

Fire-Resistant Foams for Pharmaceutical and Semiconductor Cleanrooms

RON PARTRIDGE

Fluoropolymer foams are high performance closed-cell foams based on polyvinylidene fluoride (PVDF) that bring new materials solutions to the life sciences and semi-conductor industries. Both industries require the use of ultra-high purity materials with low smoke generation and outstanding flame and chemical resistance. For many years, fluoropolymers, such as PVDF and its copolymers, have been successfully used for fluid handling and packaging systems. The introduction of new fluoropolymer foams fills a gap by adding flame retardant and chemically resistant insulation materials.

LIFE SCIENCES

Today's pharmaceutical industry uses the latest technologies to develop and manufacture medicines that dramatically improve the quality of life and increase life expectancy. The cost to develop, produce, pass FDA approvals and deliver these drugs to consumers can be as much as \$800 million per new medicine. The financial impact is very large if production of these medicines is slowed or shut down due to fire or smoke damage. Even the slightest delay in production can result in significant losses.



op, produce, pass FDA approvals and deliver these drugs to consumers can be as much as \$800 million per new medicine. The financial impact is very large if production of these medicines is slowed or shut down due to fire or smoke damage. Even the slightest delay in production can result in significant losses.

New, sophisticated medicines are made using advanced manufacturing technologies and materials. High technology, "clean-room" environments ➤

Molded fluoropolymer foams¹



Foam sheet and tubes¹

often contain polymeric sheet and polymeric foam for insulation. These are used to create lightweight structures, partitions, chemical wet benches, and pipe and ducting insulation. These environments may also include wiring, flexible non-metallic conduit for fiber optic cables, as well as process control and automation wiring.

SEMICONDUCTORS

The semiconductor manufacturing environments require the use of materials with excellent chemical resistance, purity, and low smoke generation in the event of a fire. PVDF polymers are commonly used because of their high purity and low smoke generation, and are widely used by the semiconductor industry to supply high-purity water to chip manufacturing operations. They are also used in the fabrication of wet benches. Since most chemicals do not alter PVDF, it has been adopted by the chemical process and pulp and paper industries for vessel lining and piping systems. PVDF is also characterized by its strength, toughness, and long-term resistance to both UV and gamma radiation.

In addition, PVDF is used to insulate data communications, fiber optic, fire alarm, and control cables because it will not easily propagate a fire and produces minimal smoke when burned. The excellent fire performance properties of PVDF allow for the installation of wire and cable products in building air-handling spaces without the need for metal conduits.

In order to limit the risk due to fire and smoke, Factory Mutual (FM), Underwriters Laboratories (UL), ASTM, and other testing agencies have developed fire-testing methods to characterize the fire performance of materials. It is generally recognized by these agencies that the best testing methods are full-scale tests or scaled-down versions that take into account where and how the product will be used. These test methods often use solid sheets, mounted horizontally or vertically, which are then exposed to a heat source and/or direct flame. These test methods are also used for testing polymeric foams, wire, and cable, and characterize performance by measuring flame spread and smoke generation as the polymer burns. In the case of wire and cable products, the cables are laid side by side in a closed chamber called a Steiner Tunnel (ASTM E84/NFPA 262/NFPA255) and fire performance is again characterized by flame spread and smoke generation. There are a number of nationally recognized testing laboratories that can perform these tests.

Many polymeric materials will readily burn and produce large amounts of smoke, as well as contribute significant fuel load, should a fire occur. However, fluoropolymers, especially PVDF, prevent and minimize fire hazards. PVDF is a pure polymer and is inherently flame retardant without additives. PVDF is characterized by:

STANDARD	DESCRIPTION
Factory Mutual FM 4910	Cleanroom Materials Flammability Test Protocol
ASTM E84/UL 723/NFPA 255	Standard Method of Test of Surface Burning Characteristics of Building Materials
NFPA 262	Standard Method of Test for Flame Travel and Smoke of Wires and Cables for use in Air-Handling Spaces

Table 1. Standards of real-world, full-scale fire scenarios

Sample	CHF*	TRP#	FPI**	SDI##
ZOTEK® 40 HT LS Foam	30	799	3	0.1
Cleanroom Material Limit	-	-	6	0.4

Test Method ASTM E 84	Flame Spread Index 25 max allowable	Smoke Developed Index 50 max allowable
ZOTEK® F 40 HT LS foam at a thickness of 1/8"	0	0
ZOTEK® F 40 HT LS foam at a thickness of 1"	5	5

Table 2. FM 4910 testing results

*Critical Heat Flux (kW/m²)

#Thermal Response Parameter (kW/m²s^{-1/2})

