

## MULTILAYER FILTER HOUSING

## CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This patent application claims the benefit of U.S. Provisional Patent Application No. 63/544,482, filed October 17, 2023, which is incorporated by reference.

## BACKGROUND OF THE INVENTION

[0002] Filter housings for filter devices used in applications in the semi-conductor industry such as lithography and wet-etch chemical filter applications can be exposed to challenging conditions, such as highly corrosive fluids, e.g., hydrochloric, sulfuric, and hydrofluoric acids, that can be used at extreme temperature ranges, and often in combination with dissolved hydrogen peroxide. These fluids can damage traditional devices, and can impose health risks to personnel exposed to these fluids. Additionally, the materials coming into contact with these fluids must not contaminate or add impurities to the fluids.

[0003] There is a need for improved housings.

[0004] The present invention provides for ameliorating at least some of the disadvantages of the prior art. These and other advantages of the present invention will be apparent from the description as set forth below.

## BRIEF SUMMARY OF THE INVENTION

[0005] An aspect of the invention provides a filter housing is provided comprising a hollow filter housing body and having a filter housing inlet/outlet portion having an inlet port and an outlet port, and defining a fluid flow path between the inlet port and the outlet port, wherein the hollow filter housing body comprises at least three layers: a first layer comprising perfluoroalkoxy alkane (PFA), a second layer comprising a thermoplastic elastomer, and a third layer comprising a thermoplastic; wherein the second layer is interposed between the first layer and the third layer, the second layer comprising a bonding layer bound to both the first layer and the third layer.

## BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING(S)

[0006] Figure 1A is a drawing showing a side view of an illustrative filter housing comprising a hollow filter housing body and having a filter housing inlet/outlet portion having an inlet port and an outlet port, and a filter housing vent portion having an upstream vent port and a downstream vent port, wherein at least the hollow filter housing body comprises at least three layers according to an aspect of the invention; Figure 1B is a drawing showing a cross-sectional view of the filter housing shown in Figure 1A, wherein a filter element is arranged across a flow path between the inlet port and the outlet port, forming a filter device.

[0007] Figure 2A is a drawing diagrammatically showing an aspect of a method of sequential injection overmolding to make an aspect of an at least three layer film for use in forming the filter housing according to another aspect of the invention.

[0008] Figure 2B is a drawing diagrammatically showing an aspect of a method of compression molding to make an aspect of an at least three layer film for use in forming the filter housing according to another aspect of the invention.

## DETAILED DESCRIPTION OF THE INVENTION

[0009] In accordance with an aspect of the invention, a filter housing is provided comprising a hollow filter housing body and having a filter housing inlet/outlet portion having an inlet port and an outlet port and defining a fluid flow path between the inlet port and the outlet port, wherein the hollow filter housing body comprises at least three layers: a first layer comprising perfluoroalkoxy alkane (PFA), a second layer comprising a thermoplastic elastomer, and a third layer comprising a thermoplastic; wherein the second layer is interposed between the first layer and the third layer, the second layer comprising a bonding layer bound to both the first layer and the third layer.

[0010] In some aspects, the filter housing further comprises a filter housing vent portion having an upstream vent port and a downstream vent port. In some aspects the vent portion and vent ports additionally or alternatively comprise a filter housing drain portion and drain ports.

[0011] Advantageously, filter housings according to aspects of the invention provide desirable chemical resistance and mechanical integrity. They can be produced at lower cost than commercially available single component housings produced by injection molding. Filter housings can be produced using less fluoropolymer than is used to produce commercially available single component housings produced by injection molding, thus reducing possible pollution.

[0012] Aspects of the invention can be used to produce filter housings for filter devices to filter a variety of fluids in the semi-conductor industry. Applications include, for example, the filtration of fluids containing hydrochloric, sulfuric, and hydrofluoric acid, and isopropyl alcohol, especially at increased temperatures, e.g., hot sulfuric acid and hot isopropyl alcohol.

