US 20040004079A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2004/0004079 A1**

Bhatt (43) **Pub. Date: Jan. 8, 2004**

(54) **FIRE RETARDANT FOUP WAFER CARRIER**

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(21) Appl. No.: **10/190,355**

(22) Filed: **Jul. 5, 2002**

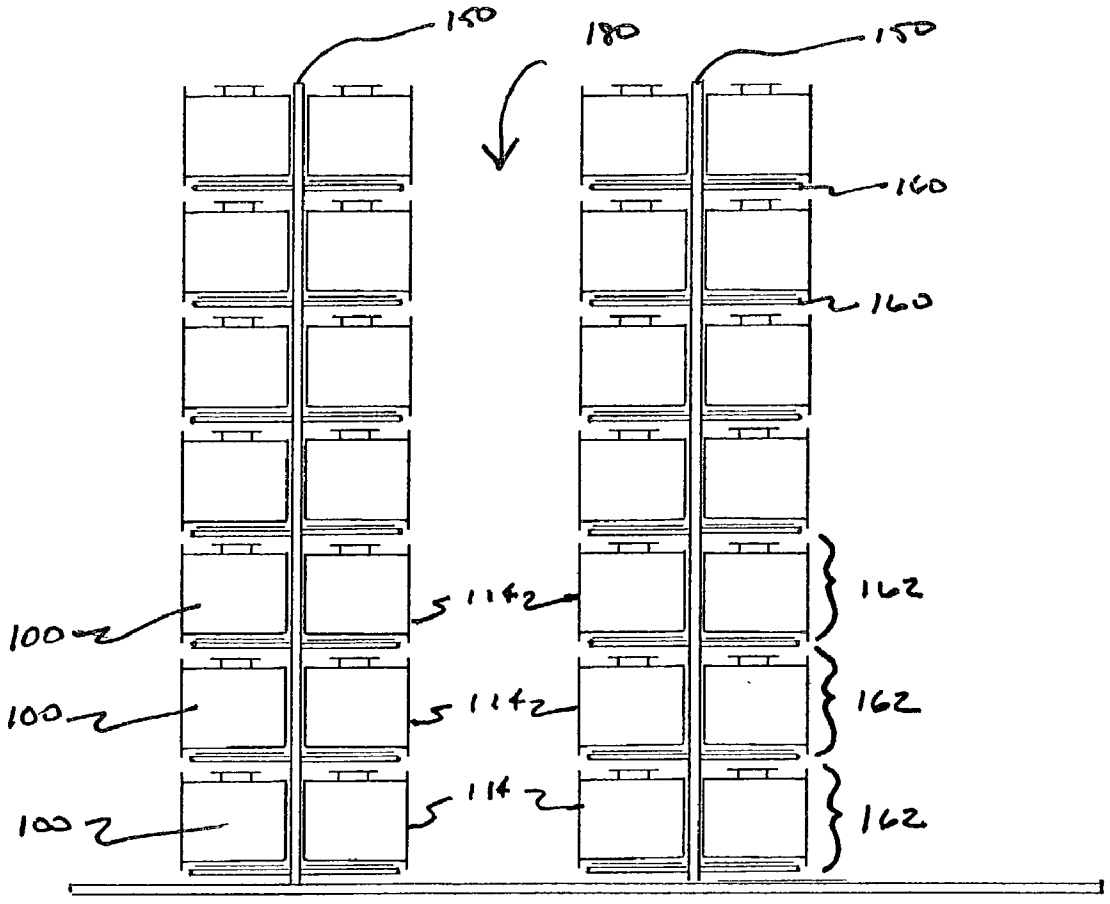
Publication Classification

(51) **Int. Cl.**[7] **B65D 90/22**

(52) **U.S. Cl.** **220/88.1**

(57) **ABSTRACT**

A fire retardant container for semiconductor wafers having an enclosure portion formed from polycarbonate plastic. The enclosure has a top, a bottom, a pair of opposing sides, a back, and an open front. The container includes a door to close the open front having an outer surface portion formed from a plastic material having a flame propagation index of not greater than 9.0 $(m/s^{1/2})(kW/m)^{-2/3}$.



