Development of a Process for Stacking Planar Functional Materials with µm-overlay Accuracy

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Abstract

To assemble multilayered systems with a high overlay accuracy using a stacking procedure, an assembly- and alignment process was developed, which guarantees the conservation of the alignment status of the layers that get covered afterwards by subsequently assembled parts.

This paper describes the basic principle of the stacking procedure and the necessary process steps. The required tools for handling and positioning will be discussed with respect to their precision requirements to reach µm-overlay accuracy. Functional requirements to the assembly devices, like actuators, grippers and the imaging system will be discussed. The achieved alignment accuracies, depending on the assembly tasks and the components, will be given by illustrating the assembly of ceramic multilayers and PCBs (Printed Circuit Boards).

1 Motivation and assembly task

Many technical applications require a stacking of several functional layers to build complex systems. By stacking up to 15 layers of LTCC (Low Temperature Co Fired Ceramics) foils, electronic PCBs with a great variety of electrical layers and passive components can be manufactured. Micro-fluidic and micro-optical structures can also be integrated into the LTCC layers. By reasons of decreasing the structure geometries down to 10 µm, e.g. for micro-fluidic structures, the overlay accuracy of the layers during the stacking process has to be improved, from about 50 µm to 100 µm for standard manufacturing processes, to better than 10 µm. During the alignment of silicon structured MOEMS (Micro-Optical, Electrical- and Mechanical Systems), complex devices for optical applications, e.g. beam forming devices for electron beam lithography, can be built.

2 Description of the stacking process

The basic process step of the alignment process is the detection of the position of the first layer of the stack with respect to the coordinate system of the assembly device by detecting alignment structures. If the first layer is fixed to the assembly device, the next layers of the stack can be aligned with respect to the first layer position. The complete stacking process can be described as follows:

1. Inserting of the first layer into the assembly device
2. Fixation of the first layer onto the assembly device
3. Determination of the position of the first layer
4. Feeding of the next layer to the assembly device
5. Determination of the position of the fed layer
6. Alignment of the fed layer to the position of the first layer
7. Fixation of the second (n+1) layer to the first layer (layer stack)

3 Applications

3.1 Stacking of LTCC layers

The stacking process was used to improve the manufacturing overlay accuracy of LTCC based PCBs. In this task green LTCC tapes were used. The "ceramic green tapes" are very sensitive to mechanical stress during the handling process. As a result, special vacuum grippers were developed and used for feeding and fixation. The vacuum grippers are made of a porous ceramic (see figure 1). Clear apertures, arranged into the upper vacuum gripper, allows the detection of alignments structures of the gripped LTCC layers. Stamped holes and functional micro-fluidic structures on the green tapes were used as alignment structures. These structures are detected by two microscopes with a magnification factor of up to 20. The positions of the fixed tapes with respect to the assembly device are detected by an image processing. The position of the first layer is recorded by the control software. All other LTCC layers of the stack are aligned to the initial position of the first layer.

To reach a stacking accuracy of less than 5 micron, a very precise handling system is necessary. The bidirectional position repeatability of the used feeding linear stages was measured to less than 1 micron. A second important factor to reach the stacking accuracy is to keep the aligned layer position during the handover process, if the aligned layer is placed on the stack. By the alignment of the upper and lower gripper of the stacking device with an accuracy of less than 0.5 mrad in tip (Rx) and tilt (Ry), a handover accuracy of less than 2 micron was reached. The fixation of the aligned layer to the stack was done by gluing or using fixation liquids.

As a result, overlay accuracies of better than 5 µm for up to 15 LTCC layer assemblies were reached using the stacking procedure.

