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Contribution to the study of electronic decapsulation
Estudi de la desencapsulació electrónica

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Dos campus d'excel·lència internacional

B:KC Barcelona Knowledge Campus

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El aprendizaje es experiencia. Todo lo demás es información.

Albert Einstein

Para mi familía y mi novia Ylenia que me han transmitido siempre su fuerza y positivismo en los momentos mas duros.

Dar las gracias a Jordi y Alexandra por prestarme su ayuda en todo momento.

Por último, dedicarle este trabajo a la sección del Inspection Center de la empresa DENSO Barcelona, gracias a Jose y Olga por confiar en mí para este trabajo y en especial a David y Susi que tanto me han enseñado durante estos meses.

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1. SUMMARY

This project has been carried out at DENSO Barcelona and it is focused on the study of electronic components decapsulation by means of automatic disassembling system using chemical products.

DENSO is a leading supplier of advanced automotive technology, systems and components for major automakers. All electronic components are encapsulated in mold to protect internal structure of external damages compound. The automatic decapsulation system takes an integrated circuit encapsulated in mold compound and removes it using a user-specified chemical solution.

The main objective of this processing at automotive industry consists in detect and seen semiconductor failure analysis. In the automatic decap user can modify the etch parameters (etching temperature, etching time, acid mixture…) depending sample measures and material composition.

The target of this project is to make experimental tests with different electronic components to create an optimal decapsulation handbook, for in the future only seeing the component user will be able to select the correct etching program, and study the effect of acids over bonding wires(connections between chip surfaces and terminals in a component) when the material used as copper.

During the study engineer will understand semiconductors materials fabrication, internal packaging structure, chemicals usage for decapsulation and rinse, safety operations in the laboratory and analysis techniques.

Trial and error method will be used to establish the best etching conditions. A total of 10 decapsulation programs are created for different electronic components (integrated circuits and transistors) during this project.

For the study of acids effects in copper material, the automatic decapsulation machine presents, Bias Voltage (method create to protect copper). Different voltages will be tested in this project in order to establish a good value for in the future protect the copper wires. Satisfactory results are obtained and an optimal voltage can be established.

Keywords: semiconductor technology, electronic components, automatic decapsulation, copper bonding wires

RESUMEN

Este proyecto se ha llevado a cabo en la empresa DENSO Barcelona, centrándose en el estudio de la desencapsulación de componentes electrónicos mediante una máquina de funcionamiento automático mediante inyección de ácidos.

DENSO es una empresa líder en el sector de la automoción que trabaja con clientes como Toyota, Jaguar o Volvo. Todos los componentes electrónicos son encapsulados en un molde de plástico para así asegurar su integridad de posibles daños externos. El sistema de desencapsulación que se estudiará pretende extraer esta protección de plástico mediante productos químicos para así poder estudiar posibles defectos del componente.

En la desencapsulación automática, la persona que realice las pruebas podrá modificar una serie de parámetros (temperatura de trabajo, tiempo, mezcla de ácidos utilizada…) para realizar una ventana en el encapsulado del componente y estudiar el chip. Los parámetros estudiados variarán en función al componente estudiado (medidas del chip, material interno…).

El objetivo por lo tanto de este proyecto será, realizar una serie de pruebas experimentales sobre distintos tipos de encapsulado, con el objetivo de establecer un manual de programas definidos para que un futuro cualquier persona que quiera realizar pruebas con la máquina, consiga obtener resultados óptimos sin cometer errores. También se estudiará el efecto del ataque ácido sobre los *bonding wires* (filamentos que conectan el chip con los terminales) cuando el material de éstos sea el cobre.

Durante el proyecto, el ingeniero deberá entender todo el proceso de fabricación de un semiconductor, la estructura interna de éstos, los productos químicos utilizados para desencapsular y posterior limpieza, cómo operar de forma segura en un laboratorio y aprenderá técnicas de análisis.

Para establecer unas condiciones de trabajo en la máquina como óptimas, el método de prueba y error será utilizado. Un total de 10 programas de desencapsulación serán establecidos al final del estudio para una gran diversidad de componentes electrónicos.

En el estudio del efecto de los ácidos sobre el cobre, un parámetro especial será utilizado, el *Bias Voltage.* Diferentes tipos de voltaje serán probados en el proyecto para así poder

establecer un parámetro óptimo que nos permita desencapsular componentes con filamentos de cobre. Al final del estudio se llegarán a resultados satisfactorios pudiendo establecer el voltaje ideal.

2. INTRODUCTION

Semiconductors are materials that have an electrical conductivity intermediate between the electrical conductivity of good conductors (such as gold, aluminum and copper) and good insulators (some glasses and plastics). There are a many materials that exhibit semiconducting behavior but only a very few of them are of much interest for electronics. Silicon is the most important semiconductor and is the active material in almost all electronic devices.

Materials are semiconductors in part because of their chemistry (electronic structure of the constituent atoms) and in part because of their structure (the way in which atoms are organized). Semiconductors materials are particularly useful for electronics because the electrical conductivity of the pure material can be greatly changed by the introduction of a small number of impurities. In addition semiconductors are strongly influenced by applied fields (electric, magnetic and electromagnetic fields).

An integrated circuit is a small but sophisticated device implementing several electronic functions. It is made up of two major parts: a tiny and very fragile silicon chip and a package which is intended to protect the internal silicon chip and to provide users with a practical way of handling the component.

The process of putting the integrated circuit inside a package to make it reliable and convenient to use is known as semiconductor package assembly. Over the years, the direction of assembly is to develop smaller, cheaper, more reliable and more environment-friendly packages. Integrated circuits are encapsulated for the following reasons:

- To provide the integrated circuit with a structure to operate in.
- To protect the delicate circuitry from atmospheric corrosion.
- To add strength and rigidity for physical stresses and handling.
- Lead / ball termination completes the circuit to the board or module.

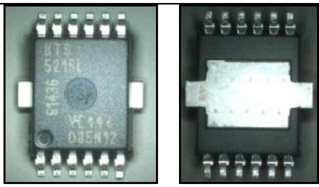


Figure 1. Integrated circuit encapsulated

This section of the work describes the process of chip manufacturing and how is the structure of integrated circuit to learn more about electronic compounds.

2.1. The fabrication of a semiconductor device

The manufacturing phase of an integrated circuit can be divided into two steps. The first, *wafer fabrication,* it is extremely sophisticated and intricate process of manufacturing the silicon chip. The second, *assembly*, is the highly precise and automated process of packaging the die. Those two phases are commonly known as "**Front-End**" and "**Back-End**". They include two test steps: wafer probing and final test. The process is schematized in the Figure 2.

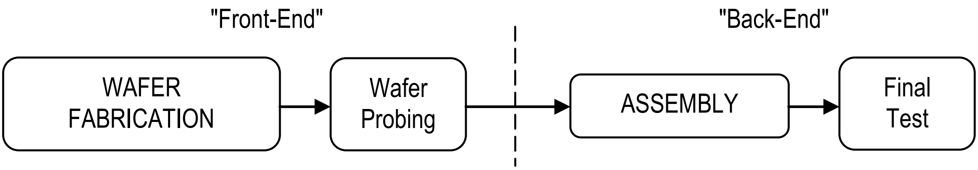


Figure 2. Manufacturing flow chart of an integrated circuit

2.1.1. Wafer fabrication (Front-End)

Identical integrated circuits, called die, are made on each wafer in a multi-step process. Each step adds a new layer to the wafer or modifies the existing one. These layers form the elements of the individual electronic circuits.

Initially, the silicon chip forms part of a very thin (650 microns), round silicon slice: the raw wafer. Wafer diameters are typically 125, 150 or 200 mm. However raw pure silicon has a main electrical property: it is an isolating material. So some of the features of silicon have to be altered. This is obtained by "doping" the silicon, which can be done in two ways.

The first one is to insert the wafer into a furnace. Doping gases are then introduced which impregnate the silicon surface. This is one part of the manufacturing process **called diffusion**.

The second way to dope the silicon is called **ionic implantation**. In this case, doping atoms are introduced inside the silicon using an electron beam.

Ionic implantation allows to put atoms at a given depth inside the silicon and basically allows a better control of all the main parameters during the process. Ionic implantation process is simpler than diffusion process but more costly (ionic implanters are very expensive machines).

The main steps for the fabrication of a die are:

- ***Diffusion and ionic implantation***
- ***Photomasking***
- ***Metal deposition***
- ***Etching***

Photomasking, diffusion and ionic implantation, metal deposition and etching processes are repeated many times, using different materials and dopants at different temperatures in order to achieve all the operations needed to produce the requested characteristics of the silicon chip.

Backlap is the final step of wafer fabrication. The wafer thickness is reduced from 650 to 180 microns approximately.

All these processes are part of the manufacturing phase of the chip itself. Silicon chips are grouped on a silicon wafer before being separated from each other at the beginning of the assembly phase.

2.1.2. Wafer probing (Front-End)

This step takes place between wafer fabrication and assembly. Prior to packaging the individual semiconductor die and while still in the wafer form, each die is probed on a tester. Traditional wafer probing methods utilize probe cards which are adapted to the particular tester being used. The probe cards typically employ a plurality of cantilever probe needles which are arranged in a peripheral configuration that matches the bond pads configured on each semiconductor devices. The probe needles are placed in contact with the bond pads of each die and diagnostic testing is performed. After the completion of testing on one die, the wafer is moved so that testing can be performed on an adjacent die. The process is reiterated until all die on the wafer have been tested.

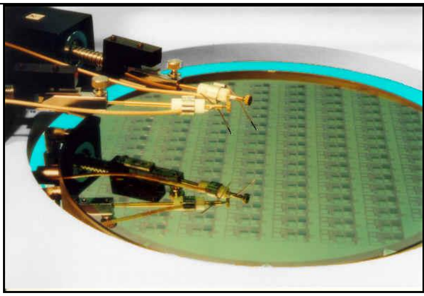


Figure 3. Image of wafer probing test

The bad dies are automatically marked with a black dot so they can be separated from the good die after the wafer is cut. A record of what went wrong with the non-working die is closely examined by failure analysis engineers to determine where the problem occurred so that it may be corrected. The percentage of good die on an individual wafer is called its yield.

2.1.3. Assembly (Back-End)

The assembly process is necessary to protect the chip (or die), facilitate its integration into electronic systems, limit electrical interference and enable the dissipation of heat from the device. Once the front-end production process is complete, the wafer is transferred to an assembly facility, where it is sawed into individual semiconductor chips. These semiconductor chips are then individually attached by means of an alloy or an adhesive to a lead frame, a metallic device used to connect the semiconductor to a circuit board. Leads on the lead frame are then connected by aluminum, copper or gold wires to the input/output terminals on the semiconductor chip through the use of automated machines known as wire bonders. Each semiconductor device is then encapsulated in a plastic molding compound or ceramic case (normally epoxy resin), forming the package.

After assembly, power semiconductors are tested for different operating specifications, including functionality, voltage, current and timing. The completed packages are then shipped to the customer or to their final end-user destination.

A number of operations have to be made to realize this: they are described on the following figure.

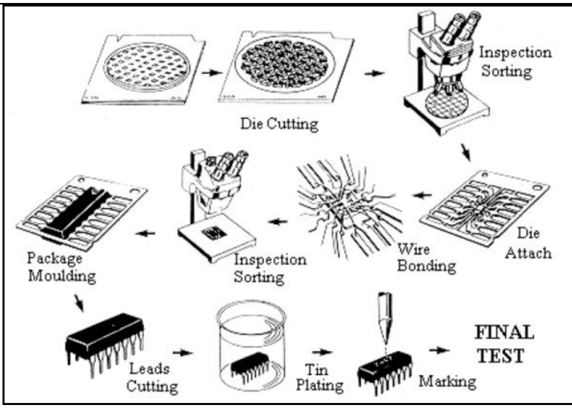


Figure 4. Description of the Assembly Process

To make connections between an integrated circuit and the leads of the package, wire bonds are used, with fine wires connected from the package leads and bonded to conductive pads on the semiconductor die. At the outside of the package, wire leads may be soldered to a printed circuit board or used to secure the device to a tag strip.

Wire bonding is the process of providing electrical connection between the silicon chip and the external leads of the semiconductor device using very fine bonding wires. The wire used in wire bonding is usually made either of gold (Au) or aluminum (Al), although copper (Cu) wire bonding is starting to gain a foothold in the semiconductor manufacturing industry. There are two common wire bonding processes: Au ball bonding and Al wedge bonding.

During a gold ball wire bonding, a gold ball is first formed by melting the end of the wire (which is held by a bonding tool known as a capillary). The free-air ball is then brought into contact with the bond pad. Adequate amounts of pressure, heat and ultrasonic forces are then applied to the ball for a specific amount of time, forming the initial metallurgical weld between the ball and the bond pad as well as deforming the ball bond itself into its final shape.

The wire is then run to the corresponding finger of the leadframe, forming a gradual arc or "loop" between the bond pad and the leadfinger. Pressure and ultrasonic forces are applied to the wire to form the second bond, this time with the leadfinger. The wire bonding machine breaks the wire in preparation for the next wire bonding cycle by clamping the wire and raising the capillary.

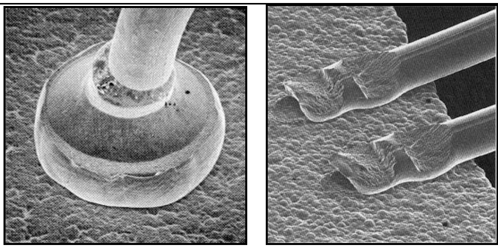


Figure 5. Gold ball bond (1st bond) and gold wedge bond (2nd bond)

During aluminum wedge wire bonding, a clamped aluminum wire is brought in contact with the aluminum bond pad. Ultrasonic energy is then applied to the wire for a specific duration while being held down by a specific amount of force, forming the first wedge bond between the wire and the bond pad. The wire is then run to the corresponding lead finger, against which it is again pressed. The second bond is again formed by applying ultrasonic energy to the wire. The wire is then broken off by clamping and movement of the wire.

The integrated circuit is connected to the leads of its package by bonding wires, which are very fine wires, composed of high-purity gold, aluminum or copper. Wirebond reliability depends greatly on the proper choice of the bonding wire, especially in advanced packaging technology which requires special loop profiles and extremely small bon spacing.

The first consideration in choosing a bond wire is the type of package it will be used for. Gold wire can't be used in hermetic packages because it won't be able to withstand the high temperature of hermetic sealing. Aluminum wire is the standard choice for hermetic assembly. For plastic packages, however, gold wire is the more logical choice because it is faster, easier to use, and therefore more cost-effective.

Other considerations to choose a bonding wire are:

- The diameter of the wire.
- Tensile strength.
- Elongation.

Copper wire is becoming one of the preferred materials for wire bonding. Copper wire of smaller diameter can achieve the same performance as gold wire of bigger diameter. Copper wire, needles to say, is also more economical than gold wire. With proper set-up, copper wire can be successfully wedge-bonded and be used as alternative to aluminum wire, especially in applications where higher current-carrying capacity is needed or complex geometry problems are encountered.

Table 1. Properties of wires types

Property	Cu	Au	Al
Electric conductivity (%IACS)	103,1	73,4	64,5
Thermal Conductivity (W/m·K)	398	317,9	243
Thermal Expansion Coeff (µm/m·K)	16,5	14,2	23,6
Tensile Elastic Module (Gpa)	115	78	62

Copper wire is harder than gold and aluminum, so it has a higher tendency to contribute to die damage if the bonding parameters are not put under tight control.

