Owlstone Nanotech Inc

PID*plus* Technical Paper

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PID*plus*- The Technology at a glance

What is it?

A minaturised chemical sensor that builds upon and extends the capability of Photo Ionization Detectors (PID) commonly used as a first-pass detector by military personnel and first responders.

How does it work?

Gas is ionized and passed through a micromachined ion filter. Low voltages applied to the filter cause ions to drift towards the sidewalls at a velocity that is dependent on the ion mobility. Ions in a particular mobility range will pass through the filter to a detector electrode. The selective ion transmission provides additional information on ion species, which improves chemical ID capability.

What makes it different?

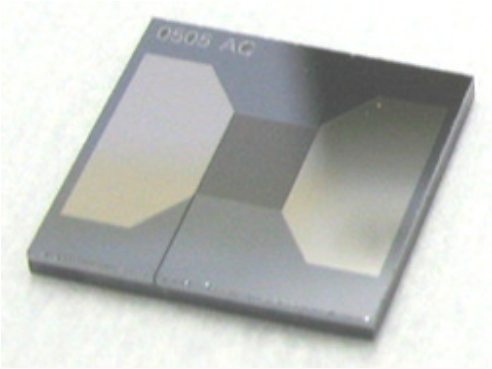
Conventional PID sensors only provide indicative information on gas concentration, with the selectivity entirely determined by the photon energy of the bulb. PID*plus* provides addional information on 1) gas concentration 2) ion mobility for improved selectivity and 3) an alarm confidence measurement.

How is it better?

High senstivity with enhanced selectivity, compared to conventional PIDs, provides the user with additional information, which helps them make faster and better decisions. PID*plus* is small, lightweight and consumes a fraction of the power of larger detection technologies such as time-of-flight IMS.

Where can it be used?

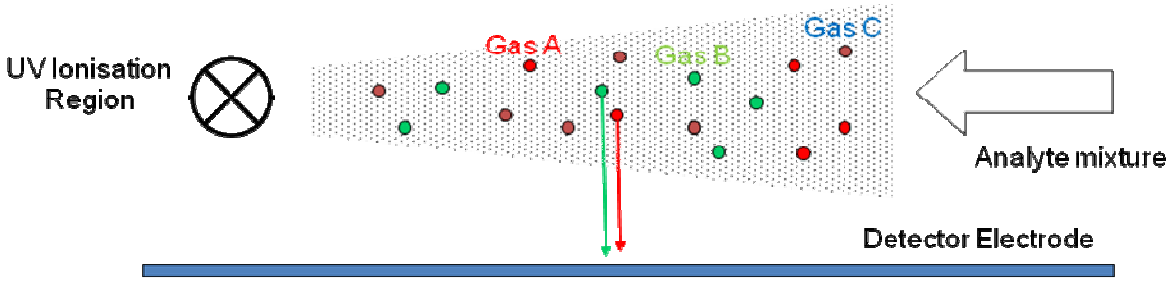
PID*plus* is ideally suited to chemical trigger applications that demand superior detection capability compared with PID without the cost, size and complexity associated with larger detection platforms.



Background to Conventional Photo Ionization Detectors (PID)

A PID is an ion detector which uses high-energy photons, typically in the ultraviolet (UV) range, to ionize gases. As a compound enters the PID it is ionized when it absorbs high-energy UV light. The UV light excites the molecule, and results in temporary loss of an electron and the formation of a positively charged ion. The gas becomes electrically charged and the ions produce an electric current, which is the signal output of the detector. The greater the concentration of the component, the more ions are produced, and the greater the current.