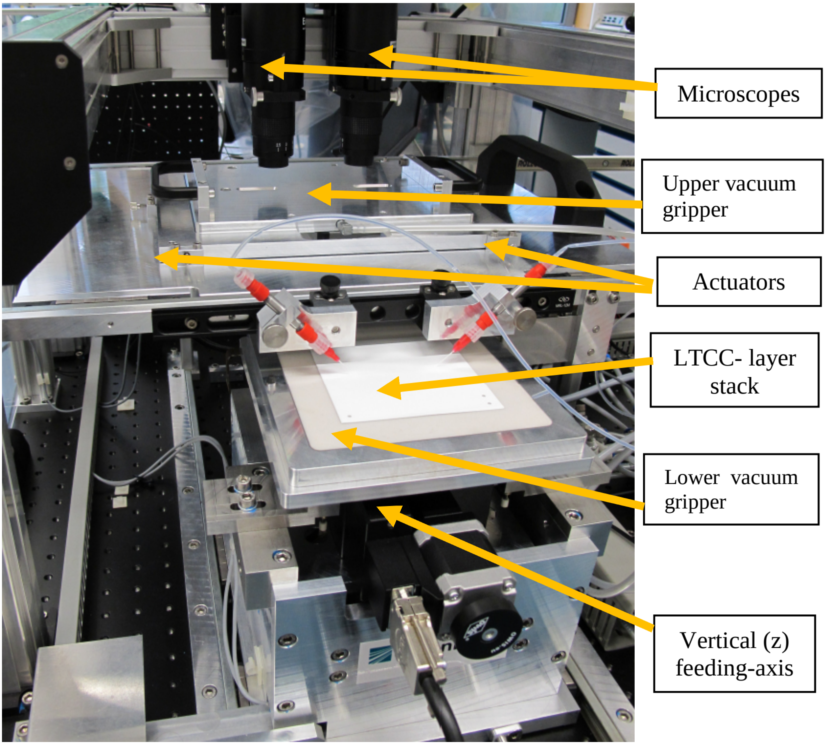

Figure 1: Assembly device for stacking LTCC tapes

3.2 Assembly and alignment of Printed Circuit Boards

During the alignment of PCBs, two sub-assemblies are aligned and mounted with respect to each other. This alignment has to be done in the x- and y- direction with better than 1 µm overlay accuracy. Tip (Rx) and tilt (Ry) degrees of freedom are defined by the contact of the PCB carriers; the rotation around z (Rz) has to be aligned with an accuracy of better than 17 mrad. Based on the stacking procedure,

the first PCB is mounted into a fixed position with respect to the assembly device. After that, the positions of the lithographically structured alignment marks of the fixed PCB are detected to define the alignment position for the second PCB. The assembly device uses three actuators with a step width of 30 nm for alignment in x-y-direction and the rotation Rz. The Rx and Rz alignment is realized by using a membrane spring for the tip and tilt compensation by a flexible mounting of the PCB gripper, which guarantees the direct contact of the PCB surfaces to each other.
The alignment status of the upper PCB with respect to the lower PCB can be calculated by comparing the lower (initial) and the upper mark position, using microscope and image processing software. The measuring uncertainty of the mark detection procedure was investigated to less than 30 nm. The accuracy of the stacking and assembly process of less than 500 nm was reached by implementing statistic calculations for position determination of the x-y-table support, eliminating the position noise of the air bearing table (about 50 nm step width) and the compensation of environmental transients, like thermal drifts and vibrations.
The alignment accuracy was not influenced by using the solder bumping technology for fixation /1/. No deviations of more than 500 nm were measured after fixation.

4 Conclusion

The process for stacking planar functional elements is described in detail. The needed tools for the realization of assembly devices are illustrated.
Overlay accuracies of the processes of 0.5 µm, at the assembly of PCBs, and of better than 5 µm, during the stacking of up to 15 LTCC single layers, are shown. The principle of the stacking process can be adapted to a lot of assembly tasks, if stacks of planar elements have to be built with required overlay accuracies in (sub)micron-range.

References:

[1] Burkhardt, Th. Et al.: Precision photonic packaging using laser-based solderjet bumping. In: Proceedings Smart systems integration 2010. 4th European Conference & Exhibition on Integration Issues of Miniaturized Systems - MEMS, MOEMS, ICs and Electronic Components. Como, Italy, 23 - 24 March 2010. Berlin: VDE-Verlag, 2010, ISBN: 978-3-8007-3208-1, Paper 14