Precision chucks for future lithography

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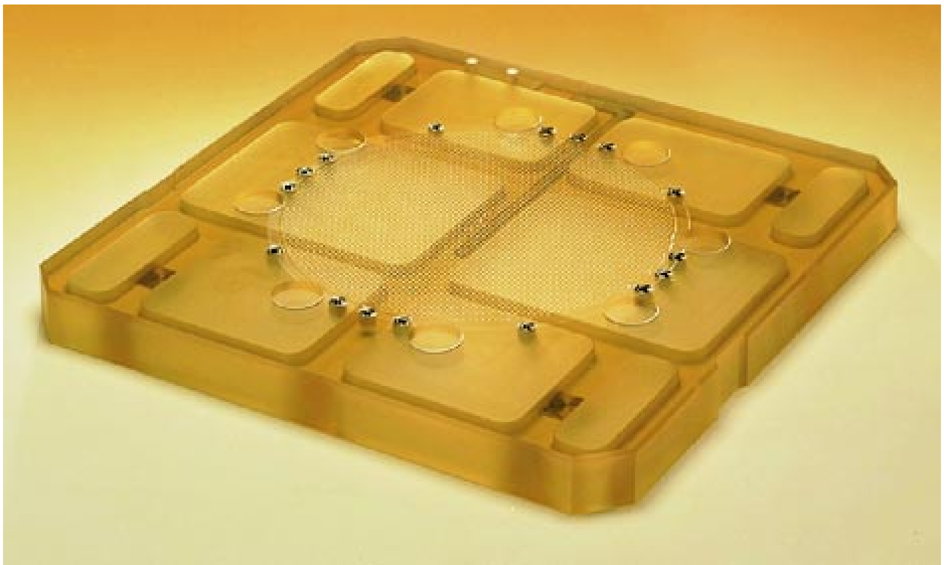
Motivation

In modern electron-beam lithography and -even more important- upcoming next generation EUV-lithography, a very high patterning accuracy (better 30 nm) is desired. This imposes considerable demands on wafer flatness and positioning stability as well as the setup used for clamping the wafer during lithographic exposure. At ambient conditions, fixture of a wafer in the exposure unit is done with a vacuum chuck, which provides a reduced air pressure on the backside of the wafer similar to gripping tools used in picking and placing. This ensures flat adherence and avoids bending or scratches as is quite common with mechanical clamps. Inside vacuum, electrostatic chucking has emerged as a means to obtain closely related results. Through the generation of an electric field between wafer and support, an attractive force is exerted on the wafer. The force is distributed homogenously over the surface, can be switched on/off and adjusted electrically. It provides flat wafer adherence to the support as well as good thermal contact. Development at the IOF comprises chucks based on both working principles -vacuum and electrostatic- and typically combines high precision with athermal design to achieve outstanding lithographic results.

Vacuum Chucks

For holding and smoothing of wafers under ambient conditions, vacuum-chucks are required.
Fig. 1 shows a recently developed 8 inch wafer-chuck at IOF. The surface is implemented with a uniform pin pattern to support the wafer on the chuck evenly with great reliability and provide a flat surface without bending or other deformation from residual particles or dust on the wafer surface. The pin pitch is 3 mm and the pin diameter is 0.8 mm. At the chuck-edge a ring-seal has been structured carefully to omit vacuum leakage. By this seal, the low pressure region below the wafer surface is separated in a controlled way from the ambient pressure above the wafer and around the chuck. The typical vacuum pressure is about 200 mbar lower than ambient pressure.
The clamping process leads to a flattening of the wafer and a defined contact distribution between backside of wafer and pins. The local flatness in a 25 mm square field is better than 0.25 µm and the global flatness of the pin surface with the wafer chucked is better than 2 µm at 8 inch diameter and 4 µm at 12 inch diameter, respectively. The chuck is made of glass ceramics. This kind of material provides high form stability, minimal thermal expansion and high specific stiffness. To reduce total mass, a light-weight structuring on the back side of the chuck has been realized. The design of the light-weight structure was tested by FEM simulation. The whole chuck design has been optimized according to the manufacturing technologies involved, the specific glass ceramic material and a very high stability of the unit.