**Fire Propagation Index, (m/s^{1/2})/(kW/m)^{2/3}

##Smoke Development Index, (m/s^{1/2})(g/g)/(kW/m)^{2/3}

Table 3. ASTM E 84 test results

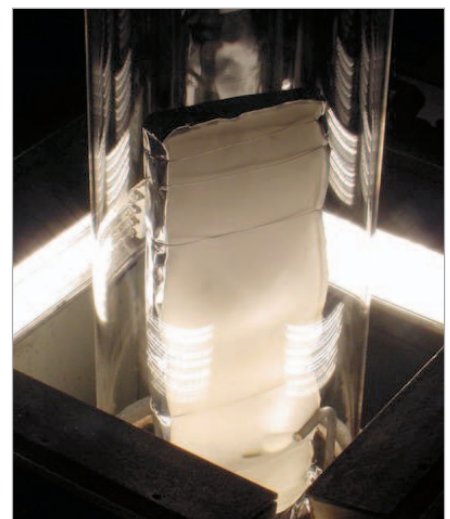
- High auto-ignition temperature
- Low caloric value
- Self extinguishes when a direct flame is removed
- Minimal fire propagation and minimal smoke generation
- Resistance to most chemicals, including typical sterilization methods
- High purity
- UV and gamma radiation resistant
- Toughness and cut-through resistance

PVDF closed-cell foams can be obtained in continuous sheets and in a variety of thicknesses. The foams can be easily thermoformed, cut, and machined to produce complex shapes. PVDF foams can also be laminated to other sheet materials, such as PVDF sheets, to produce lightweight panels, partitions, and enclosures.

These PVDF foams are extremely flexible, can be thermoformed into complex shapes, or transformed into tubes. The thickness, density, and flexibility of the finished foam can be controlled to suit a specific application. Densities as low as 30 kg/m³ (0.03 g/cm³) have been obtained, representing a 60-fold reduction in specific weight. They can be used in cleanroom areas where good thermal insulating properties and high levels of flame retardance with low smoke

generation are required. Recent FM 4910 exploratory testing has resulted in a Fire Propagation Index (FPI) of 3.0 and a Smoke Development Index (SDI) of 0.1. These preliminary results indicate that PVDF foams are capable of meeting the stringent requirements for cleanroom materials. Complete FM 4910 listings will be completed in the near future.

Specific PVDF resins and resultant closed-cell PVDF foams have been tested and passed the following fire performance standards. Fire testing and fire science is a very complicated area, and the results of fire performance testing can vary widely due to the test method used. How-



KYNAR® PVDF foams are tested to FM 4910 using the Fire Propagation Apparatus.

ever, the following standards (Table 1) are recognized as being the most stringent and best replicate of real-world, full-scale fire scenarios.

PVDF CLOSED-CELL FOAMS TEST RESULTS

Factory Mutual FM 4910

Exploratory FM 4910 testing has been completed and the results are shown in Table 2.

ASTM E84/UL 723

Surface burning characteristics of certain foam grades have been tested according to method ANSI/UL 723 (ASTM E 84 -01) used for the classification of building materials. ASTM E 84 test results are reported as Flame Spread Index (FSI) and Smoke Development Index (SDI) (Table 3). Results less than 25/50, respectively, indicate that the material has very limited combustibility and offers the highest level of fire performance other than a non-combustible (non-organic) material.

In order to pass these higher smoke release requirements, specific grades of LS foams with "LS" signifying low

smoke have been developed. An SDI less than 50 is very difficult to achieve for a foamed polymeric material in the ASTM E 84/UL 723 test. These LS foams are useful for the insulation of air conditioning ducts, steam pipes, and other process components. In addition, the thermal conductivity of foams is very low which makes them ideally suited for insulating applications.

SUMMARY

By selecting materials used in controlled environments with the best fire performance characteristics, risks to life, property, and revenue can be dramatically reduced. Reduction in risk should also translate into reduced insurance rates. Closed-cell foams offer excellent fire-, chemical-, and temperature-resistance characteristics and can be manufactured to produce solid sheets, insulation foams, complex shapes, and wiring insulation. PVDF closed-cell foams provide new options for engineers designing cleanrooms for the semiconductor and life sciences industries. Their excellent fire resistance characteris-

tics and low smoke generation should soon result in the listing of these products as FM 4910-approved materials.

See MSDS for Health & Safety Considerations. Kynar® PVDF is a registered trademark of Arkema Inc. ZOTEK® F is a registered trademark of Zotefoams PLC in the UK.

Reference

1. www.zotefoams.com



Ron Partridge is a Business Development Engineer in the Technical Polymers group at Arkema. Ron is responsible for Kynar® PVDF, foams, rotomolding, rotolining, and wire and cable business develop-

ment. He has roughly 20 years experience in the polymer industry in sales, business development, technical service and R&D. He has worked for Arkema for the last three years. He received his BS degree in Chemistry and Materials Science from The State University of New York in 1984. He can be reached at 215-419-7874; e-mail: ron.partridge@arkema-group.com

Arkema is involved in vinyl products, industrial chemicals, and performance products.