

# Implementation of On-Bonder-Curing to Maximize Array Package Manufacturing Productivity

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**René J. Ulrich** was born in Switzerland in 1945. In 1972 he graduated in M.Sc. Mechanical Engineering in Zurich, Switzerland. 1973 he began to work in the Semiconductor Industry with Philips-Faselec. 1974 he developed the world's first chip recognition system for the ESEC Die-attach machines. Up to 1981 he was employed as manufacturing manager for SOT-23 transistors and SO integrated circuits and 1981 to 1982 manager photolithography for high integrated circuits. In 1983 he joined ESEC holding positions as manufacturing manager and process engineer. 1989 - 1992 has gained experience in Hong Kong as Operation Manager for China and the Philippines. At the end of 1992 he joined again ESEC as Process Specialist in R&D for new paste- and adhesive-dispensing technologies. Due to his wide range experience, René J. Ulrich now is in charge of the International Customer Die Bonder Support for all Die attach applications.

## Abstract

The rapid technical advances and increased usage of hand-held devices throughout the world has

accelerated the acceptance and utilization of advanced array packages, both Ball Grid Arrays (BGAs) and Chip Scale Packages (CSPs). The reason for this is the drive toward small geometry designs that subsequently reduce total system size and weight while incorporating increased functionality. Trends and forecasts indicate the largest sectors of advanced array packages over the next four years will be wirebonded Bismaleimide Triazine (BT) resin laminate and polyimide (PI) Flex Tape array packages. The projected compound annual growth (CAG) of these packages is forecast to be in excess of 30%.

With this increasing demand for advanced packages, as well as total IC market growth, manufacturing capacity constraint is increasing at both original equipment manufacturers (OEMs) and sub-contract package assemblers. Therefore, packaging engineers are being challenged to seek out, investigate, and incorporate "best practices" for advanced processes, both equipment and materials.

In analyzing wirebonded integrated circuit (IC) package assembly operations, die attach (DA) curing, either on a step-cure oven or in a box oven, is the least efficient step in the total manufacturing process. In addition, delays between die placement and die attach cure can exacerbate bleed, as well as allow die shift, and subsequent die misalignment and wirebond failures. It is the purpose of this paper to explore and document productivity enhancements, as well as cost reduction, when an on-bonder cure process is implemented.

In order to accomplish these advanced package-manufacturing results, both equipment (die bonder) and materials (die attach adhesive) must possess unique characteristics and capabilities. ESEC and Dexter Electronic Materials have worked cooperatively to develop an on-bonder die attach curing process for Chip Array Ball Grid Array

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(CABGA) and Tape Ball Grid Array (TBGA) packages that offers improved device quality at reduced manufacturing cost.

## Introduction

The topic of this paper focuses on two distinct, yet synergistic technologies, processing equipment and materials. In most organizations, the individuals responsible for each of these areas, (1) die attach material, and (2) die bonding/curing equipment are independent. Although the die attach adhesive is dispensed and cured with specialized equipment, each has the requirement for technological specialization. That is why two individuals have written this paper, one from the equipment side and one from the materials side.

The paper has been segmented to allow the reader to review only those areas of individual interest. An equipment engineer may not want to review the background history of die attach materials, while the adhesive specialist may bypass details on machine operations. However, regardless of an individual engineer's area of interest, some level of additional information relevant to semiconductor packaging can be obtained. The Sections include Business Background, Die Attach Material, Equipment, and Conclusion.

## Section I – Business Background

### Technology Drivers

As the semiconductor Industry moves into the next millennium, three key drivers are moving technology forward. First, the drive for improved *performance*. This includes faster and more highly integrated devices for increased performance capability, smaller packaging size to fit into smaller form systems, more robust packaging that eliminates baking prior to attachment, and reduction and eventual elimination of hazardous constituents from the finished product.

The second technology driver is *productivity*. The ability to manufacture an increasing number of devices with diminishing resources, which are primarily equipment, labor, and facilities. The objective is to optimize the facilities' capacity capabilities through design. This includes selection of the most efficient equipment as defined by the

throughput, uptime, machine cost, operator cost, maintenance cost, and power usage cost. An additional factor that must be included with the above equation is the floor space utilization of the equipment. Another important component of capacity maximization is yield loss reduction in all areas of production, which will rely on application of best practice models to equipment, materials, and operational procedures.

The third and most significant technology driver for the semiconductor industry is *profitability*. That is, the ability to balance sales and costs through effective management in order to meet the financial objectives of the company. In its simplest form, reducing costs can always increase profitability. Therefore, improved profitability is the result of the effective application of productivity enhancing methods.

As technological innovations and advancements are ultimately the result of market driven forces, it is of value to understand those underlying motivations that instigate new technology. With the primary market drivers of computers, consumer electronics, communications, industrial electronics, and transportation, the semiconductor industry is projecting annual volume growth in excess of 10% through 2003. While a broad variety of plastic small outline (SO) and quad flat pack (QFP) IC package designs will continue to grow during this period, the BGA and CSP package designs are expected to proliferate dramatically through the next five years.

### Market Forecast

The use of BGA devices should grow at a CAGR of over 35% while CSP units will exceed 71% volume growth, combining to represent in excess of 13% of the overall semiconductor package market by 2003.<sup>1</sup> The current challenge for semiconductor packaging facilities is the proliferation of BGA and CSP designs, with no dominant design clearly leading the way. The substrate types for these packages include FR4, BT, and flextape which are interconnected within the package by wire, flip chip, or a direct chip attach (DCA) scheme. However, projections of usage by volume indicate rigid BT will account for approximately 58% and flex tape 28% (total 86%) of the array substrates by 2003. More significant is the interconnection type with wirebond dominating at 78% followed by flip chip at 14% and deposition 8%.<sup>2</sup>

With the continued dominance of wirebonding for the next generation of semiconductor packages commonly called arrays, the use of die attach adhesives will remain an important factor for both component *performance* and assembly *productivity*.

## Section II – Die Attach Materials

### History

A review of past die attach technology will establish a fundamental understanding of the importance of chemistry in the development of the newest generation die attach adhesives that will play an important role in the majority of array type packages.

In the early 1970s the microelectronics industry was looking for alternative materials that would allow attachment of electronic components at temperatures lower than traditional solder and eutectic compounds. The search led in the direction of organic polymers and focused on the 1930s invention, epoxy resin. Epoxy resin is converted from its monomeric state into a “cured” thermoset by the initiation of a cross-linking reaction. The reaction is either a catalytic homopolymerization or a heteropolymerization initiated by co-reaction of the functional epoxide groups with a cure agent. Because the conversion of an epoxy resin into a thermoset solid requires the addition of a reaction initiator, epoxy compounds can be categorized as having a *step-addition* cure.

The early epoxy component attach adhesives utilized aliphatic amines, which although being highly reactive did not completely react with the epoxy resin. The unreacted amine-curing agent then combined with moisture, which hydrolyzed the free Chloride ions (Cl<sup>-</sup>) and created corrosion on the metallic surfaces within the device or package causing catastrophic electrical failures. As early problems slowed the potential implementation of epoxy component attach adhesives in the microelectronics industry, other polymers were evaluated for this purpose.

