ELECTROSTATIC CHUCKS

System Control

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

indicates where we describe Electrogrip product features.

These documents are "works in progress" and will be updated from your comments and questions.

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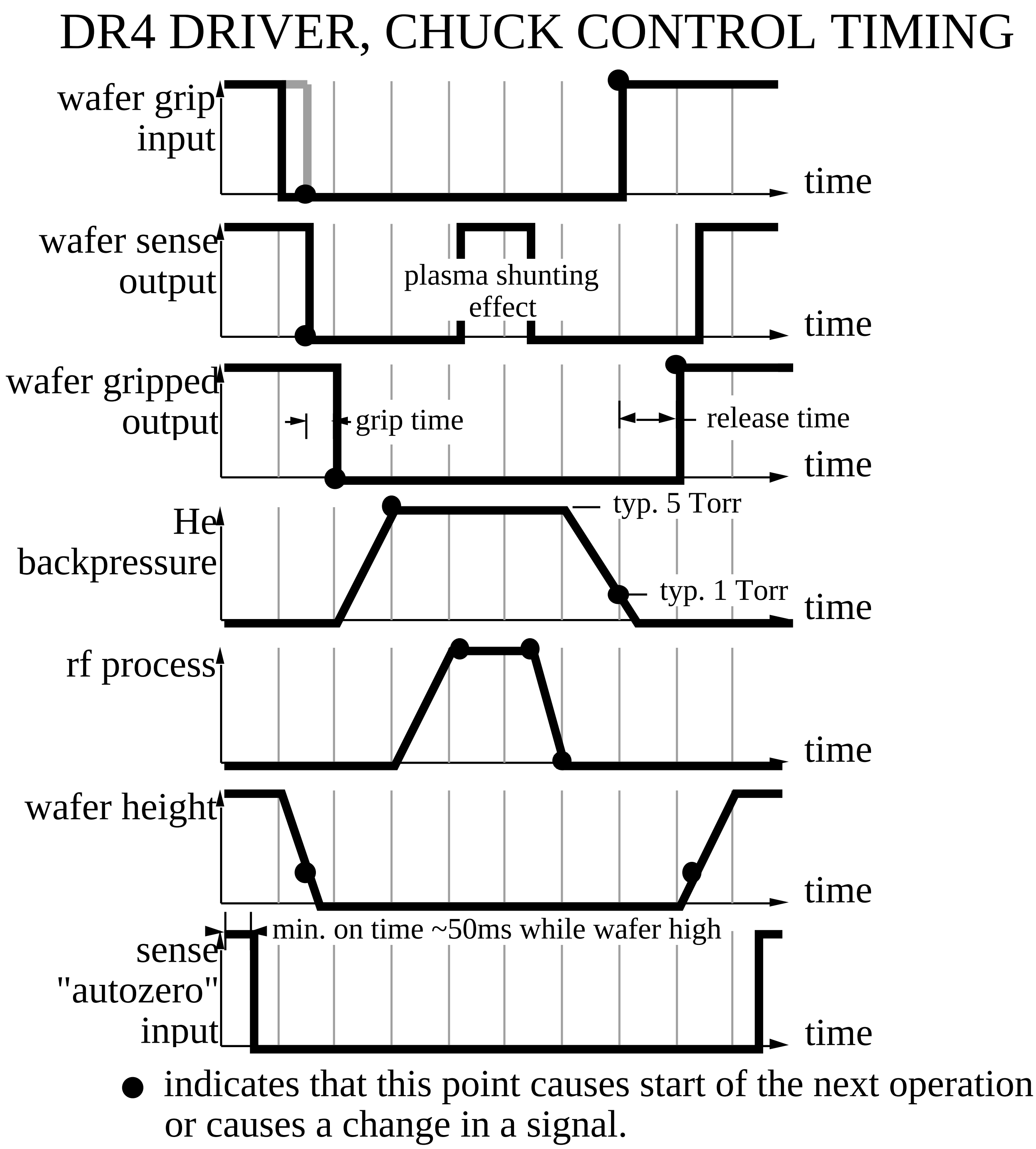
1. NORMAL OPERATION

The figure below shows the sequence of a typical plasma process.



The following page describes each step in detail.

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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 DR4 driver when a wafer is sensed.

