BEST KNOWN METHODS

Transpector® XPR3 Gas Analysis System

DESCRIPTION

The Transpector XPR3 is a third-generation, quadrupole-based residual gas analyzer that operates at PVD process pressures and is the first process monitor with an Electron Multiplier (EM) that can operate at 10 mTorr operating pressures. The XPR3 does not require the large differential pumping system normally required for PVD process monitoring. The XPR3 can operate up to 20 mTorr, and it is linear at pressures up to 10 mTorr. The XPR3 measures major components and impurities common in a process with a 10 ppm detection limit.

Using these recommended Best Known Methods will provide you with a reliable Transpector XPR3 for process monitoring a high pressure application.

XPR3 APPLICATIONS

The XPR3 utilizes a High Pressure MicroChannel Plate Electron Multiplier (HPEM). The HPEM can be used at lower pressures, such as background pressures, and it can also be used at higher pressures, such as process pressures.

The XPR3 is typically used for process monitoring of PVD applications. These applications normally operate in the mTorr range with backgrounds from 1e-6 to 1e-9 Torr. While the XPR3 can be used for other applications where the process pressure is less than 10 mTorr, precautions should be used. Applications that have high levels of hydrocarbon contamination or a significant amount of fluorines, chlorines or halogens are inappropriate for the XPR3.

PHYSICAL INSTALLATION

The XPR3 package includes an interlock weldment approximately 3.6" (91.44 mm) long with a VCR connection tube for the Pirani gauge. The Pirani gauge is used for turning the XPR3 filament off above 20 mTorr and optionally turning the filament back on at pressures below the turn off point.

The XPR3 sensor mounts within the interlock weldment. The weldment must be mounted to the process chamber via a 90° valve (or mitered elbow). This prevents any line of sight plasma from reaching the ion source plate, which prevents any material from depositing on the XPR3 sensor. A heating jacket is provided with the XPR3 package and should be installed over the interlock weldment such that the cable is oriented as seen in Figure 1.

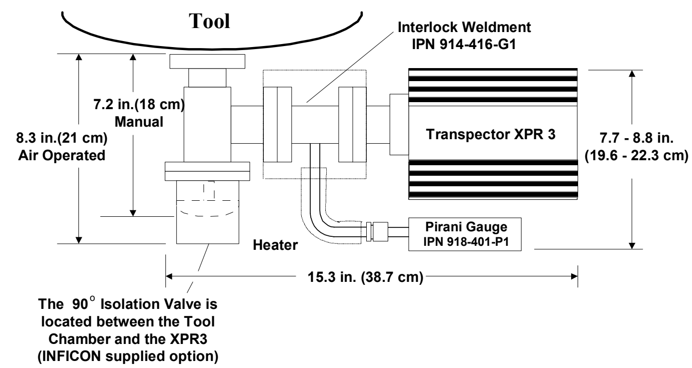


Figure 1

Once the XPR3 sensor, electronics module, valve, and Pirani gauge are installed, the valve should be opened to allow the XPR3 to obtain high vacuum. It is strongly recommended that the XPR3 be kept under high vacuum conditions for at least eight hours before the filament is turned on. It is also recommended that the XPR3 be baked out with the supplied heating jacket (which operates at 150 °C) for a period of at least eight hours. This eight hour minimum bake out is required to reduce residual water vapor levels that may be higher due to local surface outgassing effects. These recommendations should be followed whenever the XPR3 sensor is exposed to atmosphere for long periods of time and will serve to increase sensor life.

PIRANI SET-UP

Clicking first on the **XPR3** icon from the TWare32™ main screen to reach the **Sensor Properties** screen, and then selecting the **TSP User Settings** tab will display the Pirani gauge set points. The **Pressure Interlock Functions** dialog is shown in Figure 2. The **Emission OFF Pirani Interlock** function is automatically enabled and cannot be disabled. The default (and maximum) value for emission off is 20 mTorr. The **Pirani Auto Emission ON** is disabled by default, but can be enabled by checking the box and assigning a value less than or equal to 3.00e-3 Torr.

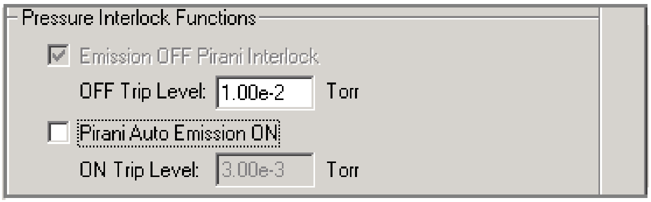


Figure 2

USING THE XPR3

Once the sensor has been conditioned, by baking it out and then keeping it under vacuum, the emission can be safely turned on. At this point, typical uses for the XPR3 would be leak detection, background monitoring, and process monitoring. The following are recommended parameters when operating the XPR3 in any of these applications.