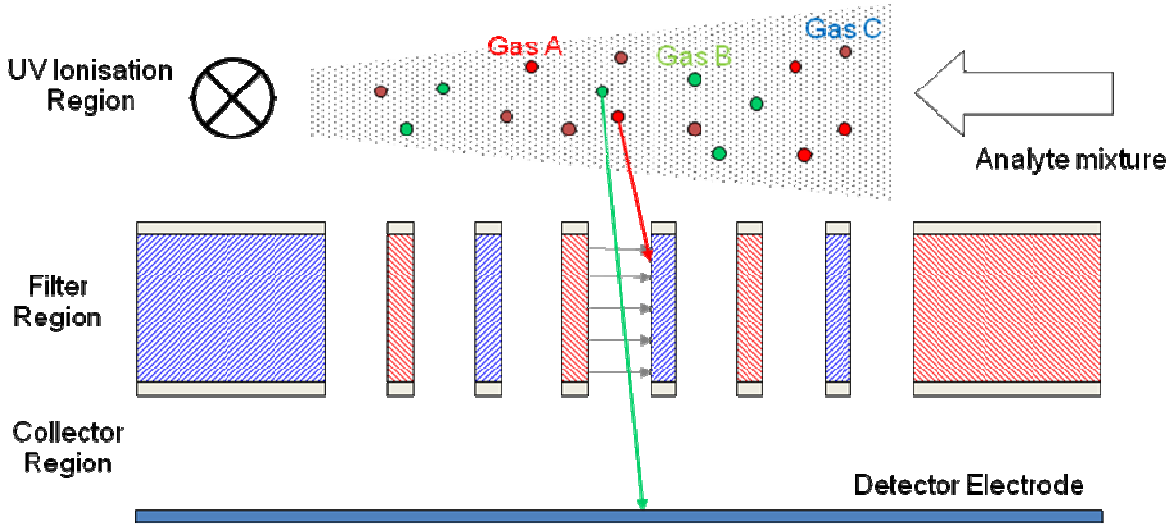
Typical PIDs measure volatile organic compounds and other gases in concentrations from 1 part per billion to 10 000 parts per million (ppm). They are capable of giving instantaneous readings and monitoring continuously. PIDs are widely used in military, industrial, and confined working facilities for safety. They are, however, fundamentally limited by the fact that the selectivity is entirely determined by the ionization energy of the gases of interest and the bulb energy.



Overview of Owlstone's PID*plus* technology

Owlstone's core technology is a 'dime size' *Field Asymmetric Ion Mobility Spectrometer (FAIMS)*, which has the ability to rapidly detect a broad range of chemical threats in very low quantities with high confidence.

While this system provides improved selectivity compared to conventional time-of-flight IMS technology, it does require ancillary electronics and pneumatic systems for chemical detection. The PID*plus* innovation seeks to leverage the same core silicon sensor but significantly simplifies the surrounding hardware that forms the complete detection system.



At a high level, the operation of the device is as follows:

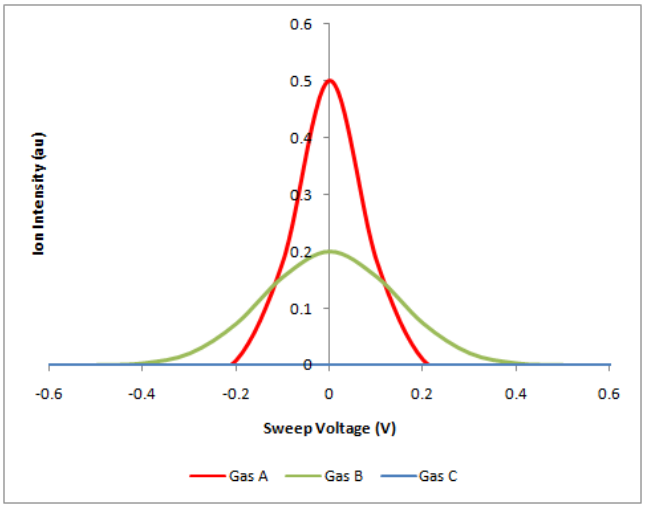
1) Ions are generated above the filter. The source can be a Nickel foil, UV bulb, corona discharge etc.

2) A DC voltage, and hence electric field, is applied across the filter channel.

3) As ions move through the filter channel, the electric field transports them toward one of the channel sidewalls. Ions that impact a sidewall are neutralized. At zero volts, most of the ions make it through the channel; conversely, at a high enough voltage none of the ions make it through the channel.

4) From the advection-diffusion equation, the minimum voltage at which no ions are transmitted depends on the ion's low field mobility coefficient, *K.*

5) If gas A has a high mobility it will drift towards the sidewall faster than gas B, which has a lower mobility.



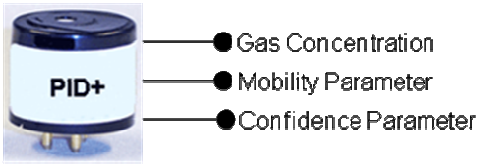
Schematic Representation of PID*plus* output

Gas A – High concentration results in increased ion intensity; High ion mobility yields narrow peaks.

Gas B – Lower concentration, therefore smaller peak; Low ion mobility yields broad peak.

