Tadin Tal Advanced Instruments Ltd.
P.O.Box 525, Yokneam 20692, Israel. Phone +972-(0)4-959 1000 Fax: +972-(0)4 –959 1100
http://www.tadin.co.il e-mail: service@tadin.co.il

Tadin Backside Helium Cooling System Monitoring

1. Background

Plasma processes like etch and CVD generate a great deal of heat, much of which dissipates to the wafer in process.

Wafer temperature is an important process parameter, with significant impact on the process quality, such as rate (etch and CVD), layer quality (CVD) and other chemical-physical parameters.

For stable and well-defined process it is absolutely necessary to keep the wafer temperature at a relatively low, uniform and controlled temperature throughout the process time.

200 mm and 300 mm process tools normally use electrostatic chucks for wafer clamping and cooled chucks for wafer heat dissipation to the external cooling media.

The transfer of heat from the wafer to the chuck is strongly dependent on the chuck's and wafer's contact and proximity. As both have hard surface, it is practically impossible to get an overall continuous face-to-face contact, thus only a few points of the surfaces actually touch, while in the majority wafer to chuck area there are air gaps, through which the heat is supposed to be transferred from wafer to chuck.

1.1. The problem

As most processes are run under vacuum conditions, (several milliTorr) the 'air-gaps' are actually vacuum-gaps, through which no heat can be transferred. The result is poor and highly uneven heat transfer resulting in poor wafer temperature control and uniformity.

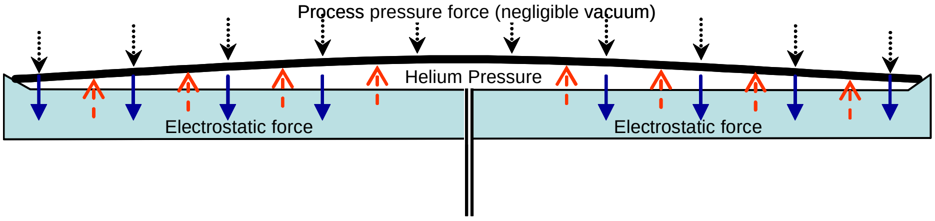
In order to overcome this heat-transfer shortcoming, the gaps between wafer and chuck are filled with low-pressure Helium gas that is used as heat transfer media.

The Helium is selected due to its high heat conduction properties and inertness.
The chuck surface is designed to enable the gas to be equality spread and keep constant pressure between the wafer and the chuck across the entire wafer-chuck area, while sealing the wafer edge by the use of an elastomer to avoid helium leak to the system.

It is necessary to supply enough Helium pressure to enable reasonable heat transfer (strongly dependent on gas density or pressure), while not exceeding a pressure level that will bend the wafer excessively or a pressure that will allow Helium to escape around the edges (let alone to enable the wafer to lose contact or float).

A typical Helium pressure setting is 5-10 Torr, or about 1000 Pa. On a 200 mm wafer this pressure will present about 3 Kg force, while on a 300 mm wafer it will be about 7 Kg. (The balancing chamber pressure of several milliTorr is negligible, and can be considered as absolute vacuum)

A delicate force balance must be maintained between the helium pressure on the wafer back side, and the balancing electrostatic chuck clamping force.

