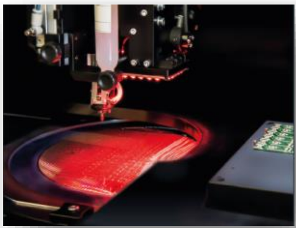
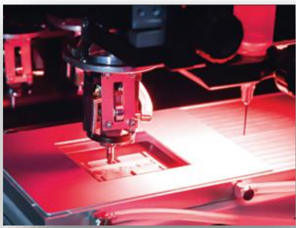
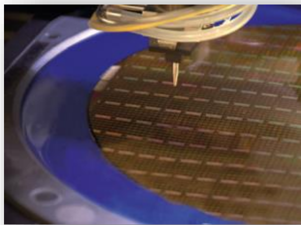
next level bonding solutions






An optimized die bonding setup for thermosonic bonding application

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1. Introduction

Thermosonic bonding (TSB) is a die-to-die bonding method, which combines the novel thermocompression bonding together with ultrasonic (US) welding during the bonding process and, thus, utilizes the best quality of each for use in microelectronics bonding applications. Originally, TSB was mainly used in the wire bonding technology [1]. The introduction of US enhances the bonding process by reducing the applied bonding pressure and temperature that are very attractive in semiconductor fabrication.

Flip-chip bonding is a solderless die-to-die bonding technology for area-array connections (Figure 1). The approach is applied to join an array of gold bumps at the bottom of an ICs (Figure 2), onto gold-plated pads on a substrate. It is a simple, clean, and dry assembly process using, generally, the thermo-compression bonding method [2]. The pure thermo-compression bonding typically requires interfacial temperatures of the order of >300°C [2,3]. This temperature can damage packaging materials, laminates and some sensitive microchips [4]. This next level bonding solution is very advantageous in the flip-chip bonding because the interface temperature and the bonding force, typically, can be much lower; between 100 and 160°C and 20 and 50g/ bump, respectively [2].

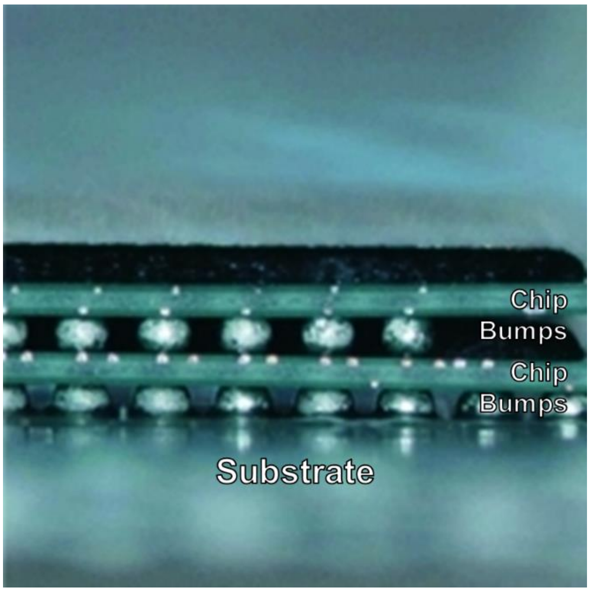

Figure 1: A semiconductor fabrication using the flip-chip die bonding to stack the chips on each other

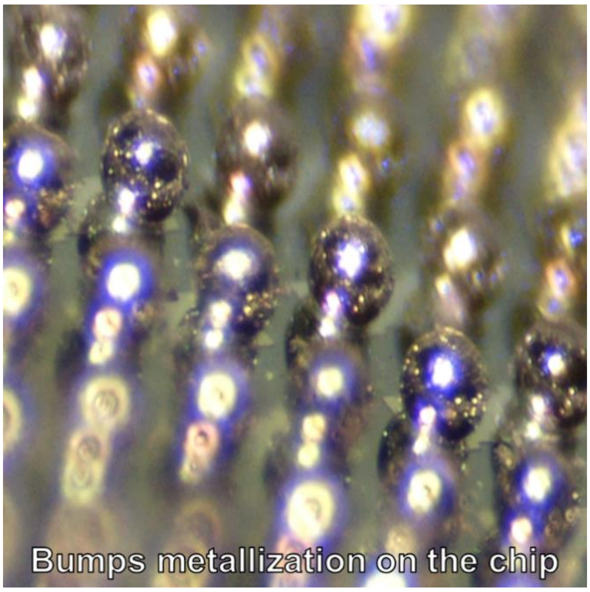

Figure 2: Au stud bumps metallized on the chip's surface

2. Thermosonic bonding Process

The TSB process begins with the substrate sitting on a heated stage, held in position by vacuum. The chip is held by a vacuum pickup tool (Figure 3), which must be designed and suitable for the TSB application, *i.e.*, Die Collet. After aligning the chip to the substrate by TRESKY Pattern Recognition System, the chip with Au stud bumps is brought into contact with the substrate. Once the required bonding force is reached, US power is applied for a predetermined length of time to complete the process. The US parameters, *i.e.*, power, time, and delay time are adjustable in the TRESKY software (Figure 4).

