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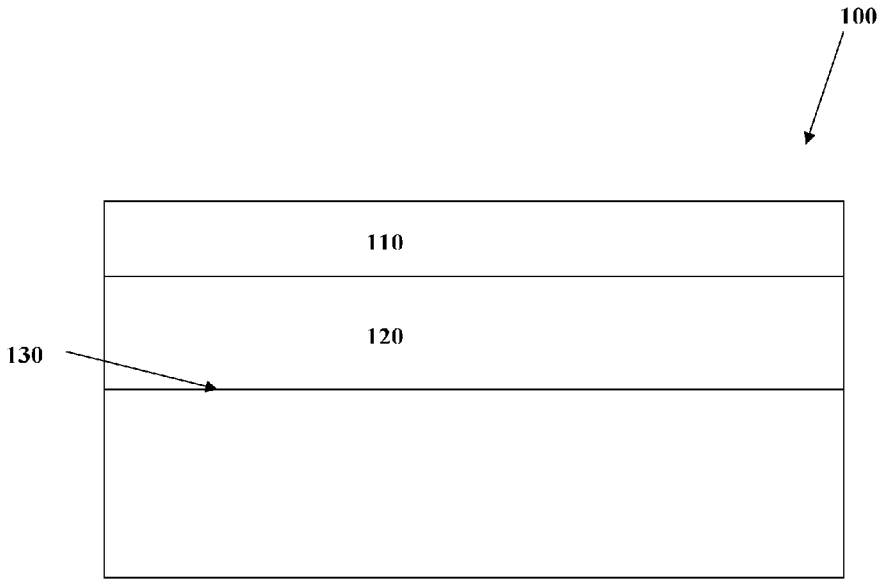


Figure 1

(57) Abstract: Some embodiments provided herein relate to a thermoplastic material that can include a thermoplastic surface, a protective coating, and a degradable intermediate layer.

DEGRADABLE POLYMERS

Technical Field

[0001] Some embodiments provided herein relate generally to compositions and/or layers that can include a removable coating.

Background

[0002] In some situations, thermoplastic devices are coated with a protective coating to provide protection to the underlying thermoplastic structure. Such coatings are often protective in nature and permanently adhered to the thermoplastic structure. In some situations, thermoplastic devices are coated with other coatings that can provide some aspect or characteristic to the thermoplastic structure.

SUMMARY

[0003] In some embodiments, a thermoplastic material is provided. In some embodiments, the thermoplastic material includes a thermoplastic surface, a protective outer coating and a degradable intermediate layer. In some embodiments, the degradable intermediate layer associates the protective coating with the thermoplastic surface.

[0004] In some embodiments, a method of processing a thermoplastic material is provided. In some embodiments, the method of processing the thermoplastic can include providing a thermoplastic material. The thermoplastic material can have a thermoplastic surface, a protective outer coating, and a degradable intermediate layer. The method of process the thermoplastic can further include breaching the protective outer coating to expose a degradable intermediate layer and removing and/or dissolving the degradable intermediate layer. In some embodiments, removing the degradable intermediate layer removes the protective outer coating, thereby allowing for the processing the thermoplastic material.

[0005] In some embodiments, a method of protecting a thermoplastic surface is provided. The method can include providing a protective coating over a thermoplastic surface. In some embodiments, the protective coating is adhered to the thermoplastic surface by a degradable intermediate layer.

[0006] In some embodiments, a method of making a protective coating for a thermoplastic material is provided. In some embodiments, the method can include providing a thermoplastic material having a thermoplastic surface, applying a degradable layer over the thermoplastic layer, and applying a protective coating over the degradable layer, thereby making a protective coating for a thermoplastic material.

[0007] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] **Figure 1** is a drawing depicting some embodiments of an arrangement of a thermoplastic material that includes an intermediate layer.

[0009] **Figure 2** is a drawing depicting a reaction of the conversion of a polyanhydride to a depolymerized monomer in the presence of water for some of the present embodiments.

DETAILED DESCRIPTION

[0010] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments can be utilized, and other changes can be made, without departing from the spirit or scope of the subject matter presented herein. 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, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

[0011] Provided herein are various compositions, materials, and methods relating to coatings associated with thermoplastic materials. Some embodiments relate to removing and/or changing a layer or coating over a thermoplastic material and/or other material. In some embodiments, this can involve an intermediate layer that can be removable. In some embodiments, the intermediate layer can allow the coating to be

separated from the thermoplastic material and/or surface by the removal of the intermediate layer itself (such as by dissolving the intermediate layer), thereby allowing for an efficient separation of the thermoplastic material from the coating. While not limited to such applications, in some embodiments, the degradable intermediate layer can allow for ease of recycling of various thermoplastic materials and/or changing various coatings on top of a thermoplastic material by making the removal of an outer coating easier.

[0012] In some embodiments, a thermoplastic material includes a thermoplastic surface, a coating and an intermediate layer. In some embodiments, the intermediate layer associates the coating (either directly or indirectly) with the thermoplastic surface. In some embodiments, the intermediate layer is degradable. In some embodiments, the degradable intermediate layer allows the coating to be removed from the thermoplastic surface by the ready degradation of the intermediate layer.

