

REPUBLIC OF SOUTH AFRICA  
PATENTS ACT, 1978**PUBLICATION PARTICULARS AND ABSTRACT**

(Section 32(3)(a) – Regulation 22(1)(g) and 31)

OFFICIAL APPLICATION NO.

LODGING DATE

ACCEPTANCE DATE

21 01 20010800

22 29 JAN 2001

43 7.8.2001

INTERNATIONAL CLASSIFICATION

NOT FOR PUBLICATION

51 C08J; C08K; C08L

CLASSIFIED BY: WIPO

FULL NAMES OF APPLICANT

71 THE DOW CHEMICAL COMPANY

FULL NAMES OF INVENTORS

72 1. VO, CHAU VAN  
2. BOUKAMI, SYLVIE

EARLIEST PRIORITY CLAIMED

COUNTRY

NUMBER

DATE

33 US

31 60/098.216

32 28 AUG 1998

TITLE OF INVENTION

54 FIRE RESISTANT STYRENE POLYMER FOAMS WITH REDUCED BROMINATED FIRE RETARDANT

57 ABSTRACT (NOT MORE THAT 150 WORDS)

NUMBER OF SHEETS 35

If no classification is finished, Form P.9 should accompany this form.  
The figure of the drawing to which the abstract refers is attached.

20010800

Abstract

Extruded, substantially closed-polystyrene foams that exhibit improved fire resistance yet contain lower levels of brominated fire retardant are disclosed. Methods of preparing the foams, comprising extruding the polystyrene with a novel fire retardant formulation comprising a mixture of a) a phosphate compound, preferably TPP; b) less than about 2.5 percent HBCD based on 100 percent polystyrene; and optionally c) a flow promoter such as dimethyldiphenylbutane, the extrusion process using a blowing agent which is preferably selected from carbon dioxide, mixtures of two or more of carbon dioxide, water, alcohol, ether and hydrocarbons, or a mixture of hydrofluorocarbons, alcohols, and hydrocarbons, are also disclosed. Use of the phosphate compound in the fire retardant formulation allows a reduction in the amount of brominated compound required and a reduction in the foaming temperature, resulting in lower density foams.

**FIRE RESISTANT STYRENE POLYMER FOAMS WITH  
REDUCED BROMINATED FIRE RETARDANT**

The present invention relates to fire retardant or fire resistant styrene polymer foams and in particular, relates to fire resistant or fire retardant styrene polymer foams having  
5 reduced brominated fire retardant.

Over the past several decades, polymer foams have become available in a wide variety of forms, either in answer to a material need in industry, or as a developmental expansion of commercialized precursors. Some of the more popular forms of foamed polymer compositions take the shape of films, sheets, slabs and profiles. Generally, these products are  
10 produced by extrusion methods in which the polymer is converted by heat and pressure into a homogeneous melt and forced through a die into the desired shape. To obtain a cellular structure, the plastic usually incorporates a blowing agent that decomposes under the heat of the extrusion process and releases gases that cause the shape to expand. It is also possible to inject propellants directly into the melt.

15 Because of the favorable combination of properties, price and ease of processing, styrene polymers, especially polystyrene, are widely used in preparing foam sheets, films and slabs for such divergent end uses as packaging, pipe and tubing, construction and insulation. For example, expanded styrene polymers such as polystyrene are widely used in the insulation of freezers, coolers, truck bodies, railroad cars, farm buildings, roof decks and  
20 residential housing. Styrene polymer foams are also used as the core material for structural sandwich panels used in refrigerated truck bodies, mobile homes and recreational vehicles.

There is an increasing demand for improving the fire retardant properties of materials used in vehicles, the building trades and consumer goods, such as furniture, radio and television cabinets, appliance housing, electrical motor housings, and switch boxes. To meet  
25 this demand, various steps have been taken to improve the fire retardant properties of thermoplastic polymers in order to make them slower to ignite and to retard flame propagation. Thermoplastic polymers can be rendered flame retardant by compounding with fire retardant additives, including halogenated organic compounds and inorganic compounds such as antimony oxide.

Brominated organic compounds have been used in both foamed and nonfoamed styrene polymer compositions, with most ignition-resistant styrene polymer foam products being made with a brominated fire retardant, optionally including a radical generator synergist or flow promoter. Of the various brominated organic compounds, typically only brominated aliphatics  
5 are utilized with vinylaromatic foams, with hexabromocyclododecane (HBCD) being the most common.

