

# UHP GASES

GAS ANALYSIS MAGAZINE

ISSUE  
TWO - 2018

SUPPORTING YOUR UHP GAS AND  
SEMICONDUCTOR APPLICATIONS

## PRODUCT FOCUS

The SERVOPRO MultiExact  
4100 analyzer

## APPLICATION STUDY

Plasma Emission Detector technology

## EXPERT ADVICE

Servomex's total solution for UHP  
gas analysis



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# EVEN BETTER UHP SUPPORT

OUR TEAM IMPROVEMENTS WILL DELIVER INCREASED EXPERT SUPPORT FOR CUSTOMERS

For many years, Servomex has delivered expert support for customers in the Ultra High Purity (UHP) gas and semiconductor industries.

Using that experience, we continue to look for ways to ensure we can make our service even better.

That's why we recently reorganized our team to make it easier than ever to access the sales and service knowledge you need.

UHP gas and semiconductor markets will now be served by the Purity and Specialty Division, which is focused on delivering our application-based expertise to customers.

It's the next step forward following the further development of our US Technical Center (US TC) in Woburn, Massachusetts, which has become a hub for industrial gas, UHP and semiconductor analysis, driving the development of new products while remaining dedicated to customer support.

I will oversee the new Purity and Specialty team in my role as Global Sales Manager, with the experienced and expert support of Senior Global Product Managers Douglas Barth and Charles Segar.



Douglas has a wealth of experience working in the industry globally to assist customers in their complex application needs. He is responsible for UHP products manufactured in the US TC, including the DF-500 and DF-700 ranges. Email: [dbarth@servomex.com](mailto:dbarth@servomex.com)



Charles has been with Servomex for 23 years and is responsible for products manufactured at the UK Technical Centre. He manages the UHP process gas chromatograph product line, including the SERVOPRO Chroma and SERVOPRO NanoChrome. Email: [csegar@servomex.com](mailto:csegar@servomex.com)

We are supported by a global network of Regional Sales Managers and their teams, all ready to supply the solutions and expertise to help you overcome the process challenges you may face in 2018 and beyond. Contact us today to find out more.



**Jim Belanger**

Global Sales Manager,  
Purity and Specialty Division

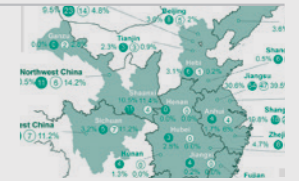
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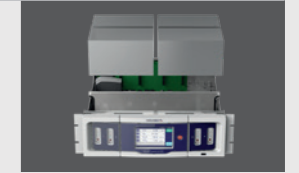
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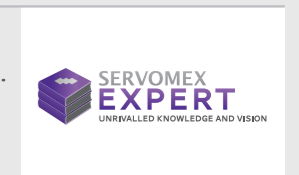
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Discover Servomex's expert support for UHP gas analyzers.



# SEE THE FULL PICTURE ONLINE

## SERVOMEX OxyDetect

Our non-depleting Paramagnetic oxygen monitor available for safe and hazardous areas – see the benefits



## DF-500 RANGE

Servomex's ultra-trace ppt oxygen analyzer range, with updated firmware for lower detection levels



## INSIDE SERVOMEX USA

Explore our manufacturing base for oxygen and moisture analyzers, and hub for global IG and semiconductor support



## DF-700 RANGE

See all the benefits of our ultra-trace moisture analyzers, monitoring high performance in specialist environments

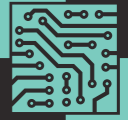


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See our latest product ranges.  
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## CHINA'S SEMICONDUCTOR MARKET CONTINUES TO BOOM

With an ever-expanding electronics and telecommunications industry, China has long been a major player in the semiconductor market, and since 2012 has accounted for more than half the global market.

To meet this growing consumption, China's manufacturing output has increased at a similar pace.

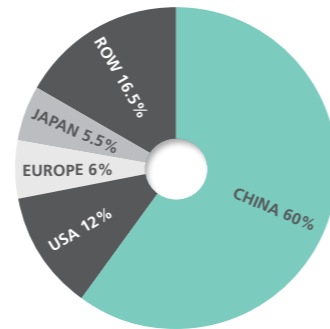
Annual revenue from Chinese semiconductors reached \$78bn in 2017, an increase of 19.4% on 2016.

For comparison, the average worldwide growth in revenue was 3.4%.

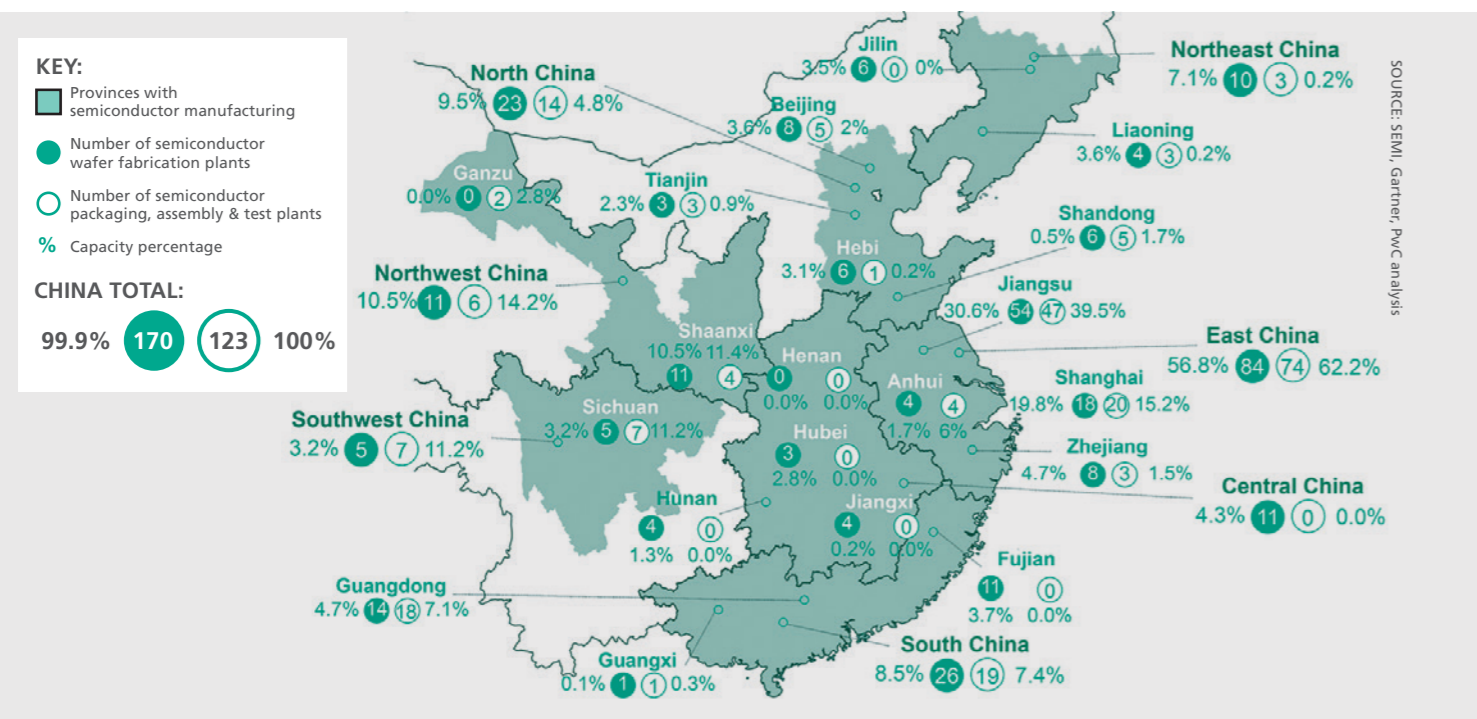
In 2016, at least 293 semiconductor wafer fabs or packaging and testing plants were recorded as operating across 20 different provinces in China. This compares with 313 in the US.

Given the current rate of expansion, it is predicted that China will overtake the US as the world leader in the global semiconductor market by 2022.

GLOBAL SEMICONDUCTOR CONSUMPTION



DATA: PwC 2016



SOURCE: SEMI, Gartner, PwC analysis

### INCREASING INVESTMENT IN FABS

China is expected to emerge as the largest spending market for fab equipment in the next two years, with more than 20 new fab projects under way or announced since 2016.