[0013] **Figure 1** depicts some embodiments of a thermoplastic material. As shown in Figure 1, the thermoplastic material **100** can include a coating **110** over a thermoplastic surface **130**. In some embodiments, an intermediate layer **120** can be between the coating **110** and the thermoplastic surface **130**. In some embodiments, while the intermediate layer can be degraded and/or broken down, so as to allow separation of the coating and the thermoplastic surface, the intermediate layer can be protected from degradation and/or break down by the presence of the coating (or other layer). Thus, in some embodiments, the breakdown of the intermediate layer can occur after a breach in the coating occurs. In some embodiments, this allows the intermediate layer to effectively keep the coating associated with the thermoplastic layer as desired, but allows one to more readily (and/or completely) remove the coating from the thermoplastic layer by breaching the coating and applying an agent (through the breached coating) to the degradable intermediate layer. The agent can then degrade the intermediate layer, allowing for separation of the coating and the thermoplastic surface. In some embodiments, prior to the breach in the coating (or other protective layer), the agent does not significantly cause degradation of the intermediate layer, due to the presence of the coating (or other protective layer).

[0014] In some embodiments, the intermediate layer **120** associates and/or adheres the coating **110** to the thermoplastic surface **130** directly and/or indirectly. In some embodiments, the intermediate layer **120** is configured to adhere to the coating **110**.

In some embodiments, the intermediate layer **120** is configured to adhere to the thermoplastic surface. In some embodiments, the intermediate layer **120** is configured to adhere to the coating **110** and the thermoplastic surface. In some embodiments, the intermediate layer **120** adheres the coating **110** directly to the thermoplastic surface **130**.

[0015] In some embodiments, the intermediate layer is located between the coating and the thermoplastic surface. In some embodiments, the intermediate layer can be above, below, have a common end point, and/or have a common border with the coating and/or the thermoplastic surface. In some embodiments, the intermediate layer is adjacent to the coating. In some embodiments, the intermediate layer is adjacent to the thermoplastic surface. In some embodiments, the intermediate layer contacts the coating and/or thermoplastic surface. In some embodiments, the intermediate layer adjoins, is contiguous with, or is juxtaposed to the coating and/or the thermoplastic surface. In some embodiments, the intermediate layer is in close proximity to but does not contact the coating and/or thermoplastic surface. In some embodiments, the coating is adjacent to the intermediate layer and the intermediate layer is adjacent to the thermoplastic surface.

[0016] In some embodiments, two or more intermediate layers **120** can be located between the coating **110** and the thermoplastic surface **130**, e.g., 2, 3, 4, 5, 6, 7, 8, 910, 20, 30, 40 or more layers, including any range above any one of the preceding values and any range defined between any two of the preceding values. In some embodiments, the second intermediate layer can be the same or substantially the same as the first intermediate layer. In some embodiments, the second intermediate layer can have the same composition as the first intermediate layer. In some embodiments, the second intermediate layer can have a different composition than the first intermediate layer. In some embodiments, the first and second intermediate layers can have different degradation rates. In some embodiments, the first intermediate layer has an interface with the second intermediate layer.

[0017] In some embodiments, beneath a first intermediate layer, there is a second or more coating. Thus, in some embodiments, one can breach a first coating, degrade the first intermediate layer, and thereby expose a second or subsequent coating, before getting to the thermoplastic surface. Thus, in some embodiments, multiple coatings can be present, one or more of which can be separated by an intermediate layer, such that by specifically breaching a coating and applying an agent to degrade the intermediate layer directly beneath it, one can remove a first coating and at least partially

expose a second or subsequent coating. In some embodiments, there are 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 15, 20, 25, 30, 40, 50, or 100 coatings, including any range defined between any two of the preceding values and any range above any one of the preceding values.

[0018] In some embodiments, the thermoplastic material **100** can include one or more intervening layers (e.g., 1, 5, 10, 15, 20, 30, 40, 50, or 100 layers, including any range defined between any two of the preceding values and any range above any one of the preceding values), which can be in addition to the coating **110**, thermoplastic surface **130** and/or intermediate layer **120**. In some embodiments, the intervening layer can be between the intermediate layer **120** and thermoplastic surface **130**. In some embodiments, the intervening layer can be between the intermediate layer **120** and the coating **110**. In some embodiments, the intervening layer can be any layer not disclosed herein.

[0019] In some embodiments, a coating is provided to protect against damage from UV light, reduce degradation by oxygen, change the texture and/or alter the color. In some embodiments, a primer or an adhesive is provided. In some embodiments, the coatings are used to enhance scratch resistance, for lubrication/friction-reduction, to increase resistance to a particular chemical for specialized application, to generate a compatible interface with another material, and/or to make the polymer surface hydrophilic/hydrophobic. In some embodiments, the coatings are also used as flame retardants and to increase impact resistance. In some embodiments, the coating can include one or more of a halogenated polymer and/or monomer (including, for example, those with fluorine, chlorine and/or bromine), dyes and/or pigments, minerals (such as, for example, silica, zirconia, titania, metal hydroxide and/or borates), polyolefins (such as, for example, polypropylene), acrylates (such as, for example, methacrylate and/or poly(methyl methacrylate)); and silicones and/or siloxanes.

[0020] In some embodiments, the thermoplastic material can include two or more thermoplastic surfaces (e.g., 1, 5, 10, 15, 20, 30, 40, 50, or 100 thermoplastic surfaces, including any range defined between any two of the preceding values and any range above any one of the preceding values). In some embodiments, the intervening layers, coatings and thermoplastic surfaces can be arranged in various configurations such that one or more intermediate layer is between each coating and thermoplastic surface.

