



(51) International Patent Classification:

B01D 39/16 (2006.01) *D04H 1/4358* (2012.01)
D04H 1/435 (2012.01)

(21) International Application Number:

PCT/US2019/056078

(22) International Filing Date:

14 October 2019 (14.10.2019)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/746,167 16 October 2018 (16.10.2018) US

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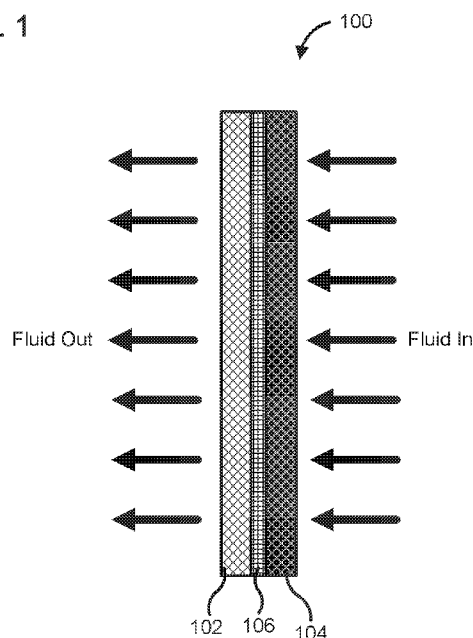
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(81) Designated States (*unless otherwise indicated, for every
kind of national protection available*): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP,
KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME,
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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,

(54) Title: ADHESIVE ALLOYS AND FILTER MEDIAS INCLUDING SUCH ADHESIVE ALLOYS

FIG. 1



(57) Abstract: Embodiments described herein relate generally to adhesive alloys and their use in filter media, and in particular to adhesive alloys that can be melt blown onto a filter media layer, and which are thermally activated to bond the filter media layer to another filter media layer. An adhesive alloy is provided. A thermally activated adhesive has a first melting temperature. A polymer has a second melting temperature greater than the first melting temperature. A ratio of the thermally activated adhesive in the adhesive alloy is in a range of 5 wt% to 70 wt%.



TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

Published:

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

ADHESIVE ALLOYS AND FILTER MEDIAS INCLUDING SUCH ADHESIVE ALLOYS

Cross-Reference to Related Applications

[0001] The present application claims priority to and benefit of U.S. Provisional Application No. 62/746,167, filed October 16, 2018, the entire disclosure of which is hereby incorporated herein by reference.

Technical Field

[0002] The present disclosure relates generally to methods for fabricating filter media for filter elements and adhesives used therein.

Background

[0003] Nonwovens, comprising randomly or sometimes directionally oriented polymer fibers, are used in applications ranging from disposable wipes to filter media. Some filter media include a plurality of filter media layers that are bonded together. Many conventional filter media use hot melt adhesives or laminates to bond the plurality of filter media layers. However, such hot melt laminates have poor surface finish and can also reduce filtration efficiency of the filter media by penetrating into and blocking pores of the filter media layers.

Summary

[0004] Embodiments described herein relate generally to adhesive alloys and their use in filter media, and in particular to adhesive alloys that can be melt blown onto a filter media layer, and which are thermally activated to bond the filter media layer to another filter media layer.

[0005] In a first set of embodiments, an adhesive alloy comprises a thermally activated adhesive having a first melting temperature, and a polymer having a second melting temperature greater than the first melting temperature. A ratio of the thermally activated adhesive in the adhesive alloy is in a range of 5 wt% to 70 wt%.

[0006] In another set of embodiments, a filter media comprises a first filter media layer, a second filter media layer, and at least one adhesive alloy layer comprising an adhesive alloy disposed between the first filter media layer and the second filter media layer. The adhesive alloy comprises a thermally activated adhesive having a first melting temperature, and a polymer having a second melting temperature greater than the first melting temperature. A ratio of the thermally activated adhesive in the adhesive alloy is in a range of 5 wt% to 70 wt%.

[0007] In still another set of embodiments, a method for forming a filter media, comprises mixing a first amount of a thermally activated adhesive with a second amount of a polymer to form a mixture. The mixture is at least one of dry blended or compounded to form an adhesive alloy. The adhesive alloy is melt blown onto a surface of a first filter media layer to form a non-woven adhesive alloy layer disposed on the first filter media layer. At least the adhesive alloy layer is heated to a temperature greater than a softening temperature of the adhesive alloy but lower than a melting temperature of the adhesive alloy. A second filter media layer is disposed over the heated adhesive alloy layer. The adhesive alloy layer is cooled to a temperature below the softening temperature of the adhesive alloy causing the adhesive alloy layer to harden and bond to each of the first filter media layer and the second filter media layer. A ratio of the thermally activated adhesive in the adhesive alloy is in a range of 5 wt% to 70 wt%.

[0008] In yet another set of embodiments, a filter media is formed by a process comprising the steps of mixing a first amount of a thermally activated adhesive with a second amount of a polymer to form a mixture. The mixture is at least one of dry blended or compounded to form an adhesive alloy. The adhesive alloy is melt blown onto a surface of a first filter media layer to form a non-woven adhesive alloy layer disposed on the first filter media layer. At least the adhesive alloy layer is heated to a temperature greater than a softening temperature of the adhesive alloy but lower than a melting temperature of the adhesive alloy. A second filter media layer is disposed over the heated adhesive alloy layer. The adhesive alloy layer is cooled to a temperature below the softening temperature of the adhesive alloy causing the adhesive alloy layer to harden and bond to each of the first filter media layer and the second filter media layer. A ratio of the thermally activated adhesive in the adhesive alloy is in a range of 5 wt% to 70 wt%.

[0009] It should be appreciated that all combinations of the foregoing concepts and additional concepts discussed in greater detail below (provided such concepts are not mutually inconsistent) are contemplated as being part of the subject matter disclosed herein. In particular, all combinations of claimed subject matter appearing at the end of this disclosure are contemplated as being part of the subject matter disclosed herein.

Brief Description of Drawings

[0010] The foregoing and other features of the present disclosure will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative implementations described in the detailed description, drawings, and claims are not meant to be limiting. Other implementations may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the figures, can be arranged, substituted, combined, and designed in a wide variety of different configurations, all of which are explicitly contemplated and made part of this disclosure.

[0011] FIG. 1 is a side cross-section view of a filter media, according to an embodiment.

[0012] FIG. 2 is a side cross-section view of a filter media, according to another embodiment.

[0013] FIG. 3 is schematic illustration of melt blowing apparatus for melt blowing adhesive alloys described herein onto a surface of a filter media layer, according to an embodiment.

[0014] FIG. 4 is a schematic flow diagram of a method for forming a filter media, according to an embodiment.

[0015] FIG. 5 is a differential scanning calorimetry curve of thermoplastic polyurethane (TPU).

[0016] FIG. 6 is scanning electron micrograph (SEM) image of a melt blown TPU layer disposed on a filter media layer.

[0017] FIG. 7A-7D are SEM images of an adhesive alloy layer including TPU and poly(butylene terephthalate) (PBT) that is melt blown and cooled to form a non-woven adhesive alloy mat on a fiber media layer (FIG. 7A); the adhesive alloy layer heated to a temperature of 170 degrees Celsius (FIG. 7B); the adhesive alloy layer heated to a temperature of 180 degrees Celsius (FIG. 7C); and the adhesive alloy layer heated to a temperature of 190 degrees Celsius.

[0018] Reference is made to the accompanying drawings throughout the following detailed description. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative implementations described in the detailed description, drawings, and claims are not meant to be limiting. Other implementations may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the figures, can be arranged, substituted, combined, and designed in a wide variety of different configurations, all of which are explicitly contemplated and made part of this disclosure.