The order of these occurrences is somewhat arbitrary since the DR4 will not grip until a wafer is sensed. Hence both conditions must be satisfied before gripping.

However 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.

If this sequence is followed, the height at which the wafer is sensed should be programmed into the DR4 driver setup parameters. There are 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, the DR4 driver takes 200 - 300ms to attain optimum grip conditions. When grip is attained, its "wafer gripped" output is pulled low. After receipt of a high wafer grip input signal, commanding wafer release, the DR4 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.

He backpressure

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 two causes.

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).

Rf process

After attaining the correct backfill pressure, the rf process is initiated by a signal from the GC1 Controller. 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.

Wafer height

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

Sense "autozero" input

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.

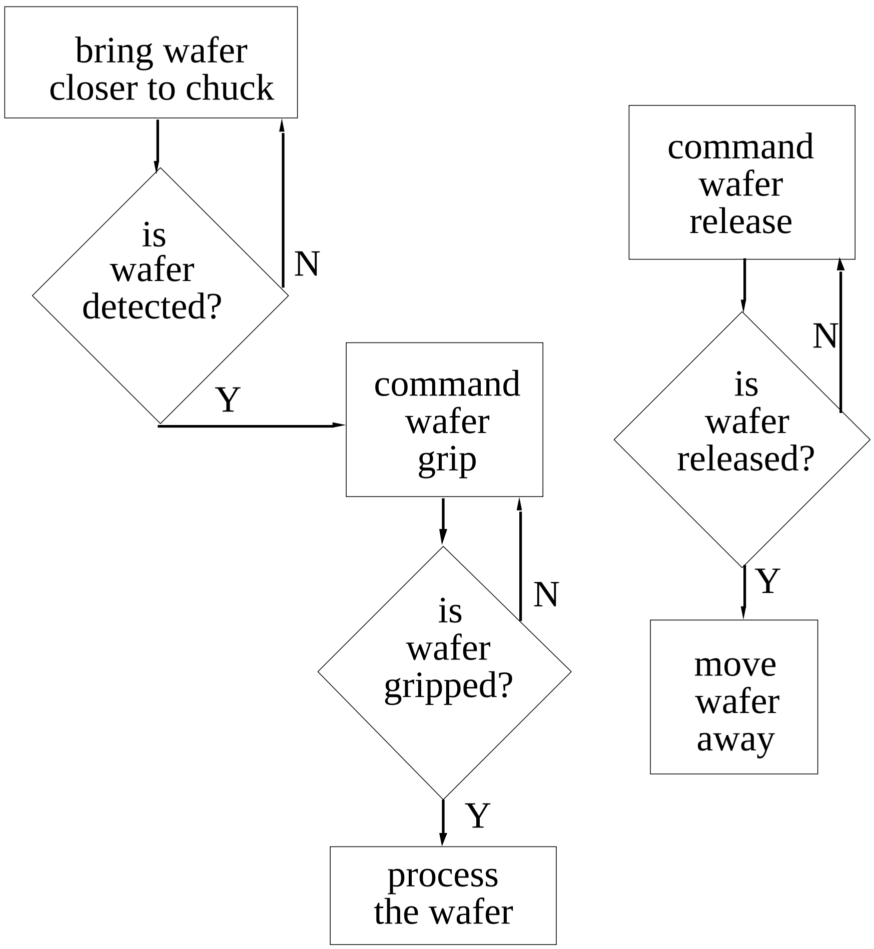
2. DR4 DRIVER INTERFACING

Robotic movement of wafers to and from a chuck surface should follow the following flow diagram. The required wafer detection and grip condition outputs are provided by the DR4 driver.

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

The GC1 system controller executes the sequence below, in addition to cooling gas backfill, monitoring, and purge functions.

