



(51) International Patent Classification:

B32B 27/18 (2006.01)

(21) International Application Number:

PCT/CN2017/075162

(22) International Filing Date:

28 February 2017 (28.02.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(71) Applicant: AVERY DENNISON CORPORATION

[US/US]; 207 Goode Avenue, Glendale, CA 91203 (US).

(72) Inventors; and

(71) Applicants (for US only): XIE, Shuhui [CN/US]; c/o Avery Dennison Corporation, 207 Goode Avenue, Glendale, CA 91203 (US). ZHANG, Jun [CN/US]; c/o Avery Dennison Corporation, 207 Goode Avenue, Glendale, CA 91203 (US). JING, Will [CN/US]; c/o Avery Dennison Corporation, 207 Goode Avenue, Glendale, CA 91203 (US). SHEN, Bill [CN/US]; c/o Avery Dennison Corporation, 207 Goode Avenue, Glendale, CA 91203 (US). ZHOU, Tyler [CN/US]; c/o Avery Dennison Corporation, 207 Goode Avenue, Glendale, CA 91203 (US).

(74) Agent: ZHONGZI LAW OFFICE; 7F, New Era Building, 26 Pinganli Xidajie, Xicheng District, Beijing 100034 (CN).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC,

SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every

kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

Published:

— with international search report (Art. 21(3))

(54) Title: FLAME RETARDANT LABEL

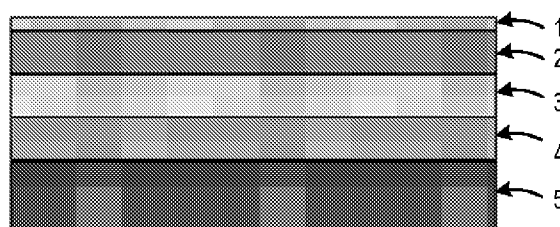


FIG. 1

(57) Abstract: The multi-layer label provided herein include a topcoat layer (2), a film layer (3), and an adhesive layer (4). The topcoat layer (2) comprises a phenoxy resin and a first flame retardant. The adhesive layer (4) is in contact with at least a portion of the film layer (3). The adhesive layer (4) may comprises an epoxy resin and a second flame retardant. The film layer (3) of the label can also comprises flame retardant or meets the UL 94 VTM-2, UL 94 VTM-1, or the UL 94 VTM-0 requirement.



FLAME RETARDANT LABEL

FIELD OF THE INVENTION

[0001] The present invention relates generally to flame retardant labels. These labels are useful for labeling electrical equipment, e.g., batteries.

BACKGROUND OF THE INVENTION

[0002] Labels that are flame retardant are desired for many situations, including labeling electrical equipment, e.g., a battery, where there is an increased chance of fire hazard due to extended period of operation of the electrical equipment. Labels also require good printability and good adhesion performance. The adhesion performance is typically measured by tack strength, shear, and 180 ° peel strength. In addition, labels must also have appropriate thickness such that the labels can be easily wrapped around a substrate. Further, the amounts of components present in the various layers of the labels must be controlled such that production of the labels is cost effective.

[0003] Conventionally, labels having flame retardant properties are produced by stacking multiple layers of fire-retardant topcoat, film, and adhesives. The topcoat layer of some conventional labels often comprise polymeric resins that lack sufficient thermal decomposition resistance e.g., having a low char yield. Char yield for polymers is defined as the amount of solid residue at 930 °C in a nitrogen atmosphere and in general, a higher char yield is associated with a higher thermal decomposition resistance and a higher flame retardance. In some cases, flame retardants may be added to a topcoat to improve the flame retardant properties thereof. However, flame retardants added to the label often compromise the label's adhesion performance. Thus, in order to compensate for the problems caused by flame retardants, manufacturers often increase the amount of other constituents of different layer that contribute to the adhesion performance of the label and increase the thickness of the label. Unfortunately, these adjustments typically cause increases in production costs and inconveniences in label application. Also, the resultant labels may often be too thick for the intended purpose.

[0004] CN 205368224U discloses a flame-retardant label, which comprises a flame-retardant print layer, a film, a flame-retardant coating layer, and an adhesive layer. Neither the film layer nor the adhesive layer is flame retardant and these two layers are separated by the flame-retardant coating layer.

[0005] US Patent No. 4,207,374 discloses a flame-retardant film containing a flame-retardant topcoat layer comprising polyester/epoxy resin. The reference also discloses a label comprising an adhesive layer comprising acrylics and rubber/resin.

[0006] US Publication No. 2014/0162058A1 discloses a flame retardant adhesive layer coated on at least a portion of a PET film backing. The adhesive layer comprises a methacrylate-based block copolymer and at least 10% halogen-free flame retarding agent. The adhesive layer may optionally contain tackifying resins. US20140162058A1 does not disclose whether the label meets the flame-retardancy requirements under any of the UL 94 VTM standards.

[0007] WO2011029225A1 discloses a multi-layer label comprising a flame-retardant topcoat layer, a film layer and a flame-retardant adhesive layer. The label demonstrates a flame-retardant performance that meets the UL 94 VTM-0 standard. The topcoat layer comprises a mixture of polyurethane resin and phenoxy resin. The top surface of the topcoat layer is a printable surface. The adhesive layer comprises pressure sensitive adhesives such as an acrylic. The backing film has a thickness of 25 microns and the topcoat layer has a thickness of 18 microns. The application discloses that the adhesive layer, if not flame retardant, is optimally 20 microns; but if the adhesive layer contains a flame retardant, it is desirable to extend the adhesive layer to a greater thickness, to as much as 100 microns to provide more flexibility.

[0008] Many of these references do not disclose whether the respective label meets the flame-retardant requirements under any of the UL 94 VTM standards. The above-identified references are incorporated by reference herein.

[0009] None of the above-disclosed references, however, provide for cost effective labels having effective and stable flame-retardant properties and at the same time having appropriate thickness as well as good adhesion, converting, and/or reposition performance. Thus, the need exists for a cost-effective label having the combination of these performance features.

SUMMARY OF THE INVENTION

[0010] In one embodiment, the invention relates to a multi-layer label comprising a topcoat

layer that comprises a phenoxy resin and a first flame retardant, a film layer, and an adhesive layer comprising an epoxy resin and a second flame retardant. Each of the topcoat layer, the film layer, the adhesive layer of the label has opposing top and bottom surfaces. In some embodiments, the adhesive layer is in contact with at least a portion of the film layer. In some embodiments, the adhesive layer is not in contact with the film layer. In some embodiments, the film layer comprises a third flame retardant. Any of the first, second, and third flame retardant may be different or the same as another. In some embodiments, the first flame retardant is selected from the group consisting of alkyl phosphinates, e.g., Exolit OP 935, metal hydroxides e.g., $\text{Al}(\text{OH})_3$, and mixtures thereof. In some embodiments, the second flame retardant is selected from the group consisting of metal alkyl phosphinates, aryl phosphates, ammonium phosphate, and mixtures thereof. The first, second, and/or the third flame retardant can also include one or more of the following: melamine based flame retardants; organophosphorous flame retardants; metal oxide hydrates, such as magnesium hydroxide hydrates, aluminum hydroxide hydrates; and polysiloxanes. The amount of flame retardants in the respective layers ranges from about 1% to about 70%, e.g., from 10% to 50%, from 20% to 60%, from 30% to 50%. The label can demonstrate flame-retardant performance of VTM-0, as measured by the UL 94 VTM-0 (current year or 2016). In some embodiments, the label demonstrates a tack strength of at least 6, e.g., at least 8, at least 9, at least 10, at least 11, at least 12 newtons per inch on a stainless steel substrate. In some embodiments, the label demonstrates a 180° peel strength of at least 10, at last 11, at least 12, at least 13 newtons/inch on a stainless steel substrate. The topcoat layer of the label may have a thickness from 2 to 50 microns. In some embodiments the multi-layer label has a thickness from 5 microns to 80 microns. In some embodiments, the multi-layer label had a thickness of less than 63 microns, e.g., less than 62 microns. In some embodiments, the film layer contains a flame retardant. The film herein can be a polymeric film or a metal foil. Preferred materials for the film layer are resins selected from polyester, ABS, polyacrylate, polycarbonate (PC), polyamide, polyimide (PI), polyamidoimide, polyacetal, polyphenylene oxide (PPO), polysulfone, polyethersulfone (PES), polyphenylene sulfide, polyether ether ketone (PEEK), polyetherimide (PEI), metallized polyethylene terephthalate (PET), polyvinyl fluoride (PVF), polyethylene ether (PEE), fluorinated ethylene propylene (FEP), polyurethane (PUR), polyvinylidene fluoride (PVDF), aramid fibers, DIALAMY (polymer alloys), polyethylene naphthalate (PEN), ethylene/tetrafluoroethylene (E/TFE), polyphenyl sulfone (PPSU) and

polymers or polymer alloys containing one or more of these materials. In some cases, the film layer is a VTM-2 PET film, VTM-1 PET film, or VTM-0 PET film. The film layer may have a thickness from 5 microns to 80 microns. The adhesive layer may comprise a hydroxyl group substituted acrylic polymer. In some embodiments, the adhesive layer further comprises a crosslinker. In some embodiment, the crosslinker is a metal salt, e.g., a titanium salt, e.g., $\text{Ti}(\text{OC}_4\text{H}_9)_4$, or titanium acetylacetonate (TiAA). The adhesive layer may also comprise a tackifier. The adhesive layer may have a thickness of about 2-50 microns. The label may also comprise a printable layer in contact with the top surface of the topcoat layer. In some cases, the printable layer has a thickness of about 0.1-10 microns. In some embodiments, the label may further comprise a liner that contacts the bottom surface of the adhesive layer.

