Study Of Decapsulation On IC With Temperature And Volume H_2SO_4 Variation

Budiana[1], Illa Aryeni[2], Hana Mutialif Maulidiah[3], Galih Hanif Arrahim[4], Muhammad Arifin[5]

{budiana@polibatam.ac.id[1], illaaryeni@polibatam.ac.id[2], hana@polibatam.ac.id[3], hanifar2107@gmail.com[4], arifin@polibatam.ac.id[5]}

Electrical Engineering Department, Politeknik Negeri Batam, Indonesia[1,2,3,4]

Abstract. Decapsulation is the process of opening the polymer layer covering the die. The purpose of decapsulation on IC is to facilitate checks on the quality of the die. The method carried out in this study uses the method of dripping H_2SO_4 on the IC surface. The variables to be examined in this study are variations in the use of H_2SO_4 volume and H_2SO_4 temperature. The volume variation used consists of 0.1130 ml (10 drops), 0.1356 ml (12 drops) and 0.1582 ml (14 drops). While the temperature variation used in this study consisted of 165 °C, 170 °C and 175 °C. The results showed that all samples is not completed decapsulation process. Some samples (B, C, E, F, H, and I) is partial decapsulation while other sample is not open die at all. Moreover, Sample C exhibits the greatest thickness reduction among all the samples under examination, and the die is distinctly visible.

Keywords: Decapsulation, Die, H_2SO_4, IC

1 Introduction

Integrated circuit (IC) packaging is the last step in the manufacturing process of an electronic device. The system board's external circuitry and the chip are connected electrically by the IC packaging, which serves this function as its primary function. Device will be put through a functional test after the packaging stage. IC packaging fills the gap between production of semiconductors and implementing the finished product [1]–[3]. Wire bonding, often referred to as sequential bonding, is a common connecting technique for packages that uses metallic wires to link IC chips and substrates [4]–[6]. To be more exact, local heat produced by ultrasonic vibrations is used to establish these first-level junctions using Cu or Au wires that span between the substrate pads and die. [7]. Nevertheless, because of its atomic structure and physical characteristics, there are certain issues regarding the reliability of copper wire. In the bond pad, copper and aluminum generate intermetallic compounds. Copper corrodes when it is exposed to moisture and the mold compound's chlorine. Additionally, due to copper's high coefficient of thermal expansion (CTE) discrepancy with molding material, cracks appear at the bond pad interface or wire neck [8]. Phenolic hardeners, epoxy resins, catalysts, silicas, pigments, and mold release agents are the main components of the molding compound, which is a composite

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material. The capability to reliably decapsulate these devices is required in order to perform quality control tests on microelectronics, which may necessitate further failure studies and subsequent circuit changes [9]. In the failure analysis process, the fundamental and crucial function of a wire bonding device's decapsulation is to produce an electrical reliable device with its die disclosed for analytical work [10]. A key factor in the failure of wire bond packages is the decapsulation process. Maintaining the wires in their packaging without causing any damage is essential while removing polymer encapsulants like epoxy molding compounds (EMC) [11]. When a device is decapsulated, the whole mold compound should be removed from the desired location without affecting the electrical properties of the device. There are three methods for package decapsulation that are frequently used: wet chemical etching, laser ablation, and plasma etching. From the previous study of Murali S, it shows that the epoxy molded packages can be decapped without affecting the copper wire bonds and their interfaces by using a mixture of fuming nitric acid and 96% concentrated sulfuric acid. The use of variation temperatures in a range of 90-230 °C where the results are good for some various temperature such as in a 150 and 160 °C [12]. Similar with the experiment of Ng S, Cu wire-bonded packages can be extracted via wet chemical etching. The findings of these tests demonstrate that it is possible to create successful Cu wire-bonded devices, which means that further failure analysis phases involving complete device functionality can be carried out without any restrictions. Due to its efficiency and speed, wet chemical etching has been regarded as the best method [10]. The wet approach is performed using nitric acid (HNO_3), sulphuric acid (H_2SO_4), or a mixture of both of those acids. A significant factor that can result in either under or over-etching is the acid volume used to remove the protective shell of the IC electronic device. Also, decapping is more effective at higher acid temperatures, although fine wire, particularly copper, may corrode [12]. In this paper we studied the effect between various temperature and acid volume in a decapsulation process of the Integrated Circuit (IC) packaging device. The manual wet method is used in this study. Furthermore, identification and analysis of the IC are presented after decapsulation process has been completed.

