DESOLDERING AND REMANUFACTURING OF SEMICONDUCTOR COMPONENTS FROM ELECTRONIC MOBILE DEVICES

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Abstract: The paper presents results of investigation obtained during desoldering process development leading to elaboration of machinery concept of automatic disassembly of electronic components from mobile and communication devices. The possibilities of different desoldering techniques and their limitations in automatic desoldering processes of components was presented. Next the issue regarding remanufacturing process of BGA semiconductor components for reuse was showed. The carried out investigations showed the best remanufacturing technique and confirmed an acceptable quality and reliability level of remanufactured BGA components for reuse in less demanding applications.

1. INTRODUCTION

With the rapid development of industry, technology changes and shorter cycles use of high-tech products, more and more electronic and electric products are produced and consumed in our daily life. As a result of that millions tons of e-wastes, containing toxic substances are generated per year. Many electronics mobile devices especially smartphones are replaced by users for new ones very often below two years of usage although are still reliable [1]. Answer for this is “Circular Economy” concept primarily led by policy makers such as the European Commission [2] and business advocacy bodies such as the Ellen MacArthur Foundation [3]. One from direction of the proposed approach is going to keeping the functional, semiconductor components such as flash memories, processors and others that are still functional and extent of their lifetime in other less complex or less demanding applications [1]. The concept for reuse of electronic components can effect economic, environmental, and social aspects in a positive way, but the automatization of disassembly and remanufacturing of electronic components for reuse is still challenge for scientists [4-15].

The paper presents research results obtained during desoldering process development leading to elaboration of machinery concept of automatic disassembly of electronic components from mobile information and communication devices in a frame of “sustainablySMART” project [16]. The possibilities of different desoldering techniques and their limitations in automatic desoldering processes of components was presented. Next the investigations regarding remanufacturing process of BGA semiconductor components for reuse are showed.

2. DESOLDERING OF BGA COMPONENTS PROCESS DEVELOPMENT

There are many challenges and aspects that have to be considered during automatic desoldering process development what was described at earlier publications of authors [1, 15]. For the record, it was stated that desoldering parameters of electronic components from mobile devices have to be adjusted to conditions of Pb-free technology as the carried out investigation confirmed that in all cases the lead-free technology was applied during investigated mobile devices manufacture. The big technical challenge of this process are properties of lead-free solders applied in components solder joints (high melting temperature: 217°C – 221°C - the most often used SAC305 alloy and higher of about 30% surface tension comparing to SnPb ones). Therefore a significant force is needed to lift BGA component during desoldering process, what was confirmed in desoldering trials. This force can be reduced by applying higher desoldering temperature (Fig. 1) or by using special flux to decrease surface tension of alloy.

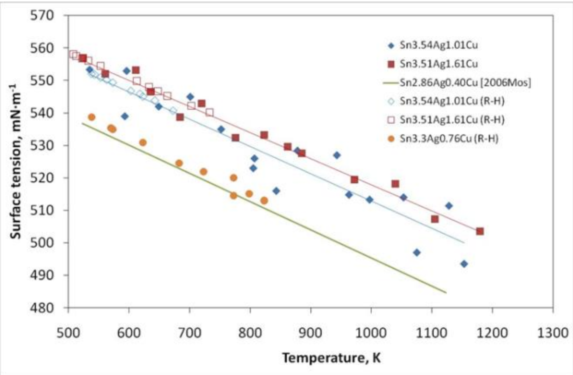


Fig.1. Temperature dependence of the surface tension of SAC alloys [17]

Both options have their drawback. The higher desoldering temperature is dangerous for electronic chips. In turn flux application requires additional process operation and material what causes raise of costs.
However the carried out investigation showed that for small BGA components the option with higher desoldering temperature settings can be chosen because required time of process is enough short. In the case of larger BGA components the application of flux is needed to prevent component damage. It was stated that the ROL1 type flux decreasing surface tension of lead-free alloys from 15 to 18% depends from alloy's composition. The highest decreasing of surface tension of the SAC305 alloy (up to 25%) obtained for the NC254 flux designed for rework processes made by AIM.
Electronics components with plastic housing or printed circuit boards absorb and release moisture at different rates. During the desoldering process heat can causes expansion of the moisture that can damage the components. This damage (crack, internal delamination, popcorning) may not be visible and therefore the risk of these defects should be limited during desoldering process planning.
The Fig.2. shows an example of drying efficiency in different conditions.

