Cleanroom fire safety enters new era

INSURANCE STANDARDS NOW CALL FOR TOOLS TO BE FABRICATED FROM NEW FIRE-RESISTANT MATERIALS. A PANEL OF MATERIALS EXPERTS CONSIDERS NEW CHALLENGES FACING FAB OWNERS AND TOOL MAKERS

***Editor's Note:** This article is taken from a panel discussion on key issues involving fire-safe plastics, cleanroom tools and fume exhaust systems with an emphasis on owner's needs, process compatibility and total cost of ownership.*

Following an analysis of several well-publicized semiconductor fabrication plant fires in Asia, the insurance firms that underwrite fabs and cleanroom facilities developed more stringent standards for materials of construction (MOC).

The initial standard, Factory Mutual (FM) 4910, defines requirements for flame progression and smoke generation. A subsequent standard, UL 2360, deals with similar requirements. Together, FM 4910 and UL 2360 serve as industry consensus standards for safer MOC choices in cleanroom tool construction.

While making cleanrooms safer, the new insurance standards call for tools to be fabricated from new fire-resistant plastics, such as Halar ethylene chlorotrifluoroethylene (ECTFE), chlorinated polyvinyl chloride (CPVC), polyvinylidene chloride (PVDF) and some compounded flame-resistant (FR) polypropylenes. Use of these new materials, in turn, creates another set of challenges.

First is the need to educate equipment suppliers on how to design and build systems with these new plastics.

A second challenge—the supply of sheet and stock shapes needed to build equipment—has been solved with the emergence of several suppliers of plastic shapes in North America, Europe and Asia.

The final challenge is the higher cost of these advanced materials. The cost issue is being solved with "hydrid" tools built from a combination of fire-safe materials to optimize affordability, purity, fire resistance, strength and process compatibility.

CleanRooms recently interviewed a panel of experts to discover how the supply chain is working to improve safety, control costs and ensure purity by incorporating the next-generation fire-resistant plastics into optimized hybrid tools and exhaust ducts.

Meet the panel of cleanroom fire-safety experts

Editor's Note: The panelists' quotations in the article are attributed to them using the initials below.

J. Karol Argasinski (KA) is a fluoropolymer applications engineer with Ausimont, USA, a global producer of fluorospecialty materials.

Ray Bastnagel (RB) is business development manager for Ausimont, USA.

Dell Burmeister (DB) is a senior procurement quality engineer with FSI International, a company providing strategic technology solutions to microelectronics manufacturers.

Gary DiFazio (GD) is a product manager for Compression Polymers Corp., a leading producer of extruded thermoplastic sheet.

Robin Douglas (RD) is vice president of Poly-Flow Engineering, a manufacturer of cleaning equipment for semiconductor manufacturers.

Stephen Fox (SF) is a senior engineer for Intel's Risk Management Department.

Mike Hyrniewicz (MH) is director of sales and marketing for GDS Manufacturing, makers of the Kem-Tuff system of fluoropolymer-coated stainless steel.

Peter Mullen (PM) is a marketing manager with Noveon, a specialty chemical manufacturer.

Heron Peterkin (HP) is semiconductor industry engineering leader of FM Global, a major insurance carrier serving the semiconductor industry.

Jerry Wagner (JW) is technical materials manager of Westlake/High Tech Plastics, a manufacturer of thermoplastic stock shapes and films.

Meeting the FM standards

CleanRooms magazine (CM): What are FM 4910 and 4922, and what is their purpose?

HP: FM Global 4910 is the cleanroom materials flammability test protocol. FM 4922 is the approval standard for fume- and smoke-exhaust ducts.

Both are designed to reduce fire-safety risks in cleanroom operation. They achieve this by demonstrating the material or product's ability to limit fire spread and smoke damage in a cleanroom fire.

Tools constructed of materials meeting FM 4910 do not require an on-board fire-suppression system when flammable and combustible liquids are not used in the tool.

Ductwork that meets FM 4922 eliminates the need to install automatic sprinklers in fume exhaust and smoke-removal systems.

CM: How are plastics and products tested for FM 4910 and FM 4922 approval?