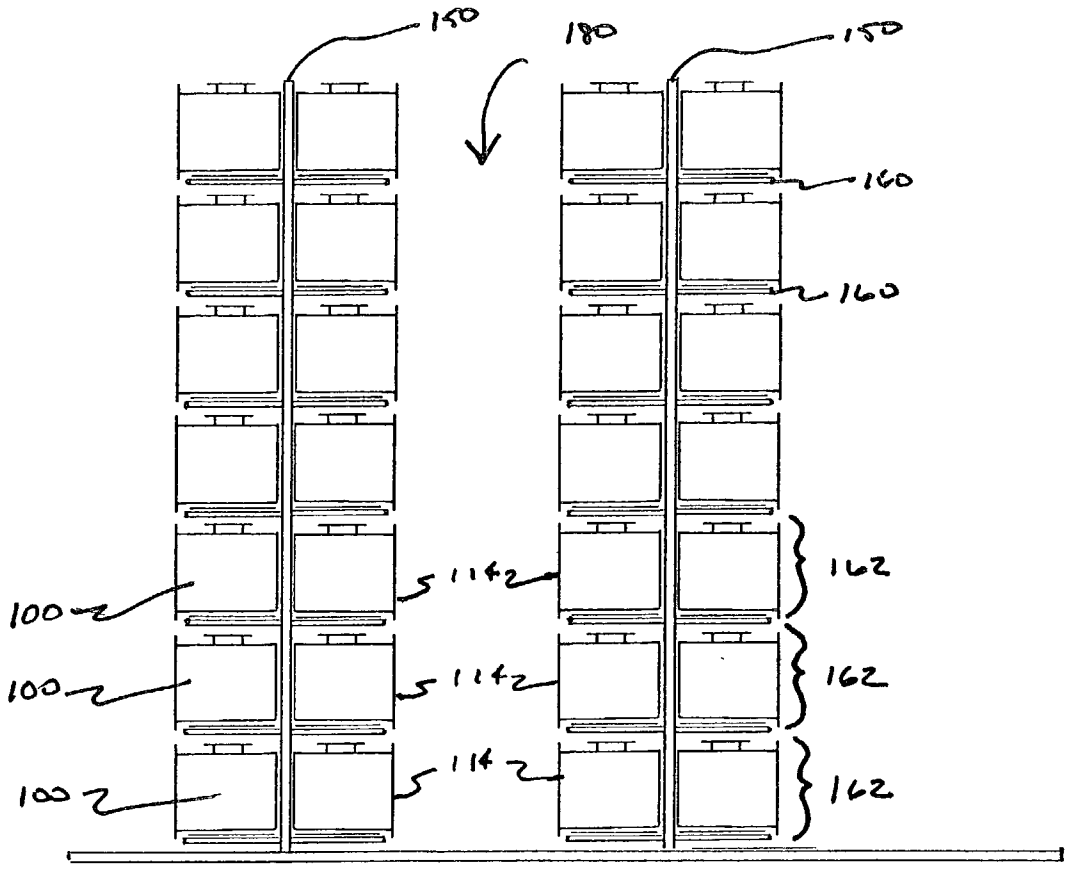

150
180
150
160
160
162
162
162
114
114
114
100
100
100

Fig. 1.

