Principles of Electrostatic Chucks

1 — Techniques for High Performance Grip and Release

Overview

Electrostatic chucks use the attraction of opposite charges to hold both insulating and conducting substrates for a variety of microfabrication processes. These processes include lithography, ion implantation, plasma etch, film deposition, and inspection.

Electrostatic chuck performance is controlled by both the materials of construction and the electronic drive. Electronic methods of attaining fast and reliable performance are described here, as applied to conducting substrates. Insulating substrates require a different grip method.

Ideal Chuck Theory

Grip force is proportional to charged plate area, so is calculated as a pressure. A non-conductive dielectric between a monopolar electrode and a conducting substrate yields a grip pressure (in Pa) of

$[\varepsilon_0 / 2]\, V^2\, [\kappa_r / \{d + \kappa_r g\}]^2$ where
$\varepsilon_0 = 8.85.10^{-12}$,
V = electrode - substrate voltage,
κ_r = dielectric constant,
d = dielectric thickness, and
g = gap size
(from dirt, warpage, etc).

Thus, if $\kappa_r \sim 10$ (alumina), a gap 1/10 of the dielectric thickness will decrease grip pressure by a factor of 4.

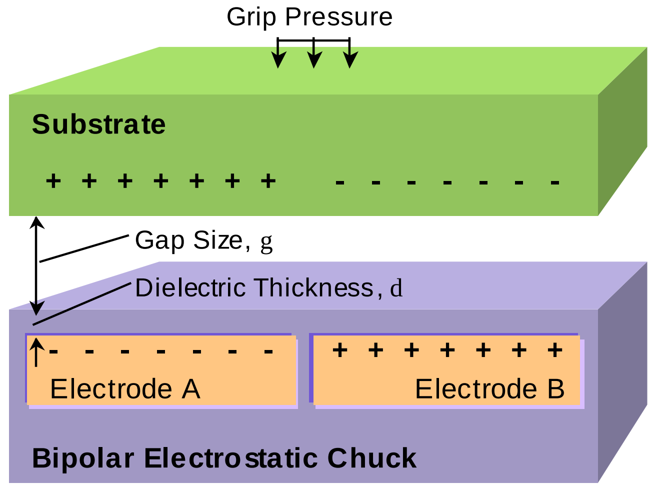

Figure 1. Basic bipolar electrostatic operation

Figure 1 illustrates a bipolar chuck for which the above V is half of the voltage between electrodes A and B; for symmetric electrodes $V = [-V_A + V_B] / 2$. The substrate potential is centered at the average potential, $V_S = [V_A + V_B] / 2$.

Non-Ideal Chuck Performance

All electrostatic chucks require a dielectric between electrodes and substrate, and all dielectrics conduct electric charges to some extent, resulting in time-dependent grip forces.

Vertical charge motion, which assists substrate gripping forces, is shown in Figure 2. Other charge motions are also possible, which may assist or hinder the grip forces.

