euspen's 19th International Conference & Exhibition, Bilbao, ES, June 2019
www.euspen.eu

Development of handling- and alignment tools for flexible substrates

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Abstract

Sensors and integrated systems are often designed as multilayer systems. In different process steps these layers are represented by flexible substrates. Also thin foils of silicon or metals are used, which are very sensitive to mechanical loads. Thus vacuum chucks for handling of sensitive flexible substrates were developed and manufactured in this research. The use of precise chucks allows the planarization of the substrates down to 1 µm surface planarity. For alignment of substrates to each other alignment marks or functional structures onto the substates are used.
For integration of multilayer stacks two or more chucked substrates need to be aligned. In most applications the x- and y- degree of freedom and rotation rot-z have to be aligned. The alignment movement is done by actuators, supported by flexure hinges for chuck guidance. The fixation technology depends on the substrate materials and structures applicated on the substrates. Adhesive bonding and soldering processes and devices are integrated into the alignment tools.
A variety of tools for handling and alignment of flexible substrates were developed in this work to realize the different process steps of multilayer system integration with overlay accuracies down to 1 µm.

Keywords: flexible substrates, alignment, handling, multilayer substrate stacks

1. Motivation

The handling and alignment of flexible substrates are important tasks during manufacturing and integration of precise multilayer systems. Stacks of up to ten layers of ceramic green foils have to be aligned and stacked with alignment overlay uncertainty of less than 50 µm at integration of multilayer circuit boards and carriers [1].
For sensor applications, silicon detector chips are grinded down to 20 µm thick membranes, which have to be assembled and aligned onto chip carriers. These thin membranes have to be handled and integrated onto sensor carriers with positioning requirements in the range of 10 to 50 µm.
Micro- and nano-structures, which are applied onto flexible substrates, will be transferred to silicon wafers or flexible substrate layers during the system integration [2].
All these flexible substrates are very sensitive to mechanical stresses and have to be handled carefully to prevent damages of structures and substrates. Thus tailored tools for handling, positioning and fixation of these substrates were developed in this work.

2. Process chain of multilayer integration process

The process chain starts with the handling of the flexible substrates. Depending on the delivery status of flexible substrates, there are planar chucks for gripping, transferring and pre-positioning necessary. The most important functions of the chucks are the planarization and the mechanical stable fixation of the sensitive flexible substrates during the handling process. The chucks have to be designed with respect to mechanical and process interfaces of previously manufacturing devices, e.g. wafer sawing and cleaning devices and ceramic green foils stamping devices. After one or more transfer steps the flexible substrates have to be chucked at a planar surface. After chucking, the flexible substrates will be positioned and aligned to each other. In most integration applications two chucks are necessary: one stationary chuck and one chuck which can be positioned with respect to the fixed chuck for aligning the substrates. Actuator modules will realize the positioning of the chucks. Alignment tools will detect alignment structures of the substrates e.g by image processing. After alignment the fixation processes will keep the position of the substrates by adhesive bonding or soldering. During manufacturing of multilayer systems the different layers will be integrated step by step in sequential process steps.

3. Handling tools and alignment devices

3.1. Handling tools - chucks

For handling and alignment processes performed on athmospheric conditions vacuum chucks can be used. The chucks have to be planar within a range of 1 to 5 µm in a chucking area (i.e. substrate size) of up to 300 mm x 300 mm. For chucking flexible substrates the size of sucking holes should not exceed 50 µm. This can be reached by drilling or milling of micro holes. As an alternative, porous materials can be used, e.g. porous ceramics or porous metal foam materials. If the detection of structures on the substrates during processing will be necessary, the structuring of glass or glass ceramics as chuck materials is also possible. Vacuum channels can be structured into glass materials by grinding using rotating tools with diameter of 0.5 to 2.0 mm. The functional parts of the chucks will be integrated into the interfaces structures for mechanical fixation and positioning.

Electrostatic chucks has been developed for handling and fixation processes under vacuum environmental conditions [3, 4].