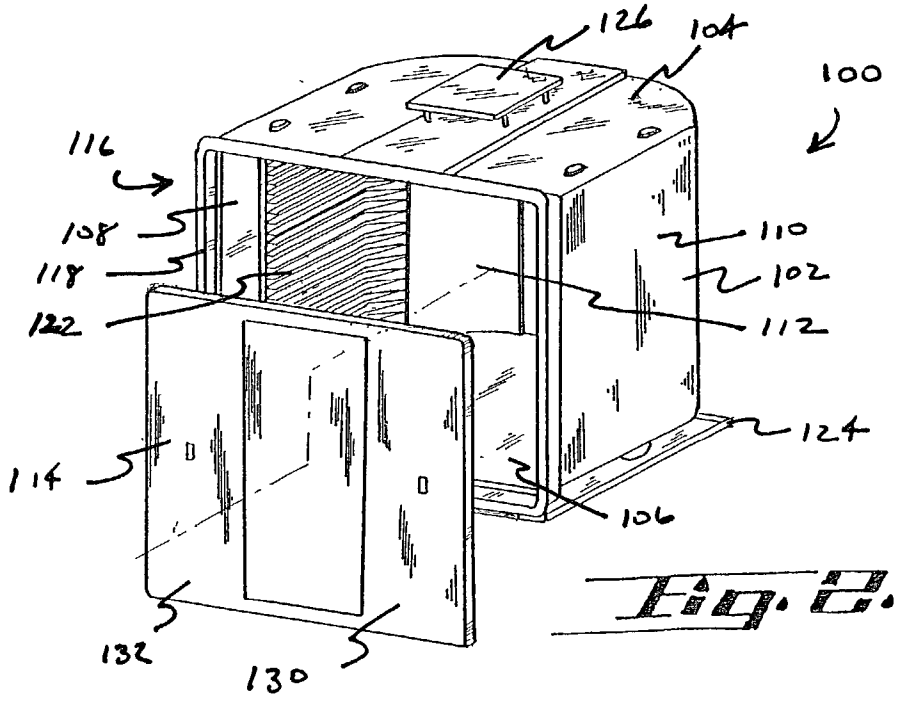

126
104
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116
108
118
122
110
102
112
124
114
106
132
130

Fig. 2.

