Gencoa’s Speedflo for Advanced Monitoring and Control of Vacuum Deposition Processes
### General Specifications and Options

- 2 hardware options; 8 channel & 3 channel - Mini
- Typical closed loop feedback times of 5-20 msec – from signal receipt to gas delivery in the target area – <1 msec signal processing and MFC actuation loop
- Auto-tuner for reactive sputtering process control
- Auto-calibration of sensors
- Off-line software simulators to aid engineers understand control of reactive sputtering processes
- Multiple sensor options
- Easy to use and intuitive software
- Proven over 15 years and 1000 installations worldwide
- Remote diagnostics function and local Gencoia staff process support in Germany, US, China & Taiwan
Spectrometer Based Sensor Specifications

• Special high sensitivity & high resolution spectrometer (x10 standard CCD & 0.4nm resolution)

OptiSuite Software

• Up to 4 different spectral lines combined for feedback controller input on a single channel
• Feedback control based upon gas ratio’s, gas and metal ratio’s, gas or metal signal with argon ratio
• Automatic identification of plasma and gas species in the spectrum
• Total gas pressure measurement
• Gas ratio’s easy visualization
• Vacuum quality & end-point monitoring
• Leak detection mode
• System moisture tracking

Please note Optisuite is available for both Speedflo and OPTIX products
Controller (Speedflo)

Actuator (MFC, PSU, PEC)

Sensor(s)
(process P.E.M, penning P.E.M, target voltage, spectrometer, Lambda etc)

Voltage Out
Gas Flow

Voltage In – single or multiple signals or ratios

Speedflo Uses
Reactive Sputtering, CVD, End-point detection
E-beam reactive gas
Drift elimination
Process diagnostics

Demanded plasma intensity etc

Plasma intensity etc
Process Control in reactive sputtering is used to both increase the rate of deposition but also to improve uniformity.

Cost of ownership of reactive feedback elements:

- Line speed increase x 2-5
- Return on Speedflo investment typically < 30 days for industrial production machines
- Multi-channel zone control allows uniformity adjustment tuning

Layer Thickness

Cost of ownership of reactive feedback elements

- Line speed increase x 2-5
- Return on Speedflo investment typically < 30 days for industrial production machines
- Multi-channel zone control allows uniformity adjustment tuning

P.E.M Setpoint

SiO2 rates at 15kW/m (dual rotatable)
There is a choice of sensor types & optical fibres depending upon process needs

**P.E.M.** (PMT, CCD, Optix), voltage, lambda, Hipims

---

**Plasma Emission Monitoring (P.E.M.)**

The visual light from the plasma contains information of all the species present via the optical emission spectrum. To monitor the intensity of any element in the plasma, a narrow band-pass filter can be used to allow through only the wavelength of light of the material or gas of interest.

**P.E.M. CCD**

The plasma light can be captured by a CCD-type spectrometer which provides a universal picture of the process. For control purposes, the wavelengths of interest are electronically filtered and input to the controller. This type of tool delivers more information, however the integration time of the spectrometer slows down the feedback speed compared to the conventional band-pass P.E.M. method.

---

In-vacuum fibre cables and collimating heads with gas bleed protection of the optical window

Ex-vacuum fibre connection and collimating head for chamber wall mounting

Penning type P.E.M. type sensor head

Vacuum wall fibre-optic feedthrough
Remote P.E.M (Penning P.E.M)
Gencoa’s Penning P.E.M sensor enables remote monitoring of gas emission levels, and is ideal if substrate interference is problematic with conventional P.E.M sensors. A small plasma is generated remotely in the Penning gaugehead. A conventional P.E.M sensor can then be used to measure light intensity at a wavelength of interest. This represents the excess gas from the process.

Lambda
The Lambda sensor is an oxygen probe which provides a direct signal of the oxygen concentrations present in the vacuum. The Gencoa Lambda sensor provides a robust signal with good response speeds. Like P.E.M, it can provide information from multiple monitoring zones down the target length.

Target voltage
A convenient sensor from the process is the target voltage output from the magnetron power supply. This can be used for some material combinations as a stand-alone signal or in addition to a secondary signal such as P.E.M. Successful materials for this type of sensor are silicon and aluminum oxides and nitrides.