[0011] In any of the above-described embodiments, the amount of phenoxy resin in the topcoat layer can range from about 20 to about 70 wt.%, and/or the amount of the first flame retardant in the topcoat layer ranges from about 10 to about 80 wt.%, based on the total weight of the topcoat layer. In any of the above-referenced embodiments, the amount of the second flame retardant in the adhesive layer can range from about 1 to about 10 wt.%; the amount of epoxy resin in the adhesive layer ranges from about 1 to about 10 wt.%; the amount of hydroxyl group substituted acrylic polymer in the adhesive layer ranges from about 30 to about 90 wt.%; and/or the amount of cross linker in the adhesive layer ranges from about 0.1 to about 2.0 wt.%.

[0012] The invention also provides a multi-layer label for use to label an electrical equipment, the label comprises: (i) a topcoat layer comprising a phenoxy resin and one or more first flame retardant; (ii) an adhesive layer comprising an epoxy resin and one or more second flame retardant; and (iii) a film layer that is in contact with the adhesive layer. In some embodiments, the electrical equipment is a battery.

[0013] The invention also provides a method to label an electrical equipment comprising applying a multi-layer label to a battery surface or a battery wrapping, wherein the label comprises: (i) a topcoat layer comprising a phenoxy resin and one or more first flame retardant; (ii) an adhesive layer comprising an epoxy resin and one or more second flame retardant; and (iii) a film layer that is in contact with the adhesive layer; wherein each of the topcoat layer, the film layer, the adhesive layer comprises a top surface and a bottom surface, the bottom surface being the surface facing an object to be labeled and the top surface being the surface on the opposite side of the bottom surface.

BRIEF DESCRIPTION OF DRAWINGS

[0014] The invention is described in detail below with reference to the appended drawing.

[0015] FIG. 1 shows a cross-sectional view of a label in accordance with aspects of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0016] Unless otherwise noted, all percentages disclosed in this application refer to weight-weight percentages. For example, a percentage of 10% is used interchangeably with 10 wt.%, a percentage of 20% is used interchangeably with 20 wt.%, etc.

[0017] Unless otherwise noted, all flame retardant performance standards, e.g., VTM-1, VTM-2, VTM-0, refer to standards according to the UL94 Vertical Burn Test (2016).

[0018] In the summary and this detailed description, each numerical value should be read once as modified by the term “about” (unless already expressly so modified), and then read again as not so modified unless otherwise indicated in context. Also, in the summary and this detailed description, it should be understood that a concentration range listed or described as being useful, suitable, or the like, is intended that any and every concentration within the range, including the end points, is to be considered as having been stated. For example, a range “from 1 to 10” is to be read as indicating each and every possible number along the continuum between about 1 and about 10. Thus, even if specific data points within the range, or even no data points within the range, are explicitly identified or refer to only a few specific data points, it is to be understood that inventors appreciate and understand that any and all data points within the range are to be considered to have been specified, and that inventors possessed knowledge of the entire range and all points within the range.

[0019] Labels for electrical equipment, e.g., a battery, must be flame retardant for protection against fire hazard. However, adding flame retardants to labels may compromise properties that are very important for its intended function, such as, adhesion, converting, and reposition performance. For example, adding flame retardants may decrease the shear strength of the label, which may cause the label to be brittle and difficult to be slit into small labels. Adding flame retardants to the adhesive layer may also cause a decrease in the label’s adhesion power and tack strength. Also, adding flame retardants to the layers of label may increase the production cost

due to the additional materials that need to be added to maintain the adhesive performance of the label.

[0020] The inventors have discovered a unique combination of layers, each of which having a particular composition, that provides for a multi-layer label that demonstrates superior flame-retardant properties as well as good adhesion, reposition and/or converting performance. The multi-layer label comprises at least three layers, the topcoat layer, a film layer, and an adhesive layer. In some embodiments, a resin having high char yield, such as a phenoxy resin, is used in the topcoat layer along with a first flame retardant. The adhesive layer is in contact with at least a portion of the film layer and comprises an epoxy resin and a second flame-retardant (and optionally specific crosslinkers). Optionally, the label comprises a printable layer and a liner. In some embodiments, the topcoat layer, the film layer, and the adhesive layer are arranged in the order from top to bottom, from the perspective of looking downward to the substrate to be labeled. Stated another way, the film layer may be configured between the topcoat layer and the adhesive layer. Other layers may also be present between the topcoat layer and the adhesive layer. In some embodiments, each of the topcoat layer, the film layer, the adhesive layer have opposing top and bottom surfaces, with the bottom surface being the surface that faces the substrate. Without being bound by theory, it is believed that an improvement is seen when (at least a portion of) the topcoat layer is not in direct contact with (at least a portion of) the adhesive layer, e.g., the lack of contact between the topcoat layer and the adhesive layer and/or the contact of the adhesive layer with at least a portion of the film layer provides for a beneficial synergistic effect.

[0021] It has now been discovered that, to minimize the negative effect of the presence of flame retardant on the bonding properties of the adhesive layer, in some cases, an epoxy resin may be employed as a component of the adhesive layer. The combination of the epoxy resin and the second flame retardant surprisingly increases tack strength and improves flame-retardant properties. In some embodiments, (specific) crosslinkers are used to increase cohesiveness of the label. The combination of these crosslinkers, the epoxy resin, and the second flame retardant unexpectedly provides for additional improvements in flame retardancy and label performance. The inventors of the application have also discovered that the use of specific concentration ranges for the components provide for a desirable combination of performance characteristics.

[0022] As shown in the exemplary embodiment of FIG. 1, the multi-layer label contains multiple basic layers, e.g., at least three, at least four or at least five, although the present

invention may include more or fewer layers. In some cases, the layers, in order from top to bottom, include a printable layer 1, a topcoat layer 2, a film layer 3, an adhesive layer 4, and a liner 5. Each layer is described in further detail below.

Printable Layer

[0023] The multi-layer label may optionally comprise one or more printable layers. In one embodiment, from the perspective of looking downward to the substrate, the printable layer is on the top surface of the label, exposed to the environment and is configured to receive printable information, such as barcode or alphanumeric characters. Printable information can be deposited on the printable layer using various printing techniques, such as screen printing, dot-matrix, ink jet, laser printing, laser marking, thermal transfer, and so on. In one embodiment, the printer layer is adhered to the top surface of the topcoat layer.

[0024] The printable layer may contain a layer of an ink-receptive composition that is utilized to form the printable information. A variety of such compositions are known in the art, and these compositions generally include a binder and a pigment, such as silica or talc, dispersed in the binder. A number of such ink-receptive compositions are described in US Patent No. 6,153,288, the disclosure of which is hereby incorporated by reference.

[0025] The printable layer may be an ink or graphic layer, and the coating weight of the print layer is typically in the range of 0.1 -10 gram per square meter, e.g., 0.2-8 gram per square meter, e.g., 0.4- 5 gram per square meter, e.g., 0.5-3 gram per square meter. In terms of upper limits, the coating weight of the printable layer is no greater than 20, e.g., no greater than 15, no greater than 10, no greater than 5, no greater than 3 gram per square meter. The thickness of the print layer is typically in the range of 0.1 -10 microns, e.g., 0.2-8 microns, e.g., 0.4- 5 microns, e.g., 0.5-3 microns. In terms of upper limits, the coating weight of the printable layer is no greater than 20, e.g., no greater than 15, no greater than 10, no greater than 5, no greater than 3 microns.

[0026] The inks used for printing on the printable layer may vary widely and may include commercially available water-based, solvent-based or radiation-curable inks. Examples of these inks include Sun Sheen (a product of Sun Chemical identified as an alcohol dilutable polyamide ink), SUNTEX® MP (a product of Sun Chemical identified as a solvent-based ink formulated for surface printing acrylic coated substrates, PVDC coated substrates and polyolefin films), X-Cel (a product of Water Ink Technologies identified as a water-based film ink for printing film substrates), Uvilith AR-109 Rubine Red (a product of Daw Ink identified as a UV ink) and

CLA91598F (a product of Sun Chemical identified as a multibond black solvent-based ink).