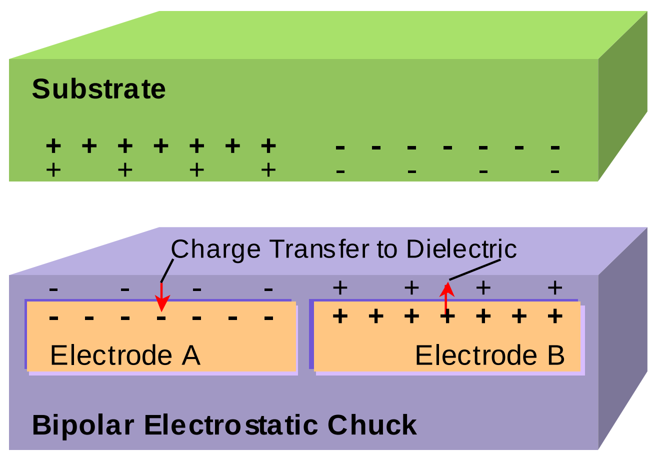

Figure 2. Charge transfer during grip

Grip and Release from Non-Ideal Chucks

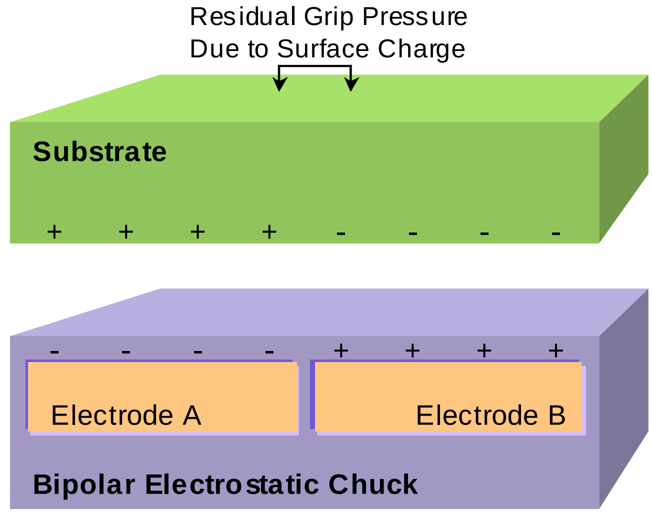

Figure 3. Removal of electrode voltages

Withdrawal of grip voltages from the chuck electrodes leaves a surface charge, yielding a residual grip force which can be comparable to the original grip force. Surface charge makes substrate release unpredictable, difficult, and slow. In addition, subsequent grip strengths will be variable unless grip electrode potentials are chosen correctly.

Surface charge can be removed by exposing the chuck surface to a brief low-power inert plasma discharge with electrode voltages zeroed. If nonuniform charge movement has resulted in a buildup of substrate potential, substrate release may be further improved by maintaining this discharge throughout the release, lift, and electrode zeroing operations.

Adaptive Release

By sensing the electric field between the chuck and substrate, electrode voltages can be programmed to cancel or augment stored dielectric charges. The ElectroGrip DR4, DR5, DR6, and DR7 electrostatic drivers use such sensing to optimize both grip and release processes*. This use of *Adaptive Charge Cancellation*™ is illustrated in Figure 4. The degree of charge cancellation can be programmed in a tradeoff between release speed and residual grip forces.

In addition an active electronic charge extraction from the chuck dielectric can be performed after the zero-field condition is attained, for further reduction of stored charge effects after long grip periods.

A close to zero-field region is thus established at the puck/substrate interface when release is required. Residual pressures of less than 0.04Torr can be attained even using chuck dielectrics with high stored charge levels.

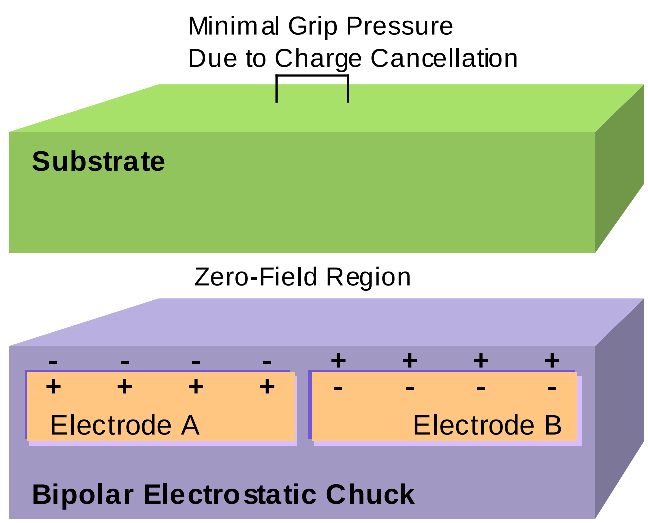

Figure 4. Cancellation of residual charges

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* US Patent numbers 5,103,367; 5,325,261; 6,922,324; and also in other countries.

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