HiPIMS
Gencoa has developed sensor technology that enables the control of reactive HiPIMS processes for reproducible depositions and stable system performance.
Different sensor control modes possible for collecting the signal from the process.
P.E.M requires the light signal from the plasma to be transmitted.
Genco have 3 sensor solutions for Hipims

Sensor 1: using a photomultiplier tube (PMT) with a electronic switch to detect the large light pulses. PMT’s are ultrafast light detectors and detect the ‘dark’ plasma time associated with Hipims. Hence an electronic conversion is needed to detect the short light pulses from the PMT.

Sensor 2: CCD spectrometer. Spectrometers have slower response and require integration time, so have no problem with Hipims as the ‘dark’ periods cannot be detected – only the light.

Sensor 3: peak current sensor. A newer type of sensor is non-optical and detects the current peaks from the Hipims plasma. This is an alternative to in-vacuum sensing by light transmission – peak current is external to the vacuum chamber.
Genco provide process setup assistance, gas delivery bars, flow rate calculations and expert advise locally in USA, China, Taiwan & Germany

Other regions are handled by staff from our UK base either by remote connection to the controllers or at the customers site.
P.E.M, gas pipes and bars provide ~ 10msec process feedback response

Gas bar design delivers gas quickly and uniformly

Lambda sensors shown
The data processing in the Speedflo box (not PC) for high speed robust operation.

Typical closed loop feedback times of 5-20 msec – from signal receipt to gas delivery in the target area. Speedflo actuates the MFC within 1 msec. Time lag for closed loop control is dependant upon gas bar size and connection. Also sensor type, PMT and target voltage the fastest – speed of light / electrons through cables.

CCD spectrometers and Lambda sensors have delays. Spectrometers will spend time integrating the signal onto the CCD. Typically integration time will vary between 5 and 60 msec depending upon plasma intensity and CCD sensitivity. Hence CCD spectrometers are not recommended as the main feedback loop for fast response and large systems with long gas delays. CCD’s can work in combination with faster sensors such as target voltage.
Example of reactive gas control for Al₂O₃ on web for ultra-barrier applications

gencoa: perfect your process
Gencoa Speedflo advanced user interface and control functionality

Gencoa: perfect your process  Software for easy process control setup and learning

Control algorithm
Speedflo utilizes a proprietary advanced PDF+ control algorithm that is capable of extremely fast and accurate feedback control. In addition to the PDF+ algorithm the Speedflo controller features a digital variable structure control law that is able to maintain fast-acting and stable control, even when the MFC becomes fully open or closed. This enables feedback control that is high performance, robust and reliable.

Multiple control channels
The Speedflo controller has up to eight fully featured and independent control channels. This allows for simultaneous feedback control of eight MFCs, with options to combine various sensors and duplicate control channels. This powerful capability is especially useful for large target areas, where precise deposition uniformity must be achieved.

Auto-calibration and controller tuning
The time-consuming process of sensor calibration and controller tuning has been eliminated with Gencoa’s latest Speedflo development. An automatic calibration and tuning procedure – unique to Speedflo – automatically detects the sensor levels corresponding to poisoned and fully metal states. The optimum controller parameters for the current sensor and process are then automatically calculated to ensure fast, accurate and robust feedback control.

Advanced user interface
A highly developed software interface includes many powerful functions to allow different methods of configuring the process control and combating difficult control situations. All of the software functions can be seamlessly incorporated into an existing PLC system.
Two simulation tools have been designed to offer a virtual experience of tuning and operating the Speedflo control system. The aim being to interactively teach the skills required for faster and more effective control system tuning and commissioning.