ROBOTIC INTERFACE



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There is one rf - isolated connection between chuck and bias decoupler (see the document "Chuck wiring" for more details), and three sets of dc - isolated connections made to the DR4 Driver. The connections are:

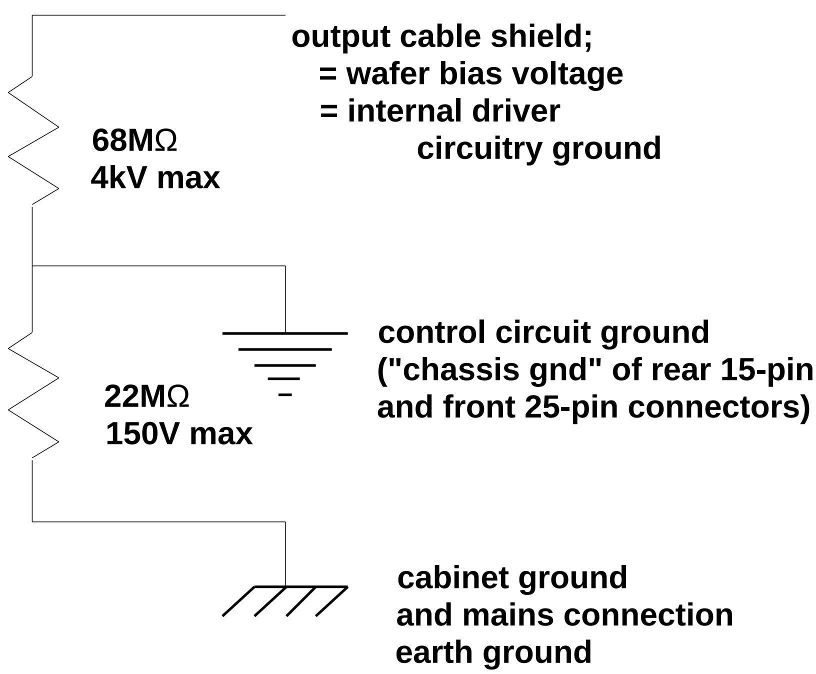
- From chuck to bias decoupler. All such wiring is at rf potential and must be shielded for low rf radiation. However the wiring should not be close to that shielding enclosure; rather, wires to the chuck electrodes must be in intimate capacitive contact with the rf drive line to the chuck baseplate.

- From bias decoupler to driver 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.

- From signal control lines to the driver serial or parallel I/O connectors. These lines are isolated to allow grounding at the signal source, minimising noise pickup. In addition the logic level at the parallel I/O connector is arbitrary, permitting logic supplies as high as 30V. The DR4 logic level transition voltage follows the logic supply midpoint, for optimum noise rejection.

- Power input and grounding to cabinet. The power line (low or high voltage, ac or dc) is isolated to greater than 4kV from all other system components. However the cabinet is also an rf shield for the internal components, and if interference or variability of sense levels is experienced it can help to earth ground the cabinet to the rack mount frame or the vacuum system frame. A jack is provided for this purpose on the DR4 rear.

SYSTEM GROUNDING



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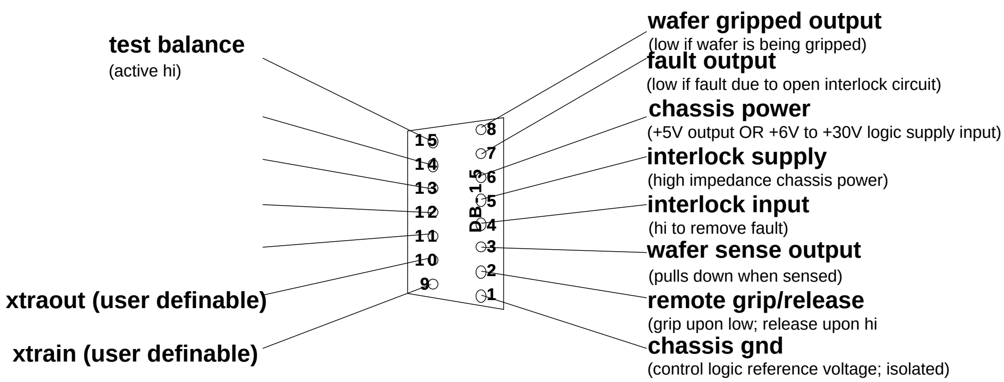
DR4 Driver back panel parallel I/O connections are shown below.

The "test balance", "xtrain", and "xtraout" connections have functions defined when the "Options" menu sets them. Otherwise they are not used.

The minimal connection required is between "interlock supply" and "interlock input". These inputs are often bridged to permit initial bench operation. However as soon as practicable an interlock switch on a high voltage access panel should be wired to this connection to ensure that setup and operation are performed safely.

