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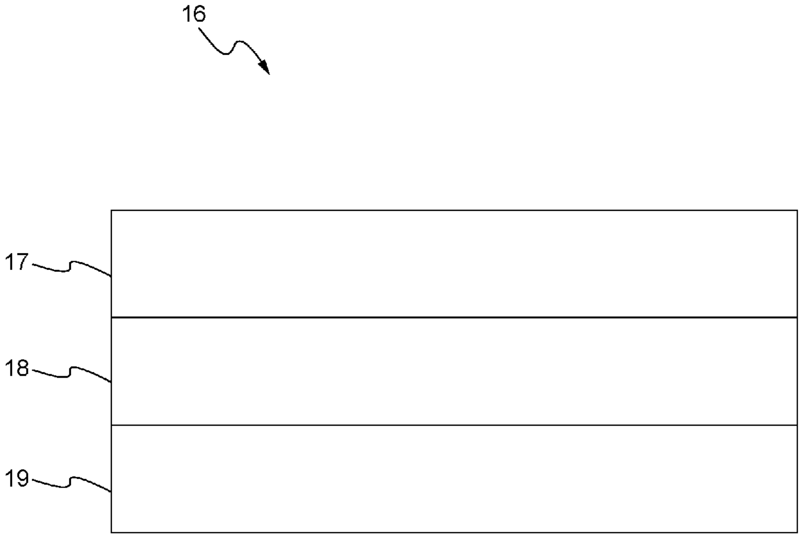

FIG. 3

(57) Abstract: Tab sealants are provided. The tab sealants may comprise three layers. The first and third layer each comprise a base polymer grafted with a monomer. At least one of the first and third layers is grafted with a monomer and a comonomer comprising a benzene ring. The second layer comprises a polyolefin polymer. The tab sealants have improved adhesion, corrosion resistance, and insulation as compared to conventional tab sealants.

[Continued on next page]

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TAB SEALANT

FIELD OF THE INVENTION

[0001] The present invention relates generally to tab sealants. The tab sealants comprise three layers and in particular, at least one of the first and third layer contains a base polymer grafted with a monomer and comonomer comprising a benzene ring.

BACKGROUND OF THE INVENTION

[0002] Tab sealants, also referred to as terminal covering resin films, are generally used for covering tabs in battery cells. The tabs have metal leads serving as a metal terminal and the tabs serve as electrode terminals to which electric power is supplied to a cell body. Tab sealants desirably have good adhesion between the tab sealant and the metal lead to prevent peeling off of the tab sealant. Tab sealants also desirably secure insulation of the lead with other parts of the cell body. Finally, tab sealants desirably have good corrosion resistance. Although tab sealants have been described in the art, they have not been able to achieve the desired adhesion and insulation.

[0003] US Pat. No. 7,972,722 discloses a lead sealant film and a non-aqueous electrolyte battery. The lead sealant film includes a laminated structure composed of an inner layer, an intermediate layer, and an outer layer. The intermediate layer includes a first acid-modified polypropylene having a high melting-point, and each of the inner layer and the outer layer includes a second acid-modified polypropylene having a low melting-point. A difference between the melting point of the first acid-modified polypropylene and the melting point of the second acid-modified polypropylene is from 20°C to 25°C.

[0004] US Pat. No. 9,123,922 discloses a lithium ion battery exterior material, including a base material layer and a sequentially laminated adhesive layer, aluminum foil layer provided with a corrosion prevention treated layer, and an adhesive resin layer on one surface of the base material layer; wherein, the adhesive resin layer contains an acid-modified polyolefin resin and a miscible elastomer dispersed in the acid-modified polyolefin at a dispersed phase size of 1 nm to less than 1 μm.

[0005] US Pub. No. 2010/0221601 discloses an electrical part comprising a lead conductor and a sealed vessel including a metal layer, the lead conductor extending from the inside of the sealed vessel to the outside, wherein the lead conductor and the sealed vessel are fusion-bonded through a thermal adhesive layer at the sealing portion, and wherein a softening-resistant layer having through holes made in the thickness direction is provided between the lead conductor and the metal layer at the sealing portion. A nonaqueous electrolyte cell comprising an electrode and a nonaqueous electrolyte are both enclosed inside the sealed vessel. Both the sealed vessel and a lead conductor having an insulating coating layer can be used in the electrical part or the like.

[0006] US Pub. No. 2015/0311483 discloses a secondary battery metal terminal coating resin film having improved overall performance. It is capable of securing filling ability, adhesive properties, insulating properties of a lead end portion, and shape retention properties of a sealant. Also disclosed is a manufacturing method for the same. Also disclosed is a battery pack using the secondary battery metal terminal coating resin film provided in the lead end portion of a tab used for a laminate-type packaging material for a secondary battery. The secondary battery metal terminal coating resin film is laminated and a coating metal terminal is connected to a positive electrode or a negative electrode of a secondary battery. The melt flow rate of at least one layer of a resin that constitutes the resin film is within a range from about 0.1 g/10 minutes to about 2.5 g/10 minutes.

[0007] US Pub. No. 2016/0099446 discloses a resin film, which is adapted for use in a packaging material for secondary cell. The secondary cell has a sealant layer formed of a polyolefin resin. The resin film is disposed between the sealant layer and leads that are connected to a positive electrode and a negative electrode. The layer includes a first layer disposed at a position close to the leads and a second layer disposed at a position close to the sealant layer. A heat quantity of the second layer, measured according to JIS K 7122, is larger than a heat quantity of fusion of the first layer.

[0008] US Pub. No. 2016/0099447 discloses a terminal covering resin film for a secondary cell, which is attached so as to cover part of an outer surface of a terminal connected to a power generation element of a secondary cell. The film comprises an innermost layer contacting the terminal and an outermost layer forming a surface opposite to the innermost layer, wherein the innermost layer is a layer of not less than 20 μm in thickness containing an acid-modified polyolefin and a melt flow rate of the innermost layer is not less than 2.0 g/10 minutes.

