Principles of Electrostatic Chucks

2 — Charge Control during Repeated Grip Cycles

Overview

Electrostatic chucks employ the attraction of opposite charges to hold both insulating and conducting substrates for a variety of microfabrication processes. Charge flow through the chuck insulating materials can yield variable grip and release characteristics unless it is understood and controlled.

Methods of programming chuck electrode voltages for high grip consistency are described here.

Vertical Charge Transfer — First Grip

During an extended grip period, charge can travel through the dielectric layer situated between the grip electrodes and the substrate. As shown in Figure 1, this charge may reside on or in the dielectric above each electrode, yielding a rising grip force. Matching “mirror” charges will move on the rear of a conducting substrate, as indicated in the Figure.

The time taken for these charge movements to have a noticeable effect varies with the dielectric material and its surface condition. Grip forces through thin anodised coatings may vary over times as short as 20 seconds, while thick quartz layers may exhibit variation over periods of several hours.

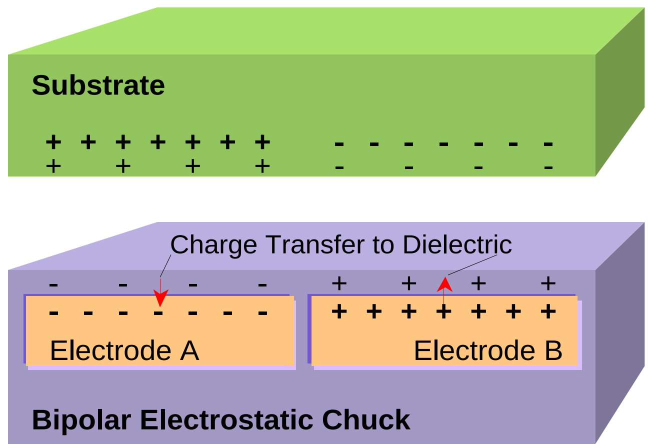

Figure 1. Vertical charge transfer during grip

Vertical Charge Transfer — Release and Subsequent Grips

The Electrogrip system of charge cancellation* obtains substrate release with appropriate electrode voltages. ***Adaptive Charge Cancellation***™ results in equal and opposite charges to those stored in the dielectric surface, hence in an almost zero electric field above the dielectric, as shown in Figure 2.

If subsequent grips employed alternating polarity on each grip, Electrode A would now be driven to +, and Electrode B to - polarities. This is similar to the released condition and will yield poor grip pressures.

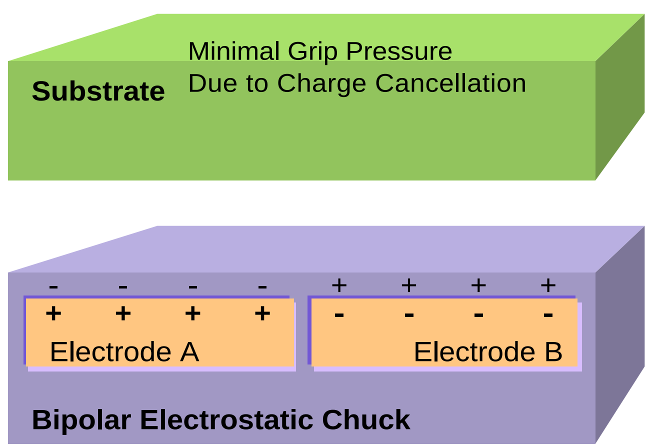

Figure 2. Vertically transferred charge cancelled at release

Consequently unipolar gripping is indicated in the case of vertical charge migration.

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Lateral Charge Transfer — First Grip

If charges are attracted by the electrode fields across the chuck dielectric surface, as would occur in the fringing field region at electrode edges, the lateral charge transfer indicated in Figure 3 will result. Falling grip pressure with time is observed for this dielectric condition.

This condition is observed when gripping in air, with surface moisture being an important controlling factor. After chuck surface cleaning, even grip performance in vacuum will be degraded until the surface is dried. Surface conduction layers will also cause this lateral charge transfer.

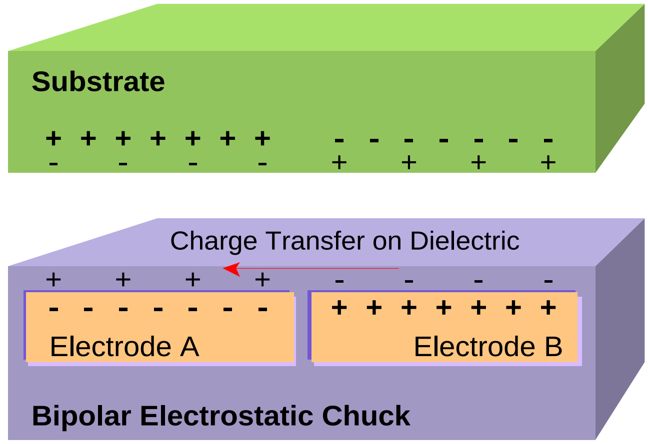

Figure 3. Lateral charge transfer during grip

Lateral Charge Transfer — Release and Subsequent Grips

The above lateral charge buildup during grip results in the released condition shown in Figure 4 after ***Adaptive Charge Cancellation***™. The electrode polarities are the same as for the prior grip state.

Subsequent grips will thus attain highest grip pressures with alternating grip polarities applied to the electrodes.

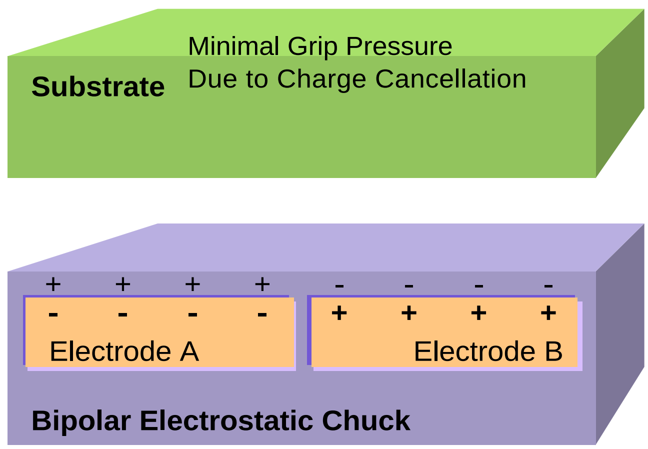

Figure 4. Laterally transferred charge cancelled at release

Strategies for Reliable Grip Pressures

Materials will in general exhibit a combination of the above lateral and vertical processes, modified by the immediate operation and cleaning history. In vertically conducting dielectrics continued unipolar gripping will yield progressively higher grip pressures in highly insulating dielectrics due to increased charge storage at trapping sites. There will however be steadily rising voltages required for adequate release, and the release quality will deteriorate due to nonuniform charge distributions.

Electrogrip's adaptive grip system chooses the grip polarity on each grip cycle that will yield the highest grip pressure. This responds to chuck conditions to yield optimal grip, but could suffer from rising charge levels in unipolar conditions. To avoid this, parameter settings allow Electrogrip drivers DR4 and DR5 to alternate grip polarity, only employing unipolar grip when necessary to assure grip.

Plasma exposure of chuck surfaces with the electrode voltages zeroed, even for a brief moment, will remove surface charge and its built-up history effects. This can assist with grip and release reliability. An option setting in Electrogrip drivers supports this mode by zeroing electrode voltages after substrate removal.

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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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