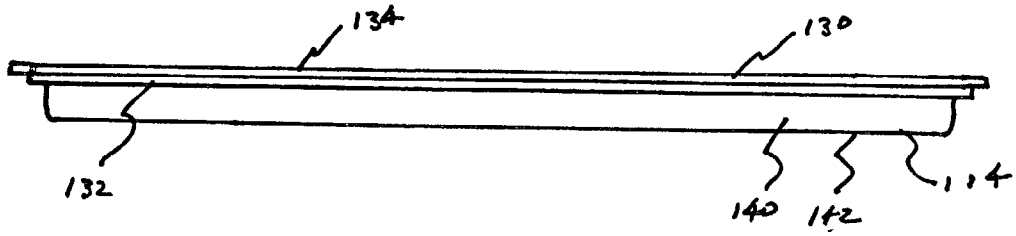

134
130
132
140
142
114

Fig. 3

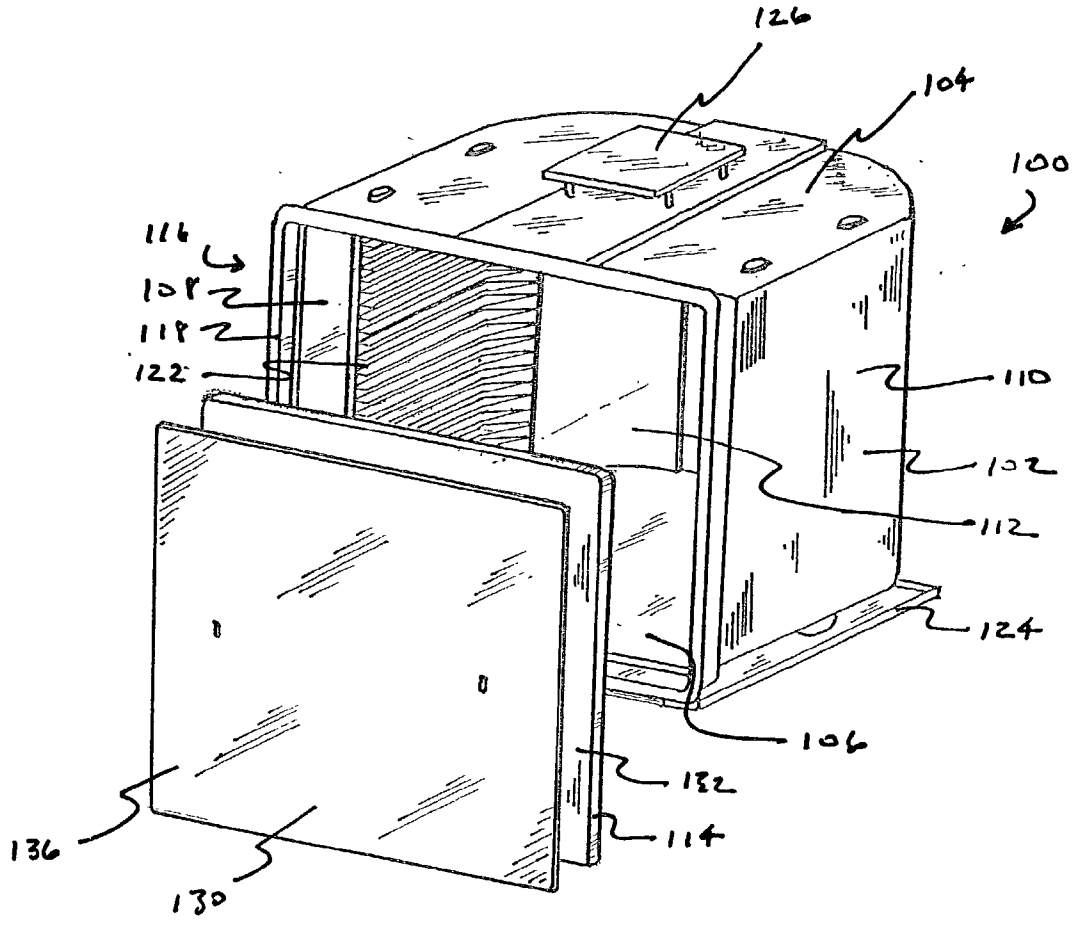

126
104
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116
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122
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102
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124
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132
114
136
130

Fig. 4

FIRE RETARDANT FOUP WAFER CARRIER

FIELD OF THE INVENTION

[0001] This invention relates to wafer carriers. More particularly it relates to fire retardant wafer carriers.

BACKGROUND OF THE INVENTION

[0002] Processing of semi-conductor wafers into finished electronic components typically requires many processing steps where the wafers must be handled and processed. The wafers are very valuable, and are extremely delicate and easily damaged by physical and electrical shocks. In addition, successful higher yield processing requires the utmost in cleanliness, freedom from particulates and other contaminants. As a result, specialized containers or carriers have been developed for use during processing, handling and transport of wafers. These containers protect the wafers from physical and electrical hazards, and are sealable to protect the wafers from contaminants. Such wafer carriers or containers generally comprise an enclosure having a number of wafer holding shelves inside. One side of the container is open for access, and is closed by a door.

[0003] The semiconductor industry is in the process of evolving fabrication facilities to use wafers having a diameter of 300 mm. The wafer carriers used for 300 mm wafers are normally configured as a Front Opening Unified Pod (FOUP). Examples of FOUP wafer carriers are disclosed in U.S. Pat. Nos. 6,010,008, 6,082,540, 6,206,196, 6,216,874 and 6,267,245, each commonly owned by the assignee of the present invention, and each of which is fully incorporated herein by reference.

[0004] The enclosure for wafer carriers and containers has typically been formed from polycarbonate plastic material. While polycarbonate has the advantages of relatively easy formability and high impact resistance, it is also a relatively flammable material that readily propagates flame. Free burn testing involving an array of only four polycarbonate FOUP wafer carriers has shown peak heat release rates of more than 1 MW. Because as many as 5,000 to 10,000 FOUP wafer carriers may be stored in a single semiconductor processing facility, there is a non-trivial risk of fire in such facilities associated with polycarbonate wafer carriers. Not only does fire in a semiconductor processing facility pose a risk of significant property loss and hazards to the life safety of occupants in the facility, even a small fire may cause extreme disruption to the semiconductor production process due to contamination from airborne particulates and combustion products. Thus, while there have been no known fire losses to date from a wafer carrier fire, the potentiality and possible consequences of such an event make improvements to fire safety associated with wafer carriers highly desirable.

[0005] Wafer carriers are often stored in multi-tier storage racks known as "stockers". In a stocker, FOUP wafer carriers are stored side-by-side in vertically stacked tiers. These stockers are typically arranged in opposing fashion across an aisle, from which they may be accessed by robotic equipment. Each stocker may be multi-floors high and may contain hundreds of FOUPs. While vertical stacking offers an efficient means of storing many types of devices and materials, including wafer carriers, it is well known that stacked arrangements of flammable materials present a heightened fire protection concern. This is due to the general tendency of fire to propagate more readily vertically through buoyant motion of pyrolysis products. In addition, fixed fire sprinkler protection covering all areas of stacked material is often very difficult and expensive to achieve. As a result, in order to minimize the size and rate of fire growth in a vertical storage arrangement, one important fire protection strategy is to retard, or preferably even prevent, the vertical propagation of fire from material in one tier of storage to next tier that is immediately vertically adjacent. To the extent that propagation of a fire beyond the area of ignition can be slowed, more time is provided for detection and suppression of the fire in its incipient stages, thus minimizing damage and process disruption.