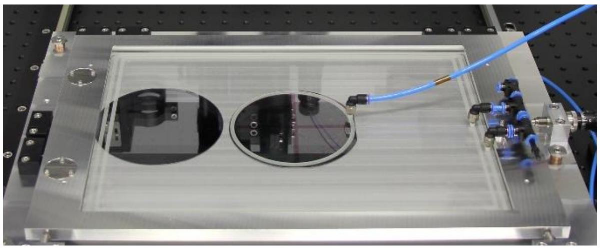

Figure 1. Vacuum chuck made of glass with chucked 4” wafer

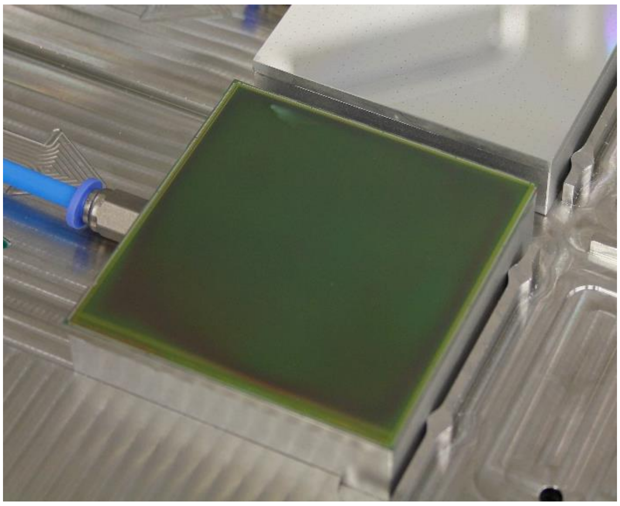

Figure 2. vacuum chuck made of aluminium and 50 µm holes (obove) and with chucked flexilbe silicon substrate size 50 mm x 50 mm (below)

3.2. Alignment devices - actuators

The degrees of freedom in x-, y- and rotation rot-z have to be aligned during stacking flexible substrates. The z- and the rotation rot-x and rot-y degrees of freedom will be defined by the chucks and the pre-alignment of the chucks to each other given by the mounting of the chucks inside the alignment device. One chuck should be only moveable along the vertical (z-) direction. The alignment chuck can be guided by flexure hinges to the alignment device. After aligning the x-, y- and rot-z degrees of freedom the substrates will be put in contact by a vertical (z-) movement with one of the chuck. The alignment movement will be applied by actuators. If alignment steps of 1 to 5 µm are necessary, manually driven screws can be used. If movements of less than 1 µm are required, then piezo driven actuators are recommended.

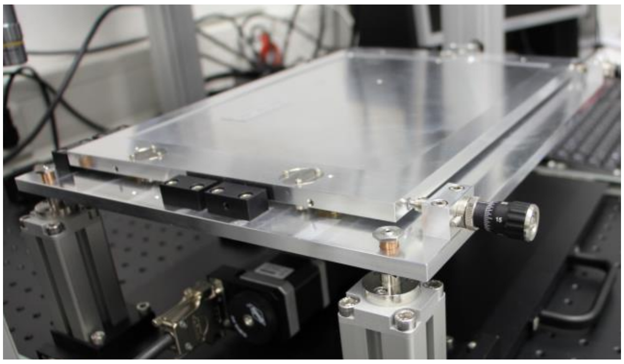

Figure 3. Alignment tool with integrated vacuum chuck and manually driven actuator screws for chuck positioning

3.3. Alignment – image processing and detection tools

Image processing and optical inspection tools are necessary for detection of alignment structures on the substrates. Depending on the structure size optical microscopes with magnification in a range of 10x to 500x can be used. If the cameras are fixed to the alignment device the position of alignment structures can be measured with respect to the camera field of view. Starting with the definition of the position of the alignment structures at the first layer of the multilayer stack, additional substrates layers can be aligned relative to the lower layer using these position informations without the alignment structures of both layers are visible at the same time.

To reach overlay uncertainties of less than 5 µm the detection of alignment structures of both substrates at the same time is required. Thus transparent substrate materials and transparent chuck materials or clear apertures in the chucks are necessary.

3.4. Fixation processes

For fixation of the substrates adhesive bonding is the preferred technology. The adhesive dots have to be applied by using dispensing systems onto the substrates after chucking the substrates and before alignment. Adhesives with short curing times (less than 5 minutes) are recommended to reach cost effective process times.

As an alternative, soldering techniques can used, if solder bumps are applied onto the substrates. The soldering process can be started after alignment by heating one chuck up to the solder melting temperature.

4. Conclusion

Flexible substrates can be handled, aligned and fixed by tools and devices for integration of multilayer systems. Vacuum chucks for substrate handling can be machined of porous ceramics, metal foam materials or structured glass. Alignment procedures are implemented to the integration process using structures of the substrates and image processing. The fixation of the layers is performed by adhesive bonding and soldering techniques. Overlay accuracies of less than 5 µm were reached during integration.

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