[0021] In some embodiments, the intermediate layer can be anything that can be broken down adequately so that a layer and/or coating on the intermediate layer can be

separated from the thermoplastic surface (or other layer or surface associated with the thermoplastic surface). In some embodiments, the intermediate layer can be anything that can be removed adequately so that a layer and/or coating on the intermediate layer can be separated from the thermoplastic surface (or other layer or surface associated with the thermoplastic surface). In some embodiments, the intermediate layer can be configured to degrade, dissolve, liquefy, erode, depolymerize, and/or generally be separated, etc. In some embodiments, the intermediate layer is degradable. In some embodiments, the intermediate layer can be configured to degrade by dissolution, chemical reaction, and/or thermally. In some embodiments, at least some of the intermediate layer is dissolved and/or dissolvable, for example, 1, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 96, 97, 98, 99, 99.9, 99.99, or all of the intermediate layer is dissolved and/or dissolvable, including any range between any two of the preceding values and any range above any one of the preceding values.

[0022] In some embodiments, the intermediate layer can be completely and/or nearly completely removable from the thermoplastic surface (or other layer or surface associated with the thermoplastic surface). In some embodiments, the intermediately layer need only be removable enough so that the outer coating can be separated from the thermoplastic surface (or other layer or surface associated with the thermoplastic surface). In some embodiments, some of the intermediate layer remains adhered to the thermoplastic surface (or other layer or surface associated with the thermoplastic surface). In some embodiments, the remaining intermediate layer can be removed after, or, alternatively, covered by a new intermediate layer.

[0023] In some embodiments, the intermediate layer can be completely and/or nearly completely removable from the coating (or other layer or surface associated with the coating). In some embodiments, the intermediately layer need only be removable enough so that the coating can be separated from the thermoplastic surface. In some embodiments, some of the intermediate layer remains adhered to the coating.

[0024] While a variety of compositions can be used, in some embodiments, the intermediate layer can be a degradable material. In some embodiments, the degradable material is anything capable of maintaining mechanical integrity until degraded, and capable of controlled rates of degradation. In some embodiments, the degradable material is a soluble material. In some embodiments, the soluble material can be degraded in a solution, water surfactant solution, or organic solvent. In some

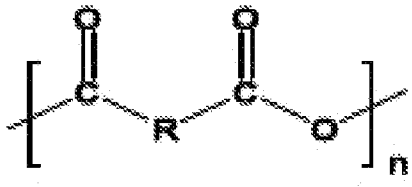
embodiments, the degradable material is not water soluble. In some embodiments, the degradable material is insoluble but can be dissolved. In some embodiments, the degradable material can be depolymerized.

[0025] In some embodiments, the intermediate layer includes one or more oligomers and/or polymers. In some embodiments, the intermediate layer includes a copolymer of two or more polymers and/or oligomers.

[0026] In some embodiments, the polymer can be a biodegradable polymer. In some embodiments, the biodegradable polymer can include, but is not limited to, 1. 3-hydroxypropionic acid, P(3-HP), polylactic acid, poly(esters) based on polylactide (PLA), polyglycolide (PGA), polycaprolactone (PCL), polyhydroxybutyrate (PHB), polyhydroxyvalerate (PHV) and their copolymers

[0027] In some embodiments, the polymer can include an anhydride linkage. In some embodiments, the polymer can include a polyanhydride. In some embodiments, the polyanhydride can include, but is not limited to, polyporopylene, polycarbonate, poly(methyl methacrylate) (PMMA), copolymer of terephthalic acid and oxalic acid, polydimethylmalonic anhydride, polymer of terephthalic acid.

[0028] In some embodiments, the polyanhydride can be, as seen in Formula I:



Formula I

wherein n can be 1 to 100,000

[0029] In some embodiments, the anhydride linkage (as represented by R in Formula I) can be an aliphatic, substituted aliphatic, aromatic, substituted aromatic or silicon-containing group. In some embodiments, the polyanhydride is unsaturated. In some embodiments, an aliphatic R group (which can be carbons in a straight or branched arrangement) can have lower melting points (about 50 to 100 degrees Centigrade), relatively high solubilities in common solvents and a comparatively swift reaction with water (e.g., converting the polyanhydride to depolymerized water, as shown in Figure 2. In some embodiments, polyanhydrides with aromatic R groups can have a higher melting

point (greater than 100 degrees Centigrade), lower solubilities, and slower reactions with water.

[0030] In some embodiments, the aliphatic group can be a straight or branched chain carbon group. In some embodiments, the aliphatic group is selected from the group of: a C_{1-10} alkane, a C_{1-10} alkene, a C_{1-10} alkyne, a C_{3-10} cycloalkyl, or combinations thereof. In some embodiments, the aliphatic polyanhydride is soluble in an organic solvent.

[0031] In some embodiments, the aromatic group is selected from the group of: a benzene, a heteroarene, a derivative thereof, or any combinations thereof. In some embodiments, the aromatic group is insoluble in organic solvents.

[0032] In some embodiments, the polymer is a copolymer of an aliphatic polyanhydride and aromatic polyanhydride. In some embodiments, the polymers of the copolymer are selected to achieve a desired degradation rate. In some embodiments, the degradation rate of the copolymer can be selected based on the solubility and/or melting point of the polymers. In some embodiments, the intermediate layer **120** includes a polyanhydride of Formula I, wherein R is an aliphatic group and a polyanhydride of Formula I, wherein R is an aromatic group.