[0009] Other references, including JP 2016091939, JP5730243, disclose tensile storage modulus, dynamic viscoelasticity and melt flow rate values for a resin film.

[0010] None of the above-disclosed references, however, provide for tab sealants that have all three desirable traits: good adhesion, insulation, and corrosion resistance.

In view of the foregoing drawbacks, the need exists for a tab sealant with good adhesion, insulation, and corrosion resistance.

SUMMARY OF THE INVENTION

[0011] In one embodiment, the invention relates to a tab sealant comprising: (a) a first layer comprising a polyolefin grafted with a monomer; (b) a second layer comprising a polyolefin; and (c) a third layer comprising a polyolefin grafted with a monomer; wherein the second layer is disposed between the first layer and the third layer, and further wherein the polyolefin in at least one of the first layer and the third layer is grafted with a monomer and a comonomer containing a benzene ring. The polyolefin of the first layer, second layer, and third layer may be independently selected from the group consisting of homo polypropylene, block polypropylene, and random polypropylene. The monomer in the first layer and/or the third layer may be selected from the group consisting of acrylic acid, methacrylic acid, maleic acid, maleic anhydride, α-methacrylic acid, methyl methacrylate, and glycidyl methacrylate. The polyolefin in the first layer may be grafted with the monomer and a comonomer. The polyolefin in the third layer may be grafted with the monomer and a comonomer. The polyolefin in the first layer and the third layer may be grafted with the monomer and a comonomer. In some aspects, the comonomer in the first layer is different than the comonomer in the second layer. In other aspects, the comonomer in the first layer is the same as the comonomer in the second layer. The comonomer may be selected from the group consisting of styrene, dipropyl phthalate, diallyl phthalate, allylbenzene, methyleugenol, and α-methylstyrene. The monomer may be present in the first layer from 1 to 20 wt.%. The comonomer may be present in the first layer from 1 to 10 wt.%. The monomer may be present in the third layer from 1 to 20 wt.%. The comonomer may be present in the third layer from 1 to 10 wt.%. The first layer and third layer may have substantially the same composition.The thickness of the first layer may be from 1 to 50 μm. The thickness of the second layer may be from 30 to 100 μm. The tab sealant of claim 1, wherein the thickness of the third layer is 1 to 50 μm. The first layer may have a melting point from 130 to 160°C. The second layer may have a melting point from 130 to 190°C. The third layer may have a melting point from 130 to 160°C. The first layer may have a melt flow rate of 2 to 20 g/10 min. The second layer may have a melt flow rate of 2 to 20 g/10 min. The third layer may have a melt flow rate of 2 to 20 g/10 min. The first layer may further comprise an additive.

BRIEF DESCRIPTION OF DRAWINGS

[0012] The invention is described in detail below with reference to the appended drawings.

[0013] FIG. 1 shows a perspective view of a cell pack in accordance with aspects of the invention;

[0014] FIG. 2 shows a perspective view of a tab in accordance with aspects of the invention; and

[0015] FIG. 3 shows a cross-sectional view of a tab sealant in accordance with aspects of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0016] The present invention is directed to tab sealants that have superior adhesion, insulation, and corrosion resistance as compared to conventional tab sealants. The tab sealant according to the present invention is a three layer film. The first and third layers each (individually) comprise a polyolefin grafted with a monomer. The second layer comprises a polyolefin. In at least one of the first and third layers, the polyolefin is grafted with the monomer and with a comonomer comprising a benzene ring. Surprisingly and unexpectedly, by utilizing the benzene ring comonomer in this manner, the adhesion, insulation and corrosion resistance of the tab sealant is greatly improved as compared to conventional tab sealants, which do not achieve this desired combination of performance characteristics.

[0017] In some embodiments of the present invention, the first layer comprises a polyolefin grafted with a monomer and a comonomer comprising a benzene ring, also referred to as a benzene ring comonomer. In other embodiments, the third layer comprises a polyolefin grafted with a monomer and a benzene ring comonomer. In yet further embodiments, both the first layer and the third layer comprise a polyolefin grafted with a monomer and a benzene ring comonomer, and the composition of the first layer and third layer may be substantially the same.

[0018] The overall compositions of the first and third layers may vary widely (as long as the benzene ring comonomer is included in at least one of the layers). For example, the base polymer may be the same in each layer while the monomer and/or inclusion of a comonomer may differ. Further embodiments may include the same monomer in each layer but with a different base polymer. In yet further embodiments, the base polymer, monomer, and optional comonomer may be the same, but the weight percentages and/or molecular weights of each component may differ between the first and third layer.

[0019] As described herein, the tab sealant may be used as a terminal covering. FIG. 1 illustrates a cell pack 10 comprising a cell body 11, packaging material 12, tabs 13 and 14, lead 15, and tab sealant 16.

[0020] FIG. 2 shows tab 13 with a lead 15 serving as a metal terminal, and tab sealant 16. The lead 15 has a first end portion 15A electrically connected to a power generation element inside of packaging material 12 (shown in FIG. 1), and a second end portion 15B which is electrically conductive and which has an outer surface that is at least partially exposed to permit connection with an external device to which electric power may be supplied.

[0021] FIG. 3 shows a cross-sectional view of tab sealant 16. As shown, tab sealant 16 contains a first layer 17 (an inner layer), a second layer 18 (an intermediate layer), and a third layer 19 (an outer layer). Although the layers are depicted as identical in thickness, as described herein, the thickness of each layer may vary. Additionally, although three layers are shown, additional layers may be included, such as additional inner layers, intermediate layers, and outer layers. Each layer is described more fully below. The tab sealant may be prepared by a co-extrusion casting process, a co-extrusion blowing process, or other processes known in the art. The first, second, and third layer may be co-extruded together in a three-layer co-extrusion machine. The processing temperature may depend on the tab sealant components. Generally, the processing temperature is in the range of 230 to 250°C.