2. Method

2.1 Description of the flowchart

The above activities can be described with the following explanation:

A. IC Preparation

The start of the activity is to prepare the IC that will be used as an experimental sample. The IC used was 9 samples.

B. Measurement of IC thickness

Before carrying out decapsulation process, the thickness of each IC is measured (in millimeters) using a digital caliper. Measurements were carried out 25 times for each IC, it was done to obtain variations in accurate IC thickness measurement results.

C. Observation surface of IC

The next step, looking at the shape of each IC using a Keyence digital microscope. Keyence is a microscope with an all-in-one system (viewing-recording-measuring). This machine can observe uneven surfaces and 3D objects, it has a depth of focus up to 20 times greater. Keyence designs its own lenses, cameras and graphics engines, so that observations can be made with an optimal balance of brightness and clarity.

D. Decapsulation process

The volume variation used consists of 0.1130 ml (10 drops), 0.1356 ml (12 drops) and 0.1582 ml (14 drops). While the temperature variation used in this study consisted of 165 °C, 170 ° C and 175 °C.

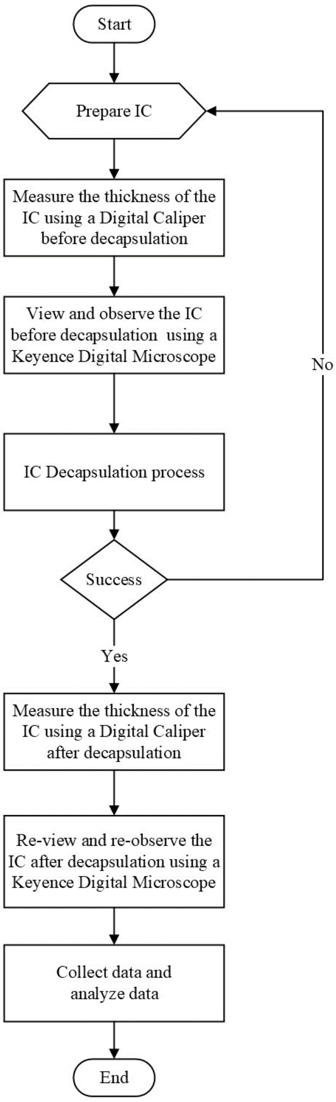


Fig 1. Flowchart of the experimental design

The research matric of decapsulation process used in this study follows Table 1.

Table 1. Variations in temperature and volume of sulfuric acid

No	Sample	Acid Temperature (°C)	Acid Volume (ml)	Acid Volume (drops)	Acid Concentration H_2SO_4 (%)
1	A	165	0.1130	10	100
2	B	165	0.1356	12	100
3	C	165	0.1582	14	100
4	D	170	0.1130	10	100
5	E	170	0.1356	12	100
6	F	170	0.1582	14	100
7	G	175	0.1130	10	100
8	H	175	0.1356	12	100
9	I	175	0.1582	14	100

2.2 Description of Decapsulation Procedure

The procedure above can be described with the following explanation:

A. Etching with Sulfuric Acid

The IC is placed on a hotplate which is based on a porcelain cup, the function of the cup is to react substances at high temperatures, then wait until the temperature on the IC reaches the desired temperature. Furthermore, drop sulfuric acid on the IC according to the desired dose as in Table 1. The epoxy molding compound is dissolved using 100% concentrated sulfuric acid. If the plastic layer on the IC packaging has peeled off, lift the IC immediately from the hotplate, so that the wire is not broken.

B. Cleaning IC

The IC is cleaned using acetone to see the condition of the IC. After cleaning the IC using acetone, then the IC is cleaned again with deionized water to see the condition of the IC.

C. Rinse the device with acetone

The function of the rinse is to clean up the remaining abrasive layers of the decapsulated mold compound.

D. Thickness measurement

After the IC decapsulation process is successful, then take measurements again on the IC to check the thickness of the IC using a digital caliper. This activity was carried out to see the difference in thickness of the IC before and after the decapsulation process.

E. Observation IC after decapsulation

View and re-observe the shape of the IC that has gone through the decapsulation process using a Keyence digital microscope. This activity was carried out to see the difference in IC shape before and after decapsulation process.