As will be seen later, when the integrated circuits are decapsulated by wet etching method, the copper bonding wires are totally damaged by the effect of fuming nitric acid. Therefore, one of the main objectives of this project is to find a proper decapsulation method on copper wires.

After wire bonding process, the next step is to encapsulated the device in plastic material (molding process) and finally the marking process that is the process of putting identification, traceability and distinguishing marks on the package on an integrated circuit (IC). The device name, company logo, date code and lot id are examples of information commonly marked on integrated circuits package. Some marks are put on the package during Assembly and some marks are put on the packaging during Test.

Once the process of manufacturing of an integrated circuit was explained, the general structure of these components is further explained, commenting the main parts to finally give the explanation of how are classified and which criteria are used to distinguish the components.

2.2. Basic structure of an integrated circuit

After the manufacturing process of integrated circuits, the component is fully encapsulated. There are many different kinds of integrated circuits in the world, but all have a similar basic structure. The main parts of an integrated circuit and its function are explained in the next figure.

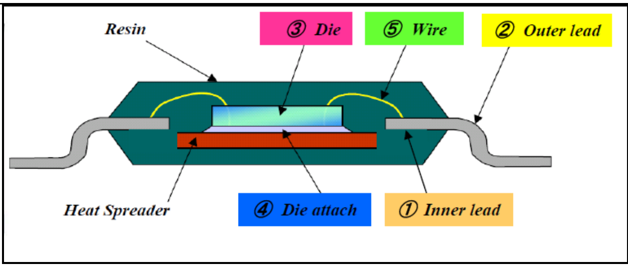


Figure 6.IC's structure

The most important part of an integrated circuit is the chip (or die). A die is a small block of semiconducting material, on which a given functional circuit is fabricated. The material of which the die is made is silicon and sometimes we can see an external polyamide film that has the function to protect the inner tracks of the chip.

Die-attach is the term reserved for processes where the face of a die is attached to a substrate by a single joint. The die-attach layer has two main functions: mechanical fixation of the die on its substrate, and dissipation of heat generated in the die. Typical die-attach materials are Ag paste, Solder paste, Polymide tape, Au-Si or silicone.

Lead frame is the metal structure (formed of Cu, Cu alloy or alloy 42) inside a chip package that carries signals from the die to the outside. Within the structure of an integrated circuit, the lead frame is divided into the inside part, inner lead frame and outside part, outer lead frame. The inner lead can be made of Ag, Ni-Pd-Au or Ni. The outer leads are made of Sn-Cu, Ni-Pd-Au, Sn, Sn-Bi, Sn-Ag, Ag or Solder ball (Sn-Ag-Cu).

The wires are used to make the connections between the die and the leads made of high-purity gold, aluminum or copper. During this project, the three materials were studied but gold wires and the effect of acid over copper wires were deeper analyzed.

Finally all these parts except the outside of the lead frame are typically coated by a plastic made of epoxy resin and SiO_2. Table 2 can be used as a summary to see what materials are used each part of an integrated circuit.

Table 2. Materials which form an IC

①② Lead frame material	Lead frame plating		③ Dicing	④ Die attach	⑤ wire
	① Inner lead frame	② Outer lead frame			
Cu	Ag	Sn-Cu	Full cut	Ag paste	Au
Cu alloy	Ni-Pd-Au	Ni-Pd-Au	Semi full cut	Solder paste	Al
alloy42	Ni	Sn	Half cut	Polymide tape	Cu
		Sn-Bi	Step cut	Au-Si	
		Sn-Ag		Silicone	
		Ag			
		Solder ball Sn-Ag-Cu			

In this work, three types of integrated circuit packaged were used, the SOP (Small Outline Package), the QFP (Quad Flat Package) and BGA (Ball Grid Array).

SOP was the most common encapsulation. The terminals were in the "gull wing" shape allowing an easy visual inspection and absorbed differential thermal expansion between the PCB (Printed Circuit Board) and the component. Small Outline Package evolution leads to the formation of QFP package where the gull wing terminals were used involving the four sides of the component. Finally the BGA package represents an innovation presented, in these last year's with the lead balls soldering on the bottom surface of the integrated circuit. The BGA is a solution to the problem of producing a miniature package for an integrated circuit with many hundreds of pins. A further advantage over packages with terminals is the lower resistance between the package and the PCB. This allows to the IC inside the package to flow more easily to the PCB, preventing the chip from overheating.

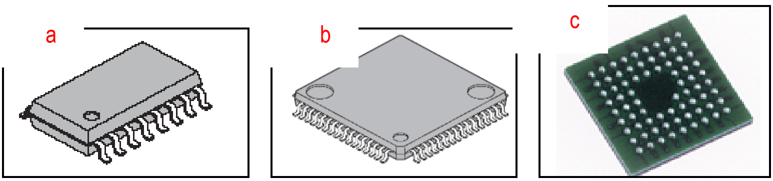


Figure 7 .IC's commonly packages (a=SOP; b= QFP; c= BGA)

2.3. The disassembling process

After explaining in detail how it is the process of encapsulation of an integrated circuit, the process of how to observe the chip was studied. Most of the IC's analyzed are plastic encapsulated. Plastic encapsulation protects the parts against physical and environmental damage, is easy to produce and inexpensive, and results in reliable parts. However, IC's are still subject to failure, regardless of their packaging. To investigate such failures, a disassembling (decapsulation or decap too) procedure is used to remove the plastic packaging and allow internal features to be observed.

Regardless of the part being inspected, decapsulation must be performed in such a way that it preserves the integrity of the die, die attach, bond pads and wires, and other components within the encapsulation. Primary wire bonds to the surface of the die are generally easy to expose and preserve; secondary bonds are more difficult, especially on larger devices such as BGA's. Enhanced techniques increase the likelihood of success decapsulation, which is defined as exposing desired features without destroying others.

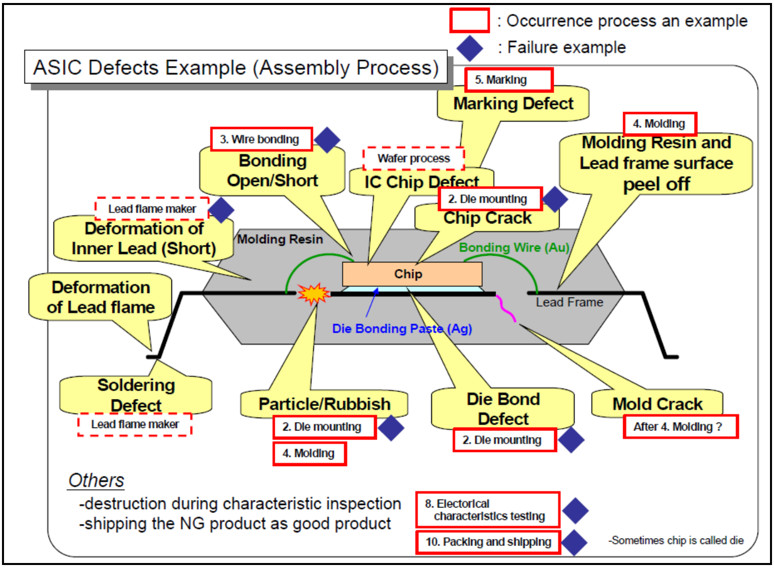


Figure 8. IC's commonly defects

Plastics can generally be grouped as "soft," "medium," or "hard." The type of plastic, size of the part, and type of substrate help determine the best parameters for decapsulation. As mentioned by [1], there are three techniques that are commonly used for package decapsulation i.e. wet chemical etch, plasma etch and laser ablation.

Plasma etching could provide a very clean and defect-free silicon chip surface but it is not popular because it is a very slow process. Laser ablation as faster decapsulation process but has a higher risk of failure due to damage on the silicon chip surface. Hence, laser ablation is commonly used together with either wet chemical etching or plasma etching to avoid any damage to die surface.

Wet chemical etching has been considered the most favorable approach due to it is fast and cost effectiveness. Fuming nitric acid is the primary choice for decapsulation purposes as it dissolves the encapsulation quickly and removes die coat materials without etching the gold wire bonds or aluminum bond pads. Typical process temperatures when using fuming nitric acid range from 70°C to 90°C. Cu wire, however, is easily consumed in the presence of nitric acid regardless of temperature. Hence, pure decapsulation using fuming nitric acid cannot be used for Cu wire package decapsulation. Fuming sulfuric acid is another option for decapsulation. It is used at higher process temperatures ranging from 150°C to 300°C and takes longer time to dissolve the mold compound. It is usually more effective on harder thermoplastic resins that are more resistant to nitric acid etching. Although fuming sulfuric acid does not etch or attack Cu metallization, it does etch and dissolve exposed Al metallization.

The two methods of chemical decapsulation are manual (Figure 9) and auto-decap (Figure 10). Manual decapsulation means adding acid to a beaker on a hotplate and dipping devices to dissolve the plastic. Special decapsulation equipment can virtually eliminate the need for the beaker and hotplate. Auto-decap is safer and quicker than manual decapsulation, and minimizes the use of acids, an advantage in terms of cost and environmental factors.

Figure 9. Manual chemical decap

Figure 9 shows the manual decap. In this process, three beakers were placed with mixture of acids (nitric and sulfuric acids) at different temperatures. The component passes through the three beakers starting with the mixture at high temperature. Finally, when the component was decapsulated correctly, distilled water was used to clean the chip surface.

In this work, the wet chemical decapsulation process was studied using an automatic decapsulation machine (Figure 10). The software of the machine can automatically control which acids to use, the proper volume and the necessary etch time to remove the encapsulant.

After a procedure has been established for a particular package type, it can be saved for future use.

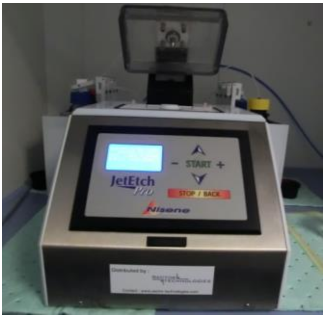


Figure 10. Auto chemical decap

Chapter 4 deals with the explanation of the use and the operation of the machine. Also, the previous steps to disassembling procedure and the machines that will be used during these steps are explained.

3. OBJECTIVES

- Get into the electronic components world in order to differentiate them without problems in the future.
- Realize the machine start-up and develop a basic instruction for anything can use it.
- Create a handbook with different decapsulation programs for any operator that requires performing an analysis, doing it without errors.
- Establish a cleaning process that allows observe correctly the chip surface and bonding wires.
- Study the effect of fuming nitric acid on copper bonding wires and determine an ideal Bias Voltage that allow to obtain optimal results.

4. MATHERIAL AND METHOD

This section describes the machine used to perform the disassembling process, providing basic instructions on how the machine is used and how a disassembling program is created.

Finally the procedure performed prior to the decap test (measures, inspection in X-rays, selection of gaskets and implementation of the machine program) and the procedure for post-decap are discussed.

4.1. Jet-etch Auto Decap Machine

The Jet Etch Pro decapsulation system is designed to expose the die and bond wires and useful for most plastic and plastic-type integrated circuit packages. It executes this process by etching the encapsulant with various types of acids and acids mixtures. The etching process is performed under pressure at inert atmosphere to diminish metal oxidation. This pressurized environment is protected by a tempered acrylic process cover that seals with the etch plate assembly such that harmful fumes are completely contained and subsequently exhausted in a safe manner. The result of this process is a clean, uncorroded die surface, which can then be used for a multitude of failure analysis and authenticity verification tests.

The etching diagram (Figure 11) illustrates the etching system and process in a simplified cross-sectional view. A gasket is placed on the etch head and the device is placed face-down onto the surface of the gasket. This gasket defines the etch the size and shape of the etch cavity, and in basic stack-up configuration is called the “Definition Gasket”. The ram nose places downward pressure on the device, sealing it to the gasket, and the gasket to the etch head. The etch head is heated to the temperature specified in the user-programmed process parameters and maintains its temperature during the etch process. This heat is transferred through the gasket to the device. A pre-heat cycle is provided at the start of the etch process to ensure that the etch head and device have had enough time to reach the temperature in the process parameters.

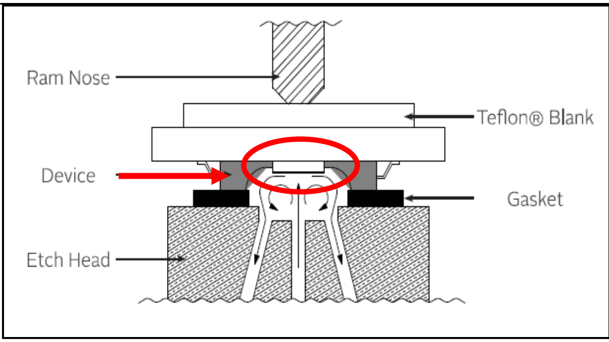


Figure 11. Etching diagram

The heating diagram (Figure 12) illustrates the heating system in a simplified cross-sectional view. Acid is drawn from the supply bottle by the pump toward the device being etched. Acid is heated to etching temperature by the heater block exchanger assembly as it is pumped to the device on the etch head. The acid remains some time to etch encapsulant before being replaced with fresh acid and forced through the waste lines to the appropriate waste bottle. The dwelling time of each small quantity of acid is controlled by a user-defined parameter called the 'volume' to optimize acid use while etching. The etching step is followed by an N_2/CDA purge to terminate the etch process prior to be removed by the end user.

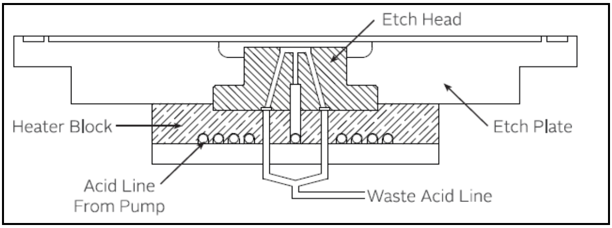


Figure 12. Heating diagram

- Pump Operation

The acid pump and mix flow control works like a syringe with inlet and outlet ports, each connected to a valve. Each possible pump arrangement shares two available displacement diaphragms acting in series. The actual ports and valves used as inlets and outlets for each particular pump path are determined by the pump controller codes issued by the control processor.

The machine features two different methods for the delivery of acid to the surface of the device during the etch process: pulse mode and vortex mode. Pulse pump cycles use only forward direction pump cycles. Vortex pump cycles include one or more reverse direction pump cycles using a displacement valve of larger fluid volume.

The simplified concept is pulse mode pumps into the etch cavity, then pumps out, and repeats. Vortex mode pumps into the etch cavity (the same as the pulse mode), but then the second step involves a plunging of the piston and special diaphragm sequencing to pump the same acid back into the etch cavity a second time before then finally flushing and delivering a new allotment of acid. Vortex is a good method of acid delivery when the die within the device is relatively large or when the sidewalls are at risk of being blown-out during the etch process.

The operation mode for the pump operation is fixed in the present work always in **pulse mode**.

- Decapsulation fixtures

Figure 13 shows the parts that are commonly used when disassembling process was performed. Next to the image appears the name with which each piece will be known. The only exception appears when bias voltage was used (the Teflon blank was replaced by an aluminum blank).

