Principles of Electrostatic Chucks
5 — System Control

Overview

This document describes how system components should interact to yield optimum electrostatic chuck operation, with an emphasis on plasma processing.

Electrostatic chuck grip and release must be timed carefully together with wafer lift, fill/purge of backfill gas, and process gas / rf application. The signal polarities described below relate to the DRx (DR4, DR5, DR6) series of electrostatic chuck driver power supplies. The DRx outputs need not be the digital logic levels graphed below, but may be serial communications.

Normal Operation

The figure shows the sequence of a typical plasma process.

Wafer grip input, Wafer sense output:
Both of these are normally high. The user must pull the wafer grip input low to command grip, and the wafer sense line is pulled low by the DR driver when a wafer is sensed.

The order of these occurrences is somewhat arbitrary since the DRx can be programmed to not grip until a wafer is sensed. Hence in such a case, both conditions must be satisfied before gripping.

The recommended sequence is as shown since then wafer gripping will commence upon sensing, before hitting the chuck surface. *See the "Wafer height" curve description.* This yields minimal wafer lateral position shift, important if there is no lateral constraint to wafer motion at the chuck edge.

DR4 DRIVER, CHUCK CONTROL TIMING

- wafer grip input
- wafer sense output — plasma shunting effect
- wafer gripped output — grip time — release time
- He backpressure — typ. 5 Torr — typ. 1 Torr
- rf process
- wafer height — min. on time ~50ms while wafer high
- sense "autozero" input

● indicates that this point causes start of the next operation or causes a change in a signal.

If this sequence is followed, the height at which the wafer is sensed should be programmed into the DRx driver setup parameters. There are then two relevant parameters; trip height (in 0.5mm increments) and a trip height calibration factor.

At process conclusion, similar minimisation of lateral wafer movement requires that wafer lift should be performed immediately upon wafer release. *See the "Wafer height" curve description.*

Wafer gripped output
After commencement of wafer gripping, a DRx driver takes 200 - 300ms to attain optimum grip. When grip is attained, the "wafer gripped" output is pulled low.

After receipt of a high wafer grip input signal, commanding wafer release, the DRx driver optimises chuck electrode potentials to mimimise grip forces. This takes a median time of 650ms in vacuum. This time falls to 150ms where there is additional force separating chuck
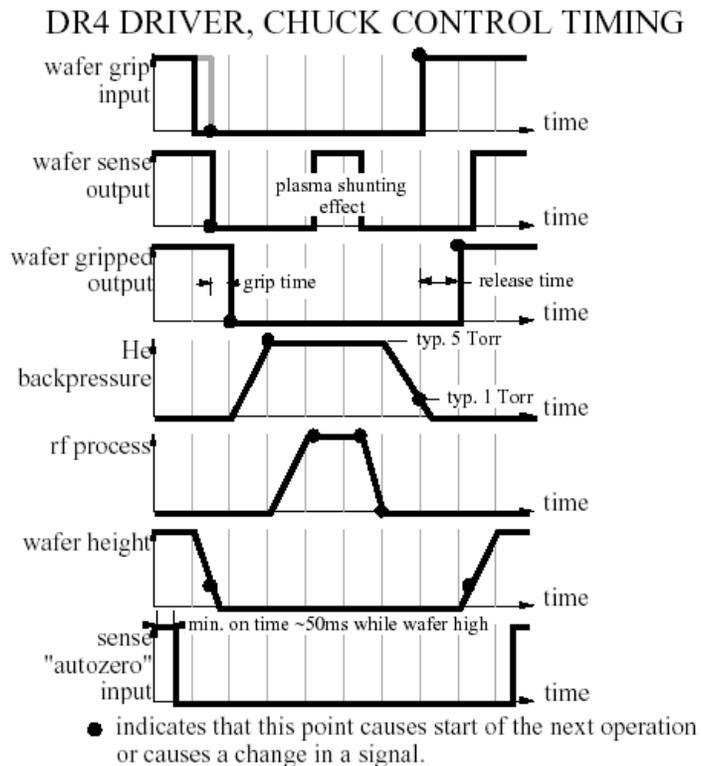
and wafer such as gravity, spring forces, or residual gas backpressure. At release termination the "wafer gripped" output goes high.

<u>He backpressure</u>
After wafer gripping, backpressure can be applied. Gas flow will be initially high, then fall to the steady state leakage value. If this value is higher than specified in the chuck datasheet, high substrate stiffness, substrate bow, dirt particles, and chuck damage are possible causes. Processing should be terminated if a high leakage value indicates the latter three causes to avoid nonuniform process results. After plasma processing is finished, wafer release would cause wafer "popping" as high as 5mm off the chuck surface due to the backfill gas pressure. Hence the backfill is purged before release, typically to less than 1 Torr, by pumping the backfill line with a rotary pump (e.g., the load lock backing line) or preferably by shunting the backpressure line to the chamber if the chamber process gases are non-corrosive. (Substrate top pressure is then equalised with that at the bottom during all process steps, until backfill.)