Detailed Description of Various Embodiments

[0019] Embodiments described herein relate generally to adhesive alloys and their use in filter media, and in particular to adhesive alloys that can be melt blown onto a filter media layer, and which are thermally activated to bond the filter media layer to another filter media layer.

[0020] Some filter media include a plurality of filter media layers that are bonded together. Many conventional filter media use hot melt lamination to bond the plurality of filter media layers. However, such hot melt laminates have poor surface finish and can also reduce filtration efficiency of the filter media by penetrating into and blocking pores of the filter media layers.

[0021] Embodiments of the adhesive alloys and filter media including such adhesive alloys described herein may provide a number of benefits including, for example: (1) providing a thermally activated adhesive alloy that can be selectively activated to allow bonding of filter media layers; (2) allowing melt blowing of the adhesive alloy onto a filter media layer or another substrate, therefore eliminating use of hot melt glues and associated equipment; (3) allowing formation of a high porosity non-woven adhesive alloy mat on the filter media layer which has negligible impact on the pressure drop across or the filtration performance of the filter media; and (4) providing greater control over adhesive alloy deposition while using lesser amount of material, thereby reducing cost.

[0022] In some embodiments, an adhesive alloy which may be used as an adhesive alloy for bonding a plurality of filter media layers includes a thermally activated adhesive having a first melting temperature. Any suitable thermally activated adhesive may be used such as, for example, TPU, acrylonitrile butadiene styrene (ABS), acrylic, polyimide, cellulose acetate, nylon, etc.. In particular embodiments, the thermally activated adhesive includes TPU. In such embodiments, the first melting temperature is about 130 degrees Celsius to 180 degrees Celsius (e.g., about 130, 140, 150, 160, 170 or 180 degrees Celsius inclusive of all ranges and values therebetween).

[0023] The adhesive alloy also includes a polymer having a second melting temperature greater than the first melting temperature. The polymer may include any suitable polymer such as, for example, polyimide, aliphatic polyamide, aromatic polyamide, polysulfone, cellulose acetate, polyether sulfone, polybenzimidazole, polyetherimide, polyacrylonitrile, poly(ethylene terephthalate), polypropylene, polyaniline, poly(ethylene oxide), poly(ethylene naphthalate), poly(butylene terephthalate), styrene butadiene rubber, polystyrene, poly(vinyl chloride), poly(vinyl alcohol), poly(vinylidene fluoride), poly(vinyl butylene), polyphenylene sulfide (PPS), liquid crystal polymer (e.g., Kevlar, Vectran, Zenite 5145L, etc.), copolymers or derivatives thereof. In particular embodiments, the polymer includes a polyester. In one embodiment, the polyester includes PBT. In such embodiments, the second melting temperature is about 200 degrees Celsius to 320 degrees Celsius (e.g., 200, 220, 240, 260, 280, 300 or 320 degrees Celsius inclusive of all ranges and values therebetween). In some

embodiments, the polymer may include any suitable polymer that can be melt blown to form a non-woven web or mat, for example, to form a filter media layer.

[0024] A ratio of the thermally activated adhesive in the adhesive alloy is in a range of 5 wt% to 70 wt% (e.g., 5 wt%, 10 wt%, 15 wt%, 20 wt%, 25 wt%, 30 wt%, 35 wt%, 40 wt%, 45 wt%, 50 wt%, 55 wt%, 60 wt%, 65 wt% or 70 wt% thermally activated adhesive inclusive of all ranges and values therebetween). For example, in a particular embodiment, the adhesive alloy may include 5 wt% to 70 wt% TPU with the remaining being PBT. The adhesive alloy may have an alloy melting temperature greater than the first melting temperature but less than the second melting temperature. The adhesive alloy melting temperature is based on the proportion of the thermally activated adhesive relative to the polymer in the adhesive alloy. For example, in embodiments in which the adhesive alloy includes 5 wt% to 70 wt% TPU with the remaining being PBT, the alloy melting temperature is between the melting temperature of TPU and the melting temperature of PBT depending upon the amount of TPU mixed with PBT.

[0025] In some embodiments, the adhesive alloy has an alloy softening temperature less than the alloy melting temperature such that heating the adhesive alloy to the alloy softening temperature causes the adhesive alloy to be adhesively bondable to a substrate (e.g., a filter media layer). In other words, the adhesive alloy may be formulated such that heating the adhesive alloy to the softening temperature thereof activates the adhesive property of the adhesive alloy without completely melting the adhesive alloy. This results in minimal reflow of the adhesive alloy such that the adhesive alloy substantially retains a shape thereof while being able to bond to the substrate (e.g., a filter media layer).

[0026] Thus, mixing the thermally activated adhesive with the polymer yields the adhesive alloy that has a lower and broader softening point, and possesses a tacky or adhesive characteristic. However, the adhesive alloy still retains melting ability of the polymer included therein, allowing the adhesive alloy to be melt blown into a non-woven web or mat. Furthermore, the adhesive alloy may have a higher tensile strength than the polymer included therein.

[0027] In some embodiments, the adhesive alloy described herein may be used in a filter media as a bonding layer. For example, FIG. 1 is a side cross-section view of a filter media 100, according to an embodiment. The filter media 100 may be configured to remove particulate matter from a fluid. The filter media 100 includes a first filter media layer 102 and a second filter media layer 104 bonded together by an adhesive alloy layer 106 disposed therebetween. The adhesive alloy layer 106 includes the adhesive alloy, previously described herein. The first filter media layer 102 may be structured to filter particulate matter (e.g., soot, ash, dust, organic or inorganic particles, etc.) from a fluid (e.g., air, water, fuel such as diesel or gasoline, air/fuel mixture, lubricant or any other fluid).

[0028] The first filter media layer 102 may be structured to have a predetermined first porosity so as to provide a predetermined first flow rate of the fluid therethrough. In some embodiments, the porosity of the first filter media layer 102 defines a porosity corresponding to filtration efficiency of the filter media 100. In particular embodiments, the first filter media layer 102 may have a permeability of 5 cfm to 1,000 cfm, a basis weight of 5 grams per square meter (gsm) to 200 gsm and a fiber size (e.g., diameter) of each of the plurality of fibers forming the fibers of 0.5 μm to 50 μm .

[0029] The first filter media layer 102 may be formed from any suitable material, for example, polyimide, aliphatic polyamide, aromatic polyamide, polysulfone, cellulose acetate, polyether sulfone, polybenzimidazole, polyetherimide, polyacrylonitrile, poly(ethylene terephthalate), polypropylene, polyaniline, poly(ethylene oxide), poly(ethylene naphthalate), poly(butylene terephthalate) (PBT), styrene butadiene rubber, polystyrene, poly(vinyl chloride), poly(vinyl alcohol), poly(vinylidene fluoride), poly(vinyl butylene), polyphenylene sulfide (PPS), liquid crystal polymer (e.g., Kevlar, Vectran, Zenite 5145L, etc.), copolymers or derivatives thereof, or a combination thereof.

[0030] In particular embodiments, the first filter media layer 102 may also include 0 wt% to 10 wt% of the thermally activated adhesive and a polymer. For example, the first filter media layer 102 includes 0 wt% to -10 wt% TPU with the remaining being a polyester. The amount of thermally activated adhesive in the first filter media layer 102 may be less than an amount of the thermally activated adhesive included in the adhesive alloy, such that a first media layer melting

temperature or a first media layer softening temperature of the first filter media layer 102 is greater than the alloy melting temperature and the alloy softening temperature, respectively. In some embodiments, the polymer may be the same polymer included in the adhesive alloy layer 106 (e.g., poly(ethylene terephthalate) (PET) or PBT). In other embodiments, the polymer used to form the first filter media layer 102 is different from the polymer included in the adhesive alloy layer 106.