[0033] In some embodiments, the length of the polymer and/or oligomer can vary. In some embodiments, the length of the polymer can be a number of repeating units or monomers (as represented by n in Formula I). In some embodiments, the number of repeating units can be from about 1 to about 100,000, e.g. 1, 100, 500, 1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, 10000, 20000, 30000, 40000, 50000, 75000, 100000, including any range below any of the preceding values, any range above any of the preceding values, and any range between any two of the preceding values. In some embodiments, the length of the oligomer can be about 2 to about 10 repeating units or monomers.

[0034] In some embodiments, the monomer can include a dicarboxylic acid. In some embodiments, dicarboxylic acids, e.g., glutaric acid, adipic acid, benzene dicarboxylic acid (terephthalic acid), phenylated succinic acid and methylated malonic acid, can be used to form one or more anhydride polymer.

[0035] It will be appreciated by the disclosure herein, that in some embodiments the moisture sensitivity of polyanhydrides can make the polyanhydride a relevant selection for some embodiments. It will be further appreciated from the

disclosure herein that a wide range of polyanhydrides with varying properties can be generated. In some embodiments, polyanhydrides can be produced by heating dicarboxylic monomers in acetic anhydride under reduced pressure. In some embodiments, the dicarboxylic acid monomers can be and/or include oxalic acid, malonic acid, succinic acid, glutaric acid, adipic acid, pimelic acid, terephthalic acid, phenyl succinic acid, and/or dimethyl malonic acid. In some embodiments, the polyanhydride employed can be one that is compatible with polymers such as polypropylene, polymethyl methacrylate (PMMA), and/or acrylonitrile butadiene styrene (ABS).

[0036] In some embodiments, glutaric acid, adipic acid, benzene dicarboxylic acid (terephthalic acid), phenylated succinic acid and/or methylated malonic acid can be used as or included in the intermediate layer. In some embodiments, these and/or others can be used without and/or with a reduced risk of causing harm to the thermoplastic surfaces.

[0037] In some embodiments, the polymer can be selected for a desired degradation rate. In some embodiments, the degradation rate of a polymer can be selected by adjusting the melting point of the polymer. Increasing or decreasing the length of the chain can raise or lower the melting point of the polymer, respectively. It will be further appreciated that incorporating structures such as aromatic rings or elements such as nitrogen or oxygen into the main chain or side groups can result in higher melting points. While not being limiting, it will be appreciated that aliphatic polymers, such as polyethylene, (based upon chains of carbon and hydrogen) can have lower melting points.

[0038] In some embodiments, the intermediate layer includes a polymer that depolymerizes in the presence of a solution or a water surfactant solution.

[0039] In some embodiments, the coating of the thermoplastic material enhances certain characteristics of the thermoplastic surface. In some embodiments, the coating is configured to enhance the UV or oxygen stability, texture, color or durability of the thermoplastic coating. In some embodiments, the coating can be a protective coating. In some embodiments, the coating is over the thermoplastic surface. In some embodiments, the coating is an outer coating. In some embodiments, the coating is an outer-most coating.

[0040] In some embodiment, the coating is practically insoluble in water and/or an organic sovlent. In some embodiment, the material of the coating can be substantially insoluble in a solution or water surfactant. In some embodiments, the

material of the coating can be poorly soluble. In some embodiments, the coating is effectively insoluble in a solution or a water surfactant solution. In some embodiments, the coating is adequately insoluble so as to prevent and/or reduce a solvent from coming into contact with the intermediate layer, when the coating is not physically breached. In some embodiments, the coating can achieve this for at least 0.1 days, e.g., 0.1, 1, 10, 20, 30, 40, 50, 100, 300, 365, 1000, 2000, 3000, 5000, or 10,000 days, including any range above any one of the preceding values and ay range between any two of the preceding values. In some embodiments, the coating is relatively insoluble to a solvent that would degrade the intermediate layer. In some embodiments, the coating is effectively insoluble to a solvent that would degrade the intermediate layer. In some embodiments, the coating is insoluble to a solvent that would degrade the intermediate layer. In some embodiments, the coating **110** can include (and/or be adjacent to) a thin film or paint, or other layer.

[0041] In some embodiments, the thermoplastic surface can be made of or include, but is not limited to acrylonitrile butadiene styrene (ABS), acrylic (PMMA), celluloid, cellulose acetate, cyclic olefin copolymer (COC), ethylene-vinyl acetate (EVA), ethylene vinyl alcohol (EVOH), efluoroplastics (PTFE, alongside with FEP, PFA, CTFE, ECTFE, ETFE), ionomers, kydex, a trademarked acrylic/PVC alloy, liquid crystal polymer (LCP), polyoxymethylene (POM or acetal), polyacrylates (Acrylic), polyacrylonitrile (PAN or acrylonitrile), polyamide (PA or Nylon), polyamide-imide (PAI), polyaryletherketone (PAEK or Ketone), polybutadiene (PBD), polybutylene (PB), polybutylene terephthalate (PBT), polycaprolactone (PCL), polychlorotrifluoroethylene (PCTFE), polyethylene terephthalate (PET), polycyclohexylene dimethylene terephthalate (PCT), polycarbonate (PC), polyhydroxyalkanoates (PHAs), polyketone (PK), polyester, polyethylene (PE), polyetheretherketone (PEEK), polyetherketoneketone (PEKK), polyetherimide (PEI), polyethersulfone (PES), chlorinated polyethylene (CPE), polyimide (PI), polylactic acid (PLA), polymethylpentene (PMP), polyphenylene oxide (PPO), polyphenylene sulfide (PPS), polyphthalamide (PPA), polypropylene (PP), polystyrene (PS), polysulfone (PSU), polytrimethylene terephthalate (PTT), polyurethane (PU), polyvinyl acetate (PVA), polyvinyl chloride (PVC), polyvinylidene chloride (PVDC), styrene-acrylonitrile (SAN) and combinations thereof. In some embodiments, the thermoplastic surface can include one or more of polypropylene, ethylene, silicone and/or acrylic. In some embodiments, the thermoplastic surface can be and/or include

