SEMICONDUCTOR
# European

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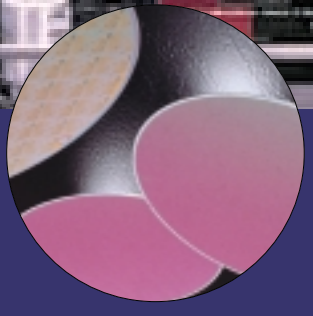
D E S I G N ● P R O D U C T I O N ● A S S E M B L Y

## Kinetics delivering gas flow solutions


Integrated gas and vacuum systems



Organic polymers into production

# The patter of tiny footprints

**There is a quiet revolution going on in the semiconductor equipment industry, and Europe seems to be leading the charge, followed by Asia. David Larner reports.**

The semiconductor industry has many unique quirks that set it apart from other forms of manufacturing. While it continues to push the envelope in one direction, it resists change in another. The fabulously expensive machines that make ICs have to learn the silent chant of 'accuracy, repeatability, reliability'. With profit margins razor thin, anything that might degrade yields could make the difference between profit and huge losses. Most production managers will grumble but make some compromise over absolute accuracy, but the rules for repeatability and reliability are cast in stone. This raises a dilemma for the industry: How to advance without changing anything too dramatically?

Don Firkins, European managing director of the fluid systems group at Kinetics says, "Compared to other sectors such as petro-chemicals or pharmaceuticals, in some areas the semiconductor industry still lags in the adoption of state-of-the-art technology. "This put enormous pressure on the sub-system makers because their customers – the process equipment OEMs - want higher reliability and lower costs, but are not always willing to adapt to new technology. Equipment such as chemical vapour deposition reactors, etch and diffusion chambers, and rapid thermal process furnaces all rely on accurate and repeatable supply of gasses.

The inside of these tools all have one thing in common, a lot of expensive systems that connect, control, and meter the delivery of up to 10-15 common gasses into the process. Each delivery system is made up of an input pressure regulator, a filter, a flow control and sensor, and an isolation valve. The common name in the industry for these is 'gas sticks', because of the way the components are arranged in series. This arrangement can cause the overall length of a stick to be more than 650mm long, and by the time 10 or more are arranged together inside a piece of equipment, a considerable amount of space gets used up. With floor space at such a premium inside a fab, all OEMs are under pressure to reduce equipment footprints.

Amongst the various standards generated by the SEMI organisation, is a specification for a modular approach to gas delivery. The traditional method of serial connection meant that each pipe coupling had to have sufficient space around it to allow access. This was because all of the gas line components had axial connections. By simply moving the inlet/outlet ports to a downward arrangement, the components could be moved closer together. The SEMI specification defines the critical dimensions such as port spacing and mounting holes, along with sealing requirements. This modular approach not only saves space, but it makes servicing quicker and easier. Traditionally, if a component in the middle of a stick needed replacing, like threading beads on a necklace the whole assembly had to be broken down. Modular construction means that components will lift out, and because


**The acquisition of Unit Instruments enables Kinetics to become a market leader.**

# MFC
## Mass Flow Control

### How it works

Mass Flow Controllers (MFCs) are used wherever accurate measurement and control of gas is required. To help understand how an MFC functions, it can be separated into two main components: a mass flow meter (MFM) and a proportioning controller (Figure 1). The mass flow meter divides the flow between a heated sensing tube, where the mass flow is actually measured, and a flow restriction or bypass, where the majority of flow passes. The flow meter electronics amplify the sensor signal and condition the output. The other main component, the proportioning controller, consists of a variable displacement solenoid valve and the control electronics. The controller drives the valve to the correct position so that the measured flow equals the desired flow setpoint.