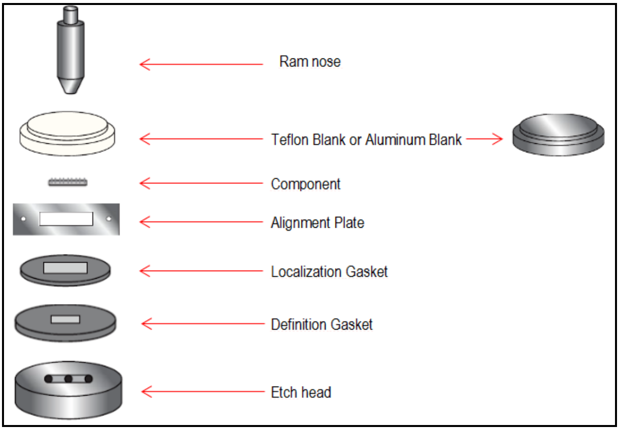


Figure 13. Disassembling fixtures

The most important fixtures are the gaskets that will make the window in the decapsulation. It is important always to choose window dimensions that match the dimensions of the chip. More information about the gaskets used and how to use them is given in section 4.2. For more information about all the fixtures used, see APPENDIX I.

4.1.1. Machine Basic Instruction

In this section, a basic instruction of Jet Etcher machine (Figure 14) is explained.

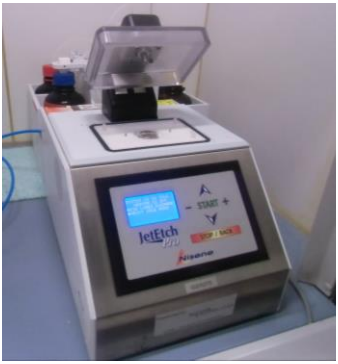


Figure 14. Jet Etcher machine

The Main Menu (Figure 15) is the starting point for all the machine activities. As with other menus, the "▲ "and "▼ " buttons on the keypad scroll the cursor, indicated by the highlighted text. The START button advances to the sub-menu indicated by the cursor. To return to the Main Menu from any sub-menu (except the Maintenance Menu) press the STOP/BACK button.

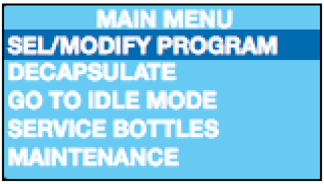


Figure 15. Main Menu screen

To decapsulate a program it is necessary to establish a program. The parameters are explained in the next point, 4.1.2 and in APPENDIX III. Once the program is set up, enter to the sub-menu “DECAPSULATE”.

The decap menu is the entry point for starting a decapsulation cycle. The prompt “●=ETCH“ indicates the machine system is ready to etch a device using the program displayed. The top line of this screen will be replaced with operator alerts if the system is not ready.

When the “●=ETCH“ prompt is displayed and the proper fixturing is installed (Figure 13) on the etch head with the sample to be etched, press the START button to begin the etch process.

Finally the machine will open the safety cover, sound the alarm, and display “REMOVE DEVICE” on the top line of the display screen when the process is complete. Remove the etched component immediately and rinse with the appropriate cleaning method (see section 6 of the work and APPENDIX II). To clean the rest of fixtures, a paper with water or alcohol is used. The gaskets need a special cleaning method and are introduced during 2 hours into beaker with alcohol.

At the end of the day when no more etches are needed, use the idle mode option to standby the Jet Etch machine. On the main menu screen (Figure 15), select "GO TO IDLE MODE". Press the START button to begin the idle mode process.

4.1.2. Process to create a disassembling procedure

For the creation of a decapsulation procedure on the machine, the steps explained at APPENDIX III can be followed. Its important learned and understood all the parameters of a decap program before using the machine.

The parameters used are showed in the following lines:

- Etch time
- Etch temperature
- Mixture of acids
- Etch volume
- Heat-up time
- Rinse time and type

Only a parameter has not been introduced, the Bias Voltage, which will be explained in the next section because, is important to understand why the copper wires are damaged by fuming nitric acid and that provides the machine to ensure that this problem not happens.

As a summary, the operation parameters fixed are the following: pump operation in pulse mode, mixture ratio of 3:1 min ($HNO3:H2SO4$) and no rinse. The remaining parameters are let with the default values of the machine or modified as indicated in the results (gasket size, temperature, time, etc).

4.1.2.1. Bias Voltage for Copper Bonding Wires

The decapsulation of a wire bonding device is required for the failure analysis process of any electrically functional device. After decapsulation, its die become exposed and visible for analysis work [1]. Copper (Cu) wire bond technology in IC's has become popular these days due to its better characteristic and cost compare to Gold and Aluminum. Nonetheless, failure analysis remains to be very challenging as Cu is easily dissolved when reacting with fuming nitric acid used during decapsulation process. This happens because when reacting nitric acid with copper, the following reaction takes place (Equation 1) and the copper bonding wires were totally damaged.

$$4\ HNO_3 + Cu \rightarrow Cu(NO_3)_2 + 2NO_2{}^{-}{}_{(g)} + 2\ H_20 \qquad (1)$$

For this reason, the Bias Voltage method was presented by Jet Etch machine. Bias Volts denotes how much voltage is applied to the leads (through of the ram nose and aluminum cap). A circuit is completed when the grounded acid contacts the positive biased wires, which helps protect copper wires and other sensitive materials from erosion. The machine can work with a voltage between 0V-20V.

This bias creates a condition in which negatively-charged sulfate ions are attracted and temporarily bond to the surface of the copper wire while the sample is being etched. This temporary sulfate ion coating protects the copper wires from corrosion while the sample undergoes the etching process. The image (Figure 16) illustrates the operating principal behind the technique.

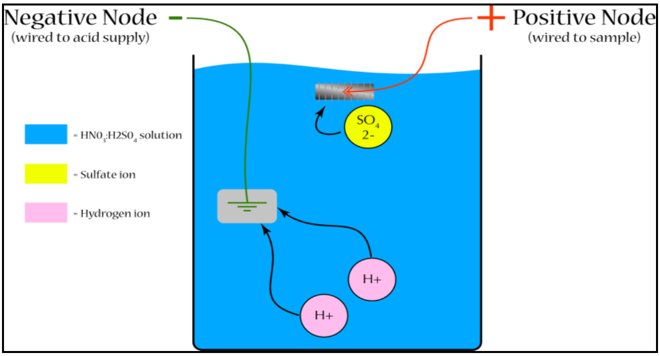


Figure 16. Bias voltage method

Now, after Bias Voltage was explained, a disassembling program was ready to be performed.

4.2. IC pre-disassembling procedure

In this section of the work all the step-by-step procedure that is performed previously to the process of decapsulation in the machine is explained. Finally a table with all the components measures is presented (APPENDIX IV).

The first step to receiving a component is to take measurements of length, width and thickness of the resin package and external package (counting the component leads). As the components have a few very small sizes (all the measurements in this work appear in millimeters) a digital caliper will be used to obtain a good precision.

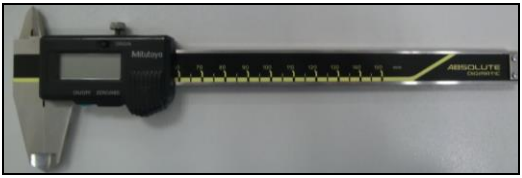


Figure 17. Caliper image

Once the component is measured, the photos of the component are taken in the optical microscope (top and bottom image). The larger component can not be totally placed in the microscope becoming outside the image range. When this happens, the photos are taken with a camera.

Figure 18. Optical microscope image

The next step is be to measure the chip inside the encapsulation. For this component, it is examined using an X-ray machine, the “Yxlon Y-Cheetah” (Figure 19) which allows calculating the dimensions of the chip with an internal program.

The X-ray is a nondestructive method to observe the internal state without unsealing the package of the device. As the transmission rate of X-rays differs according to the quality of material or the thickness, the internal structure is obtained as a contract image of the X-ray. The state of bonding wires, the state of die bond, voids and the chip position in the encapsulation resin can be observed at X-ray machine. Gold (Au) and copper (Cu) have a low transmission rate, so the bonding wires can be easily identified. Aluminum (Al) with light atomic weight has a high transmission rate and is difficult to identify. In this work the three metals are studied.

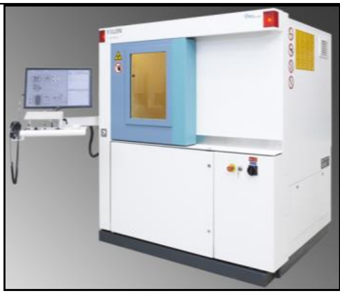


Figure 19. X-Ray machine image

The last step before the disassembling process is the selection and preparation of the gaskets. A battery of gaskets is available and they are chosen according to the size of the window required. The size of the window depends on the size of each component. Two gaskets are required, the definition gasket which will fit the chip and the localization gasket that serve to frame this window. To ensure that the gaskets do not displace when are mounted on the etch head, a vacuum grease was used to joined the two components (Figure 20).

Figure 20. Gaskets fixation

APPENDIX IV presents all the components that were studied, including: encapsulation and chip measures, the bonding wire type and the number which every component will be known in the section of results (codification contributed by the company).

4.3. IC post-disassembling procedure

After decapsulation procedure, some steps were realized before determining if a disassembling was satisfactory or not. The first step just finish the process is, perform a cleaning process on the component to remove traces of acid and resin particles. The optimal method of cleaning will be explained in the results section of the work and at APPENDIX II.

The next step will be to observe the result of our decapsulation process in the microscope. The first observation will be realized in the optical microscope (Figure 18) to have an overview of how the window has been made. Then, to observe with more precision the appearance of the chip surface, the metallographic microscope (Figure 21) will be used because allows observing the component at high magnifications.

Figure 21. Metallographic microscope image

If the component has gold or aluminum bonding wires, this procedure could already determine if the result of the process has been correct. If the result is positive, diverse images of the chip surface were realized as observed in Figure 22 thus registered as correct the process in the company's database.

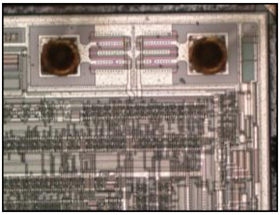


Figure 22. Chip surface image at metallographic microscope

When the component has copper bonding wires, it is necessary to observe very thoroughly the wires state to ensure that have not been damaged by the attack of the acids during the decapsulation. To realize this study, a scanning electron microscope (SEM) was used. SEM (Figure 23) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. The SEM will allow to determine the good or poor condition of our copper bonding wires.

Figure 23. SEM image

All these procedures explained in this section of the work will be applied to the point 6 of the work in which the results obtained in each of the tests will be displayed.

5. SAFETY

Security issues related to the disassembling process are explained at this point of the work. First, the products and safety material to be used for decapsulation machine are explained and the types of hazards associated to this project are presented at APPENDIX VI.

5.1. Products used to components decapsulation

In this section, the chemical products used to realize a disassembling process are exposed. It is important to understand all the hazards associated to the products used if not manipulated with safety and responsibility. In APPENDIX V section of the work all the company safety sheets are provided.

- ACID PRODUCTS

- Nitric Acid
- Sulfuric Acid

- INFLAMABLE PRODUCTS

- Ethylenediamine
- Acetone
- Alcohol

5.2. Laboratory safety material

When a disassembling procedure is performed, safety equipment is necessary to avoid damage. In the laboratory, fuming nitric acid and sulfuric acid are used for decapsulation.

First, in the laboratory it is necessary to wear at all times chemical splash goggles. These glasses were used to protect the eyes and part of the face in case of a splash during the handling of acids or other chemical product.

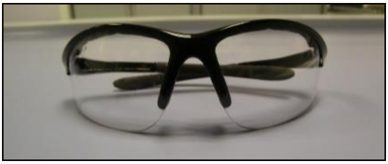


Figure 24. Chemical splash goggles

Then, for hands protection, two different types of gloves were used. First, cotton gloves were placed. This type of material was used because in the case of burns due to contact with the acid, these are much easier to remove from the skin. Above these gloves, chemical resistant latex gloves were used. These special gloves are thicker, longer and more hand-wearing than regular latex gloves. This is important because it is necessary to be comfortable with the gloves during the manipulation in the tests.

Figure 25. Chemical safety gloves (cotton and latex material)

Finally a respiration mask was used to avoid any possible inhalation of chemical products vapors such as nitric acid or ethylenediamine which could be dangerous for our health.

Figure 26. Respiration mask

In the special case of direct manipulation of the acids bottles, gloves that cover beyond the wrists of ultranitril and sleeves to protect the arm were used. These materials make the job more difficult as they may feel uncomfortable but they are necessary to protect in case of accident.

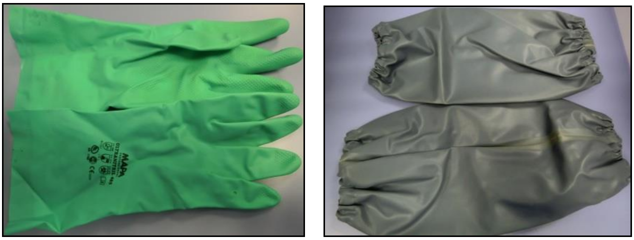


Figure 27. Chemical safety gloves and sleeves (ultranitril material)

Finally, when acid bottles were opened for changing, a safety helmet was used to protect all the face and apron as used to protect the body.

Figure 28. Safety helmet and apron

6. RESULTS AND DISCUSSION

The study is firstly focused on testing the components with gold wires. The following tests are performed on components with aluminum wires and on passive components as the transistor. Finally, to check the functioning of the Bias Voltage method on copper wires, a study was performed at different voltages in order to get the ideal voltage to realize a decapsulation sequence without damaging the copper wires.

6.1. Determination of optimal procedures for components disassembling

With the aim to establish standard operating procedures for anyone in the company to use the auto decap machine, tests are made using sequences of different conditions on each of the components presented in APPENDIX IV. For a program to be selected as the optimum to be used for a component, the window that is obtained after decapsulation must allow the visualization of the entire surface of the chip and the wires.

Each point of this section of the work, first displays an image of the encapsulated component with corresponding measures, the X-ray image, in which we can observe the type of wire material and the gaskets and alignment plates selected to perform a correct window in the component. After that, the procedures used for each tests components are presented together with some images that will justify why a program is valid compared to another. Finally, for each approved program as optimal, a number is assigned, which will remain saved in the memory of the machine (APPENDIX VII).

6.1.1. Components with gold wires

Within this section, the study begins with a large component for fast-encapsulation. Then a very similar component will be tested. The particularity of this component will be in the protective layer of the chip. Later, a component that presents the chip in inverted position will be studied. Also a component will be chosen to perform tests using only the fuming nitric acid. After that, two very similar components will be chosen to analyze if the same program can be used. Finally, three tests on rectangular components will be performed.

- ***IC Number 46***

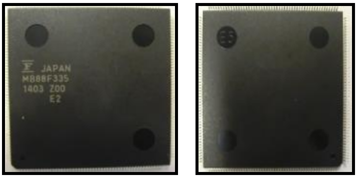


Figure 29. Top and bottom image

The initial tests were performed on a component (IC number 46 shown in figure 29) with relatively large dimensions (APPENDIX IV) to allow finding quickly an optimal program and then make various component cleaning processes to establish a good clean method for the entire work.