[0031] The first filter media layer 102 may be formed using any suitable process. In particular embodiments, the first filter media layer 102 includes a non-woven mat formed via a melt blowing process. In other embodiments, the first filter media layer 102 may be formed using melt spinning, solution spinning, wet laying, dry laying, weaving, any other suitable process or combinations thereof.

[0032] The second filter media layer 104 may be substantially similar to the first filter media layer 102 or different therefrom. In some embodiments, the second filter media layer may include, for example, a scrim layer. Suitable scrim layers may include spun bonded nonwovens, melt blown nonwovens, needle punched nonwovens, spun laced nonwovens, wet laid nonwovens, resin-bonded nonwovens, woven fabrics, knit fabrics, aperture films, paper, and combinations thereof. In particular embodiments, the second filter media layer 104 may be formed from cellulose. In some embodiments, the second filter media layer 104 may also include a melt blown non-woven mat.

[0033] The adhesive alloy layer 106 is formed from the adhesive alloy that includes the thermally activated adhesive having the first melting temperature, and the polymer having the second melting temperature greater than the first melting temperature such that a ratio of the thermally activated adhesive in the adhesive alloy is in a range of 5 wt% to 70 wt%. In particular embodiments, the adhesive alloy layer 106 may include a non-woven mat of the adhesive alloy. For example, the adhesive alloy layer 106 may include a plurality of fibers of the adhesive alloy melt blown onto a surface of the first filter media layer 102 or the second filter media layer 104, to form a non-woven mat of the adhesive alloy, and allowed to solidify to form the adhesive alloy layer 106 disposed on the first filter media layer 102. In some

embodiments, as the melt blown adhesive alloy fibers in the adhesive alloy layer 106 solidify, they may bond to the adhesive alloy layer 106.

[0034] The fibers of the adhesive alloy layer 106 may have a cross-section (e.g., diameter) in a range of 1 micron to 30 microns (e.g., 1, 2, 3, 4, 5, 10, 15, 20, 25 or 30 microns inclusive of all ranges and values therebetween). The adhesive alloy layer 106 may have thickness of less than 100 microns. Furthermore, a porosity of the adhesive alloy layer 106 may be an order of magnitude greater than the porosity of the first filter media layer 102 or the second filter media layer 104 so that the adhesive alloy layer 106 has a high permeability and thus, has negligible impact on flow rate of the fluid through the filter media 100.

[0035] To form the filter media 100, at least the adhesive alloy layer 106 may be heated to a temperature at or above the alloy softening temperature but below the alloy melting temperature of the adhesive alloy so as to thermally activate the adhesive alloy. As previously described herein, heating the adhesive alloy layer 106 to the adhesive alloy softening temperature increases the tackiness or adhesiveness of the adhesive alloy layer 106 without completely melting the adhesive alloy fibers included in the adhesive alloy layer 106 such that the adhesive alloy layer 106 substantially retains its morphology and shape. The second filter media layer 104 is then positioned on the thermally activated adhesive alloy layer 106 (or alternatively, the first filter media layer 102 is positioned on the thermally activated adhesive alloy layer 106 in embodiments in which the adhesive alloy layer 106 is initially deposited on the second filter media layer 104) and pressure may be applied to cause the second filter media layer 104 to adhere to the adhesive alloy layer 106. Cooling of the adhesive alloy layer 106 to below the alloy softening temperature bonds the second filter media layer 104 to the adhesive alloy layer 106 and thereby, the first filter media layer 102.

[0036] The adhesive alloy layer 106 may cause a negligible drop in flow rate or restriction of a fluid through the filter media 100 after thermally activated bonding, for example the air permeability may drop less than 2 cubic feet per minute (cfm) or 1 cfm with addition of the adhesive layer. For example, a drop in air permeability of the filter media 100 due to the inclusion of the adhesive alloy layer 106 may be less than about 5% of an air permeability of the filter media 100 if the adhesive alloy layer 106 was not present. Furthermore, the adhesive

alloy layer 106 may have a thickness of less than 100 microns, as previously described herein, such that the adhesive bonding layer is virtually invisible relative to hot melt adhesives conventionally used to bond filter media layers. The adhesive alloy layer 106 may also provide a more uniform bond relative to conventional hot melt adhesives.

[0037] FIG. 2 is a side cross-section view of a filter media 200, according to another embodiment. The filter media 200 includes the first filter media layer 102 and the second filter media layer. A first adhesive alloy layer 206, and a second adhesive alloy layer 208 is disposed between the first and second filter media layers 102 and 104. The first adhesive alloy layer 206 and the second adhesive alloy layer 208 may be substantially similar to the adhesive alloy layer 106. However, the first adhesive alloy layer 206 may include first amount of the thermally activated adhesive, and the second adhesive alloy layer 108 may include a second amount of the thermally activated adhesive which is greater than the first amount of the thermally activated adhesive. For example, the first adhesive alloy layer 206 may include 10 wt% of the thermally activated adhesive (e.g., TPU) and the second adhesive layer may include 20 wt% of the thermally activated adhesive. While shown as including the two adhesive alloy layers 206 and 208, in other embodiments, the filter media 200 or any other filter media described herein may include any number of adhesive alloy layers. In such embodiments, each successive filter media layer may have an increasing amount of the thermally activated adhesive therein (e.g., a step wise increase in the amount of thermally activated adhesive in each layer included in the filter media).

[0038] FIG. 3 is a schematic illustration of a melt blowing apparatus 300, according to an embodiment. The melt blowing apparatus 300 may be used to melt blow fibers of the adhesive alloy onto a substrate, for example, the first filter media layer 102 or the second filter media layer 104, to form a non-woven web (e.g., the adhesive alloy layer 106, 206, 208) of the adhesive alloy thereon. The melt blowing apparatus 300 comprises a melt blowing die 302. An adhesive alloy 310, for example, any of the adhesive alloys described herein, is disposed in an internal volume defined by the melt blowing die 302. The melt blowing die 302 defines an orifice 304, and a plunger 306 is configured to be selectively moved towards the orifice 304 so as to force melted adhesive alloy 310 out of the orifice 304 to form adhesive alloy fibers 320.

[0039] The melt blowing die 302 defines a pair of conduits 308 configured to deliver heated air to the orifice 304. The heated air or any other heated gas delivered to the orifice may be at a first predetermined temperature (e.g. in a range of 220 degrees Celsius to 260 degrees Celsius) sufficient to maintain the molted state of the adhesive alloy 310. The melted adhesive alloy stream is extruded out of the orifice 304 and travels towards a substrate 312 (e.g., a filter media layer), which is positioned below the orifice 304. A non-woven web of the adhesive alloy fibers 320 is formed on the substrate 312 to form an adhesive alloy layer. As the adhesive alloy layer formed from the adhesive alloy fibers solidifies on the substrate 312, the adhesive alloy layer may bond to the substrate 312.

[0040] FIG. 4 is a schematic flow diagram of a method 400 for forming a filter media (e.g., the filter media 100, 200), according to an embodiment. The method 400 includes mixing a first amount of a thermally activated adhesive with a second amount of a polymer to form a mixture, at 402. For example, pellets of the thermally activated adhesive may be mixed with pellets of the polymer to form the mixture. In a particular embodiment, the thermally activated adhesive includes a mixture or alloy of PBT and TPU.

[0041] At 404, the mixture is at least one of dry blended or compounded to form the adhesive alloy. As described herein, dry blending includes physically mixing pellets or particles of the thermally activated adhesive with pellets or particles of the polymer, for example, in a paddle or rotary mixer or a blender. As described herein, compounding includes physically mixing and then heating the mixture to a temperature above a melting temperature of each of the thermally activated adhesive and the polymer to form an adhesive alloy melt which solidifies on cooling to form the adhesive alloy.

