# Electrostatic chucks for vacuum lithography

G. Kalkowski, S. Risse, G. Harnisch, and V. Guyenot

## Motivation

At ambient conditions, picking and placing of silicon wafers or fixture during lithographic exposure is done with vacuum chucks. This ensures flat adherence and avoids scratches and other damage as is common when using mechanical clamps. Inside vacuum, this principle doesn't work and mechanical clamps are still used widely. As a consequence, wear and generation of particles, uncontrolled wafer bending and poor thermal contact of the wafer to the support are encountered.
For advanced lithography applications this is not acceptable and electrostatic chucking has emerged as a means to avoid such problems. Through the generation of an electric field between wafer and supporting chuck, 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 ensures flat wafer adherence to the support as well as good thermal contact. Handling behaves in many respects similar to vacuum gripping, while the principle works inside and outside vacuum.

## Chucking principle

The basic design of an electrostatic chuck is illustrated in Fig. 1. It 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, the wafer is attracted to the chuck. The thickness d of the dielectric film between the wafer and chuck electrode and the relative dielectric constant e of the film material contribute to the force. From theoretical considerations the electrostatic force F per area A has been estimated to

$$F/A = \tfrac{1}{2}\, e\, e_0\, (U/d)^2$$

with an ideally insulating dielectric /1/.

Here $e_0$ denotes the electric permittivity of free space. For dielectrics with a finite conductivity, much higher forces due to so-called Johnsen-Rahbek behavior are known /2/. There are different electrical design possibilities. In the basic design a single chuck electrode is used and direct electrical contact of the voltage source to the wafer is required. Implementing a bipolar or multipolar electrode configuration circumvents the need for contacting the wafer directly and may be appropriate when wafer charging by impinging electrons or ions is not a problem.

## Materials investigations

Optimizing the chuck for a specific application includes a careful materials selection. Alumina (clean and doped) and $SiO_2$ are well-established dielectrics, while other materials are less common, albeit of great potential for vacuum lithography and