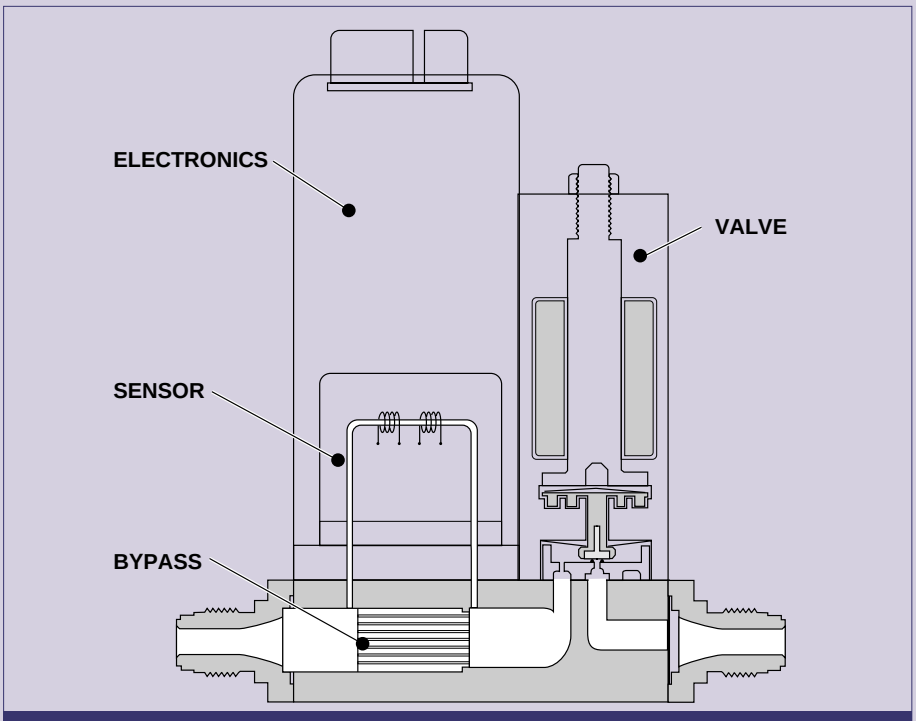



**Fig 1: A partial cutaway showing the basics of a mass flow control valve. The development of digital control has tightened the control loop and added diagnostics.**

#### * THE MASS FLOW METER

Mass flow meters use the thermal properties of a gas to directly measure the mass flow rate. The MFM uses the basic principle that each gas molecule has a specific ability to pick up heat. This property, called the "specific heat" ($C_p$), directly relates to the mass and physical structure of the molecule and can be determined experimentally. The specific heat is well known for many gases and is generally insensitive to changes in temperature or pressure. By adding heat to a gas and monitoring the change in temperature, the mass flow rate can be determined.

#### * THE SENSOR

To maximise the performance and versatility of the sensor, the majority of gas is shunted through the bypass. A small portion of the flow is split off before entering the bypass region and directed into the sensor. The percentage of the mass flow through the sensor relative to the mass flow through the bypass is essentially constant for the operational range of the device. Since the flow measured by the sensor is directly proportional to the total flow, only a small portion of the flow is actually measured, but the total flow is accurately determined.

At the midpoint of the capillary tube, two wire coils are wrapped side by side. The windings serve two functions: first as heaters, and second as temperature sensors. The MFM electronics provide a constant current source to the coils which is converted to heat by the wire's resistance. Since the resistance of the coils varies with temperature, the coils also function as temperature detectors.

When there is no gas flow, heat from the coils generates a uniform temperature gradient about the midpoint of the tube. However, as gas flows through the sensor, heat is picked up from the upstream heater and is carried towards the downstream heater. This movement of heat by the gas shifts the temperature gradient so that a temperature difference develops between the two heaters.

Since both coils initially generate the same amount of heat, when gas flows through the sensor the upstream coil will cool as the cool gas absorbs heat. When the gas stream gets to the downstream coil, the gas temperature has been raised significantly, so the downstream coil cools only slightly. Assuming all other heat losses for the coils are the same, the net difference in heat lost between the coils can be linearly correlated to the mass flow rate.

#### * ELECTRONICS

The electronics in the MFM convert the temperature difference between the two coils into 0-5VDC output. The coils are the two resistive legs in a Wheatstone bridge circuit. Small changes in temperature correspond directly to changes in resistance. When there is no gas flow through the sensor, the legs are balanced to read zero volts. As the flow increases, the temperature difference increases, therefore, the difference in resistance increases.

#### * THE CONTROL VALVE

The control valve is similar in form to a solenoid valve. However, the valve is a proportioning valve with almost infinite resolution. The major components of the valve include the plunger assembly, the valve jet and the valve core. The valve seat is attached to the end of the plunger and covers the orifice in the jet. Depending on the environment, the seat can be either viton, teflon, neoprene, or metal. The plunger is supported by two flat springs that supply a low friction motion.

there is a shorter distance between each component, purge and dry-down time is reduced by as much as 30%. However, no matter how good the new method is, take up-has been slow. It's new, and 'new' is what some fab managers fear.

### TAKING UP THE CHALLENGE

"Kinetics decided some three years ago to fully embrace the semiconductor gas systems business, and in that arena, modular gas delivery stood out as a key technology to invest in", says Firkins. Kinetics also looked at the critical component in the gas stick, the mass flow controller (MFC), and decided it needed that technology in-house. "The leading MFC supplier Unit Instruments was a key acquisition for us," says Firkins, "and its manufacturing and testing facility in Ireland was ideal for providing local service and support in Europe."

Unit Instruments' MFC instrumentation facility in Dublin has now been integrated with the Kinetics' Irish flow systems design and manufacturing company in Mountrath – to create a fluid systems centre of excellence for Europe. Peter English, general manager of the Dublin office explains the importance of the acquisition of Unit Instruments. "Ultimately, the accuracy and repeatability of the gas delivery system – and to a significant extent the flexibility of the tool - rests on the mass flow controller. Advances in this area have a direct impact on tool performance".

And many advances have been made. Five years ago, the valves alone on MFCs – which contain two main

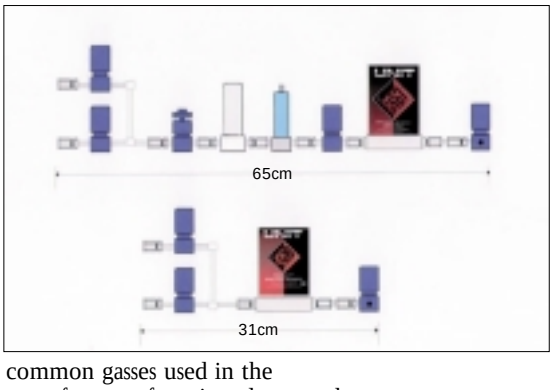
components: a mass flow meter and a proportioning controller - contained at least 15 individual mechanical components. Unit set about reducing that number to reduce costs and improve reliability, and today that component count is down to six.

The control electronics have also made the transition from analogue, which required a great deal of calibration and adjustment, to a digital system with in-built intelligence – leading to many important gains in flexibility. Whereas analogue-controlled MFCs use a 0–5V control signal, the digital variants will operate via serial buses such as RS485, or industrial fieldbuses. The most common fieldbus protocol today in the semiconductor arena is DeviceNet. However, because the Kinetics facilities in Ireland are dedicated to serving the European market, engineers there also developed a Profibus interface to meet local needs.

But the latest development is the most interesting of all says Kinetics: an MFC which integrates the functions of a pressure regulator. Shown for the first time at Semicon Europa, the FloGuard MFC allows gas sticks to be reduced in size by as much as 50% by eliminating the need for an in-line pressure regulator. This subsequently makes associated components such as the pressure transducer/gauge, the filter to clean up particle shedding, and the isolation valve, redundant. The cumulative benefits of this technology include reductions in footprint, inventory, maintenance and down-time. Process performance and repeatability are also enhanced through elimination of particles, the first wafer effect, and cross-talk between gas stick components.