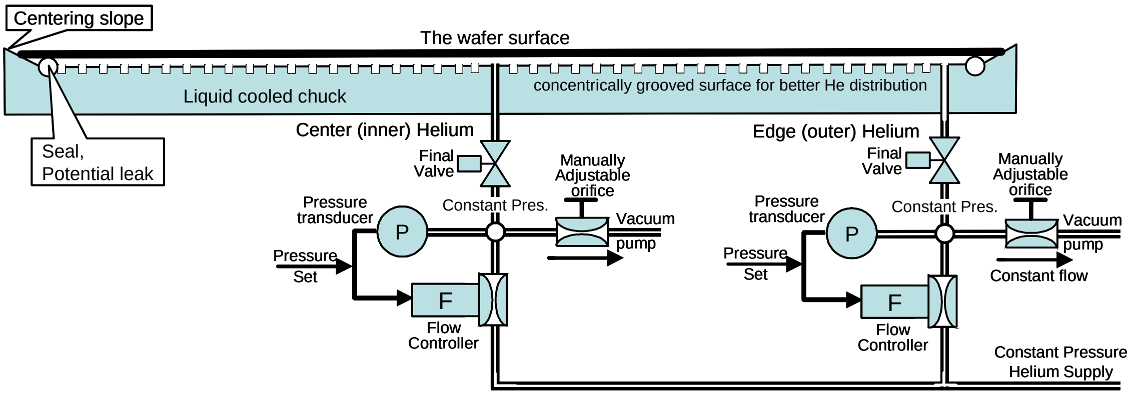


The wafer force balance

2. Backside Helium Pressure Control

For optimal, uniform and repeatable process, it is necessary to maintain the Helium pressure constant and stable.
As the backside Helium pressure is normally supposed to be static (no flow), it is necessary to add a flow in order to control it. The way to maintain the pressure is therefore by applying a higher supply pressure through a flow control valve (Actually a backside He pressure-controlled flow valve), after which a fixed leak orifice to the outer (normally to the vacuum pump) is maintained. Under normal conditions, if no leak is present between the wafer and the chuck, the controlled flow and the fixed orifice leak will be identical and constant, maintaining a fixed backside pressure.

For better gas pressure and temperature uniformity, the chuck surface is normally concentrically grooved and there are two identical Helium injection points: One at the chuck's center ('inner') and the other at the chuck's perimeter ('outer', 'edge').

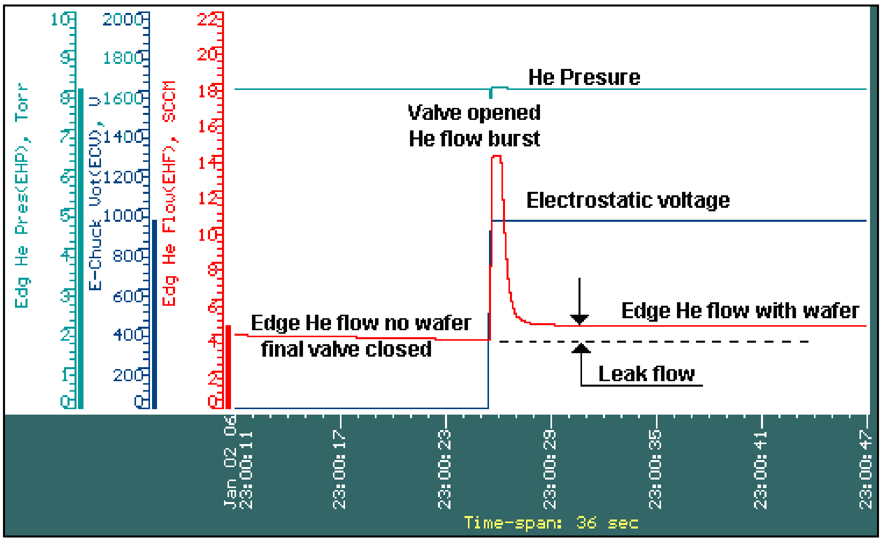


Typical Helium backside cooling arrangement

On loading and unloading, when no wafer is present, an isolation valve between the Helium system and the chuck is kept closed ('final valve') to avoid unnecessary Helium flow into the process chamber, while maintaining the constant pressure of the Helium system.

The Helium flow will be that of the fixed manual leak only.

After a wafer is being placed on the chuck, and ones the electrostatic force is applied, the final valve opens, which cause a temporary flow surge that fills up the chuck-to-wafer gap, until a pressure balance is built. At that balance point the flow is supposed to drop to close to zero, and the pressure reaches its set point.



The Helium flow and the electrostatic voltage

If the wafer is properly set and no leak to the chamber is present, the Helium flow with the wafer on will be identical to the flow with no wafer and final valve closed.

A leak will cause the flow with the wafer to be higher than the flow with the valve closed. The flow difference of the outer system (edge, closer to the surroundings) is a good indication to wafer's cooling and consequently temperature uniformity.

3. The problem

To maintain constant and even Helium back-pressure, both the wafer and the chuck must be reasonably flat, and the wafer centered on the chuck, which is the normal working condition.

Occasionally, a slightly deformed wafer may arrive, a wafer misplacement may occur, a large particle may be present on the chuck, the edge seal may be damaged (scratched, degraded) or the chuck may be degraded to a level that it will not be sufficiently flat or even any more.

If one of the above mentioned conditions occur, the result may be poor contact between the wafer perimeter and chuck, resulting in Helium leak to the system.

Such helium leak will lead to Helium flow in certain areas between the wafer and the chuck,, resulting in non-uniform pressure, and consequently non uniform heat transfer that will further lead to poorly controlled and non-uniform wafer temperature.

4. Backside Helium leak detection

If a leak is present between the chuck and the wafer for whatever reason, the back-pressure will drop. Consequently, the closed loop pressure control will increase the controlled flow to compensate for the leak, in order to maintain the pressure.
The controlled flow will now increase, and be higher than normal, which is the fixed orifice flow.