F. Analysis of Data

Collect all data from observations and measurements, and then carry out data analysis. It aims to determine the differences in thickness and shape of IC before and after IC decapsulation, the influence of acid temperature and acid volume and concentration of sulfuric acid. The decapsulation process in the research can be seen in **Figure 2.**

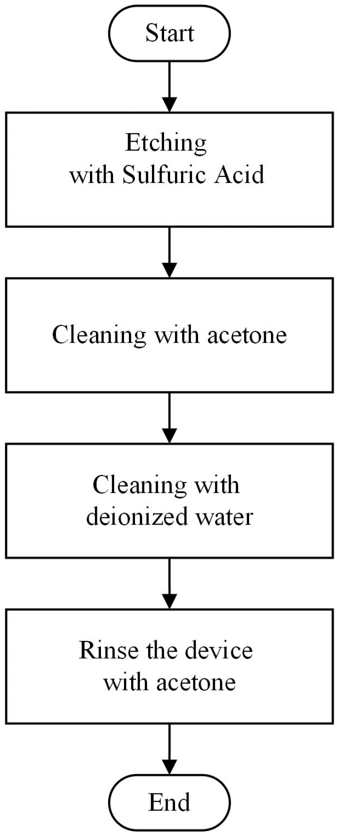


Fig 2. Decapsulation Procedure

3 Result and Discussion

The effect of volume variation on IC thickness for all samples can be shown in **Figure 3**.

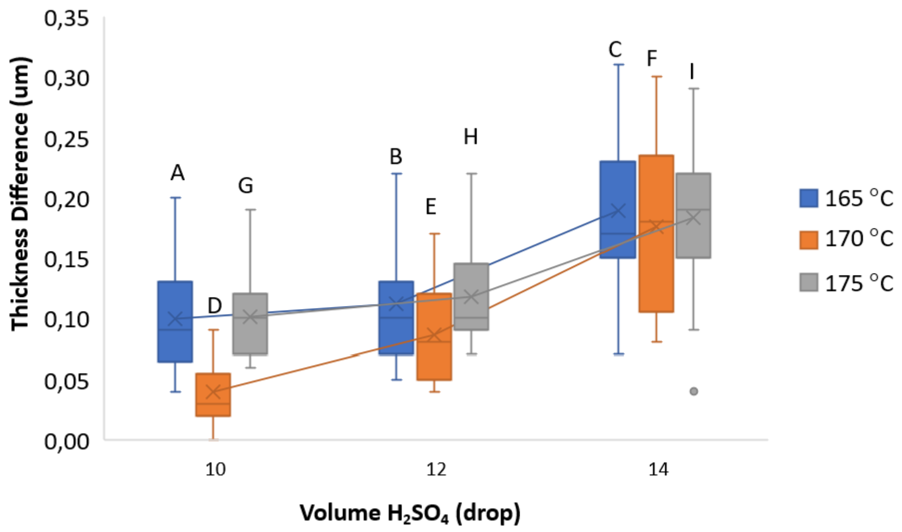


Fig. 3 Box Plot the effect of H_2SO_4 volume variation on the thickness of all samples

Based on **Figure 3**, the variation in the volume of H_2SO_4 dripped on the IC surface affects the thickness of the IC. The highest thickness difference belonged to the sample group given 14 drops of H_2SO_4. In general, an increase in the volume of H_2SO_4 on the IC surface has a linear relationship with the reduction in IC thickness.

The same data, data processing was carried out to see the effect of temperature on all samples (**Figure 4**).