Due to the low level of hydrolizable Cl<sup>-</sup>, pre-imidized polyimide had a distinct advantage over epoxy adhesives for microelectronic devices that were susceptible to corrosion. This type polyimide adhesive was used for semiconductor die attach beginning in the late 1970s, and in some applications are still

currently being utilized. However, their requirement for a long two-step cure profile (>1 hour) to evolve the high level of solvent they contain reduces productivity. Other typical properties of Polyimide die attach adhesives are high modulus and high temperature processing.

By mid 1980s the difficulties with epoxide systems were being resolved by the use of “cleaner” constituents with the resulting improvement in Chloride levels and subsequent reduction of component or package corrosion. This second generation of microelectronic adhesives was implemented in the production of military hybrids conforming to MIL STD 883C Method 5011 and in plastic dual inline package (PDIP) semiconductors. At the end of the 1980s an ever increasing volume of semiconductors was being placed into plastic packages and silver filled epoxy became the primary die attachment adhesive for the industry. The emphasis became high productivity rates which challenged the epoxy die attach manufacturers to develop better rheology products that would not exhibit stringing or tailing of material during the very high speed dispensing processes.

Throughout the following decade, managers of semiconductor packaging facilities worldwide began viewing productivity improvement as a means of cost reduction and an increasingly important factor for improving profitability and competitiveness. In the early 1990s, as the quality and reliability of epoxy die attach gained stability, interest was expressed about reducing the cure time for the epoxy from the traditional one-hour minimum. The term for this new concept was *snap-cure*, and is generally accepted to mean a cure time of less than one minute in duration.

Although epoxy die attach compounds have provided good overall results for semiconductor die attach during the last twenty years as modifications were attempted to reduce moisture absorption, lower modulus, and accelerate cure reaction time, the results are now falling short of advanced processing requirements. Although epoxy polymerization reactions can potentially be accelerated to a few seconds, the dynamics of die attach rheology have intervened. To assure optimum dispensability with single needle, multi needle, or pattern write technology, die attach adhesives are typically formulated to a viscosity between 6,000 to 10,000 cP

(Brookfield CP51 cone and plate @ 5 rpm) and a thixotropic index (TI) of 3.5 – 6.0 (Brookfield CP51 cone and plate .5 rpm ÷ 5rpm). To meet these criteria, epoxy die attach formulations typically included diluents to lower the viscosity to the target. Although current technology epoxy die attach adhesives utilize diluents that react into the crosslink matrix rather than evolve during cure, they must have sufficient time to react, otherwise voiding occurs.

The solution for overreacting an *epoxy snap-cure* die attach adhesive, and generating voids, is to heat the material in a ramping, or stepped cure operation. This type processing requires the installation of special designed “stepped cure” ovens into the factory as stand alone units. While this process slowly evolved in the semiconductor packaging industry, more advanced solutions were being explored. These solutions required a new perspective on the type of materials, equipment, and processing that could bring revolutionary change to the industry rather than the slow evolutionary paradigm from the past.

### Die Attach Adhesive Curing on Die Bonder

The changes that are currently underway in semiconductor packaging directly address the three *technology drivers* discussed earlier in this paper, *Performance, Productivity, and Profitability*. Cure on bonder describes the process of dispensing die attach adhesive onto the substrate, placing the die, and curing the die attach adhesive in a continuous process self-contained within the die bonder unit; and without the loss of die bonding speed. With this new processing technology, the cure of the die attach material no longer requires ‘stand-alone’ curing equipment that takes clean-room floor space. Also, the process typically does not slow the die bonder units-per-hour (UPH) rate. Therefore, with no floor space consumed by curing equipment and no additional time consumed for curing, the cure process becomes transparent in the assembly operation. One die attach manufacturer has identified this advanced processing as *Skip-Cure®*.

In order to cure on-bonder, without reducing throughput, the die attach material must be capable of completing a significant portion of its cross-linking reaction in  $\leq 10$  seconds and develop a void free bondline. As previously described, epoxies with their step-addition reactions and diluent additives have

been unable to meet this objective. Therefore, alternate polymer chemistries have developed over recent years, including systems containing acrylate and liquid bismaleimide (BMI). These new systems which employ monomers that will co-polymerize are beginning to replace traditional epoxies due to several unique characteristics they possess. Of greatest differentiation with epoxies is the curing mechanism that is free radical initiated rather than the step-addition of epoxy. A free radical chain reaction, once initiated, proceeds at an extremely rapid rate. In Chart 1, a series of time of reaction kinetics curves are presented at temperatures from 110°C to 170°C for a commercial BMI based die attach adhesive.

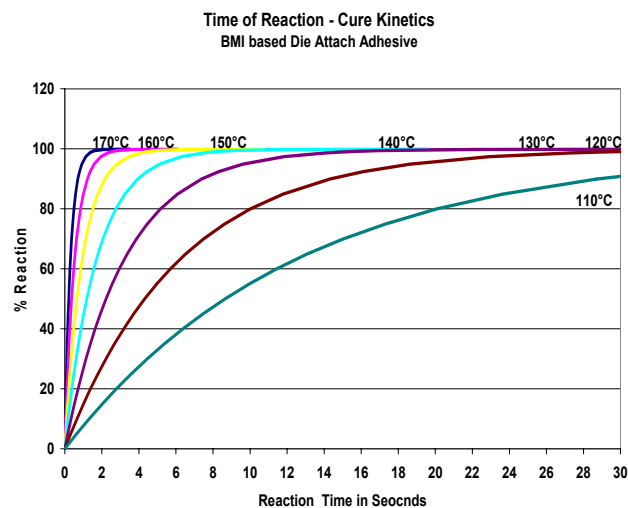


Chart 1

The free radical chain reaction of advanced polymer systems, in which all the chemical constituents co-polymerize, support extremely rapid reactions in which the majority of cured adhesive characteristics are attained in a period of time as short as 5 seconds. These free radical curing systems typically contain “100% solids” which reduces the weight loss during cure to  $<0.2\%$  compared to a commercial epoxy snap-cure die attach adhesive that reports a weight loss of 2.1% during a 60 second cure @ 200°C. Weight loss at cure reflects the weight volume of cure reaction byproducts that are released as a gaseous volume. This can be a factor of consideration when evaluating the percentage of cure following a cross-linking reaction.

Historically, semiconductor packaging engineers have “required” die attach adhesive be 100% cured when emerging from the cure oven. Their concern was to

reduce or eliminate the evolution of outgassed constituents from the die attach adhesive during subsequent processing steps, including wire bonding, molding/encapsulation, and post mold bake. In reality, polymer reactions never achieve 100% polymer chain cross-linking. With the very low level of weight loss during cure from the new systems (<0.2%), any post-cure reaction that may take place during subsequent operations, has nominal impact in processing. Chart 2 is an isothermal DSC of a commercial production L-BMI die attach adhesive. The reaction on-set occurs at 73.4°C with a peak at 84.8°C.