Spending on fab equipment grew by 180% in the period from 2006 to 2016, going from \$2.3bn to \$6.5bn. In contrast, spending in both North America and Europe declined by 39%, and Japan's spending fell by 50%.

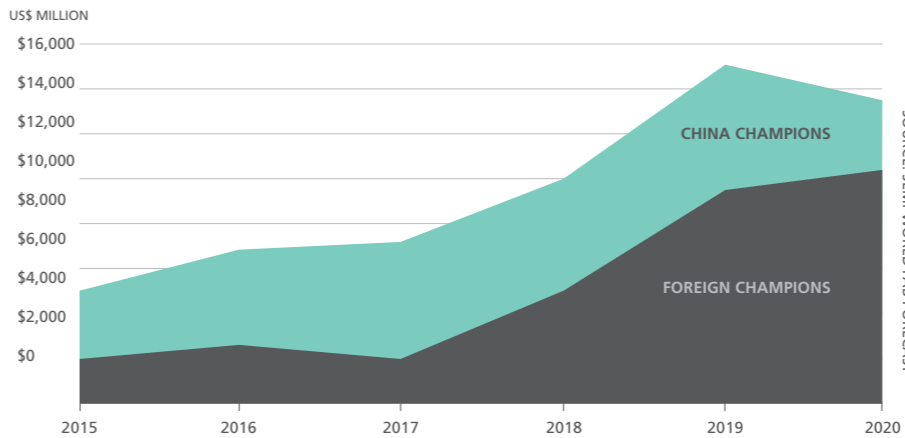
Statistics from 2016 show China's spending was still behind that of Taiwan (\$12.2bn) and South Korea (\$7.7bn), but it is expected to surpass both by 2019.

China's growth in the market is likely to be more moderate, but sustainable, over the next few years, boosted by government incentives and strong market conditions.

This sustained increase in investment represents an important opportunity for companies providing equipment, materials, services, critical systems and more.

In addition, the drive to introduce smaller chip sizes is leading to a requirement for UHP gases to achieve even more stringent levels of purity with a high degree of reliability.

### CHINA FAB INVESTMENT BY PARTIES



### THE SERVOMEX SOLUTION

Servomex delivers the high-precision analysis required for this demanding industry, with the lowest detection limits available for oxygen and moisture.

Our reliable analyzer range is backed by expert sales, application and service support, enabling us to provide the systems required by both semiconductor manufacturers and the UHP gas suppliers that supply them.

Our Asia Pacific semiconductor team, led by Chee Wee Yap, the region's Purity & Specialty Sales Manager, supports fabs in China, and UHP gas suppliers, through Servomex's Shanghai Business Centre.

**SERVOPRO NanoChrome**

A high-performance analyzer designed specifically for the semiconductor manufacturing industry, the NanoChrome provides ultra-trace monitoring of UHP gases using Plasma Emission Detector sensing technology.

Find out more: see page 22

**DF-500 Range**

A range of ultra-trace oxygen analyzers, the DF-500 range has been verified by independent experts as measuring oxygen to the lowest parts-per-trillion levels available, using non-depleting Coulometric sensing technology.

Find out more: see page 18

**DF-700 Range**

A sophisticated set of process moisture analyzers, the DF-700 range provides a comprehensive solution for trace and ultra-trace moisture measurement, using advanced Tunable Diode Laser absorption spectroscopy technology.

Find out more: see page 19

*"Servomex's integrated solution for UHP and semiconductors is tried and tested even at the most demanding levels. In addition, we offer in-depth expert advice and support that will be invaluable to customers as the market continues to expand."*

Chee Wee Yap - Asia Pacific Purity & Specialty Sales Manager. Email: cyap@servomex.com



Contact our Asia Pacific Business Centre: +86 (0)21 6489 7570 or asia\_sales@servomex.com

# APPLICATION STUDY

## STABLE AND COST-EFFECTIVE MEASUREMENT OF UHP GASES



In the field of gas chromatography, many sensors are available that cover a broad range of measurements. Each sensor has advantages and drawbacks, so a solid understanding of the different technologies is important.

Thermal Conductivity (TCD) and Flame Ionization Detector (FID) sensors are long-established and are the most widely used measurement technologies. However, a more recent technological development has surpassed their performance, especially when ultra-trace level measurement is required.

FID technology is commonly used for hydrocarbons analysis, being relatively simple to use and offering a very sensitive, selective and linear measurement.

However, this sensor type uses a flame to burn hydrocarbons, which requires air and hydrocarbon-free hydrogen fuel gas. Increasingly stringent health and safety requirements means concerns over using flammable pure hydrogen have been raised by users.

Challenged to find a safer alternative to the FID, Servomex's R&D team undertook extensive research on Servomex's existing Plasma Emission Detector (PED) technology, aiming to improve the technology's sensitivity and identify a configuration specific to hydrocarbons, while avoiding the use of explosive gases.

Their intensive research led to the development of a PED sensor optimized for the trace-level analysis of hydrocarbons.

### ADVANTAGES OF PLASMA EMISSION DETECTOR TECHNOLOGY

#### PLASMA



The new Servomex PED sensor offers many advantages over FID technology. It is very sensitive and selective to any molecules containing carbons (organic or inorganic), being up to 100 times more sensitive than a FID measurement, depending on the carrier gas.

FID sensors are traditionally renowned for sensitivity, with the best FID sensors offering a detection limit between 10 parts per billion (ppb) and 20ppb methane equivalent. This limitation is due to the FID sensor requiring carrier gas, fuel and air to operate, making the

sensor more prone to noise from low-level hydrocarbon contamination from those three potential sources.

Any hydrocarbons contained in any of these gases are ionized by the sensor, causing drift and noise which limits reliable performance for ultra-trace level measurements.

This level of detection is usually acceptable for General Gas (G-Gas) made before the main purifier, which requires a lower detection limit (LDL) of about 10ppb.

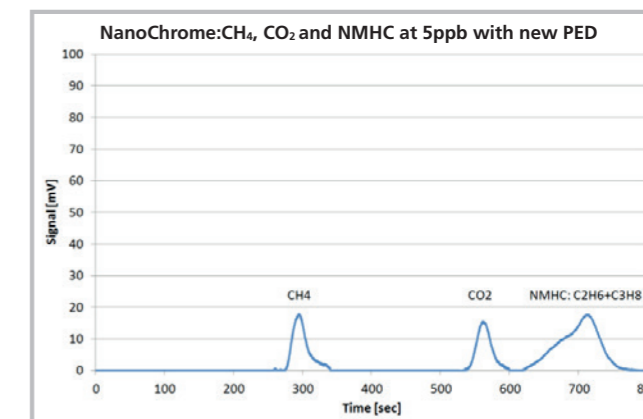
However, the Pure Gas (P-Gas), used inside the fab after the purifier stage, has much lower LDL requirements of 1ppb or less.

As the PED sensor requires only a carrier gas, external contamination from air and fuel is removed. While it is still very important to have a clean carrier gas, techniques exist to obtain a clean helium or argon carrier gas with a total impurity level below 1ppb. In addition, avoiding the use of hydrogen and air reduces cost of ownership, as less gas is consumed and fewer purification systems are required.

There are some limitations to using PED technology. The sensitivity of the measurement means it is suitable only for trace analysis applications (<1000 parts per million). Due to the nature of the plasma, the sensor also exhibits some occasional mild cross-interferences due to the sample matrix, which requires more demanding chromatographic methods – also sometimes the case with FID technology. Overall, however, the PED sensor revolutionizes the analysis of hydrocarbons, CO and CO<sub>2</sub>, improving measurement sensitivity, successfully addressing the safety concerns associated with the use of hydrogen and reducing the cost of ownership.

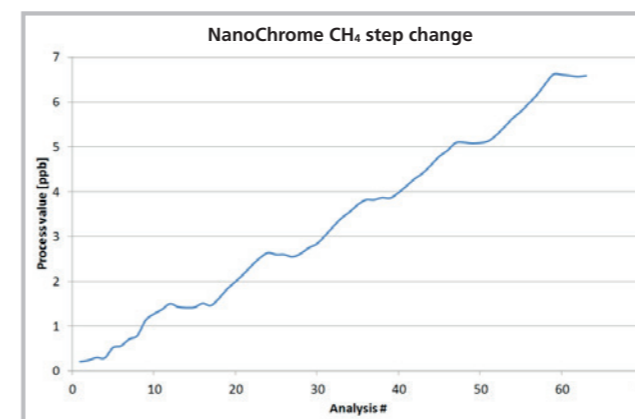
Right: a chromatogram obtained with a PED sensor at 5ppb for CH<sub>4</sub>, CO<sub>2</sub> and NMHC. This chromatogram shows clear sensitivity to hydrocarbons, as well as sensitivity to CO<sub>2</sub> achieved without the use of a methanizer. While a methanizer is always required to measure CO and CO<sub>2</sub> with a FID sensor, it is not required by the PED – improving measurement reliability, avoiding catalyst poisoning risks associated with methanizers and creating a further reduction in cost of ownership.