While effective in improving flame retardancy, the incorporation of flame retardant additives into thermoplastic polymer compositions can negatively impact the strength of the foam, particularly at higher levels of such additives. In non-foamed polymers, the bromine  
10 content is typically quite high, for example, in excess of 5 parts of bromine per 100 parts of styrene polymer. However, in foamed styrene polymers, the degree of bromine loading has to be significantly lower to avoid detrimentally impacting the structural qualities and skin quality of the foam.

For example, when utilizing HBCD as a fire retardant in a styrene polymer foam,  
15 a high level of HBCD is required in order to meet fire retardancy requirements, particularly the stringent European fire retardancy tests. Depending on the foam characteristics (for example, density, blowing agents, etc.), the amount of HBCD typically required to meet fire retardancy requirements is from 2.5 percent to 4 percent by weight of the styrene polymer (the higher the foam density, the higher the percentage of HBCD). However, the incorporation of HBCD into  
20 the styrene polymer foam at these levels may result in 1) a poor dispersion of the HBCD in the foam, resulting in non-uniform expansion and poor skin quality and 2) a high degree of degradation of the styrene polymer and of the regrinded material in the extrusion process due to excessive heating, resulting in reduction of the molecular weight of the styrene polymer foam and of the regrinded styrene polymer and a resultant drop in physical properties.

25 Therefore, there remains a need in the art for fire-retardant styrene polymer foams which utilize hexabromocyclododecane (HBCD) as the fire retardant, which meet fire retardancy requirements, and which are amenable to extrusion processes, but which do not exhibit poor structural qualities and/or skin qualities.

Those needs are met by the present invention. Thus, the present invention  
30 provides extruded, flame retardant, foamed styrene polymer compositions which utilize hexabromocyclododecane (HBCD) as the fire retardant, which meet fire retardancy

requirements, and which are amenable to extrusion processes, but which do not exhibit poor structural qualities and/or skin qualities. The extruded, flame-retardant, foamed styrene polymer compositions of the present invention utilize a fire retardant formulation which is comprised of a mixture of hexabromocyclododecane (HBCD) and a phosphorous compound. The use of the phosphorous compound in the fire retardant formulation allows the use of less than about 2.5 percent of HBCD while maintaining a high level of fire resistance. Because a lower level of HBCD is utilized, the foams of the present invention do not suffer from poor structural qualities and/or skin qualities. Furthermore, the use of such a fire retardant composition allows a production of polystyrene foam with lower foam density, thus effecting appreciable cost savings.

Thus, in one embodiment of the present invention, there is provided a polymer foam composition comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than about 2.5 percent by weight, based on 100 percent of styrene polymer, of HBCD; and 2) from 0.1 percent to 4.0 percent by weight, based on 100 percent of styrene polymer, of a phosphorous compound.

In another embodiment, there is provided a polymer foam composition comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than about 2.5 percent by weight, based on 100 percent of styrene polymer, of HBCD; and 2) from 0.1 percent to 4.0 percent by weight, based on 100 percent of styrene polymer, of a phosphorous compound; and c) 0.01 percent to 0.2 percent by weight based on 100 percent of styrene polymer, of a flow promoter.

The present invention provides an extruded, fire-retardant, styrene polymer foam in which the fire retardant formulation is comprised of a mixture of HBCD and a phosphorous compound. The use of the phosphorous compound in the fire retardant formulation allows the use of less than about 2.5 percent of HBCD while maintaining a high level fire resistance. Because a lower level of HBCD is utilized, the HBCD is well dispersed in the foam and the foam is uniformly expanded with good skin quality. In addition, the presence of the phosphorous compound results in a lower density foam. A foam with lower density is formed even though the foaming temperature is lowered to account for the lowering of the glass transition temperature of the styrene polymer (due to the higher solubility of the phosphate compound in the styrene polymer).

The flame retardant foamed polymer compositions of the present invention comprise: a) a styrene polymer; b) a fire retardant formulation comprising HBCD and a phosphorous compound; and optionally, c) a flow promoter.

Suitable styrene polymers for use in the present invention include polystyrene or a copolymer formed from styrene monomer and copolymerizable ethylenically unsaturated co-  
5 monomers. The co-monomer content is typically less than about 50 percent, and preferably less than about 20 percent based upon the weight of the styrene polymer. Examples of copolymerized compounds include  $\alpha$ -methylstyrene, acrylonitrile, acrylic or methacrylic acids having one to eight carbon atoms, esters of acrylic or methacrylic acid with alcohols having one  
10 to eight carbon atoms, fumaric esters having one to eight carbon atoms, maleic anhydride or a small amount of divinyl benzene.