polypropylene, PMMA, polycarbonate, a copolymer of terephthalic acid and oxalic acid, polydimethylmalonic anhydride, and/or a polymer of terephthalic acid.

[0042] In some embodiments, a method of removing a coating **110** from a thermoplastic surface **130** is provided. In some embodiments, the method includes providing a thermoplastic material **100**, breaching a coating **110,** and at least partially removing an intermediate layer **120**. This can be done by applying an agent, through the breach in the coating, to the intermediate layer. This can allow one to thereby remove the coating **110** from the thermoplastic surface **130**. In some embodiments, the intermediate layer is a degradable intermediate layer that associates the protective coating with the thermoplastic surface. In some embodiments, breaching the protective outer coating **110** exposes the degradable intermediate layer **120**.

[0043] In some embodiments, any of the various embodiments including at least one intermediate layer can be used in any of the methods provided herein. In some embodiments, removing the intermediate layer can include degrading, dissolving, and/or eroding the intermediate layer. In some embodiments, removing the degradable intermediate layer includes dissolving the degradable intermediate layer. In some embodiments, removing the degradable intermediate layer includes depolymerizing the intermediate layer. As noted above, "removal" of the intermediate layer does not require the complete removal of the layer in all embodiments, and encompasses anything from complete removal, to adequate removal to allow for separation of at least part of the thermoplastic surface from at least part of the coating.

[0044] In some embodiments, a solvent can be used to facilitate removing the intermediate layer. In some embodiments, the solvent can include a solution and/or a water surfactant. In some embodiments, the solution can include water. In some embodiments, the solvent can be an organic solvent. In some embodiments, the organic solvent can include, but is not limited to, ethyl acetate, tetrahydrofuran, or any combination thereof.

[0045] In some embodiments, heat can be used to remove the intermediate layer (and/or facilitate it). In some embodiments, various devices and techniques can be employed to facilitate removing the intermediate layer. In some embodiments, ultrasonic baths and/or water jets can be used to facilitate removing the intermediate layer. In some embodiments, various agents (such as a solvent and heat) can be combined for removal of the intermediate layer.

[0046] In some embodiments, exposing at least a portion of the intermediate layer can facilitate removing the intermediate layer. In some embodiments, dissolving includes exposing the degradable intermediate layer.

[0047] In some embodiments, removing the degradable intermediate layer includes exposing the degradable intermediate layer and depolymerizing the polyanhydride to form a depolymerized monomer.

[0048] In some embodiments, the coating **110** is breached to allow access to the intermediate layer **120**. In some embodiments, breaching the coating **110** exposes at least a portion of the intermediate layer **120**. In some embodiments, exposing more surface area of the intermediate layer **120** can allow for faster degradation of the intermediate layer **120**.

[0049] In some embodiments, breaching can include breaking the thermoplastic material **100** into smaller pieces. In some embodiment, breaching can include shredding, chipping, crushing, and/or scoring the coating **110**, the thermoplastic material **100**, or both. In some embodiment, breaching can include shredding, chipping, crushing, and/or scoring the coating **110**, the intermediate layer **120**, and/or the thermoplastic material **100**. In some embodiments, breaching can allow for ease of handling, transportation, and/or storage of the thermoplastic material **100**.

[0050] In some embodiments, the method further includes reusing at least a part of the thermoplastic material **100** after the thermoplastic material **100** has been processed (e.g., reusing the thermoplastic). In some embodiments, the method further includes recycling the thermoplastic. In some embodiments, the thermoplastic surface **130** can be left intact or substantial intact during the process. In some embodiments, the method further includes recoating the thermoplastic surface **130** after the coating **110** has been removed.

[0051] In some embodiments, a method of protecting a thermoplastic surface **130** is provided. In some embodiments, the method can include providing a protective coating **110** over the thermoplastic surface **130**. In some embodiments, the protective coating **110** can be adhered to the thermoplastic surface **130** by a degradable intermediate layer **120**.

[0052] In some embodiments, a method for making a thermoplastic material **100** is provided. In some embodiments, the method can include providing a thermoplastic

material **100** having a thermoplastic surface **130**, applying an intermediate layer (e.g., a degradable layer) over the thermoplastic surface **130**, and applying a protective coating **110** over the intermediate layer (e.g., the degradable layer), thereby making a protective coating **110** for a thermoplastic material **100**.

[0053] In some embodiments, one or more intermediate layers (e.g., degradable layers) are applied over the thermoplastic surface **130**. In some embodiments, the intermediate layer (e.g., the degradable layer) adheres to the thermoplastic surface **130**. In some embodiments, the protective coating **110** adheres to the intermediate layer (e.g., a degradable layer). In some embodiments, additional adhesive layers and/or other layers can be applied between one or more the layers and/or coatings.