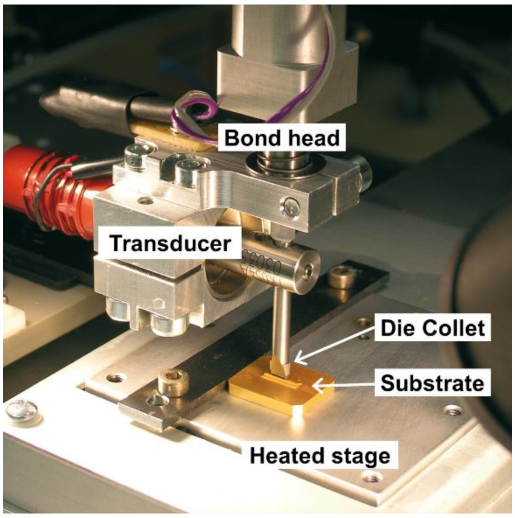

Figure 3: TSB process setup in a TRESKY Die Bonder machine

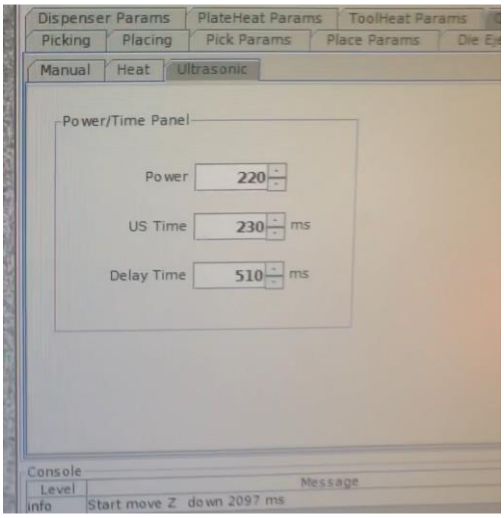

Figure 4: The TRESKY Die Bonder software shows the adjustable US parameters

Co-planarity and parallelism of Die Collet with respect to the substrate is a very important parameter to achieve a good bonding result. Misalignment can produce uneven force distribution which creates an established joint on side A but an insufficient connection on side B (Figure 5). TRESKY´s Vertical Technology guarantees stable and accurate co-planarity and parallelism over the whole Z-axis stroke. In combination with the force control, an excellent bonding result is achieved on every height (Figure 6).

Typical TSB parameters:

Heated stage (substrate): 100°C to 160°C
Ultrasonic power: 100 to 200mW/ bump
Bond force: 20 to 50g/ bump

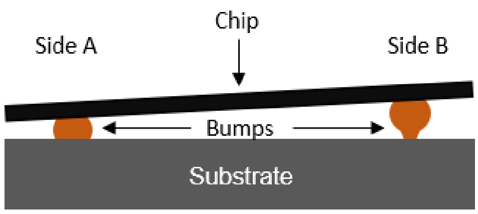

Figure 5: Insufficient connection due to the misalignment

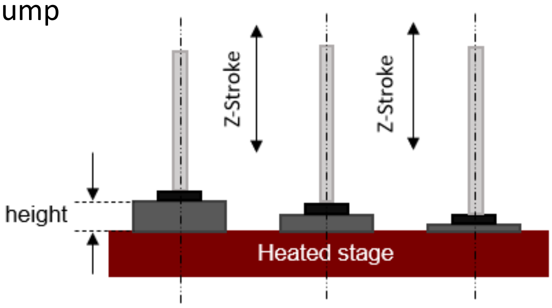

Figure 6: Stable and accurate co-planarity and parallelism over the whole Z-axis stroke of TRESKY Vertical Technology

3. Influence of bond paramaters to the process

Force, time, temperature, US power, and US time are parameters that have a great influence on the TSB process and can be programmed individually on TRESKY systems. Generally, higher setting than the optimized parameters leads to more collapsed bump area and higher strength of the connection. However, when increasing these parameters, it is important to recognize the risk of an electric short circuit between adjacent bumps as well as possible breakage of the chip (Figure 7-9).