In this case, a component with a large encapsulation is used; therefore, a window can be easily created, in which the chip can be observed. This is the reason for selecting the large gaskets. As definition gasket, number 69 (6.4x6.4)mm was selected and as localization gasket the number 70 (7.6x7.6)mm. Finally, the alignment plate number 9 (30x30)mm was used to fix the chip.

The next step is to observe the component in the X-ray machine (Figure 30). As seen in the top view of the component, the chip is very small compared to the rest of the encapsulation and can be seen, as there are many wires.

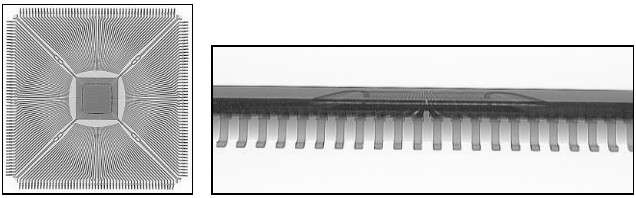


Figure 30. Top and side X-ray image

Program Number 1 at APPENDIX VII presents the conditions used for the initial testing procedure. A relatively low temperature and too low etching time were chosen. Although the manual recommended to perform the initial test with a program using only fuming nitric acid, the first test was performed with a 3:1 mix (fuming nitric acid and sulfuric acid mix) for less aggressive disassembling.

After auto-decap process, the test performed was verified if successful by the supervisor and good window was achieved (Figure 31), allowing to study a possible defect in the chip or wires.

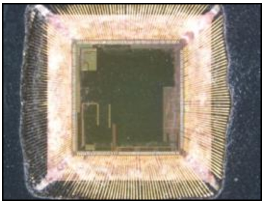


Figure 31. Chip image after decap process

This program was set as correct and the next step is to determine the best cleaning process after decapsulation. APPENDIX II presents the six different processes performed in this purpose. Analyzing all processes, procedure 6 was established as the best cleaning process, which is further used for all the rest components under study after the completion of the decap process.

To select a cleaning process method as correct, the chip surface must be completely clean when the image was studied in the optical microscope.

- ***IC Number 42***

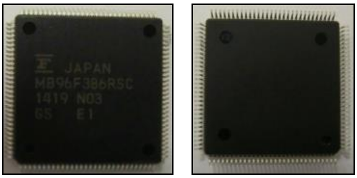


Figure 32. Top and bottom image

In this case, a similar component as the number 46 was selected to test whether similar components can use the same programs. As in the previous case, the encapsulation considered was quite larger compared to the chip (APPENDIX IV). For this reason, the window may be largest, the gaskets used in this test are the numbers 69 and 70 and the alignment plate this time is number 6 (18x18)mm.

The X-ray image of the component (Figure 33) is very similar to the above component, in which appreciated many wires and by the hue to be seen are gold wires.

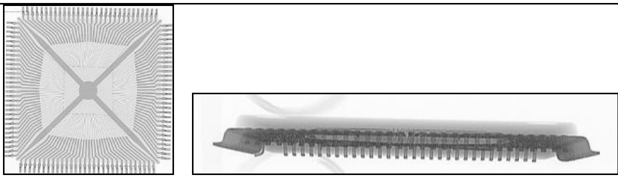


Figure 33. Top and side X-ray image

As already mentioned, the program to use for this component is the same as in the component number 46 (APPENDIX VII). After performing the decapsulation process and the cleaning process established, the chip is still very dirty. This is because the surface of the chip has a protective layer of polyamide (Figure 34). Ethylenediamine heated at 80ºC during 2 minutes was used to remove this layer.

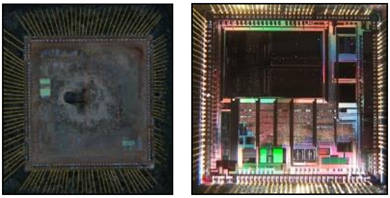


Figure 34. Chip image before and after ethylenediamine clean

While ethylenediamine used, the operating conditions impose working with the extractor in the half-open position and with a protective mask to avoid inhaling the fumes. The generated waste is let to cool to room temperature before introducing it into corresponding bottle.

- ***IC Number 41***

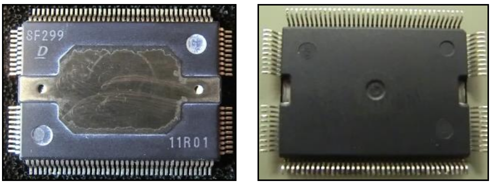


Figure 35. Top and bottom image

This component is again very similar to that already shown before (Figure 35), but in this case the dimensions of the chip are larger than in previous IC's (APPENDIX IV). For its decapsulation in this case, a definition gasket the number 85 (12.2x8.1)mm and as a localization gasket the number 89 (14x14)mm were used. The alignment plate number 11 (20x15)mm was used to fix the chip.

The X-ray images illustrate the chip is mounted upside down (Figure 36). As this is an inverted chip, when fixing the component on the plate, it will be placed contrary to the usual position.

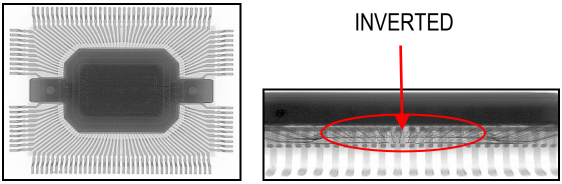


Figure 36. Top and side X-ray image

For decapsulation, the program number 1 (APPENDIX VII) was used. After the test, the results are not good because there is still a lot of resin to be removed and don't appreciate the chip (Figure 37). This is due to the grater thickness of this chip compared to the other two components studied before. Therefore, the parameters of the program were changed for a more aggressive decap.

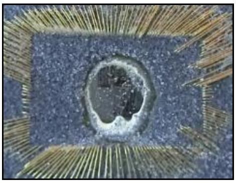


Figure 37. Chip image after decap process (not good results)

The most important change in the new program is the increase of the etch volume (1 mL/min more). The etch time is also increased. After testing these newly established conditions, a good decap was observed, allowing to see the whole surface of the chip.

After performing the cleaning process (Figure 38), this program was established as a good one and saved in the machine as Program number 2 (APPENDIX VII).

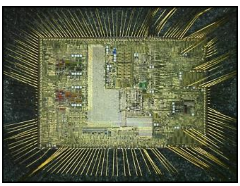


Figure 38. Chip image after decap process

- ***IC Number 32***

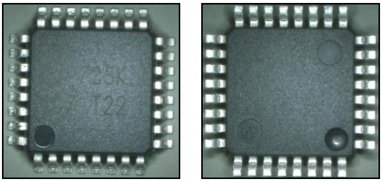


Figure 39. Top and bottom image

This component is different compared to the previous ones (Figure 39). In this case, the encapsulation is smaller (APPENDIX IV), as well as the die. For this decap, the window cannot be very big because a big gasket would cause, the acid to attack the entire component. A spherical gasket (nº30 (3 mm of diameter)) and a localization gasket of number 43 (3.1x3.1)mm were used. The alignment plate used in this case is the number 17 (41x7)mm. With this plate the component is only fixed in its width.

The X-ray image (Figure 40), allows to see that this component contains a less number of wires because it has fewer leads.

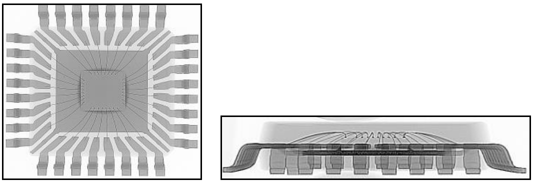


Figure 40. Top and side X-ray image

In this component, the decapsulation was performed using only fuming nitric acid. For the first test, a short program time (300s) was used, intermediate temperature (50ºC) and etch volume of 1 mL/min. Figure 41 illustrates that the component is badly damaged after the decap process. Two tests more were conducted, reducing time (200s and 150s) but the component continues being badly damaged.

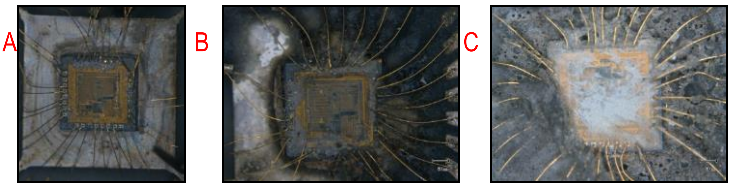


Figure 41. Chip image after decap process (A=300s; B=200s; C=150s)

After these unsatisfactory tests, the 3:1 mix of acids was used again, the etch volume was increased to 2mL/min and the etch time was increased to 500 and 600 seconds. The first tests in these new conditions did not provide good results because the resin is not removed, therefore the etch volume was increased to 3mL/min. Under these conditions, a good component decap was observed. The only difference between these tests is related to the etch time (600s and 500s). The first is discarded because when observing the component at the metallographic microscope highly magnified (Figure 42), the pads and bondings were damaged.

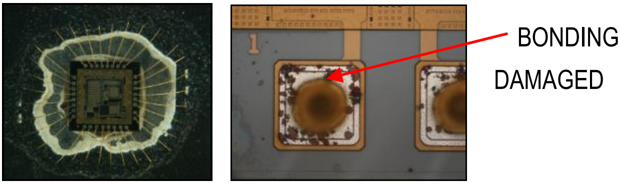


Figure 42. Chip image after decap process at 600s (BONDING DAMAGED)

Therefore the order program is the correct program and it was saved in the machine as Program Number 3 (APPENDIX VII).

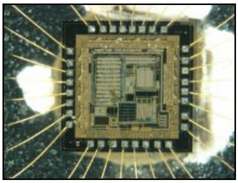


Figure 43. Chip image after correct decap process at 500s

- ***IC Number 50B and IC Number 50C***

At this point of the study, these two components (Figure 44 and Figure 45) were chosen to work with because they have similar dimensions and are part of the same components family (SOP8 – 8 leads).

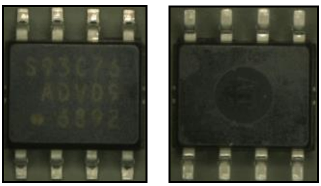


Figure 44. 50B Top and bottom image

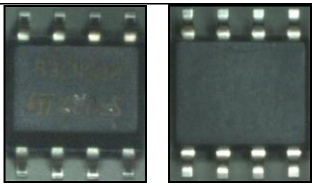
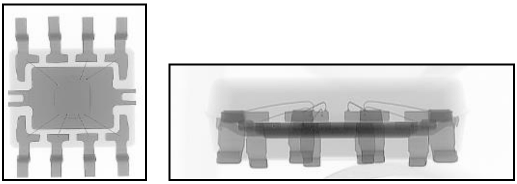


Figure 45. 50C Top and bottom image

These two components have the smallest encapsulation (APPENDIX IV) encountered so far. A problem arises because any alignment plate can't serve to fix the components. To solve this problem, another localization gasket was used for fixing the component. As definition gasket the number 66 (2x2) and as a localization gasket the number 64 (2.5x2.5)mm were selected. Finally the gasket number 9 (4.6x4.6)mm was used to fix the component.

The X-ray image of both components (Figure 46), shows that the chips have a different number of wires: component number 50B has seven wires and component 50C has connections in all the leads with eight wires.

A



B

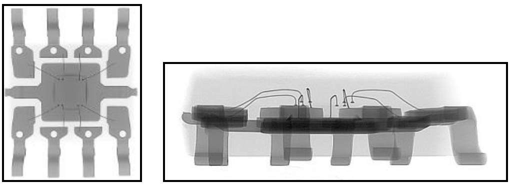


Figure 46. Top and side X-ray image (A=50B; B=50C)

The two components are practically the same. For this reason, it is supposed that the program should serve to decap the two components. A program with low temperature (45ºC) but with a long time (650s) was used therefore. The etch volume was of 1mL/min.

After applying the disassembling program to 50B component, a very good result was obtained as the whole surface of the chip and all the wire bonding were seen. The pads were checked for any possible damage, and good results were obtained this case (Figure 47).

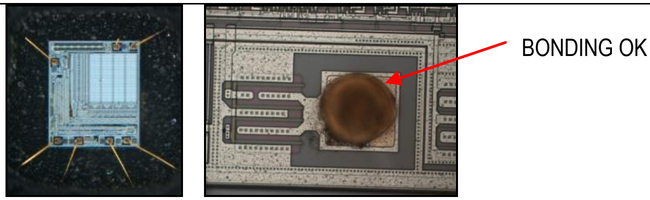


Figure 47. 50B chip image after decap process (BONDING OK)

The program applied to 50C component, also provided a good decapsulation. However, the problem appears when the pads were analyzed, Figure 48 illustrating in the microscope image that they are totally damaged. For this reason, in order to avoid damaging both pads, the process temperature was reduced to 35ºC. In these conditions, the program provided a positive result and the bonding pads are not damaged (Figure 49).

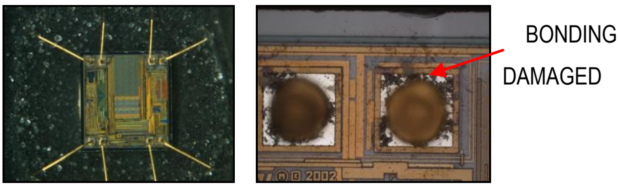


Figure 48. 50C chip image after 45ºC decap process (BONDING DAMAGED)

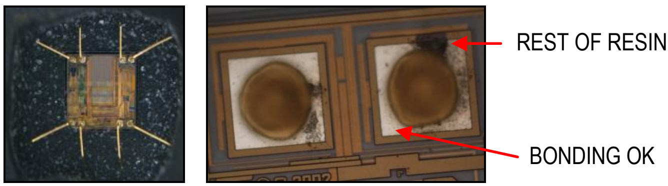


Figure 49. 50C chip image after 35ºC decap process (BONDING OK)

Considering all the above observations, as the same program couldn't be used for both components, program 4 and program 5 (APPENDIX VII) were saved in the machine memory as program for 50C component and as program for 50B component, respectively.

- **IC Number 52**

This component has a different encapsulation compared to the others already studied (Figure 50).

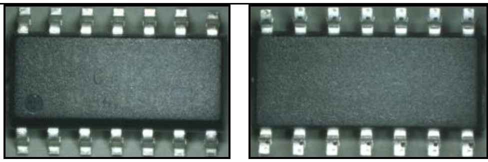


Figure 50. Top and bottom image

So far, all the components analyzed were more or less square, but the present one and the following ones present a more rectangular shape (APPENDIX IV). It will be very important to center the components with the gasket to obtain a good decap process. For this process, as definition gasket the number 37 (3.8x1.5)mm was selected and as localization gasket the number 5 (4.5x2.5)mm. The alignment plate used in this case is the number 23 (33x6)mm.

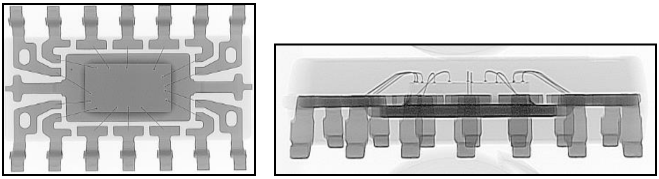


Figure 51. Top and side X-ray image

The program with the same etch temperature characteristic as in program 5 was tested for this component but changing the etch volume to 2 ml/min. For this reason, the etch time is reduced to 425s. After performing the decapsulation and the cleaning processes established, the chip is still very dirty. As in component 42, the chip has a protective layer of polyamide and therefore, ethylenediamine was used to clean the chip surface (Figure 52).