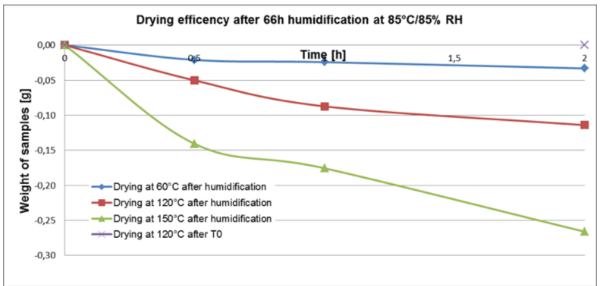


Fig. 2. The relation of moisture content in test samples from temperature and time of drying after 66h humidification at 85°C/85% RH.

It was stated that drying efficiency is strongly related with drying temperature and drying speed increases when temperatures are above 100°C. Drying during 0.5h at 150°C is about two times more effective in comparison to 0.5h drying at 120°C, and about four times more effective than 0.5 h drying at 60°C. Drying longer than 1h becoming less effective as time goes by, but almost 2h at 150°C was needed to remove completely moisture from test boards with high content of humidity. In reality the moisture content in electronic components is not as high as in carried out investigations. Taking into account speed of intermetallic compounds growth with temperature [18] or possibility of component degradation it was decided that drying 1h at 120°C is enough for drying procedure of components before desoldering operations.
The automatization of desoldering process of BGA components requires usage of special heating techniques. The results of industrial trials showed that reverse reflow process using typical reflow ovens cannot be used for automatic desoldering processes. The components solder joints temperature decreased below melting point of solder directly after leaving reflow zone. In the case of the ERSA HOTFLOW 2/14 reflow oven (with long cooling zone) (Fig.3) this decrease of solder temperature was very high (up to 90°C - 105°C). In the case of shorter reflow ovens the temperature decrease was smaller (up to (205 - 210°C), but it was still about 30°C too low for effective component desoldering.

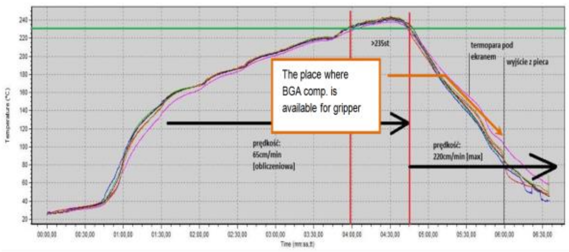


Fig. 3. An example of reverse reflow profile for process using reflow oven in industrial conditions with long cooling zone.

Many other trials using different heating techniques and settings were carried out. But the most effective method of heat transfer during desoldering process was semi-automatic desoldering system containing independently managed "Top" and "Bottom" modules of hot-air heating (Fig. 4). The minimal desoldering time for a single BGA component was 75 seconds for elaborated settings.

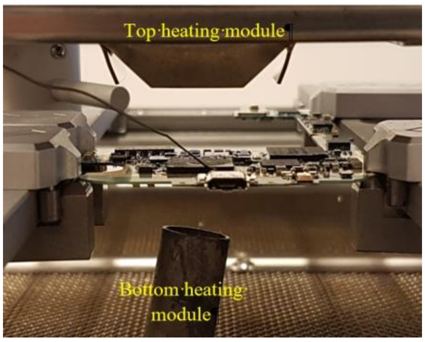


Fig. 4. “Top” and “Bottom” heating modules in desoldering system.