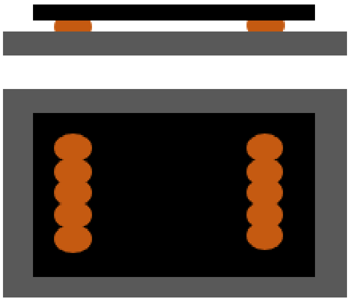

Figure 7: Parameters too high – short between bumps

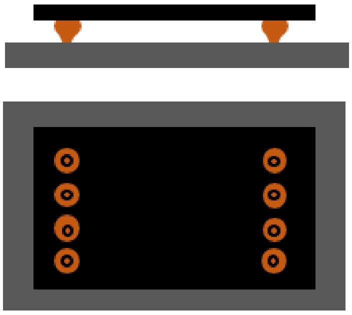

Figure 8: Parameters too low – insufficient connection

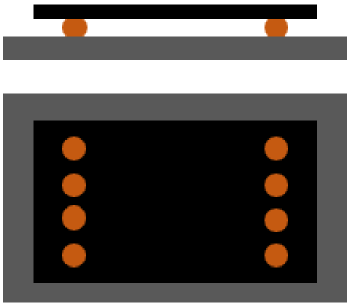

Figure 9: Parameters optimized – good connection

4. Die-Collets

4.1. Types

The Inverted Pyramid (IP) Die Collet is suitable for most applications and should be chosen if there are no special requirements. The Channel Type (CH) Die Collet is useful where tool access is limited or when two sides of the chip are used for alignment. The chip is retained against only two Die Collet's side walls, where the length of the wall is shorter than the chip. Both Die Collet types are shown in Figure 10 and 11.

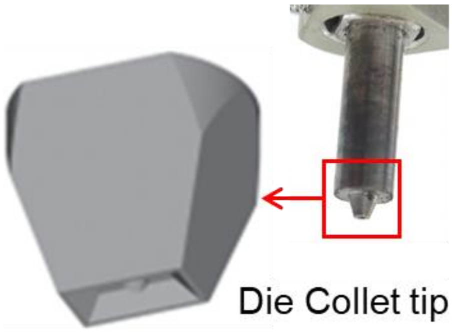

Figure 10: Inverted pyramid (IP) Die Collet

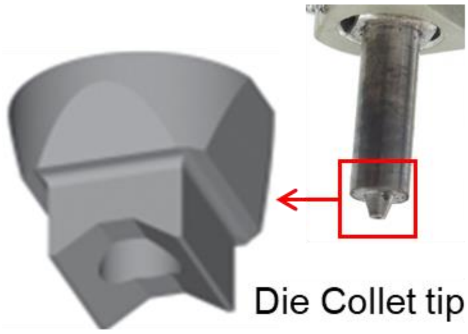

Figure 11: Channel type (CH) Die Collet

4.2. Internal pyramidal angle Φ

When looking at the force distribution generated within the chip by Die Collet, as, *e.g.*, at the moment of chip placement, one may distinguish the case between an IP angle of 90° and an CH angle of 110°.

With 90° angle (Figure 12), the longitudinal and vertical forces have the same amplitude but the force distribution in the bulk is completely different. Longitudinal forces are acting on a quite thin superficial material layer while the vertical forces have their counter-reaction forces applied on the bottom side of the chip with a theoretical force gradient toward the axes of symmetry.
With an angle higher than 90° (Figure 13), the amplitude of the vertical force component becomes predominant rather than the longitudinal component. Choosing an angle of 110°or

120° is recommended for reducing chip break, especially if the chip, which will be bonded, has length more than 2,00 mm. However, even if the break occurs, a higher angle than 90° will help push the die along the die sides rather than over the die surface.

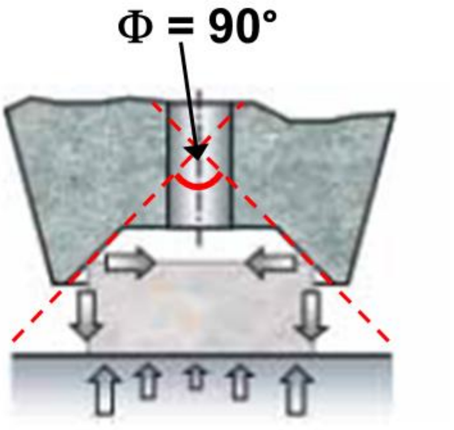

Figure 12: The longitudinal and vertical forces have the same amplitude at Φ of 90°

