Control Concept for an Ultra-Fast Assembly Technology for Electronic Components

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Abstract

A new, ultra-fast assembly technology for electronic components is being researched and developed to increase the assembly rate of a die bonder. The increment of the assembly rate originates from a continuous movement of wafer and substrate instead of the state of the art Stop-and-Go-Motion. It bases on a laser technique for contactless transfer of the bare-chips on a substrate.

The die assembly process is supported by a complex control to reach the research project goals. This paper presents the control concept and the different needed control groups with multiple feedbacks to increase the positioning accuracy.

1 INTRODUCTION

The profitability of a die bonder in the field of bare-chip placement is measured by a combination of various things, such as: Mean Time Between Assists (MTBA), Mean Time Between Failures (MTBF), Mean Time To Assemble (MTTA), Mean Time To Repair (MTTR), availability of the process, energy consumption, assembly rate of the bare-chip and the die size. This paper focusses the assembly rate and die size. According to manufacturers, current die bonders achieve a maximum assembly rate of 20,000 units per hour (UPH) with a die edge length of 150 µm using a pick-and-place process. With the current state of the art technology components with edge length under 150 µm can be manufactured, however with decreasing component edge length the handling-difficulty of the chips increases. With an assembly technology for smaller chips at a sufficient assembly rate a new, wider and more profitable area of application for bare-chips will become possible. Therefore the handling of small dies is of significant importance.

In the research project "ULTRABEST", funded by the Federal Ministry of Education and Research (BMBF), a multi-purpose, ultra-fast and self-controlling assembly unit for bare-chip bonding is being developed. It will be usable for different applications and products in complex production facilities, where the requirements of control systems of the Industry 4.0 are taken into account. The intended goal of the research project is to place and bond different bare-chips with component edge lengths between 30 and 150 µm for various tasks with an accuracy of $c_p = \pm 10$ µm and $c_{pK} \geq 1.33 = 4\sigma$ and an assembly rate of 100,000 UPH which will revolutionize the current process.

In order to realize this, new methods will be developed and integrated into the assembly process. Including a laser-based mounting head for a contactless transfer of the electrical components to allow a consistent movement during the detachment process and a quicker release time. Furthermore, lateral camera sensors are included in the control process to measure the component placement position in real time and to optimize the assembly process continuously. This and the aforementioned method are displayed in the course of this paper as well as the major challenges in terms of the control technology.

Overall, multiple project partners, coming from industry and research, work on different parts of the “ULTRABEST” project. The Institute of Transport and Automation Technology of the Gottfried Wilhelm Leibniz University of Hannover (ITA) is responsible for the control technology and the monitoring of the entire system. At the ITA the controls for the individual positioning devices are developed, the motor controls are optimized and the necessary interfaces of the individual components are defined.

2 STATE OF THE ART OF THE DIRECT ASSEMBLY TECHNOLOGY

The process of bonding can be subdivided into three working steps: pre-bonding, pick and place and final bonding. At this time it is assumed that the dicing has already happened and the swap of wafer and substrate has no influence on the die bonding process [1, 2].

In the pre-bonding step a suitable conductive adhesive paste or fluid is applied to the substrate, in order to enable a mechanical fixation and creating an electrical contact [3, 4].

In the pick and place step, using the direct place method, the electronic components such as LEDs and semiconductors are detached directly from the wafer with a die-ejector and placed on a substrate. For this purpose the wafer is clamped into a wafer-table and positioned with stepwise X-Y movement under the fixed die-ejector. The deposition location for the die on the substrate is positioned equivalently in the vertical working space below the die-ejector. A camera system checks the positioning to increase the deposition accuracy. The die-ejector then releases the respective component from the wafer and places it at the selected location. During the pick and place phase, the mounting head, wafer and substrate are standing still. This leads to a Stop-and-Go-Motion. With decreasing dimensions the dies are prone to be damaged by the die-ejector during the peel-off process [5, 6].

In the final bonding step, the placed chip is fixed. The adhesive medium is cured depending on its mechanical properties and locks the die in place. At the same time the electrical contact is created [1, 7].

3 NEW APPROACH TO THE DIRECT ASSEMBLY TECHNOLOGY

As mentioned in the introduction the profitability of a die bonder depends on the bare-chip dimensions and the maximum assembly rate. The state of the art shall be improved with an alternative, new assembly technology. This assembly technology mainly tackles the pick and place phase of the bonding process.

In order to improve the handling of very small chips, a contactless transfer using a laser-based placement technology for the electronic components is being realized. In comparison to the classical peel-off using a die-ejector no mechanical force is used to peel of the dies but physical effects like heat. Smaller dies can be peeled off by using a focus on the laser beam rather than using a die-ejector. This also reduces the time to pick a die compared to the state of the art. Since the pick time is reduced a consistent movement of wafer and substrate will be used instead of the “Stop and Go Motion” to further increase the assembly rate by a total desired factor of five.