### PED SENSITIVITY TO CH<sub>4</sub>, CO<sub>2</sub> AND NMHC WITH NanoChrome



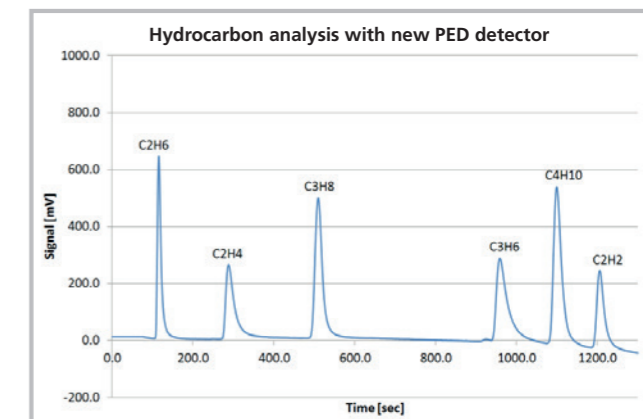
### NEW PED SENSITIVITY STEP CHANGE

A step response using a SERVOPRO NanoChrome analyzer at ppb level, again showing the sensitivity achieved with this sensor. The achievable limit of detection for CO, CO<sub>2</sub>, CH<sub>4</sub> and NMHC is below 1ppb.



### NEW PED RESPONSE TO HYDROCARBONS

A chromatogram obtained for speciated hydrocarbons analysis, showing the PED sensor's clear sensitivity to the different hydrocarbons.



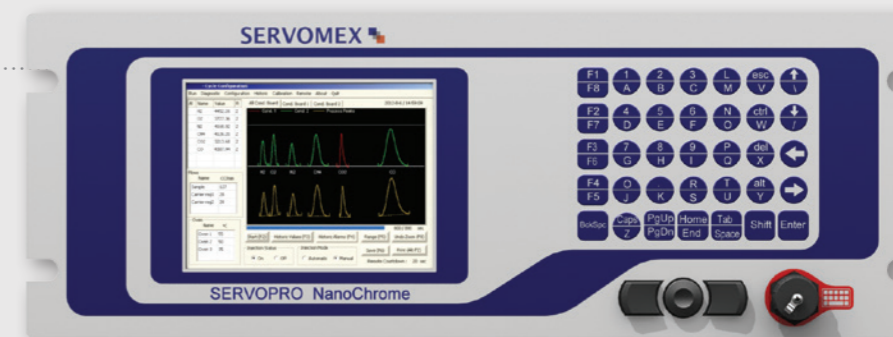
### THE SERVOPRO NanoChrome

The PED sensor is at the heart of the SERVOPRO NanoChrome analyzer, designed to measure ultra-trace levels of impurities in electronic gases.

Offering the most stable P-Gas analysis on the market, even at the lowest levels, the NanoChrome delivers a superb sub-ppb measurement of the contaminant gases and hydrocarbons that can be present at ultra-trace levels in semiconductor manufacture.

It also provides an industry-leading LDL of 0.5ppb for impurities in an oxygen background – this includes measurements for CO, CO<sub>2</sub>, CH<sub>4</sub> and NMHC.

This analytical sensitivity and ultra-stable reliability is enhanced by



advanced signal recovery, utilizing specially developed adaptive chromatographic filtering methods and ProPeak peak detection techniques for a sensitive, selective measurement.

Using a Direct Analysis Methodology, the NanoChrome removes the doubt associated with FID and RGD measurements.

Alongside the DF-500 ultra-trace range and DF-700 moisture analyzer range, the NanoChrome ensures Servomex provides the semiconductor industry with a complete, single-supplier solution for reliable UHP gas analysis.



Download the NanoChrome brochure today: [servomex.com/downloads](http://servomex.com/downloads)

## A STEP FORWARD IN MEDICAL AND INDUSTRIAL GAS ANALYSIS

THE SERVOPRO MultiExact 4100 IS SERVOMEX'S NEW FOUR-MEASUREMENT ANALYZER

Gas analysis has evolved with the launch of Servomex's high-performance digital multi-gas analyzer, the SERVOPRO MultiExact 4100, suitable for a wide range of industrial and medical gas applications.

Configurable with up to four of Servomex's world-leading range of gas analysis sensors in a single package, the MultiExact 4100 is designed to digitally measure simultaneous gas streams including oxygen, nitrogen, methane, nitrous oxide, carbon monoxide, argon, helium and carbon dioxide.

The new MultiExact 4100 is an advanced successor to the SERVOPRO 4100 and SERVOPRO MultiExact 5400 analyzers, using the same tried and trusted sensor technologies while delivering the improved measurement stability of a digital format. It is backwards compatible with existing installations, and complies with the same standards and agreements, so it is easy to upgrade.

New features include advanced communications for remote access, 32 alarms, 32 relays, and intelligent functionality, including independent auto-calibration. It offers the latest digital communications protocols, including 0-10V DC, 4-20mA, RS232, RS485, Serial Modbus, Ethernet Modbus TCP/IP and PROFIBUS.

Low cost of ownership is delivered through Servomex's ultra-stable non-depleting digital sensing technologies, which help extend maintenance intervals.



An independent auto-calibration function helps keep operational and maintenance costs minimal.

It's easy to interact with the MultiExact 4100, using the intuitive, icon-driven color touchscreen. A USB serial port allows data logging and software upgrades, and makes it simple to duplicate analyzer configurations using a thumb drive.

With flexible, customizable analysis solutions capable of meeting specific process monitoring needs, the MultiExact 4100 delivers precise, stable results at every point of the ASU process.

It is also suitable for an extensive range of applications, including bottling/filling plant applications and validation of medical gas purity.

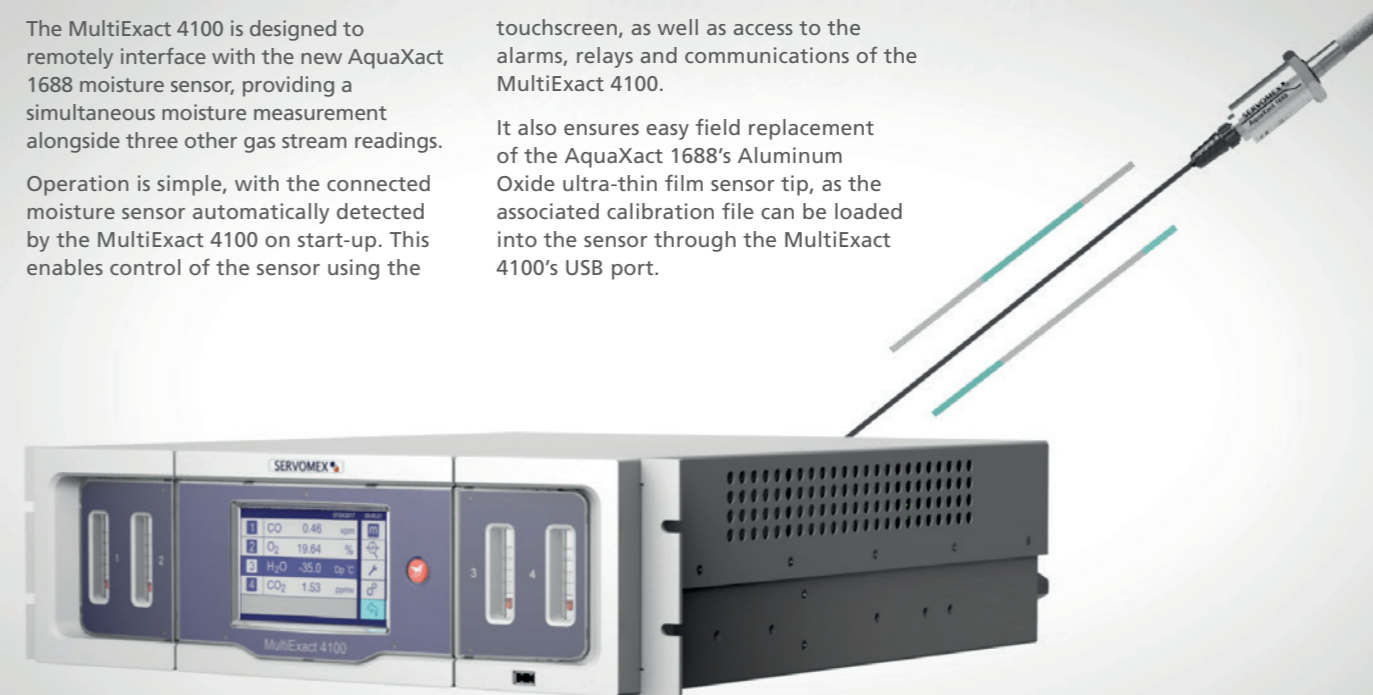
## SEAMLESS INTEGRATION WITH THE AquaXact 1688 SENSOR

The MultiExact 4100 is designed to remotely interface with the new AquaXact 1688 moisture sensor, providing a simultaneous moisture measurement alongside three other gas stream readings.