The HBCD portion of the fire retardant formulation is present in the styrene polymer foam in an amount less than about 2.5 percent by weight based on 100 percent of the styrene polymer, with amounts less than 2.0 percent being preferred, amounts from 1.0 percent  
15 to 1.6 percent being more preferred, and an amount of 1.4 percent being especially preferred.

The phosphorous compound portion of the fire retardant formulation may be any organic compound which contains one or more phosphorous atoms and includes, but is not limited to, phosphates of the formula  $(RO)_3PO$  wherein each R is independently selected from a substituted or unsubstituted, saturated or unsaturated, branched or straight-chain aliphatic  
20 moiety or a substituted or unsubstituted aromatic moiety. Suitable phosphates include, but are not limited to, triphenylphosphate (TPP), tributylphosphate, triethylphosphate, trimethylphosphate, tripropylphosphate, trioctylphosphate, diphenyl cresylphosphate, diphenyl methylphosphate, tris-(2-ethylhexyl)phosphate, isodecyl diphenylphosphate, isooctyl diphenylphosphate, bisphenyl diphenylphosphate, trixylil phosphate, and  
25 triisopropylphenylphosphate. Other phosphorous compounds suitable for use in the present invention are phosphites of the formula  $(RO)_3P$ , phosphonates of the formula  $(RO)_2RPO$ , phosphinates of the formula  $(RO)R_2PO$ , phosphine oxides of the formula  $R_3PO$ , phosphines of the formula  $R_3P$ , and phosphonium salts of the formula  $R_4PX$ , wherein each R is independently selected from substituted or unsubstituted, saturated or unsaturated, branched or straight-chain  
30 aliphatic moieties or substituted or unsubstituted aromatic moieties and X is a suitable counter

ion, such as chloride or bromide. Of the above-described phosphorous compounds, phosphates are preferred and TPP is especially preferred.

The phosphorous compound is present in the styrene polymer foam in an amount from 0.1 percent to 4.0 percent by weight based on 100 percent of the styrene polymer, with 0.5  
5 percent to 2.0 percent being preferred, with 1.0 percent to 2.0 percent being more preferred.

The polystyrene fire retardant formulations of the present invention may optionally include a flow promoter (melt flow modifiers) to assist initiation of the decomposition of the HBCD. By providing a source of reactive radicals (generated at a lower temperature than HBCD) which will abstract protons off the aliphatic portion(s) of HBCD and subsequently release  
10 the bromine radical, flow promoters are able to assist in the degradation of the HBCD. In addition, the reactive radicals from the flow promoter are capable of breaking down the styrene polymer chain during a fire, hence allowing the foam to melt away from the fire source. Suitable flow promoters include 2,3-dimethyl-2,3-diphenylbutane (that is, dicumyl or DMDPB); dicumyl peroxide;  $\alpha,\alpha'$ -bis-tert-butylperoxydiisopropylbenzene; bis( $\alpha$ -phenylethyl)sulfone;  
15 1,1'-diphenylbicyclohexyl; 2,2'-dimethyl-2,2'-azobutane; 2,2'-dichloro-2,2'-azobutane; 2,2'-dibromo-2,2'-azobutane; 2,2'-dimethyl-2,2'-azobutane-3,3',4,4'-tetracarboxylic acid; 1,1'-diphenylbicyclopentyl; 2,5-bis(tribromomethyl)-1,3,4-thiadiazole; 2-(bromophenyl-5-tribromophenyl)-2,3,4-thiadiazole; dioctyl tin maleate; and dibutyl tin maleate. The most preferred flow promoter for use in the present invention is dimethyldiphenylbutane (that is,  
20 dicumyl or DMDPB).

Typically, when utilized, the flow promoter is present in the styrene polymer foam in an amount from 0.01 percent to 0.2 percent by weight based on 100 percent of the styrene polymer, with from 0.02 percent to 0.1 percent being preferred, and with 0.03 percent to 0.08 percent being especially preferred.

25 Various additives may also be incorporated in the present foam such as inorganic fillers, pigments, dyes, antioxidants, acid scavengers, ultraviolet absorbers, flame retardants, processing aids, dispersing agents, and extrusion aids.