[0013] In an aspect of the filter housing, the second layer comprises a thermoplastic elastomer selected from the group consisting of a styrene block copolymer, a polyolefin, a polyamide, or a polyester elastomer. The thermoplastic elastomer can have the ability to stretch to moderate elongations and return to near its original shape, creating a longer life and better physical range than some other materials. In some aspects, the thermoplastic elastomer comprises polymethylpentene (PMP).

[0014] Desirably, the thermoplastic elastomer is kept in a state of compression to maintain good pressure sensitive adhesive characteristics to ensure adequate stress transfer in supporting the loads required by the application. Typically, the thermoplastic elastomer has a tensile modulus of less than 1 GPa, and a tensile strength of at least 5 MPa.

[0015] In an aspect of the filter housing, the third layer comprises a thermoplastic (such as an engineering thermoplastic) selected from the group consisting of polyimides, polyphenylene sulfide, aromatic polyesters, aliphatic polyesters, polyolefin homopolymers, polyolefin copolymers, cyclic olefin homopolymers, copolymers of cyclic olefins, ethylene vinyl acetate copolymers, polyesters, polyamides, polyvinyl chloride, polyvinylidene chloride, polystyrene, styrenic copolymers, ethylene ethyl acrylate, ethylene acrylic acid copolymers and combinations thereof. In some aspects, thermoplastic comprises polyetherimide (PEI).

[0016] The thermoplastic can be filled or unfilled, and typically has a tensile modulus of at least 2 GPa, and tensile strength of at least 100 MPa.

[0017] In a typical aspect of the filter housing, the first layer has a first layer thickness, the second layer has a second layer thickness, and the third layer has a third layer thickness, and the third layer thickness is larger than the first layer thickness. In some aspects, the third layer thickness is larger than the second layer thickness. In some aspects, the first layer thickness and the second layer thickness are similar in thickness.

[0018] Typically, the first layer thickness is in the range of from 0.060" to 0.125" (1.5 mm to 3.2 mm); the second layer thickness is in the range from 0.060" to 0.125" (1.5 mm to 3.2 mm); and the third layer thickness is in the range from 0.060" to 0.125" (1.5 mm to 3.2 mm). For example in one aspect, the third layer thickness is at least 20% larger than the first layer thickness. In some aspects, the third layer thickness is at least 30% larger than the first layer thickness. In another aspects the third layer thickness is at least 50% larger than the first layer thickness.

[0019] In some aspects, the filter housing body has an interior surface comprising the first layer, and an exterior surface comprising the third layer.

[0020] In some other aspects, the filter housing body has an interior surface comprising the third layer, and an exterior surface comprising the first layer.

[0021] Typically, the filter housing inlet/outlet portion and the filter housing vent portion each comprise at least three layers corresponding to those of the hollow filter housing body: a first layer comprising perfluoroalkoxy alkane (PFA), a second layer comprising a thermoplastic elastomer, and a third layer comprising a thermoplastic; wherein the second layer is interposed between the first layer and the third layer, the second layer comprising a bonding layer bound to both the first layer and the third layer.

[0022] One aspect of a method for forming the filter housing include sequential injection overmolding, which includes sequentially adding material (overmold) to an existing part or structure, wherein the first material added is typically applied to a rigid substrate. Typically, a molding machine injects the first material into a closed cavity, and then moves the mold to create a second cavity, using the first component as an insert for the second injection using a different material, and then then moves the mold to create a third cavity, using the second component as an insert for the third injection using a different material; and the resultant material is removed from the mold.

[0023] Another aspect of a method for forming the filter housing include compression molding in which the first molding material, generally preheated, is first placed in an open, heated mold cavity. The mold is closed with a top force or plug member, pressure is applied to force the material into contact with all mold areas, while heat and pressure are maintained until the first molding material has cured; followed by placing the second molding material on top of the first cured material, in another open, heated mold cavity, wherein the mold is closed and pressure applied until the second molding material has cured; followed by placing the third molding material on top of the second cured material, in another open, heated mold cavity, wherein the mold is closed and pressure applied until the third molding material has cured, and the resultant material is removed from the mold.

[0024] Yet another aspect of the method for forming the filter housing includes vacuum thermoforming of a three layer sheet material comprising the layers identified above. The sheet material is exposed to heating elements to enable sufficient softening, then transferred to a male or female template wherein the PFA layer is oriented towards the interior of the capsule.