This concept is visualized in Figure 1 and focuses on the positioning of the dies, neglecting up- and downstream processes such as wafer swapping and substrate changes, although these have an impact on the control concept. As shown in Figure 1, the control concept divides into three parts: the placement head, the wafer and the substrate.

The mounting head releases the components from the wafer when they are in the correct position and orientation over the deposition-point on the substrate. A lens focuses the laser beam to fit the dimensions of the die, which also enables the transfer of smaller die sizes. Each die is located on a wafer, which has to be positioned in the horizontal plane. The wafer can be oriented around the vertical axis to compensate a possible rotation error of the wafer after a wafer change.

The positioning of the substrate happens in the horizontal plane by two linear axis. Two cameras check the lateral positioning while Camera 1 observes the deposition point before placing a die and Camera 2 observes the deviation of the placed die from the deposition point. Both cameras process the image in real time and provide the offsets for the control system.

Due to technical circumstances the placement head is selected fixed in its position. In order to achieve the desired target of 100,000 UPH, which leads to an average process time of 27 ms per die, the wafer and substrate are moved continuously. In the placement process a deposition accuracy of $c_p = \pm 10$ µm and $c_{pK} \geq 1.33 = 4\sigma$ is intended. During the component transfer, a synchronized wafer and substrate movement is required since the die is in free fall during the transfer. This results in a two-

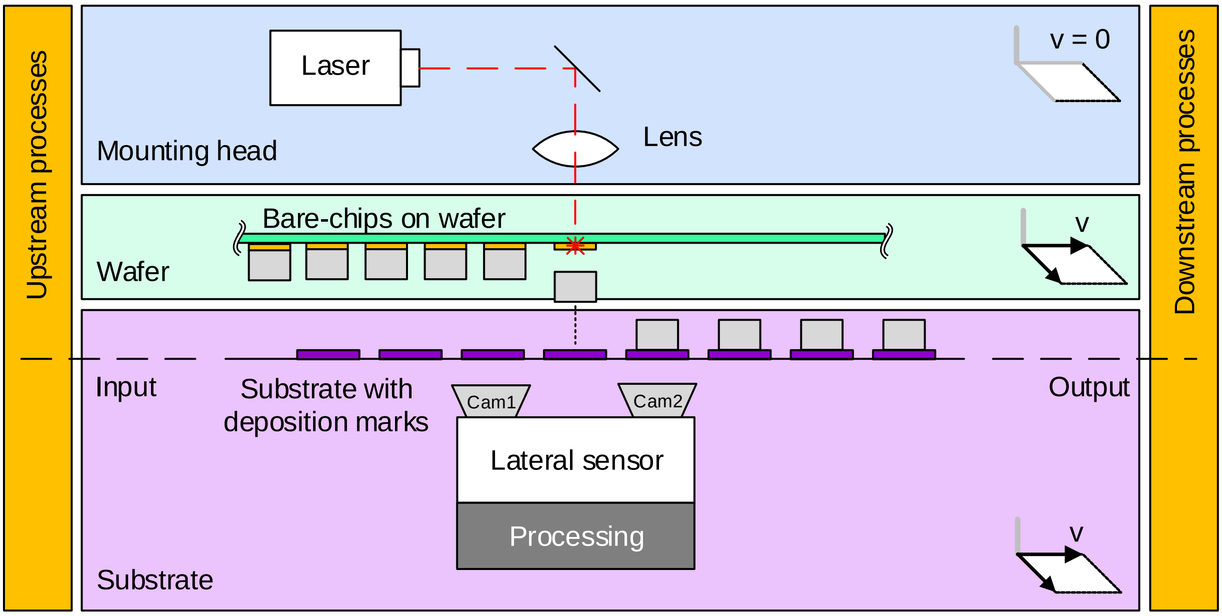

Figure 1: Concept drawing of the assembly unit with positioning directions

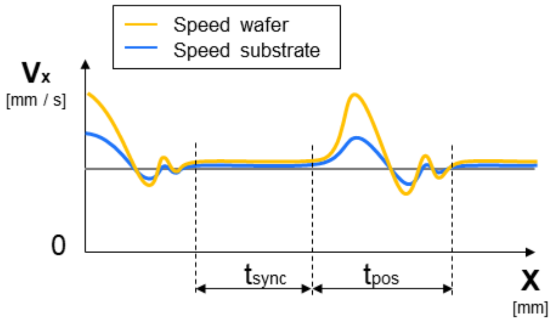

Figure 2: Schematic representation of the motion profile during component placement

part motion profile, as shown in Figure 2, consisting of a positioning phase with different speeds in t_{pos} and a synchronous phase with the same speed in t_{sync}. The positioning systems are always in motion.