[0006] Two important variables that can have a significant effect on fire propagation in vertical storage are the geometry of the stored items and the flame propagation characteristics of the material composition of the items. In common fire protection engineering practice, these variables may sometimes be altered so as to obtain an optimal result from a fire protection standpoint. Wafer carriers, however, present a unique challenge in this regard in that the requirements of the semiconductor industry for wafer carriers are very stringent and process critical. For instance, in a FOUP wafer carrier, there are over 200 precise dimensions required to hold wafers in place repeatably, and there are also stringent material standards for mechanical strength, structural integrity, and chemical stability of the materials used in the carrier. Any modifications made to carriers for the purposes of fire safety must not compromise these standards. Because of these difficulties, previous efforts to improve the fire safety of wafer carriers, both existing and new, have proceeded slowly and have not produced significant changes in wafer carrier design to date.

[0007] What is still needed is some type of apparatus or method for improving the fire safety of new and existing wafer carriers stacked in a multi-tier stocker.

SUMMARY OF THE INVENTION

[0008] The present invention is a front opening unified pod wafer container comprising an enclosure portion formed substantially from polycarbonate plastic having at least a top, a bottom, a pair of opposing sides, a back, and an open front, and a door to close the open front. The door has an outer surface portion formed substantially from a plastic material having a Fire Propagation Index of not greater than 9.0 $(m/s^{1/2})(kW/m)^{-2/3}$. Suitable plastic materials include polyimide, polyether imide, polyamide imide, polyketone, polyetherketone, polyetheretherketone, polyetherketoneketone, polyether sulphone, and polytetrafluoroethylene. The invention may also be characterized as a method of making a fire retardant wafer container and as a method of retrofitting an existing wafer container to improve its fire retardancy.

[0009] The present invention recognizes meets the need for a wafer container that is resistant to the vertical propagation of fire, especially when multiple wafer containers are stored in a vertical stocker arrangement. In addition, the present invention permits the use of less-expensive, more easily formable, polycarbonate plastic for the container, while still offering resistance to the vertical propagation of fire.

[0010] Additional objects, advantages, and novel features of the invention will be set forth in part in the description

which follows, and in part will become apparent to those skilled in the art upon examination of the following or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] **FIG. 1** is an elevation view of a plurality of wafer carriers arrayed in stockers.

[0012] **FIG. 2** is a perspective view of a FOUP wafer carrier.

[0013] **FIG. 3** is an elevation view of a wafer carrier door according to a preferred embodiment of the present invention.

[0014] **FIG. 4** is a perspective, partially exploded view of an alternative embodiment of a FOUP wafer carrier and door according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] The accompanying Figures depict embodiments of the wafer container of the present invention, and features and components thereof. Any references to front and back, right and left, top and bottom, upper and lower, and horizontal and vertical are intended for convenience of description, not to limit the present invention or its components to any one positional or spacial orientation. Any dimensions specified in the attached Figures and this specification may vary with a potential design and the intended use of an embodiment of the invention without departing from the scope of the invention.

[0016] In **FIG. 1**, there is shown a simplified elevation view of a plurality of FOUP wafer carriers **100** arrayed in typical vertical stockers **150**. A typical semiconductor processing facility may have multiple rows of stockers **150** arranged in parallel fashion with aisles **180** between the rows as shown. Robotic handling equipment may be used in aisles **180** to transfer wafer carriers **100** to and from stockers **150**. Within each stocker **150**, wafer carriers **100** are supported side-by-side by horizontal supports **160**, forming vertically stacked tiers **162** of wafer carriers **100**. Wafer carriers **100** are normally arranged in stockers **150** so that the door of the carrier faces outward into aisle **180**.