[0025] In another aspect, a method of making a filter housing comprising a hollow filter housing body and having a filter housing inlet/outlet portion having an inlet port and an outlet port and defining a fluid flow path between the inlet port and the outlet port, wherein the hollow filter housing body comprises at least three layers: a first layer comprising perfluoroalkoxy alkane (PFA), a second layer comprising a thermoplastic elastomer, and a third layer comprising a thermoplastic; wherein the second layer is interposed between the first layer and the third layer, the second layer comprising a bonding layer bound to both the first layer and the third layer is provided, the method comprising sequentially (a) injecting a fluoropolymer resin comprising perfluoroalkoxy alkane (PFA) at a temperature above the melting point of the PFA and forming molded PFA; (b) injecting the thermoplastic elastomer at a temperature above the melting point of the thermoplastic over the molded PFA and forming molded thermoplastic elastomer; and (c) injecting the thermoplastic at a temperature above the melting point of the thermoplastic and forming molded thermoplastic.

[0026] In another aspect, a method of making a filter housing comprising a hollow filter housing body and having a filter housing inlet/outlet portion having an inlet port and an outlet port and defining a fluid flow path between the inlet port and the outlet port, wherein the

hollow filter housing body comprises at least three layers: a first layer comprising perfluoroalkoxy alkane (PFA), a second layer comprising a thermoplastic elastomer, and a third layer comprising a thermoplastic; wherein the second layer is interposed between the first layer and the third layer, the second layer comprising a bonding layer bound to both the first layer and the third layer is provided, the method comprising (a) injecting, between two plates, the fluoropolymer resin comprising perfluoroalkoxy alkane (PFA) at a temperature above the melting point of the PFA, compressing the two plates, and cooling compressed PFA; (b) separating the two plates; (c) injecting between one of the two plates and the compressed PFA, the thermoplastic elastomer at a temperature above the melting point of the thermoplastic, and cooling compressed thermoplastic elastomer; (d) separating the two plates; (e) injecting between the other of the two plates and the compressed thermoplastic elastomer, the thermoplastic at a temperature above the melting point of the thermoplastic, and cooling compressed thermoplastic, forming a composite comprising a first layer comprising PFA, a second layer comprising a thermoplastic elastomer, and a third layer comprising a thermoplastic; wherein the second layer is interposed between the first layer and the third layer, the second layer being bound to both the first layer and the third layer; (f) separating the two plates; and (g) removing the composite.

[0027] Typically, in aspects of methods for making the filter housing, the mold has a cavity width of at least 0.06 inches (1.5 mm).

[0028] Aspects of the resultant first layer comprising perfluoroalkoxy alkane (PFA), second layer comprising a thermoplastic elastomer, and third layer comprising a thermoplastic; wherein the second layer is interposed between the first layer and the third layer, the second layer comprising a bonding layer bound to both the first layer and the third layer provide a desirable mechanical strength and stiffness, e.g., tensile strength  $\geq 15.5$  MPa, tensile modulus  $\geq 0.483$  GPa)

[0029] Each of the components of the invention will now be described in more detail below, wherein like components have like reference numbers.

[0030] Figures 1A and 1B show an illustrative filter device 500, comprising an illustrative filter housing 100. The cross-sectional view in Figure 1B shows a filter element 50 arranged in the housing.

[0031] Filter housing according to aspects of the invention can have a variety of configurations as is known in the art. For example, in accordance with the illustrative aspect shown in Figures 1A-1B, the housing 100 has an inlet/outlet portion 101 having an inlet port 101B and an outlet port 101A, a hollow housing body (sometimes referred to as a shell) 102 and a vent portion 103 having an upstream vent port 103B and a downstream vent port 103A.

[0032] The housing 100 provides a fluid flow path between the inlet port 101B and the outlet port 101A and a filter element 50 is arranged in the housing across the fluid flow path, providing a filter device 500. The inlet/outlet portion (and the vent portion, if present) can be joined to the hollow housing body as is known in the art, e.g., by welding or mechanical attachment.