Operation is simple, with the connected moisture sensor automatically detected by the MultiExact 4100 on start-up. This enables control of the sensor using the

touchscreen, as well as access to the alarms, relays and communications of the MultiExact 4100.

It also ensures easy field replacement of the AquaXact 1688's Aluminum Oxide ultra-thin film sensor tip, as the associated calibration file can be loaded into the sensor through the MultiExact 4100's USB port.



### SENSING TECHNOLOGIES:



### COMPLIANCES:

- UNITED STATES PHARMACOPEIA COMPLIANT METHOD FOR ASSAY OF MEDICAL OXYGEN AND AIR
- EUROPEAN PHARMACOPEIA COMPLIANT FOR MEDICAL OXYGEN AND AIR
- IN COMPLIANCE WITH LOW VOLTAGE, EMC AND APPLICABLE EU DIRECTIVES

### NEW FEATURES INCLUDE 32 ALARMS, 32 RELAYS AND INDEPENDENT AUTO-CALIBRATION



*"The MultiExact 4100 is a new milestone in our continued leadership of multi-gas analysis, delivering a performance that further optimizes processes, improves product yields and ensures high product quality."*

Jim Belanger - Global Sales Manager, Purity & Specialty Division. Email: [jbelanger@servomex.com](mailto:jbelanger@servomex.com)



See the video: [servomex.com/me4100video](http://servomex.com/me4100video)



SERVOPRO MonoExact DF310E  
OXYGEN ANALYZER



AquaXact 1688  
MOISTURE SENSOR



DIGITAL  
SIMULTANEOUS  
ANALYSIS

# DUAL MEASUREMENT SOLUTION FOR OXYGEN AND MOISTURE

THE SERVOPRO MonoExact DF310E AND AquaXact 1688 ARE DESIGNED TO COMBINE FOR SIMULTANEOUS ANALYSIS

Servomex's gas analysis expertise means there's now a single, combined solution for the measurement of oxygen and moisture.

The SERVOPRO MonoExact DF310E digital oxygen analyzer and AquaXact 1688 moisture sensor were developed together at our US Technical Center to ensure seamless integration and a simultaneous dual analysis of oxygen and moisture.

Built around the latest innovations in software and hardware, the MonoExact DF310E provides customers with a choice of accurate, reliable oxygen measurement technologies.

It offers an updated Coulometric sensor, for three different parts-per-million (ppm) ranges, or a non-depleting Paramagnetic sensor, for percentage measurements.

COULOMETRIC



PPM RANGES

PARAMAGNETIC



% MEASUREMENTS

The AquaXact 1688 is a fast-response moisture sensor using stable, sensitive Aluminum Oxide technology. It measures dew point from -100°C to 20°C, and ppm moisture.

With industry-leading sensitivity and stability, the AquaXact is accurate to within ±3°C, and offers repeatability of 0.5°C for a wide range of gas phase process applications.

Working together, they provide an ideal solution for applications that need simultaneous monitoring of oxygen and moisture.

Connecting the AquaXact to the MonoExact DF310E is simple: once the sensor is connected and powered on, the digital analyzer automatically detects it.

This allows control via the color touchscreen, access to eight alarms and eight relays, and advanced digital communication options, including Ethernet, Modbus TCP/IP and PROFIBUS.

It also makes it easy to replace the AquaXact's ultra-thin film sensor tip in the field, without losing measurement quality. Simply upload the calibration file using the USB port on the MonoExact DF310E, so there's no need for return-to-factory calibrations.



TYPICAL DUAL MEASUREMENT APPLICATIONS INCLUDE:

- SOLDER FURNACE MONITORING
- METALS ANNEALING
- AIR SEPARATION
- INSTRUMENT AIR PRODUCTION
- GLOVE BOX PURGING

FEATURES INCLUDE 8 ALARMS, 8 RELAYS AND ADVANCED DIGITAL COMMUNICATIONS

<p>INNOVATIVE SOFTWARE AND HARDWARE</p> <p>COULOMETRIC</p> <p>0-100ppm 0-1,000ppm 0-10,000ppm</p> <p>NEW FOR QUALITY CONTROL</p>	<p>INNOVATIVE SOFTWARE AND HARDWARE</p> <p>PARAMAGNETIC</p> <p>A range of 0-25%</p> <p>NEW FOR PROCESS CONTROL</p>	<p>DEW POINT</p> <p>-100°C to +20°C</p>	<p>ACCURACY</p> <p>±3°C</p>	<p>REPEATABILITY</p> <p>±0.5°C</p>	<p>ANALOG &amp; DIGITAL OUTPUTS</p> <p>4-20mA RS232 RS485 Ethernet TCP/IP Modbus RDU PROFIBUS</p>
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Get the combined solution for your process and watch the videos today:  
[servomex.com/medf310evideo](http://servomex.com/medf310evideo) [servomex.com/aqua1688video](http://servomex.com/aqua1688video)

# PROCESS STUDY FROM PMS



This edition of UHP magazine features a guest article by Servomex's sister company Particle Measuring Systems (PMS), which we think our UHP readers will find valuable.

Setting the standard for contamination monitoring, PMS specializes in viable and non-viable particle counters that measure impurity levels in clean, controlled environments.

Like Servomex, it is part of the Spectris Group, a leading supplier of productivity-enhancing instrumentation and controls. Find out more about PMS at [www.pmeasuring.com](http://www.pmeasuring.com)

# NANOPARTICLE MONITORING IN ULTRA-CLEAN MANUFACTURING ENVIRONMENTS

The NPC10 is a Condensation Particle Counter (CPC) and is different from traditional 0.1µm OPCs that are based solely on optical light scattering.

The Nano-ID® NPC10 NanoParticle Counter can detect 10nm particles and provides a solution for the sub-0.1µm monitoring gap in manufacturing process control and yield enhancement initiatives in the semiconductor and data storage industries.

The instrument is suitable for use in routine production tool monitoring, as well as during preventive maintenance and qualification. It is commonly used for troubleshooting yield problems related to particulate contamination and as a complementary monitoring instrument to traditional portable and fixed 0.1µm aerosol counters.

The instrument is designed for use in very clean areas such as ISO Class 1 and 2, does not require any user upkeep, and operates continuously and unattended.



NPC10 Condensation Particle Counter (CPC)

# PROCESS STUDY FROM PMS

## CPC TECHNOLOGY

The NPC10 works by growing nanometer-sized particles in the aerosol sample into micrometer-sized particles by passing them through a super-saturated vapor of working fluid and creating conditions promoting the condensation of the fluid on the particle surface.

Consider the original particle serving as a nucleation site for the condensation process. The condensate causes the particles to grow sufficiently in size so that they can be detected and counted using traditional optical light scattering approaches.

The benefit of the CPC is the ability to detect very small particles with the trade-off being that the condensation process lacks size resolution in the growth process. As a result, instruments based on this technique currently provide only a single channel measurement result.

A reasonable argument can be made that multiple channels are not necessary for monitoring ultra-clean manufacturing processes because contamination trends and excursions can be easily identified above background levels using only a single channel of data.

## COMPARISON STUDY

A study was conducted to compare the counting performance of the new, high-flow 10nm instrument with a traditional 0.1µm optical particle counter when monitoring ISO Class 1 to ISO Class 4 environments.