[0017] Referring to **FIG. 2**, each FOUP wafer container **100** has an enclosure portion **102**, constructed of polycarbonate plastic, and having a top **104**, a bottom **106**, a pair of opposing sides **108** and **110**, and a back **112**. A door **114** closes the open front **116** of the enclosure portion **102**, fitting into door recess **118**. Wafer supports **122** are provided to support semi-conductor wafers within the enclosure. Kinematic coupling **124**, mounted to the exterior surface of enclosure bottom **106** is provided to facilitate automated handling of the container during use and to provide a reference datum for locating the wafers in the housing during processing. Robotic lifting flange **126** is mounted on the exterior surface of enclosure top **104** and is provided to facilitate automated handling and transport of container **100** during use.

[0018] As may be seen from reference now to **FIGS. 1 and 2**, vertical propagation of fire within stockers **150** can be retarded between tiers **162** at the sides **108**, **110** and back **112** of wafer carriers **100** by providing solid portions in horizontal supports **160**, blocking any vertical openings between tiers. At the front, however, doors **114** are vertically aligned, forming a pathway for vertical propagation of fire between tiers **162**.

[0019] It is known in the art to classify materials according to the relative propensity of the materials to propagate fire. One such classification, considered particularly indicative of the fire propagation behavior of materials under highly radiative flame conditions prevalent in large scale fires, uses a Fire Propagation Index (FPI) value that is determined for the material. To determine the FPI of a material, the material is tested according to methods well known in the art to determine a peak chemical heat release rate per unit width (Q'_{ch}), and a Thermal Response Parameter (TRP), which is calculated according to the relation:

$$TRP=\Delta T_{ig}\sqrt{k\rho c_p}$$

[0020] where ΔT_{ig} is the ignition temperature of the material above ambient in K°, k is the material thermal conductivity in kW/m-K°, ρ is the material density in g/m^3, and c_p is the material specific heat in kJ/g-K°. The FPI may then be calculated according to the relation:

$$FPI = 1000\left(\frac{(0.42Q'_{ch})^{\frac{1}{3}}}{TRP}\right)$$

[0021] Materials may be generally classified according to their FPI value. Materials having an FPI of under 7.0 (ms$^{1/2}$)(kW/m)$^{-2/3}$ are classified as Group N-1 "Non-Propagating" materials, those having an FPI of less than 10.0 (m/s$^{1/2}$)(kW/m)$^{-2/3}$ but at least 7.0 (m/s$^{1/2}$)(kW/m)$^{-2/3}$ are classified as Group D-1 "Decelerating" materials, those having an FPI of between 10.0 (m/s$^{1/2}$)(kW/m)$^{-2/3}$ and 20.0 (m/s$^{1/2}$)(kW/m)$^{-2/3}$ are Group 2 "Non-Accelerating Propagation" materials and those having an FPI of over 20.0 (m/s$^{1/2}$)(kW/m)$^{-2/3}$ are Group 3 "Accelerating Propagation" materials.

[0022] Polycarbonate plastic, as is commonly used for the enclosure and doors of wafer carriers, normally has a Fire Propagation Index (FPI) of greater than about 10.0 (m/s$^{1/2}$)(kW/m)$^{-2/3}$, which classifies it as a Group 2 or Group 3 fire propagating material. In the invention, at least the outer surface portion **130** of door **114** of each wafer carrier is formed substantially from a Group N-1 or Group D-1 fire retardant plastic material that has an FPI of 9.0 (m/s$^{1/2}$)(kW/m)$^{-2/3}$ or less. Although any fire retardant plastic material having an appropriate FPI may be suitable for the purpose, plastics that are known to be acceptable for use in wafer carriers and that have the appropriate FPI are polyimide (PI), polyether imide (PEI), polyamide imide (PAI), polyketone (PK), polyetherketone (PEK), polyetheretherketone (PEEK), polyetherketoneketone (PEKK), polyether sulphone (PES), and polytetrafluoroethylene (PTFE). The currently most preferred material is PEI having an FPI from between about 8.1 (m/s$^{1/2}$)(kW/m)$^{-2/3}$ to about 8.6(m/s$^{1/2}$)(kW/m)$^{-2/3}$, such as for example, Ultem 1000 made by GE Plastics, Inc. of Pittsfield, Mass.

