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# PVD Processes: Mass Flow Control of Gases

The most common gas mass flow meters (MFM) use cooling by the flowing gas as the basis of measurement. An element is heated by electrical power to about 100 °C, and the power needed to maintain a constant temperature, or the temperate at a constant power or a temperature gradient, is measured. The output from this measurement is used to indicate the gas flow by appropriate calibration. The output can be used to control the flow through a metering valve that is located either upstream or downstream from the mass flow meter, to give a mass flow controller (MFC) as shown in the figure.

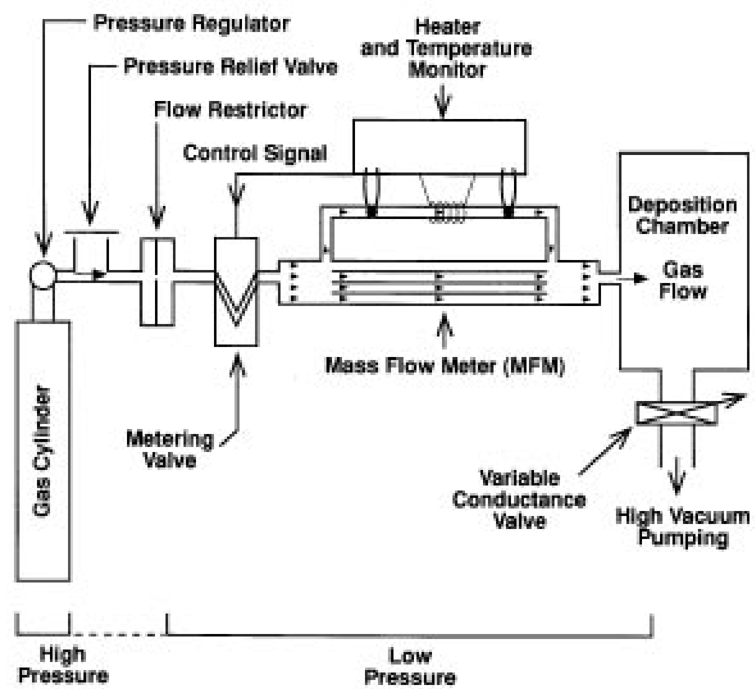
The opening through the metering valve is generally controlled by an electromagnetic solenoid or piezo-electric actuator. The metering valve should never be used as a gas shut-off valve. Other types of flow meters are the rotating vane (rotameters) type and the gas-levitated ball meters.

## Measuring Gas Flow Rates

The cooling rates of different gases vary, so the calibration of the MFM varies with the gas species. Relative correction factors for one make of MFM, for example, are: Nitrogen=1.0, argon=1.45, helium=1.45 and $CH_4$=0.72. The cooling rate also depends on the amount of turbulence in the gas flow, so the flow meters are designed for specific mass flow ranges. The most reproducible measurements are made with a laminar gas flow. The gas flow, therefore, is split in the meter to allow laminar gas flow to be established in the branch used for flow measurement. For PVD processing, mass flow meters are available to measure gas flow rates from ~0.1 sccm (standard cubic centimeters/min) to >100 sLm (standard liters/min), with inlet pressures from a few tens of psi to 100 Torr.

The gas mass flow meters generally are designed only to withstand several hundred psi inlet pressure. Higher pressures can result in violent failure of the meter. Because the gas source for PVD processing is often from high-pressure gas cylinders, it is important that the full cylinder pressure never be applied to the flow meter. This is accomplished by using a pressure regulator on the gas cylinder and including an appropriated flow restrictor and pressure-relief valve in the gas line, as shown in the figure. If the regulator should fail, the






*Mass flow controller and gas distribution system.*

flow restrictor causes the line pressure to increase to the point that the pressure-relief valve is actuated before pressure in the downstream line exceeds the design pressure of the mass flow meter.

When using a flow of processing gas into the deposition chamber, the high-vacuum pumping speed is generally reduced to limit the gas flow through the system. This can be done by having a variable conductance valve (throttling valve) in the high-vacuum pumping line (as can be seen in the figure), or by using a bypass line containing a flow-control orifice in the pumping manifold. A typical flow rate for argon in a sputtering process is about 100 sccm (1.267 Torr-liters/sec).

Mass flow through the deposition chamber with processes using inert gases can be an important deposition parameter, because it determines how much "flushing action" takes place in the chamber. This flushing action carries contaminating gases and vapors from the deposition chamber. In a low-flow or static system, the contaminant level can build up during processing.

### Reactive Deposition Processes

In reactive deposition processes, such as the deposition of titanium nitride (TiN), the mass flow is important in making the reactive gas (nitrogen) available during the deposition. It should be recognized that the reactive gas is pumped in the deposition chamber by reaction with the freshly deposited film material ("getter-pumped"). This means that the amount of reactive gas available for reaction in the chamber will depend on a number of factors other than the mass flow into the chamber. These factors include the deposition rate and the area on which the film is being deposited ("loading factor"). If TiN, for example, is being deposited over 1000 $cm^2$ of surface area at 10 Å/sec, it will be getter-pumping about 90 sccm (1.14 Torr-liters/sec) of nitrogen gas in the deposition chamber. The way the reactive gas is introduced into the deposition chamber can also affect the reactive gas availability, so the gas injection geometry is an important design consideration in reactive deposition processing, particularly if the reactive gas flow rate is low. Special mass flow meters and controllers are used with condensable vapors. They are heated to prevent condensation of the vapors in the control system.

Mass flow controllers are often used to mix gases either outside the deposition chamber or in the chamber. Again, the getter-pumping action in the chamber prevents the MFM from giving a correct indication of the reactive gas availability in the chamber, and some type of in-chamber monitoring technique is needed. This in-chamber gas composition monitoring can be done with a differentially pumped mass spectrometer, or by an optical-emission spectrometer if a plasma is used. One problem with these types of monitors is that they only analyze the gas mixture at a certain place in the chamber, and variations with position are difficult to determine. For reproducible processing, the mass flow of each of the constituent gases, and the total chamber pressure should be measured. ***P&SF***

## NMFRC News

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- **Quality Assurance/Quality Control** (program description, certifications attained, applicable specifications/ standards, QA/QC methods, test equipment used).
- **Educational Information** (general information about metal finishing, applicability and limitations of processes, alternative finishes, design considerations for finishing, answers to frequently asked questions).
- **Boasting** (client list, special projects/ case studies, testimonials, unique capabilities).
- **Environmental** (policy statement, compliance status/record, description of treatment processes, pollution prevention accomplishments).
- **Pricing** (request for quotation via e-mail or database).
- **Communications** (link to e-mail or database to request further information, contacts/telephone numbers for sales, engineering, etc., guest book).
- **Links** (AESF, NMFRC, other affiliations or industry resources).

There are many other potential functions of websites of which metal finishing shops have not taken advantage. A metal finishing shop, for example, could implement a job tracking service for customers right on its website. Such a system would allow customers to check on the status, shipping dates, even the QA data, of their parts by logging on to the website. Password protection and other security measures would ensure that each customer sees only information about his/her parts. ***P&SF***