<u>Rf process</u>
After attaining the correct backfill pressure, rf processsing is initiated by a signal from the GCx Controller or the host control computer. Conductive plasmas shunt the wafer sense signal which normally is conducted through the wafer between the two gripping electrodes, resulting in temporary loss of the "wafer sense" signal. However wafer sensing is restored when the plasma is shut off.

<u>Wafer height</u>
Wafer lift and grip are synchronised to minimise lateral shift (see *wafer grip input, sense output*).

<u>Sense "autozero" input</u>
An aid to the DR4 Driver wafer sensing. The DR4 "Options" menu can set a special input pin function. When lift pins are high (and wafers could not be on the chuck), a high logic level at that this special input pin will zero the wafer sense level. Useful for very small sensing signals, such as from semi-insulating GaAs. In more normal cases the inbuilt DR4 wafer sense memory progressively updates wafer sensing conditions and this input is not required.
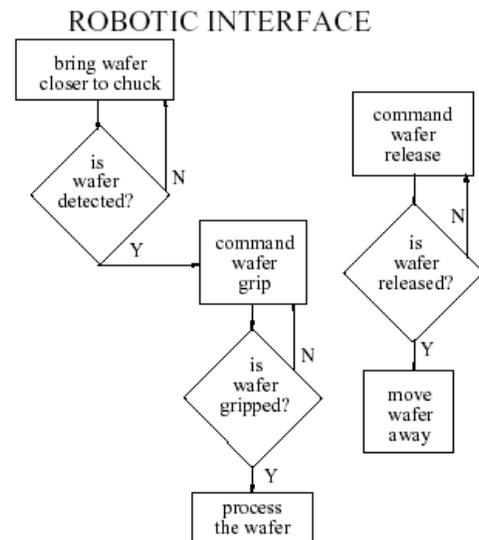

DRx Driver Interfacing

Robotic movement of wafers to and from a chuck surface should follow this flow diagram. The required wafer detection and grip condition outputs are provided by the DRx driver.

As described in the previous section, the sense and grip timing may be interchanged, depending on application details.

The GCx executes the sequence below, in addition to cooling gas backfill, monitoring, and purge functions. If using another system controller it should do likewise.

Three connection wires go from a bipolar electrostatic chuck and the BD3 bias decoupler or DrxVI high voltage outputs. These wires are at rf potential. Two are the chuck grip electrodes, and the third is the chuck baseplate. All are at rf potential, following the chuck baseplate voltage, and also possibly picking up a second rf signal from a top-excited plasma generator. Such rf wiring must be held close to and in intimate contact with the rf connection line from match network to chuck baseplate, and away from any grounded surface, to minimise rf current flow in the electrode wiring.
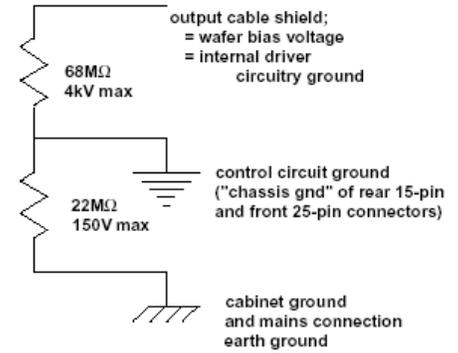

ROBOTIC INTERFACE

SYSTEM GROUNDING

output cable shield;
= wafer bias voltage
= internal driver
circuitry ground

68MΩ
4kV max

control circuit ground
("chassis gnd" of rear 15-pin
and front 25-pin connectors)

22MΩ
150V max

cabinet ground
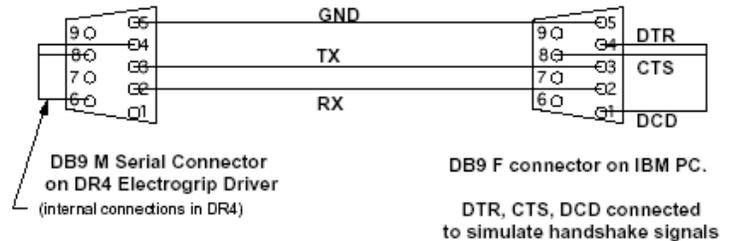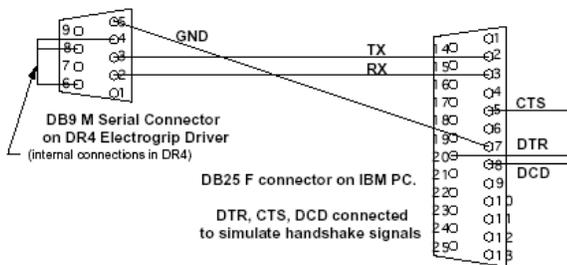and mains connection
earth ground

• If a BD3 bias decoupler is used, then the coaxial cables connecting to DR4 high voltage outputs. These connections are shielded at the plasma dc bias potential of the chuck baseplate. The input impedance of the bias-level circuitry in the DR4 is normally 68MΩ. For chucks with high bias voltage source impedance, this resistance may shunt the bias signal. In such cases it can be removed through removal of the DR4 rear panel. The DR4 internal resistances are shown at the right.