Gas C – Ionization energy of gas is greater than photon energy of the UV source, therefore no ions are generated and no signal is detected. This additional selectivity can be tailored by appropriate UV bulb selection.

What additional information is available in the PID*plus* spectra?



Gas Concentration – the integral of the spectrum is the total ion current, which similarly to a standard PID, gives a gas concentration reading.

Mobility Parameter – The peak width is indicative of the ion mobility, which in turn is dependent on mass, shape and cross-section of the species. This additional mobility information enables improved selectivity.

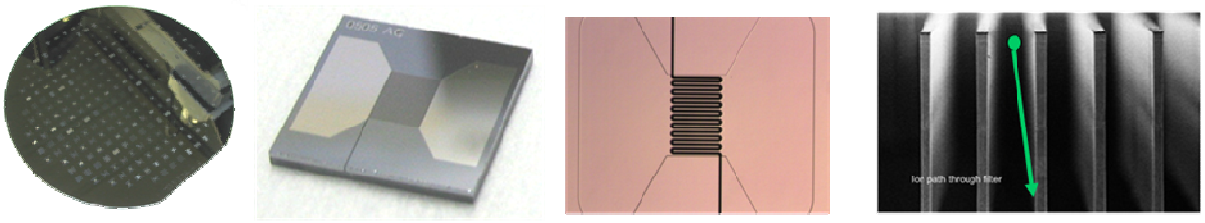
Confidence Parameter - The kurtosis (i.e. pointedness) of the spectra indicates whether multiple species of ions are present, as a sum of dissimilar Gaussians may be pointed or blunt. If this parameter indicates a single species is present we will have a higher degree of confidence in an alarm for a particular mobility and concentration. Conversely, if the kurtosis indicates that multiple gases are present, we will be more cautious with action taken on an alarm event.

The silicon microchip at the heart of PID*plus*

Leveraging Owlstone's existing FAIMS technology, the core silicon filter can be manufactured in a

massively parallel fashion, using MEMS technology, to achieve a small footprint and significant economies of scale.

The PID*plus* technology builds on the multimillion dollar investment Owlstone has made in developing and maturing its FAIMS sensor, which is currently deployed in a range of instruments and applications.



Hundreds of devices are manufactured in parallel on six-inch silicon wafers. These are diced to form the core silicon ion filter. The top view and cross-section highlight the micro machined structures, which have feature sizes on the order of tens of microns.

Advantages of PID*plus*

For use in chemical trigger and first responder applications the PID*plus* offers significant advantages compared with existing PID technologies and absorbent sensors.

Advantage	Description
Selectivity	Additional information on the mobility of gases being detected, improves overall selectivity compared to a standard PID.
System Size	The entire system is contained within a footprint under one inch square.
Power Consumption	The power draw for the entire system, including pneumatics is less than one Watt.
Alarm confidence	The confidence parameter indicates whether a single gas or more complex mixture is being detected.
Speed	A single sweep of the filter takes a quarter of a second or less.
Robustness	The silicon filter is inherently robust against shock and vibration.
Stability / Lifetime	Compared with sensors that use absorbent materials, the monolithic silicon structure contains no reactive or consumable materials, and therefore will not drift. Drift mechanisms due to the ionization source are similar to those experienced with PIDs.
Ease of use / integration	The device contains an integrated microcontroller with data processing algorithms onboard. It communicates concentration, mobility and alarm confidence via simple voltage outputs, facilitating integration with instrumentation and systems.

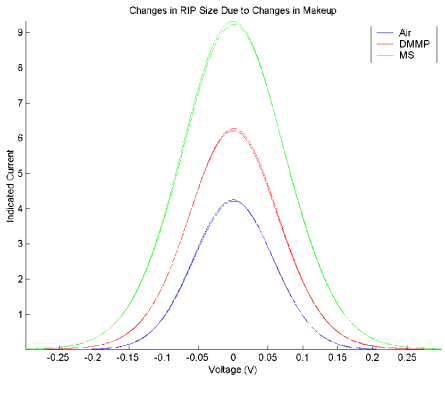
PID*plus* prototype test results

A prototype PID*plus* spectrometer was developed for initial testing and evaluation. In the first instance a standard FAIMS package with nickel ionization source was used instead of a UV bulb. The specs for the system were;-