By observing this control valve opening magnitude, one can tell if the wafer-to-chuck sealing is sufficient to maintain constant pressure.

Under ideal conditions, just measuring the absolute pressure would suffice, but for practical reasons this is not quite as simple as it looks, for several reasons, such as he Helium supply pressure may vary, some inconstant leak will always prevail, the controlled flow may vary for different type wafers, processes, chuck, etc.

It is therefore preferably to use a relative measurement rather than an absolute one.

5. Tadin's solution

5.1. General

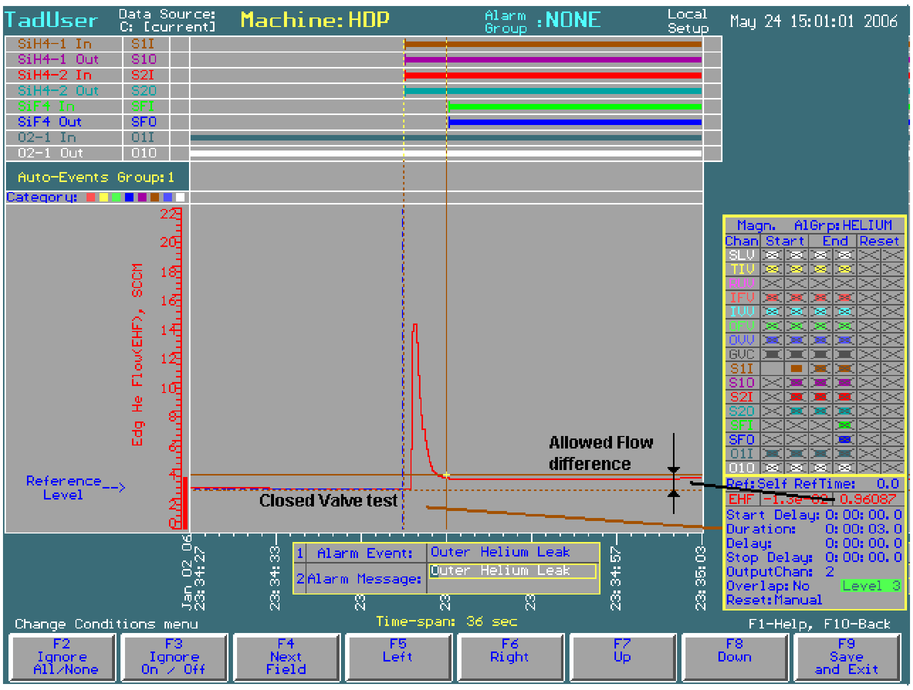
Tadin's TadiGuard can measure the flow **difference** between the flow with the final valve closed, and the flow with the wafer set when the electrostatic voltage is applied.

By setting a warning and alarm levels on that flow difference, the TadiGuard can issue a warning or hold the process in the case of bad process conditions that will lead to out of spec results.

5.2. The Backside Helium test setup

Using the TadiGuard's Relative Alarm setup, the Helium flow for each wafer is measured prior to the wafer clamping, while the final isolation valve is still closed, and the measured value is retained as a reference for current wafer.

After the electrostatic clamping is applied (the electrostatic voltage is monitored), the final valve opens, and a 2 sec. flow burst fills up the wafer to chuck gap. After about 3 Sec. the flow stabilizes, and a second measurement is carried out, and compared to the saved reference. If the flow difference exceeds the pre-set limit, the system will generate an output signal that can be used to alarm, shut off the process, send an e-mail, or any other action to be taken.



1 Alarm Event: Outer Helium Leak
2 Alarm Message: Outer Helium Leak

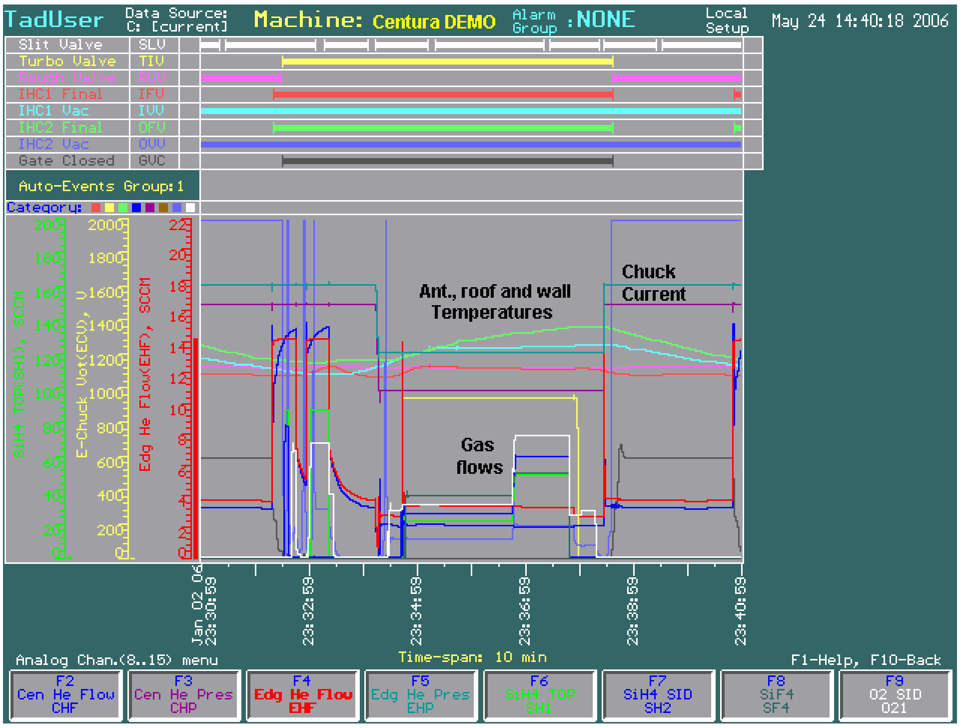
Ref: Self RefTime: 0.0
EHF -1.3e-02 0.96087
Start Delay: 0:00:00.0
Duration: 0:00:03.0
Delay: 0:00:00.0
Stop Delay: 0:00:00.0
OutputChan: 2
Overlap: No Level 3
Reset: Manual

Typical flow test alarm setup

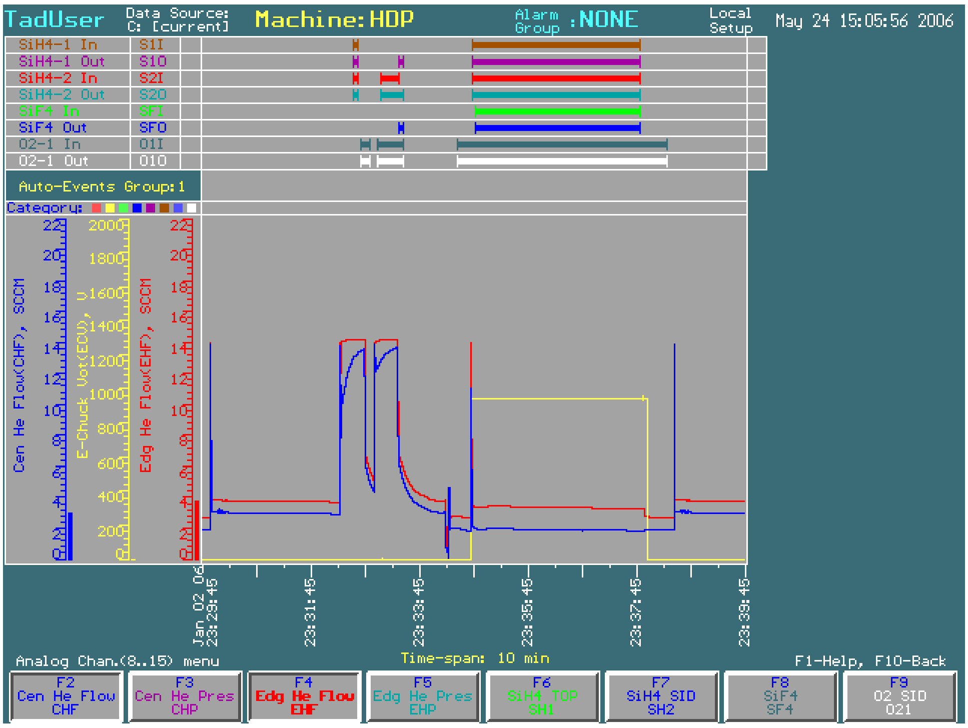
5.3. Bonus functions

In addition to measuring the critical backside Helium flow parameter, the TadiGuard also measures the actual Helium flows and pressure, the electrostatic voltage and current, the Helium and other valves' position (Vacuum, slit, etc.), the chamber pressure, and several additional parameters.

All data are displayed graphically and saved for history for future display and analysis (SPC). Test and alarm levels can be set to each parameter separately, or a combination of several parameters (multivariate).



A typical multivariable display of chamber related parameters



Typical inner and Outer Helium flow patterns with electrostatic voltage