[0027] The printable layer can be formed by depositing, by gravure printing or the like, on the topcoat layer of the label, with the bottom surface in contact with the top surface of the topcoat layer. Optionally, the printable layer comprises a crosslinker CX-100 (DSM's polyfunctional aziridine liquid crosslinker).

Topcoat Layer

[0028] The multi-layer label further comprises the topcoat layer. In one embodiment, the topcoat layer is configured as having its top surface in contact with the bottom surface of the printable layer and a bottom surface in direct contact with the top surface of a film layer, i.e., the topcoat layer is positioned above the film layer and below the printable layer.

[0029] In one embodiment, the topcoat layer of the label comprises a resin that has a high thermal decomposition resistance, e.g., a high char yield. The topcoat layer further comprises a first flame retardant. In preferred embodiments, the resin comprises a phenoxy resin. A phenoxy resin may be a high-molecular-weight thermoplastic polyether resin based on bisphenol-A and epichlorohydrin with bisphenol-A terminal groups. Any phenoxy resin can be used in the topcoat layer. Many exemplary phenoxy resins are commercially available, for example, from Dow Chemical, Huntsman, Shell or Inchem. Other phenoxy resins suitable for use in the present invention include those described in US Patent Nos. 6, 261,730; 4, 578,312; and 4, 526,912. In some embodiments, the topcoat layer consists essentially of a phenoxy resin, a flame retardant, and a solvent. Any solvent that can be used to dissolve the resin and provide coatability can be used for this topcoat layer. Non-limiting examples of solvents that can be used herein include ketones, esters, and hydrocarbons.

[0030] In some embodiments, the topcoat layer contains from 20 to 70 wt.% of a phenoxy resin, based on the total weight of the topcoat, e.g., 25 to 60 wt.% or from 30 to 50 wt.%, e.g., from about 30 to about 40 wt.%. In terms of lower limits, in some embodiments, the topcoat layer comprises at least 30%, at least 50%, at least 60%, at least 70%, at least 80%, at least 90%, at least 95% of phenoxy resin by based on the total weight of the topcoat layer. In terms of upper limits, in some embodiments, the topcoat layer comprises no more than 98% of phenoxy resin based on the total weight of the topcoat layer, e.g., no more than 95%, no more than 90%, no more than 80%. The amount of resin may be chosen based on the desired stiffness of the topcoat layer, the amount of flame retardant present in the topcoat layer and the ability to provide

sufficient anchorage of the topcoat on the base film. In general, a lower weight percentage of resin or a higher weight percentage amount of flame retardant is correlated with a higher stiffness of the label. The stiffness of the label may affect the converting performance of the label, i.e., the capability of being slit into small labels of suitable shapes and sizes.

[0031] In some embodiments, the topcoat layer comprises a mixture of a phenoxy resin and one or more other resins none of which is a polyurethane resin, e.g., the topcoat layer comprises no polyurethane resin.

[0032] The topcoat layer of the multi-layer label comprises a flame retardant. For purpose of this disclosure, a flame retardant, when used in any layer of the multi-layer label, although used in singular form, is not necessarily limited to a single chemical compound. In some cases, a flame retardant is a single compound that has flame-retardant property.

[0033] In some cases, a flame retardant is a mixture of more than one compound or agent, each being flame-retardant. Non-limiting examples of flame-retardant agents include metal alkyl phosphinates, melamine based flame retardants; organophosphorus flame retardants; metal oxide hydrates, such as magnesium hydroxide hydrates, aluminum oxide hydrates; polysiloxanes; phosphates such as ammonium polyphosphates and aryl phosphates; ammonium polyphosphates, metal alkyl phosphinates; and mixtures thereof. In some cases, the flame retardant used for this layer or any other layer of the label is a halogen-free flame retardant, i.e., free of chlorine and bromine. In some embodiments, the flame retardant is selected from the group consisting of metal alkyl phosphinates (e.g., Exolit OP 935), metal hydroxides (e.g., $\text{Al}(\text{OH})_3$), and mixtures thereof. In some embodiments, the weight ratio between the metal alkyl phosphinates and the metal hydroxide in the flame retardant can be a ratio ranging from 1:2 to 2:1, for example, about 1:1.

[0034] The weight percentage of each flame-retardant agent of the flame retardant in the topcoat layer may vary, typically the topcoat layer comprises the total flame retardant in a range of 10-80%, 30-50%, 40-70%, 10-50%, 20-70%, or 55-65%, based on the weight of the topcoat layer. In terms of upper limit, the flame retardant may be present in an amount that is not more than 80% of the weight of the topcoat. In terms of lower limit, the flame retardant may be present in an amount that is not less than 10% of the weight of the topcoat. The amount of flame retardant in the topcoat layer may be chosen based on the desired flame retardancy and the stiffness of the label; a higher amount of flame retardant increase flame retardancy but could also

increase the stiffness of the label. Thus, to confer the appropriate flame retardancy and stiffness to the label, it is desirable to control both the amount of flame retardant and amount of resin, e.g., phenoxy resin, within appropriate ranges, as described above. The flame retardant can be dispersed throughout the topcoat layer, or any other layer of the label, in any fashion, e.g., homogeneously or nonhomogeneously. In some cases, the flame retardant is in a form of particles.

[0035] The thickness or the coating weight of the topcoat layer according to the invention may vary widely. In some embodiments, the topcoat layer has a coating weight from 1 to 100 grams per square meter, e.g., 2 to 50, 3 to 20, 4 to 30, 5 to 25, 10 to 20, or 10 to 15 grams per square meter. In terms of upper limits, the topcoat layer may have a coating weight of no more than 100 grams per square meter, e.g., no more than 80, no more than 70, no more than 60, no more than 30, no more than 25, no more than 20 grams per square meter. In terms of lower limits, the topcoat layer may have a coating weight of at least 1 gram per square meter, e.g., at least 2, 4, 5, 10, 10, 30, 50, or 100 grams per square meter. The thickness of the topcoat layer may also vary. In some embodiments, the topcoat layer has a thickness of 1 to 100 microns, e.g., 2 to 50 microns, 3 to 20 microns, 4 to 30 microns, 5 to 25 microns, or 10-20 microns, or 10-15 microns. In terms of upper limits, the topcoat layer may have a thickness of no more than 100 microns, e.g., no more than 80 microns, no more than 70 microns, no more than 60 microns, no more than 30 microns, no more than 25 microns, or no more than 20 microns. In terms of lower limits, the topcoat layer may have a thickness of at least 1 micron, e.g., at least 2 microns, at least 4 microns, at least 5 microns, at least 10 microns, or at least 20 microns.

[0036] The thickness or coating weight of the topcoat layer may be chosen based on the desired stiffness of the topcoat on balance of the amount of flame retardant present in the topcoat layer – if the layer comprises lower percentage of flame retardant, it can be thinner or can have a lower coating weight; and if the layer comprises a higher percentage of flame retardant, it may require a thicker layer in order to maintain the optimal performance of the label, e.g., good adhesion, converting, and reposition performance.

[0037] Optionally, the topcoat layer of the label also comprises a crosslinker. In one embodiment, the crosslinker used in the topcoat layer is N75 (Bayer's poly-isocyanate crosslinker). The crosslinker may be present in the topcoat layer in an amount ranging from about 0.1% to about 2%, about 0.5% to about 1%, or about 0.65- about 0.9%, based on the total

weight of the topcoat layer. In some embodiments, the crosslinker is present in an amount of about 0.8% based on the total weight of the topcoat layer.

[0038] The topcoat layer, in accordance with certain embodiments of the present invention, may be applied onto the film layer and the printable layer by any known techniques in the art, such as spray, roll, brush, or other techniques.

Film layer

[0039] As noted above, the labels may comprise at least one film layer, at least a portion of which is in contact with the topcoat layer. The film layer can be a polymeric film or a metal foil. Preferred materials for the film layer are resins selected from polyester, ABS, polyacrylate, polycarbonate (PC), polyamide, polyimide (PI), polyamidoimide, polyacetal, polyphenylene oxide (PPO), polysulfone, polyethersulfone (PES), polyphenylene sulfide, polyether ether ketone (PEEK), polyetherimide (PEI), metallized polyethylene terephthalate (PET), polyvinyl fluoride (PVF), polyethylene ether (PEE), fluorinated ethylene propylene (FEP), polyurethane (PUR), liquid crystal polymers (LCPs, class of aromatic polyester), polyvinylidene fluoride (PVDF), aramid fibers, DIALAMY, (polymer alloys), polyethylene naphthalate (PEN), ethylene/tetrafluoroethylene, (E/TFE), polyphenyl sulfone (PPSU) and polymers or polymer alloys containing one or more of these materials. In some embodiments, the flame retardancy of the film layer meets the VTM-2, VTM-2, or VTM-0 standard. In one preferred embodiment, the film is a polyethylene terephthalate (PET) film. In some embodiments, the film meets the requirement of VTM-0, VTM-1, or VTM-2. In some embodiments, the film layer also contains a flame retardant. Any of the flame retardants, e.g., those suitable for use in the topcoat or the adhesive layer as described herein, can be used in the film layer. The flame retardant used in the film layer may or may not be the same as the flame retardant used in the other layers of the multi-layer label. In some embodiments, the film is a PET film. In some embodiments, the film is a VTM-0 PET film or a VTM-2 PET film. Various PET films are commercially available, for example, from Dupont Teijin Films' MELINEX[®] series, Mitsubishi's HOSTAPHAN[®] series, etc.