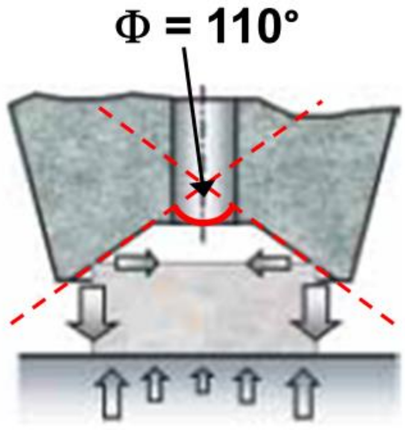

Figure 13: The vertical force is predominant to the longitudinal force at Φ of 110°

4.3. Compatibility

The cycled Die Collet movement during US process, a sensitive chip's surface, and heat transfer are at least 3 factors showing a Die Collet is compatible for TSB. As the US power is applied during TSB, the transducer vibrates, so that the Die Collet will move in X and Y directions for a few microns distance and in a very short time (Figure 14). This movement is cycled in the kilohertz frequency range. Because the Die Collet grips the chip along the chip's edges, the chip will follow the Die Collet vibration, which occurs within a 10 thousand times below than 1 second and at the same time it is pressed by the bond head with a given bond pressure. Further, this grip is also advantageous because there will be no mechanical contact on the chip's surface that will not damage the structures (Figure 15). Moreover, there will be only very small contact area between the chip and the Die Collet (along the chip's edges) that a very low heat will be transferred into the Die Collet, in other words, most of the heat of the bond temperature from the heated stage will be accumulated between the chip and the substrate, thus, the thermal energy will be dissipated within the bumps and the pads on the substrate.

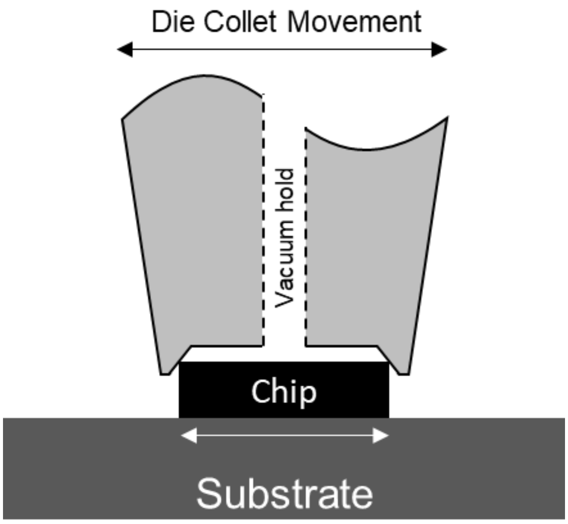

Figure 14: Allow the ultrasonic action

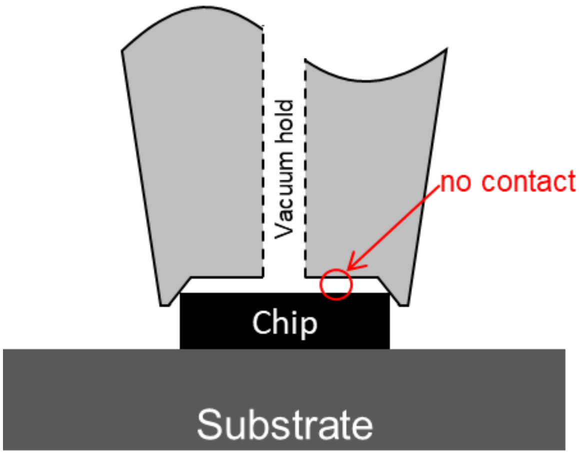

Figure 15: No physical contact with sensitive chip surface allowed

5. Conclusion/Summary

Thermosonic bonding is one of the next level bonding solutions offered by TRESKY that applies US power and Die Collet to establish an excellent joint between a chip and a substrate. This solution is very interesting for semiconductor fabrication because TSB works at low bonding temperature and pressure. In the same time, the TRESKY pick & place systems also offers an excellent co-planarity and parallelism along the Z-axis stroke to ensure the straightness of the thermosonic-bonded chip.

About TRESKY

For over 40 years, TRESKY has been perfecting the art of creating and pick & place systems. As a solutions provider, TRESKY supports a wide range of applications with our highly accurate and innovative systems. This is made possible by TRESKY´s extensive experience and modular setup which allows adapting various basic systems with countless options for new processes. With more than one thousand devices installed across the world, often with special & customized equipment, TRESKY diligently works to fulfill complex process requirements. As the TRESKY´s motto is *Next Level Bonding Solutions*, TRESKY always offers a unique and attractive die bonding method that can give a breakthrough solution to the customers for now and the future.

For more information visit www.tresky.de/en

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