Based upon the above, the following are typical flame retardant foamed polymer compositions of the present invention:

A polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than about 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) from 0.1 percent to 4.0 percent by weight, based on  
5 100 percent of styrene polymer, of a phosphorous compound;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than about 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) from 0.5 percent to 2.0 percent by weight, based on  
10 100 percent of styrene polymer, of a phosphorous compound;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) from 1.0 percent to 2.0 percent by weight, based on  
15 100 percent of styrene polymer, of a phosphorous compound;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than about 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) about 1.0 percent by weight, based on 100 percent of  
20 styrene polymer, of a phosphorous compound;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) from 0.1 percent to 4.0 percent by weight, based on  
25 100 percent of styrene polymer, of a phosphorous compound; and c) 0.01 percent to 0.2 percent by weight, based on 100 percent of styrene polymer, of a flow promoter;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) from 0.5 percent to 2.0 percent by weight, based on  
30 100 percent of styrene polymer, of a phosphorous compound;

100 percent of styrene polymer, of a phosphorous compound; and c) 0.01 percent to 0.2 percent by weight, based on 100 percent of styrene polymer, of a flow promoter;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most  
5 preferably 1.4 percent, of HBCD; and 2) from 1.0 percent to 2.0 percent by weight, based on 100 percent of styrene polymer, of a phosphorous compound; and c) 0.01 percent to 0.2 percent by weight, based on 100 percent of styrene polymer, of a flow promoter;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant  
10 formulation comprising: 1) less than 2.5 percent by weight based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) 1.0 percent by weight, based on 100 percent of styrene polymer, of a phosphorous compound; and c) 0.01 percent to 0.2 percent by weight, based on 100 percent of styrene polymer, of a flow promoter;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant  
15 formulation comprising: 1) less than 2.5 percent by weight based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) from 0.1 percent to 4.0 percent by weight, based on 100 percent of styrene polymer, of TPP;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant  
20 formulation comprising: 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) from 0.5 percent to 2.0 percent by weight, based on 100 percent of styrene polymer, of TPP;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant  
25 formulation comprising: 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) from 1.0 percent to 2.0 percent by weight, based on 100 percent of styrene polymer, of TPP;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) about 1.0 percent by weight, based on 100 percent of styrene polymer, of TPP;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) from 0.1 percent to 4.0 percent by weight, based on 100 percent of styrene polymer, of TPP; and c) 0.01 percent to 0.2 percent by weight, based on 100 percent of styrene polymer, of a flow promoter;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) from 0.5 percent to 2.0 percent by weight, based on 100 percent of styrene polymer, of TPP; and c) 0.01 percent to 0.2 percent by weight, based on 100 percent of styrene polymer, of a flow promoter;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) from 1.0 percent to 2.0 percent by weight, based on 100 percent of styrene polymer, of TPP; and c) 0.01 percent to 0.2 percent by weight, based on 100 percent of styrene polymer, of a flow promoter;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than 2.5 percent by weight based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) about 1.0 percent by weight, based on 100 percent of styrene polymer, of TPP; and c) 0.01 percent to 0.2 percent by weight, based on 100 percent of styrene polymer, of a flow promoter;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) from 0.1 percent to 4.0 percent by weight, based on  
5 100 percent of styrene polymer, of TPP; and c) 0.01 percent to 0.2 percent by weight, based on 100 percent of styrene polymer of dimethyldiphenylbutane;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most  
10 preferably 1.4 percent, of HBCD; and 2) from 0.5 percent to 2.0 percent by weight, based on 100 percent of styrene polymer, of TPP; and c) 0.01 percent to 0.2 percent by weight, based on 100 percent of styrene polymer of dimethyldiphenylbutane;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant formulation comprising: 1) less than 2.5 percent by weight, based on 100 percent of styrene  
15 polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) from 1.0 percent to 2.0 percent by weight, based on 100 percent of styrene polymer, of TPP; and c) 0.01 percent to 0.2 percent by weight, based on 100 percent of styrene polymer, of dimethyldiphenylbutane;

a polymer foam, comprising: a) a styrene polymer; and b) a fire retardant  
20 formulation comprising: 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, preferably less than 2.0 percent, more preferably 1.0 to 1.6 percent, and most preferably 1.4 percent, of HBCD; and 2) about 1.0 percent by weight, based on 100 percent of styrene polymer, of TPP; and c) 0.01 percent to 0.2 percent by weight, based on 100 percent of styrene polymer, of dimethyldiphenylbutane.

25 The foams of the present invention may be prepared by extrusion processes well known to one of ordinary skill in the art.