[0042] At 406, the adhesive alloy is melt blown onto a surface of a first filter media layer to form a non-woven adhesive alloy layer. For example, the adhesive alloy is melt blown on to the first filter media layer 102 to form the adhesive alloy layer 106 thereon. At 408, at least the adhesive alloy layer (e.g., the adhesive alloy layer 106) is heated to a temperature greater than a softening temperature of the adhesive alloy but lower than a melting temperature thereof. In some embodiments, the softening temperature may be in a range of 175 degrees Celsius to 185

degrees Celsius (e.g., 175, 180 or 185 degrees Celsius). Heating the adhesive alloy layer activates the adhesiveness of the adhesive alloy, as previously described herein.

[0043] At 410, a second filter media layer (e.g., the second filter media layer 104) is positioned on the heated adhesive alloy layer. Pressure may be applied on the second and/or first adhesive layers to cause the adhesive alloy layer to adhere to the second filter media layer. In some embodiments, melt blowing the adhesive alloy fibers on the first filter media layer only forms the adhesive alloy layer thereon which is not yet adhered to the first filter media layer. In such embodiments, the adhesive alloy layer adheres to each of the first and second filter media layers at operation 410. At 412, the adhesive alloy layer is cooled to a temperature below the softening temperature of the adhesive alloy causing the adhesive alloy layer to harden and bond to the first and second filter media layers, thereby forming the filter media.

[0044] The following section describes various examples of adhesive alloys, methods of forming adhesive alloys, and adhesive alloy layers and filter media including the adhesive alloy. It should be appreciated that these examples are for illustrative purposes only and should not be construed as limiting the disclosure in any shape or form.

Experimental Examples

Forming a TPU/PBT adhesive alloy

[0045] A mixture of PBT and TPU is dry blended until well dispersed in a rotating mixer assembly with one or more paddle(s) to facilitate turnover of all material. Once blended, the mixture is loaded into a dehumidifying drier and dried at a temperature of 110 degrees Celsius for a minimum of 4 hours to form the adhesive alloy. The ratio of TPU in the adhesive alloy is 40 wt%.

Melt blowing the adhesive alloy to form adhesive alloy fibers

[0046] The adhesive alloy is conveyed or placed into the feed hopper of an extruder with a barrier style feed screw designed for engineered polymers, having a Maddux mixer in the final section. The extruder has a 1.5" barrel and screw which rotates about 40-50 rpm with temperature zones ranging from 220 degrees Celsius in the first melting section to 230, 240, 250 and finally

260 degrees Celsius in the remaining progressive zones. The adhesive alloy exits the extruder at about 260 degrees Celsius fully molten and blended, and into a positive displacement pump rotating at about 15 revolutions per minute and delivering 150 cc per minute of the molten adhesive alloy to a melt blowing die.

[0047] The melt blowing die has an active width of about 0.75 meters with about 900 nozzles in a spinneret arranged in a straight line. The die body of the melt blowing die is set to a controlled temperature of about 260 degrees Celsius and the melted adhesive alloy flowing into the die is distributed by means of a coat hanger manifold located inside the die to be uniform across the width of the die spinneret. Melted adhesive alloy exits each spinneret nozzle, and on each side of the spinneret nozzles are heated air curtains or jets that attenuate the adhesive alloy melt to produce adhesive alloy fibers in a continuous but molten filament. The adhesive alloy flow rate is about 0.18 gram per minute per nozzle, the total air flow rate is about 120 liters per minute per cm and the air is heated to about 270 degrees Celsius. The adhesive alloy fibers produced vary in diameter from about 2 microns to 20 microns. The melt spun adhesive alloy fibers rapidly cool and collect, forming a mass of adhesive alloy fibers.

Forming filter media using adhesive alloy as a bonding material

[0048] To form a filter media, the adhesive alloy fibers are directed toward, and form on the surface of a first filter media layer (e.g., a fibrous media). The first filter media layer may be produced in similar manner (i.e., via melt blowing) but without the mixture of the thermally activated adhesive, and is moving perpendicular in relationship to the adhesive alloy mat being formed. A filter media second layer is formed and cooled to a solidified state and is composed of the same or similar PBT resin as used in the first filter media layer, with the adhesive alloy fibers now sticking and or clinging to its surface. The second filter media layer may contain an amount of TPU or other PBT, PBT resin or modifiers but in a small amount less than about 5 wt% to 10 wt% such that its properties and specifically softening temperature remain higher than the adhesive alloy layer.

[0049] The first and second filter media layers have very different fiber diameter, weight, structure and properties that are advantageous to the intended filtration from the filter media,

while the PBT/TPU adhesive alloy is primarily intended as an adhesive coating. Speed of the first filter media layer passing the adhesive alloy fiber formation determines the amount of fiber per unit area collected on the previously formed first filter media layer. Only enough adhesive alloy to form a substantial bond is required and about 20 gsm to about 25 gsm is deposited. The first filter media layer may be a single or multiple layers of material with similar or greater weight per unit area and the adhesive alloy fiber mat is deposited on this media. The complexity and number of layers of the first filter media layer may make it beneficial to bond together various sub-layers of the first or second filter media layers and this may be done in conjunction with the adhesive alloy layer using a rotating engraved pattern roll and ultrasonic horns that apply energy to melt sub-layers of the first or second filter media layer together in a pattern matching the engraved roll. The adhesive alloy layer is applied to the side of this composite. This occurs prior to bonding of the first filter media layer to the second filter media layer using the adhesive alloy layer.

[0050] The first filter media layer as formed above is either rolled into a master roll or continues to an additional processing step. In this next processing step the surface of the media which has been covered with fibers formed of the adhesive alloy is re-heated to soften the fibers without completely melting the fibers at a temperature of about 180 degrees Celsius to 200 degrees Celsius. The temperature is kept below about 210 degrees Celsius to 220 degree Celsius range in order to avoid any impact to the structure or fibers the first or second filter media layers. This is done with radiant heat energy or radiant heat assisted by low velocity moving air in close proximity to the surface of the first filter media layer with the adhesive alloy layer.

[0051] Immediately upon reaching the prescribed surface temperature and softening of the adhesive alloy fibers, the first filter media layer is placed on contact with another roll of previously manufactured second filter media layer and pressure is applied. As described herein, the second filter media layer is produced on a paper machine and is primarily composed of cellulose fibers but may contain other natural or synthetic fiber and resins. Heating and re-activating the adhesive alloy fiber allows bonding of the first and second filter media layers without the use of any additional glue or materials while preserving the function and performance of the first and second filter media layers to which the adhesive alloy is applied.

The heating step may alter the adhesive alloy but not significantly or to the extent that the initially formed adhesive alloy fibers retain their basic morphology and impart little or no impact to the performance of the final composite other than providing adhesion of the dissimilar materials.

Melting characteristics of TPU

[0052] FIG. 5 is a DSC curve of a TPU showing that the TPU starts to melt and flow at a temperature about 150 degrees Celsius. In the example given with PBT and TPU blended where the PBT has a melt point in excess of 300 degrees Celsius and the TPU a melting point above about 130 degrees Celsius, the onset and range of the softening region has been tailored for its specific end use in fuel with a maximum service temperature of about 150 degrees Celsius. FIG. 6 is a SEM image of TPU fibers melt blown on to PBT filter media layer. Large variation in TPU fiber size from 1.5 microns to 15 microns is observed.