[0040] From the perspective of looking downwardly toward the substrate, the film may be configured beneath the topcoat, e.g., the top surface of the film is in contact with the bottom surface of the topcoat layer. As noted above, the configuration of the film layer between the topcoat layer and the adhesive layer (optionally along with the specific compositions of the

various layers) has been found to unexpectedly provide for improved flame retardant properties and an additional combination of performance characteristics.

[0041] The films according to certain embodiments of the present invention may comprise a thickness ranging from 1 to 400 microns, e.g., from 10 to 300 microns, from 25 to 200 microns, from 15-50 microns, or from 50 to 150 microns, or from 12.5 to 50 microns and other ranges in the foregoing amounts. In terms of lower limits, the film layer may have a thickness of at least 1 micron, e.g., at least 10 microns, at least 25 microns, or at least 50 microns. In terms of upper limits, the polyolefin films may have a thickness less than 100 microns, e.g., less than 80 microns, less than 50 microns, less than 40 microns, or less than 30 microns. In some embodiments, the film layer is about 36 or about 50 microns.

Adhesive Layer

[0042] The adhesive layer, according to certain embodiments of the present invention, varies widely and may comprise any adhesive that is effective in binding the label to an external surface of the substrate to which the label may be affixed.

[0043] In one embodiment, the adhesive layer of the label according to the invention comprises an epoxy resin and a flame retardant. In some cases, the polymeric resin comprises epoxy resin and one or more additional polymeric resins. Polymeric resins that are suitable for the use in the adhesive layer may include melamine resin or epoxy resin. In some embodiments, the adhesive layer is in contact with at least a portion of the film layer. In some embodiments, the adhesive layer is not in contact with the film layer.

[0044] As noted above, the addition of flame retardants often compromises adhesion performance. Specifically, the relative amount of the polymeric resin and the flame retardant present in the adhesive layer affects the tack strength of the adhesive layer, and thus the tack strength of the label. In general, it is desirable for maintain the tack strength of the label within appropriate ranges, if the tack strength is too high, the label has poor reposition performance; if the tack strength is too low, the label cannot adhere to the substrate well. In general, the higher amount of an epoxy resin in the adhesive layer, the greater the tack strength of the label. In contrast, a higher amount of flame retardant in weight percentage in the adhesive layer, the lower the tack strength of the label. The inventors of the application have discovered critical compositions and weight percentage ranges for the resin and the flame retardant in the adhesive layer, that produce a label having the a superior combination of performance characteristics.

[0045] As noted above, the adhesive layer may comprise a flame retardant as described herein with the discussion of the topcoat layer. The flame retardant in the adhesive layer may be the same as in the topcoat and/or film layer, or may be different. For example, the topcoat layer could contain a flame retardant that is a mixture of Exolit OP 935 and $\text{Al}(\text{OH})_3$, while the adhesive layer may contain a different flame retardant, such as a mixture of Exolit OP 935 and triphenyl phosphate (TPP). In further embodiments, the adhesive layer contains the same flame retardant as the topcoat and the film layer. In even further embodiments, the adhesive layer contains the flame retardant as the topcoat layer, while the film contains different flame retardant, or the adhesive layer contains the same flame retardant as the film layer, and the topcoat layer has a different flame retardant. In some embodiments, the flame retardant used for the adhesive layer is selected from the group consisting of metal alkyl phosphinates, aryl phosphates, and mixtures thereof. In one embodiment, the flame retardant is a mixture of Exolit OP 935 and Triphenyl phosphate (TPP).

[0046] The flame retardant in the adhesive layer may be present from 1 to 10 wt.%, based on the total weight of the adhesive layer, e.g., from 1 to 5 wt.%, from 4 to 8 wt.%, from 6 to 9%, from 2 to 10 wt.% or from 5 to 10 wt.%. As for upper limits, the flame retardant is no greater than 10% as for the lower limit, the flame retardant is no less than 1%. In one embodiment, the flame retardant is Exolit OP935, which is present in an amount within the range of 7%-10%, e.g., about 8.8%, based on the total weight of the adhesive layer.

[0047] The adhesive layer may have a thickness ranging from 1 to 200 microns, e.g., from 5 to 100 microns, or from 10 to 50 microns, or from 5-25 microns, e.g., from 20-25 microns. In terms of lower limits, the adhesive layer may have a thickness of at least 1 micron, e.g., at least 5 microns, or at least 10 microns. In terms of upper limits, the adhesive layer may have a thickness no more than 200 microns, e.g., no more than 100 microns, no more than 50 microns, no more than 25 microns, no more than 20 microns, or no more than 10 microns. The adhesive layer may have a coating weight from 1 to 200 grams per square meter, e.g., from 5 to 100 grams per square meter, or from 10 to 50 grams per square meter, or from 5-25 grams per square meter. In terms of lower limits, the adhesive layer may have a thickness of at least 1 grams per square meter, e.g., at least 5 grams per square meter, or at least 10 grams per square meter. In terms of upper limits, the adhesive layer may have a thickness no more than 200 grams per square meter,

e.g., no more than 100 per square meter, no more than 50 per square meter, no more than 25 per square meter, no more than 20 per square meter, or no more than 10 per square meter.

[0048] In some embodiments, the adhesive layer may comprise a pressure sensitive adhesive, e.g., a hydroxyl group substituted acrylic polymer. In some embodiments, an aggressive pressure sensitive adhesive may be used, such as one of the high-strength or rubber- modified acrylic pressure sensitive adhesives, such as Duro-Tak® 80-115 A available from National Starch and Chemical Co. or Aroset™ 1860-Z-45 available from Ashland Specialty Chemical Company. Suitable pressure sensitive adhesives may include, for example, copolymers of alkyl acrylates that have a straight chain of from 4 to 12 carbon atoms and a minor proportion of a highly polar copolymerizable monomer such as acrylic acid. These adhesives are more fully described in U.S. Pat. Re. 24,906 and U.S. Pat. No. 2,973,286, the contents of each are hereby incorporated by reference in their entirety. Alternative pressure sensitive adhesives include ultraviolet curable pressure sensitive adhesives, such as Duro-Tak 4000, which is available from National Starch and Chemical Co. In some embodiments, the adhesive layer comprises a hydroxyl group substituted acrylic polymer. In some embodiments, the hydroxyl group substituted acrylic polymer is present in an amount ranging from 30% to 90%, e.g., 40%-85%, 60%-85, 70%-85%, 60%-90%, or about 80% or about 88.2% based on the total weight of the adhesive layer.

[0049] Besides the pressure sensitive adhesive, the polymeric resin and the flame retardant, the adhesive layer may also comprise a crosslinker, and/or a tackifier. Non-limiting examples of crosslinkers include a polyisocyanate compound, a dialdehyde, a metal chelate compound, a metal alkoxide, a metal salt, and mixtures thereof. The crosslinker contribute to the cohesiveness strength, i.e., the shear, of the label. In one embodiment, the crosslinker is a titanium salt, e.g., $\text{Ti}(\text{OC}_4\text{H}_9)_4$ or Titanium acetylacetonate (TiAA). These additives generally may be present in amounts of less than 5 wt.% based on the total weight of the adhesive layer, e.g., less than 4 wt.% or less than 3 wt.%. Specifically, when a titanium salt, e.g., $\text{Ti}(\text{OC}_4\text{H}_9)_4$ or TiAA is employed along with the epoxy resin, the titanium salt may be present in an amount ranging from 0.1 wt.% to 2.0 wt.%, e.g., from 0.8 wt.% to 1.8 wt.%, or from 1.2 wt.% to 1.8 wt.%, or from 0.5 wt.% to 0.9 wt.%. In one embodiment, the crosslinker is TiAA, which is present in an amount of about 1.6 wt.%. The epoxy resin may be present in an amount ranging from 1.0% to 10%, e.g., from 2 wt.% to 8 wt.% or from 5 wt.% to 10 wt.%. In one embodiment, the epoxy

resin is present in an amount of about 1.4 wt.% based on the total weight of the adhesive layer. The inventors of the application discovered that titanium salt is strongly reactive with epoxy resin and even used in a relatively smaller amount, titanium salt cross linkers, such as those described above and in the examples, can sufficiently cross link the epoxy resin. This is advantageous because a high amount of cross linker would compromise adhesion performance of the label. In addition, epoxy, in addition to its strong adhesiveness, also has a high char yield and thus offers good thermal decomposition resistance and flame retardance. The combination of the specific polymeric resin, e.g., epoxy resin, and the specific crosslinker, e.g., titanium salt, provides for an unexpected improvement in performance, e.g., adhesion and flame retardant properties (as shown in the examples).