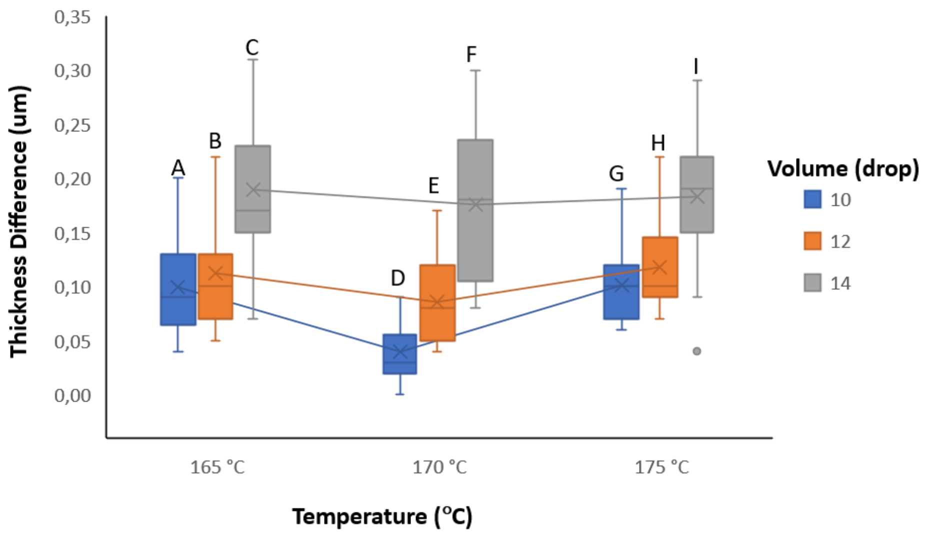


Fig. 4 Box Plot the effect of temperature variations on the thickness of all samples

Based on **Figure 4,** the temperature variation of H_2SO_4 applied to the IC surface affects the thickness of the IC. Overall, the sample group given H_2SO_4 with a temperature of 170 °C showed a lower IC thickness difference compared to other temperature variations. As for the sample group given H_2SO_4 with temperatures of 165 °C and 175 °C relatively has the same pattern for IC thickness reduction.

The value of the difference in thickness before and after decapsulation is shown in **Figure 5.**

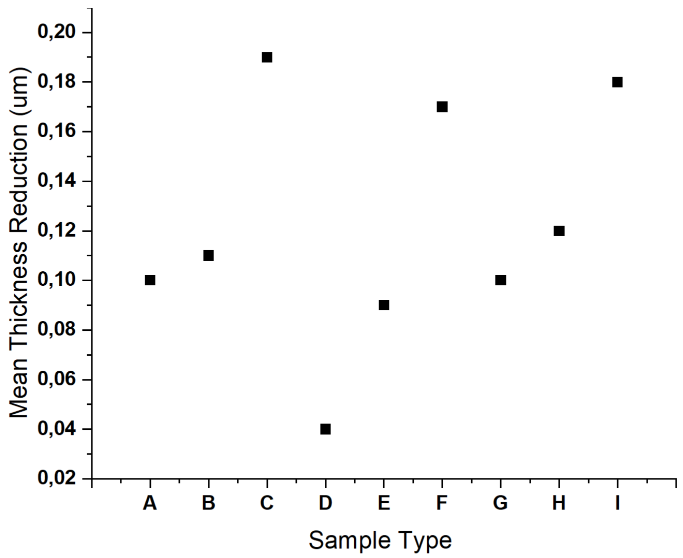
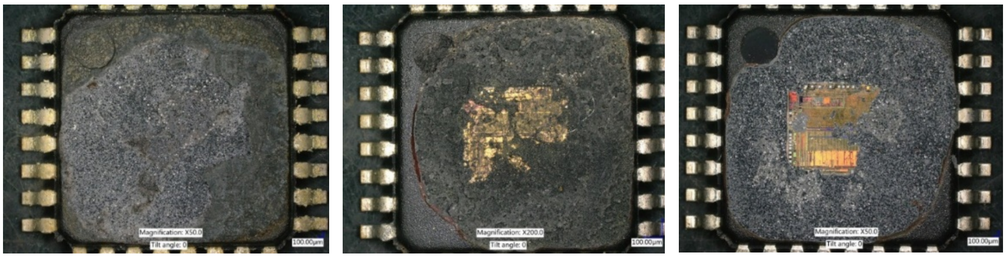


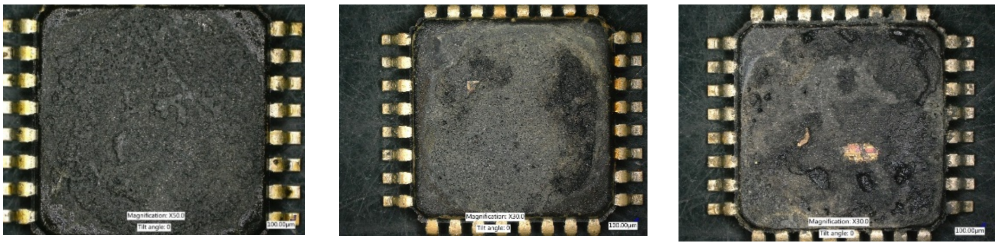
Fig. 5 Mean Thickness reduction for all samples