First Layer

[0022] The first layer 17, also referred to as an inner layer, is the layer which seals the outer surface of the lead 15 and is therefore in contact with the outer surface of the lead. The first layer may be comprised of a base polymer grafted with a monomer. Preferably, the base polymer may be an olefin polymer. The olefin polymer may include, but is not limited to, polyethylene, including low, medium and high density polyethylenes; polypropylene, including homo, block or random polypropylene; polymethylpentene, polybutene-1; and ethylene-α-olefin copolymers. In some aspects, the olefin polymer is polypropylene.

[0023] The base polymer may be grafted with a monomer. The monomer may include, but is not limited to acrylic acid, methacrylic acid, maleic acid, and maleic anhydride, α-methacrylic acid, methyl methacrylate, and glycidyl methacrylate. In some aspects, the monomer is maleic anhydride.

[0024] In addition to the base polymer being grafted with a monomer, the base polymer in the first layer may also be grafted with a comonomer, e.g., a monomer containing a benzene ring. For example, the comonomer may be an olefin monomer containing a benzene ring, such as styrene, dipropyl phthalate, diallyl phthalate, allylbenzene, methyleugenol, and α-methylstyrene.

[0025] The inventors have now discovered that by including a comonomer with a benzene ring when grafting the base polymer and monomer, the grafting reaction rate is surprisingly increased, resulting in improved adhesion of the tab sealant. Additionally, the inclusion of a comonomer with a benzene ring when grafting the base polymer and monomer has been found to unexpectedly improve corrosion resistance of the base polymer, e.g., polypropylene.

[0026] The base polymer may be present in the first layer in an amount from to 70 to 98 wt.%, based on the entire weight of the first layer, e.g., from 78.5 to 96.5 wt.% or from 85 to 95 wt.%. In terms of lower limits, the first layer comprises at least 70 wt.% base polymer, based on the entire weight of the first layer, e.g., at least 78.5 wt.% or at least 85 wt.%. In terms of upper limits, the first layer comprises no more than 98 wt.% base polymer, based on the entire weight of the first layer, e.g., no more than 96.5 wt.% or no more than 95 wt.%.

[0027] The monomer may be present in the first layer in an amount from 1 to 20 wt.%, e.g., from 2 to 15 wt.% or from 3 to 10 wt.%, based on the entire weight of the first layer. In terms of lower limits, the first layer comprises at least 1 wt.% monomer, based on the entire weight of the first layer, e.g., at least 2 wt.% or at least 3 wt.%. In terms of upper limits, the first layer comprises no more than 20 wt.% monomer, based on the entire weight of the first layer, e.g., no more than 15 wt.% or no more than 10 wt.%.

[0028] When a comonomer is included, the first layer may comprise from 1 to 10 wt.% comonomer, based on the entire weight of the first layer, e.g., from 1.5 to 7.5 wt.% or from 2 to 5 wt.%. In terms of lower limits, the first layer comprises at least 1 wt.% comonomer, based on the entire weight of the first layer, e.g., at least 1.5 wt.% or at least 2 wt.%. In terms of upper limits, the first layer comprises no more than 20 wt.% monomer, based on the entire weight of the first layer, e.g., no more than 15 wt.% or no more than 10 wt.%.

[0029] In some aspects, the first layer may comprise an additive. The additive may be present from 1 to 15 wt.%, based on the entire weight of the first layer, e.g., from 1 to 12 wt.% or from 1 to 10 wt.%. Additives known in the art may be included, such as antioxidants.

[0030] The first layer may be thinner than those of conventional tab sealants. In one embodiment, the first layer has a thickness ranging from 1 to 50 microns, e.g., from 5 to 25 microns, or from 10 to 20 microns. In terms of lower limits, the first layer may have a thickness of at least 1 micron, e.g., at least 5 microns, or at least 10 microns. It has now been discovered that a thinner first layer may lead to improved corrosion resistance as compared to a thicker first layer. In some cases, the thickness of the first layer may be selected based on the desired corrosion resistance. Without being bound by theory, it is believed that the existence of the polar groups in the first (and/or third layer) reduce corrosion resistance. Since the second layer may not contain polar groups, its corrosion resistance is better as compared to the first and/or third layer. Therefore, by having a thinner first layer (and/or third layer), the impact of the first (and/or third layer) on the corrosion resistance of the tab sealant is reduced.

[0031] The first layer may have a melting point from 130 to 160°C, e.g., from 130 to 150°C, or from 130 to 140°C. In terms of lower limits, the first layer may have a melting point of at least 130°C, e.g., at least 133°C or at least 135°C . In terms of upper limits, the first layer may have a melting point no greater than 160°C, e.g., no greater than 150°C or 140°C. A melting point below 130°C may not provide satisfactory heat resistance while a melting point above 160°C may require too much heat to seal the first layer to the lead, resulting in decreased adhesion and insulation.

[0032] The melt flow rate of the first layer may range from 2 to 20 g/10 minutes, e.g., from 3 to 10 g/10 minutes or from 5 to 6 g/10 minutes. In terms of lower limits, the first layer may have a melt flow rate of at least 2 g/10 minutes, e.g., at least 3 g/10 minutes or at least 5 g/10 minutes. In terms of upper limits, the first layer may have a melt flow rate of no greater than 20 g/10 minutes, e.g., no greater than 10 g/10 minutes or no greater than 6 g/10 minutes. The melt flow rate is an index showing the fluidity of the layer during heating. If the melt flow rate is less than 2 g/10 minutes, sealing of the tab sealant around the lead may be insufficient due to reduced fluidity. If the melt flow rate is greater than 20 g/10 minutes, the first layer may flow too easily, resulting in thinning of the layer during sealing.