[0050] The flame retardant-containing adhesive layer can be prepared by applying a flame retardant-containing adhesive coating on the film layer via conventional processes, such as slot die, reverse roll coating, knife over roll, gravure, etc. In some embodiments, either the topcoat layer or the adhesive layer may be coated onto the layer below as a solvent-based system. The amount of carriers and/or solvent(s) in the topcoat composition may vary depending on the desired coating viscosity. In accordance with certain embodiments, the solvent(s) may comprise any conventional solvent for phenoxy resin systems. For example, such solvents may include ketones of from 3 to 15 carbon atoms (e.g., methyl ethyl ketone or methyl isobutyl ketone), alkylene glycols and/or alkylene glycol alkyl ethers having from 3 to 20 carbon atoms, acetates and their derivatives, ethylene carbonate, and other suitable solvents. Suitable alcohol solvents include mono-alcohols, such as methyl, ethyl, propyl, butyl alcohols, as well as cyclic alcohols such as cyclohexanol. In certain embodiments, most acetate-type solvents may be used, such as n-butyl acetate, n-propyl acetate, and other acetate-type solvents. In accordance with certain embodiments, a portion of the solvent system may include water is so desired. In other embodiments, however, the solvent system may be devoid of water.

Liner

[0051] In accordance with certain embodiments of the present invention, the labels may comprise a releasable liner. The releasable liner may be positioned directly adjacent to the adhesive layer, on the opposite side of the adhesive layer from the primer layer. In this regard, the releasable liner may protect the adhesive layer before the label is applied (or intended to be applied) to an object or facestock, such as during manufacture, printing, shipping, storage, and at

other times. Any suitable material for a releasable liner may be used. Typical and commercially available releasable liners, which can be suitable for embodiments of the present invention, can include a silicone-treated release paper or film, such as those available from Loparex, including products such as 1011, 22533 and 1 1404, CP Films, and Akrosil™.

Additives

[0052] The topcoat layer, film layer, and/or adhesive layer may optionally include one or more fillers, antioxidants, UV-absorbers, photo-stabilizers, and/or fillers. These additives may be incorporated into the topcoat layer in conventional quantities using conventional equipment and techniques. For example, representative fillers can include tale, calcium carbonate, organo-clay, glass fibers, marble dust, cement dust, feldspar, silica or glass, fumed silica, silicates, alumina, various phosphorus compounds, ammonium bromide, titanium dioxide, antimony trioxide, antimony trioxide, zinc oxide, zinc borate, barium sulfate, silicones, aluminum silicate, calcium silicate, glass microspheres, chalk, mica, clays, wollastonite, ammonium octamolybdate, intumescent compounds and mixtures of two or more of these materials. The fillers may also carry or contain various surface coatings or treatments, such as silanes, fatty acids, and the like. Still other fillers can include flame-retardant agents, such as the halogenated organic compounds. In certain embodiments, the topcoat layer may include one or more thermoplastic elastomers that are compatible with the other constituents of the layer, such as etherified melamine, hydroxylated polyester, polyester-melamine, and other suitable elastomers.

[0053] The topcoat layer, film layer, and/or adhesive layer can also include pigment dispersants, such as Nuospense® 657 available from Elementis Specialties. In accordance with certain embodiments, the topcoat layer may also include carbon pigments, such as carbon black, ivory black, or the like, and/or one or more of a variety of other pigments, such as copper pigments (e.g., phthalocyanine dyes such as phthalocyanine blue), cadmium pigments (e.g., cadmium yellow), chromium pigments (e.g., chrome yellow), cobalt pigments (e.g., cobalt blue), iron oxide pigments (e.g., oxide red), and any other suitable pigments. Any colorants, pigments, and pigment dispersant are suitable to the extent that they do not interfere with desired loadings and/or physical or mechanical properties of the topcoat layer.

[0054] In accordance with certain embodiments, the topcoat layer, film layer, and/or adhesive layer can also include one or more flow and/or leveling agent to mitigate the occurrence of any surface defects (e.g., formation of pinholes, cratering, peeling, scarring, blistering, air

bubbles, etc.). Suitable flow and/or leveling agents utilized are those that do not interfere with desired loadings and/or physical or mechanical properties of the topcoat. In certain embodiments, for instance, several commercially available flow and/or leveling agents may be utilized, including, for example BYK-392 (solution of a polyacrylate) from BYK Additives & Instruments; BY -310 (solution of a polyester modified polydimethylsiloxane) from BYK Additives & Instruments; EFKA 3277 (fluorocarbon modified polyacrylate) from BASF, and/or EFKA 3740 (polyacrylate) from BASF.

[0055] The topcoat layer, film layer, and/or adhesive layer may also include one or more defoaming agents. A defoaming agent generally reduces or mitigates the formation of foaming in the topcoat layer when deposited or generally handled or transferred from one location to another. Generally, any defoaming agent that does not interfere in some embodiments, desired loadings and/or physical or mechanical properties of the topcoat layer may be used. For instance, the defoaming agent may be mineral-based, silicone-based, or non-silicone-based.

[0056] In accordance with some embodiments, the topcoat layer, film layer, and/or adhesive layer may also include one or more antioxidants. Any suitable antioxidants for a particular embodiment may be used. In some embodiments, antioxidants may be selected that exhibit good heat resistance and mitigate the discoloration of polymeric-based articles/coatings. Exemplary antioxidants suitable for use according to certain embodiments of the present invention include, but not limited to, CHINOX 626, CHINOX 62S (organophosphite antioxidant), CHINOX 245 (steric hindered phenolic antioxidant), and CHINOX 30N (blend of hindered phenolic antioxidants), each of which is commercially available from Double Bond Chemical Ind., Co., Ltd.

[0057] The topcoat layer, film layer, and/or adhesive layer may also include one or more matting agents which may facilitate formation of a smooth layer. Any suitable matting agent for a particular embodiment may be utilized. In some embodiments, the matting agents may have a small particle size. For example, in some embodiments, the matting agents may have a particle size of less than 10 microns on average or less than 5 microns on average, such as modified or surface treated silica. The silica may be treated a variety of organic polymers depending on the particular resin system employed in the topcoat layer. In certain embodiments, the matting agent may include untreated silicon dioxide.

[0058] According to certain embodiments of the present invention, suitable catalyst may also be used. For instance, the constituents of the topcoat layer may include one or more acid catalysts, such as para-toluene sulfonic acid (PTSA) or methyl sulfonic acid (MSA). Useful acid catalysts may include, by way of example, boric acid, phosphoric acid, sulfate acid, hypochlorides, oxalic acid and ammonium salts thereof, sodium or barium ethyl sulfates, sulfonic acids, and similar acid catalysts. Other useful catalysts, according to certain embodiments, may include dodecyl benzene sulfonic acid (DDBSA), amine blocked alkane sulfonic acid (MCAT 12195), amine blocked dodecyl para-toluene sulfonic acid (B YK 460), and amine blocked dodecyl benzene sulfonic acid (Nacure 5543).

[0059] After the layers of the labels are assembled as described above, the label can be passed through a series of drying ovens, after which the label may be passed through a series of drying ovens, after which the film may be finally cut to an appropriate size and converted into small labels. In some cases, the multi-layer label is printed before being slit. In some cases, the multi-layer label is printed after being slit and converted into small labels.

[0060] The thickness of the multi-layer label is no more than 80 microns, e.g., no more than 65 microns, e.g., no more than 64 microns, no more than 63 microns, no more than 62 microns, no more than 60 microns, no more than 50 microns, no more than 49 microns, no more than 48, no more than 47, no more than 46, no more than 45, no more than 44, no more than 43, no more than 42, no more than 41, no more than 40 microns. In some embodiments the multi-layer label has a thickness from 5 microns to 80 microns, e.g., from 40 to 80 microns, from 35 to 62 microns, from 40-62 microns, from 45 to 60 microns.

[0061] In some embodiments, the label comprises a topcoat layer comprising phenoxy resin and a flame retardant, a film layer, and an adhesive layer. The amount of phenoxy resin may range from 20% to 70%, e.g., about 37.15%. based on the total weight of the FR topcoat. The flame retardant in the topcoat layer of the label may be a mixture of Exolit OP 935 and $\text{Al}(\text{OH})_3$, where Exolit OP 935 is present in an amount ranging from 20%-60%, e.g., about 30.95%, based on the total weight of the topcoat layer. The $\text{Al}(\text{OH})_3$ is present in an amount ranging from 40%-70%, e.g., about 30.95%, based on the total weight of the topcoat layer. The ratio between the weight of Exolit OP 935 and $\text{Al}(\text{OH})_3$ can be a ratio ranging from 2:1 to 1:2, e.g., about 1:1. The adhesive layer of the label may comprise a hydroxyl group substituted acrylic polymer, epoxy resin, titanium acetylacetonate (TiAA), and a flame retardant that is a mixture of Exolit

OP 935 and Triphenyl phosphate (TPP). The hydroxyl group substituted acrylic polymer is present in the amount ranging from 40% to 85%, e.g., 80%, based on the total weight of adhesive layer. The TiAA is present in an amount of 0.4 wt.% to 2.0 wt.%, e.g., about 1.6%, based on the total weight of the adhesive. The expoxin resin is present in an amount of 0.4% to 2%, e.g., 1.4%, based on the total weight of the adhesive. Exolit OP 935 is present in an amount of 1% to 10%, e.g., about 1.4%, based on the total weight of the adhesive. In some embodiments, the film is a VTM-2 PET film. The label may optionally comprise a printable layer and a liner. In preferred embodiments, the thickness of the label is less than 63 microns.