A typical apparatus for making the foam according to an extrusion process is comprised of an extruder, a mixer, a cooler, and a die in series. Typically, the apparatus is maintained such that the feeding zone is maintained at 120°C to 160°C; the melting zone is  
30 maintained at 150°C to 190°C, the metering zone is maintained at 180°C to 220°C, and the

mixing zone is maintained at 180°C to 200°C. The fire retardant HBCD is in the form of a powder or as a granulate. Depending upon the physical state of the phosphorous compound (that is, liquid or solid), the phosphorous compound may be injected directly into the mixer, or introduced directly into the extruder. Alternatively, the phosphorous compound may be

5 introduced in the form of a styrene polymer concentrate. The flow promoter, due to its required low concentration, is usually used in the form of a styrene polymer concentrate. All solid materials are fed to the extruder, while the liquid materials can be injected directly into the mixer. The fire retardant formulation and the other additives are mixed with the styrene polymer resin in the desired ratio. The blowing agent is then incorporated into the blended polymer melt

10 at an elevated pressure in the mixer to form a foamable gel. The temperature of the foamable gel is reduced to a suitable foaming temperature (typically about 120°C) by reducing the temperature of the cooling zone. The foamable gel is then conveyed through the die into a region of reduced pressure to form the foam, adjusting the die opening as required and expanding the foam between substantially parallel forming plates. The foam structure is

15 preferably closed-cell, and has a closed-cell content of at least 90 percent according to ASTM D-2856. The foam structure preferably has a density of 16 kg/m<sup>3</sup> to 80 kg/m<sup>3</sup> according to ASTM D-1622. The foam further has an average cell size of 0.05 to 2.4 mm.

Suitable blowing agents for use in the present invention may be CO<sub>2</sub> or mixtures of blowing agents in any of the following proportions:

20	CO <sub>2</sub> :	from 0 percent to 100 percent of the blowing agent mixture;
	Alcohol:	from 0 percent to 50 percent of the blowing agent mixture;
	Water	from 0 percent to 50 percent of the blowing agent mixture;
	Dimethyl ether	from 0 percent to 50 percent of the blowing agent mixture;
	Hydrocarbon:	from 0 percent to 50 percent of the blowing agent mixture;
25	HFC-134a:	from 0 percent to 80 percent of the blowing agent mixture;
	HFC-152a:	from 0 percent to 80 percent of the blowing agent mixture; and
	HFC-134:	from 0 percent to 80 percent of the blowing agent mixture,

wherein HFC-134 is 1,1,2,2-tetrafluoroethane, HFC-134a is 1,1,1,2-tetrafluoroethane, and HFC-152a is 1,1-difluoroethane.

Preferred blowing agents are 100 percent CO<sub>2</sub>, mixtures of CO<sub>2</sub>, water, alcohol, dimethyl ether, and hydrocarbon, and mixtures of HFC-134a, HFC-134 and/or HFC-152a, alcohol, and hydrocarbon. The blowing agent is typically used at a concentration of between 0.05 to 0.20 mole/100 g polystyrene.

5 The following are examples of the present invention, and are not to be construed as limiting. Unless otherwise indicated, all percentages, parts, or proportions are by weight.

Examples 1 to 3 and Comparative Examples A through E

Closed-cell styrene polymer foams in accordance with the present invention are prepared utilizing a 5.08 cm (2 inch) diameter extruder which feeds a spline mixer, into which  
10 the blowing agents are injected. The spline mixer discharge is passed through heat exchangers. The discharge from the heat exchangers is passed through a static mixer and expanded through a slot die into a lower pressure region.

The styrene polymer is fed to the extruder with a fire retardant formulation comprising HBCD and optionally dimethyldiphenylbutane (dicumyl) from a dicumyl concentrate  
15 of 17 percent of dicumyl pure, and TPP is hot melt injected directly into the mixer, in accordance with the present invention, in amounts indicated in Table I. Blowing agents were injected into the mixer in amounts also indicated in Table I. The foamable gel was cooled down to approximately 120°C and extruded through the die, and expanded between substantially parallel forming plates.

20 Table 1 shows the composition and foam properties of three foams of the present invention (Example 1 to 3) as well as five control foams (Comparative Examples A through E) for comparative purposes. The foams of Comparative Examples A to D was produced with only HBCD (HBCD) as the fire retardant. The amount of HBCD was increased from 1 to more than 2.7 percent of HBCD, in order to achieve a concentration of bromine ranging from 0.5 to 2  
25 percent. All other additives remained unchanged. The foam of Comparative Example E was produced with a fire retardant composed of 5.5 percent of triphenyl phosphate and 0.068 percent dicumyl. The bromine percent in the foam is determined using the Oxford Lab X1005 x-ray Fluorescence analyzer. The foam is submitted to x-ray radiation from a radioactive Cadmium source and the x-rays correspond to the energy of the bromine element. By  
30 measuring the intensity of x-rays emitted, it is possible to quantify the bromine element in the

sample. The bromine percent is obtained from an average of measurement of three foam specimens. The compressive strength is determined with the method ASTM 1621-79.