Second Layer

[0033] As noted above, the second layer 18 may also be referred to as an intermediate layer, and is disposed between the first layer 17 and third layer 19 of the tab sealant. The second layer may be comprised of a polyolefin. The polyolefin film may vary widely. In some embodiments, the polyolefin may include polyethylene, including low, medium and high density polyethylenes; polypropylene, including homo, block or random polypropylene; polymethylpentene, polybutene-1; and ethylene-α-olefin copolymers. In some aspects, the olefin polymer is polypropylene, and may be a casting polypropylene film. In other embodiments, the polyolefin film may comprise any polyolefin material that exhibits good mechanical strength and heat resistance. Exemplary polyolefin films may comprise at least one of a polyimide, a polyester, a polyetherimide (PEI), a polyethylene naphthalate (PEN), a polyether sulfone (PES), a polysulfone, polymethylpentene (PMP), a polyvinylidene fluoride (PVDF), an ethylene-chlorotrifluoroethylene (ECTFE), or combinations thereof. In some aspects, the polyolefin in the second layer may be the same polyolefin as in the first layer, though the molecular weight and/or melting point may differ.

[0034] Exemplary polyolefin films made of polyimide include Kapton®, available from DuPont, and Apical©, available from Kaneka Texas Corporation, Exemplary polyolefin films made of polyester include Mylar©, avai lable from DuPont, and 2600 polyethylene terephthalate film, available from American Hoechst. Other commercially available polyolefin films include Tempalux™ (PEI), available from Westlake Plastics Company; Superio-UT™ (PEI), available from Mitsubishi Plastics, Kaladex™; (PEN) and Teonex (PEN), both available from DuPont.

[0035] The second layer may be thicker than the first layer and/or third layer. For example, the second layer may be at least 10% thicker, e.g., at least 20% thicker, at least 30% thicker, or at least 40% thicker than at least one of the first and third layer. In terms of ranges, the second layer may have a thickness ranging from 30 to 100 microns, e.g., from 45 to 90 microns or from 60 to 80 microns. In terms of lower limits, the second layer may have a thickness of at least 30 microns, e.g., at least 45 microns, or at least 60 micros. In terms of upper limits, the second layer may have a thickness of no more than 100 microns, e.g., no more than 90 microns or no more than 80 microns.

[0036] The second layer may have a melting point from 130 to 190°C, e.g., from 140 to 180°C, or from 150 to 170°C. In terms of lower limits, the second layer may have a melting point of at least 130°C, e.g., at least 140°C or at least 150°C . In terms of upper limits, the second layer may have a melting point no greater than 190°C, e.g., no greater than 180°C or 170°C. As compared to at least one of the first and third layer, the melting point of the second layer may be at least 10°C greater, e.g., at least 20°C greater or at least 30°C greater.

[0037] The melt flow rate of the second layer may range from 2 to 20 g/10 minutes, e.g., from 5 to 10 g/10 minutes or from 7 to 9 g/10 minutes. In terms of lower limits, the second layer may have a melt flow rate of at least 2 g/10 minutes, e.g., at least 5 g/10 minutes or at least 7 g/10 minutes. In terms of upper limits, the second layer may have a melt flow rate of no greater than 20 g/10 minutes, e.g., no greater than 10 g/10 minutes or no greater than 9 g/10 minutes.

[0038] The tensile strength and flexural modulus of the second layer may be selected based on the desired heat and moisture resistance of the layer, since the second layer provides insulation for the tab sealant. In some aspects, the tensile strength at yield ranges from 25 to 35 MPa, e.g., from 28 to 34 MPa or from 30 to 32 MPa. The flexural modulus may range from 800 to 1500 MPa, e.g., from 900 to 1450 MPa or from 1100 to 1400 MPa.

Third Layer

[0039] The third layer 19, also referred to as an outer layer, is in contact with the second layer 18. The third layer may be the same, substantially the same, or different than the first layer. The third layer may be comprised of a base polymer grafted with a monomer. The base polymer may be an olefin polymer. The olefin polymer may include, but is not limited to, polyethylene, including low, medium and high density polyethylenes; polypropylene, including homo, block or random polypropylene; polymethylpentene, polybutene-1; and ethylene-α-olefin copolymers. In some aspects, the olefin polymer is polypropylene.

[0040] The base polymer may be grafted with a monomer. The monomer may include, but is not limited to acrylic acid, methacrylic acid, maleic acid, maleic anhydride, α-methacrylic acid, methyl methacrylate, and glycidyl methacrylate. In some aspects, the monomer is maleic anhydride.

[0041] In addition to the base polymer being grafted with a monomer, the base polymer in the third layer may also be grafted with a comonomer, e.g., a monomer containing a benzene ring. For example, the comonomer may be an olefin monomer containing a benzene ring, such as styrene, dipropyl phthalate, diallyl phthalate, allylbenzene, methyleugenol, and α-methylstyrene.

[0042] As described herein, surprisingly and unexpectedly, it has been discovered that by including a comonomer with a benzene ring when grafting the base polymer and monomer, the grafting reaction rate in increased, resulting in improved adhesion of the tab sealant. This effect is seen when the comonomer is included in the first layer, third layer, or both. Additionally, the inclusion of a comonomer with a benzene ring when grafting the base polymer and monomer results in improved corrosion resistance of the base polymer, e.g., polypropylene.