These settings are reached from the Recipe Editor by choosing **Recipe Editor >> Sensor State >> Advanced Functions** (see Figure 3).

- **Baseline** should be enabled by checking the box **Baseline Subtract On** and choosing **Spectra** as the **Baseline Type**. Use the default **Subtraction Masses of 9, 23, 33, and 47**.
- Linearization should always be ON, by checking the box. Use the Factory determined values that have been programmed into the Transpector firmware.
- **Peak Lock** should always be **OFF**, by not checking the box.

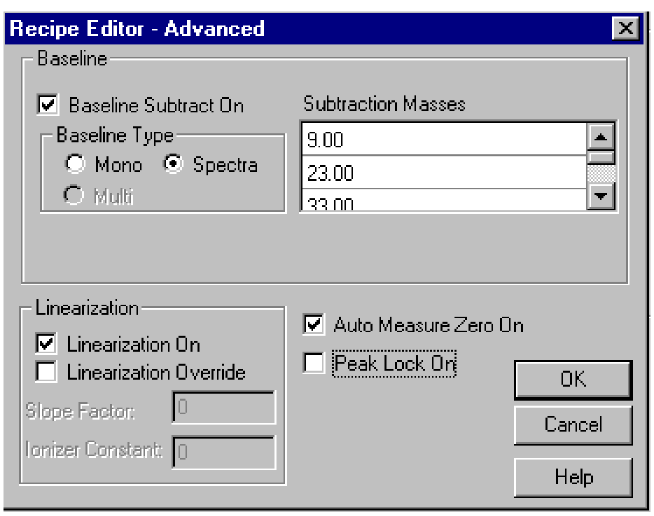
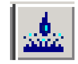
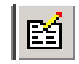


Figure 3

LEAK DETECTION 

Using TWare32, there is no recipe required for operating in Leak Mode. Select the Leak Mode icon as pictured above to default to sampling Helium (Mass 4) over time. When leak checking a vacuum system that has a pressure of $1x10^{-5}$ Torr or lower, the HPEM should be used. The HPEM voltage that is necessary is based on the level of the leak that you are searching for. Adjust the HPEM voltage so that the Helium (Mass 4) signal can be observed, but do not exceed an intensity of 1e-7 amps.

RECIPE GENERATION 

Using the XPR3 for background monitoring or process monitoring is accomplished by creating and running a recipe. The XPR3 user can generate these recipes, or sample recipes can be obtained from INFICON. The recipe file sizes are rather small (about 1 Kb) and can easily be e-mailed if desired. Please contact INFICON by phone at (315) 434-1128 or by e-mail at reachus@inficon.com.

BACKGROUND MONITORING
BEST PRACTICAL DETECTION LIMITS
BKG-BEST.RCP

For acquiring a spectrum where the full mass range is desired, the recipe parameters should be:

- Spectrum Scanning
- Mass Range 0-50
- 1 point per AMU
- Dwell time = 128 ms
- EM ON
- EM voltage set for 300 gain The EM voltage is set for 300 gain at the Factory, and may require periodic adjustment depending on the current levels delivered to the EM.
- Electron Energy = 40 eV

The above recipe will provide the best results for background monitoring, but will take approximately 11 seconds for one scan. See Figure 4 for typical background results.

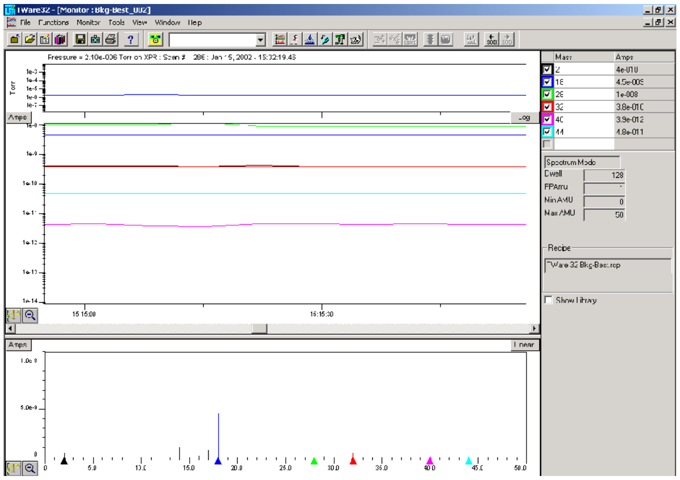


Figure 4

BACKGROUND MONITORING FAST RESULTS - BKG-FAST.RCP

Faster scanning can be accomplished, but detection limit and accuracy will be sacrificed. For faster scanning, the dwell time can be reduced to 32 ms. This will lower the scan time to about 4 seconds.