Experimental and field data demonstrate that ISO Class 1 and 2 environments, which have very low concentrations of particles greater than 100nm, can possess much higher concentrations of nanoparticles.

This suggests that the current ISO classification system may be insufficient to properly describe the cleanliness of the high purity environments required for advanced electronics manufacturing.



## SETUP

The experiment compared the Lasair® III 110, a traditional 0.1µm particle counter with six fixed-size channels sampling at 28.3 LPM (1 CFM), to two NPC10 NanoParticle Counters, which counts all particles >10nm in size and samples at 2.8 LPM.

Testing was conducted using a laminar flow hood as a proxy for a manufacturing process or mini-environment. The hood provided high velocity air flow and a

variable speed fan that allowed the cleanliness of the environment to be controlled to the desired cleanroom class.

Additional isolation was used around the sample collection point within the hood to generate the Class 1 environment. The setup allowed small volumes of ambient room air to be introduced on a controlled basis to create the ISO Class 2, 3, and 4 environments.

The test instruments were placed inside the environment and sample inlet tubes of 1 meter and 0.5 meter were attached to the OPC and CPCs, respectively. The inlet end of all three sample tubes were bundled together and attached to a fixed post inside the flow hood. The OPC was first used to determine the class of the environment per ISO 14644.

## RESULTS

Table 1 shows the normalized counts for each of the three instruments under test in each of the ISO environments, and the counting performance of the 10nm and the 0.1µm instruments in ISO Class 1 through 4.

**Table 1. Experimental Test Results Comparing the 10nm NPC10 and the 0.1µm Lasair III 110**

Instrument	ISO Class 1	ISO Class 2	ISO Class 3	ISO Class 4
	Particle counts per m <sup>3</sup>			
Lasair III 110	2.3	49	693	3,480
NPC10 unit 1	93	952	8,160	17,719
NPC10 unit 2	79	669	6,174	13,514
Results Summary				
NPC10 matching	8%	17%	14%	13%
Count ratio NPC10 vs Lasair III 110	37	17	10	4

# NANOPARTICLE MONITORING IN ULTRA-CLEAN MANUFACTURING ENVIRONMENTS

## DISCUSSION

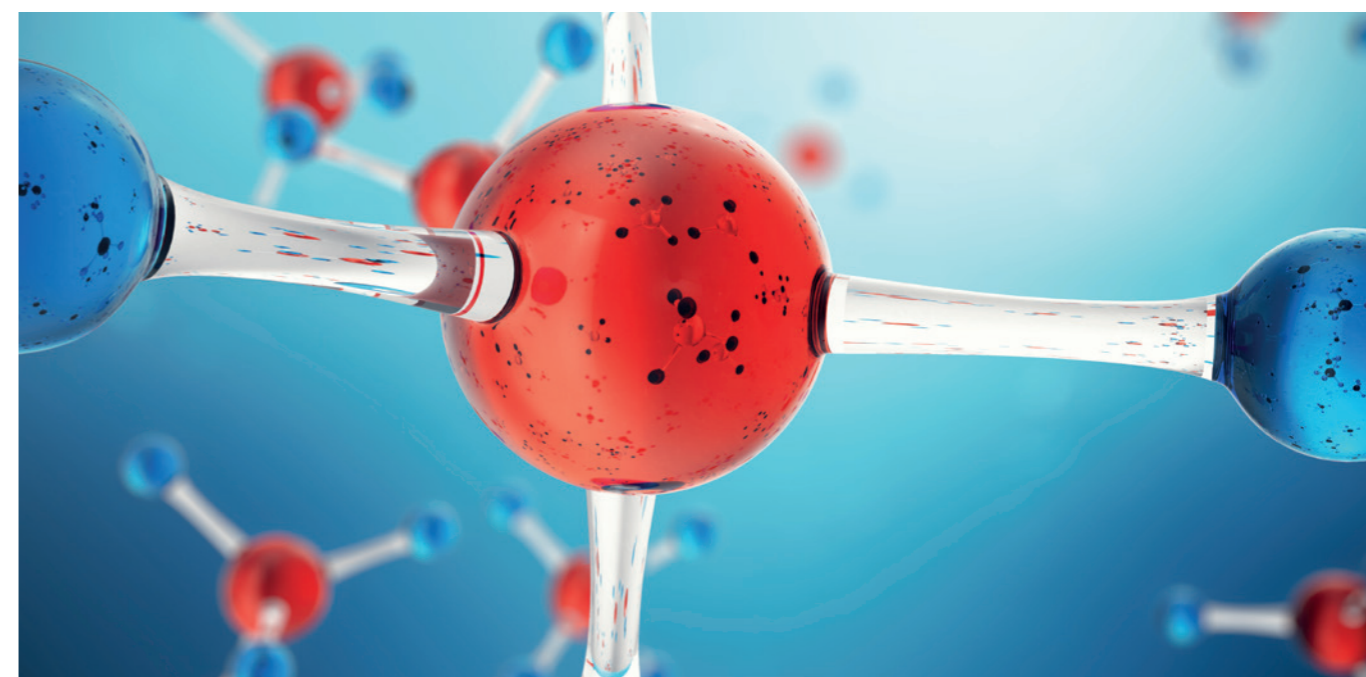
The NPC10 counted more particles than the Lasair III 110 in each of the ISO Class environment experiments due to its 10nm sensitivity. The ratio was the largest for the Class 1 test (37 times more) and decreased for Class 2 through Class 4 (17x, 10x and 4x, respectively).

In the ISO Class 1 test, there were a significant number of particles present

below 0.1µm and very few particles present above 0.1µm. The data shows there were a considerable number of nanoparticles present throughout the testing. Although it is difficult to pinpoint the exact source of these particles, it is likely the two sources during this experiment are the preferential diffusion of nanoparticles

from the outside ambient air and low-level particle generation from the instruments themselves.

The agreement or “matching” between the two NPC10 instruments was within 20% for all ISO environments tested, which meets industry expectations.



## CONCLUSION

With its 10nm sensitivity, the NPC10 NanoParticle Counter bridges the gap between conventional aerosol optical particle counting at 0.1µm (100nm) and sub-nm scale airborne molecular contamination. The experimental results provided two key findings:

1. The 10nm instrument provides higher counts than a less-sensitive instrument, indicating that nanoparticles can be present in very clean areas – likely caused by sources within the operational environment (chemical, thermal, etc.).
2. CPC technology has agreement between like instruments across a wide spectrum of contamination challenges – ISO Class 1 through ISO Class 4.

The test results indicate that a particle monitoring strategy for very clean manufacturing processes can be improved by adding a high-sensitivity CPC instrument.

While a traditional optical counter providing 0.1µm sensitivity is needed for certification of the ISO class as given in ISO 14644-1, the CPC counter is a complementary instrument that can detect contamination excursions and be used to identify changes in contamination trends that have been previously undetectable to 0.1µm sensitivity instruments.

Find out about PMS at: [pmeasuring.com](http://pmeasuring.com)

# TECHNOLOGY FOCUS

## INSIDE THE COULOMETRIC OXYGEN SENSOR

Servomex's non-depleting Hummingbird Coulometric sensor technology is at the heart of our high-purity oxygen analyzer range. It enables direct measurements at trace and ultra-trace levels, without the requirement for periodic replacement or false low readings associated with fuel cell sensors.

The sensor operates on a simple coulometric process whereby oxygen in the sample gas is reduced in an electrochemical reaction. The sample gas is in direct contact with the sensor cathode.

Oxygen (O<sub>2</sub>) in the sample gas is reduced electrochemically at the cathode to hydroxyl ions (OH<sup>-</sup>). The electrolyte solution contains potassium hydroxide (KOH) which assists in the migration of OH<sup>-</sup> to the high-purity, non-carbon anode, where they are oxidized to complete the reaction.

A voltage of approximately 1.3V DC, applied to the sensor electrodes, drives the reduction and oxidation reactions. The current flow resulting from the reaction is proportional to the oxygen content in the sample gas. The processed signal is then displayed on the front panel in parts-per-million (ppm) or parts-per-billion (ppb) units of O<sub>2</sub>. This provides a direct measurement for O<sub>2</sub>, eliminating the errors that inevitably result from technologies that measure the O<sub>2</sub> content indirectly.

The Coulometric sensor also responds very quickly to changing O<sub>2</sub> concentrations: the 0-1,000ppm range sensor can be exposed to air and in less than a minute will measure <10ppm on pure nitrogen – beneficial for users who have upset-prone applications.

