

Principles of Electrostatic Chucks

3 — Chuck Leakage Current and Release Strategies

Overview

Electrostatic chucks employ the attraction of opposite charges to hold both insulating and conducting substrates for a variety of microfabrication processes. Current flow through chuck insulating materials into a gripped substrate can yield variable release characteristics unless it is properly allowed for.

Methods of programming chuck electrode voltages for reliable release in the presence of leakage currents are described here.

Vertical Current Flow During Grip

During grip of a substrate, charges will migrate through the dielectric layer situated between grip electrodes and substrate. Even in nominally insulating dielectric layers, sometimes this leakage is so high as to be measurable, due to partial breakdown of the dielectric layer above an electrode. This is indicated in Figure 1 by a red arrow. The breakdown above Electrode A results in a lowered voltage drop between the electrode and substrate, consequently in less charge on Electrode A and on the substrate above it.

In bipolar chucks Electrode B will then exhibit a higher voltage relative to the substrate than it would otherwise have. This in turn will yield a higher grip pressure

above Electrode B. Leakage current from Electrode B may rise to equal the current flow into Electrode A, thus partially breaking down the dielectric above Electrode B.

Note the additional charges shown above Electrode B, caused by bulk migration through the dielectric in the presence of the higher electric field there.

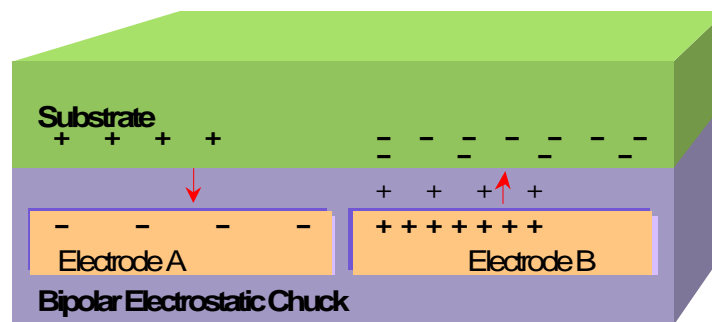


Figure 1. Vertical asymmetric current flow during grip

Substrate Charging

Thus voltage drops between electrodes and substrate redistribute to balance leakage currents. This may yield a reduced grip pressure, and indicate the approaching end of chuck life. However the chuck may remain serviceable for some time, and the distribution of charges will be equalized during operation of a plasma that conducts from the substrate to a point of average potential such as a chuck baseplate. The only noticeable effect of this leakage may be difficulties with substrate release.

The time taken for charge levels to stabilize varies with chuck condition and the operation performed. An electrode with about 100G_Ω leakage resistance and 1nF capacitance to the substrate yields a time constant of order 100 seconds. The nonlinear leakage resistance falls with rising applied voltage, so this time becomes shorter with a higher applied voltage between electrode and substrate. Conversely, lowered voltages yield longer time constants. Hence a short stabilization time constant during grip becomes a longer one during releasing steps.

Release of a Charged Substrate

The net negative charge of the substrate is the charge attained during grip. This charge takes time to discharge through the lowered electric fields present during the release process. We'll assume that this charge is initially constant in the discussion below.

Release of a substrate from an electrostatic chuck requires appropriate electrode voltages. One example of such voltages may be a reversal and reduction of the original voltages, as shown in Figure 2.

The upper level of charges diagrammed in the substrate shows the lateral separation of charge in the substrate which mirrors the applied electrode charge. Underneath is shown the total attained substrate charge during grip. In practice a conducting substrate would have all such charges on its surface.

The charge shown in the dielectric above Electrode B is that remaining from charge migration in the dielectric during grip, and is here assumed to be cancelled by the Electrode B charge. Hence Electrode B should have no electric field above it, and no residual grip force.

The charge shown above Electrode A is all in the substrate, and mirrors the electrode charge. Hence residual grip force will appear above Electrode A.

Other combinations of Electrode A and B charge may be imagined and will all yield imperfect charge balance and a consequent residual grip force. Over time this residual force will decline due to conduction of the substrate charge through the leaky chuck dielectric. Sometimes this charge moves suddenly, indicative of a spark-like discharge, and at other times this charge may gradually decline. After each partial charge extraction, the electrode voltages for best release will alter.

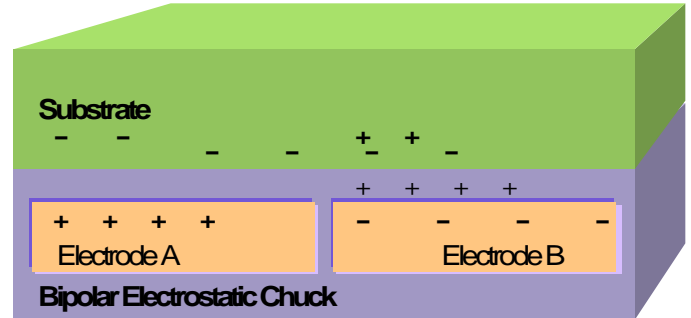


Figure 2. Attempted release of a charged substrate

Strategies for Reliable Release of Charged Substrates

The *Adaptive Charge Cancellation*[™] system employed in ElectroGrip drivers DR4 and DR5* arranges electrode voltages to minimise the residual force on a released substrate. In the presence of a charged substrate this best average level of voltage changes as the substrate charge alters, sometimes rapidly. Consequently the DR4 and DR5 can, if required, sense the presence of longer time-constant effects in the substrate, move electrode potentials to more effectively discharge the substrate, and respond adaptively to observed medium-term changes in the level of release residual pressure that is attainable.

The substrate charge could also be held close to zero using a low level plasma exposure of substrate and chuck *during* release. Appropriate timing of electrode voltages, substrate motion, and plasma can yield minimal chuck surface charge and reduced substrate charging effects. System programming and process timing may not permit this to be used in production but it can be useful as a diagnostic.

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