[0043] The base polymer may be present in the third layer in an amount from to 70 to 98 wt.%, based on the entire weight of the third layer, e.g., from 78.5 to 96.5 wt.% or from 85 to 95 wt.%. In terms of lower limits, the third layer comprises at least 70 wt.% base polymer, based on the entire weight of the third layer, e.g., at least 78.5 wt.% or at least 85 wt.%. In terms of upper limits, the third layer comprises no more than 98 wt.% base polymer, based on the entire weight of the third layer, e.g., no more than 96.5 wt.% or no more than 95 wt.%. The base polymer in the third layer may be the same base polymer as in the first layer, or it may be substantially the same due to differences in melting point or molecular weight. In some aspects, a different base polymer is used in the third layer as compared to the first layer. In further aspects, the base polymer in the third layer may be the same as the polyolefin in the second layer or it may be substantially the same due to differences in melting point or molecular weight. In still further aspects, a different base polymer is used in the third layer as compared to the polyolefin in the second layer.

[0044] The monomer may be present in the third layer in an amount from 1 to 20 wt.%, e.g., from 2 to 15 wt.% or from 3 to 10 wt.%, based on the entire weight of the third layer. In terms of lower limits, the third layer comprises at least 1 wt.% monomer, based on the entire weight of the third layer, e.g., at least 2 wt.% or at least 3 wt.%. In terms of upper limits, the third layer comprises no more than 20 wt.% monomer, based on the entire weight of the third layer, e.g., no more than 15 wt.% or no more than 10 wt.%. The monomer polymer in the third layer may be the same monomer as in the first layer, or it may be substantially the same due to differences in melting point or molecular weight. In some aspects, a different monomer is used in the third layer as compared to the first layer.

[0045] When a comonomer is included, the third layer may comprise from 1 to 10 wt.% comonomer, based on the entire weight of the third layer, e.g., from 1.5 to 7.5

wt.% or from 2 to 5 wt.%. In terms of lower limits, the third layer comprises at least 1 wt.% comonomer, based on the entire weight of the third layer, e.g., at least 1.5 wt.% or at least 2 wt.%. In terms of upper limits, the third layer comprises no more than 20 wt.% monomer, based on the entire weight of the third layer, e.g., no more than 15 wt.% or no more than 10 wt.%. When both the first layer and the third layer include a comonomer, the comonomer in the third layer may be the same comonomer as in the first layer, or it may be substantially the same due to differences in melting point or molecular weight. In some aspects, a different comonomer is used in the third layer as compared to the first layer.

[0046] In some aspects, the third layer may comprise an additive. The additive may be present from 1 to 15 wt.%, based on the entire weight of the third layer, e.g., from 1 to 12 wt.% or from 1 to 10 wt.%. Additives known in the art may be included, such as antioxidants.

[0047] The third layer may have a thickness ranging from 1 to 50 microns, e.g., from 5 to 25 microns, or from 10 to 20 microns. In terms of lower limits, the third layer may have a thickness of at least 1 micron, e.g., at least 5 microns, or at least 10 micros. The thickness of the third layer may be selected based on the desired corrosion resistance. Without being bound by theory, it is believed that a thinner first layer leads to improved corrosion resistance as compared to a thicker first layer. The thickness of the third layer may be the as the first layer, or it may be different. In some aspects, the thickness of the third layer is within ± 30% of the thickness of the first layer, e.g., within ± 20% or ± 10%. The total thickness of the first and third layer combined may range from 2 to 100 microns, e.g., from 10 to 80 microns, or from 20 to 40 microns. The total thickness of the first layer, second layer, and third layer, combined, may range from 32 to 200 microns, e.g., from 55 to 190 microns, or from 80 to 120 microns.

[0048] The third layer may have a melting point from 130 to 160°C, e.g., from 130 to 150°C, or from 130 to 140°C. In terms of lower limits, the third layer may have a melting point of at least 130°C, e.g., at least 133°C or at least 135°C. In terms of upper limits, the first layer may have a melting point no greater than 160°C, e.g., no greater than 150°C or 140°C. In some aspects, the melting point of the third layer is within 10°C of the melting point of the first layer, e.g., within 5°C or within 3°C. In further aspects, the melting point of the third layer is within 40°C of the melting point of the first layer, e.g., within 35°C or within 30°C.

[0049] The melt flow rate of the third layer may range from 2 to 20 g/10 minutes, e.g., from 3 to 10 g/10 minutes or from 5 to 6 g/10 minutes. In terms of lower limits, the third layer may have a melt flow rate of at least 2 g/10 minutes, e.g., at least 3 g/10 minutes or at least 5 g/10 minutes. In terms of upper limits, the third layer may have a melt flow rate of no greater than 20 g/10 minutes, e.g., no greater than 10 g/10 minutes or no greater than 6 g/10 minutes. In some aspects, the melt flow rate of the third layer is within 3 g/10 minutes of the melt flow rate of the first layer, e.g., within 2 g/10 minutes or within 1 g/10 minutes. In some aspects, the melt flow rate of the third layer may be within 5 g/10 minutes of the melt flow rate of the second layer, e.g., within 4 g/10 minutes or within 3 g/10 minutes.

[0050] The following embodiments are contemplated. All combinations of features and embodiments are contemplated.

[0051] Embodiment 1: A tab sealant comprising: (a) a first layer comprising a polyolefin grafted with a monomer; (b) a second layer comprising a polyolefin; and (c) a third layer comprising a polyolefin grafted with a monomer; wherein the second layer is disposed between the first layer and the third layer, and further wherein the polyolefin in at least one of the first layer and the third layer is grafted with a monomer and a comonomer containing a benzene ring.

[0052] Embodiment 2: An embodiment of embodiment 1, wherein the polyolefin of the first layer, second layer, and third layer is independently selected from the group consisting of homo polypropylene, block polypropylene, and random polypropylene.

[0053] Embodiment 3: An embodiment of any one of the embodiments of embodiments 1-2, wherein the monomer in the first layer and/or the third layer is selected from the group consisting of acrylic acid, methacrylic acid, maleic acid, maleic anhydride, α-methacrylic acid, methyl methacrylate, and glycidyl methacrylate.