HP: The manufacturer provides FM Global with details on the material, including composition, manufacturing process and quality control. We visit the plant to confirm that the manufacturing process can consistently and reliably produce a uni-

"Vinyl and polyolefins should be considered for structural and other non-ultra-pure applications in the wet bench. Their rigidity makes them an ideal material for use in the shells of cleanroom tools." —Peter Mullen (PM)

"Controlling costs for the end user is achieved by engineering a combination of materials that match each application." —Robin Douglas (RD)

"Every process engineer knows that with smaller device line widths, process contamination becomes more of an issue. Conventional FR polypropylenes can be a source of contamination. By replacing them with a material like Halar or PVDF, you eliminate extractable and particle micro-contamination and increase yield." —Ray Bestnagel (RB)

"Tools constructed of materials meeting FM 4910 do not require an on-board fire suppression system when flammable and combustible liquids are not used in the tool. Ductwork that meets FM 4922 eliminates the need to install automatic sprinklers in fume exhaust and smoke removal systems." —Heron Peterkin (HP)

"Fabrication of fluoroplastics does not create any safety problems as long as it is done according to the resin manufacturer's recommendations. The 'Guide to the Safe Handling of Fluoropolymer Resins,' distributed by The Society of the Plastic Industry, contains a summary of safety measures and recommendations." —Karol Argasinski (KA) form product.

Next we conduct lab tests of the material or product. If the testing is successful, we certify the product as FM 4910 or FM 4922 compliant. A list of FM 4910-compliant materials can be found at www.fmglobal.com/fm4910.

We also conduct annual audits of FM-approved products and materials to ensure that they remain compliant with our standards.

The fab's fire safety challenge

CM: How difficult is it for fabs to comply with insurance safety standards?

SF: Questions as to cost, availability and process compatibility are being addressed as more products enter the market and the industry becomes familiar with these productions.

The next step for the standards industry would be to better define what quantity and arrangement of fire-safe plastic meets the intent of the National Fire Prevention Association (NFPA) and Semiconductor Equipment and Materials International (SEMI) standards for mitigating fire risks in cleanroom equipment.

On many wet process tools there are still internal plastics for which listed alternatives are scarce. And these are the applications where the process risk is greatest.

CM: Is there a cost premium for fire-safety equipment? How have you handled this?

SF: There are often significant cost premiums for equipment constructed of fire-safe plastics.

In some cases, elimination of the need to install fire-suppression systems can help offset the added cost of using fire-safe materials of construction, although they typically do not result in a net savings.

Intel has identified other cost savings in facility design and process application—e.g., fire-rated barriers, chemical controls—that can be achieved by using fire-safe plastics.

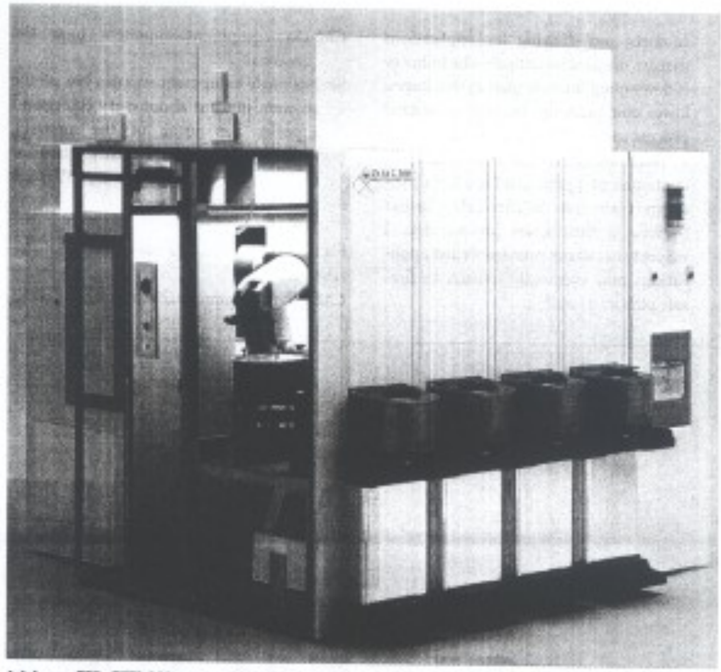
Fire-safe plastics can also reduce costs by controlling risk exposure and lowering insurance premiums. But to achieve these cost savings requires consistent application of these new materials throughout a production line or factory.