[0023] In a preferred embodiment of the invention, at least outer surface portion **130** of door **114** is formed from PEI

material. It is currently most preferred that the thickness of outer surface portion **130** formed from the fire retardant plastic material be at least the typical thickness of enclosure portion **102**, which is generally about 0.3 mm. It is currently most preferred that outer surface portion **130** is the exterior panel **132** of door **114** alone as shown in **FIG. 2**, but may also be a separate fire-retardant layer **134** laid over exterior panel **132** of door **114** as shown in **FIG. 3**. Such a fire retardant layer **134** may be overmolded on exterior panel **132**, forming a thermal as well as a mechanical bond with exterior panel **132**, or may be a separate shield panel **136** as shown in **FIG. 4**, attached by any suitable method, including adhesives or mechanical fasteners. As an alternative, shield panel **136** may have structures allowing it to removably "snap" on and off suitable receiving structures on door **114**. Additionally, the outer fire resistant layer can be a thin film that has been insert molded on the forward facing surface of the front door. Other portions of door **114**, such as the chassis **140**, latching components, and inner surface **142** may also be formed from the same fire retardant material used for outer surface portion **130**, and this may serve to improve the overall fire retardancy of wafer carrier **100**.

[**0024**] Existing wafer carriers having doors with polycarbonate outer surfaces may be retrofitted using the apparatus and methods of the present invention. Such a retrofit may be accomplished by replacing the polycarbonate door with a door **114** manufactured according to the present invention, or by overlaying exterior panel **132** with shield panel **136** as described above. Such a shield panel may be a flexible sheet material suitably adhered to existing door structure.

[**0025**] Although the discussion above has been focused on FOUP wafer carrier doors, since the doors present the most likely path of vertical propagation, the methods of the present invention could also be applied to other vertical surfaces on the wafer carrier. Thus, for example, if fire retardant surfaces are made necessary by openings in horizontal supports **162** of stocker **150**, sides **108**, **110** and/or back **112** could be made with an outer surface of fire retardant plastic as described herein.

[**0026**] Although the description above contains many specificities, these should not be construed as limiting the scope of the invention but as merely providing illustrations of some of the presently preferred embodiments of the invention. Thus, the scope of the invention should be determined by the appended claims and their legal equivalents, rather than by the examples given.

What is claimed is:

1. A front opening unified pod wafer container comprising:

an enclosure portion formed substantially from polycarbonate plastic having at least a top, a bottom, a pair of opposing sides, a back, and an open front; and

a door to close the open front, wherein said door has an outer surface portion formed substantially from a plastic material selected from the group of plastic materials consisting of polyimide, polyether imide, polyamide imide, polyketone, polyetherketone, polyetheretherketone, polyetherketoneketone, polyether sulphone, and polytetrafluoroethylene, and wherein said plastic material has a Fire Propagation Index of not greater than 9.0 $(m/s^{1/2})(kW/m)^{-2/3}$;

whereby the outer surface portion is relatively retardant to vertical propagation of fire.

2. The wafer container of claim 1, wherein said outer surface portion is formed from polyether imide plastic.

3. The wafer container of claim 1, wherein said outer surface portion is formed from polyetheretherketone plastic.

4. The wafer container of claim 1, wherein said outer surface portion comprises an exterior panel of said door.

5. The wafer container of claim 1, wherein said outer surface portion comprises a layer of fire retardant plastic over a layer of polycarbonate plastic.

6. The wafer container of claim 5, wherein said layer of fire retardant plastic is molded over said layer of polycarbonate plastic.

7. The wafer container of claim 1, wherein said outer surface portion comprises a shield panel affixed to said door with an adhesive.

8. The wafer container of claim 1, wherein said outer surface portion comprises a shield panel affixed to said door with a plurality of fasteners.

9. A wafer container comprising:

an enclosure portion formed substantially from polycarbonate plastic having at least a top, a bottom, a pair of opposing sides, a back, and an open front; and

a door to close the open front, wherein said door has an outer surface portion formed from a plastic material having a flame propagation index of not greater than 9.0 $(ms^{1/2})(kW/m)^{-2/3}$;

whereby the outer surface portion is relatively retardant to vertical propagation of flame.

10. The wafer container of claim 9, wherein said plastic material is selected from the group of plastic materials consisting of polyimide, polyether imide, polyamide imide, polyketone, polyetherketone, polyetheretherketone, polyetherketoneketone, polyether sulphone, and polytetrafluoroethylene.