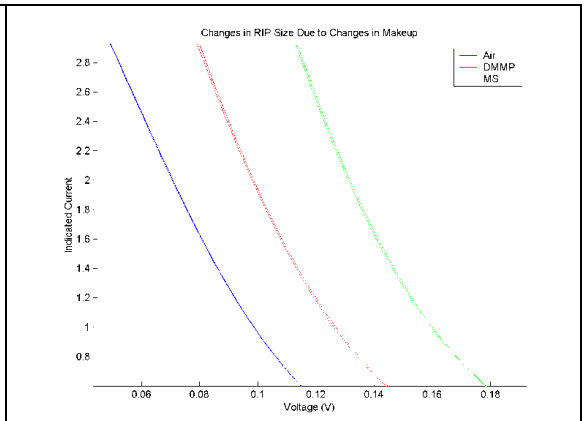
- Calculator-size footprint
- Communications and power provided by USB interface

- Consumes <100 mW when active
- Continuous scanning capability
- 1/4 second scan time
- Positive and negative ion mode scans

Initial trials were conducted on common chemical warfare simulants. Significant differences in the shape and magnitude of the response were found , depending on chemical composition of the challenge sample. As predicted by theory, lower-mobility compounds result in a broader curve (MS) while higher-mobility compounds result in narrower curves (DMMP).

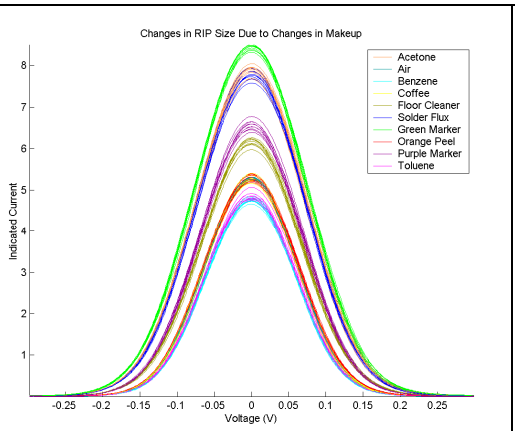


Spectra for DMMP and MS (warfare simulants)

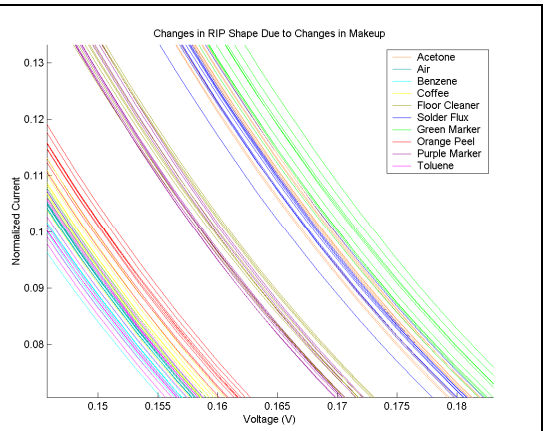


Peak width difference due to mobility differences

To assess the degree of additional orthogonal information provided by the mobility parameter, further trials were conducted on common consumer goods and foodstuffs, which have a complex headspace and multiple volatiles.

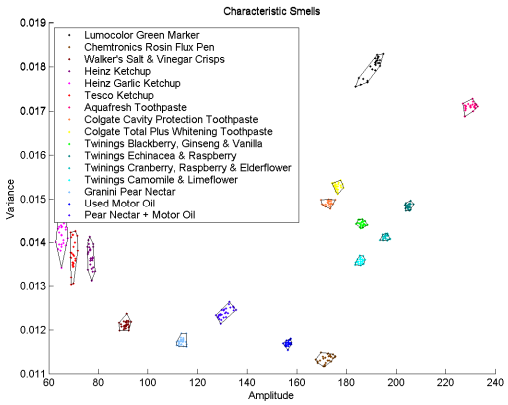


Spectra of ambient headspace for range of chemicals and consumer goods

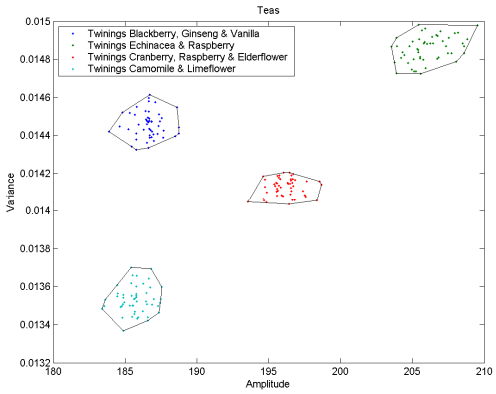


Peak width differences easily detected

The peak shapes are noticeably different by eye; powerful yet computationally inexpensive algorithms are used to analyse individual peaks to extract the gas concentration, ion mobility and confidence parameter data. Ionization chemistry plays a key role in determining the dominant ion species within a mixture. If a nickel source is used instead of a UV source the detectability will depend on the proton affinity of the compound of interest. As a rule, gases with a higher affinity will be easily detected. For chemical warfare agents this is useful, as organophosphate compounds have high affinities and are easily ionizable.