CM: How do you balance process compatibility issues when evaluating fire-safe materials of construction?

SF: Process compatibility is a paramount concern for our industry, and a comfort level with the current materials has grown through data and operational experience.

Many suppliers have developed hybrid designs that manage a mix of fire-safe plastics and sometimes non-listed plastics according to cost, quantity and process performance. Hybrids can control costs in the more sophisticated workstations where process compatibility is an issue.

In less complicated workstations—



Intel uses FSI's ZETA 300 system for back-end solvent strip applications on cutting-edge logic devices on the chipmaker's 300 mm pilot line.

cabinets and shelving for applications that are *not* process critical—the industry is developing fire-safe plastics that have a lower cost premium because of relaxed process compatibility requirements.

Shell construction and secondary containment equipment have been easier to transition to fire-safe plastics because of their lower process risks. I suspect that many process-wetted applications may eventually transfer to fire-safe plastics as well.

CM: Do equipment suppliers have the answers?

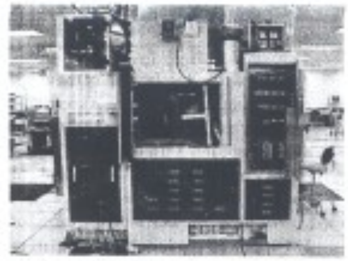
SF: No single equipment supplier has all the answers, but just about every equipment supplier has some of the answers. Although most of the industry is familiar with fire-safe plastics, there are still many questions to be resolved.

Fire safety starts with raw materials

CM: What commercially available MOC meet FM 4910 and FM 4922 standards?

RB: There are several. Materials for FM 4910 and UL 2360 include Halar ECTFE; clear Halar ECTFE and PVDF fluoropolymers; compounded FR polypropylenes; Corzan CPVC and clear CPVC and other chlorinated polymers.

For FM 4922 exhaust systems, the materials of construction include stainless steel—coated with either Halar E-CTFE or ETFE—and fiber-reinforced plastic (FRP) ducts.



There are often significant cost premiums for equipment constructed of fire-safe plastics. In some cases, elimination of the need to install fire suppression systems can help offset the added cost of using fire-safe materials of construction, although they typically do not result in a net savings, says Intel's Stephen Fox.

PM: These materials were tested by International Sematech for outgassing properties and leaching parameters in common industry solutions, including DI water, ozonated water and mixed-process chemicals.

CM: How are these materials used?

RB: Typically, cleanroom tool structures are fabricated from these materials. Halar E-CTFE and PVDF can also be used in plastic process tanks and modules, or as coatings and linings in metal vessels. The materials to be used are selected based on a number of criteria, including fire safety, purity, process compatibility, corrosion-resistance, strength and cost.

Every process engineer knows that with smaller device line-widths, process contamination becomes more of an issue. Conventional FR polypropylenes can be a source of contamination. By replacing them with a material like Halar or PVDF, you eliminate extractable and particle micro-contamination and increase yield.

The highly corrosive solutions used in wafer processing can cause polyolefins to pit, corrode and crack. Halar is the only material that can handle the full pH range. Even PVDF is vulnerable to surface cracking and particulation in chemistries where the pH is greater than 12.

PM: Fire-safe materials have many different applications within the cleanroom based on the different properties of the various families of plastics.

Vinyl and polyolefins should be considered for structural and other non-ultra-pure applications in the wet bench. Their rigidity makes them an ideal material for use in the shells of cleanroom tools. Vinyl and polyolefins can't be used in the ultra-pure tools themselves, because heat stabilizers, pigments, flame-retardants and other additives will leach out and contaminate process fluids.

CM: Isn't it expensive to build the entire tool using these costly FM-listed materials?

RB: That's where the new hybrid-tool concept comes in. Different materials are used in different parts of the tool to deliver specific performance characteristics. You don't use costly fluoropolymers throughout the tool. Instead, you use them just where they are needed.