[0054] In some embodiments, the intermediate layer (e.g., the degradable layer) is applied as a pre-polymer. In some embodiments, the intermediate layer (e.g., the degradable layer) is applied as a solution in a solvent. In some embodiments, applying the intermediate layer includes applying a solution of a polyanhydride in a suitable solvent. In some embodiments, this can be followed by dipping or spraying of the intermediate coated thermoplastic material.

[0055] In some embodiments, a first intermediate layer (e.g., degradable layer) or part thereof can be applied to the thermoplastic surface. In some embodiments, a second intermediate layer (e.g., degradable layer) or part thereof can be applied to the protective coating **110**. In some embodiments, the first intermediate layer can be polymerized by the presence of a material in the second intermediate layer, when the two come into contact with one another.

[0056] One skilled in the art will appreciate that, for this and other processes and methods disclosed herein, the functions performed in the processes and methods can be implemented in differing order. Furthermore, the outlined steps and operations are only provided as examples, and some of the steps and operations can be optional, combined into fewer steps and operations, or expanded into additional steps and operations without detracting from the essence of the disclosed embodiments.

[0057] In some embodiments, the thermoplastic surface can have any of a variety of shapes for any of a variety of purposes. In some embodiments, the thermoplastic material **100** can have its shape determined by the initial starting shape of the surface of the thermoplastic material **130** (which can be molded by any of a variety of techniques). In some embodiments, the thermoplastic material **100** can have its shape

determined after the intermediate layer **120** and the coating **110** have been applied and the entire thermoplastic material **100** is reformed.

[0058] In some embodiments, the thermoplastic material provided herein can be part of vehicle part (such as an automotive or aircraft part, etc.), electrical part, electronic equipment, personal electronics, storage material and/or other device or part.

EXAMPLE 1

RECYCLING A COATED PRODUCT

[0059] The present example outlines some embodiments for how to recycle a product with a coating.

[0060] A piece of a thermoplastic material is obtained from an automobile. The thermoplastic material includes a thermoplastic layer having a thermoplastic surface, coated by an ethanol degradable intermediate layer, which is coated by an ethanol resistant outer coating.

[0061] The material is placed into a chipper and chipped into pieces that are, on average, less than 10 cm across. The chipped product is then soaked in ethanol for five hours, separating the coating from the thermoplastic layer. The thermoplastic layer is then collected, dried and used as a starting material for recycling of the thermoplastic.

EXAMPLE 2

METHOD OF APPLYING A PROTECTIVE COATING

[0062] The present example outlines an implementation for applying a protective coating to a thermoplastic material. A thermoplastic layer is provided. A polyanhydride is dissolved in an appropriate solvent and is sprayed onto the thermoplastic layer to form a polymer intermediate layer. A coating is spray applied over the intermediate layer. The coating is allowed to harden to form a water resistant coating, which, until breached, can reduce the likelihood that water will come into contact with the polyanhydride polymer layer.

EXAMPLE 3

REMOVING AND REAPPLYING A COATING

[0063] The present example outlines an implementation for recycling a thermoplastic material.

[0064] The product from Example 2 is provided. The water resistant coating is breached by gently scoring the outer coating, without excessively penetrating the intermediate layer. The scored product is then placed into a water bath and sonicated for 1 hour. The intermediate layer is dissolved and the outer coating removed. The thermoplastic layer is allowed to dry, a new intermediate layer is applied and a new coating is applied (as outlined in Example 2).

[0065] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations can be expressly set forth herein for sake of clarity.

[0066] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims can contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation

should be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., " a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., " a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

[0067] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[0068] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, etc. As will also be understood by one skilled in the art all language such as "up to," "at least," and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having

1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

[0069] From the foregoing, it will be appreciated that various embodiments of the present disclosure have been described herein for purposes of illustration, and that various modifications can be made without departing from the scope and spirit of the present disclosure. Accordingly, the various embodiments disclosed herein are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

WHAT IS CLAIMED IS:

1. A thermoplastic material, the material comprising:

a thermoplastic surface;

a protective outer coating; and

a degradable intermediate layer that associates the protective coating with the thermoplastic surface.

2. The thermoplastic material of claim 1, wherein the degradable intermediate layer comprises a soluble material.

3. The thermoplastic material of claim 1, wherein the protective outer coating is effectively insoluble in a solution or a water surfactant solution.

4. The thermoplastic material of claim 1, wherein the protective outer coating is adjacent to the degradable intermediate layer.

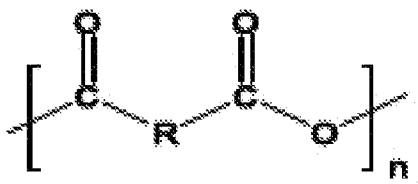
5. The thermoplastic material of claim 1, wherein the degradable intermediate layer is adjacent to the thermoplastic surface.

6. The thermoplastic material of claim 1, wherein the protective outer coating is adjacent to the degradable intermediate layer and the degradable intermediate layer is adjacent to the thermoplastic surface.

7. The thermoplastic material of claim 1, wherein the degradable intermediate layer comprises a polymer that depolymerizes in the presence of a solution or a water surfactant solution.

8. The thermoplastic material of claim 1, wherein the degradable intermediate layer comprises a polyanhydride.

9. The thermoplastic material of claim 8, wherein the polyanhydride is one represented by the structure in Formula I:



Formula I

wherein R can be an aliphatic group or an aromatic group and wherein n can be 1 to about 100,000.