Thermal activation of TPU/PBT adhesive alloy

[0053] FIG. 7A is a SEM image of a melt blown TPU/PBT adhesive alloy layer including a plurality of TPU/PBT fibers disposed on a PBT filter media layer at room temperature. The amount of TPU in the adhesive alloy is 40 wt%. FIG. 7B is a SEM image of the TPU/PBT adhesive alloy layer heated to a temperature of 170 degrees Celsius. At this temperature, the adhesive alloy fibers soften and are thermally activated to have adhesiveness, but there is very little change in the morphology of the PBT/TPU adhesive alloy fibers. FIG. 7C is a SEM image of the TPU/PBT adhesive alloy layer heated to a temperature of 180 degrees Celsius. At this temperature, various fibers of the TPU/PBT adhesive alloy layer start to melt and join together while still retaining some of its initial morphology. FIG. 7D is a SEM image of the TPU/PBT adhesive alloy layer heated to a temperature of 190 degrees Celsius. At this temperature, the adhesive alloy fibers completely melt and merge together such that interconnected patches of melted adhesive alloy remain on the filter media layer. These figures illustrate that while the DSC curve of FIG 5 shows the softening of the alloy to begin just below or at about 150 degrees Celsius, there is little loss of fiber morphology below about 180 degrees Celsius. This

illustrates an advantage in that the alloy can be engineered to soften and bond media layers before there is any substantial change of the structure.

[0054] As used herein, the singular forms “a,” “an” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, the term “a member” is intended to mean a single member or a combination of members, “a material” is intended to mean one or more materials, or a combination thereof.

[0055] As used herein, the terms “about” and “approximately” generally mean plus or minus 10% of the stated value. For example, about 0.5 would include 0.45 and 0.55, about 10 would include 9 to 11, about 1000 would include 900 to 1100.

[0056] It should be noted that the term “example” as used herein to describe various embodiments is intended to indicate that such embodiments are possible examples, representations, and/or illustrations of possible embodiments (and such term is not intended to connote that such embodiments are necessarily extraordinary or superlative examples).

[0057] It is important to note that the construction and arrangement of the various exemplary embodiments are illustrative only. Although only a few embodiments have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter described herein. Other substitutions, modifications, changes and omissions may also be made in the design, operating conditions and arrangement of the various exemplary embodiments without departing from the scope of the present invention.

[0058] While this specification contains many specific implementation details, these should not be construed as limitations on the scope of any inventions or of what may be claimed, but rather as descriptions of features specific to particular implementations of particular inventions. Certain features described in this specification in the context of separate implementations can also be implemented in combination in a single implementation. Conversely, various features

described in the context of a single implementation can also be implemented in multiple implementations separately or in any suitable subcombination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a subcombination or variation of a subcombination.

WHAT IS CLAIMED IS:

1. An adhesive alloy, comprising:
a thermally activated adhesive having a first melting temperature; and
a polymer having a second melting temperature greater than the first melting temperature;
wherein a ratio of the thermally activated adhesive in the adhesive alloy is in a range of 5 wt% to 70 wt%.
2. The adhesive alloy of claim 1, wherein the thermally activated adhesive comprises thermoplastic polyurethane.
3. The adhesive alloy of claim 1, wherein the adhesive alloy has an alloy melting temperature greater than the first melting temperature but less than the second melting temperature.
4. The adhesive alloy of claim 3, wherein the adhesive alloy has an alloy softening temperature less than the alloy melting temperature, and wherein heating the adhesive alloy to the alloy softening temperature causes the adhesive alloy to be adhesively bondable to a substrate.
5. The adhesive alloy of claim 1, wherein the polymer comprises polyamide, aliphatic polyamide, aromatic polyamide, polysulfone, cellulose acetate, polyether sulfone, polybenzimidazole, polyetherimide, polyacrylonitrile, poly(ethylene terephthalate), polypropylene, polyaniline, poly(ethylene oxide), poly(ethylene naphthalate), poly(butylene terephthalate), styrene butadiene rubber, polystyrene, poly(vinyl chloride), poly(vinyl alcohol), poly(vinylidene fluoride), poly(vinyl butylene), polyphenylene sulfide, liquid crystal polymer, copolymers or derivatives thereof.
6. The adhesive alloy claim 5, wherein the polymer comprises poly(butylene terephthalate).

7. A filter media, comprising:
 - a first filter media layer;
 - a second filter media layer; and
 - at least one adhesive alloy layer comprising an adhesive alloy disposed between the first filter media layer and the second filter media layer, the adhesive alloy comprising:
 - a thermally activated adhesive having a first melting temperature, and
 - a polymer having a second melting temperature greater than the first melting temperature,wherein a ratio of the thermally activated adhesive in the adhesive alloy is in a range of 5 wt% to 70 wt%.
8. The filter media of claim 7, wherein the thermally activated adhesive comprises thermoplastic polyurethane.
9. The filter media of claim 7, wherein the adhesive alloy has an alloy melting temperature greater than the first melting temperature but less than the second melting temperature.
10. The filter media of claim 9, wherein the adhesive alloy has an alloy softening temperature less than the alloy melting temperature, and wherein heating the adhesive alloy to the alloy softening temperature causes the adhesive alloy to be adhesively bondable to a substrate.
11. The filter media of claim 7, wherein the polymer comprises polyamide, aliphatic polyamide, aromatic polyamide, polysulfone, cellulose acetate, polyether sulfone, polybenzimidazole, polyetherimide, polyacrylonitrile, poly(ethylene terephthalate), polypropylene, polyaniline, poly(ethylene oxide), poly(ethylene naphthalate), poly(butylene terephthalate), styrene butadiene rubber, polystyrene, poly(vinyl chloride), poly(vinyl alcohol), poly(vinylidene fluoride), poly(vinyl butylene), polyphenylene sulfide, liquid crystal polymer, copolymers or derivatives thereof.

12. The filter media of claim 11, wherein the polymer comprises poly(butylene terephthalate).
13. A method for forming a filter media, comprising:
mixing a first amount of a thermally activated adhesive with a second amount of a polymer to form a mixture;
at least one of dry blending or compounding the mixture to form an adhesive alloy;
melt blowing the adhesive alloy onto a surface of a first filter media layer to form a non-woven adhesive alloy layer disposed on the first filter media layer;
heating at least the adhesive alloy layer to a temperature greater than a softening temperature of the adhesive alloy but lower than a melting temperature of the adhesive alloy;
disposing a second filter media layer over the heated adhesive alloy layer; and
cooling the adhesive alloy layer to a temperature below the softening temperature of the adhesive alloy, causing the adhesive alloy layer to harden and bond to each of the first filter media layer and the second filter media layer,
wherein a ratio of the thermally activated adhesive in the adhesive alloy is in a range of 5 wt% to 70 wt%.
14. The method of claim 13, wherein the thermally activated adhesive comprises thermoplastic polyurethane.
15. The method of claim 13, wherein the adhesive alloy has an alloy melting temperature greater than the first melting temperature but less than the second melting temperature.
16. The method of claim 15, wherein the adhesive alloy has an alloy softening temperature less than the alloy melting temperature, and wherein heating the adhesive alloy to the alloy softening temperature causes the adhesive alloy to be adhesively bondable to a substrate.
17. The method of claim 13, wherein the polymer comprises polyamide, aliphatic polyamide, aromatic polyamide, polysulfone, cellulose acetate, polyether sulfone, polybenzimidazole, polyetherimide, polyacrylonitrile, poly(ethylene terephthalate),

polypropylene, polyaniline, poly(ethylene oxide), poly(ethylene naphthalate), poly(butylene terephthalate), styrene butadiene rubber, polystyrene, poly(vinyl chloride), poly(vinyl alcohol), poly(vinylidene fluoride), poly(vinyl butylene), polyphenylene sulfide, liquid crystal polymer, copolymers or derivatives thereof.