In addition to fast response to changes in O<sub>2</sub> concentration, the performance of the sensor is unaffected by reasonable changes in flow rate. Because the non-depleting sensor is not consumed when exposed to O<sub>2</sub>, it has a long lifespan and does not require a purge gas to protect it when it's not in use.

Coulometric sensing complements Paramagnetic oxygen sensing by being able to measure ppm level measurements, where Paramagnetic lacks sensitivity at these levels. There are some limitations however: the sensor cannot be used with gases containing alcohols, aldehydes and solvents.



DF-550E



Delivering ultra-trace measurements of O<sub>2</sub> as a contaminant in UHP electronic gases, the DF-550E's fast response and highly-sensitive 200ppt Lower Detection Limit (LDL) provides dependable process monitoring.

Find out more: [see page 18](#)

DF-560E



Designed to measure ultra-trace O<sub>2</sub> to an industry-leading 45ppt LDL, the DF-560E delivers a fast-response measurement in multiple background gases.

Find out more: [see page 18](#)

DF-760E



Providing a unique, simultaneous dual measurement for trace moisture and trace O<sub>2</sub>, the DF-760E is a compact solution for monitoring UHP bulk gases in integrated circuit board manufacture.

Find out more: [see page 21](#)

# EXPERT FOCUS



## A COMBINED SOLUTION FOR YOUR UHP GAS PROCESS

PROVIDING A COMPREHENSIVE, SINGLE-SUPPLIER SOLUTION FOR YOUR UHP PROCESS – FROM PRECISION GAS ANALYSIS TO ENTIRE SYSTEMS AND EXPERT GLOBAL SUPPORT



Discover our analyzer range:  
[servomex.com/gas-analyzers](http://servomex.com/gas-analyzers)

Servomex's analyzer range is the most comprehensive available from a single manufacturer, setting the standard for the ultra-high-purity (UHP) gas market for decades with a unique 'all of market' solution.

Powered by reliable, ground-breaking sensor technologies, our range delivers accurate, stable measurements for every

point in your process, with a full range of percent to ultra-trace measurements.

Servomex analyzers support quality control, maintaining gas purity during the production process and detecting impurities during processes such as medical gas supply or semiconductor production.

We also provide solutions for process control and ensure safety and emissions monitoring for potentially hazardous processes.

Our commitment to ongoing development ensures that even the most trusted measurements are continuously improved, with added features that increase ease of use and reduce the cost of ownership.



Discover our systems solutions:  
[servomex.com/systems](http://servomex.com/systems)

In addition to individual analyzers, Servomex also supplies complete system solutions designed to order for your project.

State-of-the-art systems engineering centers in the US, China, India and Europe provide a global service, offering solutions ranging from simple utilities panels to fully-contained air-conditioned shelters.

Proven experience ensures the optimum level of efficiency, safety and cost-effective operation for your application.



Discover our service solutions:  
[servomex.com/service-network](http://servomex.com/service-network)

Servomex support doesn't end with the supply of your analyzer or system. Our expert team delivers gas analysis expertise directly to your plant.

With global coverage provided by service centers and mobile engineers worldwide, the Servomex Service Network ensures your processes run efficiently, safely and profitably.

Support offered includes service contracts, spares, calibration kits, commissioning, health checks, training, and equipment rental. We also provide expert support from our extensive network of service centers, or on-site at your facility.



## ASIA PACIFIC SERVICE SUPPORT FOR UHP PRODUCERS

**SERVOMEX PROVIDES EXPERT ENGINEER COVER ACROSS ITS GLOBAL NETWORK, WITH GROWING SUPPORT FOR THE IMPORTANT ASIA PACIFIC MARKET**

The Servomex Service network offers a range of service products developed to ensure optimum business performance. This includes commissioning, on-site servicing and the supply of spare parts.

This network of regional service centers is located close to customers, ready to receive analyzers for repair, preventative maintenance and upgrades.

Support for customers in the Asia Pacific region has increased from a team of five just four years ago to its current level of 11. In addition, a dedicated engineer for Korea is set to join the center in the second quarter of 2018, to support the busy Korean semiconductor market.

Service center capabilities differ slightly depending on location. For example, the Asia Pacific region service center in Singapore has access to purified gases, enabling local calibration for the DF analyzer range instead of returning the device to the US Technical Center. It also means the service team is able to repair and test DF analyzers locally.

Servomex ensures that the Singapore office and its other service center in Shanghai both stock sufficient spares to support key accounts in the region at all times. It also keeps commercial partners fully stocked with spares to support urgent customer needs.



**“We have trained our commercial partners’ engineers, so we have qualified engineering cover in almost all countries in Asia. They support after-sales services for us whenever our own engineers have a full schedule. This means the response time for getting a qualified engineer on site is never an issue for customers in Asia.”**



Leong Kee Keat - Servomex Service Manager and IG Market Manager, Asia Pacific. Email: kleong@servomex.com

Customers outside the Asia Pacific region also benefit from Servomex’s growing service network. We operate workshops in Houston, Boston and the UK, with

service centers and offices around the world. In addition, our field service teams will attend your site, providing truly global coverage. The Americas currently

has five field service engineers, while the Europe and Middle East team has nine, providing a rapid response whenever you need it.

HEALTH CHECK



COMMISSIONING



ON-SITE SERVICE SUPPORT



SERVICE CONTRACTS



SPARES



SERVICE CENTER SUPPORT



RENTAL EQUIPMENT



TRAINING



CALIBRATION KITS



Get the expert support you need: [servomex.com/service](http://servomex.com/service)

## UHP PRODUCT GUIDE

Servomex has set the standard for gas analysis in the UHP gases and semiconductor market for many years, pioneering the monitoring technologies and ground-breaking systems solutions that deliver unparalleled performance and reduced cost of ownership.

Servomex offers the most extensive range of analyzer technologies available from a single gas analysis manufacturer, ensuring delivery of the precise, correct solution for every point in your process.

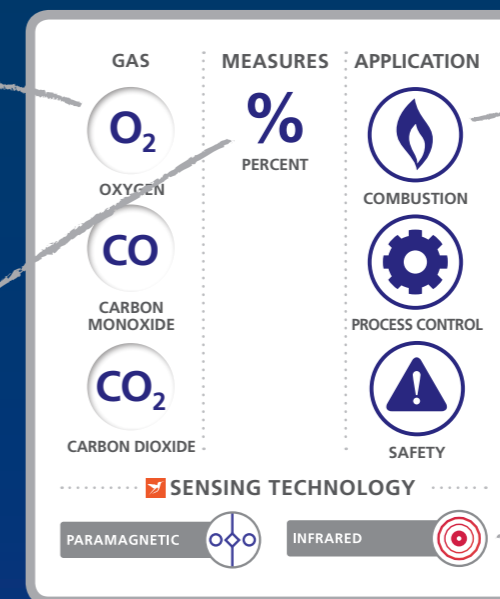
Leading the field in measurement sensitivity, Servomex provides accurate, stable monitoring from percent levels down to the very lowest ultra-trace levels demanded by the semiconductor market. When these exceptional technology range and measurement capabilities are combined, Servomex is unique in offering a genuine ‘all of market’ solution to the industry.

## FIND YOUR PRODUCT NOW

## HOW TO GUIDE

*Some analyzers are optimized for single gas measurements while others monitor multiple gas types.*

*We offer all measurement ranges from percentage to ultra trace parts per trillion analysis.*



*We identify which application types the analyzer is suitable for operating in.*

*The Hummingbird sensing technologies used are listed.*

For the full range of Servomex analyzers, visit [servomex.com/gas-analyzers](http://servomex.com/gas-analyzers)

## DF

When your processes need high-purity gas measurements for oxygen and moisture, DF analyzers deliver industry-leading performance that reaches down to the very lowest ultra-trace levels.

Utilizing the exceptional sensing capabilities of Servomex's Coulometric and TDL sensing technologies for the measurement of oxygen and moisture respectively, DF analyzers are optimized for a sensitive and stable analysis at ppm, ppb and ppt levels.

Delivered through the DF-500 ultra-trace oxygen range and DF-700 moisture range, DF products are the recognized standard for ultra-low measurements in the semiconductor, specialty gas, industrial gas and hydrocarbon processing industries.