Based on carried out trials and investigations the following procedure of desoldering process was elaborated.
In the first stage the PCBA with valuable components is dried at 120°C for 1h to remove moisture from components. Next the PCBA is placed on the disassembly line and fixed. The operator selects the correct programme tailored for the disassembly of selected components and PCBA. Installed camera system makes visual identification of EMC shield or component and marking the position, where the system should measure the temperature during desoldering process. If the EMC shield is soldered this part must be desoldered first. Removing EMC shield from PCBA is the main step to uncover hidden valuable components. Next the machine applying flux around the EMC shield. The flux will reduced the surface tension of the solder for easier and quicker desoldering. After that, the PCBA is transported to the desoldering section. In the first step of desoldering process the PCBA have to be preheated up to temperature 170 Celsius degrees using “Top” and “Bottom” hot-air heating modules. After that “Bottom” heating module is switch off. One has to be sure that the heating rate will not exceed 2 Celsius degrees per second. The temperature should rise up to 240°C. Exposure time can’t exceed 10-15 seconds depends size of component. During this time, the machine picks up the shield by head with vacuum nozzle. After removing the shield, the procedure has to be repeated for the selected valuable components.
All dissembled components are collected and sorted. When all recoverable components are removed from the PCBA, the PCBA is transferred to scrap box for recycling. Next the desoldered components are transferred in the ESD tray to remanufacturing section.

The carried out implementation trials of desoldering processes (Fig. 5) confirmed that elaborated desoldering procedures are correct for BGA components not protected by underfilling materials. All desoldered components works correctly what was verified using special designed measurements stands described wider at [15].
Desoldering of BGA components protected by undefining technique required additional force to pick up the component exceeding possibility of typical vacuum nozzles.

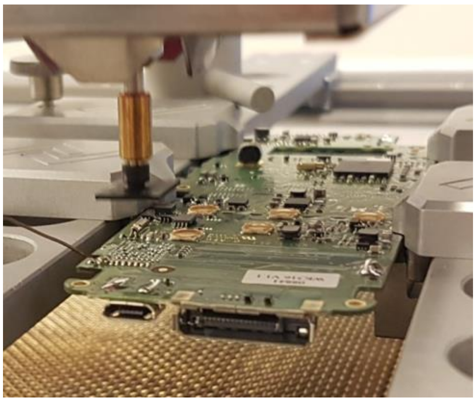


Fig. 5. Desoldering of BGA component from DVR PCBA.

3. REMANUFACTURING OF BGA COMPONENTS PROCESS DEVELOPMENT

The BGA components after desoldering process have destroyed leads which have to be remanufactured (Fig. 6) using many operations.

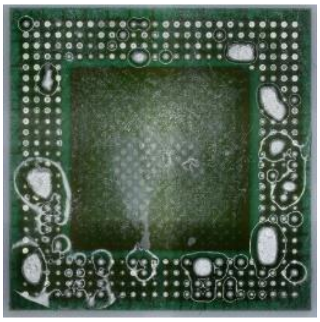


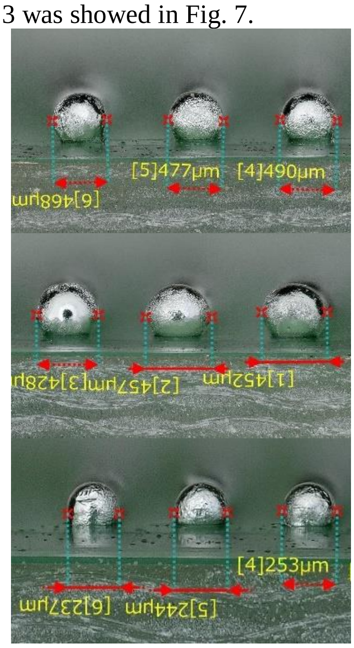
Fig. 6. An example of BGA component before balls manufacturing.

These operations included e.g.: preparation of component pads surface for re-balling, solder materials application on components pads, balls leads creation using different high temperature techniques, removing of residues and humidity after soldering operations by cleaning and drying, quality control after critical steps and finally marking and ESD and MSD packaging of remanufactured components.
After preliminary industrial trials three the most promising techniques of remanufacturing of BGA components leads were selected for further investigation. The goal of these investigation was selection of the best technique and equipment for automation of the process in a machinery concept.