Fig. 1:
Vacuum chuck (8 inch). Courtesy of Leica Microsystems (Wetzlar).



Electrostatic Chucks

The basic design of an electrostatic chuck closely resembles that of a parallel plate capacitor, with the wafer being used as one of the plates. The second is a metal electrode incorporated into an insulating substrate that supports the wafer from below. By applying a voltage U between the two plates, which are typically separated by a dielectric film of thickness d of several 100 µm, the wafer is attracted to the chuck with a force proportional to $(U/d)^2$. Fig. 2 shows a high precision 12 inch diameter electrostatic chuck made from glass ceramics.

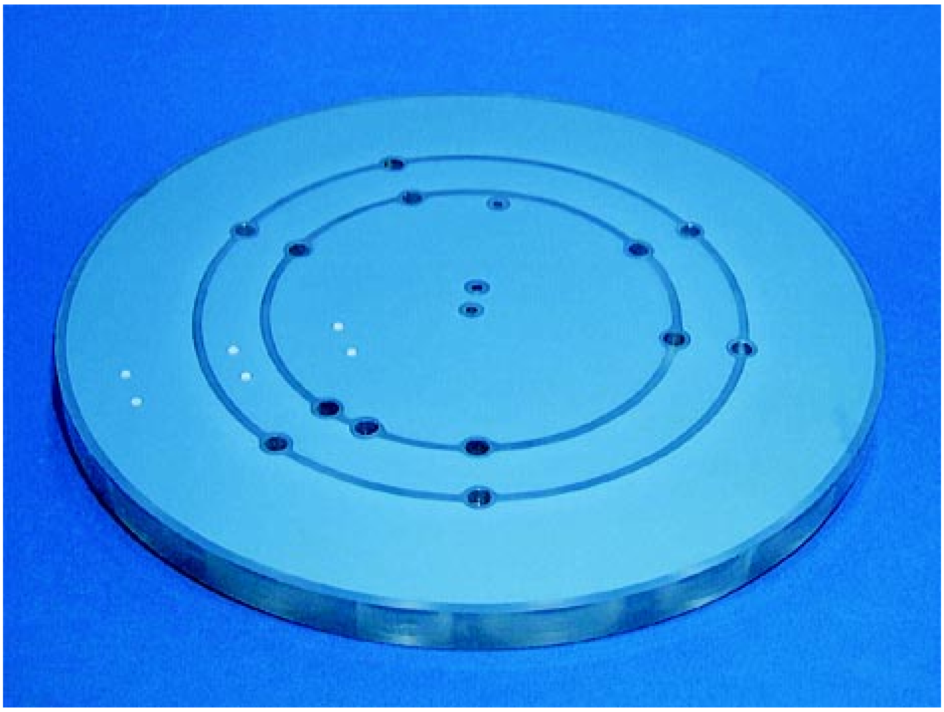


Fig. 2:
Electrostatic chuck (12 inch).

Planarity of chucking surface is about 2 µm and chuck thickness deviations are even less. The chuck electrode can be clearly seen through the transparent dielectric and has been segmented into rings of 6, 8 and 12 inch diameter, to precisely adapt to these wafer sizes. Electrostatic forces were measured in vacuum with smaller test chucks of equivalent design.
Fig. 3 shows the corresponding results (force normalized to chuck area, e.g. pressure) as obtained for different voltages. The pressure variation clearly reflects the $(U/d)^2$ dependency. Note the relatively high pressure values, which apparently are similar to those of vacuum chucks and due to Johnsen-Rahbek behavior of the glass-ceramic dielectric /1, 2/.
Currently, 12 inch chucks which integrated wafer-lift mechanisms for use in Ultra-High-Vacuum are under development.

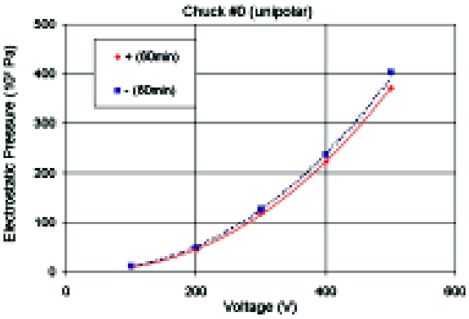


Fig. 3:
Force versus voltage.

References

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