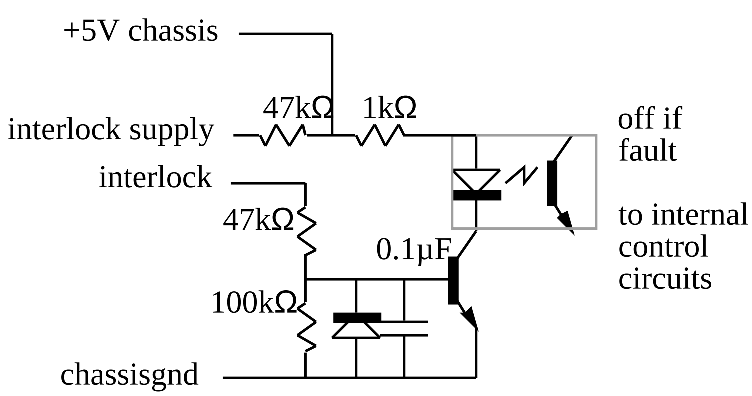
For automatic control from a remote location, wires to remote grip/release, chassis gnd, and chassis power are required. As long as the remote grip/release line is ACTIVELY POWERED to logic high OR to logic low, this line will override the front panel grip/release switch, as evidenced by the front panel "external control" light turning on.

CONTROL CIRCUIT WIRING



Internal high voltage interlock wiring is shown below. "Interlock" may be driven by central control computer logic, or by microswitch closure. Note the high line impedance which renders ground leakage an interlock trip condition, and that open circuit failure in any active device will also cause interlock trip.

INTERFACE; DRIVER INTERLOCK INPUT



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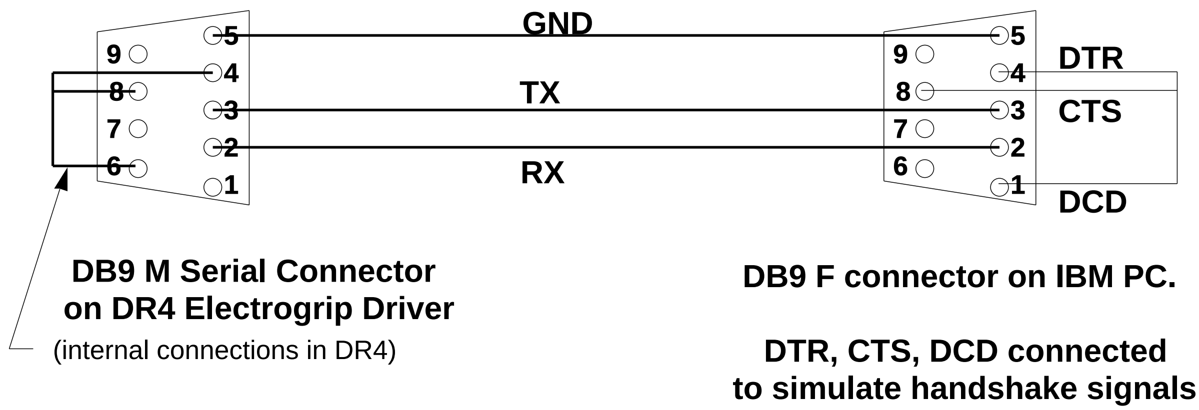
Serial communications are required for initial DR4 Driver setup and for detailed system condition monitoring. Typical connections are shown below, and are used with a separate computer terminal emulator if the Electrogrip DS-1 handheld terminal is not available.