10. The thermoplastic material of claim 9, wherein the aliphatic group is selected from the group consisting of: a C_{1-10} alkane, a C_{1-10} alkene, a C_{1-10} alkyne, a C_{3-10} cycloalkyl, and combinations thereof.

11. The thermoplastic material of claim 9, wherein the aromatic group is selected from the group consisting of: a benzene, a heteroarene, or derivatives thereof, and combinations thereof.

12. The thermoplastic material of claim 9, wherein the intermediate layer comprises:

a polyanhydride of Formula I, wherein R is an aliphatic group; and

a polyanhydride of Formula I, wherein R is an aromatic group.

13. The thermoplastic material of claim 8, wherein the thermoplastic surface comprises at least one of: acrylonitrile butadiene styrene (ABS), acrylic (PMMA), celluloid, cellulose acetate, cyclic olefin copolymer (COC), ethylene-vinyl acetate (EVA), ethylene vinyl alcohol (EVOH), efluoroplastics (PTFE, alongside with FEP, PFA, CTFE, ECTFE, ETFE), ionomers, kydex, a trademarked acrylic/PVC alloy, liquid crystal polymer (LCP), polyoxymethylene (POM or acetal), polyacrylates (Acrylic), polyacrylonitrile (PAN or acrylonitrile), polyamide (PA or Nylon), polyamide-imide (PAI), polyaryletherketone (PAEK or Ketone), polybutadiene (PBD), polybutylene (PB), polybutylene terephthalate (PBT), polycaprolactone (PCL), polychlorotrifluoroethylene (PCTFE), polyethylene terephthalate (PET), polycyclohexylene dimethylene terephthalate (PCT), polycarbonate (PC), polyhydroxyalkanoates (PHAs), polyketone (PK), polyester, polyethylene (PE), polyetheretherketone (PEEK), polyetherketoneketone (PEKK), polyetherimide (PEI), polyethersulfone (PES), chlorinated polyethylene (CPE), polyimide (PI), polylactic acid (PLA), polymethylpentene (PMP), polyphenylene oxide (PPO), polyphenylene sulfide (PPS), polyphthalamide (PPA), polypropylene (PP), polystyrene (PS), polysulfone (PSU), polytrimethylene terephthalate (PTT), polyurethane (PU), polyvinyl acetate (PVA), polyvinyl chloride (PVC), polyvinylidene chloride (PVDC), styrene-acrylonitrile (SAN) and combinations thereof.

14. The thermoplastic material of claim 9, wherein the thermoplastic material is part of an automotive part, electrical or electronic equipment.

15. A method of processing a thermoplastic material, the method comprising:

providing a thermoplastic material comprising:

a thermoplastic surface;

a protective outer coating; and

a degradable intermediate layer that associates the protective coating with the thermoplastic surface;

breaching the protective outer coating to expose the degradable intermediate layer; and

removing the degradable intermediate layer to thereby remove the protective outer coating, thereby processing the thermoplastic material.

16. The method of claim 15, wherein processing further comprises recycling the thermoplastic material.

17. The method of claim16, wherein breaching comprises shredding, chipping, crushing, or scoring the protective outer coating, the thermoplastic material, or both.

18. The method of claim 16, wherein removing the degradable intermediate layer comprises dissolving the degradable intermediate layer.

19. The method of claim 18, wherein dissolving comprises exposing the degradable intermediate layer.

20. The method of claim 16, wherein the degradable intermediate layer comprises a polyanhydride.

21. The method of claim 20, wherein removing the degradable intermediate layer comprises exposing the degradable intermediate layer and depolymerizing the polyanhydride to form a deopolymerized monomer.

22. A method of protecting a thermoplastic surface, the method comprising:

providing a protective coating over a thermoplastic surface, wherein the protective coating is adhered to the thermoplastic surface by a degradable intermediate layer.

23. A method of making a protective coating for a thermoplastic material, the method comprising:

providing a thermoplastic material comprising a thermoplastic surface;

applying a degradable layer over the thermoplastic surface; and

applying a protective coating over the degradable layer, thereby making a protective coating for a thermoplastic material.