[0054] Embodiment 4: An embodiment of any one of the embodiments of embodiments 1-3, wherein the polyolefin in the first layer is grafted with the monomer and a comonomer.

[0055] Embodiment 5: An embodiment of any one of the embodiments of embodiments 1-4, wherein the polyolefin in the third layer is grafted with the monomer and a comonomer.

[0056] Embodiment 6: An embodiment of any one of the embodiments of embodiments 1-5, wherein the comonomer in the first layer is different than the comonomer in the second layer.

[0057] Embodiment 7: An embodiment of any one of the embodiments of embodiments 1-5, wherein the comonomer in the first layer is the same as the comonomer in the second layer.

[0058] Embodiment 8: An embodiment of any one of the embodiments of embodiments 1-7, wherein the comonomer is selected from the group consisting of styrene, dipropyl phthalate, diallyl phthalate, allylbenzene, methyleugenol, and α-methylstyrene.

[0059] Embodiment 9: An embodiment of any one of the embodiments of embodiments 1-8, wherein the monomer is present in the first layer from 1 to 20 wt.%.

[0060] Embodiment 10: An embodiment of any one of the embodiments of embodiments 1-9, wherein the comonomer is present in the first layer from 1 to 10 wt.%.

[0061] Embodiment 11: An embodiment of any one of the embodiments of embodiments 1-10, wherein the monomer is present in the third layer from 1 to 20 wt.%.

[0062] Embodiment 12: An embodiment of any one of the embodiments of embodiments 1-11, wherein the comonomer is present in the third layer from 1 to 10 wt.%.

[0063] Embodiment 13: An embodiment of any one of the embodiments of embodiments 1-12, wherein the first layer and third layer have substantially the same composition.

[0064] Embodiment 14: An embodiment of any one of the embodiments of embodiments 1-13, wherein the thickness of the first layer is from 1 to 50 μm.

[0065] Embodiment 15: An embodiment of any one of the embodiments of embodiments 1-14, wherein the thickness of the second layer is from 30 to 100 μm.

[0066] Embodiment 16: An embodiment of any one of the embodiments of embodiments 1-15, wherein the thickness of the third layer is from 1 to 50 μm.

[0067] Embodiment 17: An embodiment of any one of the embodiments of embodiments 1-16,

[0068] Embodiment 18: An embodiment of any one of the embodiments of embodiments 1-17, wherein the first layer has a melting point from 130 to 160°C.

[0069] Embodiment 19: An embodiment of any one of the embodiments of embodiments 1-18: wherein the second layer has a melting point from 130 to 190°C.

[0070] Embodiment 20: An embodiment of any one of the embodiments of embodiments 1-19: wherein the third layer has a melting point from 130 to 160°C.

[0071] Embodiment 21: An embodiment of any one of the embodiments of embodiments 1-20: wherein the first layer has a melt flow rate of 2 to 20 g/10 min.

[0072] Embodiment 22: An embodiment of any one of the embodiments of embodiments 1-21: wherein the second layer has a melt flow rate of 2 to 20 g/10 min.

[0073] Embodiment 23: An embodiment of any one of the embodiments of embodiments 1-22: wherein the third layer has a melt flow rate of 2 to 20 g/10 min.

[0074] Embodiment 24: An embodiment of any one of the embodiments of embodiments 1-23: wherein the first layer further comprises an additive.

[0075] The present invention will be better understood in view of the following non-limiting examples.

Examples

Example 1

[0076] A tab sealant was prepared having the following composition:

[0077] First layer: Polypropylene was grafted with maleic anhydride and styrene to form a polymer comprising 1-10 wt.% monomer and 2-5 wt.% comonomer. The polymer was cast and had a thickness of 10-20 microns, a melting point of 135°C and a melt flow rate of 5-6 g/10 minutes.

[0078] Second layer: Polypropylene having a melting point of 165°C and a melt flow rate of 8 g/10 minutes was cast to a thickness from 60 to 80 microns.

[0079] Third layer: Identical to the first layer.

Example 2

[0080] A tab sealant was prepared as in Example 1, except that the comonomer was allylbenzene.

Comparative Example 1

[0081] A tab sealant was prepared as in Example 1, except that no comonomer was included in either the first or third layer.

Comparative Example 2

[0082] A tab sealant was prepared as in Example 1, except that glycidyl acrylate, which lacks a benzene ring, was used as a comonomer.

Comparative Example 3

[0083] A tab sealant was prepared as in Example 1, except that the comonomer was present in an amount of less than 1 wt.%.

Testing

[0084] In order to compare the effect of including a comonomer on corrosion resistance and adhesive strength, the tab sealant was high frequency welded to the tab lead. Then the welded tab sealant and tab lead were immersed in an electrolyte solution for 72 hours at 85°C to test the peeling of the tab sealant from the tab lead. The corrosion resistance and adhesive strength were rated as follows:

[0085] A score of 1 represented bad adhesion and the surface of the tab sealant was clear, indicating poor corrosion resistance. A score of 2 represented medium adhesion and the surface of the tab sealant was partially white, indicating that the tab lead and tab sealant had good adhesion strength and that the tab sealant had good corrosion resistance, and partially clear. A score of 3 represented strong adhesion and the surface of the tab sealant was completely white.

[0086] The results of the testing of tab sealant of Examples 1-2 and Comparative Examples 1-3 are shown below in Table 1.

Table 1
Electrolyte Solution Immersion Testing

	Immersion Test Score	Comments
Example 1	3	good corrosion resistance and good adhesion performance
Example 2	3	good corrosion resistance and good adhesion performance
Comparative Example 1	1	bad corrosion resistance and bad adhesion performance
Comparative Example 2	1	bad corrosion resistance and bad adhesion performance
Comparative Example 3	1	bad corrosion resistance and bad adhesion performance

[0087] 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.