PM: As a tool's construction is evaluated, there are places where ultra-pure conditions need to be met, and other places where structural integrity is most valuable.

In a hybrid tool, ultra-pure areas, such as the wet deck, splash areas and tanks can be made of Ausimont's Halar ECTFE. In ultra-pure water applications, Halar process surfaces significantly reduce the formation of bacteria and films compared with electropolished stainless steel and PVDF.

Structural areas, such as the tool's shell, can be fabricated from Noveon's CPVC—which provides structural integrity at lower cost than the fluoropolymer materials.

Building fire-safe tools

CM: How do you supply requests for FM 4910 fire-safe tools?

RD: We evaluate the chemical compatibility of the entire process against a list of potential MOC.

Our first choice is to build tools made of incombustible materials, including stainless steel and quartz. Because some applications use only hot UPW or solvents, we can easily meet SEMI S-14. For processes that are only mildly corrosive, our tools incorporate PVDF process sinks mounted in a stainless-steel structure.

In processes with concentrated acids, we select the material based on the physical characteristics needed. For a transparent access panel covering a plenum handling hot piranha, clear Halar ECTFE would be the material of choice because it can withstand constant exposure to hot aggressive vapors.

DB: While our established tools are offered in FM and non-FM versions, new tools are available only with FM-listed materials. Purchasing these materials in large volumes helps reduce our costs and improves material forecasting.

Historically, approximately 80 percent of our tool shipments have been built with FM-listed materials, and we expect customer requests for these materials to grow. We also expect FM 4910 material costs to continue to drop.

CM: What can be done to control costs?

RD: Controlling costs for the end user is achieved by engineering a combination of materials that match each application.

The outer cabinet shells in Poly-Flow tools have no contact with process fluids, so they are made from Corzan PVC, which, as a pigmented material, has a suitable cleanroom appearance.

Although higher in price than non-FM listed PVC, Corzan PVC is significantly less expensive than Halar ECTFE and PVDF, which have never been affordable materials of construction for cabinets.

DB: By understanding the user's needs and translating those needs into material specifications early in the design process, we can eliminate unnecessary costs in machining, fabricating and testing of FM 4910 materials.

It is a competitive market, so suppliers have to understand, anticipate, and act on our needs to be successful. We take advantage of technical expertise offered by our suppliers in fabrication techniques, safety and welding training and fabrication equipment recommendations.

CM: Do you have examples of hybrid tools?

DB: All of our etching, cleaning and immersion tools use various FM 4910-listed materials. These materials include modified PVC, CPVC, Halar ECTFE and PVDF, which are brought to final form through welding, vacuum forming and thermal forming.

Through intelligent material selection, hybrid tools can help us keep our products competitively priced and help our customers reduce their total cost of ownership.

RD: We offer hybrid structures in our wafer processing stations as well as our parts cleaning line.

In our dual-chambered Typhoon quartzware cleaner, for example, the process chamber and exhaust tank are fabricated from FM-listed PVDF. The piping and storage tanks are either PFA or PVDF.

We built a stainless-steel space frame and encapsulated it with a Corzan sheet. The inner PVDF process chamber is welded inside the Corzan CPVC outer cabinet, and then the HTP 800 clear access panels and door are fitted. This yields a structure that is strong, chemically resistant to HF-based etchants and fully FM compliant.

For our wafer processing stations, like our single-wafer 300 mm Expose, we frequently use Halar ECTFE for those sections handling sulfuric acid and APM. Halar primary and secondary containment plenums are physically held in place inside stainless reinforced Corzan outer shells. This allows us to engineer for maximum chemical resistance based upon exposure and appearance with physical strength based on cost.

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Exhaust duct systems

CM: What are the requirements for building an FM-approved exhaust duct system?

MH: FM 4922 addresses the issue of corrosion resistance in duct systems in the 12- to 60-inch diameter range. FM-listed exhaust systems do not require internal sprinkler protection and can be used in special-purpose areas such as cleanrooms.

CM: What are the materials of construction?

MH: Conventional metal duct systems typically cannot handle the variety of corrosive chemistries found in semiconductor manufacturing. The solution is to use either FRP composites or fluoropolymer-coated stainless steel.