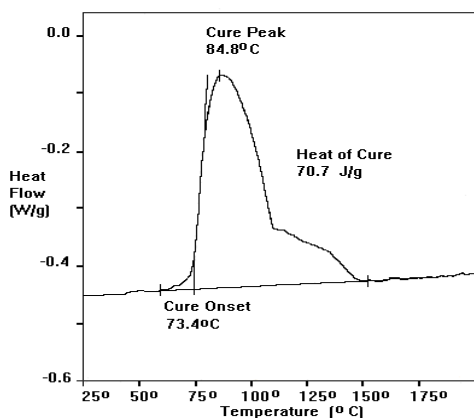


Chart 2

To evaluate completion of reaction after various cure methods, 5mm and 7mm die were placed on BT substrates with a commercial Ag filled BMI material. Three cure schedules were utilized, 12 seconds @ 160°C and 12 seconds @ 175°C on the die bonder, and 15 minutes @ 150°C in a standard box oven. Following these cure profiles, the die were removed and the cured die attach adhesive collected. DSC kinetics were run on each residual sample to determine if the cure kinetics had been completed during the initial cure. Chart 3 (160C @ 12 seconds) is representative of the six scans taken. In review of each result, no additional reaction is present and indicates the reaction was completed during the initial curing process.

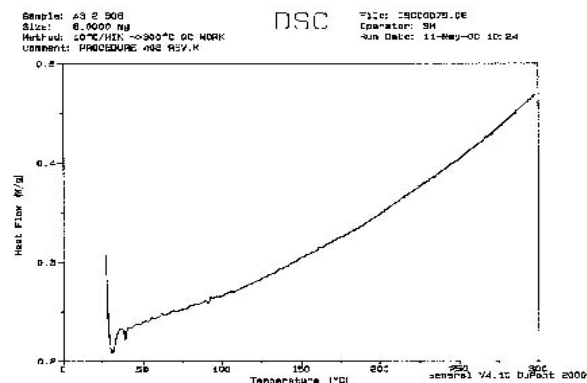


Chart 3

These methods are typical for evaluation of the bulk material properties. An additional area of importance is the interfacial reaction boundary (IRB) and the physical, chemical, and molecular interactions that occur in this critical area. It is typical of free radical initiated die attach materials to demonstrate increased adhesion over time, following initial cure. It is hypothesized that these changes occur as a result of interfacial coupling within the IRB rather than as a result of additional bulk reaction cure.

### BGA Flex Application

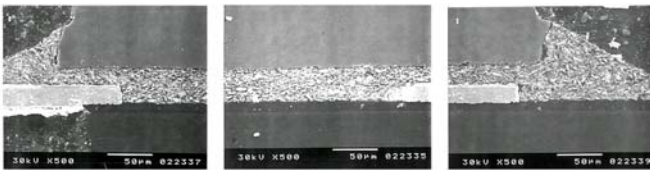
The current growth in BGA flex tape packages can be attributed to both technical and market driven advantages.<sup>3</sup> However, the packaging process of flex tape devices can be challenging due to the thin flexible polyimide tape. This difficulty is exacerbated as the tape thickness narrows to near 50 microns. Die bonding on flex tape is difficult due to the nature of the polyimide and its tendency not to remain flat. To resolve this, Cu rails have been attached to some designs, while bare tape is used in others. However, the die bonding, handling, and transportation of flex tape from the time the die is placed until it is cured can cause bondline shift and die movement resulting in misalignment and die tilt. The delay between placement and cure also allows time for resinous bleed to escape from the die attach materials and contaminate wirebond pads on the substrate. Each of these phenomenon, bond line shift, die movement, and bleed can create the need for additional processing steps such as cleaning, and may also create yield loss.

The cure on bonder is capable of eliminating each of these problems, as well as eliminating the floor space need for cure equipment and cure time.

**Experiment on Flex Polyimide Tape Array**

Parts were assembled on an ESEC 2007 die bonder retrofitted with a cure on bonder heater block assembly and cured at 160°C for 18 seconds. In addition to the heater block on the bonder is the vacuum hold down during die attach dispense, die placement, and die adhesive cure, maintaining the planarity and stability of the polyimide flex tape during all critical die attach functions.

Photo 1 is the bondline of one of twelve devices mounted with Ag filled BMI die attach adhesive on a 79 micron thick polyimide 4 x 4 matrix flex BGA substrate. The die size is 5mm x 5mm x 355 microns and the cross sectional photograph is taken at a magnification of 500X. The die was bisected equally along a centerline and the three sections shown are the left end of the die, the center of the die, and the right end of the die.



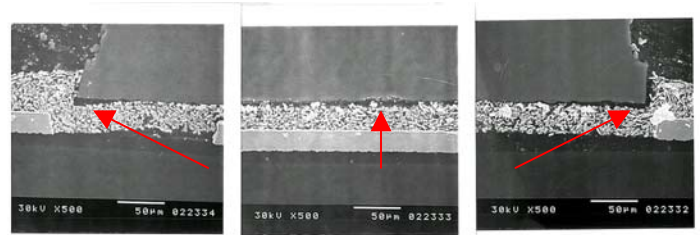
**Photo 1**

The bond line thickness is 21 microns in the center, and 21 at each end. Twelve devices were attached with the results in listed in Chart 4 below.

| <b>SKIP-CURE B</b> |              |               |              |
|--------------------|--------------|---------------|--------------|
| <b>Device</b>      | <b>Left</b>  | <b>Center</b> | <b>Right</b> |
| 1                  | 23           | 23            | 22           |
| 2                  | 21           | 22            | 22           |
| 3                  | 19           | 21            | 22           |
| 4                  | 21           | 21            | 21           |
| 5                  | 20           | 21            | 20           |
| 6                  | 22           | 23            | 23           |
| 7                  | 22           | 23            | 24           |
| 8                  | 22           | 22            | 21           |
| 9                  | 23           | 26            | 25           |
| 10                 | 23           | 23            | 24           |
| 11                 | 20           | 22            | 23           |
| 12                 | 21           | 22            | 22           |
| <b>Average B/L</b> | <b>21.42</b> | <b>22.42</b>  | <b>22.42</b> |
| <b>STD DEV</b>     | <b>1.31</b>  | <b>1.38</b>   | <b>1.44</b>  |

**Chart 4**

Photo 2 is the same substrate and die, with a “leading” high volume Ag filled oven cure epoxy die attach adhesive. The twelve devices were assembled and staged for one hour, followed by an oven cure, with a 30 minute ramp to 150°C and held at 150°C for one hour.



**Photo 2**

The results for these devices in Chart 5 indicate the die attach adhesive has pulled back from the periphery of the die creating an average bondline thickness at the center of the die of 27.42 microns and combined average of both ends of 14.48 microns. Also observable in the photographed cross sections are resin rich areas (red arrows) in which the movement of the die, flex substrate, and die attach adhesive during handling and cure have displaced the Ag filler in the adhesive and allowed the epoxy resin to pool in the voided areas.

| <b>EPOXY A - OVEN</b> |              |               |              |
|-----------------------|--------------|---------------|--------------|
| <b>Device</b>         | <b>Left</b>  | <b>Center</b> | <b>Right</b> |
| 1                     | 14           | 22            | 15           |
| 2                     | 19           | 24            | 12           |
| 3                     | 16           | 23            | 14           |
| 4                     | 20           | 20            | 20           |
| 5                     | 24           | 32            | 24           |
| 6                     | 19           | 31            | 21           |
| 7                     | 19           | 29            | 19           |
| 8                     | 18           | 27            | 21           |
| 9                     | 24           | 29            | 22           |
| 10                    | 17           | 31            | 22           |
| 11                    | 17           | 31            | 21           |
| 12                    | 18           | 30            | 24           |
| <b>Average B/L</b>    | <b>18.75</b> | <b>27.42</b>  | <b>19.58</b> |
| <b>STD DEV</b>        | <b>2.93</b>  | <b>4.12</b>   | <b>3.90</b>  |

**Chart 5**

A third set of devices was assembled with the same substrate and die, using a quick cure Ag filled die attach adhesive. The material was dispensed and devices placed and staged for one hour. They were then oven cured for 15 minutes at 150°C in a pre-heated oven without ramp. The results showed an

increase in die attach adhesive shift during handling and cure. See Photo 3.

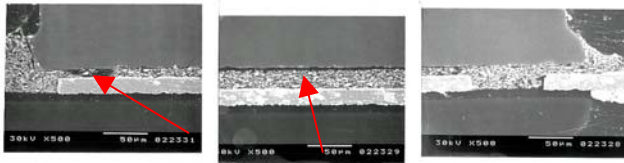


Photo #3

As with the traditional oven cured **Epoxy A**, the quick-cure processing also allowed the polyimide flex to deflect upward around the die edges while maintaining a relatively constant adhesive bond thickness (29.00 microns) in the center of the die. The edges of the flex were pulled upward creating a substantial bow to the bottom of the package. Although wirebonding was not a component of these experiments, it could be anticipated that the deformation in the backside of the flex polyimide tape due to the variation in the bondline thickness could instigate die cracking. This may occur as downward pressure on the perimeter structure of the tape created a levering action across the package due to the fulcrum point under the center of the die. Further experimentation will be necessary to confirm this hypothesis.

A compilation of the results from the three cure modes described above are shown in Chart 6 and include: cure on die bonder with a commercial BMI system, quick 15 minute cure in box oven, and 1 hour cure in box oven with widely used standard epoxy. The die width (5mm) is represented by the x-axis, and the y-axis depicts the maximum average difference ( $\Delta$ ) in bondline thickness between the polyimide tape and the die back from the center to the end of the die.

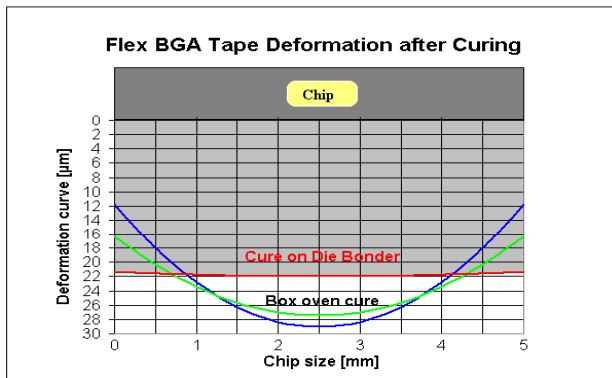


Chart 6

## Experiments on Rigid BT Substrate Array

A series of die attach adhesion tests were performed on four different BT substrate designs (A-D) and 32 5mm x 5mm die per substrate type. Each substrate design was cured at 150°C for 10 seconds on the die bonder. The results indicate a variation in substrate surfaces that translates into adhesion variation up to 35% as shown in Chart 7.

10 Seconds @ 150C on Bonder

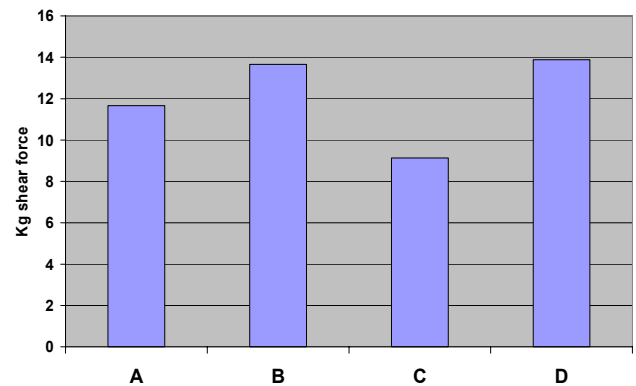


Chart 7

Substrate B was selected for further adhesion testing. Four legs, with 16 die each, were run using a standard commercial Ag filled BMI cured on the die bonder. Each leg was exposed to the heater block on the bonder for approximately 18 seconds. In production, time on heater is reliant on the number of sites in the matrix, in this case 16. The objective was to determine adhesion at two temperatures with two die sizes.

The results at 160°C show the average adhesion strength on a 5mm x 5mm die at 14.97Kg with STD DEV of 1.27 and on a 7mm x 7mm die at 33.38Kg with STD DEV of 4.92. When the cure temperature was increased to 175°C the adhesion on the 5mm x 5mm was 12.73Kg STD DEV 1.77, and on 7mm x 7mm adhesion was 31.06Kg STD DEV 5.22. When these adhesion results are compiled with the results on substrate B in Chart 7 (cure @ 150°C), it indicates the adhesion properties of the material are acquired very quickly at a relatively low temperature.

## Section III - Equipment

### On-Bonder-Cure (OBC) Overview

To achieve the optimum quality level for the adhesive layer, between the chip and substrate, the following points must be considered:

- Stable bond line thickness
- Minimum die tilt
- Regulated fillet with 100 % coverage
- Homogeneous adhesive layer (no voids)
- Precise and regularly dispense volume

To accomplish this it is necessary to use a chip assembly machine that includes a precise adhesive dispense system. But, not only the dispense system should work precisely. There are many more points, to take care about it.

The system needs a special, integrated cure system, which is controlled by exact timing and temperature levels to guarantee a stable and reliable process.

Before explaining the details of the integrated curing system, it is helpful to know more about the advantages. The following points can make the decision to implement such a system easier.

- No bleeding
- Not uncontrolled adhesive flow
- No surface contamination on devices
- No transportation damages
- No chip shifting during waiting time
- Perfect planarity of flexible material
- Controlled curing time for all devices
- Precise bondline thickness
- Minimum of die tilt.
- Minimal thermal stress for device

Because of these quality aspects, the integrated on-bonder-cure becomes very attractive. To run such a process, it is necessary to focus attention on the following points.

The footprint of the die attach machine should not change because of the integrated curing system (cost saving). Therefore, because of the necessity for a fast temperature ramp up, only extremely fast curing

material can be used for this process. The adhesive system has to be designed for this new method.

Beside the previously listed benefits, the new process also opens the door for completely new manufacturing methods. Multi-pass applications are no longer as difficult to process. Using single chip machines instead of the more complicated Multi-chip machines can increase both productivity and throughput. Cost savings overall will be one of the results.

The next few pages will explain in detail what is necessary to implement the process properly. Therefore it is necessary to understand more about the material which has to be processed for the “Skip-Cure processing”.

### Thermal response of substrates

To know how a die attach adhesive material reacts in

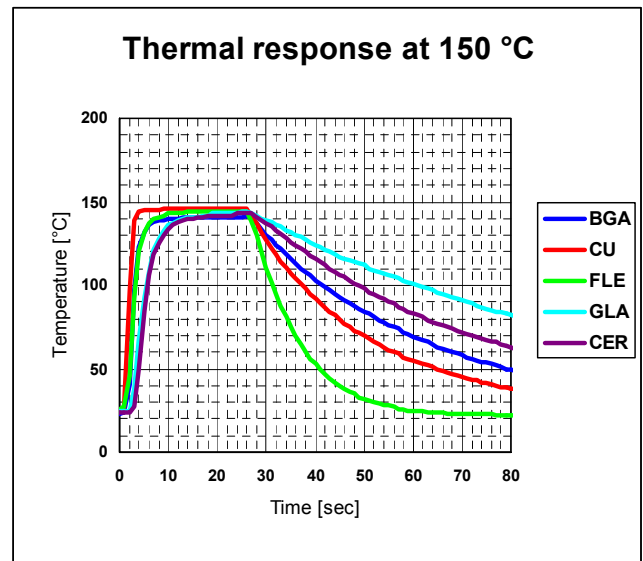


Diagram 1

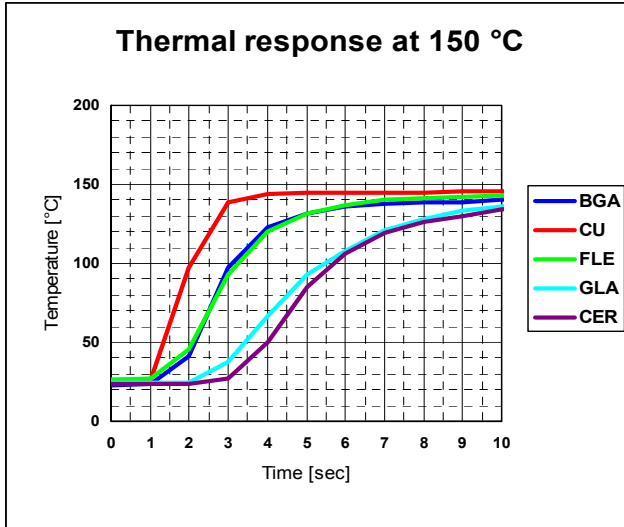
the curing position, it is necessary to know the thermal response of the substrate on which it will be placed. This allows estimation of the percentage of the curing reaction that may take place during the die attach process. Will it cure 100 % or maybe only 40%.

The above Diagram 1 shows in detail the rate at which different substrate materials allow thermal transfer through their mass to the die bond site while on a close contact hot plate at 150°C. The cooling curve

shows the temperature decrease when the substrate is only surrounded by air at room temperature (24.°C).

The next Diagram 2 shows now the stretched heat up profile.

**Diagram 2**



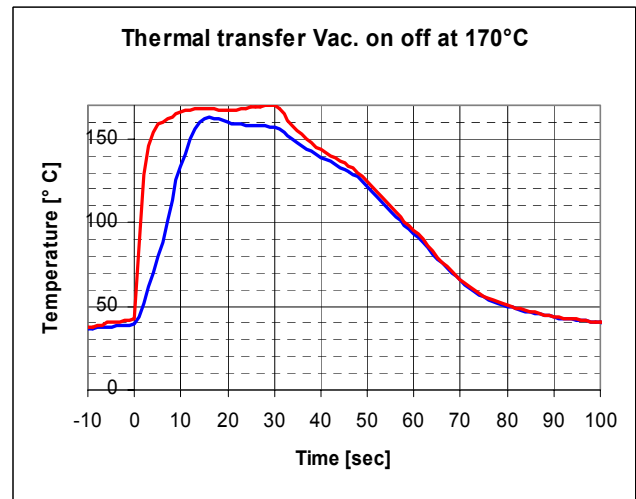
Legend for Diagrams 1 and 2:

- BGA = BGA strip, 0.3mm thickness
- CU = copper 0.21mm
- FLE = Flex or tape BGA 0.11mm
- GLA = glass plate 1.05 mm,
- CER = Ceramic substrate 0.5mm

After only two seconds, the temperature of a copper leadframe has reach 100 °C.

To obtain these temperature profiles it is important to have perfect thermal contact with the oven (heater) surface. Therefore, the vacuum holding system is one of the essential parts for the on-bonder oven design. Based on the bonding layout, the vacuum area has to be designed for this size to guarantee the necessary downhold force for the highest thermal transfer. If possible, the dimension of the vacuum panel should be slightly bigger than the bonding area or exactly the same size of the bond pad to have the most reliable process. If the substrate does not fit exactly the vacuum area, leaking air can cool down the heater plate and damage to the vacuum valves can be possible.

To speed up throughput and have a reliable, stable process it is important to give attention to the above points.

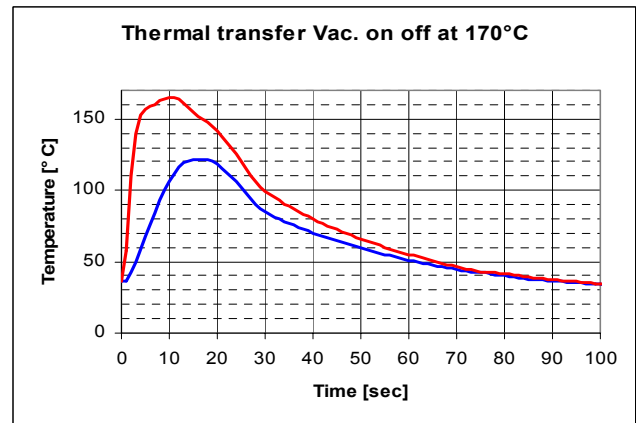


**Diagram 3**

From the Diagram 3 it is possible to see the influence of the downhold vacuum. The blue curve shows the temperature profile of a substrate without any vacuum hold down. This profile can change from substrate to substrate. If the substrate is perfectly flat, it can show a curve nearly like the red profile but it can also be worse than the blue profile.

The above Diagram 3 is the profile of a 16 Chip (4x4) matrix application. But if the matrix is smaller, 2x2 (4 chip), which is shown in Diagram 4, the available curing time will become much shorter.

The next Diagram 4 shows very clearly this new situation.



**Diagram 4**

The blue curve does guarantee a reliable process and the percentage of completed cure reaction varies in a wide range. The thermal contact time between substrate and oven heater plate in Diagram 4 is 11

seconds. The previous Diagram 4 is based on contact time off at 31 seconds. The curing time is primarily governed by the actual process time. The equipment cycle time has some influence on this. But if the actual bonding time is higher than the cycle time, then this will take the first priority for the curing cycle time of a single device or a complete matrix.

In addition to these influences, it is also possible to set the actual curing time as a value for each processed chip.

*Example:*

36 chip matrix

Bonding time: = 90 ms

Cycle time = 700 ms

Aux. Mod.t. = 0 ms

Throughput =  $3600 / 0.7 = 5142$  UPH

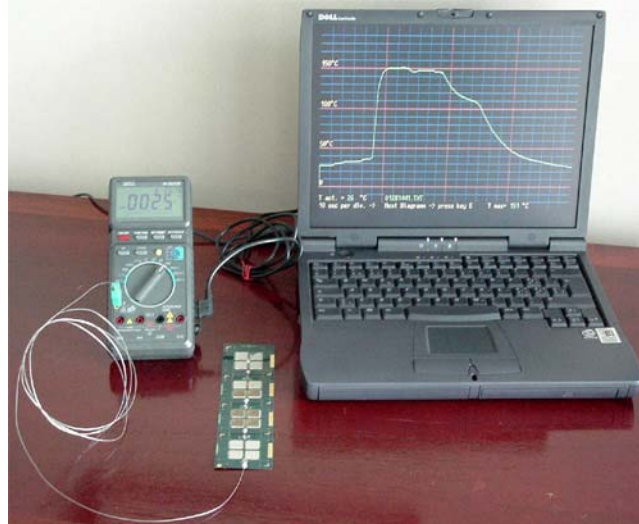
Curing time =  $36 \times 2 \times 0.7 = 50.4$  sec.

The throughput varies dependent on what functions are activated on the die bonder. If full quality checking, optical dispense alignment, etc are activated, the throughput goes down to 3600 to 4000 UPH. Therefore it is important to take the actual profile of an existing application, and to know more about the curing conditions.

### Measuring method to collect the thermal profile

The handling of the measuring equipment should be easy as possible. The best method is to use a personal computer with a digital multi meter that has the capability to communicate through the serial port. These are standard instruments, available for a reasonable price.

The next Photo 4 shows the complete measuring equipment to take thermal profiles on the die bonder heater assembly.



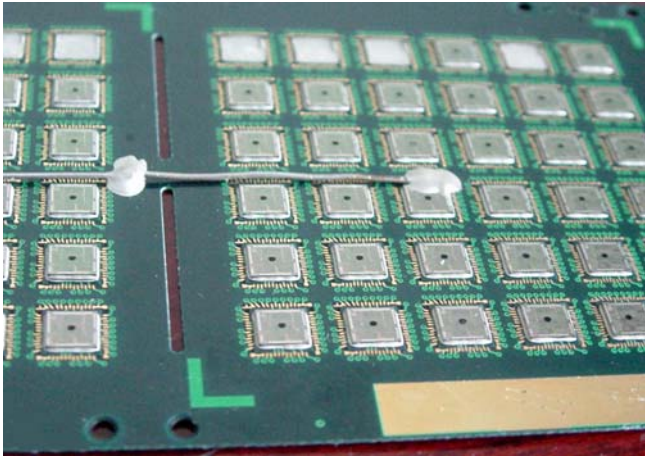
**Photo 4**

Very simple but efficient software allows collecting all the necessary information. When the machine starts, the leadframe with attached thermocouple proceeds into the feed area to begin the measurement cycle and sends the data to the computer. It is important to watch closely that the coax thermocouple cable as it passes through the die bonder so it will not catch on any objects or crash.

After starting, the computer program should create automatically the filename, related to the date and time. The values are stored in a text file in a way that it can be easily loaded back into any spreadsheet calculation program and create the graphic of the profile.

The screen is automatically scaled to the length of the chosen measuring time. All the necessary information is available from the screen (file name, actual temperature etc.).

The thermocouple is attached to the substrate with the Ag filled ultra fast cure adhesive QMI-506. In order to replicate the actual curing process during thermal profiling, a populated substrate is used. This can be observed in Photo 5 below.



**Photo 5**

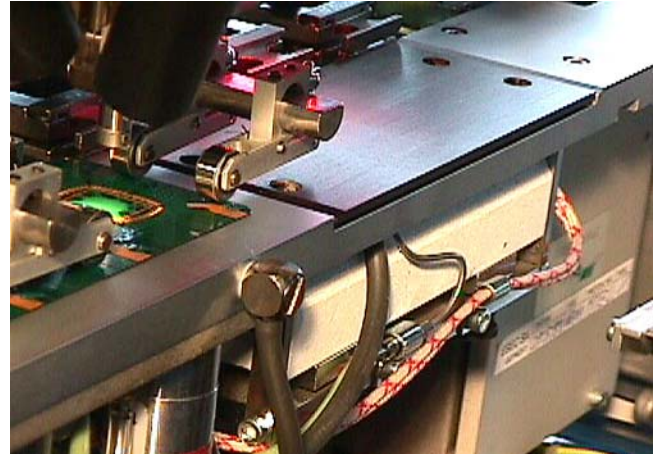
From the text file that is generated it is possible to retrieve more information for further calculations. This is especially the case if registration index timing capability of the software program is utilized to set timing marks, by using the number keys from 0 to 9.

For example, if the epoxy *writing position* has the number 1, then the *bond position* can be No. 4, with the *first curing position* number 5 and the *second curing position* number 6. The software code lines below demonstrate how the information is stored in the text file "05041508.TXT"

```
31,36,"5"
32,58,""
33,110,""
34,140,""
35,153,""
36,157,""
37,159,"6"
38,160,""
39,163,""
40,164,""
41,165,""
42,165,"7"
```

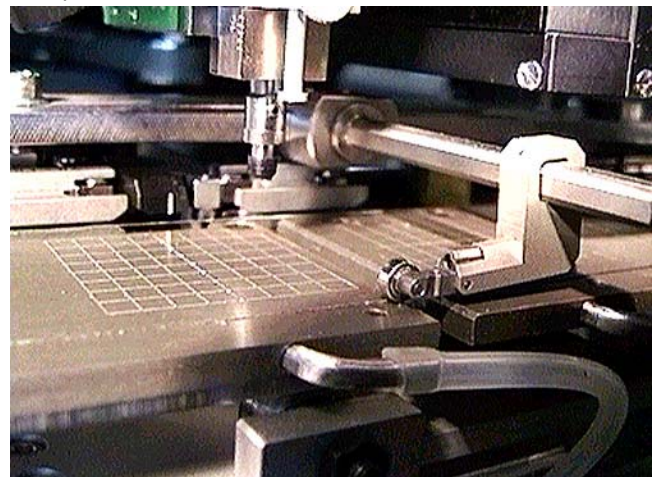
The first value shows the time in seconds, the second value shows the temperature and the third column contains the remark sign. Therefore, it is easy to have the real contact time for entry into the *first curing position* ("5") and exit from the *second curing position* ("7"). In our sample these time are 42 seconds – 31 seconds = 11 seconds curing time.

## On-Bonder Heater System



**Photo 6**

Due to the very sensitive flexible BGA materials the construction has changed from the fix oven heater block (see above Photo 6) station to the movable shuttle oven heater block (see Photo7 below). The primary reason for this change was to minimize any movement of the substrate during the die attach process. The substrate is held in position until the full



**Photo 7**

matrix is completed. During the transportation, the vacuum hold down is momentarily switched off.

Because of the very short transportation time and distance to the curing position after adhesive dispense and die placement, the adhesive on a BGA flex

polyimide substrate remains in place with minimal disturbance.

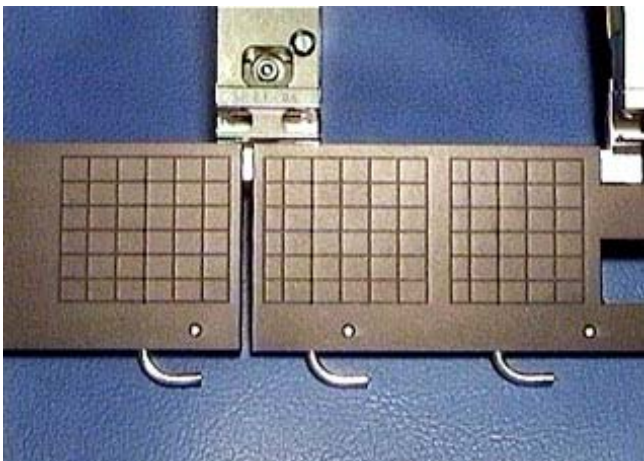
With the on-bonder-cure process, when the substrate with cured die exits the die bonder, storage time in the magazine no longer has an influence on die movement, die tilt, or adhesive resin bleed.



**Photo 8**

This is particularly of advantage with thin polyimide flex film that may be only 50 microns thick and sags in the magazine, as shown in Photo 8.

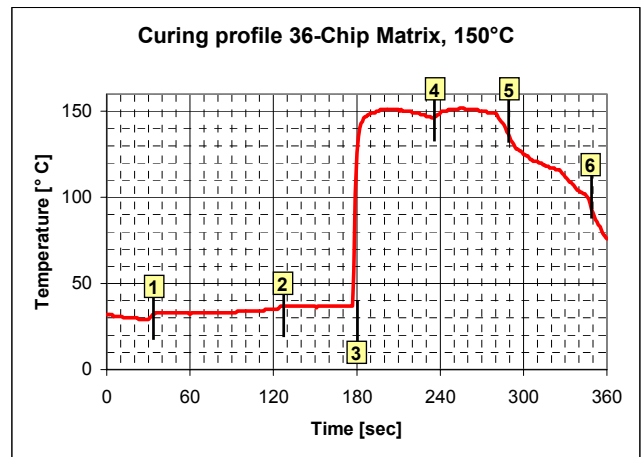
For rigid BGA substrates additional “down-holders” may be recommended to minimize any movement in z-axis during the transport cycle. In the next Photo 9 it is possible to see the shuttle plate with the bond position, curing position one, and cure position two.



**Photo 9**

Between the bonding area and the curing position is a gap that interrupts the thermal flow back into the bond position. This is necessary due to the extreme fast chain reaction die attach materials used in this process, which could initiate curing if the gap were not present.

From the profile in Diagram 5, it is possible to see the influence of this gap between the bonding and the curing zone. No. 1 shows the arrival at the dispensing position. No.2=Bond position. No. 3=curing position 1. No 4=arrival at curing position 2.



**Diagram 5**

### Bondline thickness and Die tilt

Due to immediate curing after the die attach position,

**DIE tilt analyse** Blank BGA strip Adhesive: QMI-536  
Data file: 05031425.TXT 1. Pad (16 units)

CHIPSIZE x 4.000 y 4.000 z 0.731

**Measurements (BLT)**

| No. | E1 μm | E2 μm | E3 μm | E4 μm | TILT μm | BLT μm |
|-----|-------|-------|-------|-------|---------|--------|
| 1   | 28    | 28    | 26    | 25    | 3       | 27     |
| 2   | 32    | 29    | 27    | 29    | 5       | 29     |
| 3   | 29    | 26    | 25    | 27    | 4       | 27     |
| 4   | 31    | 28    | 27    | 30    | 4       | 29     |
| 5   | 32    | 29    | 30    | 31    | 3       | 31     |
| 6   | 31    | 29    | 29    | 31    | 2       | 30     |
| 7   | 32    | 29    | 29    | 31    | 3       | 30     |
| 8   | 29    | 27    | 28    | 29    | 2       | 28     |
| 9   | 28    | 29    | 29    | 29    | 1       | 29     |
| 10  | 32    | 30    | 30    | 31    | 2       | 31     |
| 11  | 30    | 29    | 28    | 30    | 2       | 29     |
| 12  | 31    | 29    | 30    | 30    | 2       | 30     |
| 13  | 31    | 29    | 29    | 31    | 2       | 30     |
| 14  | 29    | 27    | 28    | 30    | 3       | 29     |
| 15  | 31    | 29    | 30    | 31    | 2       | 30     |
| 16  | 27    | 28    | 30    | 29    | 3       | 29     |

AVG 3 29  
STDEV 1.014 1.220

**Diagram 6**

the bondline thickness is more stable and therefore it is much easier to measure and collect the values for setup. An example of this data collection can be seen in Diagram 6.

To take the bondline thickness (BLT) and die tilt measurements, a mechanical micrometer with a stable stand and computer interface was utilized. The values were directly transmitted to the personal computer. From the next Diagram 7 it is possible to see the measuring points.

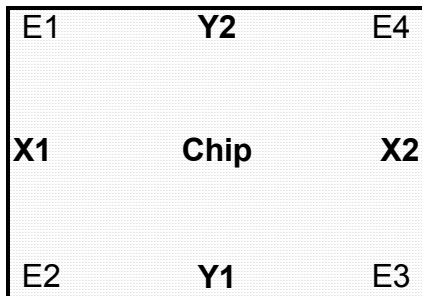


Diagram 7

To prevent any measuring errors the point E4 is also calculated in addition to the collected value, to check that there is no reading mistake. The tilt value is distance between the lowest and the highest chip corner.

**DIE tilt analyse** Cu-LF, PLCC68 LF3, pad 1 & 2  
 Data file: 05051334.TXT 9 units/pad  
 Adhesive: QMI-536

CHIPSIZE x 4.000 y 4.000 z 0.727

**Measureings (BLT)**

| No.          | E1 $\mu\text{m}$ | E2 $\mu\text{m}$ | E3 $\mu\text{m}$ | E4 $\mu\text{m}$ | TILT $\mu\text{m}$ | BLT $\mu\text{m}$ |
|--------------|------------------|------------------|------------------|------------------|--------------------|-------------------|
| 1            | 29               | 26               | 26               | 27               | 3                  | 27                |
| 2            | 30               | 27               | 23               | 26               | 7                  | 27                |
| 3            | 29               | 26               | 24               | 27               | 5                  | 27                |
| 4            | 28               | 26               | 25               | 26               | 3                  | 26                |
| 5            | 28               | 25               | 25               | 27               | 3                  | 26                |
| 6            | 28               | 26               | 25               | 27               | 3                  | 27                |
| 7            | 27               | 27               | 27               | 28               | 1                  | 27                |
| 8            | 28               | 26               | 26               | 28               | 2                  | 27                |
| 9            | 28               | 26               | 27               | 28               | 2                  | 27                |
| 10           | 28               | 28               | 26               | 25               | 3                  | 27                |
| 11           | 30               | 28               | 23               | 26               | 7                  | 27                |
| 12           | 29               | 26               | 24               | 27               | 5                  | 27                |
| 13           | 27               | 27               | 26               | 26               | 1                  | 27                |
| 14           | 27               | 27               | 25               | 26               | 2                  | 26                |
| 15           | 28               | 25               | 25               | 27               | 3                  | 26                |
| 16           | 26               | 26               | 26               | 28               | 2                  | 27                |
| 17           | 27               | 24               | 25               | 27               | 3                  | 26                |
| 18           | 27               | 26               | 26               | 27               | 1                  | 27                |
| <b>AVG</b>   |                  |                  |                  |                  | <b>3</b>           | <b>26.6</b>       |
| <b>STDEV</b> |                  |                  |                  |                  | <b>1.811</b>       | <b>0.382</b>      |

Diagram 8

To obtain excellent results it is necessary to adjust the bond head (leveling). The tilt adjusting is done by the prior calculated correction value for the bond head adjusting screw. To ensure that this result is not a chance, the test was repeated with a metallic leadframe.

**DIE tilt analyse** Cu-LF, PLCC68 LF3, pad 5 & 6  
 Data file: 05051344.TXT 9 units/pad  
 Adhesive: QMI-536

CHIPSIZE x 4.000 y 4.000 z 0.727

**Measureings (BLT)**

| No.          | E1 $\mu\text{m}$ | E2 $\mu\text{m}$ | E3 $\mu\text{m}$ | E4 $\mu\text{m}$ | TILT $\mu\text{m}$ | BLT $\mu\text{m}$ |
|--------------|------------------|------------------|------------------|------------------|--------------------|-------------------|
| 1            | 27               | 25               | 25               | 28               | 3                  | 26                |
| 2            | 29               | 27               | 22               | 24               | 7                  | 26                |
| 3            | 28               | 26               | 23               | 26               | 5                  | 26                |
| 4            | 26               | 26               | 25               | 27               | 2                  | 26                |
| 5            | 27               | 26               | 25               | 26               | 2                  | 26                |
| 6            | 28               | 25               | 24               | 29               | 5                  | 27                |
| 7            | 26               | 25               | 25               | 27               | 2                  | 26                |
| 8            | 25               | 25               | 26               | 27               | 2                  | 26                |
| 9            | 26               | 24               | 26               | 26               | 2                  | 26                |
| 10           | 27               | 27               | 25               | 25               | 2                  | 26                |
| 11           | 29               | 27               | 22               | 24               | 7                  | 26                |
| 12           | 28               | 24               | 22               | 25               | 6                  | 25                |
| 13           | 26               | 25               | 23               | 24               | 3                  | 25                |
| 14           | 26               | 25               | 24               | 25               | 2                  | 25                |
| 15           | 28               | 25               | 23               | 26               | 5                  | 26                |
| 16           | 26               | 25               | 25               | 27               | 2                  | 26                |
| 17           | 28               | 25               | 26               | 28               | 3                  | 27                |
| 18           | 27               | 25               | 25               | 27               | 2                  | 26                |
| <b>AVG</b>   |                  |                  |                  |                  | <b>3</b>           | <b>25.7</b>       |
| <b>STDEV</b> |                  |                  |                  |                  | <b>1.854</b>       | <b>0.564</b>      |

**DIE tilt analyse** Cu-LF, PLCC68 LF3, pad 3 & 4  
 Data file: 05051339.TXT 9 units/pad  
 Adhesive: QMI-536

CHIPSIZE x 4.000 y 4.000 z 0.727

**Measureings (BLT)**

| No.          | E1 $\mu\text{m}$ | E2 $\mu\text{m}$ | E3 $\mu\text{m}$ | E4 $\mu\text{m}$ | TILT $\mu\text{m}$ | BLT $\mu\text{m}$ |
|--------------|------------------|------------------|------------------|------------------|--------------------|-------------------|
| 1            | 28               | 25               | 25               | 27               | 3                  | 26                |
| 2            | 30               | 26               | 22               | 25               | 8                  | 26                |
| 3            | 27               | 25               | 23               | 26               | 4                  | 25                |
| 4            | 26               | 26               | 24               | 26               | 2                  | 26                |
| 5            | 27               | 24               | 23               | 27               | 4                  | 25                |
| 6            | 25               | 26               | 26               | 27               | 2                  | 26                |
| 7            | 26               | 24               | 25               | 27               | 3                  | 26                |
| 8            | 26               | 24               | 26               | 27               | 3                  | 26                |
| 9            | 26               | 25               | 25               | 27               | 2                  | 26                |
| 10           | 25               | 24               | 27               | 29               | 5                  | 26                |
| 11           | 28               | 26               | 21               | 23               | 7                  | 25                |
| 12           | 27               | 23               | 22               | 27               | 5                  | 25                |
| 13           | 28               | 28               | 22               | 24               | 6                  | 26                |
| 14           | 26               | 24               | 24               | 26               | 2                  | 25                |
| 15           | 26               | 24               | 23               | 25               | 3                  | 25                |
| 16           | 25               | 24               | 25               | 26               | 2                  | 25                |
| 17           | 25               | 23               | 25               | 26               | 3                  | 25                |
| 18           | 25               | 23               | 25               | 27               | 4                  | 25                |
| <b>AVG</b>   |                  |                  |                  |                  | <b>4</b>           | <b>25.3</b>       |
| <b>STDEV</b> |                  |                  |                  |                  | <b>1.801</b>       | <b>0.550</b>      |

Diagram 9

From the three data charts above (Diagrams 8 and 9), it is possible to see that achieving good die tilt results are realistic and reliable. Several tests show a similar result about the values. An important influence is also related to the pick up tools. Stable and precise tools are also necessary. The traditional soft rubber pickup tool makes it very difficult to obtain stable, repeatable results.

The following values were used for the tests above:

- Die size = 4 x 4 mm
- Bond force = 80 gr.
- Bond time = 90 ms
- Adhesive volume = 0.086 mm<sup>3</sup>

#### **Section IV - Conclusion**

At present, the liquid BMI and acrylate based die attach systems have gained worldwide acceptance throughout the semiconductor packaging industry with an estimated 45% of the rigid and flex array die attach market in 1999. It is anticipated that within the next year, all four major die attach suppliers will have a broad offering of new materials that are either entirely free radical initiated, or hybridized formulations of epoxy, polyimide, BMI, acrylate, and other unique monomers. The proven JEDEC and EIAJ reliability of these materials is no longer a question or issue. The focus is now on manufacturing process optimization in the semiconductor package factory in order to mine the full capabilities of these advanced technology materials.

Based on the experiments described in this paper the results demonstrate the ability to improve both the quality and manufacturing productivity of advanced semiconductor packages, such as tape and rigid arrays, by the implementation of both advanced free radical curing die attach adhesives and advanced die bonding equipment.

The combination of material and equipment is essential to derive the maximum capabilities and benefits of this advanced packaging model. The authors believe that on-bonder-cure will become the array package processing *benchmark* for the semiconductor packaging industry based on the significant benefits it offers. As the industry continues to be driven by the desire to improve performance, productivity, and profitability, new manufacturing systems will be embraced. Since the on-bonder-cure process addresses all three areas, it is anticipated it will receive wide spread interest and implementation.

#### **References**

<sup>1</sup> Advanced IC Packaging Markets and Trends – Third Edition, Electronic Trend Publications, Inc., San Jose, 1999, p.3-14 & 15

<sup>2</sup> *ibid.* pgs.4-6 & 5-10

<sup>3</sup> Flex tape for BGA applications, Diorio, Mark, Advanced Packaging, May 2000

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