If however a DRxVI high voltage module is used, with x=5 or 6, then all rf and plasma bias potentials are enclosed in that module and the coaxial cable connecting to the DRxA base station is at ground potential.

Electrogrip RS-232 Connection

GND
TX
RX
CTS
DTR
DCD

DB9 M Serial Connector
on DR4 Electrogrip Driver
(internal connections in DR4)

DB25 F connector on IBM PC.

DTR, CTS, DCD connected
to simulate handshake signals

GND
TX
RX
DTR
CTS
DCD

DB9 M Serial Connector
on DR4 Electrogrip Driver
(internal connections in DR4)

DB9 F connector on IBM PC.

DTR, CTS, DCD connected
to simulate handshake signals

IBM PC-compatible computer 9600 Baud, No parity, 8 bit, one stop, one start bit

GC3 CONTROLLER INTERFACING

The GC3 system controller interfaces with all components which affect chuck operation and synchronises their actions to attain optimum chuck operation with minimal installation and setup time.

• Only one control wire is required to initiate and terminate all gripping, backfill, wafer lift, and purge functions.

• Additional control lines are available which permit a central control computer to monitor and control gas backfill pressure and flow, as well as overall system status. Thus the GC3 controller facilitates retrofits into existing equipment with simple, complete system control.

The GC3 Controller accepts a start/stop signal to initiate sequenced start / stop of an rf-driven electrostatic chuck process. The GC3 Controller interfaces through its back panel connectors, and its separate connector interface box, with:
• backfill gas mass flow controller (and also the GC3 and pressure gauge power tap-off);
• backfill gas purge valve;
• backfill gas pressure gauge;
• backfill gas pressure output;
• stepper motor rf filter RFF-1;
• stepper motor wafer lifter;
• stepper motor gas purge valve;
• Electrogrip DR4/DR5 Electrostatic Driver on their parallel I/O port;
• central host computer.
• In addition the GC3 has front panel displays for backfill gas flow and pressure, and their remote and manually set setpoints, and front panel switches for manual / automatic control.

<u>No clamping</u>
• Lowering the lift pins without clamping a wafer / substrate to an electrostatic chuck surface is required during wafer acceptance or handoff; and is also possible during processing a wafer if wafer lateral retention is sufficient to prevent the wafer from shorting to the outer rf shielding guard ring. In general this will be possible only with the "consumable surround ring" and "retainer ring" chuck designs (see the "Chuck Edge Design" document). Alternatively a carrier wafer could be used (see below), or a special passive metal puck which incorporates a lateral retainer used in place of the cooling electrostatic surface puck.

• Clamping voltage should NOT be turned off at the front panel of the DR4 Driver, or by opening its high voltage interlock line, to lower lift pins without grip. The GC3 backfill setpoints would have to be zeroed to prevent backfill gas flow, and the serial port would output a fault "beep" when gripping in this mode. Instead, the GC3 has a 'lower without grip' mode and this should be done. Such a mode is used when lowering wafer lift pins during wafer handoff and acceptance, and is simpler than the above 'fakeout' methods.

• The DR4 driver can be "fooled" into thinking that a wafer and chuck are present, even if they are not, using a serial port override command. This will enable grip and release "operations" to be performed, keeping the remainder of the system operating.

<u>Backside carrier film</u>
• Small wafers can be mounted onto a larger electrostatic chuck using a carrier film, with a supporting surround Si ring. Such a carrier film of polyester or similar material permits electrostatic gripping of both surround ring and central wafer.
• Cooling will be poor due to the lack of backfill gas under the wafer being processed.
• Wafer sensing will be altered and should be "learned" using the serial port setup commands for this new condition.

<u>Backside carrier wafer / disk</u>
• Wafers or fragments can be heatsunk onto a carrier Si wafer using silicone diffusion pump oil or wax for small fragments.
• Silicone grease, wax, 'Woods metal', In, or Ga must be used for larger pieces close to full wafer size, where pump oil would ooze out and around the carrier wafer edge.
• System operation and device cooling will be almost the same as with a virgin wafer; no adjustments should be required.

<u>Operation without a wafer present (chuck cleaning)</u>
• Clean with inert or non-etching gases for longest chuck lifetime
• Gas backfill and appropriate driver settings must be as for the "No clamping" case above, to force zero backfill gas flow and zero applied electrode voltages.

FAULT MODES AND SIGNALLING
The GC3 outputs single words describing the actions being taken and has various debugging modes. The GC3 parallel fault line can be programmed to be quiescent or to flash during system fill or purge waiting times, and to be active when preprogrammed wait times have been exceeded. In addition it allows the DRx driver fault output to pass through to the host computer.