11. The wafer container of claim 10, wherein said plastic material is polyether imide.

12. The wafer container of claim 10, wherein said plastic material is polyethylethylketone.

13. The wafer container of claim 9, wherein said outer surface portion comprises an exterior panel of said door.

14. The wafer container of claim 9, wherein said outer surface portion comprises a layer of fire retardant plastic over a layer of polycarbonate plastic.

15. The wafer container of claim 14, wherein said layer of fire retardant plastic is molded over said layer of polycarbonate plastic.

16. The wafer container of claim 9, wherein said outer surface portion comprises a shield panel affixed to said door with an adhesive.

17. The wafer container of claim 9, wherein said outer surface portion comprises a shield panel affixed to said door with a plurality of fasteners.

18. A method of making a flame retardant front opening unified pod wafer carrier comprising:

forming, from polycarbonate plastic, an enclosure portion having at least a top, a bottom, a pair of opposing sides, a back, and an open front; and

forming a door for closing the open front, said door having an outer surface portion comprising plastic material with a Fire Propagation Index of not more than 9.0 $(m/s^{1/2})(kW/m)^{-2/3}$.

19. The method of claim 18, wherein said door has an outer panel, and further comprising the step of molding said outer surface portion over said outer panel.

20. The method of claim 18, wherein said door has an outer panel, and further comprising the steps of molding a fire retardant layer member and affixing said layer member to said outer panel.

21. A method of improving the fire retardancy of a front opening unified pod wafer carrier, said carrier comprising an enclosure portion having at least a top, a bottom, a pair of opposing sides, a back, an open front, and a door to close the open front, all formed substantially from polycarbonate plastic, the method comprising overlaying an outer surface of said door with a layer of plastic material having a flame propagation index of not more than 9.0 $(m/s^{1/2})(kW/m)^{-2/3}$.

22. The method of claim 21, wherein said plastic material is selected from the group consisting of polyimide, polyether imide, polyamide imide, polyketone, polyetherketone, polyetheretherketone, polyetherketoneketone, polyether sulphone, and polytetrafluoroethylene, and further comprising the steps of molding said plastic material into a separate shield panel and affixing said shield panel to said door.

23. The method of claim 22, wherein said affixing step comprises fastening said shield panel to said door with an adhesive.

24. The method of claim 22, wherein said affixing step comprises fastening said shield panel to said door with a plurality of fasteners.

25. A front opening unified pod wafer container comprising:

an enclosure portion formed substantially from polycarbonate plastic having at least a top, a bottom, a pair of opposing sides, a back, and an open front;

a door to close the open front, wherein said door has an exterior surface portion; and

means for retarding the spread of fire on said exterior surface portion.

26. The wafer container of claim 25, wherein said means for retarding the spread of fire on said outer surface portion comprises an exterior panel of said door, said exterior panel being formed from a plastic material having a Fire Propagation Index of 9.0 $(m/s^{1/2})(kW/m)^{-2/3}$ or less.

27. The method of claim 26, wherein said plastic material is selected from the group consisting of polyimide, polyether imide, polyamide imide, polyketone, polyetherketone, polyetheretherketone, polyetherketoneketone, polyether sulphone, and polytetrafluoroethylene.

28. The method of claim 26, wherein said plastic material is polyether imide.

29. The wafer container of claim 25, wherein said door is formed from polycarbonate plastic, and wherein said means for retarding the spread of fire on said outer surface portion comprises a separate layer of fire retardant plastic material overlaid on said exterior surface portion, said fire retardant plastic material having a Fire Propagation Index of 9.0 $(m/s^{1/2})(kW/m)^{-2/3}$ or less.

30. The method of claim 29, wherein said fire retardant plastic material is selected from the group consisting of polyimide, polyether imide, polyamide imide, polyketone, polyetherketone, polyetheretherketone, polyetherketoneketone, polyether sulphone, and polytetrafluoroethylene.

31. The method of claim 29, wherein said plastic material is polyether imide.

32. The wafer container of claim 29, wherein said separate layer of fire retardant plastic material is molded over said exterior surface portion.

33. The wafer container of claim 29, wherein said separate layer of fire retardant plastic material is molded as a separate shield panel and affixed to said exterior surface portion with an adhesive or with a plurality of fasteners.

* * * * *