The basic version teaches tuning the algorithm and the advanced tools includes other parameter variables.
Speedflo locally controls and powers the MFC’s for secure and fast closed loop control. Process parameters are downloaded to Speedflo from the Gencoa windows software interface or via the machine control interface. Connection to Speedflo from the PLC or machine controller is via DLL or OPC server interface.
Gencoa patented auto-tuner for reactive sputtering process control

- Reduced set-up time
  - Minutes instead of hours!
- Reduced complexity of feedback control system
  - Transition to a feedback process less “intimidating”
- Improved process stability
  - Optimized parameters based on real data – not “feeling”

WHY

Gencoa: perfect your process

a major innovation in the field of process control

WHY auto-tune
Gencoa patented auto-tuner for reactive sputtering process control

gencoa: perfect your process

da major innovation in the field of process control

Tuning - gas pulse process system dynamics diagnostic stage

Tuned in 80 seconds and now controlling around the set-point

After performing an integrated system calibration and identification procedure, the auto-tuner instantly generates the optimum controller parameters for your process by using advanced inverse dynamics algorithms to analyse the collected data.
## The tuned parameters can be adjust easily via a slider further adjust how your process will respond

<table>
<thead>
<tr>
<th>gencoa: perfect your process</th>
<th>Tuning completed.</th>
</tr>
</thead>
</table>

- Auto-tuner defaults to a safe response speed

- This can be increased or decreased by moving a single slider.
  - Previously had to tune 2 **interacting** parameters!
  - There is still the option to tune K1 and K2 individually if you are an “expert”

- As the response time is changed the “shape” of the response should remain the same

- Always a trade-off between stability and speed – fine tuning can find the edge of this trade-off
By moving the slider left toward the ‘Responsive’ end the process is quicker to the setpoint.
Comparison of auto-tuned control and manually established set-points input to the pdf controller algorithm.

- PEM (Al) Autotuned
- MFC (O2) Autotuned
- Setpoint
- PEM (Al) Default
- MFC (O2) Default
The CCD type spectrometer used by Gencoa is specially configured to enhance the sensitivity of data collection from plasma systems. This extra sensitivity has a higher signal to noise ratio and allows 10 x smaller integration times and hence much faster response speeds when compared to off-the-shelf spectrometers.

Comparative data gathered from the same plasma and with the same integration time. The ‘standard’ spectrometer is the off-the-shelf market leader.
The Gencoa *Optisuite* software is available for any Speedflo fitted with a Spectrometer and is also used with the OPTIX plasma gas sensor.
Other benefits of the *Optisuite* software are available for any Speedflo fitted with a spectrometer and is also used with the OPTIX plasma sensor.

**Vacuum quality monitoring**

![Graph showing vacuum quality analysis with specific peaks at 1 mBar and water vapor removal](image)

- **1 mBar**
- **Air pumping**
- **Water vapor removal**

*gencoa: perfect your process*
Highly advanced technology based upon the experience and know how of 1000 units controlling industrial plasma processes

Gencoa can predict and simulate the controllable areas of any sputter process with different sensor types – based upon real process data taken into the modelling

Target Voltage

Stability analysis for Al2O3 reactive deposition from dual rotatable magnetrons and target voltage as the sensor input – Red zone is an area of instability to be avoided. Presented at PSE 2014
The industry standard for controlling industrial reactive gas plasma processes & high levels of process support worldwide.
Gencoa will advise on PEM sensor locations and gas delivery method & the sizes of the MFC's required for the process
Gencoia provide process controllers, remote access or on-site process tuning

gencoia: perfect your process

Typical AR production line Speedflo installation
Continuous DC with the highest deposition rate, nearly doubling that for pulsed DC.

Ion source considerably reducing deposition rate, due to very high ion energy.

After deposition for 30 mins

Before HMDSO/O₂ input

Multi-signal monitoring by spectrometer, Speedflo; Al signal suppressed during deposition

Reactive gas control – not just for PVD – example of CVD deposition with Speedflo

gencoa: perfect your process

PEM control
Speedflo is very effective in stabilizing CVD type plasma deposition to maintain composition and transparency.

Light transmission at 550 nm: 97.5%
The emergence of vacuum artificial intelligence for thin film processes

genco: perfect your process
remote plasma gas sensing for vacuum processes

The method relies upon the generation of a remote plasma over a very wide pressure range on the chamber wall and spectral analysis of the plasma spectrum to yield information on the process that can be used for a variety of intelligent purposes. The OPTIX device allows gas and vacuum analysis from near atmospheric pressure down to $10^{-6}$ mbar.
The OPTIX plasma gas sensor operates in the range of industrial vacuum processes without the need for differential pumping.
Vacuum Artificial Intelligence – intelligent use of spectral data to automatically sense and control processes