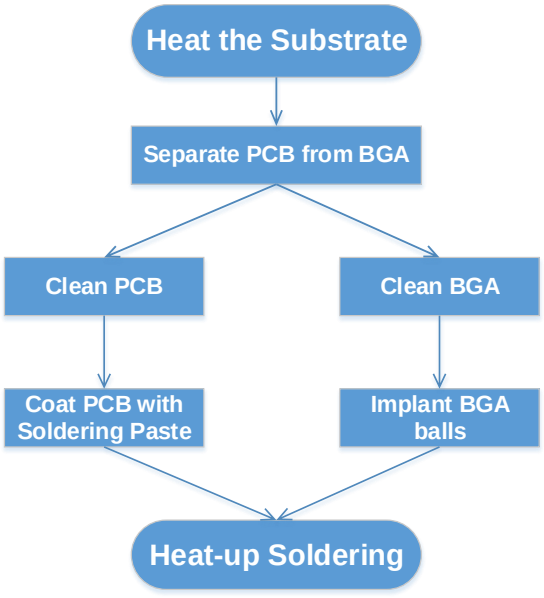

Figure 15: Repair Procedure

The repair steps are illustrated below:

- Fix the substrate with the commonly-used welding and repairing fixture and put a heating platform under the substrate. Then heat the BGA evenly with a heating gun for 30 seconds, keeping the temperature at 300–350 °C.

Figure 16: Heating up the PCB

- Remove the softened adhesive around the BGA with plastic ESD-proof tweezers before swiftly removing the BGA.

Figure 17: Remove BGA

- Remove the flux on PCB with ESD-proof brush or lint-free wipes (cleanroom wipers) and use a magnifying glass to check if there is any flux remains.

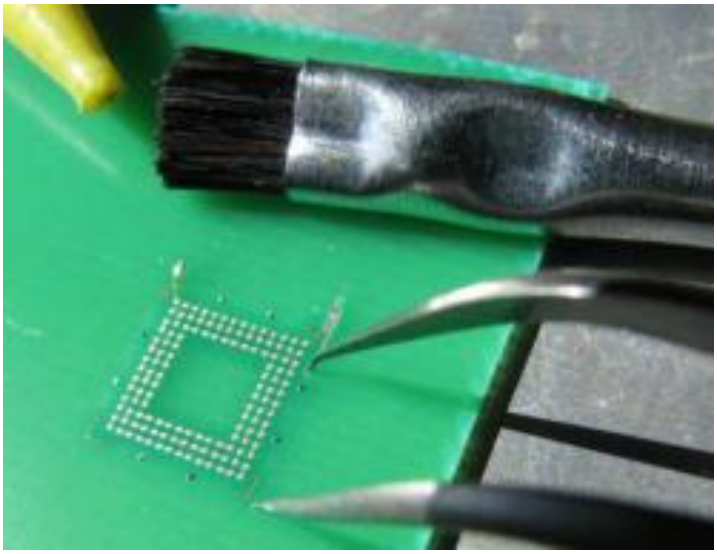

Figure 18: Clean the PCB

- Remove the soldering tin on the surface of soldering pads with a solder wick/braid after cleaning flux off the PCB.

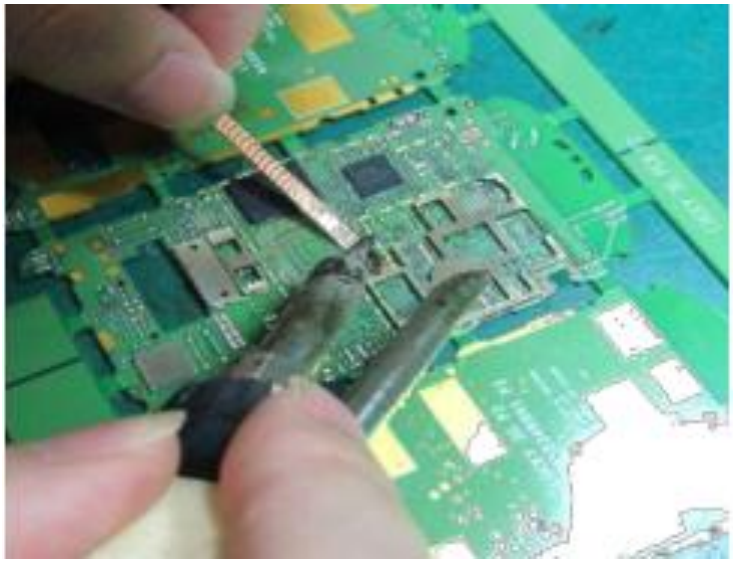

Figure 19: Clean the Soldering Pads on PCB

- Solder BGA, new or ball implanted, onto the cleaned PCB area; A dedicated BGA rework platform is recommended.

The repair takes 5–10 minutes, after which the product needs to be X-rayed for quality checking.

7 Appendix A References

Table 4: Terms and Abbreviations

Abbreviation	Description
BGA	Ball Grid Array
CPK	Process Capability
ESD	Electrostatic
PCB	Printed Circuit Board
SAT	Scanning Acoustic Tomography