The main idea of investigated techniques were as follow:

- Technique No. 1 - This technique covered creation of BGA component leads using solder paste, which was screen printed on component pads.
- Technique No. 2 - The thin layer of solder paste was screen printed on component pads. Next the solder balls were placed on the solder paste using pick and place machine and special head designed for this purpose.
- Technique No. 3 – The thin layer of flux was applied on component pads and next similar to technique No. 2 the solder balls were placed on the flux using pick and place machine using special head designed for this purpose.

The carried out investigations have shown that all three remanufacturing techniques are suitable for BGA components' balls remanufacturing from quality point of view. The sizes of balls that would be closest to the set target were obtained using techniques No. 2 and No. 3 and had similar values to catalogue information concerning alike BGA components [19]. Therefore during selection of final technique for BGA components' balls remanufacturing other aspects as possibility of process automatizations, complexity of operations and needed equipment as well as possibility of defects were considered. Finally the technique No. 3 was selected as the less problematic and easy for implementation and automatization. Examples of view of components balls after remanufacturing using technique No. 3 was showed in Fig. 7.



a)

b)

c)

Fig. 7. Examples of components balls view after remanufacturing using technique No. 3: a) pitch 1.0; b) pitch 0.8 and c) pitch 0.5 mm.

Based on the investigation results and industrial trials the machinery concept of semi-automatic technology of BGA components remanufacturing after desoldering was elaborated. The scheme of this technology is presented in Fig. 8.

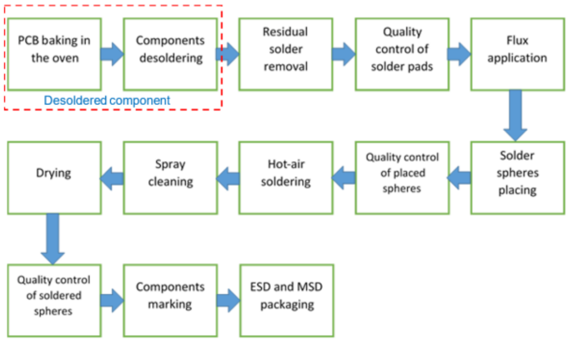


Fig. 8. Machinery concept of remanufacturing technology of semiconductor BGA components.

The most difficult and critical operation are automatic solder spheres placing on component pads (Fig. 9) and hot-air soldering step using head with hot gun. All other operations are ancillaries in this technology.

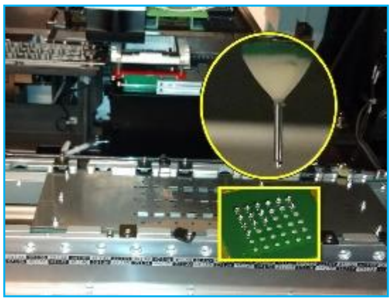


Fig. 9. Automatic solder spheres placing on solder pads using pick and place machine and special head [19].

The correctness of technology was verified in laboratory investigations using microscopic and X-ray observations as well as in functional tests described at [15]. The results of remanufactured components verification showed that the eMMC chips are functional even after 12 lead-free reflow processes [15].

4. SUMMARY AND CONCLUSSION

The carried out investigation showed that semi-automatic desoldering and remanufacturing of valuable components from electronics devices is possible. It was stated that desoldering system containing independent managed "Top" and "Bottom" modules of hot-air heating is the most effective method of desoldering process of BGA components.

The minimal desoldering time for a single BGA component was 75 s for elaborated settings, but further possibilities of efficiency increasing are possible.
The investigations showed the best remanufacturing technique of components and confirmed their acceptable quality level. The obtained results allow to formulate conclusion that BGA components after elaborated desoldering and remanufacturing procedures are much more temperature resistance than it was expected based on data sheets of their producers. Therefore can be safely reuse in less complex or less demanding applications according to Circular Economy principles.
The investigation show also that automatic recovery of components protected by corner bonding or underfilling materials is technically complicate for automatization and therefore it is considered that recovery of such components is not economically viable. The environmental friendly mobile product designed for short life time shouldn't use corner bonding or underfilling techniques to enable recovery of valuable components.

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