18. The method of claim 17, wherein the polymer comprises poly(butylene terephthalate).

19. A filter media formed by a process comprising:

mixing a first amount of a thermally activated adhesive with a second amount of a polymer to form a mixture;

at least one of dry blending or compounding the mixture to form an adhesive alloy;

melt blowing the adhesive alloy onto a surface of a first filter media layer to form a non-woven adhesive alloy layer disposed on the first filter media layer;

heating at least the adhesive alloy layer to a temperature greater than a softening temperature of the adhesive alloy but lower than a melting temperature of the adhesive alloy;

disposing a second filter media layer over the heated adhesive alloy layer; and

cooling the adhesive alloy layer to a temperature below the softening temperature of the adhesive alloy, causing the adhesive alloy layer to harden and bond to each of the first filter media layer and the second filter media layer,

wherein a ratio of the thermally activated adhesive in the adhesive alloy is in a range of 5 wt% to 70 wt%.

20. The filter media of claim 19, wherein the thermally activated adhesive comprises thermoplastic polyurethane and the polymer comprises poly(butylene terephthalate).

FIG. 1

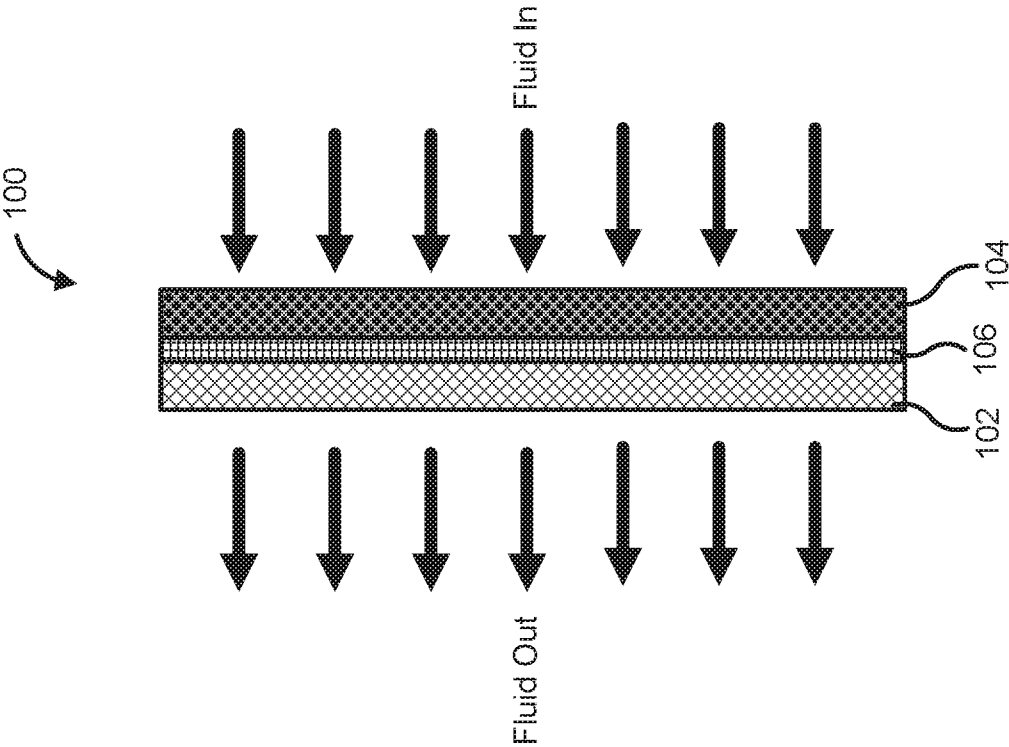
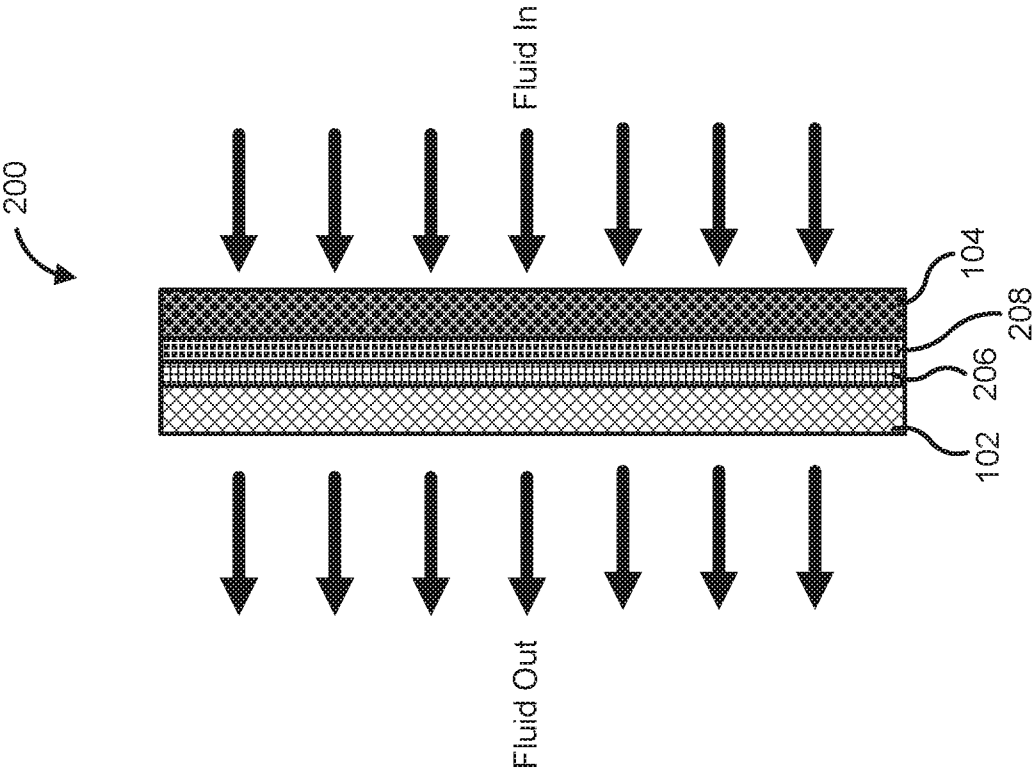