The FRP composite materials rely on a corrosion-resistant inner layer with a non-flammable exterior.

The coated stainless steel systems use a fluoropolymer coating on the inner surface of a stainless steel duct construction.

The two fluoropolymers currently in use are ECTFE and ETFE. Both of these materials provide excellent corrosion resistance in a system with the mechanical integrity of stainless steel.

GDS produces the Kem Tuff system of Halar ECTFE fluoropolymer-coated stainless steel. It is the same Halar ECTFE used in plastic sheet for FM 4910-compliant cleanroom tools, and offers excellent fire-resistance and corrosion protection.

PM: No system being manufactured solely from vinyl meets FM 4922 as it is tested today for the semiconductor industry. CPVC compounds used to manufacture ducts have been tested to FM 4910 and may be a suitable material for fire-safe tool hook-ups within the cleanroom.

Plastic fabrication

CM: Is welding and fabrication training for the new FM-compliant materials available?

KA: Knowledge of the properties of the different fluoropolymer resins and their grades is essential in developing proper fabrication techniques. Ausimont assists customers in solving fabrication problems by sharing our experience in fluoropolymer processing.

PM: Key components of successful thermoplastic welding include accurate temperature control, a clean, dry gas source (either air or nitrogen) and the proper tools for preparation and execution of the welding process.

The sheet and welding rod must be manufactured from like materials. Even within a family of materials, such as CPVC, manufacturers formulate their compounds in different ways and therefore welding parameters may be different. This can result in poor weld quality in the finished product.

CW: What are the fabrication challenges of these materials?

KS: Poorly welded parts can develop leaks and cause premature failures. To help develop proper welding techniques, [illegible] offers fabrication training at customer locations.

PM: [illegible] has developed guidelines for welding its CPVC materials. Welded joints can be tested following the guidelines of [illegible].

CW: Are there safe handling issues to be concerned about?

KS: Fabrication of fluoroplastics does not create any safety problems as long as it is done according to the resin manufacturer's recommendations. The "Guide to the Safe Handling of Fluoropolymer Resins" distributed by The Society of the Plastics Industry contains a summary of safety measures and recommendations.

We retained Clayton Environmental Consultants to determine potential employee exposure to HCl and HF during [illegible] welding. The air samples taken during welding showed the concentrations of HCl and HF to be below the limit of detection.

PM: [illegible] also contracted with Clayton to assess the effects of off-gassing of hydrogen chloride during multiple fabrication processes typical in the construction of a cleanroom including hot gas welding, cutting, tapping and milling. Clayton's assessment showed that CPVC is safe to work with during the typical eight-hour day.

In addition, Clayton evaluated acetone exposure, because acetone is sometimes used as a cleaner on CPVC prior to welding. This procedure did not exceed exposure limits for acetone vapors.

Conclusion

If the new generation of FM-listed plastics were as inexpensive as the polyolefins they replaced, there would be no need for hybrid wet benches; you could afford to use these new materials of construction throughout the tool. In hybrid tools, different materials are selected for different tool components based on a variety of criteria: cost, structural integrity, corrosion resistance, fire safety, purity and process compatibility.

While the new generation of FM-listed plastics is fully developed and commercially available, equipment suppliers are still on a learning curve when it comes to selecting, specifying and fabricating these materials. The more often product data, best practices and training are shared throughout the supply chain, the better the end users and [illegible] will be served. ■

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Letters

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the chip business was going, I probably would not have been offered the job.

Later while employed by the chip manufacturer, where I spent 13 productive years, many of the conferences I attended [illegible] the advances and insights we in the semiconductor business had made in cleanroom design, AMC control, microbial detection and control in CPW systems, as well as a host of new instrumentation techniques.

My ex-colleagues from the pharmaceutical and medical device industry scoffed at or turned a deaf ear to these ideas, refusing to see how "semiconductor techniques" could be easily applied to problems frequently encountered in their own plants.

A number of years ago, NIH had developed a program creating the linkage between the biological sciences with those applied specifically to the semiconductor industry. Hopefully some heads have been turned, and eyes opened to the possibility of what we can learn from each other, as we [illegible] stop debating which of ours is really a "hard" science.

—[illegible]