Achieving better-controlled coatings with faster, more precise pressure control

Issue:

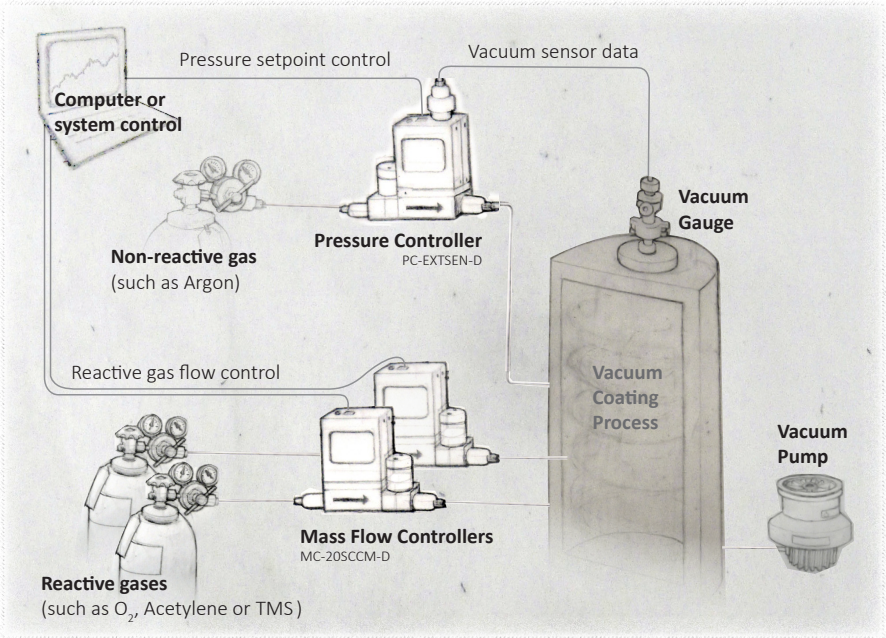
Uneven coating quality and poor repeatability, resulting from fluctuations in vacuum chamber pressure.

Cause and context:

Vacuum coating process control engineers create a vacuum (pressures below atmosphere) in a sealed chamber. They remove atmospheric gases which would interfere with the desired reactions between the substances in the process. Into the vacuum, they introduce other gases and materials—things like vaporized metals, ionized molecules or plasma-reactive compounds—to bind them with the surfaces of other materials.

A simplified description of a system has two key features: first, a vacuum chamber plumbed to several stages of vacuum pumps, with a throttle valve between the chamber and the pumps. The throttle valve regulates how hard the pumps draw, as well as providing a strong shut-off to prevent leakage.

Second, gas sources, which are selectively introduced into the emptied chamber through mass flow controllers (meters with integrated flow control valves). These gases are used to bring the coating environment to appropriate operating levels of density.



Some gases are used as non-reactive 'neutral' gases, to keep the chamber pressure at an ideal sub-atmospheric level without affecting the concentrations of process chemicals. Others are reactive gases, which are an integral part of a process, such as oxygen for an oxidation coating. In some processes, non-reactive gases are used as carriers to spread and dilute the reactive materials. Reactive materials may be a vaporized metal which has been ionized through melting and electrical field manipulation. Still other gases may be used to "purge" or cleanse the system of the last traces of the previous phase.

Coating mechanisms vary. Some are fairly passive—for example, allowing the vapor to settle slowly on the substrate. Others involve bonding films to substrates through plasma arcing the vapor cloud. Or the process may require charging the substrate electrically, to attract specific ions.

In these rarified atmospheres, pressure fluctuations arise—and small changes count for a lot. From the interaction of control components and asynchronous operation of those elements—non-reactive gas flows, reactive gases being introduced, and vacuum pumps turning on and off—all may affect the pressure and balance of the ingredients.

More subtly, transient fluctuations due to poor timing of on-off switching, or long settling times in reaching a flow set point may throw a chamber's delicate balance of chemicals off, affecting evenness, adherence and

thickness of the coatings. Control and settling times exceeding 100ms of valves and flow controllers can, depending on the application, have a qualitative effect on film thickness and uniformity, and repeatability of the process.

Solution:

Gain a well-controlled coating environment using an **Alicat Pressure Controller with an External Sensor** (PC-EXTSEN-D) to control the pressure of the vacuum chamber through controlled introduction of Argon gas. The ongoing process pressure is measured by an external vacuum gauge, directly connected to the process chamber. The pressure measurement is read by the pressure controller via analog connection.

Reactive gases are introduced to the process chamber through Alicat Mass Flow Controllers (MFCs). As the Alicat Pressure Controller detects changes in the chamber pressure from the inflow, it adjusts the level of non-reactive gas to regulate the process pressure and create optimal deposition conditions.

Faster control response times help to maintain optimal deposition results, reducing fluctuations. By customizing PID loop tuning for specific process conditions, control response times in the range of 20-30 milliseconds can be achieved, reducing settling time and spikes sharply, and ensuring stable pressures and gas exchanges.

Both the pressure and flow control instruments use a common control interface, standardizing commands and programming. Serial or analog communications can be used to control the instruments.

Through either the remote or the onboard interfaces, the MFCs can be reset to flow new gases while retaining the NIST-traceable accuracy specification accorded to the the instrument. Changing gases is a matter of a simple selection, without wasted hours spent calculating K-factors, and without affecting accuracy.

Instruments for low and micro flow rates (as low as 0.5 sccm full scale) provide unique flexibility. Drop-in replacements for competitive MFCs provide identical form, fit and function.

Advantages:

Normally, changes in the flow rate of reactive gases will disturb the system pressure and result in inconsistent coatings.

The Alicat pressure controller maintains the chamber pressure precisely at the desired level, while the system control manipulates the reactive gases independently.

Coating system integrators who have adopted this method report that the faster control response time of Alicat instruments substantially improve their results by providing a well-controlled coating environment, with repeatable results.

Additional benefits are realized through the instruments' high accuracy, and ease in changing fluids.

Selected specifications:[1]

Pressure controller:

Repeatability: ±0.08% Full Scale
Operating range: 0.5% to 100% Full Scale / 200:1 Turndown
Typical response time: 100ms (Adjustable)

Mass flow controller MCV and MCE:[2]

Accuracy at calibration conditions after tare: up to ±(0.4% of reading + 0.2% of full scale) NIST-traceable
Repeatability: ±0.2% of Full Scale
Operating range: 0.5% to 100% Full Scale / 200:1 Turndown
Typical control response times: 50-100 ms (Adjustable)
User selectable 98 gases at specified accuracy
Lifetime warranty

Left to right: Pressure controller PC-EXTSEN-D, Mass flow controller MCV-100SCCM, Mass flow controller MCE-100SCCM

[1] Contact Alicat for full specifications and available options

[2] MCV has same form fit and function as MKS 2179A, while MCE has same form, fit and function as MKS 1179A

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