Performance

[0062] The multi-layer label of the invention meets the flame-retardant requirements under the UL94 VTM standards (2016). UL94 is a standard for determining the material's tendency to either extinguish or spread the flame once the specimen has been ignited. The test procedures for evaluating flame-retardant performance under the UL 94 VTM are well known, for example, as described in <http://industries.ul.com/plastics-and-components/plastics/plastics-testing#ul94>. Typically, to evaluate the flame-retardant performance of the labels disclosed herein, at least one set of five specimens are tested. Each specimen is burned for 3 seconds. The burning source ("burner") is then removed and the time from the removal to the time when the burning stops is recorded as T1. The specimen is then burned again for three minutes. The burning source is once again removed and the time from removal to the time when the second burning stops is recorded as T2. The VTM tests typically measure the flame retardant performance of a set of five specimen and the total flaming combustion time for each specimen; the total flaming combustion time for all 5 specimens of any set; the glowing combustion time for each specimen after second burner flame application; whether the glowing or flaming combustion of any specimen is up to holding clamp; whether the cotton placed below the sample is ignited by flaming drips from any specimen are observed and recorded.

[0063] Table 1 shows the requirement for the VTM-0, VTM-1, or VTM standard.

Table 1. VTM-0, VTM-1 and VTM-2 standards

VTM test parameter	VTM-0	VTM-1	VTM-2
Total flaming combustion time for each specimen (T1+T2)	≤10 sec	≤30 sec	≤30 sec
Total flaming combustion time for all 5 specimens of any set	≤50 sec	≤250 sec	≤250 sec
Glowing combustion for each specimen after second burner flame application	≤30 sec	≤60 sec	≤60 sec
Glowing or flaming combustion of any specimen up to holding clamp	NO	NO	NO
Whether Cotton can be ignited by flaming drips from any specimen	NO	NO	YES

[0064] In some cases, the label meets the requirements of UL 94 VTM-3 standard. In some cases, the label's flame-retardant performance meets the UL 94 VTM-2 standard. In preferred embodiments, the label's flame-retardant performance meets the UL 94 VTM-0 standard. In some cases, the film layer meets the VTM-0 standard, VTM-1 standard, or VTM-2 standard and the film is referred to as VTM-0 film, VTM-1 film, or VTM-2 film, respectively, in this disclosure.

[0065] The multi-layer label's adhesion, reposition, and converting performance are evaluated according to methods well known in the art. Tack strength is a measure of the force required to remove the label and adhesive from the substrate immediately after application with minimal pressure. It usually refers to the measure of initial attraction of adhesive to the substrate. The label of the invention demonstrate a tack strength from 1 to 20 newtons per inch, e.g., from 2-10 Newtons per inch, from 5-10, from 7-15, from 8-12 newtons per inch tested on stainless steel according to the method as described in <https://www.astm.org/Standards/D6195.htm>. In terms of lower limits, the tack strength of the label is at least 5, at least 6, at least 7, at least 8 newtons per inch. Peel strength reflects the bond strength of the adhesive and is typically measured by the average load per unit width of bond line required to separate bonded materials where the angle of separation is 180 degrees. Peel strength is thus commonly referred to as 180 ° peel strength. The label of the invention demonstrates a 180 ° peel strength of between 5 to 30 newtons per inch, e.g., between 6 and 20, between 10 and 15 newtons per inch tested on stainless steel according to the method <https://www.astm.org/Standards/D3330.htm>. In terms of lower limits, the 180 ° peel strength of the label is at least 10, at least 11, at least 12, at least 13 newtons per inch. Shear reflects the strength and durability of the bonding formed between the adhesive

and the substrate. In a shear test the labeled substrate is mounted vertically and has a weight attached. The shear is measured by the time it takes for the label to slip off the substrate. The label according to the invention demonstrates a shear between 1000 and 6000 min, e.g., between 2000 and 4000 min, between 2500 and 3500 min, as tested on stainless steel according to the method described in <https://www.astm.org/Standards/D3654.htm>. In terms of lower limits, the shear of the label is at least 1000, at least 2000, at least 2500, at least 3000 min as measured using standard methods on stainless steel. The label also has good reposition performance, i.e., the label retains the adhesiveness after being removed from a location on the substrate such that it can adhere to a new substrate or a different location on the substrate.

Embodiments

Exemplary embodiments of the disclosed flame retardant labels are as follows:

[0066] A multi-layer label comprising: (i) a topcoat layer comprising a phenoxy resin and a first flame retardant; (ii) a film layer; and (iii) an adhesive layer comprising an epoxy resin and a second flame retardant.

[0067] The multi-layer label of paragraph [0066], wherein the adhesive layer is in contact with at least a portion of the film layer.

[0068] The multi-layer label as described in paragraph [0066] or [0067], wherein the film layer further comprises a third flame retardant.

[0069] The label as described in any of the preceding paragraphs [0066]- [0068], wherein the first flame wherein the first flame retardant, the second flame retardant and the third flame retardant are different from one another.

[0070] The label as described in any of paragraphs [0066] – [0069], wherein the first flame retardant is selected from the group consisting of metal alkyl phosphinates, e.g., Exolit OP 935, metal hydroxides, e.g., $\text{Al}(\text{OH})_3$, and mixtures thereof.

[0071] The label as described in any of paragraphs [0066] – [0070], wherein the second flame retardant is selected from the group consisting of metal alkyl phosphinates, aryl phosphates, $\text{Al}(\text{OH})_3$, $\text{Mg}(\text{OH})_2$, melamine-based flame retardants; polysiloxanes; and mixtures thereof.

[0072] The label as described in any of paragraphs [0066]-[00071], wherein the adhesive layer further comprises a crosslinker.

[0073] The label as described in paragraph [0072], wherein the crosslinker is a metal salt.

[0074] The label as described in paragraph [0072], wherein the crosslinker is $\text{Ti}(\text{OC}_4\text{H}_9)_4$.

[0075] The label as described in any of the paragraphs, wherein the label demonstrates a flame retardant performance of VTM-0, as measured by the UL 94 VTM-0 (current year or 2016).

[0076] The label of any of the preceding paragraphs [0066]-[0075], wherein the label demonstrates a tack strength of at least 8 newtons/inch on a stainless steel substrate.

[0077] The label of any of the preceding paragraphs [0066]-[0076], wherein the label demonstrates a 180° peel strength of at least 13 newtons/inch on a stainless steel substrate.

[0078] The label of any of the preceding paragraphs [0066]-[0077], wherein the label demonstrates a shear of at least 3000 min on a stainless steel substrate.

[0079] The label of any of the preceding paragraphs [0066]-[0078], wherein the coating weight of the topcoat layer is from 2 to 50 grams per square meter.

[0080] The label of any of the preceding paragraphs [0066]-[0079], wherein the film layer comprises one or more resins selected from the group consisting of polyester, ABS, polyacrylate, polycarbonate (PC), polyamide, polyimide (PI), polyamidoimide, polyacetal, polyphenylene oxide (PPO), polysulfone, polyethersulfone (PES), polyphenylene sulfide, polyether ether ketone (PEEK), polyetherimide (PEI), metallized polyethylene terephthalate (PET), polyvinyl fluoride (PVF), polyethylene ether (PEE), fluorinated ethylene propylene (FEP), polyurethane (PUR), liquid crystal polymers (LCPs, class of aromatic polyester), polyvinylidene fluoride (PVDF), aramid fibers, DIALAMY, (polymer alloys), polyethylene naphthalate (PEN), ethylene/tetrafluoroethylene, (E/TFE), polyphenyl sulfone (PPSU).

[0081] The label of any of the preceding paragraphs [0066]-[0080], wherein the label has a thickness less than 63 microns.

[0082] The label of any of the preceding paragraphs [0066]-[0081], wherein the film has a thickness from the 5 microns to 80 microns.

[0083] The label of any of the preceding paragraphs [0066]-[0082], wherein the adhesive layer further comprises a hydroxyl group substituted acrylic polymer.

[0084] The label of any of the preceding paragraphs [0066]-[0083], wherein the coating weight of the adhesive layer is about 2-50 grams per square meter.

[0085] The label of any of the preceding paragraphs [0066]-[0084], further comprising a printable layer in contact with the top surface of the topcoat layer.

[0086] The label of paragraph [0085], wherein the printable layer has a coating weight of about 0.1-10 grams per square meter.