## SUPPORTING



PROCESS CONTROL



PROCESS SAFETY



EMISSIONS MONITORING



COMBUSTION CONTROL



PRODUCT QUALITY

## DELTA F DF-730 NanoTrace

HIGH PURITY



### TUNABLE DIODE LASER (TDL) TRACE MOISTURE MEASUREMENTS, SUITABLE FOR MONITORING ELECTRONIC GRADE HCl GAS PRODUCTION IN SEMICONDUCTOR FABs

Designed to analyze moisture contamination in electronics grade HCl used in semiconductor fabs, the DF-730 NanoTrace's highly sensitive performance is ideal for quality control and leak detection applications, with a fast-response measurement that is stable, accurate and consistent.

- TDL sensing provides high stability and minimal moisture contact with optical elements
- Broad detection range: 1ppb – 10ppm
- High reliability; repeatable baseline measurements unaffected by loss in mirror reflectivity

GAS	MEASURES	APPLICATION
H <sub>2</sub> O	ppb ULTRA TRACE	QUALITY
WATER	ppt ULTRA TRACE	
	ppm TRACE	

SENSING TECHNOLOGY



## DELTA F DF-550E NanoTrace

HIGH PURITY



### AN ULTRA-TRACE OXYGEN ANALYZER OPTIMIZED FOR QUALITY MEASUREMENTS IN HIGH-PURITY ELECTRONIC GASES

Suitable for use with multiple background gases, the DF-550E NanoTrace is designed to deliver ultra-trace measurements of O<sub>2</sub> as a contaminant in ultra-high-purity electronic gases, and is unaffected by sample and flow rate changes, delivering sensitive and dependable process monitoring.

- Ultra-trace Coulometric sensing (200ppt Lower Detection Limit)
- Recovers quickly from process upsets and compensates for sample and flow rate fluctuations
- Various portability options

GAS	MEASURES	APPLICATION
O <sub>2</sub>	ppb ULTRA TRACE	QUALITY
OXYGEN	ppt ULTRA TRACE	

SENSING TECHNOLOGY



## DELTA F DF-740 NanoTrace

HIGH PURITY



### TUNABLE DIODE LASER (TDL) TRACE MOISTURE MEASUREMENTS, SUITABLE FOR QUALITY CONTROL OF ELECTRONIC-GRADE AMMONIA GAS PRODUCTION IN LED PLANTS

Designed to monitor trace levels of moisture in electronics-grade ammonia, the DF-740 NanoTrace uses industry-leading TDL sensing technology and a robust, long-path-length Herriott Cell for an exceptionally broad measurement range of 10ppb to 10ppm.

- Simplified ongoing maintenance requirements with no consumables required
- High reliability; repeatable baseline measurements unaffected by loss in mirror reflectivity
- Trace-level TDL sensing provides high stability and minimal moisture contact with optical elements

GAS	MEASURES	APPLICATION
H <sub>2</sub> O	ppb ULTRA TRACE	QUALITY
WATER	ppm TRACE	

SENSING TECHNOLOGY



## DELTA F DF-560E NanoTrace

HIGH PURITY



### ULTRA-TRACE COULOMETRIC OXYGEN MEASUREMENTS IN ULTRA-HIGH-PURITY ELECTRONIC GRADE GAS FOR QUALITY CONTROL

Designed to measure ultra-trace oxygen to the very lowest levels, the flexible and adaptable DF-560E NanoTrace delivers to the semiconductor sector an industry-leading 45ppt Lower Detection Limit and can monitor O<sub>2</sub> in multiple background gases while logging data in a variety of formats.

- Industry-leading 45ppt Lower Detection Limit
- Flexible portability
- Compensates for sample and flow rate fluctuations and ideal for upset prone applications

GAS	MEASURES	APPLICATION
O <sub>2</sub>	ppm TRACE	QUALITY
OXYGEN	ppb ULTRA TRACE	
	ppt ULTRA TRACE	

SENSING TECHNOLOGY



## DELTA F DF-745 NanoTrace

HIGH PURITY



### TUNABLE DIODE LASER (TDL) TRACE/ULTRA-TRACE MOISTURE MEASUREMENTS FOR ULTRA-HIGH-PURITY ELECTRONIC GAS CHECKS IN LED/LCD MANUFACTURING PROCESSES

Able to monitor multiple background gases, the DF-745 NanoTrace delivers exceptional performance and operational flexibility in a compact unit, using industry-leading TDL sensing technology to offer a Lower Detection Limit of 2ppb.

- Analysis immune to gas cell concentration: DF-745 operates to specification with up to 90% signal loss
- Simplified ongoing maintenance requirements with no consumables required
- High reliability; repeatable baseline measurements are not affected by a loss in mirror reflectivity

GAS	MEASURES	APPLICATION
H <sub>2</sub> O	ppm TRACE	QUALITY
WATER	ppb ULTRA TRACE	
	ppt ULTRA TRACE	

SENSING TECHNOLOGY



## DELTA F DF-745 SGMMax

HIGH PURITY



### TUNABLE DIODE LASER (TDL) SENSOR-BASED TRACE MOISTURE ANALYZER, DESIGNED FOR MEASURING DIVERSE GAS MIXTURES IN SPECIALTY GAS BLENDING APPLICATIONS

This device includes a database of 17 standard background gases – with blends of up to 8 gases – providing an adaptable solution for diverse application needs. Thirty custom gas mixtures can be predefined directly via the front panel interface.

- Trace-level TDL sensing provides high-stability measurements through minimal moisture contact with optical elements
- Integrated LCD display shows real-time analysis and reference spectrum for increased user confidence
- 5ppb Lower Detection Limit lowest available without need for a pump

GAS	MEASURES	APPLICATION
H <sub>2</sub> O WATER	ppb ULTRA TRACE ppm TRACE	QUALITY

#### SENSING TECHNOLOGY



## DELTA F DF-749 NanoTrace

HIGH PURITY



### TUNABLE DIODE LASER (TDL) SENSOR TRACE/ULTRA-TRACE MOISTURE MEASUREMENTS FOR CHECKS OF ULTRA-HIGH-PURITY ELECTRONIC GASES

Ideal for quality checking of UHP gases used in LCD and LED manufacture, the compact DF-749 NanoTrace provides trace and ultra-trace moisture contaminant measurements in various background gases including nitrogen, hydrogen, helium, argon and oxygen.

- Ultra-sensitive Lower Detection Limit of 250ppt
- Compact with a low weight; moves easily from port to port and is ideal for other mobile applications
- Trace-level TDL sensing provides high-stability measurements through minimal moisture contact with optical elements

GAS	MEASURES	APPLICATION
H <sub>2</sub> O WATER	ppb ULTRA TRACE ppt ULTRA TRACE ppm TRACE	QUALITY

#### SENSING TECHNOLOGY



## DELTA F DF-750 NanoTrace

HIGH PURITY



### TUNABLE DIODE LASER (TDL) ULTRA-TRACE MOISTURE MEASUREMENTS FOR QUALITY CONTROL IN SEMICONDUCTOR FABs

Designed specifically to make trace and ultra-trace measurements in a range of ultra-high-purity gases, the DF-750 NanoTrace is the leading choice in moisture analysis for the semiconductor industry, measuring moisture as a contaminant in electronics grade nitrogen, hydrogen, helium, argon and oxygen.

- Industry-leading 100ppt Lower Detection Limit
- Simplified ongoing maintenance requirements through the use of non-depleting, high-stability TDL sensing technology with zero drift
- High reliability; repeatable baseline measurements are not affected by a loss in mirror reflectivity

GAS	MEASURES	APPLICATION
H <sub>2</sub> O WATER	ppm TRACE ppb ULTRA TRACE ppt ULTRA TRACE	QUALITY

#### SENSING TECHNOLOGY



## DELTA F DF-760E NanoTrace

HIGH PURITY



### UNIQUE DUAL-MEASUREMENT TRACE/ULTRA-TRACE MOISTURE/OXYGEN ANALYZER FOR QUALITY CONTROL OF UHP BULK GASES

Combining the industry-leading properties of Servomex's non-depleting Coulometric sensor and robust Tunable Diode Laser (TDL) technology, the DF-760E NanoTrace is a compact integrated solution for monitoring UHP bulk gases used in the manufacture of integrated circuit boards.