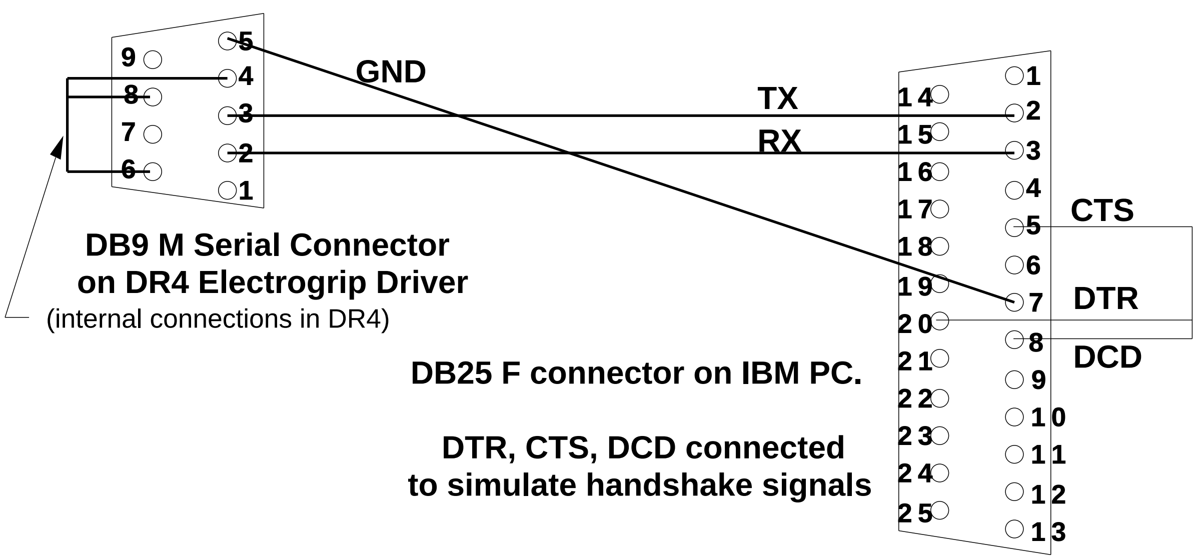
Electrogrip RS-232 Connection
IBM PC-compatible computer

9600 Baud, No parity, 8 bit, one stop, one start bit



Electrogrip RS-232 Connection
IBM PC-compatible computer

9600 Baud, No parity, 8 bit, one stop, one start bit



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3. GC1 CONTROLLER INTERFACING

The GC1 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 GC1 controller facilitates retrofits into existing equipment with simple yet complete system control.

Original equipment manufacturers prefer to perform their own system integration, yielding long-term savings and centralised control of all functions. However the time taken for such integration (at least 3 person-weeks for programming, plumbing, wiring and metalworking) is often forbidding for limited quantity installations.

The Electrogrip GC1 Controller accepts a start/stop signal to initiate sequenced start / stop of an rf-driven electrostatic chuck process. The GC1 Controller interfaces through its back panel connectors and remote connector interface boxes with:

- backfill gas mass flow controller (which also yields the GC1 and pressure gauge power tap-off);
- backfill gas purge valve;
- backfill gas pressure gauge;
- backfill gas pressure output (dummy mfc) line;
- stepper motor rf filter RFF-1;
- stepper motor wafer lifter;
- stepper motor gas purge valve;
- Electrogrip DR4 Electrostatic Driver on its parallel I/O port;
- central control computer.

- In addition the GC1 has front panel displays for backfill gas flow and pressure, and their remote and manually set setpoints, and front panel switches for manual or automatic control.

4. ADDITIONAL OPERATING MODES

No clamping

- Processing without clamping a wafer / substrate to an electrostatic chuck surface is possible 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 can be turned off at the front panel of the DR4 Driver, as well as by opening the interlock line. The serial port will output a fault "beep" when gripping in this mode but will continue with operation. The GC1 backfill setpoints should be zeroed to prevent backfill gas flow.
- 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.

Backside carrier film

- 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.

Backside carrier wafer / disk

- Wafers or fragments can be heatsunk onto a carrier Si wafer using silicone diffusion pump oil for small fragments.
- Silicone grease, 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.

Operation without a wafer present (chuck cleaning)

- Clean with inert or non-etching gases for longest chuck lifetime
- Gas backfill and driver "fooling" must be set as for the "No clamping" case above, to force wafer sensing and zero backfill gas flow.

5. FAULT MODES AND SIGNALLING

The DR4 driver and GC1 controller both update system status on their serial data lines upon any action being commanded, and have parallel port fault outputs:

The DR4 warns with text and a beep if gripping or autozeroing are attempted with high voltage disabled. The DR4 also continuously outputs the output voltage level and sensing signal level in ASCII hex format. It also has extensive debugging and forced operation modes, and can be programmed to perform a variety of special operations.

The DR4 also has a parallel port fault line used to signal high voltage or other major system fault.

The GC1 outputs single words describing the actions being taken and has various debugging modes.

The GC1 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 DR4 driver fault output to pass through.

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