FIG. 2



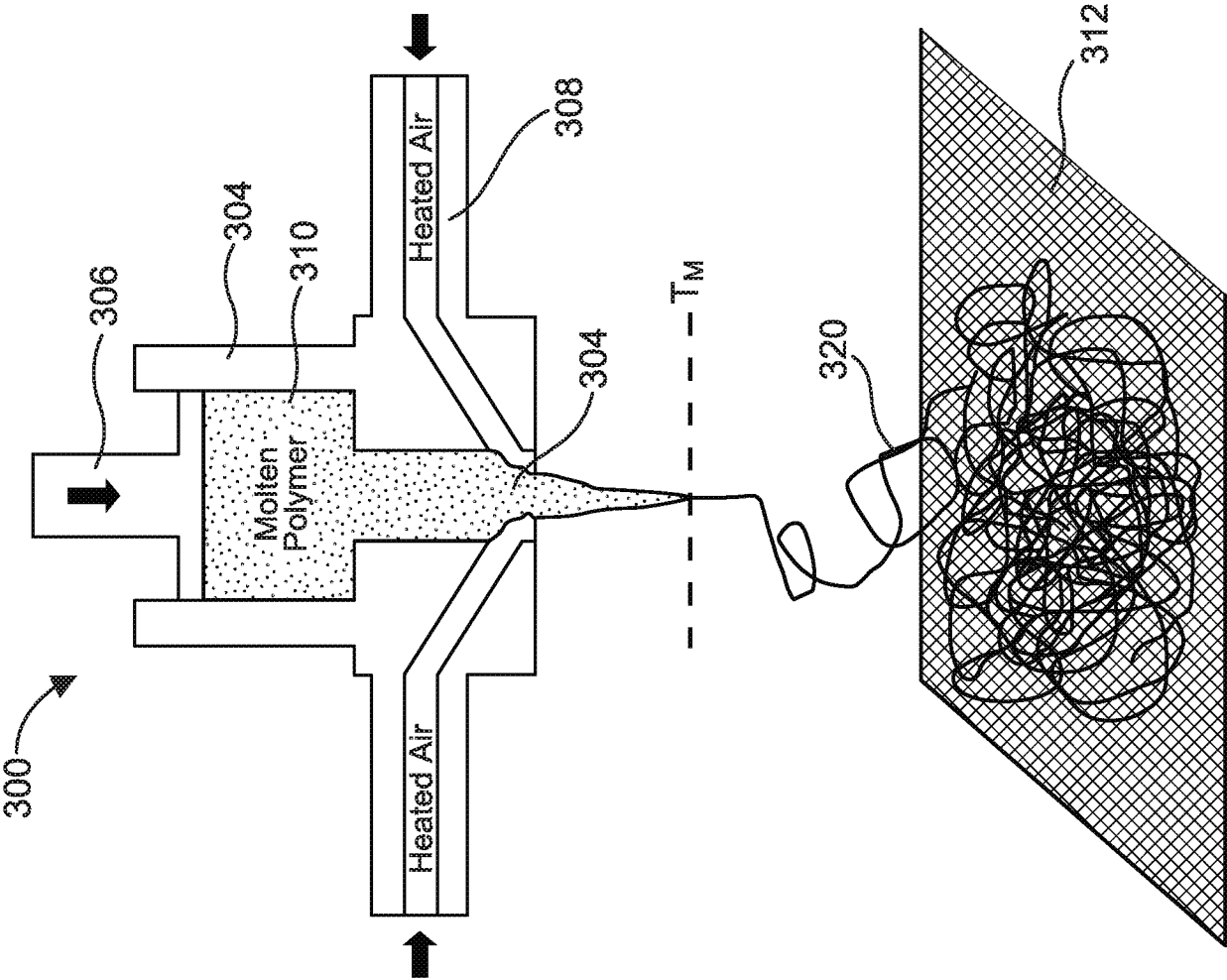
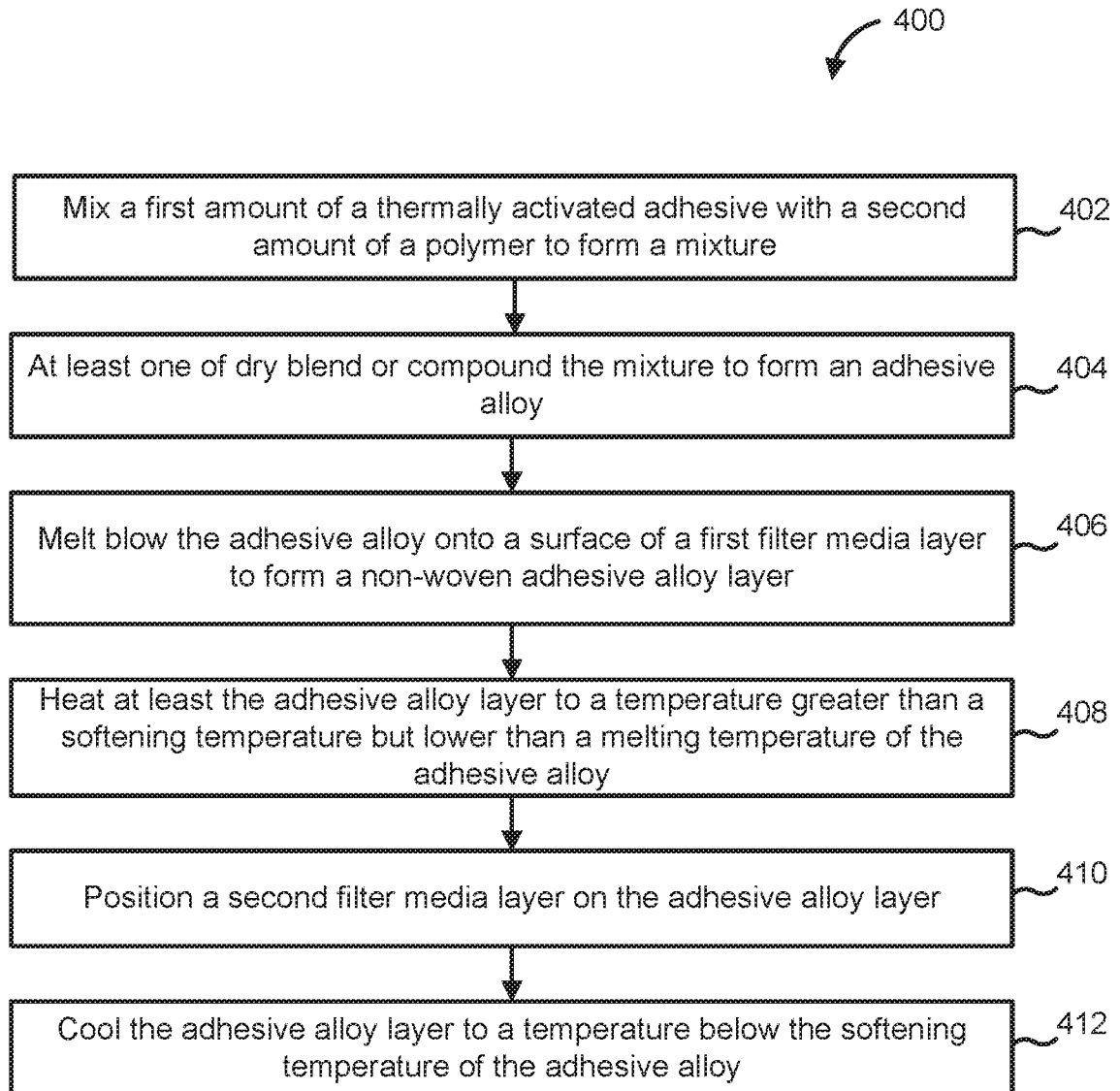