[0087] The label of any of the preceding paragraphs [0066]-[0086] further comprising a liner that contacts the bottom surface of the adhesive layer.

[0088] The label of any of the preceding paragraphs [0066]-[0087], wherein each of the topcoat layer, the film layer, the adhesive layer has opposing top and bottom surfaces.

[0089] The label of any of the preceding paragraphs [0066]-[0088], the amount of phenoxy resin in the topcoat layer ranges from 20 to 70 wt.%, based on the total weight of the topcoat.

[0090] The label of any of the preceding paragraphs [0066]-[0089], the amount of the first flame retardant in the topcoat layer ranges from 10 to 80 wt.%, based on the total weight of the topcoat.

[0091] The label of any of the preceding paragraphs [0066]-[0090], the amount of the second flame retardant in the adhesive layer ranges from 1 to 10 wt.%, based on the total weight of the adhesive layer.

[0092] The label of any of the preceding paragraphs [0066]-[0091], the amount of the epoxy resin in the adhesive layer ranges from 1 to 10 wt.%, based on the total weight of the adhesive layer.

[0093] The label of any of the preceding paragraphs [0066]-[0092], the amount of the hydroxyl group substituted acrylic polymer in the adhesive layer ranges from 30 to 90 wt.%, based on the total weight of the adhesive layer.

[0094] The label of any of the preceding paragraphs [0066]-[0093], the amount of the crosslinker in the adhesive layer ranges from 0.1 to 2.0 wt.%, based on the total weight of the adhesive layer.

EXAMPLES

Example 1

[0095] A label according to the present invention was prepared as follows. The label contained in the order from top to bottom, a printable layer ("TCY" layer), a topcoat layer, a VTM-2 PET film layer, an adhesive layer, and a liner. The topcoat was formed from a phenoxy resin, a flame retardant comprising Exolit OP 935 and $\text{Al}(\text{OH})_3$ and a solvent, cyclohexone. The

topcoat has a thickness of about 10 microns or having a coating weight about 10 grams per square meter. The formulation of the topcoat is shown in Table 2.

[0096] The adhesive layer was formed from a hydroxyl group substituted acrylic polymer, tackifier, Exolit OP 935, TPP, epoxy resin, and $\text{Ti}(\text{OC}_4\text{H}_9)_4$. The formulation of the adhesive is shown in Table 3. The adhesive layer generally had a coating weight about 25-35 grams per square meter and a thickness of about 25 microns.

[0097] The VTM-2 PET film layer has a thickness of 36 microns.

[0098] The printable layer used in this example comprises polyurethane dispersion (“PUD”) crosslinked with CX-100 (DSM’s polyfunctional aziridine liquid crosslinker). has a thickness of about 1 microns and a coating weight of about 1 gram per square meter. The 180° peel strength, tack strength, shear, reposition performance and flame retardancy of the label are shown in Table 4 below.

Table 2 Formulation of FR topcoat

Items	Usage (g)	Weight percentages based on the total weight of the FR topcoat
Phenoxy resin	48.0	37.15%
Cyclohexone (solvent)	200	-
Exolit OP 935	40.0	30.95%
$\text{Al}(\text{OH})_3$	40.0	30.95%
N75	1.0	0.80%
BYK 3550 (additive)	0.2	0.15%

Table 3. Formulation of FR adhesive

Items	Usage (g)	Weight percentage based on the total weight of the FR adhesive
Acrylate pressure sensitive adhesive (PSA) solution (50%) (hydroxyl group substituted polymer)	65.3	88.2%
Isopropyl alcohol (IPA) (solvent)	26.0	-
Exolit OP935	6.5	8.8%
Titanium acetylacetonate (TiAA)	1.2	1.6%
Epoxy resin	1.0	1.4%

Table 4. Performance Characteristics

Tack on SS	180 ° peel on SS	Shear on SS	Reposition	FR (total product)
8 N/inch	13 N/inch	>3000 min	OK	Meets the VTM-0 standard

Note: “N/inch” stands for “newtons/inch”; “SS” stands for “stainless steel”.

Comparative Example A

[0099] A label was prepared as described above in Example 1, except that the resin in the topcoat layer employed a polyester resin instead of a phenoxy resin. The flame retardant performance of the labels of Example 1 and Comparative Example A were evaluated under the VTM test (2016). The results are shown in Tables 3 and 4. As shown, the label of Example 1, with the aforementioned topcoat layer composition, surprisingly and unexpectedly outperformed (significantly) the label of Comparative Example A in most aspects of the VTM test.

[00100] The flame retardant performance of the label of Example 1 and the label of comparative Example A, five specimen of each group, were then evaluated according to the UL94 VTM standards (2016), as described above. . Each specimen was burned for 3 seconds. The burning source (“burner”) was then removed and the time from the removal to the time

when the burning stops is recorded as T1. The specimen was then burned again for three minutes. The burning source was once again removed and the time from removal to the time when the second burning stops is recorded as T2. Also recorded were the total flaming combustion time; the total flaming combustion time for all 5 specimens of any set; the glowing combustion time for each specimen after second burner flame application; whether the glowing or flaming combustion of any specimen is up to holding clamp; whether the cotton placed below the sample is ignited by flaming drips from any specimen are observed and recorded. Tables 6 and 5 show that the label of the Example 1 passed VTM-0 test while the label of the Comparative Example did not.

[00101] Importantly, in addition to demonstrating superior flame retardant performance, the label of Example 1 also performed well in other areas, e.g., tack, peel strength, and repositionability using the methods described above (Table 4). This beneficial result is surprising because the addition of flame retardants typically compromise such properties.

Table 5. Test results of the comparative example

Test Results: Comparative Example A				
VTM test parameter	VTM-0	1 st ignition	2 nd ignition	Pass/fail
Total flaming combustion time for each specimen (T1+T2)	≤10sec	T1<10s	T2<10s	Did not pass VTM-0
Total flaming combustion time for all 5 specimens of any set	≤50sec	T1<10s	T2<10s	
Glowing combustion for each specimen after second burner flame application	≤30sec	T1<10s	T2<10s	
Glowing or flaming combustion of any specimen up to holding clamp	NO	NO	YES	
Whether Cotton can be ignited by flaming drips from any specimen	NO	NO	YES	

Table 6. Test results of Example 1

Test Results: Example 1				
VTM test parameter	VTM-0			
		1 st ignition	2 nd ignition	Pass/fail
Total flaming combustion time for each specimen (T1+T2)	≤10sec	T1<10s	T2<10s	Passed VTM-0
Total flaming combustion time for all 5 specimens of any set	≤50sec	T1<10s	T2<10s	
Glowing combustion for each specimen after second burner flame application	≤30sec	T1<10s	T2<10s	
Glowing or flaming combustion of any specimen is up to holding clamp	NO	NO	NO	
Whether Cotton can be ignited by flaming drips from any specimen	NO	NO	NO	

[00102] While the invention has been described in detail, modifications within the spirit and scope of the invention will be readily apparent to those of skill in the art. It should be understood that aspects of the invention and portions of various embodiments and various features recited herein and/or in the appended claims may be combined or interchanged either in whole or in part. In the foregoing descriptions of the various embodiments, those embodiments which refer to another embodiment may be appropriately combined with other embodiments as will be appreciated by one of ordinary skill in the art. Furthermore, those of ordinary skill in the art will appreciate that the foregoing description is by way of example only, and is not intended to limit the invention.

WHAT IS CLAIMED IS:

1. A multi-layer label comprising:
 - (i) a topcoat layer comprising a phenoxy resin and a first flame retardant;
 - (ii) a film layer; and
 - (iii) an adhesive layer comprising an epoxy resin and a second flame retardant.
2. The label of claim 1, wherein the adhesive layer is in contact with at least a portion of the film layer.
3. The label of claim 1 or 2, wherein the film layer comprises a third flame retardant.
4. The label of claim 3, wherein the first flame retardant, the second flame retardant and the third flame retardant are different from one another.
5. The label of any of claims 1-4, wherein the first flame retardant is selected from the group consisting of metal alkyl phosphinates, metal hydroxides, and mixtures thereof.
6. The label of any of claims 1-4, wherein the second flame retardant is selected from the group consisting of metal alkyl phosphinates, aryl phosphates, $\text{Al}(\text{OH})_3$, $\text{Mg}(\text{OH})_2$, melamine-based flame retardants; polysiloxanes; and mixtures thereof.
7. The label of any of the preceding claims, wherein the adhesive layer further comprises a crosslinker.
8. The label of claim 7, wherein the crosslinker is a metal salt.
9. The label of claim 7, wherein the crosslinker is $\text{Ti}(\text{OC}_4\text{H}_9)_4$ or titanium acetylacetonate (TiAA).