The internal microcontroller and embedded algorithms directly extract the concentration and mobility parameter which can be represented on a 2D plot.

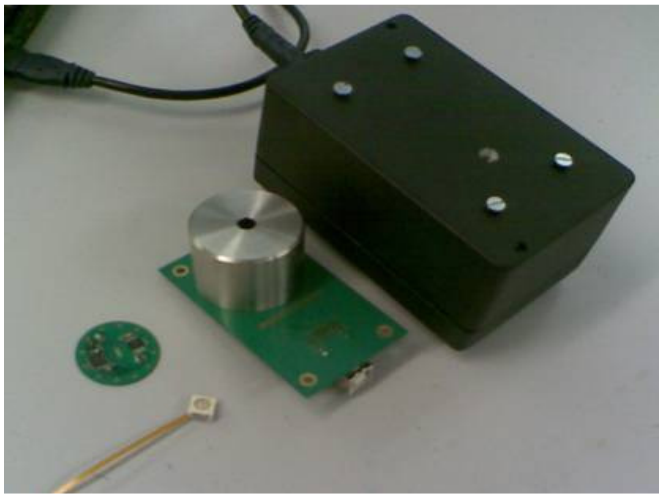


This plot illustrates compounds that would have yielded identical concentration measurements. With the additional mobility parameter they can be resolved.

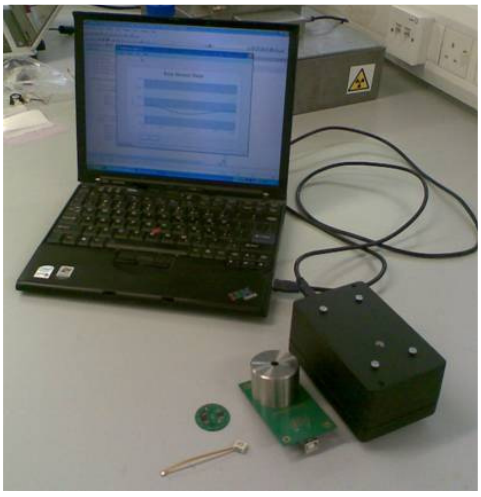
The close 'bunching' of measurement points illustrates the stability of measurements over time; any overlapping regions are used to calculate the receiver operating characteristic curve for that particular operating environment and background matrix. Alarm windows can be set in this 2D space to monitor for specific chemicals or to detect changes from a baseline.

PID*plus* Development Platforms Now Available

Owlstone is currently working with selected partners to demonstrate feasibility of PID*plus* for a range of military, industrial, environmental and process-control applications. The current generation of development platform contains a nickel ionization source. The 1" sensor is mounted inside a metal housing and is connected to a laptop via a USB. The system is powered completely via the USB. Batch spectra can be collected on the customized software, which is included with the development kit.



From left to right: Bare 1" sensor board. Mounted into can and attached to daughter board with comms. The sensor is then fixed into a metal housing with sample inlet.



The unit is connect to a laptop, which runs custom software. The complete sensor system is powered via USB.

For additional information please contact Owlstone directly; contact details are provided below.

About Owlstone

Owlstone is developing and commercializing innovative new technologies to address the critical need for compact, dependable and cost-effective chemical and biological detection solutions for a wide range of markets. We were formed through the recognition of the opportunities created by the application of micro- and nano- technology to develop improved sensing solutions.

Owlstone is focused on the innovation of detection technologies to address unmet needs. We develop solutions that are flexible enough to target a range of markets with the potential for growth by enabling new application opportunities.

From homeland security to home safety, Owlstone is working with leading manufacturers and integrators across a range of markets to develop products incorporating our microchip chemical sensing solution.

Owlstone is headquartered in the United States and has laboratory facilities in the United Kingdom.

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