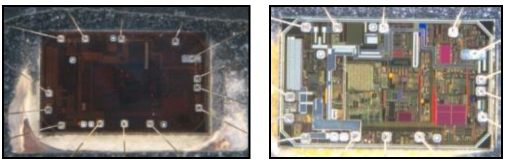


Figure 52. Chip image before and after ethylenediamine clean

This program was saved as program number 6 in the machine memory (APPENDIX VII).

- ***IC Number 53***

A similar component to IC number 52 was tested now (Figure 53).

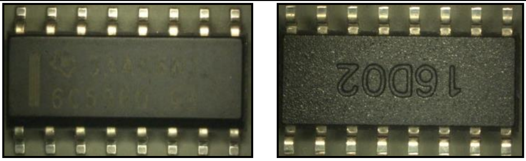


Figure 53. Top and bottom image

The size of the chip is very small compared to the encapsulated as seen in APPENDIX IV. As definition gasket the number 66 (2x2) was selected and as a localization gasket the number 64 (2.5x2.5)mm. The alignment plate used in this case is the number 23 (33x6)mm. With this plate the component is only fixed in its width. In this process, centering the sample is very important to ensure a good disassembling.

In the X-ray image (Figure 54), the small size of the chip can be observed.

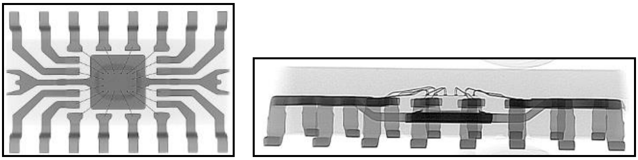


Figure 54. Top and side X-ray image

For the decap process, the same program as in the component 52 (number 6) was used (APPENDIX VII). The first tests are not satisfactory because the component has not been centered and the decap process has been displaced (Figure 55 and Figure 56). After two attempts to center the component, a small mark was made on the plate to ensure a correct centering. Figure 57 illustrates that a well centered decapsulation was achieved.

NOT CENTERED AND TERMINAL DAMAGED

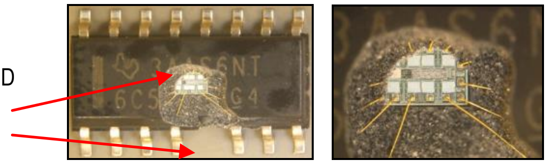


Figure 55. Component and chip image after TEST 1 decap process

BEST CENTERED BUT NOT ENOUGH

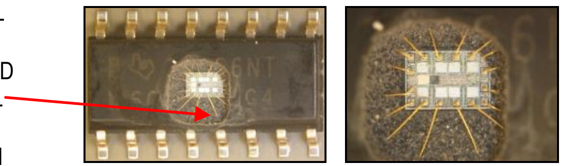


Figure 56. Component and chip image after TEST 2 decap process

CORRECT

WINDOW

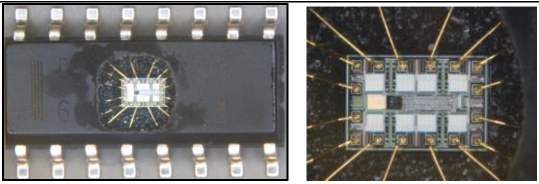


Figure 57. Component and chip image after TEST 3 decap process

- ***IC Number 55***

This component is very similar to number 52, but in this case there is a larger chip (Figure 58).

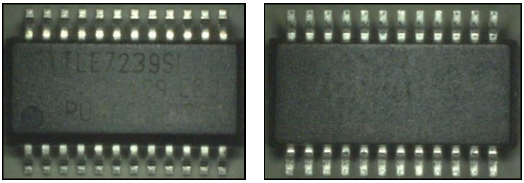


Figure 58. Top and bottom image

This chip size (APPENDIX IV) will create problems when making the window because the terminals could be damaged. To prevent this, some gaskets that adjust as much as possible to fit the chip were chosen (especially in width). As a definition gasket the number 26 (5.2x3.8)mm was selected and as localization gasket the number 44 (5x5)mm. To fix the component the same plate as for components 52 and 53 was used: alignment plate number 23.

In the X-ray image (Figure 59) can be seen that the chip almost touches the leads so it's important center very well the component on the plate to avoid damaging the terminals.

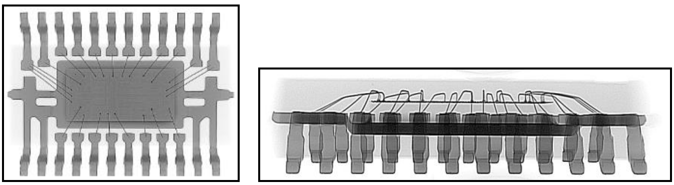


Figure 59. Top and side X-ray image

Program number 6 (APPENDIX VII) was selected again to realise the decap. The first tests carried out provided negative results, as it can be seen in Figure 60, the terminals being badly damaged.

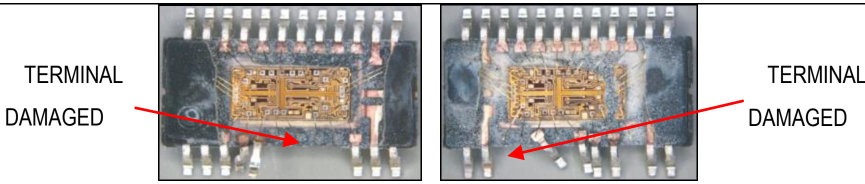


Figure 60. Component image after TEST 1 and 2

Although these tests are not valid, this allows us to see that the chip has a protective film of polyamide at the surface. A good disassembling was obtained when using the standard method to clean the polyamide and a new method proposed by [2] that consists in a manual cleaning process in which the component was introduced in a 2:1 mix of fuming nitric acid and sulfuric acid at 40ºC for two minutes.

A change of gaskets was made to solve the problem in the decap process. As gasket definition the number 5 (4.5x2.5)mm was selected and as localization gasket the number 26 (5.2x3.8)mm. A good result is achieved (Figure 61).

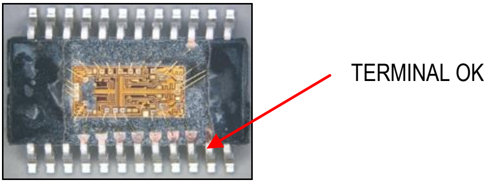


Figure 61. Component image after TEST 3 with new gaskets

The explained new cleaning process of polyamide was performed for this component. The results obtained using this cleaning process are not satisfactory because, when introducing the component into the mixture of acids the surface of the chips and the terminals were damaged. Therefore this method of cleaning was discarded (Figure 62).

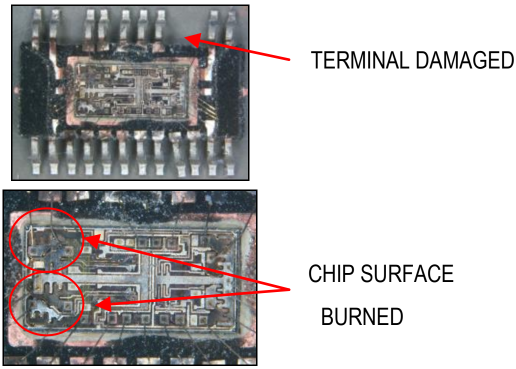
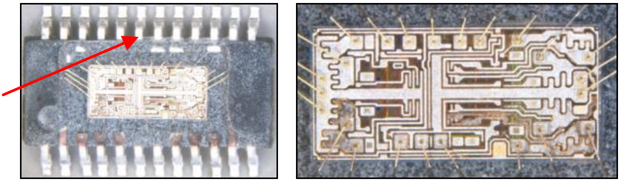


Figure 62. Component and chip image after TEST 3 (polyamide new clean method)

Finally, the classic method of polyamide cleaning with ethylenediamine was performed this time obtaining good results and both the terminals and the chip surface are in optimal conditions (Figure 63).

TERMINAL OK



CHIP SURFACE OK

Figure 63. Component and chip image after TEST 4 (polyamide classic clean method)

- ***IC Number 56***

The next test was realized on IC number 56 (Figure 64).

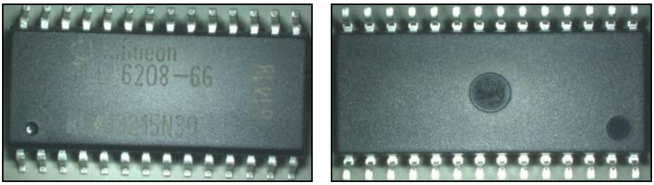


Figure 64. Top and bottom image

This component compared to the previous ones, was bigger in size especially in the thickness (APPENDIX IV). For the component decap, definition gasket number 5 (4.5x2.5)mm was selected and as localization gasket the number 2 (5x4)mm. This time a gasket with a low window size compared to the chip was selected and is enough for a good decap because the acid attack always generates a bit larger window. To fix the component alignment plate number 17 (41x7)mm was used.

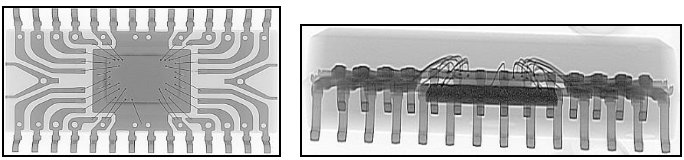


Figure 65. Top and side X-ray image

To start the test, program number 6 was selected but after disassembling test the chip can't be appreciated because resin is not removed (Figure 66).

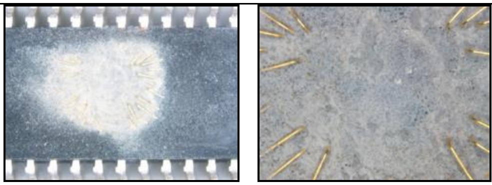


Figure 66. Component and chip image after TEST 1

For the next test, the etch temperature (increasing 10ºC) was changed and the etch volume was increased to 3mL/min, but the resin is still not removed (Figure 67). Finally, the etch time was increased to 500s and the result obtained is correct. However, this component also presents the film of polyamide (Figure 68) and the cleaning process using with ethylenediamine is required (Figure 69).

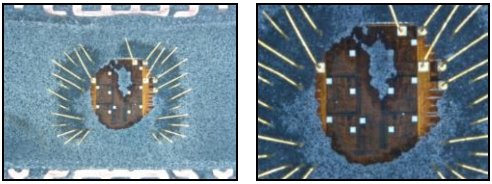


Figure 67. Component and chip image after TEST 2

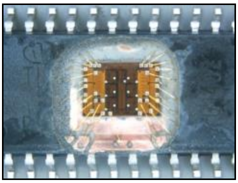


Figure 68. Component image after TEST 3

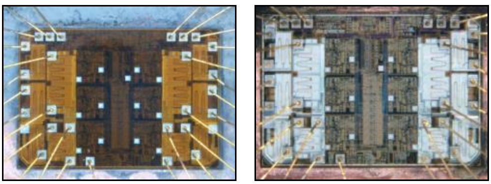


Figure 69. Chip image before and after ethylenediamine clean

The program was saved as program number 7 in the machine memory (APPENDIX VII).

With this decap, the target of integrated circuits with gold bonding wires disassembling were finished. Before continuing to aluminum and copper wires, a BGA package integrated circuit decapsulation was tested. As mentioned in the introduction explanation, BGA packages have lead balls soldering on the bottom surface of the integrated circuit.

6.1.2. BGA Integrated Circuit

In this section of the work only one component test was performed.

- ***IC BGA Number 64***

The test was performed on a component (IC number 64 shown in figure 70) with relatively large dimensions (APPENDIX IV).

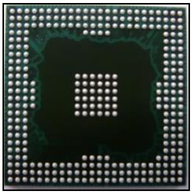


Figure 70. Top and bottom image

For the component decap, definition gasket number 80 (8.5 x 8.5)mm was selected and as localization gasket the number 81 (10 x 10)mm. To fix the component alignment plate number 7 (20 x 20)mm was used. The large encapsulation package allows to perform a wide window without any risks involved.

The X-ray image of this component (Figure 71) allows the visualization of the solder balls and of the great number of wires available.

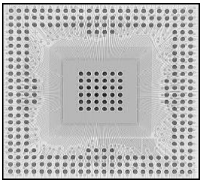
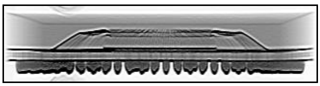



Figure 71. Top and side X-ray image

For its similarity with component 46 dimensions, program number 1 (APPENDIX VII) was selected to perform the first test using this component. Due to a wrong fixation of the component on the plate, an unwanted erroneous result was obtained (Figure 72).

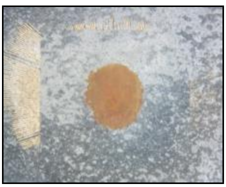


Figure 72. Component image after TEST 1

To fix the component a third gasket (number 94 (20 x 20)mm) was used. Using this assembly the results obtained were good and a correct disassembling was performed (Figure 73). The program number 1 was the correct procedure to obtain good results on this component.

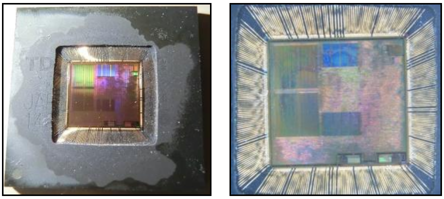


Figure 73. Component and chip image after TEST 2

The following tests are performed on components with alluminum wires.

6.1.3. Components with aluminum wires

There are two different types of components for decapsulation. On one side there is the integrated circuit number 51 and another test will be perfomed on the transistor number 8. The most important feature of the components with alluminum wires is that in the X-ray images, wires can't be observed.

- ***IC Number 51***

This component has a different encapsulation respect to the other components. As seen in Figure 74, the component is wider and shorter.

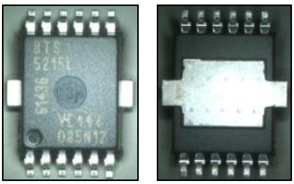


Figure 74. Top and bottom image

As the chip has roughly square dimensions (APPENDIX IV), gaskets will be chosen with this form. Definition gasket number 43 (3.1x3.1)mm was selected and as localization gasket the number 41 (4.1 x 4.1)mm. The alignment plate used in this case is the number 17 (41x7)mm. With this plate the component is only fixed in its width.

As explained before, in the X-ray image component (Figure 75), aluminum bonding wires are not be observed because aluminum is a material with light atomic weight and is difficult to identify.

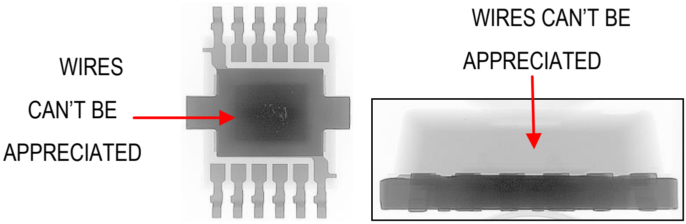


Figure 75. Top and side X-ray image

As it is a component with special features, a new disassembling program had to be established. It works at relatively low temperature and etch time (45ºC and 450 seconds). In the first test a good result is achieved but the chip surface presents the polyamide protective film; therefore ethylenediamine cleaning was needed (Figure 76). Another test is performed to check the repeatability of the program. As the result is again good (Figure 77), the program is saved in the memory of machine as program number 8 (APPENDIX VII).