[0033] In some other aspects, the inlet/outlet portion can be integral with the housing body and/or the vent portion can be integral with the housing body.

[0034] The filter housing has an interior surface and an exterior surface. Typically, the filter housing (at least the hollow housing body, typically also the inlet/outlet portion and the vent portion) has an interior surface comprising the first layer, and an exterior surface comprising the third layer.

[0035] A wide variety of filter elements are suitable for use in housings according to aspects of the invention, and are known in the art.

[0036] The filter element 50 (illustrated as a hollow cylindrical element) comprises at least one porous medium, and can include additional elements, layers, or components, that can have different structures and/or functions, e.g., at least one of any one or more of the following: prefiltration, support, drainage, spacing and cushioning. Illustratively, the filter element can also include at least one additional element such as a mesh and/or a screen. After the filter element is sealed in the housing, the filter device is typically cleaned with cleaning fluids (such as hot acids) which can sterilize the filter device.

[0037] All references, including publications, patent applications, and patents, cited herein are hereby incorporated by reference to the same extent as if each reference were individually and specifically indicated to be incorporated by reference and were set forth in its entirety herein.

[0038] The use of the terms “a” and “an” and “the” and “at least one” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The use of the term “at least one” followed by a list of one or more items (for example, “at least one of A and B”) is to be construed to mean one item selected from the listed items (A or B) or any combination of two or more of the listed items (A and B), unless otherwise indicated herein or clearly contradicted by context. The terms “comprising,” “having,” “including,” and “containing” are to be construed as open-ended terms (i.e., meaning “including, but not limited to,”) unless otherwise noted. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., “such as”) provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the invention.

[0039] Preferred aspects of this invention are described herein, including the best mode known to the inventors for carrying out the invention. Variations of those preferred aspects may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the invention to be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

## CLAIM(S):

1. A filter housing comprising a hollow filter housing body and having a filter housing inlet/outlet portion having an inlet port and an outlet port and defining a fluid flow path between the inlet port and the outlet port, wherein the hollow filter housing body comprises at least three layers: a first layer comprising perfluoroalkoxy alkane (PFA), a second layer comprising a thermoplastic elastomer, and a third layer comprising a thermoplastic; wherein the second layer is interposed between the first layer and the third layer, the second layer comprising a bonding layer bound to both the first layer and the third layer.
2. The filter housing of claim 1 wherein the second layer comprises a thermoplastic elastomer selected from the group consisting of a styrene block copolymer, a polyolefin, a polyamide, or a polyester elastomer.
3. The filter housing of claim 1 or 2, wherein the thermoplastic elastomer comprises polymethylpentene (PMP).
4. The filter housing of any one of claims 1-3, wherein the third layer comprises a thermoplastic selected from the group consisting of polyolefin homopolymers, polyolefin copolymers, cyclic olefin homopolymers, copolymers of cyclic olefins, ethylene vinyl acetate copolymers, polyesters, polyamides, polyvinyl chloride, polyvinylidene chloride, polystyrene, styrenic copolymers, polyisoprene, polyurethanes, ethylene ethyl acrylate, ethylene acrylic acid copolymers and combinations thereof.
5. The filter housing of claim 4, wherein the thermoplastic comprises polyetherimide (PEI).
6. The filter housing of any one of claims 1-5, further comprising a filter housing vent portion having an upstream vent port and a downstream vent port.
7. The filter housing of any one of claims 1-5, wherein the first layer has a first layer thickness and the third layer has a third layer thickness, and the third layer thickness is at least 20% larger than the first layer thickness.

8. The filter housing of any one of claims 1-7, wherein the hollow filter housing body has an interior surface comprising the first layer and an exterior surface comprising the third layer.

9. The filter housing of any one of claims 1-8, wherein the filter housing inlet/outlet portion each comprise at least three layers: a first layer comprising perfluoroalkoxy alkane (PFA), a second layer comprising a thermoplastic elastomer, and a third layer comprising a thermoplastic; wherein the second layer is interposed between the first layer and the third layer, the second layer comprising a bonding layer bound to both the first layer and the third layer.