FIG. 3

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FIG. 4



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FIG. 5

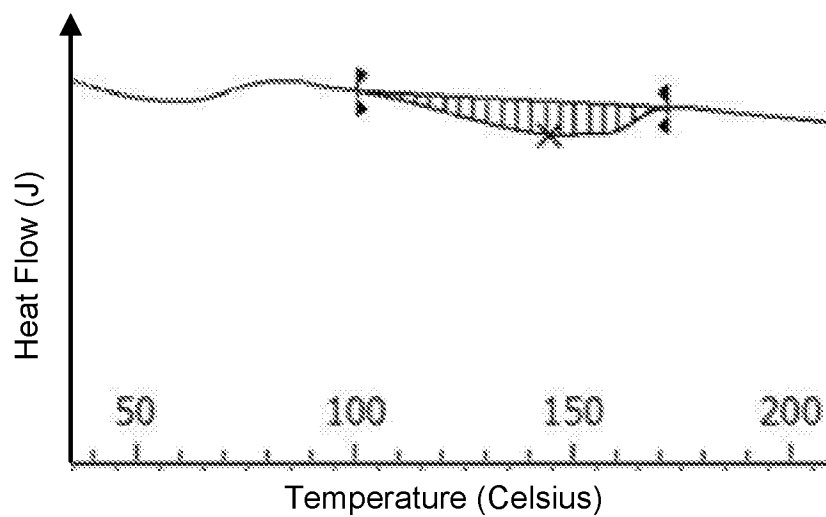
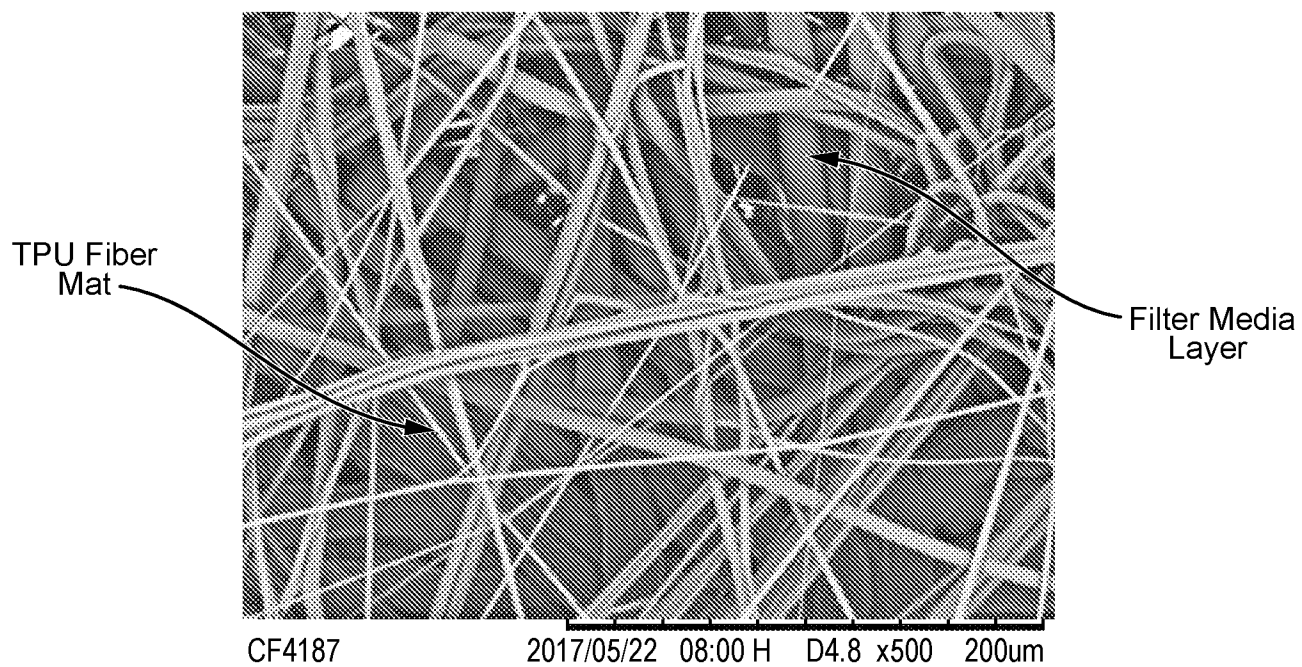
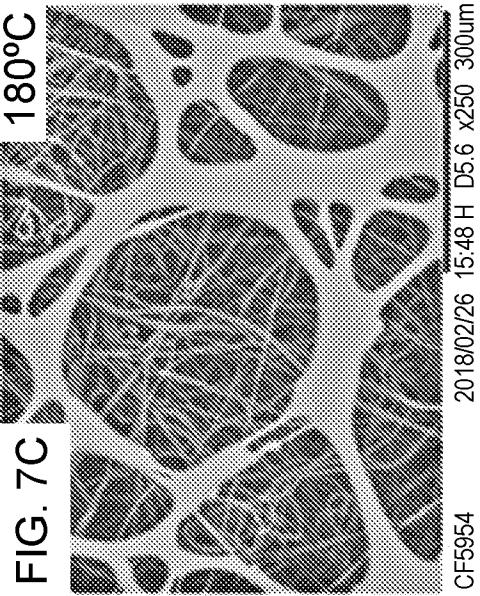
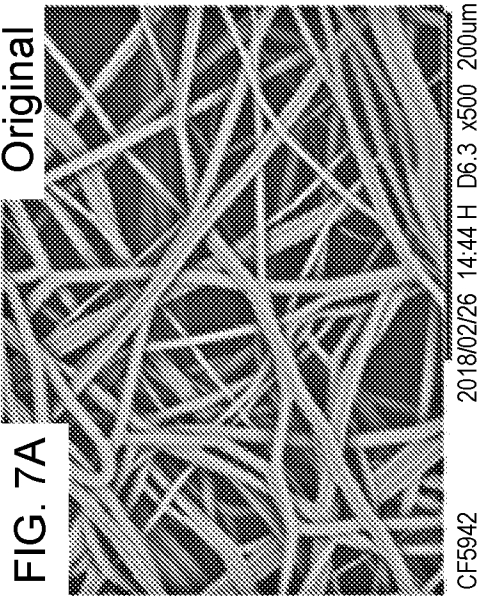
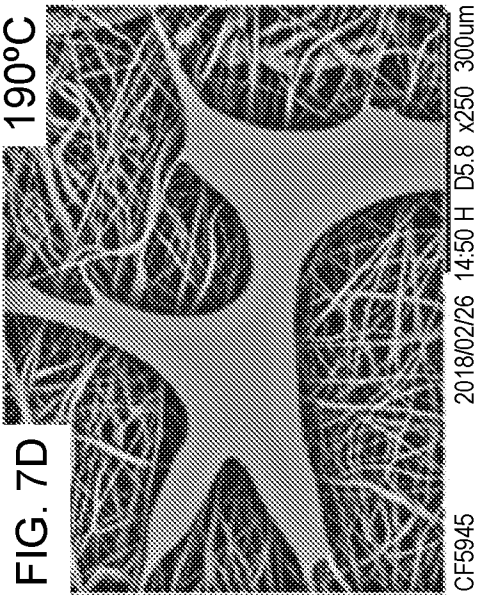
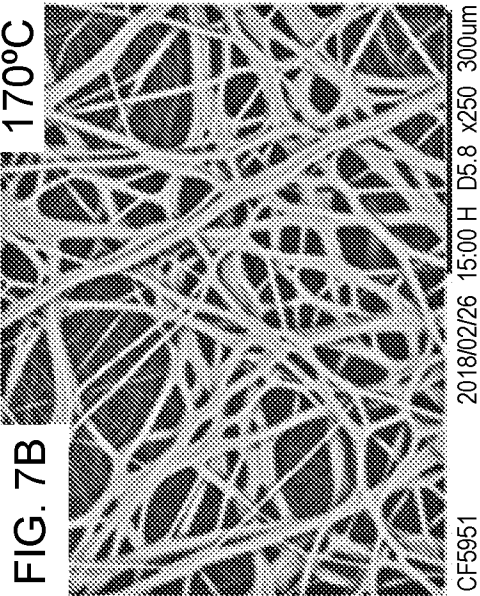


FIG. 6





INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/056078

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B01D 39/16; D04H 1/435; D04H 1/4358 (2019.01)
CPC - B01D 39/16; D04H 1/435; D04H 1/4358 (2019.08)

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)

See Search History document

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

USPC - 427/536 (keyword delimited)

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

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/0047469 A1 (HILMER et al) 25 February 2010 (25.02.2010) entire document	1-3, 5, 6
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Y		4, 7-12, 19, 20
Y	US 2007/0110949 A1 (ABRAMS) 17 May 2007 (17.05.2007) entire document	4, 10
Y	US 6,746,517 B2 (BENSON et al) 08 June 2004 (08.06.2004) entire document	7-12, 19, 20

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:

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"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

02 December 2019

Date of mailing of the international search report

23 DEC 2019

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