Table I

Comp. Ex. or Ex. No.	Total Rate (kg/h)	HBCD (phr) <sup>1</sup>	Tpp (phr)	Dicumyl (phr)	CO <sub>2</sub> (phr)	Foaming Temperature (°C)	Foam Properties					
							Bromine (%)	Vertical Compressive Strength (kPa)	Thickness (mm)	Width (mm)	Density (kg/m <sup>3</sup> )	Vertical Cell Size (mm)
Comp. Ex. A	70	0.7	0	0	4.7	124	0.5	426	43	148	38.3	0.33
Comp. Ex. B	70	1.4	0	0	4.7	124	1.1	394	48	143	38.8	0.33
Comp. Ex. C	70	2.1	0	0	4.7	124	1.5	410	48	158	38.1	0.33
Comp. Ex. D	75	2.7	0	0	4.7	121	2.2	384	44	143	38.9	0.34
Comp. Ex. E	75	0	5.5	0.068	4.7	114	0.0	291	29	156	6.2	0.33
Ex. 1	75	1.4	2	0	4.7	119	0.9	373	34	139	36.3	0.33
Ex. 2	75	1.4	2	0.068	4.7	116	0.9	289	32	152	36.0	0.29
Ex. 3	75	1.4	1	0	4.7	119	0.9	225	29	157	36.2	0.32

<sup>1</sup>phr = parts per hundred parts of resin

Fire performance and fire retardancy performance are indicated in Table II, wherein the fire performance is measured according to the Limited Oxygen Index (LOI) and the fire retardancy performance is measured according to the German B2 test, French M1 test and Swiss Class V test.

5                   The Limited Oxygen Index (LOI) is determined according to test method ASTM-D2863. This is the minimum concentration of oxygen, expressed as volume percent, in a mixture of oxygen and nitrogen that will just support flaming combustion of a material initially at room temperature under the conditions of this test method.

10                   The German B2 test is performed according to the DIN-4102 Part 1. Five samples were tested. The lower the flame average height, the better the fire retardancy performance. The burning time should also be as low as possible. If the filter paper underneath the sample ignites within 20 seconds, the material is considered to burn with flaming droplet. The number reported in Table II is the number of burning papers during the test.

15                   The French M1 test is performed according to NF-P 92-501/4/5 composed of two tests: flame persistency and burning droplet. Three samples are tested. The average time for the flame to be self-extinguished should be as low as possible. The percentage of the number of burners with burning time above 2 percent as well as the number of the burning droplets should also be as small as possible.

20                   The Swiss test is performed according to SIA 183/2.5. The lower the flame average height, the better the fire retardancy performance.

Table II

Comp. Ex. or Ex. No.	Fire Performance	German B2 Test				Swiss Test		French M1 Test		
		Average Flame Height (cm)	Burning Time (sec)	Paper Ignition No.	Flame Height (cm)	Flame persistence-mean (sec) (	Flame persistence %> 2sec	Burning drop number		
Comp. Ex. A	24.0	14.2	47	4	20	23.7	90	4		
Comp. Ex. B	26.6	11	18.2	1	18	7.3	91	4		
Comp. Ex. C	28.9	10	14.4	1	15	1.6	29	4		
Comp. Ex. D	30.9	8.2	11.9	0.6	13	0.6	4	3		
Comp. Ex. E	25.6	13.6	21.8	4	20	25.2	100	4		
Ex. 1	28.5	6.8	10.7	0.2	15	3.0	53	2		
Ex. 2	30.5	5.8	8.2	0	14	1.0	14	2		
Ex. 3	29.8	6.4	9.8		15	1.0	11	4		

As can be seen from Table I and Table II, the formulations according to the present invention exhibited a lower foam density than the foams of the Comparative Examples, although the formulations were produced at a lower foaming temperature. The foam products, according to the invention, presented good fire performance in German B2 test, Swiss and  
5 French M1 fire retardancy tests. To achieve that performance, very high amounts of HBCD (that is, high bromine percentage) for the comparative foam is required. The foams of the present invention also exhibited excellent dimensional stability and mechanical properties as do the comparative foams. However, the foams of the present invention exhibited good  
10 mechanical properties despite having a lower density. Therefore, the foams of the present invention are suitable for use in insulation applications and building construction.

CLAIMS:

1. A flame retardant foamed polymer composition comprising:
  - a) a styrene polymer; and
  - b) a fire retardant formulation comprising:
    - 5 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, of HBCD; and
    - 2) from 0.1 percent to 4.0 percent by weight, based on 100 percent of styrene polymer, of a phosphorous compound.
2. The polymer composition of Claim 1 wherein the phosphorous compound  
10 is selected from 1) phosphates of the formula  $(RO)_3PO$ ; 2) phosphites of the formula  $(RO)_3P$ ; 3) phosphonates of the formula  $(RO)_2RPO$ ; 4) phosphinates of the formula  $(RO)R_2PO$ ; 5) phosphine oxides of the formula  $R_3PO$ ; 6) phosphines of the formula  $R_3P$ ; and 7) phosphonium salts of the formula  $R_4PX$ , wherein each R is independently selected from substituted or unsubstituted, saturated or unsaturated, branched or straight-chain aliphatic moieties or  
15 substituted or unsubstituted aromatic moieties and X is a suitable counter ion.
3. The polymer composition of Claim 1 further including from 0.01 percent to 0.2 percent by weight, based on 100 percent of styrene polymer, of a flow promoter.
4. The polymer composition of Claim 3 wherein the flow promoter is selected from dimethyldiphenylbutane, dicumyl peroxide or  $\alpha,\alpha'$ -bis-tert-butylperoxydiisopropyl-benzene.
- 20 5. The polymer composition of Claim 4 wherein the flow promoter is dimethyldiphenylbutane.
6. The polymer composition of Claim 2 wherein the phosphorous compound is a phosphate of the formula  $(RO)_3PO$  wherein each R is independently selected from substituted or unsubstituted, saturated or unsaturated, branched or straight-chain aliphatic  
25 moieties or substituted or unsubstituted aromatic moieties.
7. The polymer composition of Claim 6 wherein the phosphate is selected from TPP, tributylphosphate, triethylphosphate, trimethylphosphate, tripropylphosphate, trioctylphosphate, diphenyl methylphosphate, tris-(2-ethylhexyl)phosphate, isodecyl

diphenylphosphate, isooctyl diphenylphosphate, bisphenyl diphenylphosphate, trixylyl phosphate or triisopropylphenylphenylphosphate.

8. The polymer composition of Claim 7 wherein the phosphate is TPP.
9. The polymer composition of Claim 1 wherein the HBCD is present in an amount less than 2.0 percent by weight, based on 100 percent of styrene polymer.
10. The polymer composition of Claim 1 wherein the phosphorous compound is present in an amount of from 0.5 percent to 2.0 percent by weight, based on 100 percent of styrene polymer.
11. The polymer composition of Claim 3 wherein the flow promoter is present in an amount of from 0.02 percent to 0.1 percent by weight, based on 100 percent of styrene polymer.
12. The polymer composition of Claim 10 wherein the HBCD is present in an amount of from 1.0 percent to 1.6 percent by weight based on 100 percent of styrene polymer.
13. The polymer composition of Claim 12 wherein the HBCD is present in an amount of 1.4 percent by weight, based on 100 percent of styrene polymer.
14. The polymer composition of Claim 1 wherein the phosphorous compound is present in an amount of from 1.0 percent to 2.0 percent by weight, based on 100 percent of styrene polymer.
15. A flame retardant foamed polymer composition comprising:
  - a) a styrene polymer;
  - b) a fire retardant formulation comprising:
    - 1) less than 2.5 percent by weight, based on 100 percent of styrene polymer, of HBCD; and
    - 2) from 0.1 percent to 4.0 percent by weight, based on 100 percent of styrene polymer, of a phosphorous compound selected from 1) phosphates of the formula  $(RO)_3PO$ ; 2) phosphites of the formula  $(RO)_3P$ ; 3) phosphonates of the formula  $(RO)_2R'PO$ ; 4) phosphinates of the formula

- (RO)R'<sub>2</sub>PO; 5) phosphine oxides of the formula R<sub>3</sub>PO; 6) phosphines of the formula R<sub>3</sub>P; and 7) phosphonium salts of the formula R<sub>4</sub>PX, wherein R and R' are each independently selected from substituted or unsubstituted, saturated or unsaturated, branched or straight-chain aliphatic moieties or substituted or unsubstituted aromatic moieties and X is a suitable counter ion; and
- 5
- c) from 0 percent to 0.2 percent by weight, based on 100 percent of styrene polymer, of a flow promoter.
- 10
16. A flame retardant foamed polymer composition comprising:
- a) a styrene polymer; and
- b) a fire retardant formulation comprising:
- 1) less than 2.0 percent by weight, based on 100 percent of styrene polymer, of HBCD; and
- 15
- 2) from 0.5 percent to 2.0 percent by weight, based on 100 percent of styrene polymer, of a phosphorous compound selected from 1) phosphates of the formula (RO)<sub>3</sub>PO; 2) phosphites of the formula (RO)<sub>3</sub>P; 3) phosphonates of the formula (RO)<sub>2</sub>R'PO; 4) phosphinates of the formula (RO)R'<sub>2</sub>PO; 5) phosphine oxides of the formula R<sub>3</sub>PO; 6) phosphines of the formula R<sub>3</sub>P; and 7) phosphonium salts of the formula R<sub>4</sub>PX, wherein R and R' are each independently selected from substituted or unsubstituted, saturated or unsaturated, branched or straight-chain aliphatic moieties or substituted or unsubstituted aromatic moieties and X is a suitable counter ion; and
- 20
- 25
- c) from 0.02 percent to 0.1 percent by weight, based on 100 percent of styrene polymer, of a flow promoter.
17. A flame retardant foamed polymer composition comprising:

- a) a styrene polymer; and
- b) a fire retardant formulation comprising:
- 1) 1.0 percent to 1.6 percent by weight, based on 100 percent of styrene polymer, of HBCD; and
  - 2) from 0.5 percent to 2.0 percent by weight, based on 100 percent of styrene polymer, of a phosphorous compound selected from 1) phosphates of the formula  $(RO)_3PO$ ; 2) phosphites of the formula  $(RO)_3P$ ; 3) phosphonates of the formula  $(RO)_2R'PO$ ; 4) phosphinates of the formula  $(RO)R'_2PO$ ; 5) phosphine oxides of the formula  $R_3PO$ ; 6) phosphines of the formula  $R_3P$ ; and 7) phosphonium salts of the formula  $R_4PX$ , wherein R and R' are each independently selected from substituted or unsubstituted, saturated or unsaturated, branched or straight-chain aliphatic moieties or substituted or unsubstituted aromatic moieties and X is a suitable counter ion; and
  - c) from 0.02 percent to 0.1 percent by weight, based on 100 percent of styrene polymer of a flow promoter.
18. A flame retardant foamed polymer composition comprising:
- a) a styrene polymer; and
  - b) a fire retardant formulation comprising:
    - 1) 1.4 percent by weight, based on 100 percent of styrene polymer, of HBCD; and
    - 2) 2.0 percent by weight, based on 100 percent of styrene polymer, of a phosphorous compound selected from 1) phosphates of the formula  $(RO)_3PO$ ; 2) phosphites of the formula  $(RO)_3P$ ; 3) phosphonates of the formula  $(RO)_2R'PO$ ; 4) phosphinates of the formula  $(RO)R'_2PO$ ; 5) phosphine oxides of the formula  $R_3PO$ ; 6) phosphines of the formula  $R_3P$ ; and 7)

phosphonium salts of the formula  $R_4PX$ , wherein R and R' are each independently selected from substituted or unsubstituted, saturated or unsaturated, branched or straight-chain aliphatic moieties or substituted or unsubstituted aromatic moieties and X is a suitable counter ion; and

5

- c) 0.03 percent to 0.08 percent by weight, based on 100 percent of styrene polymer of a flow promoter.

19. A flame retardant foamed polymer composition comprising:

a) a styrene polymer; and

10

b) a fire retardant formulation comprising:

1) 1.4 percent by weight, based on 100 percent of styrene polymer, of HBCD; and

2) 2.0 percent by weight, based on 100 percent of styrene polymer, of TPP; and

15

c) 0.03 percent to 0.08 percent by weight, based on 100 percent of styrene polymer, of dimethyldiphenylbutane.

20. A flame retardant foamed polymer composition comprising:

a) a styrene polymer; and

b) a fire retardant formulation comprising:

20

1) 1.4 percent by weight, based on 100 percent of styrene polymer, of HBCD; and

2) 2.0 percent by weight, based on 100 percent of styrene polymer, of TPP.

5

21. A flame retardant foamed polymer composition comprising:
  - a) a styrene polymer; and
  - b) a fire retardant formulation comprising:
    - 1) 1.4 percent by weight, based on 100 percent of the styrene polymer, of HBCD; and
    - 2) 1.0 percent by weight, based on 100 percent of styrene polymer, of TPP.