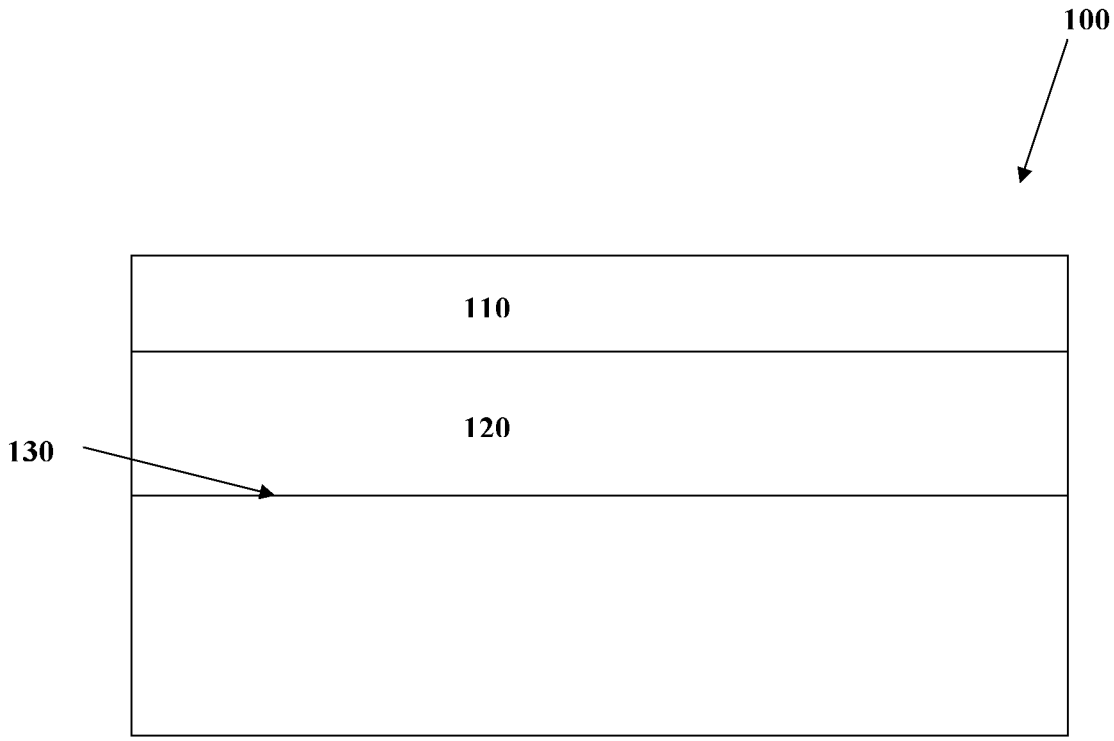


Figure 1

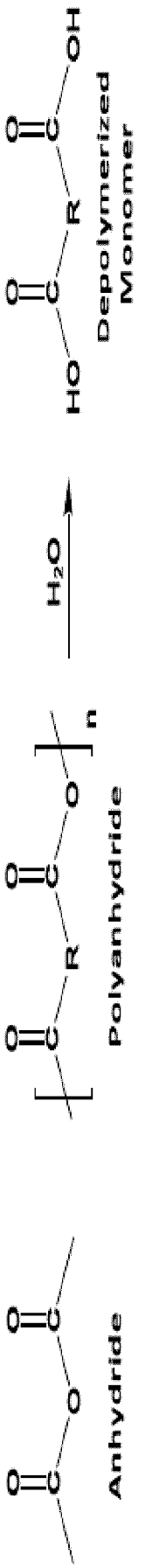

Anhydride
Polyanhydride
n
H_2O
Depolymerized Monomer
OH
HO
R
O

Figure 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/031627

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

C08J 7/04 (2006.01) ***B29B 17/02*** (2006.01)

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)

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)
EPODOC, WPI, CAPLUS, JAPIO: Key words: thermoplastic, polymer, coating, surface layer, remove, release, strip, bonding, layer, intermediate, tie, degrade, depolymerise, break down, dissolve, recycle, polyanhydride

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2011/130855 A1 (MYLAN GROUP) 27 October 2011 Paragraph 18	1-7, 15-19, 22-23
X	US 2011/0104602 A1 (YU et al) 5 May 2011 Paragraphs 14, 25, 39 and 44	1-7, 15-19, 22-23

[X] Further documents are listed in the continuation of Box C [X] 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	Date of mailing of the international search report
02 May 2012	10 May 2012
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer **CATHY DOUGLAS** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 2664

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 1999/058328 A2 (EASTMAN CHEMICAL COMPANY) 18 November 1999 Abstract, pages 3 and 8, page 10 lines 22-26, page 20 lines 19-29	1-7, 15-19, 22-23
X	US 5534556 A (BAUER) 9 July 1996 Abstract, column 2 lines 30-35, column 4 line 27	1-7, 15-19, 22-23
X	US 2006/0194010 A1 (HISCOCK) 31 August 2006 Abstract, paragraphs 5, 57, 73, claim 3	1-7, 15-19, 22-23
X	US 2008/0210120 A1 (FOUKES et al) 4 September 2008 Abstract, paragraphs 50 and 56	1, 3-7, 15-17 22-23
X	WO 2011/059625 A1 (EMPIRE TECHNOLOGY DEVELOPMENT LLC) 19 May 2011 Abstract, claim 5	1, 3-7, 22-23
X	JP 2002-256442 A (DAISHIN KAGAKU KK; OMURA TORYO KK; TOKYO SANYO ELECTRIC CO) 11 September 2011 Paragraphs 12, 14, 16, 19 and 36	1-7, 15-19, 22-23
Y		8-14, 20-21
Y	US 5270419 A (DOMB) 14 December 1993 Column 8 lines 60-65	8-14, 20-21

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2012/031627

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
WO	2011130855	US	2011277653				
US	2011104602	JP	2011100127				
WO	9958328	AR	016475	AU	40717/99		
US	5534556	DE	4323558	JP	7149942		
US	2006194010	NONE					
US	2008210120	NONE					
WO	2011059625	US	2011114260				
JP	2002256442	NONE					
US	5270419	AU	26444/92	AU	72257/91	CA	2073561
		CA	2083161	CA	2118584	EP	0511292
		EP	0532638	EP	0605536	FI	941087
		IE	910100	JP	H05505632	JP	H06503588
		JP	H07503030	NO	940837	NZ	236807
		US	5171812	US	5175235	US	5179189
		US	5240963	US	5317079	WO	9110696
		WO	9118940	WO	9305096	ZA	9100381

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX