Case Study: PACs Automate Semiconductor Tooling

Opto 22 SNAP PAC System solves system integration challenge for semiconductor OEM while expanding networking capabilities and I/O options.

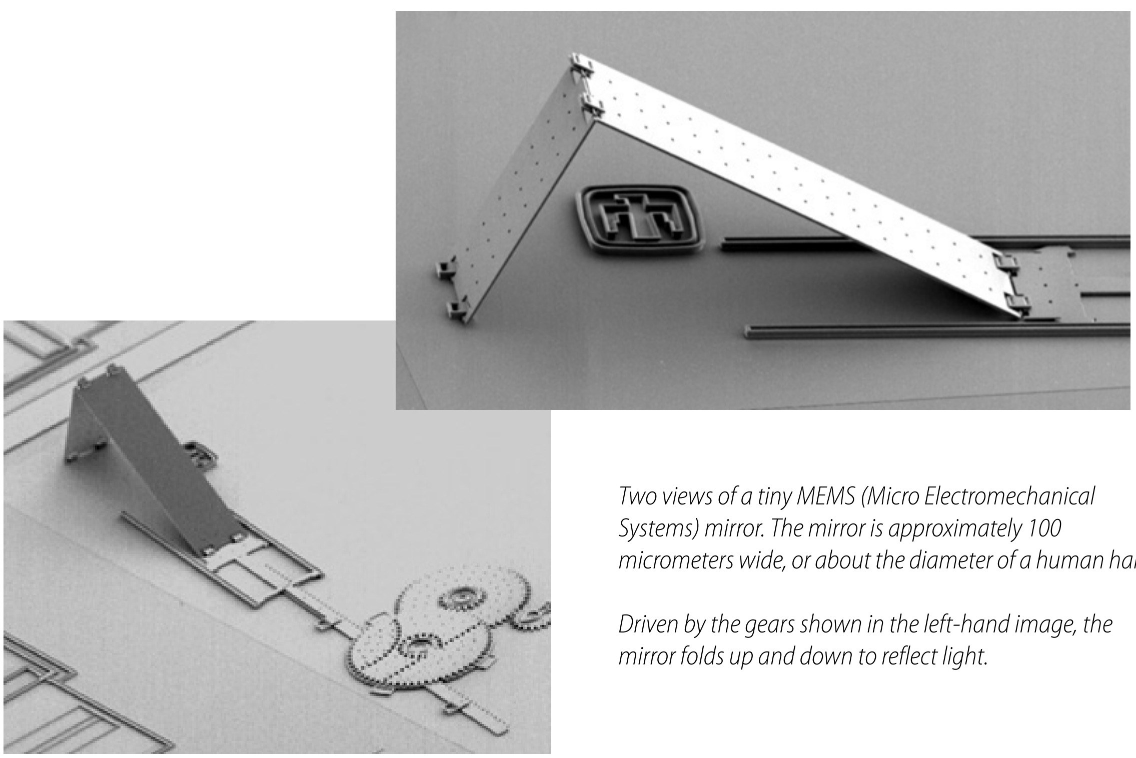
Have you ever wondered how your smartphone knows it needs to rotate its display when you turn it sideways? Or how it determines the direction and angle you're holding it at? To do that your smartphone uses a device called an *accelerometer* that works by sensing acceleration due to gravity.

That rate of acceleration is used to calculate the direction the phone is facing. In fact, some smartphones use several three-axis accelerometers to provide greater accuracy. But how does a piece of electronics sense something physical, like acceleration due to gravity, from a mechanical device like an accelerometer?

Mechanically measuring movements with MEMS

The answer is MEMS (Micro Electromechanical Systems). MEMS are similar to silicon integrated circuits but are mechanical in nature, not electronic or solid-state. MEMS manufacturers use techniques similar to those used to make electronics to build tiny mechanical structures that can interface with electronics. MEMS are found in many common electronic devices today, including:

- **Piezoelectrics** in inkjet printers, which deposit ink on paper by thermal bubble ejection
- **Accelerometers** in modern cars; their uses include airbag deployment and electronic stability control



Two views of a tiny MEMS (Micro Electromechanical Systems) mirror. The mirror is approximately 100 micrometers wide, or about the diameter of a human hair.

Driven by the gears shown in the left-hand image, the mirror folds up and down to reflect light.

Courtesy Sandia National Laboratories, SUMMiT™ Technologies, www.sandia.gov/mstc

- **Gyroscopes** in remote-controlled or autonomous helicopters, planes, and multirotors (known better as drones), which automatically sense and balance flying characteristics of roll, pitch, and yaw
- **MEMS microphones** in portable devices like mobile phones, headsets, and laptops
- **Silicon pressure sensors** in car tire pressure sensors and disposable blood pressure sensors, which are inexpensive and accurate
- **Digital displays,** such as Digital Light Projection (DLP) systems, which use MEMS to control hundreds of thousands of micromirrors
- **Bio-MEMS applications** such as stents, biosensors, and chemosensors

As MEMS technology advances, these tiny electromechanical systems shrink even smaller, and new uses are being found every day. However, one hurdle inherent to MEMS technology is the difficulty in controlling surface forces such as wear and "stiction" (permanent adhesion). These surface forces often restrict the operational environment and limit the lifetime of MEMS-based devices.

Reducing wear- and stiction-related failures in MEMS applications requires carefully controlling the topography and chemical composition of MEMS contacting surfaces during manufacturing. Currently the best way to achieve this control is to apply advanced surface coatings to contacting surfaces of MEMS devices. These surface coatings limit chemical bonding and electrostatic forces.

Reducing wear and stiction in MEMS devices isn't just about the type of coating used, but also about the process. As MEMS become smaller, it's increasingly difficult to apply a thorough and complete coating to the entire surface of these tiny mechanical systems.

Molecular Vapor Deposition (MVD)

To combat this challenge, San Jose, California-based company Applied Microstructures (AMST) developed and patented a new technology platform for MEMS coating applications, called Molecular Vapor Deposition (MVD). MVD was invented by AMST to help semiconductor manufacturers grow ultra-thin, functionalized, organic and inorganic films with higher yields and better cost efficiencies than traditional liquid deposition techniques.

Molecular vapor deposition replaces traditional liquid coating processes with a vapor process that is well suited for manufacturing applications. MVD technology uses vapor deposition at low temperatures to deposit ultra-thin films on a broad range of substrate materials.

Films created with MVD serve as lubricant, protective, hydrophobic, hydrophilic, biocompatible, or reactive coatings. In MEMS applications, for example, MVD films are typically used as anti-stiction coatings that improve device performance and increase overall device lifetime.

AMST's MVD platforms are highly flexible systems that can run processes like atomic layer deposition (ALD) and chemical vapor deposition (CVD), both used extensively in the semiconductor industry. These systems feature optional integrated plasma generation for substrate conditioning. They allow for the use of up to four precursors and can process multiple wafers or other three-dimensional objects in a single batch. These platforms deliver extremely high conformality on aggressive aspect ratios of up to 2000:1.

The Challenge

AMST's flagship MVD300 product handles the MVD process. The MVD300 employs a vapor-phase process that uses substantially less coating material than traditional methods; so much less material, in fact, that the exhaust system no longer requires time- and cost-intensive cleaning.

AMST's MVD300 molecular vapor deposition system

The MVD300 integrates several different systems that, together, perform the MEMS coating process. Systems include a programmable logic controller (PLC) for process control, an industrial PC running an operator interface (Human Machine Interface, or HMI), and the equipment front-end module (EFEM).

EFEMs are the mainstay of semiconductor manufacturing automation and are responsible for shuffling product (silicon wafers or quartz photo-masks) between ultra-clean storage carriers and a variety of processing, measurement, and testing systems. An EFEM contains the components that unload product, deliver it to the parent tool for processing, and return the product to its carrier upon completion. The machine's built-in control system manages all these steps.

Lindsey Eastburn, Senior Software Engineer at AMST, knew that integrating these different systems and getting them to work together as one cohesive system would be a difficult problem to solve. Eastburn also felt the PLC-based control system and related custom communication protocol would slow down customized application development. AMST's customers needed fast EFEM reconfiguration to run different MEMS coating jobs, and in general simply needed a lot of flexibility in their EFEM workflows.

The Solution

Eastburn decided the EFEM's control system needed to be replaced with an alternative that could meet the communications and integration challenges he faced in developing the MVD300. He and his colleagues turned to the Opto 22 SNAP PAC control system to interface the separate systems in the MVD300, as well as provide system-wide control and monitoring capabilities.

Eastburn found many features and benefits in using the SNAP PAC control system. "The ease of configuring the Opto 22 SNAP PAC control system set it apart from other control system manufacturers," Eastburn says. "We found the SNAP PAC system had a better overall capability to scale from a small application to a large application, and do so without having to change much in software or hardware other than adding additional I/O."

"In our experience," continues Eastburn, "it seemed like Opto 22 sticks with what they know best, which is providing a solid, application-agnostic control platform that engineers can easily tailor to their specific needs. The system is extremely flexible and fits into a wide range of application scenarios. And the software and hardware tools are organized and structured to support fundamental engineering and problem solving, instead of having to completely tailor your engineering approach around a specific control system."