10. The label of any of the preceding claims, wherein the label demonstrates a flame retardant performance of VTM-0, as measured by the UL 94 VTM-0 (2016).
11. The label of any of the preceding claims, wherein the label demonstrates a tack strength of at least 8 newtons/inch on a stainless steel substrate.
12. The label of any of the preceding claims, wherein the label demonstrates a 180° peel strength of at least 13 newtons/inch on a stainless steel substrate.
13. The label of any of the preceding claims, wherein the label demonstrates a shear of at least 3000 min on a stainless steel substrate.
14. The label of any of the preceding claims, wherein the coating weight of the topcoat layer is from 2 to 50 grams per square meter.
15. The label of any of the preceding claims, wherein the film layer comprises one or more resins selected from the group consisting of polyester, ABS, polyacrylate, polycarbonate (PC), polyamide, polyimide (PI), polyamidoimide, polyacetal, polyphenylene oxide (PPO), polysulfone, polyethersulfone (PES), polyphenylene sulfide, polyether ether ketone (PEEK), polyetherimide (PEI), metallized polyethylene terephthalate (PET), polyvinyl fluoride (PVF), polyethylene ether (PEE), fluorinated ethylene propylene (FEP), polyurethane (PUR), liquid crystal polymers (LCPs, class of aromatic polyester), polyvinylidene fluoride (PVDF), aramid fibers, DIALAMY, (polymer alloys), polyethylene naphthalate (PEN), ethylene/tetrafluoroethylene, (E/TFE), polyphenyl sulfone (PPSU).
16. The label of any of the preceding claims, wherein the label has a thickness less than 63 microns.
17. The label of any of the preceding claims, wherein the film has a thickness from the 5 microns to 80 microns.

18. The label of any of the preceding claims, wherein the adhesive layer further comprises a hydroxyl group substituted acrylic polymer.
19. The label of any of the preceding claims, wherein the coating weight of the adhesive layer is 2-50 grams per square meter.
20. The label of any of the preceding claims, further comprising a printable layer in contact with the top surface of the topcoat layer.
21. The label of claim 20, wherein the printable layer has a coating weight of 0.1-10 grams per square meter.
22. The label of any of the preceding claims, further comprising a liner that contacts the bottom surface of the adhesive layer.
23. The label of claim 1, wherein each of the topcoat layer, the film layer, the adhesive layer has opposing top and bottom surfaces.
24. The label of any of the preceding claims, wherein the amount of phenoxy resin in the topcoat layer ranges from 20 to 70 wt.%, based on the total weight of the topcoat.
25. The label of any of the preceding claims, wherein the amount of the first flame retardant in the topcoat layer ranges from 10 to 80 wt.%, based on the total weight of the topcoat.
26. The label of any of the preceding claims, wherein the amount of the second flame retardant in the adhesive layer ranges from 1 to 10 wt.%, based on the total weight of the adhesive layer.
27. The label of any of the preceding claims, wherein the amount of epoxy resin in the adhesive layer ranges from 1 to 10 wt.%, based on the total weight of the adhesive layer.

28. The label of any of the preceding claims, wherein the amount of hydroxyl group substituted acrylic polymer in the adhesive layer ranges from 30 to 90 wt.%, based on the total weight of the adhesive layer.

29. The label of any of claims 7-28, wherein the amount of cross linker in the adhesive layer ranges from 0.1 to 2.0 wt.%.

30. A multi-layer label for use to label an electrical equipment, the label comprises:

- (i) a topcoat layer comprising a phenoxy resin and one or more first flame retardant;
- (ii) an adhesive layer comprising an epoxy resin and one or more second flame retardant; and
- (iii) a film layer that is in contact with the adhesive layer.

31. The label of claim 30, wherein the electrical equipment is a battery.

32. A method to label an electrical equipment, comprising applying a multi-layer label to a battery surface or a battery wrapping, wherein the label comprises:

- (i) a topcoat layer comprising a phenoxy resin and one or more first flame retardant;
- (ii) an adhesive layer comprising an epoxy resin and one or more second flame retardant; and
- (iii) a film layer that is in contact with the adhesive layer;

wherein each of the topcoat layer, the film layer, the adhesive layer comprises a top surface and a bottom surface, the bottom surface being the surface facing an object to be labeled and the top surface being the surface on the opposite side of the bottom surface.

33. The method of claim 32, wherein the electrical equipment is a battery.

34. The method of claim 32, wherein the film layer comprises a third flame retardant.

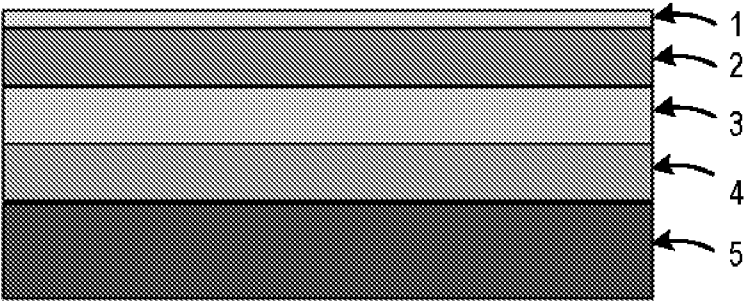


FIG. 1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2017/075162

A. CLASSIFICATION OF SUBJECT MATTER

B32B 27/18(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B32B, C08K, B29C, B65D, G09F, H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

USTXT;CNTXT;CNABS;VEN,DWPI,CNKI,Web or Knowledge: muti+, film?, coat+, layer?, flame w retardant?, label?, epoxy, phenoxy, adhesive, metal w hydroxide

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 102131640 A (BRADY WORLDWIDE INC.) 20 July 2011 (2011-07-20) paragraph [0002]、[0008]-[0010]、[0012]、[0034]、[0039]、[0040]-[0044]、[0048]、 [0050]、[0068]、[0070]、[0072]、[0073]、[0077]、Fig1 and 4	1-34
X	CN 1960867 A (MITSUBISHI PLASTICS INC.) 09 May 2007 (2007-05-09) page3, paragraph3, page5, paragraph3, page16, paragraph3, 4, page17, paragraph1, 2, 5, page18, paragraph1	1-9, 14-34
A	CN 103131341 A (LINTECK CORP.) 05 June 2013 (2013-06-05) full text	1-34
A	CN 101107731 A (LG CHEM. LTD. ET AL.) 16 January 2008 (2008-01-16) full text	1-34
A	US 6440567 B1 (ISOLA LAMINATE SYSTEMS CORP. ET AL.) 27 August 2002 (2002-08-27) full text	1-34
A	US 2011092640 A1 (TZOU, MINGJEN ET AL.) 21 April 2011 (2011-04-21) full text	1-34

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

10 May 2017

Date of mailing of the international search report

27 May 2017

Name and mailing address of the ISA/CN

STATE INTELLECTUAL PROPERTY OFFICE OF THE
P.R.CHINA
6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing
100088
China

Facsimile No. (86-10)62019451

Authorized officer

ZHU,Hong

Telephone No. (86-10)01062414390

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2017/075162

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
CN	102131640	A	20 July 2011	KR	20120049299	A	16 May 2012
				HK	1159028	A1	13 November 2015
				KR	101355642	B1	28 January 2014
				US	2012164442	A1	28 June 2012
				CN	102131640	B	25 February 2015
				EP	2477814	A1	25 July 2012
				WO	2011029225	A1	17 March 2011
				BR	112012004700	A2	12 April 2016
				IN	201200745	P4	26 April 2013
				HK	1159028	A0	27 July 2012
CN	1960867	A	09 May 2007	CN	100503234	C	24 June 2009
				US	8962113	B2	24 February 2015
				JP	2006015745	A	19 January 2006
				US	2008026170	A1	31 January 2008
				JP	4326460	B2	09 September 2009
				TW	200613130	A	01 May 2006
				JP	4688750	B2	25 May 2011
				JP	2006123482	A	18 May 2006
				KR	1437682	B1	03 September 2014
				TW	1382930	B	21 January 2013
				JP	2006315416	A	24 November 2006
				JP	3867095	B2	10 January 2007
				EP	1752285	A1	14 February 2007
				KR	20070031314	A	19 March 2007
				WO	2005118288	A1	15 December 2005
				EP	1752285	B1	30 November 2011
CN	103131341	A	05 June 2013	CN	103131341	B	06 April 2016
				JP	2013112788	A	10 June 2013
				JP	5785861	B2	30 September 2015
CN	101107731	A	16 January 2008	KR	100857034	B1	05 September 2008
				EP	1849199	A1	31 October 2007
				WO	2006101330	A1	28 September 2006
				KR	20060102823	A	28 September 2006
				BR	PI0609009	A2	12 January 2010
				JP	2008529237	A	31 July 2008
				TW	200640053	A	16 November 2006
				US	2007065718	A1	22 March 2007
				RU	2343592	C1	10 January 2009
				IN	200706379	P1	31 August 2007
US	6440567	B1	27 August 2002	TW	I238846	B	01 September 2005
				WO	0174960	A2	11 October 2001
				WO	0174960	A3	28 March 2002
				US	2003108746	A1	12 June 2003
US	2011092640	A1	21 April 2011	US	8114508	B2	14 February 2012