- Unique industry solution for ppt monitoring of moisture and O<sub>2</sub>
- Industry-leading Lower Detection Limits of 100ppt (H<sub>2</sub>O) and 45ppt (O<sub>2</sub>)
- Single analyzer can be used for multiple background gases: N<sub>2</sub>, H<sub>2</sub>, He, Ar and O<sub>2</sub>

GAS	MEASURES	APPLICATION
O <sub>2</sub> OXYGEN	ppb ULTRA TRACE ppt ULTRA TRACE	QUALITY
H <sub>2</sub> O WATER	ppm TRACE	

#### SENSING TECHNOLOGY



## SERVOPRO

The SERVOPRO range makes Servomex's reliable, stable and accurate gas measurements available to a diverse range of safe area applications.

An extensive range of non-depleting Servomex gas sensing technologies – including Paramagnetic, Zirconium Oxide, Thermal Conductivity, Plasma and Gas Chromatography – are integrated into flexible analyzers that either meet specific measurement requirements, such as for syngas, hydrocarbons or trace gas mixtures, or provide multi-gas monitoring capabilities for applications including ASU production and continuous emissions monitoring (CEMS).

Designed for benchtop use, or mounting in a 19" rack, all SERVOPRO analyzers feature extensive functionality, remote communication options and can be operated directly via intuitive onboard software.

## SUPPORTING



PROCESS CONTROL



PROCESS SAFETY



EMISSIONS MONITORING



COMBUSTION CONTROL



PRODUCT QUALITY

## SERVOPRO Chroma

SAFE AREA



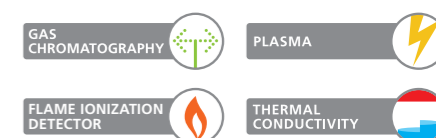
### HIGHLY VERSATILE TRACE GAS ANALYZER PLATFORM CONFIGURABLE TO A WIDE RANGE OF APPLICATIONS

Offering a unique, non-depleting plasma emission detector, the Chroma (K4000) analyzer is one of the most versatile gas analyzers for trace gas measurement available. Most applications will be satisfied by a single 4U rack analyzer configuration, making the Chroma a compact, cost-effective solution for continuous process control or quality monitoring.

- PlasmaHC measurement system requires no FID for THC measurement
- Fully automated – tune to the application – system for unique simplicity of use
- Standalone systems requires no third-party software or computer to operate

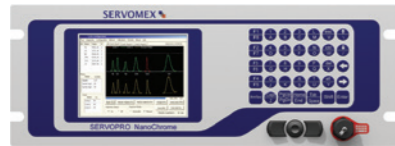
GAS	MEASURES	APPLICATION
MULTIPLE	% PERCENT ppm TRACE ppb ULTRA TRACE	QUALITY PROCESS CONTROL

#### SENSING TECHNOLOGY



# SERVOPRO NanoChrome

SAFE AREA



## SUB-PPB TRACE MEASUREMENT OF H<sub>2</sub>, CH<sub>4</sub>, CO, CO<sub>2</sub>, N<sub>2</sub>, Ar AND NMHC FOR THE SEMICONDUCTOR INDUSTRY

Incorporating the latest advances in gas sensing technology and signal processing methodology, the NanoChrome revolutionizes ultra-trace purity measurements for the semiconductor industry.

- In compliance with Low Voltage, EMC and applicable Directives
- New PED sensor technology enables sub-ppb measurements of H<sub>2</sub>, CH<sub>4</sub>, CO, CO<sub>2</sub>, N<sub>2</sub>, Ar and NMHC
- Enables unique total Servomex solution for UHP gas analysis

GAS	MEASURES	APPLICATION
MULTIPLE	ppb ULTRA TRACE ppt ULTRA TRACE	QUALITY

SENSING TECHNOLOGY

GAS CHROMATOGRAPHY PLASMA

# SERVOPRO MultiExact 4100

SAFE AREA



## A SOPHISTICATED, NEXT-GENERATION MULTI-GAS ANALYZER PROVIDING A HIGHLY ADAPTABLE ANALYSIS SOLUTION

The SERVOPRO MultiExact 4100 is a high-performance multi-gas analyzer designed to provide up to four simultaneous gas stream measurements including: O<sub>2</sub> (trace, control, and purity), CO<sub>2</sub>, CO, N<sub>2</sub>O, CH<sub>4</sub> (trace), Ar in O<sub>2</sub>, N<sub>2</sub> in Ar, O<sub>2</sub> or air, and He in Ar, O<sub>2</sub> or N<sub>2</sub>.

- Comprehensive solution for industrial and medical gas manufacture and for pharmacopeia applications
- Integrated support for the AquaXact 1688 Aluminum Oxide moisture transmitter
- Uses ultra-stable, non-depleting digital sensing technologies that help extend maintenance intervals

GAS	MEASURES	APPLICATION
MULTIPLE	% PERCENT ppm TRACE	PROCESS CONTROL QUALITY

SENSING TECHNOLOGY

GAS FILTER CORRELATION ZIRCONIA  
PARAMAGNETIC THERMAL CONDUCTIVITY  
INFRARED ALUMINUM OXIDE

# SERVOPRO MonoExact DF150E

SAFE AREA



## TOUCHSCREEN PPM OXYGEN ANALYZER FOR GENERAL INDUSTRIAL APPLICATIONS

With a brand new digital, programmable touchscreen and easier navigation, the MonoExact DF150E combines the reliability of Servomex's tried and tested Coulometric oxygen sensor with a more user-friendly package.

- Advanced touchscreen GUI for intuitive hands-on setup and operation
- Back-compatible with DF-150E platform, including hardware wiring inputs and gas inlets
- Servomex proprietary software makes reporting and parameter control simple

GAS	MEASURES	APPLICATION
O <sub>2</sub> OXYGEN	ppm TRACE ppb ULTRA TRACE	PROCESS CONTROL QUALITY

SENSING TECHNOLOGY

COULOMETRIC

# AquaXact 1688

SAFE AREA



## A FAST, ACCURATE AND RESILIENT MOISTURE MEASUREMENT SOLUTION

A rugged ultra-thin film Aluminum Oxide moisture sensor that enables the measurement of moisture in a wide variety of gas phase process applications, such as glove boxes, air separation units, natural gas processing, transportation, and instrument air, with no calibration required after sensor replacement or dry-out.

- Functions as a standalone 4-20mA transmitter or remotely interfaces with the AquaXact 1688 Controller, SERVOPRO MonoExact DF310E and MultiExact 4100 gas analyzers
- High-performance field-replaceable sensor element unaffected by condensation and liquid water
- Stainless steel, weatherproof casing. North America C1D2 and IECEx Zone 1 approvals pending

GAS	MEASURES	APPLICATION
H <sub>2</sub> O WATER	DEW POINT ppmv	PROCESS CONTROL

SENSING TECHNOLOGY

ALUMINUM OXIDE

# SERVOPRO MonoExact DF310E

SAFE AREA



## NEXT-GENERATION DIGITAL OXYGEN ANALYZER DESIGNED FOR INDUSTRIAL GAS APPLICATIONS

Designed specifically to accurately measure oxygen in industrial gas applications, the MonoExact DF310E is a next-generation digital oxygen analyzer that combines precision trace-level measurement with new performance benefits and extended digital communications compatibility.

- Advanced touchscreen GUI for intuitive hands-on setup and operation
- Back-compatible with DF-310E platform, including hardware wiring inputs and gas inlets
- Field-proven Servomex Coulometric electrochemical performance and reliability

GAS	MEASURES	APPLICATION
O <sub>2</sub> OXYGEN	% PERCENT ppm TRACE ppb ULTRA TRACE	PROCESS CONTROL QUALITY

SENSING TECHNOLOGY

COULOMETRIC PARAMAGNETIC

# GAS DETECTION OxyDetect

SERVOMEX



## NON-DEPLETING PARAMAGNETIC OXYGEN MONITOR DESIGNED FOR LIFE SAFETY APPLICATIONS

Life safety monitor designed for safe area or hazardous area environments, utilizing superior performance of non-depleting Hummingbird Paramagnetic O<sub>2</sub> sensing technology.

- IP66 (indoor use only)
- The most reliable O<sub>2</sub> detector on the market
- No more false readings or false alarms caused by depleting cell technologies
- SIL 2 approval

GAS	MEASURES	APPLICATION
O <sub>2</sub> OXYGEN	% PERCENT	SAFETY

SENSING TECHNOLOGY

PARAMAGNETIC

# > WE'RE READY TO HELP

WHATEVER YOUR GAS ANALYSIS REQUIREMENTS, WHEREVER YOU ARE