PVD PROCESS MONITORING WITH ARGON PROCESS GAS: BEST RESULTS - PRO-BEST.RCP

Since it is assumed that speed is very important in monitoring various gases during the process, Selected Peaks mode should be used instead of Spectrum Scanning. The recipe parameters should be:

- Electron Energy = 40 eV
- EM ON with a gain set to 300. The EM voltage is set for 300 gain at the Factory, and may require periodic adjustment depending on the current levels delivered to the EM.

While the masses to be sampled are customer selectable, the following masses and dwell times are recommended for a typical PVD application involving Argon process gas: (see Table 1).

Table 1 Recommended Masses and Dwell Times for Typical PVD Applications

Mass	Species	Dwell Time	Multiplier
2	H_2	32 ms	1
18	H_2O	128 ms	1
28	N_2 / CO	128 ms	1
32	O_2	128 ms	1
36	Ar^{36}	32 ms	297*
44	CO_2	128 ms	1
Optional: 15 or 42	Hydrocarbons	128 ms	1

* Multiplier is derived from the natural abundance of Ar^{36} in Argon gas: 100/.0337 = 297

CAUTION

Do not scan over any peak with the EM ON that produces ion currents in excess of 1e-7 amps. For example, do not scan over Mass 40 Argon in a PVD process involving Argon gas since this mass will produce large peaks. Use Mass 36 Argon isotope as a safe alternative. Scanning over any large ion currents for extended periods of time will damage the Electron Multiplier and substantially shorten its lifetime.

This recipe will take about 3 seconds per scan and will produce results similar to those shown in Figure 5. Peaks for hydrocarbons can be added at mass 15 and/or 42.

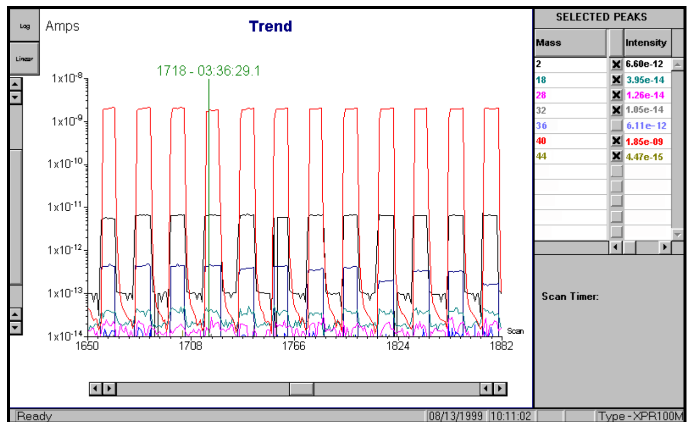


Figure 5

PVD PROCESS MONITORING WITH ARGON-NITROGEN PROCESS GAS

For metal-nitride processes, the presence of nitrogen can also generate high ion currents at Mass 28. For these processes, alternate recipes are recommended with peaks listed in Table 2.

Table 2 Recommended Peaks for Metal-Nitride PVD Process Using Argon-Nitrogen Gases

Mass	Species	Dwell	Multiplier
2	H_2	32 ms	1
14	N_2 / CO	128 ms	25 **
18	$H_2 0$	128 ms	1
32	O_2	128 ms	1
36	Ar^{36}	32 ms	297
44	CO_2	128 ms	1
Optional: 15 or 42	Hydrocarbons	128 ms	1

** Default value. Sensor specific value can be found by FC measurement of N_2: Multiplier = I(28)/I(14)

CAUTION

Do not scan over any peak with the EM ON that produces ion currents in excess of 1e-7 amps. For example, do not scan over Mass 28 Nitrogen in a PVD process involving Argon-Nitrogen gas since this mass will produce large peaks. Use Mass 14 Nitrogen isotope as a safe alternative. Scanning over any large ion currents for extended periods of time will damage the Electron Multiplier and substantially shorten its lifetime.

PVD PROCESS MONITORING WITH ARGON-OXYGEN PROCESS GAS

For metal-oxide processes, the presence of oxygen can also generate high ion currents at Mass 32. For these processes, alternate recipes are recommended with peaks listed inTable 3.

Table 3 Recommended Peaks for Metal-Oxide PVD Processes Using Argon-Oxygen Gases

Mass	**Species**	**Dwell**	Multiplier
2	H_2	32 ms	1
16	O_2	128 ms	15 ***
18	H_20	128 ms	1
28	N_2 / CO	128 ms	1
36	Ar^{36}	32 ms	297
44	CO_2	128 ms	1
Optional: 15 or 42	Hydrocarbons	128 ms	1
*** Default value. Sensor specific value can be found by FC measurement of O_2: Multiplier = I(32)/I(16)			

CAUTION

Do not scan over any peak with the EM ON that produces ion currents in excess of 1e-7 amps. For example, do not scan over Mass 32 Oxygen in a PVD process involving Argon-Oxygen gas since this mass will produce large peaks. Use Mass 16 Oxygen isotope as a safe alternative. Scanning over any large ion currents for extended periods of time will damage the Electron Multiplier and substantially shorten its lifetime.

PREVENTIVE MAINTENANCE

The XPR3 sensor has yttria-coated iridium filaments with a defined lifetime as well as a high-pressure electron multiplier that may degrade over time.

XPR3 FILAMENT

The XPR3 filaments should last a minimum of 4000 hours when following these Best Known Methods. It is strongly recommended that the filaments be replaced after 4000 hours of operation (approximately six months of continuous operation).

CAUTION

If the filaments are not replaced and are allowed to burn out, coating from the filament could contaminate the ion source plate and create electrical shorts preventing operation with a new set of filaments.

The yttria-coated filament kit (INFICON part number 914-022-G2) is field replaceable. Replacement instructions are included in the filament kit and in the Transpector XPR3 Operating Manual (INFICON part number 074-378).

To determine how many hours the filaments have been operational, click on the **XPR3** icon from the TWare32 main screen to reach the **Sensor Properties** screen and then select the **Maintenance** tab. The information displayed is shown in Figure 6.

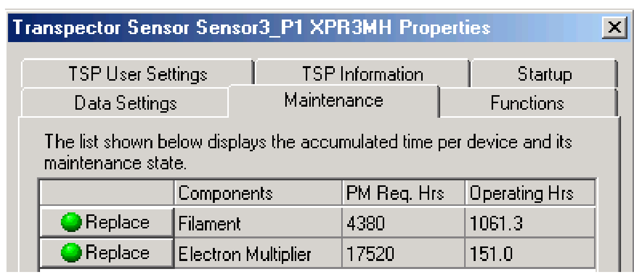


Figure 6

HIGH PRESSURE ELECTRON MULTIPLIER

Since the HPEM is used at background and process pressures, the EM hours will mirror those of the emission hours. The HPEM gain may degrade over time and it is recommended to replace the EM when the EM voltage can no longer be adjusted to achieve a 300 gain. It is expected that the HPEM will last longer than one year, when used continuously.

The HPEM degrades from monitoring high ion currents. Figure 7 shows estimated age for the EM as a function of process pressure for common gas mixtures and for monitoring different peaks. The plot highlights the increased lifetime advantage of measuring the recommended mass peaks. [These are estimates based on test data. Individual HPEMs may have different lifetimes depending on usage history.]

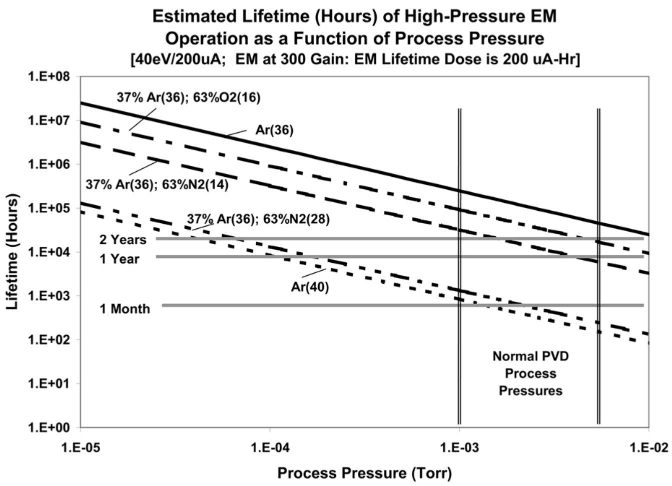


Figure 7

MASS SCALE TUNING

Another part of preventative maintenance is checking the functional operation of the XPR3. This includes the mass position and mass resolution of the instrument. While this mass scale tuning is accomplished in a similar fashion to any other Transpector, the XPR3 does have some slightly different values for peak width adjustment.

The grid on the right of the screen shown in Figure 8 shows the typical masses from a factory calibration gas mixture. The TWare32 Operating Manual (INFICON part number 074-334) provides details on how to tune the resolution and mass position for any Transpector and the following sections are to be used for mass scale tuning in the field.

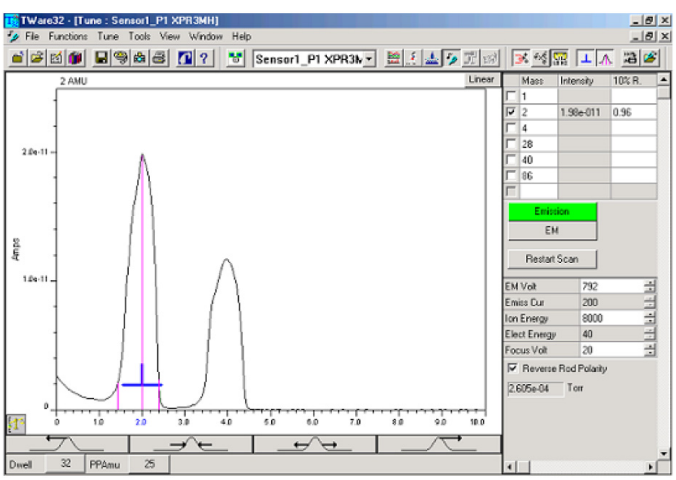


Figure 8

MASS SCALE TUNING AT BASE PRESSURE

Mass scale tuning can be done at base pressure using the background peaks of water vapor (18 AMU) and Nitrogen (28 AMU). The following procedure should be used to check peak location and peak widths at mass 18 and mass 28 and to make adjustments as needed.

CAUTION

Do not attempt to remove masses 1, 2, 4, or 86 AMU from the Tune Table or adjust the resolution at these masses.

1. Open the Tune window and set the points per AMU to 25 for all Tune masses.
2. If necessary, enable the Low energy setting: 40 eV (200 μA emission).
3. Delete mass 40 from the Tune Table and insert mass 18 AMU into the Tune Table.
4. Turn on the Electron Multiplier so that the mass 18 and 28 peaks are visible in the 5e-11 amp range (or greater). It might be necessary to increase the dwell time so that the amount of noise on the peaks is reduced.
5. Adjust the peak width and peak position of mass 18 and/or 28 AMU as needed. Set the peak width of these masses to 1.00 +/- 0.04 AMU wide at 10% of the peak height. Also set the peak position to nominal mass.
6. Save the mass calibration upon exiting Tune mode.

NOTE: Do not attempt to add or delete Tune masses prior to exiting Tune mode.

MASS SCALE TUNING WITH PROCESS GAS

For mass scale tuning at process pressures, the following procedure should be used to adjust the Argon (40 AMU) and/or Nitrogen (28 AMU). This tuning procedure can be used for Argon, Argon-Nitrogen, or Argon-Oxygen processes.

NOTE: For this mass scale tuning procedure, the Tune Mass Table should be the default Tune list, which is masses 1, 2, 4, 28, 40, and 86. If this list is not present when the Tune window is opened, modify the Tune Mass Table as necessary to show only masses 1, 2, 4, 28, 40, and 86.

CAUTION

Do not attempt to remove masses 1, 2, 4, or 86 AMU from the Tune Table or adjust the resolution at these masses.

1. Open the Tune window and set the points per AMU to 25 for all Tune masses.

2. If necessary, enable the Low energy setting: 40 eV (200 µA emission). Turn off the EM so that the XPR3 is operating in the FC mode.
3. Adjust the dwell time as needed to reduce the amount of noise on the peaks.
4. Adjust the peak width and peak position of mass 28 and/or 40 AMU as needed. Set the peak width of these masses to 1.00 +/- 0.04 AMU wide at 10% of the peak height. Also set the peak position to nominal mass.
5. Save the mass calibration upon exiting Tune mode.

NOTE: Do not attempt to add or delete Tune masses prior to exiting Tune mode.

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