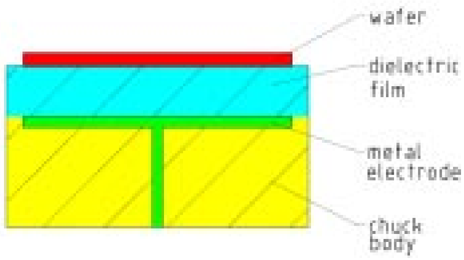


Fig. 1:
Electrostatic chuck

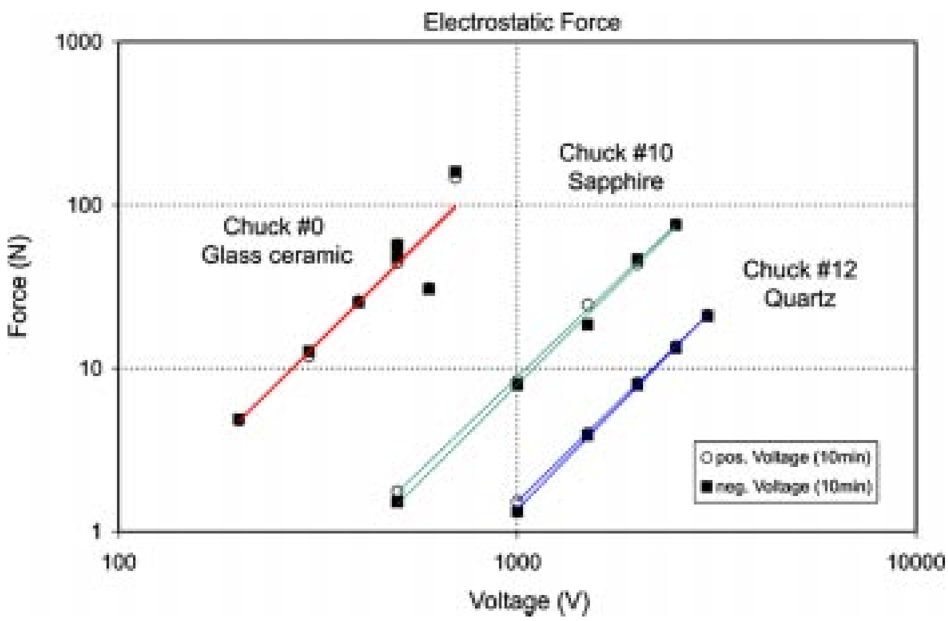


Fig. 2:
Electrostatic forces versus voltage for various chuck materials

measurement applications. We have investigated a series of materials, including glass and glass-ceramics with respect to its use as a dielectric in electrostatic chucks /3/.
Electrostatic forces were measured in a vacuum equal or better $10^{-4}$ mbar using unipolar test chucks of about 70-80 mm diameter and a dielectric film thickness around 250 µm. The results are displayed graphically in Fig. 2. Note the logarithmic scales. Large differences in electrostatic force for quite similar geometry are apparent.
In particular, the glass-ceramic dielectric is identified as a Johnsen-Rahbek system, providing forces about two orders of magnitude larger than with quartz.
By using this material as chuck dielectric, a highly attractive force on the wafer at moderate voltage can be obtained.

## Lithography chuck

Chuck designs of different size and material for a diversity of lithographic applications have been realized in our institute. As an example, Fig. 3 shows a 12-inch chuck made out of glass-ceramics for use in Ion Projection Lithography /4/. Planarity and absolute height dimensions of the chuck are controlled to µm precision. This ensures a well-defined plane of focus for the lithography process and a clear geometrical relationship to the underlying metrology stage. Electrical design is somewhat more complex than described above due to a multi-polar electrode configuration, which allows for flexible electrical adoption to different process requirements. In fact, part of the chuck is even movable and can be extended or retracted with high precision to ease wafer transfer off and onto the chuck.

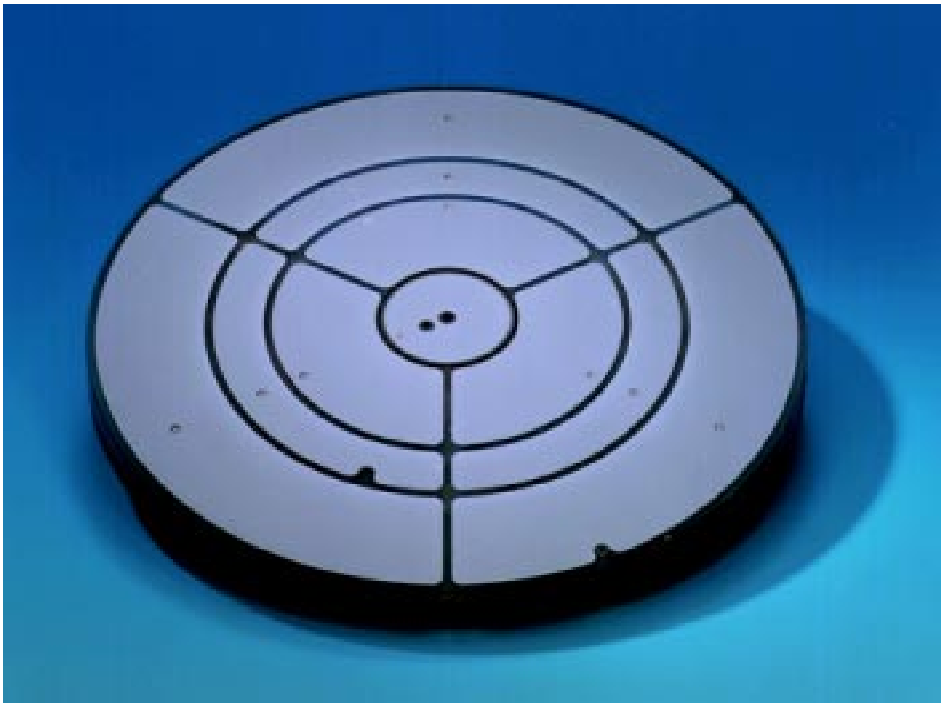

Fig. 3:
12-inch electrostatic chuck for Ion Projection Lithography

## References


/1/ T. Watanabe, T. Kitabayashi, C. Nakayama," Relationship between Electrical Resistivity and Electrostatic Force in Alumina Electrostatic Chucks", Jpn. J. Appl. Phys. 32 (1993) 864
/2/ D. Wright, L. Chen, P. Federlin, K. Forbes," Manufacturing issues of electrostatic chucks“, J. Vac. Sci. Technol. B13 (1995) 1910
/3/ G. Kalkowski, S. Risse, G. Harnisch and V. Guyenot, "Electrostatic Chucks for Lithography Applications", Proceedings of Micro- and Nano- Engineering (MNE), Jena 2000, in print
/4/ in cooperation with Leica Microsystems Lithography GmbH (patent pending)