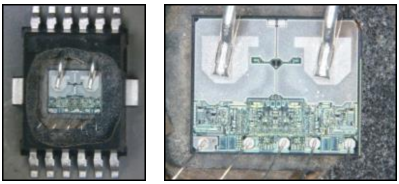


Figure 76. Component and chip image after TEST 1 (polyamide clean)

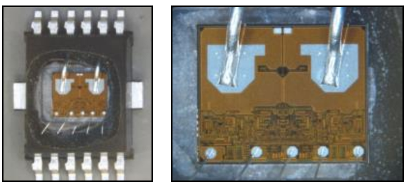


Figure 77. Component and chip image after TEST 2 (good repeatability)

- ***Transistor Number 8***

For the first time in this work, tests are performed on a passive component. A transistor is a semiconductor device used to amplify and switch electronic signals and electrical power. It is composed of semiconductor material with at least three terminals for connection to an external circuit (Figure 78). A voltage or current applied to one pair of the transistor's terminals changes the current through another pair of terminals.

Figure 78. Top and bottom image

Resin encapsulation is square but the dimensions of the chip are rectangular (APPENDIX IV) so the gasket selected will be of this type. In this test, only definition gasket was selected. Gasket number 2 (4x5)mm and alignment plate number 23 (33x6)mm to fix the component were used.

In the X-ray image component (Figure 79), aluminum bonding wires cannot be appreciated. Some spots are seen in the area of the chip. This spots are generated by the soldering.

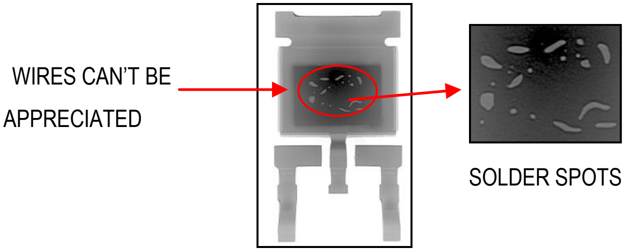


Figure 79. Top X-ray image

To start the test, program number 8 was selected (APPENDIX VII) but can't be appreciated the chip and bonding wires because resin covers the surface of the chip (Figure 80).

Figure 80. Component image after TEST 1

To achieve a good disassembling, a more aggressive program was needed. Etch volume, etch time and etch temperature were increased to 3mL/min, 700 seconds and 60ºC respectively. With this new program established, the result obtained was good because all chip surface is observed.

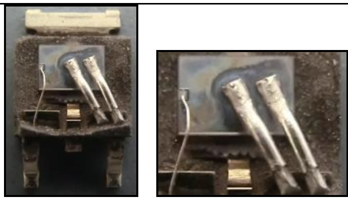


Figure 81. Component and chip image after TEST 2

Therefore the order program is the correct program and it was saved in the machine as Program Number 9 (APPENDIX VII).

In the next section of the work the decapsulation study on copper bonding wires is carried out. As the auto decap in the machine has the option to enable the method of bias, a series of tests on the same component (Nº 51B) will be realized at different voltages with the objective to establish, therefore having the security that any disassembly on components with copper wires is not damaging.

6.2. Determination of the ideal voltage for copper bonding wires

As mentioned in previous sections of the work, the current trend is the emergence of components with copper bonding wires. The machine purchased by the company, allows the Bias Voltage as explained in section 4.3. This feature of the Jet-Etcher allows to operate in a range of 0-20V and that is why a study was done at different voltages on several samples of the same component in order to determine the ideal voltage that should work whenever a component with copper bonding wires was used. For the proposed study, the component number 51B (Figure 82), which has the following dimensions (APPENDIX IV) and characteristics once observed in x-ray machine (Figure 83), was selected.

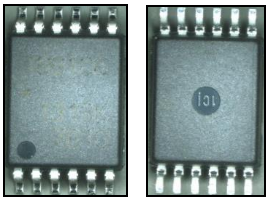


Figure 82. Top and bottom image

The chip size is highlighted with a different color because the component presents a double chip, as shown in the following the x-ray image of the component (Figure 83). Due to this particularity, the window to a correct decap in this case is one that is capable of rendering the two chips correctly.

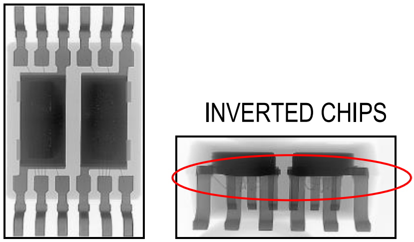


Figure 83. Top and side X-ray image

The above X-ray image also shows that the copper bonding wires are not providing the same shade as the gold wires. The side X-ray picture also illustrates that the chips are inverted to the normal position so that when inserting the component in the machine, the component is placed in opposite position.

To make a good decapsulation and ensure that a study of bonding wires state was made after the process, some tests are performed using various programs to find the optimal decap program. This program was saved as program number 10 (APPENDIX VII).

As explained above, the variable that will be played throughout the study, it will be the Bias Voltage. To carry out the component window, definition gasket number 2 (5x4) mm and the alignment plate number 18 were used. The component in this case will be between the gasket and the plate, in order to wrap the plate with foil and secure a good contact with the metal part (except the first test with Bias voltage disabled) so that the process is carried out without errors. The assembly used can be seen in the following image:

Figure 84. Assembly process

The study begins performing a first test with Bias Voltage disabled, continuing at 2V test and then move to a voltage of 4V then increasing the voltage 2 by 2 in the following tests until reaching the maximum of 20V. Altogether a total of 11 tests are performed.

The component has a total of fourteen wires. All the images presented in the following studies were in the same position. To consider a bonding wire condition as correct anything mark (similar as a bite) can appear during the SEM inspection.

6.2.1. Sample 1: Bias Voltage → OFF

After the component disassembling with Bias Voltage deactivated, a good window was obtained to study the bonding wires state (Figure 85). Obviously, with this image, the wires state can't be observed with precision.

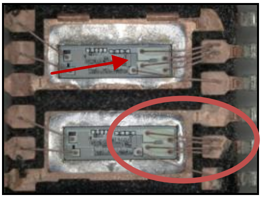


Figure 85. Chips and terminals image after decap

For a better observation, SEM was used. Two images were showed after SEM inspection; the first was a general view of the bonding wires (marked the part of general view) and the second was the image of one wire at high resolutions. In the Figure 85, the wire chosen for the SEM observation was marked (this procedure was established for all the next cases of study). Only one wire was presented but all of them were studied to determine the number of damaged bonding wires.

Figure 86 shows that the wires with bias voltage deactivated were totally damaged, the wire being burnt by the effect of fuming nitric acid, which can observed in the high resolution image how The fourteen bonding wires present the same state using this voltage.

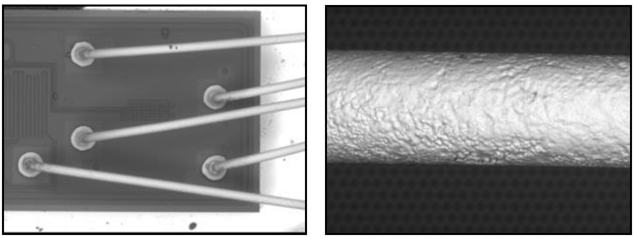


Figure 86. SEM inspection at 0V

6.2.2. Sample 2: Bias Voltage → 2V

In this case, the bias voltage was increased to 2V. Again a bad decap was obtained because the terminals of the component were damaged and wires have moved (Figure 87).

Figure 87. Chips and terminals image after decap

In this case, the bonding wires are not observed at SEM because the disassembling procedure damaged all the wires. The fourteen wires are considered as incorrect result for this reason.

6.2.3. Sample 3: Bias Voltage → 4V

The bias voltage is established at 4V in this procedure. The result obtained is better compared to 2V decap but the problem in the terminal continues appearing. In this decap, only two terminals are damaged (Figure 88)

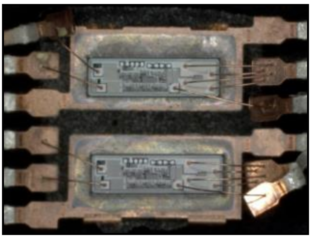


Figure 88. Chips and terminals image after decap

The following results are obtained at SEM inspection (Figure 89).

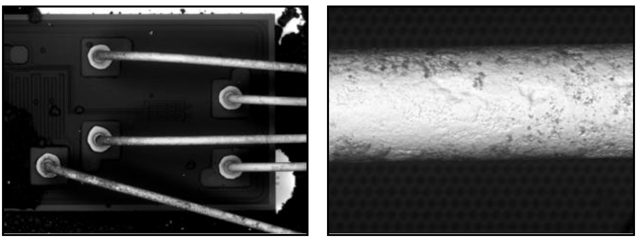


Figure 89. SEM inspection at 4V

The first observation is that some wires were dirty (especially the wire of the damaged terminal) but the wires were not burnt. In this case, three wires present a good result for the first time in all the bias voltage case studies.

6.2.4. Sample 4: Bias Voltage → 6V

After a better result with bias voltage at 4V, the voltage was increased to 6V, obtaining a good decap (Figure 90) with the terminals in perfect conditions.

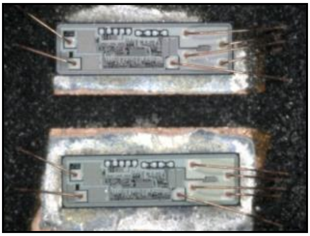


Figure 90. Chips and terminals image after decap

After SEM inspection, the result obtained was very similar compared with sample 4. The four bonding wires at left position were in correct condition but the other eight were damaged (Figure 91).

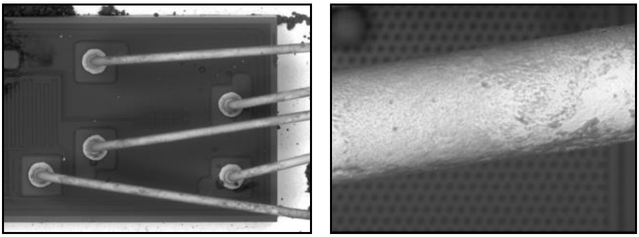


Figure 91. SEM inspection at 6V

The wires continuing damaged but observing the image at high resolutions, a not heavy damage compared with the first cases can be appreciated.

6.2.5. Sample 5: Bias Voltage → 8V

A new sample was tested, this time at 8V. The decapsulation process was satifactory (Figure 92) and good window was obtained to study at SEM the wires state.

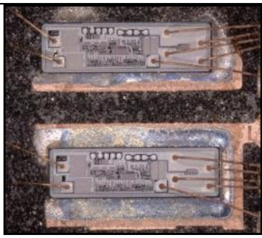


Figure 92. Chips and terminals image after decap

The problem with this sample appears during the cleaning process because a new type alcohol was used and very bad cleaning was obtained. When the sample was introduced to SEM inspection its dificulte to appreciate the real state of the wires (Figure 93) but finally can be obtained a good results.

After SEM inspection, 6 bondings wires were detected in good state. Probably with the sample in perfect conditions of cleaning, better results can be awarded.

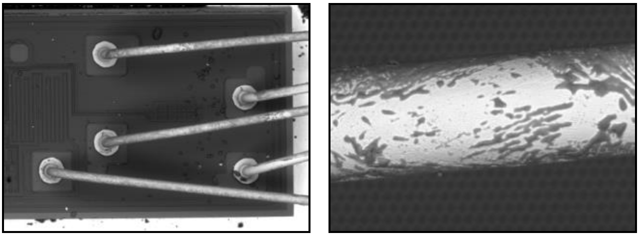


Figure 93. SEM inspection at 8V

6.2.6. Sample 6: Bias Voltage → 10V

Correct decap was obtained at 10V (Figure 94). For this sample, the old alcohol bottle was utilized another time to get a good cleaning of the component.

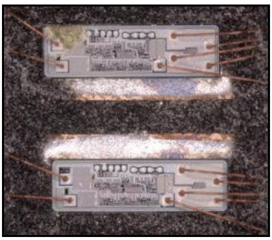


Figure 94. Chips and terminals image after decap

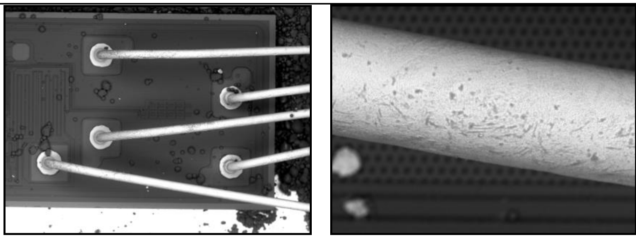


Figure 95. SEM inspection at 10V

Figure 95 shows the results obtained at this voltage. Only 4 wires appear with little marks by the effect of fuming nitric acid but the rest were in perfect state.

6.2.7. Sample 7: Bias Voltage → 12V

This sample was tested at 12V. The decap result obtained was very similar to the last studies (Figure 96).

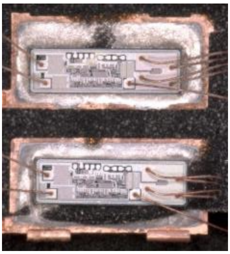


Figure 96. Chips and terminals image after decap

At SEM inspection, a very similar result compared with sample 7 was obtained. In the Figure 97, a little part of the wire damaged was detected in three cases.

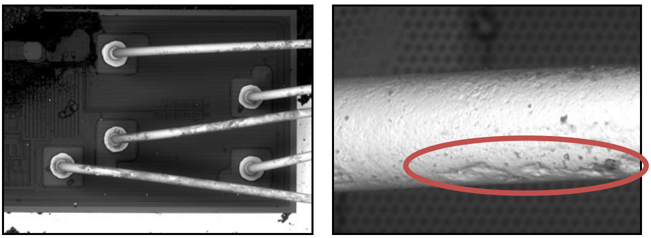


Figure 97. SEM inspection at 12V

6.2.8. Sample 8: Bias Voltage → 14V

In this case, the voltage used was 14V. A bad decap was obtained because one terminal was damaged (Figure 98) and the bonding wire was displaced.

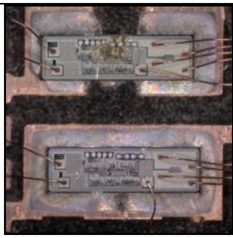


Figure 98. Chips and terminals image after decap

After inspection all the bonding wires except the displaced wire at SEM (Figure 99), a good state was obtained in the 13 wires. The state was not perfect but this voltage not damaged the copper material.

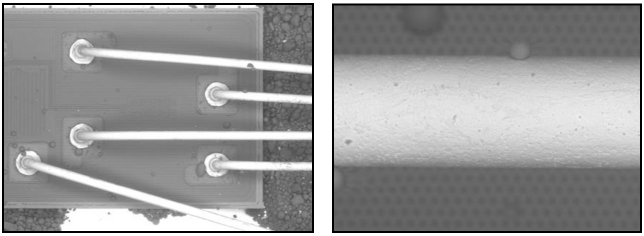


Figure 99. SEM inspection at 14V

6.2.9. Sample 9: Bias Voltage → 16V

At 16V the result obtained at decap window (Figure 100) and SEM inspection (Figure 101) was very good. Only one wire has a little mark of the acid effect but this voltage was considered as good to decap when copper bonding wires were presented.

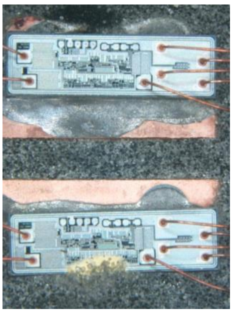


Figure 100. Chips and terminals image after decap

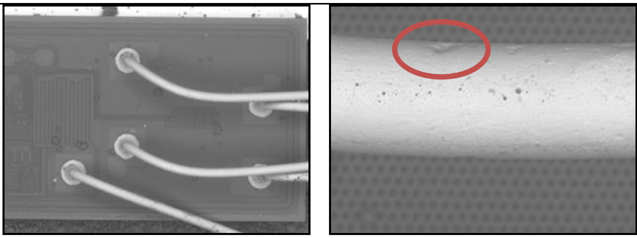


Figure 101. SEM inspection at 16V

6.2.10. Sample 10: Bias Voltage → 18V

At 18V the decap result was very good (Figure 102) but two wires in bad condition were detected after SEM inspection (Figure 103).

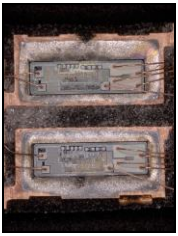


Figure 102. Chips and terminals image after decap

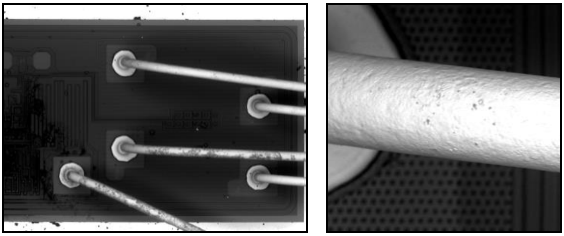


Figure 103. SEM inspection at 18V

6.2.11. Sample 11: Bias Voltage → 20V

The last sample studied was this with Bias voltage at 20V. The chip after decap was very dirty but the wires can be observed well at SEM. After exhaustive observation, four bonding wires were damaged.

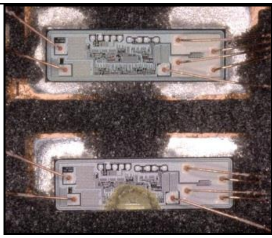


Figure 104. Chips and terminals image after decap

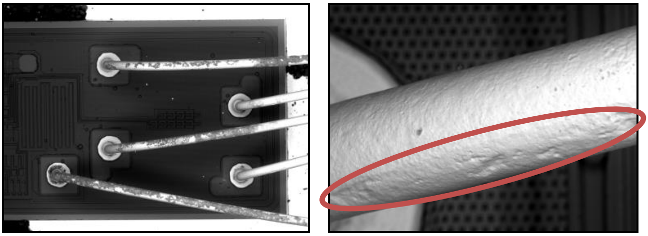


Figure 105. SEM inspection at 20V

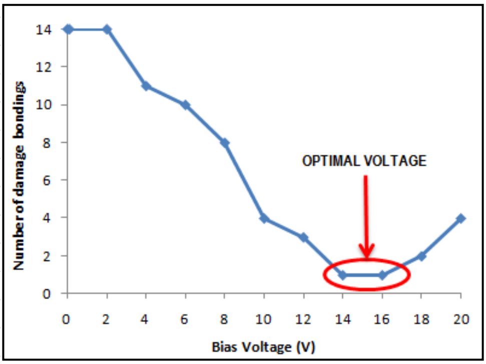
With all the study realized, a bias voltage can be determined as the best for components with copper bonding wires.

6.2.12. Optimal Bias Voltage

After all the samples procedures realized, Table 3 and Figure 106are presented to determine the optimal voltage when a component with copper wires was studied.

Table 3 and Figure 106. Study results

	Wires state	
Voltage (V)	O	X
0	-	14
2	-	14
4	3	11
6	4	10
8	6	8
10	10	4
12	11	3
14	13	1
16	13	1
18	12	2
20	10	4



As seen the optimal voltage was between 14 and 16V. A test with Bias Voltage at 15V was realized to comprove that these results were correct. Figure 107 showed the image of the component after disassembling process. The decap result was excellent and after first observation the wires presents a perfect condition.

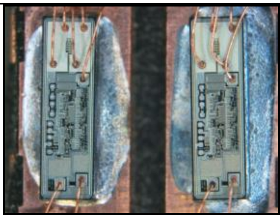


Figure 107. Chips and terminals image after decap

At SEM inspection (Figure 108), the bias voltage at 15V was confirmed and established as the optimal because the bonding wires were in a very good state. All the samples in the future will be realized with this works conditions when copper appear as material of bonding wires.

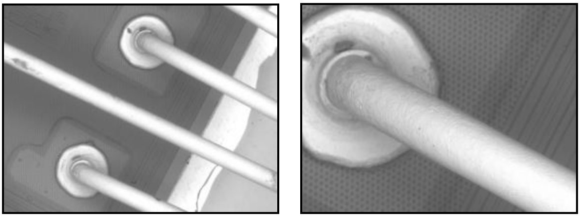


Figure 108. SEM inspection at 15V

7. CONCLUSIONS

Extensive knowledge of the electronic components world have been adquired during this projects. It has learned to differentiate components and detect possible failures and defects on components.

A lot of tests are performed during this work in many different electronic components (different bonding wire material, differents measures...) obtaining 10 different decapsulations programs in order to establish a guidelines in the company. More test are performed in a component with copper bonding wires to study the optimal bias voltage to protect the material of the wires from the attack of fuming nitric acid. The optimal voltage is established at 15V.

In the text, safety materials are explained. Its very important to work in a optimal safety conditions. Similarities are found in this topic with the subjets about security studied at university during the degree.

8. REFERENCES AND NOTES

1. Whye Ng, S.; Zhang, H.B.; Nan Liew, K.; Lee, W.; De Lin, R. Copper wirebond package decapsulation technique using mixed acid chemistry. United Microelectronics Corporation Ltd.
2. Liu, C.P.; Liu, Y.F.; Li, C.H.; Cheng H.C.; Kung, Y.C.; Lin J.Y. A novel decapsulation technique for failure analysis of epoxy molded IC packages with Cu wire bonds. Microelectronics Reliability, 52, **2012,** 725–734

9. ACRONYMS

IC: Integrated circuit

PCB:Printed circuit board

SOP: Small outline package

QFP:Quad flat package

BGA: Ball grid array

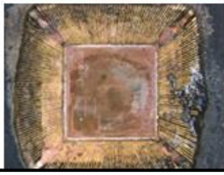
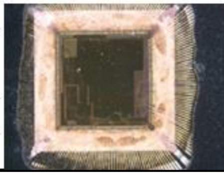
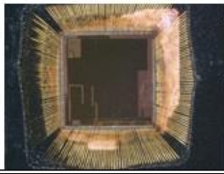
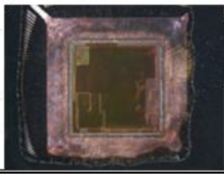
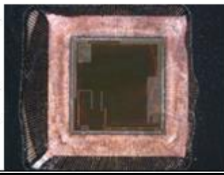
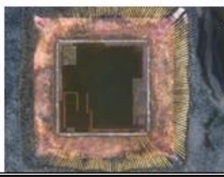
SEM: Scanning electron microscope

APPENDICES

APPENDIX I: FIXTURES DESCRIPTION

- Etch head: The etch head is where the acid escapes the heat exchanger assembly on its way to the surface of the sample being etched. It also has ports for transporting the acid waste to the waste acid bottles.
- Ram nose: The ram nose applies pressure to the stack-up during the etch and other processes.
- Definition gasket: Is used as a mask for the sample during the etch processes. It defines the etch cavity.
- Localization gasket: Is used to align the sample above the Definition gasket during the etch process.
- Alignment plate: Aligns the sample to the Definition gasket during the etch process.
- Teflon blank: Spreads the force of the ram nose evently across the backside of the sample during the etch process.
- Aluminum Blank: Spreads the force of the ram nose evently across the backside of the sample during the etch process. The aluminum blank is also an integral fixture in the decapsulation of samples with copper wires where wire preservation is a priority, as it completes the electrical circuit during a process with bias voltage applied.

APPENDIX II: DIFFERENT CLEANING PROCESS

Number	Cleaning Process	Result	Observations
1	1- Acetone vaporized 2- Warm water (70-90ºC) 1 minute + Ultrasounds 3- Jet Alcohol 4- Dry air		Bubbles appeared when acetone was applied. Chip is not correctly cleaned and a little damage can be observed.
2	1- Acetone + Ultrasounds 2- Rinse with warm water (70-90ºC) 3- Alcohol 4- Dry air		Good cleaning in general but the chip presents a trace of particles. Chip presents sort of a water spotting.
3	1- Acetone + Ultrasounds 2- Rinse with warm water (70-90ºC) 3- Dry air		Good cleaning but chip drying is difficult. Chip already presents small particles and water spotting.
4	1- Acetone 2- Water + Ultrasounds 3- Alcohol 4- Dry air		Good cleaning but the chip surface presents many orange tones.
5	1- Acetone 2- Warm Water (70-90ºC) + Ultrasounds 3- Alcohol 4- Dry air		Very good cleaning. Chip already presents orange tones but less than in process number 4.
6	1- Rinse with warm water (70-90ºC) + Ultrasounds 2- Acetone 3- Alcohol 4- Dry air		Very good cleaning, chip is in good conditions.

APPENDIX III: PROCESS TO CREATE A PROGRAM

For the creation of a decapsulation procedure on the machine, the next steps are followed. Its important to familiarize with all the parameters of a decap program before using the machine.

The START button activates the Program Menu on screen. Using the “+” and “-“ buttons, the user modifies the program parameter highlighted in the cursor line as required. Pressing the STOP button cancels changes in progress, including unsaved process parameters.

The next step is to introduce the following machine operation parameters:.

- **Etch time (seconds):**, Etch time refers to the time that the acid attacks the device. It is greatly depends on device size and encapsulant resistance to etching. At longer time, the reaction between the acid and the material achieves a higher extend.
- **Etch temperature (ºC):** Temperature ranges depend on the acid type selected. The reaction rate constant between a certain acid and certain material follows an Arrhenius expression and therefore at higher temperature then higher reaction rate. Working with only HNO_3 for example the optimal recommended temperature is 90ºC with very short etch time, depending on the package thickness. Sulfuric acid is more reactive at higher temperatures, but it is not necessary stronger or better than nitric acid.
- **Flow type and mixture ratio:**"N" denotes nitric acid and "S" denotes sulfuric acid. Different molding materials reacts differently depending on the acid, for instance, some plastics will react with nitric acid, but not sulfuric and some others react with sulfuric but not nitric acid. Usually, mixing acids provides the best operation conditions depending on the sort of plastic to be etched. A 3:1 mix (HNO_3:H_2SO_4) is chosen for the present work.
- **Etch volume (mL/min)**:, This parameter is fixed according to the encapsulant residuals present in the waste acid that depend on how easily the material dissolves. The waste that flows out the back of the system and into the waste bottles is a mixture of acid and melted encapsulant. The color of the waste

material in the waste tube during an etch helps determine if the volume setting should be changed. If the waste acid is light brown to clear, the volume may be too high. If it is dark brown or black and not moving freely, the volume is too low. If it is medium brown and moving freely, then the volume is correct. The volume is small for smaller openings or harder packages and large for larger openings or softer packages.

- **Heat-up time (s):** This lag time allows the device reach the same temperature than the etch head. It ensures a consistent etch and more efficient usage of etching acids. For all the programs, will be use a heat-up time with the same value as etch temperature.
- **Rinse time** (s): A short rinse is run at the end of every process. A rinse with a small amount of acidr emoves any etch debris left on the die surface. The rinse time may also be used to add a very small amount of etching to the end of an etch process. Rinse type parameter allows choosing which acid is to be used in the rinse process. The choices are Sulfuric rinse, Nitric rinse or No rinse. “NO RINSE” is selected always in this work.

APPENDIX IV: COMPONENTS MEASUREMENTS

Component	Bonding Type	SIZE	Length	Width	Thickness
8 (transistor)	Aluminum	External Size	6.2	10	2.25
		Resin Size	6.2	6.2	2.25
		Chip Size	3.8	2.57	-
32	Gold	External Size	8.97	8.97	1.5
		Resin Size	6.99	6.99	1.5
		Chip Size	2.18	2.16	-
41	Gold	External Size	23.2	17.2	2.65
		Resin Size	20	14	2.65
		Chip Size	7.42	4.94	-
42	Gold	External Size	18.01	18.01	1.43
		Resin Size	16.01	16.01	1.43
		Chip Size	5.34	5.16	-
46	Gold	External Size	30.03	30.03	1.46
		Resin Size	28.07	28.07	1.46
		Chip Size	4.78	4.73	-
50B	Gold	External Size	5.06	6.5	1.49
		Resin Size	5.06	3.83	1.49
		Chip Size	1.46	1.71	-
50C	Gold	External Size	4.96	6.61	1.52
		Resin Size	4.96	3.82	1.52
		Chip Size	1.22	1.3	-
50E	Copper	External Size	5.02	6.41	1.45
		Resin Size	5.02	4.01	1.45
		Chip Size	1.17	1.23	-
51	Aluminum	External Size	7.54	10.28	2.37
		Resin Size	6.11	7.34	2.37
		Chip Size	2.72	3.29	-
51B	Copper	External Size	6.43	11.02	2.64
		Resin Size	6.43	7.63	2.64
		Chip Size	4.21	3.78	-

52	Gold	External Size	8.85	6.35	1.45
		Resin Size	8.85	3.89	1.45
		Chip Size	3.13	1.92	-
53	Gold	External Size	9.97	6.32	1.52
		Resin Size	9.97	3.87	1.52
		Chip Size	1.68	1.15	-
55	Gold	External Size	8.78	6.03	1.46
		Resin Size	8.78	4.02	1.46
		Chip Size	4.32	2.1	-
56	Gold	External Size	18.08	10.52	2.37
		Resin Size	18.08	7.42	2.37
		Chip Size	4.87	3.38	-
64 (BGA)	Gold	External Size	20.04	20	1.45
		Resin Size	20.04	20	1.45
		Chip Size	8.14	7.82	-

APPENDIX V: SAFETY SHEETS

- ## FUMING NITRIC ACID

REGISTRO DE IDENTIFICACIÓN DE SUSTANCIAS

NOMBRE DE LA SUSTANCIA: ACIDO NÍTRICO FUMANTE

SINÓNIMOS/USOS: ACIDO

Nº MSDS: M-041

Nº SIR: SIR-041

PROVEEDOR:
PANREAC QUIMICA, S.L.U
C/ GARRAF, 2
POLÍGONO PLA DE LA BRUGUERA
08211 CASTELLAR DEL VALLÈS
BARCELONA

Tel. Nº 34 93 748 94 00
34 93 748 94 99 (URGÉNCIAS)

CÓDIGO DE PELIGRO

Rojo: Peligroso

Amarillo: Potencialmente peligroso

Verde: No peligroso

DESCRIPCIÓN FÍSICA: LÍQUIDO AMARILLENTO DE OLOR PICANTE

PRESENTACIÓN: ENVASE DE CRISTAL DE 1L

CÓDIGO: 20-030-18

COMPONENTES:

	Nº CAS	Nº EINECS	FRASES H
ACIDO NÍTRICO FUMANTE	7697-37-2	231-714-2	272/314

ALMACENAMIENTO Y PRECAUCIONES:

ALMACENAR EN RECIPIENTES BIEN CERRADOS, EN UN LOCAL BIEN VENTILADO, A TEMPERATURA AMBIENTE. NO ALMACENAR EN RECIPIENTES METÁLICOS. MANTENER ALEJADO DE FUENTES DE IGNICIÓN Y CALOR. ALMACENAR POR SEPARADO O EN RECINTO EXCLUSIVAMENTE DESTINADO A SUSTÁNCIAS QUE FAVORECEN LA IGNICIÓN. POSIBLE FORMACIÓN DE PRESIÓN INTERNA EN EL ENVASE. MANTENER ALEJADO DE SUSTANCIAS INFLAMABLES, COMPUESTOS OXIDABLES, DISOLVENTES ORGÁNICOS, ALCOHOLES, ALDEHÍDOS, CETONAS ACETILUROS, ACIDOS, AMINAS, AMONÍACO, ANHÍDRIDOS, ANILINAS, COMPUESTOS HALOGENADOS, FOSFUROS, HALÓGENOS, HALOGENUROS NO METÁLICOS, HIDRACINA Y DERIVADOS, HIDRUROS, LITIO SILICIURO, METALES ALCALINOS, METALES ALCALINOTÉRREOS, METALES Y SUS ALEACIONES, NITRILOS, COMPUESTOS ORGÁNICOS DE NITRÓGENO, NITRUROS, NO METALES, OXIDOS METÁLICOS, OXIDOS NO METÁLICOS, PERÓXIDO DE HIDRÓGENO, SOLUCIONES ALCALINAS.

CLASIFICACIÓN DE RIESGO Y SÍMBOLOS APLICABLES A LA SUSTANCIA:

COMBURENTE (O) PELIGRO
CORROSIVO (C)

INSTRUCCIONES DE ELIMINACIÓN:

EN CASO DE GENERAR RESIDUOS, CUMPLIMENTAR EL CORRESPONDIENTE WASTE SLIP SEGÚN WSHE-C-ENV-003. DEPOSITAR EL ENVASE VACIO COMO ENVASES CONTAMINADOS.

CONTROL DE LA EXPOSICIÓN / PROTECCIÓN PERSONAL:

USAR GUANTES Y GAFAS APROPIADOS
ASEGURAR UNA BUENA VENTILACIÓN
EN CASO DE FORMARSE VAPORES/AEROSOLES,
USAR EQUIPO RESPIRATÓRIO APROPIADO
LAVARSE LAS MANOS ANTES DE LAS PAUSAS
Y AL FINALIZAR EL TRABAJO

- **SULFURIC ACID**

REGISTRO DE IDENTIFICACIÓN DE SUSTANCIAS

NOMBRE DE LA SUSTANCIA: ACIDO SULFÚRICO 93-98%	**Nº MSDS**	**Nº SIR**
SINÓNIMOS/USOS: ACIDO	M-042	SIR-042

PROVEEDOR:

PANREAC QUIMICA, S.L.U
C/ GARRAF, 2
POLÍGONO PLA DE LA BRUGUERA
08211 CASTELLAR DEL VALLÈS
BARCELONA

Tel. Nº 34 93 748 94 00
34 93 748 94 99 (URGÉNCIAS)

CÓDIGO DE PELIGRO
Rojo: Peligroso
Amarillo: Potencialmente peligroso
Verde: No peligroso

DESCRIPCIÓN FÍSICA: LÍQUIDO INCOLORO
PRESENTACIÓN: ENVASE DE CRISTAL DE 1L
CÓDIGO: 20-030-21

COMPONENTES:

	%	Nº CAS	Nº EINECS	FRASES H
ACIDO SULFÚRICO	93-98	7664-93-9	231-639-5	314

ALMACENAMIENTO Y PRECAUCIONES:

ALMACENAR EN RECIPIENTES BIEN CERRADOS. EN LOCAL BIEN VENTILADO. A TEMPERATURA AMBIENTE. NO ALMACENAR EN RECIPIENTES METÁLICOS. MANTENER ALEJADO DE AGUA (SE GENERA CALOR), COMPUESTOS ALCALINOS, METALES ALCALINOS, AMONÍACO, COMPUESTOS ALCALINOTÉRREOS, SOLUCIONES ALCALINAS, ACIDOS, METALES Y SUS ALEACIONES, FÓSFORO, OXIDOS DE FÓSFORO, HIDRUROS, HALOGENUROS DE HALÓGENO, HALOGENATOS, NITRATOS, CARBUROS, DISOLVENTES ORGÁNICOS, SUSTANCIAS INFLAMABLES, ACETILUROS, NITRILOS, COMPUESTOS ORGÁNICOS DE NITRÓGENO, ANILINAS, PERÓXIDOS, PICRATOS, NITRUROS Y LITIO SILICIURO.

CLASIFICACIÓN DE RIESGO Y SÍMBOLOS APLICABLES A LA SUSTANCIA:

CORROSIVO (C) PELIGRO

INSTRUCCIONES DE ELIMINACIÓN:

EN CASO DE GENERAR RESIDUOS, CUMPLIMENTAR EL CORRESPONDIENTE WASTE SLIP SEGÚN WSHE-C-ENV-003. DEPOSITAR EL ENVASE VACIO COMO ENVASES CONTAMINADOS.

CONTROL DE LA EXPOSICIÓN / PROTECCIÓN PERSONAL:

USAR GUANTES Y GAFAS APROPIADOS
ASEGURAR UNA BUENA VENTILACIÓN
EN CASO DE FORMARSE VAPORES/AEROSOLES,
USAR EQUIPO RESPIRATÓRIO APROPIADO
LAVARSE LAS MANOS ANTES DE LAS PAUSAS
Y AL FINALIZAR EL TRABAJO

- **ETHYLENEDIAMINE**

REGISTRO DE IDENTIFICACIÓN DE SUSTANCIAS

NOMBRE DE LA SUSTANCIA: ETILENDIAMINA	**Nº MSDS**	**Nº SIR**
SINÓNIMOS/USOS: 1,2-DIAMINOETANO	M-351	SIR-351

PROVEEDOR:

PANREAC QUIMICA, S.L.U.
C/ GARRAF, 2
POLÍGONO PLA DE LA BRUGUERA
08211 CASTELLAR DEL VALLÈS
BARCELONA

Tel. Nº 34 93 748 94 00
34 93 748 94 99 (URGÉNCIAS)

CÓDIGO DE PELIGRO
Rojo: **Peligroso**
Amarillo: **Potencialmente peligroso**
Verde: **No peligroso**

DESCRIPCIÓN FÍSICA: LÍQUIDO INCOLORO DE OLOR CARACTERÍSTICO

PRESENTACIÓN: ENVASE DE CRISTAL DE 1L

CÓDIGO: 20-020-27

COMPONENTES:

	Nº CAS	Nº EINECS	FRASES H
ETILENDIAMINA	107-15-3	203-468-6	226/312/302/314/334/317

ALMACENAMIENTO Y PRECAUCIONES:

ALMACENAR EN RECIPIENTES BIEN CERRADOS, EN UN LUGAR FRESCO Y SECO, PROTEGIDO DEL AIRE Y DE ÁCIDOS. MANTENER ALEJADO DE LA LUZ SOLAR. EVITAR LA FORMACIÓN DE CARGAS ELECTROSTÁTICAS. MANIPULAR BAJO CAMPANA EXTRACTORA.

CLASIFICACIÓN DE RIESGO Y SÍMBOLOS APLICABLES A LA SUSTANCIA:

INFLAMABLE (F)
NOCIVO (Xn) PELIGRO
CORROSIVO (C)
SENSIBILIZANTE

INSTRUCCIONES DE ELIMINACIÓN:

EN CASO DE GENERAR RESIDUOS, CUMPLIMENTAR EL CORRESPONDIENTE WASTE SLIP SEGÚN EL PROCEDIMIENTO CP-PC-8002
DEPOSITAR EL ENVASE VACIO COMO ENVASES CONTAMINADOS

CONTROL DE LA EXPOSICIÓN / PROTECCIÓN PERSONAL:

USAR GUANTES Y GAFAS APROPIADOS
EN CASO DE FORMARSE VAPORES/AEROSOLES, USAR EQUIPO RESPIRATÓRIO APROPIADO
LAVARSE LAS MANOS ANTES DE LAS PAUSAS Y AL FINALIZAR EL TRABAJO

- **ALCOHOL**

REGISTRO DE IDENTIFICACIÓN DE SUSTANCIAS

NOMBRE DE LA SUSTANCIA: ETANOL ABSOLUTO 99,8%

SINÓNIMOS/USOS: ALCOHOL ETÍLICO

Nº MSDS M-456 | **Nº SIR** SIR-456

PROVEEDOR:
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08211 CASTELLAR DEL VALLÈS
BARCELONA

Tel. Nº 34 93 748 94 00
34 93 748 94 99 (URGÉNCIAS)

CÓDIGO DE PELIGRO
Rojo: Peligroso
Amarillo: Potencialmente peligroso
Verde: No peligroso

DESCRIPCIÓN FÍSICA: LÍQUIDO INCOLORO DE OLOR CARACTERÍSTICO

PRESENTACIÓN: ENVASE DE PLÁSTICO DE 1L

CÓDIGO: 20-010-09

COMPONENTES:

	Nº CAS	Nº EINECS	FRASES H
ETANOL ABSOLUTO	64-17-5	200-578-6	225

ALMACENAMIENTO Y PRECAUCIONES:

ALMACENAR EN RECIPIENTES BIEN CERRADOS, EN UN LUGAR BIEN VENTILADO Y A TEMPERATURA AMBIENTE. MANTENER ALEJADO DE FUENTES DE IGNICIÓN Y CALOR, METALES ALCALINOS, ÓXIDOS ALCALINOS Y AGENTES OXIDANTES FUERTES.

CLASIFICACIÓN DE RIESGO Y SÍMBOLOS APLICABLES A LA SUSTANCIA:

FÁCILMENTE INFLAMABLE (F) PELIGRO

INSTRUCCIONES DE ELIMINACIÓN:

EN CASO DE GENERAR RESIDUOS, CUMPLIMENTAR EL CORRESPONDIENTE WASTE SLIP SEGÚN WSHE-C-ENV-003. DEPOSITAR EL ENVASE VACIO COMO ENVASES CONTAMINADOS.

CONTROL DE LA EXPOSICIÓN / PROTECCIÓN PERSONAL:

USAR GUANTES Y GAFAS APROPIADOS
ASEGURAR UNA BUENA VENTILACIÓN
EN CASO DE FORMARSE VAPORES, USAR EQUIPO RESPIRATÓRIO APROPIADOS
LAVARSE LAS MANOS ANTES DE LAS PAUSAS Y AL FINALIZAR EL TRABAJO

APPENDIX VI: MACHINE HAZARDS

The types of hazards associated to the machine are chemical, electrical, mechanical and thermal. Knowing the types of hazards prior to using the machine will minimize the risk of personnel injury or damage to the system or facilities.

- **Chemical Hazards**

Chemical hazards exist where improperly contained chemicals have the potential to cause serious injury and/or equipment damage. Such hazards include poisonous, corrosive, oxidizing and flammable liquids. Chemical hazards associated with the Jet Etch include:

- *Nitric Acid (HNO_3):* Nitric acid is contained in the bottle boxes in 500mL supply bottles and is used to decapsulate integrated circuits.

- *Sulfuric Acid (H_2SO_4):* Sulfuric acid is contained in the bottle boxes in 500mL supply bottles and is used to decapsulate integrated circuits.
- *Nitric Acid and Sulfuric Acid waste:* Acid waste is contained in the bottle boxes in 500mL waste bottles.
- *Alcohols:* Small amounts of alcohols, typically Isopropyl Alcohol (IPA) or Methanol, are used to rinse etched devices and clean Alignment Plates, Location Rings and gaskets during daily maintenance.
- *Acetone:* Small amounts of acetone are used to rinse etched devices and clean Alignment Plates and Location Rings during daily maintenance. Do not use acetone to clean gaskets.
- *Nitrogen (N_2) or clean dry air (CDA):* Nitrogen gas (N_2) or clean dry air (CDA) is used for purging and operational purposes. In our case, the machine use clean dry air.

- **Thermal Hazards**

The operating temperature of the Jet Etch Pro ranges from 20ºC to 250ºC.

- **Mechanical Hazards**

The machine has pinch points and areas where fingers and hands could be injured.

- **Electrical Hazards**

The machine uses electricity to operate.

APPENDIX VII: MACHINE PROGRAMS

Program Number: 1	
Etch Temperature:	50ºC
Etch Time:	225s
Ratio HNO_3:H_2SO_4:	3:1
Etch Volume:	2mL/min
Heat Up Time:	45s
Rinse Time:	0
Rinse Type:	No
Bias Voltage:	Off
Program Number: 2	
Etch Temperature:	45ºC
Etch Time:	500s
Ratio HNO_3:H_2SO_4:	3:1
Etch Volume:	3mL/min
Heat Up Time:	45s
Rinse Time:	0
Rinse Type:	No
Bias Voltage:	Off
Program Number: 3	
Etch Temperature:	60ºC
Etch Time:	500s
Ratio HNO_3:H_2SO_4:	3:1
Etch Volume:	3mL/min
Heat Up Time:	60s
Rinse Time:	0
Rinse Type:	No
Bias Voltage:	Off

Program Number: 4	
Etch Temperature:	35ºC
Etch Time:	650s
Ratio HNO_3:H_2SO_4:	3:1
Etch Volume:	1mL/min
Heat Up Time:	35s
Rinse Time:	0
Rinse Type:	No
Bias Voltage:	Off

Program Number: 5	
Etch Temperature:	45ºC
Etch Time:	650s
Ratio HNO_3:H_2SO_4:	3:1
Etch Volume:	1mL/min
Heat Up Time:	45s
Rinse Time:	0
Rinse Type:	No
Bias Voltage:	Off

Program Number: 6	
Etch Temperature:	35ºC
Etch Time:	425s
Ratio HNO_3:H_2SO_4:	3:1
Etch Volume:	2mL/min
Heat Up Time:	35s
Rinse Time:	0
Rinse Type:	No
Bias Voltage:	Off

Program Number: 7	
Etch Temperature:	45ºC
Etch Time:	500s
Ratio HNO_3:H_2SO_4:	3:1
Etch Volume:	3mL/min
Heat Up Time:	45s
Rinse Time:	0
Rinse Type:	No
Bias Voltage:	Off
Program Number: 8	
Etch Temperature:	45ºC
Etch Time:	425s
Ratio HNO_3:H_2SO_4:	3:1
Etch Volume:	2mL/min
Heat Up Time:	45s
Rinse Time:	0
Rinse Type:	No
Bias Voltage:	Off
Program Number: 9	
Etch Temperature:	60ºC
Etch Time:	700s
Ratio HNO_3:H_2SO_4:	3:1
Etch Volume:	3mL/min
Heat Up Time:	60s
Rinse Time:	0
Rinse Type:	No
Bias Voltage:	Off

Program Number: 10	
Etch Temperature:	55ºC
Etch Time:	660s
Ratio HNO_3:H_2SO_4:	3:1
Etch Volume:	2mL/min
Heat Up Time:	50s
Rinse Time:	0
Rinse Type:	No