Better Software

"The flowchart programming interface was intuitive," says Eastburn, "and easier to use than ladder-logic-based development environments I've worked with in the past. There's also a wide variety of programming options for developing a control program. Between the flowcharting and scripting support, programming simple tasks in PAC Control is much easier than traditional ladder-logic-based systems."

Programming in ladder logic often requires writing a lot of code to perform a single basic task. In comparison, Eastburn found the built-in command blocks used in PAC Control programming software ideal for simple tasks; command blocks are first dragged and dropped into a control flowchart, and then configured using a drop-down, point-and-click interface. For advanced control programming, Eastburn uses PAC Control's built-in scripting language, OptoScript, to do things ladder logic just can't, or at least can't do "without considerably more hours invested in software development."

Flexible Hardware That Scales

I/O configuration tools included with the SNAP PAC control system allowed AMST hardware engineers to get their system up and running without having to use an HMI. These I/O configuration tools also made troubleshooting and diagnostics easy to perform, even before an application was in place. Opto 22 also provided a wide variety of I/O layout and I/O module options to meet AMST's application needs.

AMST used Opto 22's high-density I/O modules to save space in the MVD300 tool. The MVD300's hardware layout consists of a SNAP-PAC-R2 controller, a fully populated 8-module rack with five 32-point digital input modules and three 32-point digital output modules.

"We fully populated the rack [with I/O modules] but didn't use all of the I/O points on each module," says Eastburn. "We wanted to have a number of discrete and analog inputs for future sensor connections. So our tool

Dual independent Ethernet network interfaces on a SNAP PAC controller separate communications on different subnets, increasing network performance.

32-point SNAP I/O modules used in AMST's MVD300 conserve valuable internal space.

management software reads all inputs and maps them to the Modbus/TCP interface, and the client application uses whatever I/O is needed. If we add devices later we can update the client without changing anything else."

AMST also took advantage of the dual Ethernet interfaces on the SNAP-PAC-R2 controller. With dual Ethernet interfaces AMST was able to isolate functions of the tool on their own networks to reduce network latency and improve network response time. One network interface is used for a double-armed robot that grabs wafers and loads them into the tool. The other interface is connected to the process control network.

With most process and logic controllers, adding a single Ethernet interface to the system increases costs. In comparison, the SNAP-PAC controllers provide great value by having two network interfaces already built into the controller at no extra charge.

Enhanced Communications Support

AMST also leveraged the SNAP PAC controller's enhanced communication support in their application development. The SNAP PAC controller sends a heartbeat signal between itself and the EFEM. If the connection is dropped, the SNAP PAC System controls a tower stack light to let the operator know there is a problem.

The EFEM and SNAP PAC controller also exchange communication over Ethernet using the Modbus/TCP protocol. Polling I/O status from the EFEM is easy to do over Modbus using the SNAP PAC controller's built-in scratch pad memory space. The SNAP PAC System also reads all EFEM environmental signals using the Modbus/TCP protocol.

Looking Ahead

With the success AMST has seen with the MVD300, they're planning to use the SNAP PAC System to automate their next-generation EFEM and enhance system communication even further.

About Applied Microstructures (AMST)

Applied Microstructures (AMST) makes technology and equipment used to fabricate microelectronics devices found in smartphones, computers, automobiles, and products that enable the Internet of Things (IoT). AMST invented Molecular Vapor Deposition (MVD®), a unique technology platform that deposits high-performance anti-stiction and other protective ultra-thin films with superb precision on applications with miniscule feature sizes. Such films are essential enablers of MEMS devices like digital displays, motion sensors, microphones, and accelerometers—the type of devices found in virtually every smartphone on the planet.

Customers rely on MVD to achieve exceptional film uniformity in volume production, with industry-leading reliability—advantages that increase manufacturing yields and optimize device performance, while lowering overall costs. Since its debut in 2004, more than 7 billion MEMs devices have been produced using the MVD platform. Today, the MVD platform is deployed worldwide in volume production, and supported by a global team of AMST technical experts. Founded in 2003, AMST is a venture-backed company, headquartered in San Jose, California, with sales and support operations located globally.
www.appliedmst.com

About Opto 22

Opto 22 develops and manufactures hardware and software for applications involving industrial automation and control, energy management, remote monitoring, and data acquisition. Designed and made in the U.S.A., Opto 22 products have an established reputation worldwide for ease-of-use, innovation, quality, and reliability.

Opto 22 products, including the *groov* mobile operator interface, use standard, commercially available networking and computer technologies, and are used by automation end-users, OEMs, and information technology and operations personnel in over 10,000 installations worldwide.

The company was founded in 1974 and is privately held in Temecula, California, U.S.A. Opto 22 products are available through a global network of distributors and system integrators. For more information, contact Opto 22 headquarters at +1-951-695-3000 or visit www.opto22.com.