We claim:

1. A tab sealant comprising:

(a) a first layer comprising a polyolefin grafted with a monomer;

(b) a second layer comprising a polyolefin; and

(c) a third layer comprising a polyolefin grafted with a monomer;

wherein the second layer is disposed between the first layer and the third layer, and further wherein the polyolefin in at least one of the first layer and the third layer is grafted with a monomer and a comonomer containing a benzene ring.

2. The tab sealant of claim 1, wherein the polyolefin of the first layer, second layer, and third layer is independently selected from the group consisting of homo polypropylene, block polypropylene, and random polypropylene.

3. The tab sealant of any of the preceding claims, wherein the monomer in the first layer and/or the third layer is selected from the group consisting of acrylic acid, methacrylic acid, maleic acid, maleic anhydride, α-methacrylic acid, methyl methacrylate, and glycidyl methacrylate.

4. The tab sealant of any of the preceding claims, wherein the polyolefin in the first layer is grafted with the monomer and a comonomer.

5. The tab sealant of any of the preceding claims, wherein the polyolefin in the third layer is grafted with the monomer and a comonomer.

6. The tab sealant of any of the preceding claims, wherein the polyolefin in the first layer and the third layer is grafted with the monomer and a comonomer.

7. The tab sealant of claim 6, wherein the comonomer in the first layer is different than the comonomer in the third layer.

8. The tab sealant of claim 6, wherein the comonomer in the first layer is the same as the comonomer in the third layer.

9. The tab sealant of any of the preceding claims, wherein the comonomer is selected from the group consisting of styrene, dipropyl phthalate, diallyl phthalate, allylbenzene, methyleugenol, and α-methylstyrene.

10. The tab sealant of any of the preceding claims, wherein the monomer is present in the first layer from 1 to 20 wt.%.

11. The tab sealant of any of the preceding claims, wherein the comonomer is present in the first layer from 1 to 10 wt.%.

12. The tab sealant of any of the preceding claims, wherein the monomer is present in the third layer from 1 to 20 wt.%.

13. The tab sealant of any of the preceding claims, wherein the comonomer is present in the third layer from 1 to 10 wt.%.

14. The tab sealant of any of the preceding claims, wherein the first layer and third layer have substantially the same composition.