## LOOKUP TABLES REDUCE INVENTORY

Perhaps the best example of the benefits of digital technology applied to MFCs is dynamic reconfiguration for different gasses. As there are around 20 common gasses used in the manufacture of semiconductors, there has to be an MFC for each gas and flow rate, because of rangeability constraints and gas characteristics. The result is that the spares inventory for the wafer fab is large. However by embedding the various density and flow characteristics in an EPROM within the digital control electronics, it is now possible to simply download a change request via the data bus. So now one 'MultiFlo' MFC can suit a range of gasses and flow rates, and this flexibility is particularly attractive to foundries who need flexibility in their process to suit different recipes – many of which are located in the Asia-Pacific region. But not all of the analogue technology has been thrown away explains English. "The final current drive to the MFC's control valve is still analogue (as opposed to a pulse width modulated drive) as we can use the analogue drive for a lot of diagnostics. By monitoring the drive current and valve voltage behaviour we can tell if things are going wrong well before a failure occurs. For instance if contamination particles start to build up on the valve, this will affect the amount of drive power needed, so an alarm will be generated." The built in test (BIT) saves down time because now, instead of sending in a team to break down a stick assembly, the data bus can be used to run a proprietary Kinetics software package called Virtual Interface that is bundled free with the MultiFlo MFC. "Ten minutes of Virtual Interface analysis can save a whole shift period swapping MFCs around," said English.




**Axial gas stick (top) *vs* a radial stick below. FloGuard MFCs can negate the need for several in-line components such as filters and regulators.**

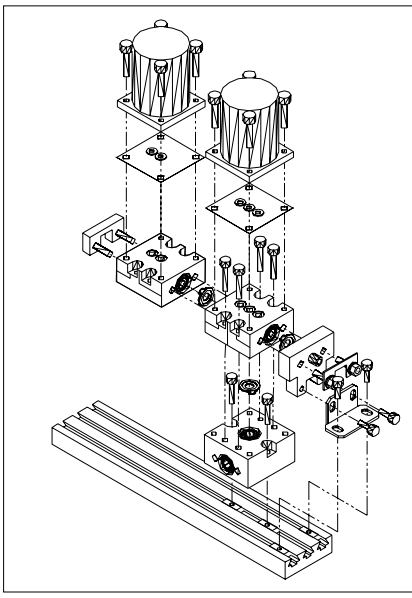
## DOWN TO THE VILLAGE

An hour and a half from Dublin by car is Mountrath, a place that epitomises the stereotypical Southern Ireland market village. Narrow lanes, Wellington boot clad locals, and farm animals galore. Pulling into the

Kinetics site, you drive over a cattle grid and what at first glance might be taken for some dairy equipment turns out to be a bulk gas tank. All becomes clear once inside the building, for this is Kinetics' flow systems facility, a very high-tech operation where the company assembles, welds and tests gas sticks and panels for its European customers. Inside, Kinetics has constructed a large class 10 clean room.

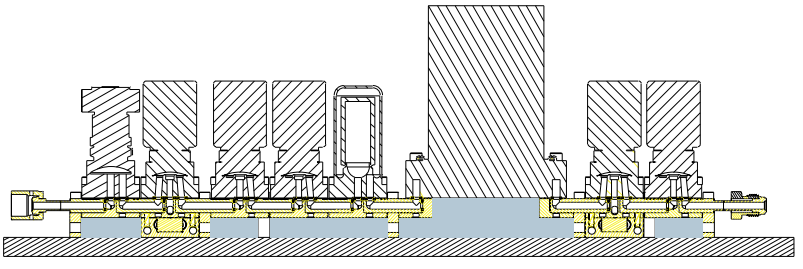
Managing director Don Firkins said, "Kinetics builds more semiconductor gas systems than anyone else in the world, and last year only a tiny proportion of them were based on modular substrates. But this year it's a very different story, in Europe around 20% of the sticks we will produce will use the surface mount modular system. Suddenly everyone wants a smaller footprint."Well, almost everyone.

There's still conservatism,within the industry, but the small-to-medium OEMs in particular now seem ready to adopt modular technology, and Europe has a lot of these OEMs. So for Kinetics, business in Europe and Asia is projected to ramp, and lead the take-up of modular gas delivery technology.



**The Full-Modular integrated gas platforms save valuable space because all of the porting arrangements are radial, and defined by a SEMI specification.**

**The substrate blocks are available in a selection of configurations which bolt together with Torx screws. The use of metal seals does away with traditional pipe fittings, and makes possible the replacement of individual components without the need to strip down the entire system.**



**Sectional drawing showing the gas flow route through the substrate.**