Based on **Figure 5**, there are 3 samples with a high average thickness difference, namely samples C, F and I. The highest average thickness difference is owned by sample C while the lowest average thickness difference is owned by sample D. The high average thickness difference owned by sample C indicates that the IC surface opening process by H_2SO_4 is faster than all samples being tested. The temperature and volume for sample C are 165 °C and 0,1682 ml **(Table 1)**. With the given temperature and volume parameters on sample C, the decapsulation of the IC surface is more effective than other temperature and volume combinations. Furthermore, according to **Figures 3** and **4**, changing volume has a greater effect than changing temperature.



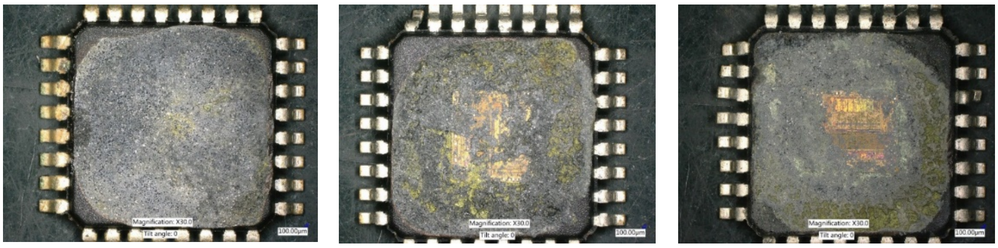
A B C

Fig. 6. The surface of the IC was measured at temperature of 165 °C



D E F

Fig. 7 The surface of the IC was measured at temperature of 170 °C



G H I

Fig. 8 The surface of the IC was measured at temperature of 175 °C

The surface of A sample begins to decapsulate which is characterized by differences in color and surface topography between parts **(Figure 6)**. As for the surface of sample B and sample C, the die has begun to appear in the middle of the surface. The die on the surface of sample C is more clearly visible than the die on the surface of sample B.

The surface of D sample has not been clearly decapsulated. As for samples E and F, decapulation begins to appear on the surface. The die begins to be clearly visible in samples E and F. However, the die in F sample looks clearer and larger than sample E. The surface state of samples D, E and F can be seen in **Figure 7**.

Based on **Figure 8**, it can be seen that the surface of G sample has undergone decapsulation which is characterized by a change in color on the surface. As for sample H and sample I, Die has begun to appear. The die in sample I is more clearly visible than sample I.

Overall, the die on C sample looks clearer compared to all samples. In addition, sample C has a higher average value of surface thickness reduction than all samples. This shows that sample C is the most rapid decapsulation of all samples being tested. While the die in D sample is not visible on the surface and the average value of surface thickness reduction in sample D is the lowest compared to all samples. This shows that sample D is not undergone decapsulation or the D sample has undergone decapsulation with a process that tends to be slow compared to all other samples.

The final result after decapsulation with temperature and volume variations can be seen in **Table 2.**

Table 2. The Final result after decapsulation with temperature and volume variation

No	Sample	Result
1	A	Not Open
2	B	Partially Open
3	C	Partially Open
4	D	Not Open
5	E	Partially Open
6	F	Partially Open
7	G	Not Open
8	H	Partially Open
9	I	Partially Open

The surface condition of IC after decapsulation can be grouped into two conditions, namely not open surface conditions and partially open surface conditions (**Figure 8-10)**. Not open surface conditions is a condition where the die is not visible at all on the surface of the IC after decapsulation using H_2SO_4. Partially open surface conditions is a condition where the die is visible on the surface.

4 Conclusion

Decapsulation is the technique that can be used to analyse failures in ICs. When the complete decapsulation process occurs on the IC surface, the condition of the Die covered with polymer material can be analysed for its functionality. Based on the research, complete decapsulation has not occurred in all samples. Decapsulation is only partially open in some samples (B, C, E, F, H, and I). While other samples (A,D,G) have no open surface at all. The die is more clearly visible on sample C with the temperature used and the volume used is 165 °C, 14 drop respectively. In addition, sample C has the highest thickness reduction of all samples under test.

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