15. The tab sealant of any of the preceding claims, wherein the thickness of the first layer is from 1 to 50 µm.

16. The tab sealant of any of the preceding claims, wherein the thickness of the second layer is from 30 to 100 µm.

17. The tab sealant of any of the preceding claims, wherein the thickness of the third layer is from 1 to 50 µm.

18. The tab sealant of any of the preceding claims, wherein the first layer has a melting point from 130 to 160°C.

19. The tab sealant of any of the preceding claims, wherein the second layer has a melting point from 130 to 190°C.

20. The tab sealant of any of the preceding claims, wherein the third layer has a melting point from 130 to 160°C.

21. The tab sealant of any of the preceding claims, wherein the first layer has a melt flow rate of 2 to 20 g/10 min.

22. The tab sealant of any of the preceding claims, wherein the second layer has a melt flow rate of 2 to 20 g/10 min.

23. The tab sealant of any of the preceding claims, wherein the third layer has a melt flow rate of 2 to 20 g/10 min.

24. The tab sealant of any of the preceding claims, wherein the first layer further comprises an additive.

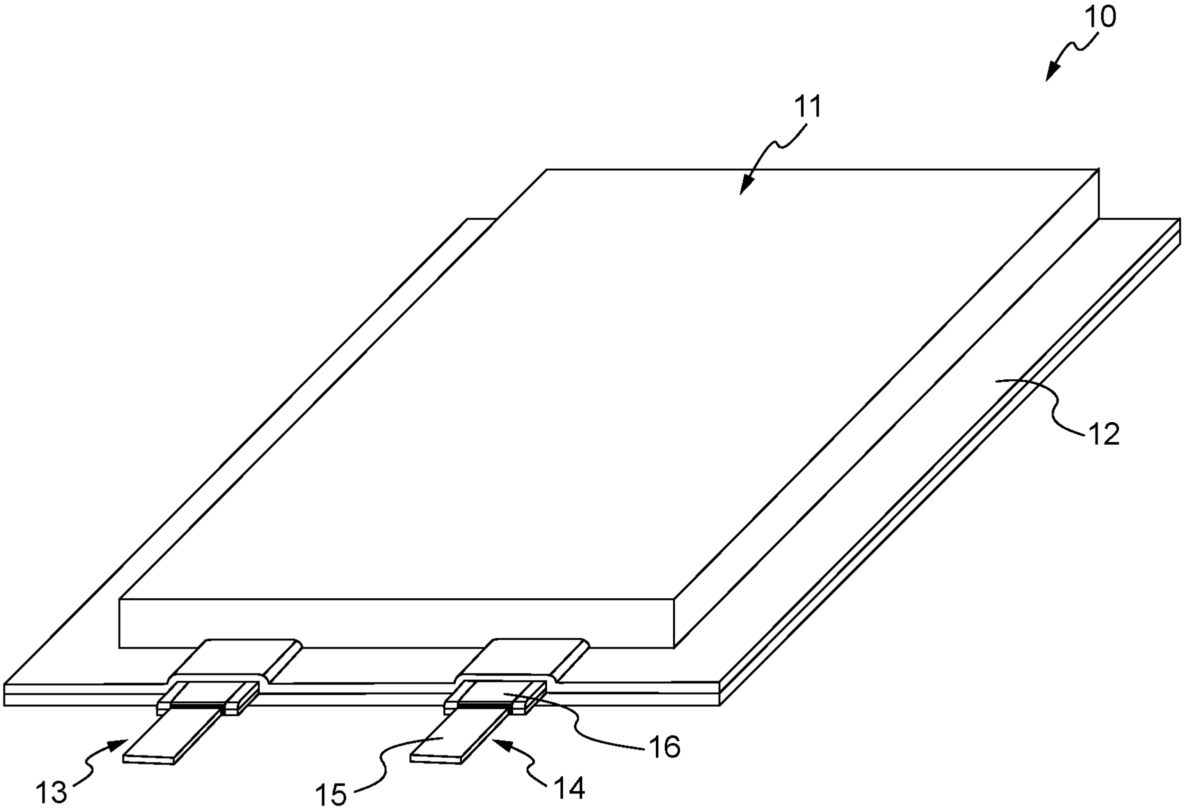

FIG. 1

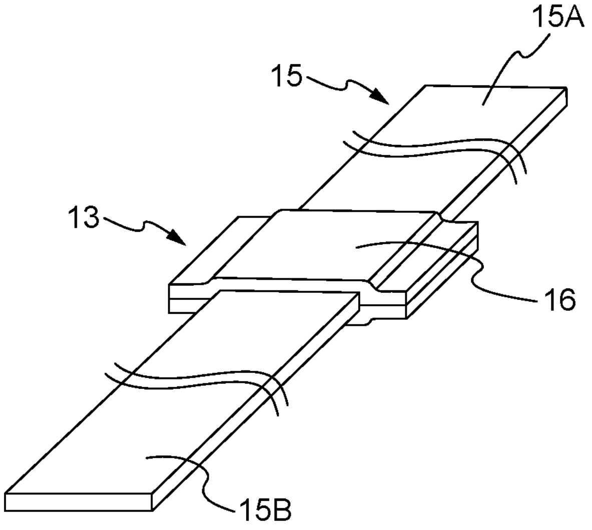

FIG. 2

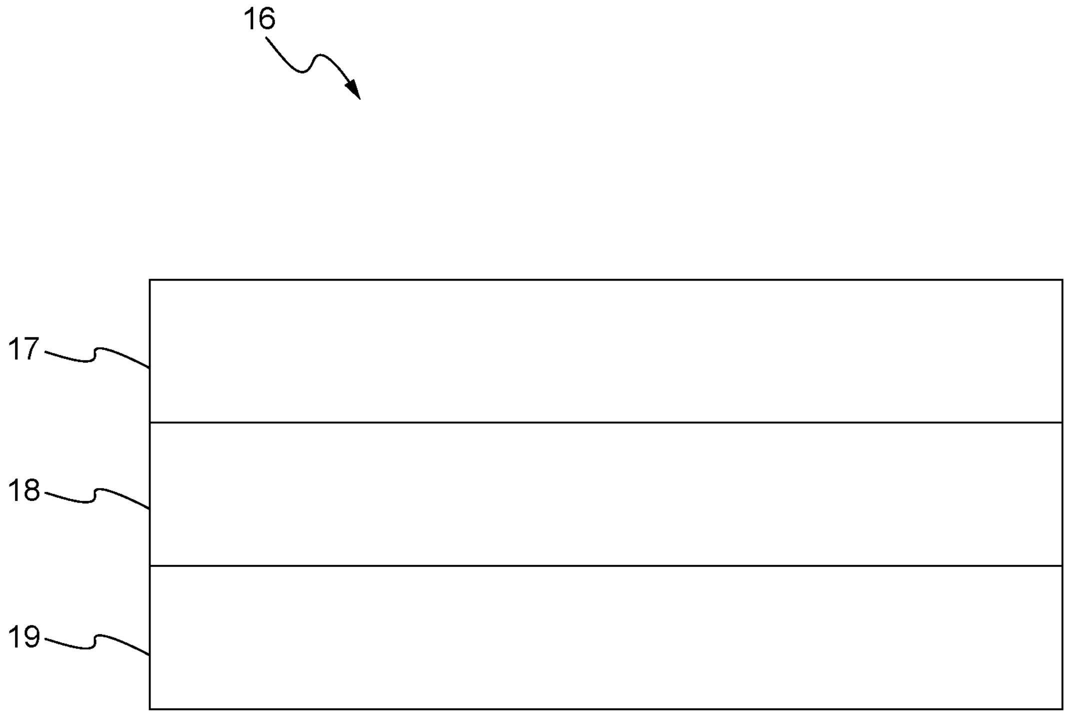

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2017/071918

A. CLASSIFICATION OF SUBJECT MATTER

H01M 2/02(2006.01)i; H01M 2/08(2006.01)i; B32B 15/08(2006.01)i; B32B 23/08(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)

H01M/-; B32B/-

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)

WPI,EPODOC,CNPAT,CNKI; seal+, layer, film, +olefin+, +propylene, +ethylene, polymethylpentene, polybutene, acrylic acid, methacrylic acid, maleic acid, maleic anhydride, methacrylic acid, methyl methacrylate, glycidyl methacrylate, benzene, styrene, dipropyl phthalate, diallyl phthalate, allylbenzene, methyleugenol, methylstyrene, graft+, modif+, monomer, comonomer, copolymer, adhesi+, insulat+, corrosi+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	KR 101366217 B1 (HANWHA POLYDREAMER CO. LTD.) 24 February 2014 (2014-02-24) WPI abstract	1-24
A	CN 103155207 A (OPPAN PRINTING CO. LTD.) 12 June 2013 (2013-06-12) abstract, claims 1-24	1-24
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A	CN 86108901 A (AMERICAN CAN CO. LTD., ET AL) 23 December 1987 (1987-12-23) abstract, claims 1-8	1-24

☐ 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 **24 September 2017**	Date of mailing of the international search report **18 October 2017**
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2017/071918

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