4 CONTROL CONCEPT OF THE APPROACH

The process specifications lead to a very high requirement profile on the control, which plays a central role in the development of the new direct assembly technology. The previously presented concept is further detailed in Figure 3 and shows the individual, required control groups for the project. The integration into an existing process chain is intended to produce various products through the most self-sufficient subcomponents.

The control concept can be subdivided into three hierarchical control levels, which differ in function and tasks and are defined by this. The outermost control system is for the integration into a process chain and connects the placement machine with the up- and downstream processes, such as pre-bonding and final bonding. It also exchanges process-specific data via standardized interfaces. In this control level, the wafer and substrate swap is performed. In the next control level, the position of wafer and substrate are specified and coordinated by target position. The sensor data of the lateral real time measurement is sent to the controller and are integrated into its control loop. When the wafer and substrate are in position, a trigger signal is

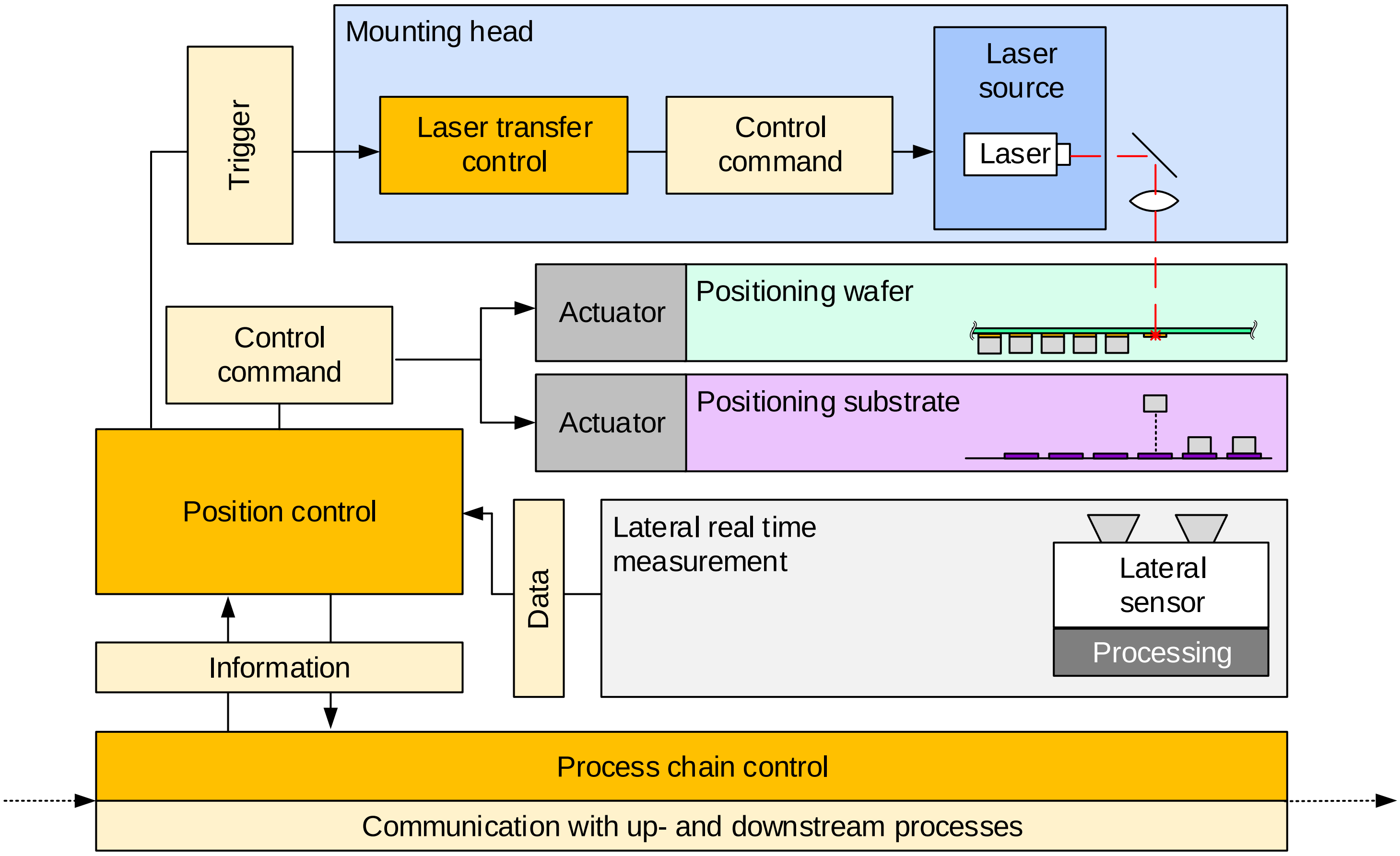

Figure 3: Extension of the concept drawing with the control groups

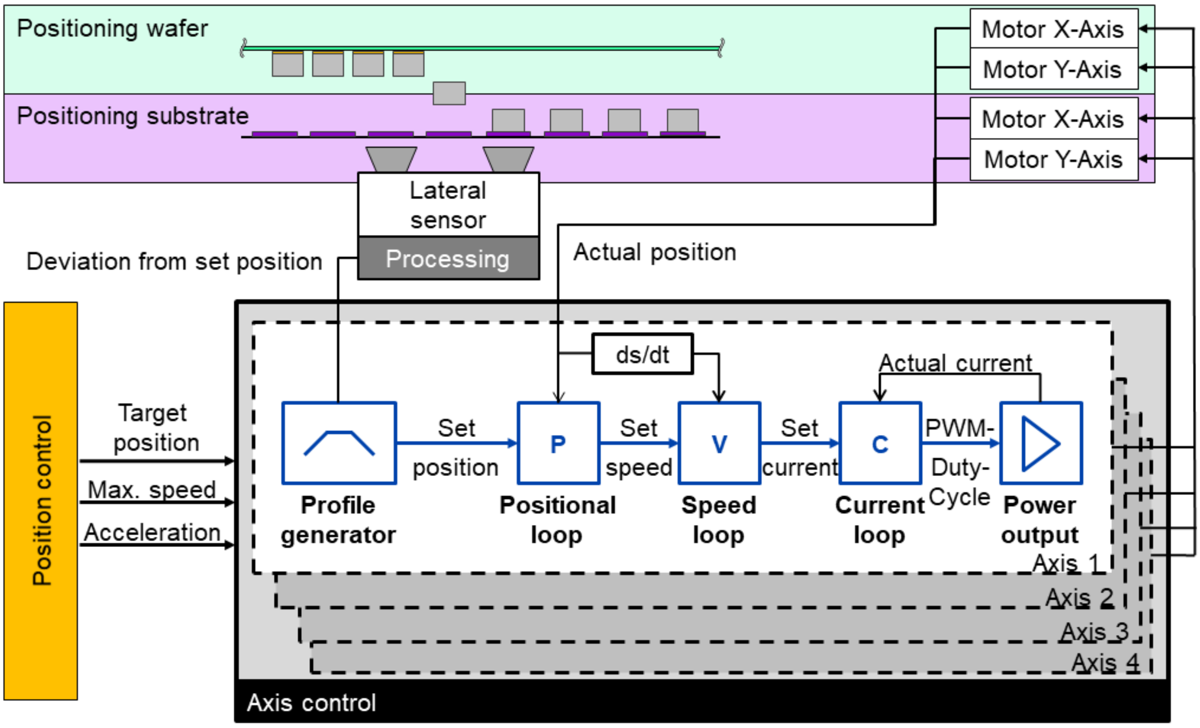

Figure 4: Control concept with two feedbacks to increase positioning accuracy

sent to the third control level: the laser transfer control. In this, the component release process is initiated and processed. Control commands are sent to the laser source to detach the die from the wafer. The transfer process is detected by a vertical sensor and its real-time image processing is fed back into this control loop.

The lateral real-time measurement is intended to increase the positioning accuracy, with the measured data being included in the control loop of the controller. In detail, the control concept for the control of the positioning is visualized in Figure 4, in which the control specifies the target position, the maximum speed and the acceleration of the respective axes.

First, the lateral sensor detects the deviation of the actual position of the component on the substrate. Depending on the offset, a motion profile is generated which specifies the target position of the motor for the next deposit. The actual position of the motor and its speed is fed back into the control loop and thereby adapts the target position. The last part of the regulation relates the set current and actual current of the motor and, with the power output stage, specifies the actual movement of the positioning device.

5 CONCLUSION

In this presented project a new, ultra-fast assembly technology for electronic components to increase the assembly rate of a die bonder is investigated. In order to realize this a continuous movement of wafer and substrate will be used.

Another advantage of this approach compared to the state of the art is the possibility to focus the laser beam using a lens. Smaller dies can be detached compared to using a die-ejector.

The assembly process is supported by a complex control containing a process chain control, a position control and a laser transfer control. Each control level has an influence on the assembly rate of the die bonder. The most important part is the synchronization of wafer and substrate to guarantee a coordinated placement of the die. The current position and the current speed of wafer and substrate have to be aligned.

The next steps in this project are to define all needed interfaces and protocols for the data exchanges. With a first focus on solving the feedback problem of the computing of the lateral real time measurement loop.

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