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(54) Title: RECYCLABLE WIRELESS CONSTRUCTIONS

(57) Abstract: Recyclable wireless constructions, and methods of making, and methods of using the recyclable constructions are disclosed.

WO 2025/003922 A1

RECYCLABLE WIRELESS CONSTRUCTIONS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application Serial Number 63/511,448, filed on June 30, 2023, and U.S. Provisional Application Serial Number 63/610,594 filed on filed on December 15, 2023, both of which are incorporated herein in their entirety.

FIELD OF THE INVENTION

[0002] The present invention generally relates to recyclable wireless constructions, and methods of making and methods of using the recyclable constructions.

BACKGROUND OF THE INVENTION

[0003] Wireless inlays are utilized on and in a wide range of objects, for various uses. There are a variety of different wireless inlays, for example ultra-high frequency (UHF), near field communication (NFC), bluetooth low energy (BLE), long term evolution (LTE), and electronic article surveillance (EAS) inlays. The type of inlay selected depends on the desired use. For example, RFID inlays are commonly used on articles to be tracked. In the retail field, tracking is often used to help businesses determine when they need to restock a particular product, or to keep track of where specific items of inventory are located. In commercial retail, plastic is typically used in product packaging, and many products are themselves made of plastic. To mitigate their negative effect on the environment, plastic articles are often recycled. To achieve this, the articles are sorted, shredded into flakes, washed, and dried. During the washing process, heavier materials sink in the washwater, while lighter materials float. However, plastic articles and packaging to which wireless inlays have been attached typically cannot undergo recycling.

[0004] Conventional wireless inlays are typically not recyclable, as they are unable to go through plastic recycling waste streams. Conventionally, wireless inlays include an antenna and, for intelligent inlays such as RFIDs, a chip, attached to a support (typically a polyethylene terephthalate (PET) support). A pressure sensitive adhesive can be applied to the support, thereby enabling the inlay to be adhered to an article. A large proportion of plastic articles, such as for example plastic bottles, plastic containers, and plastic packaging are made of the same material as the wireless inlay support. The plastic recycling process includes the separation of materials having different densities. Materials having a density of greater than 1 g/cubic centimeter will sink in the wash water, while materials having a density of less than 1 g/cubic centimeter will float in the wash water. If one were to shred an article to which is

adhered an inlay including a support made of the same or similar composition as the support or having the same or similar density as the support, and put the shredded pieces in a recycle stream, disadvantageously, the pieces of the article will sink, along with the inlay, due to the support. Accordingly, the recycling attempt would not be successful, as the inlays would not be separated from the article pieces. Rather, the inlays would be mixed with the article pieces, preventing the inlay-free pieces from being collected for processing into a new article.

[0005] PET films are highly preferred as the material for inlay carriers, for a variety of reasons. PET has dimensional stability, which ensures that the antenna and any adhesive adhering the antenna to the support will be precisely placed on the PET support, without stretching of the PET during processing. The inlay antenna is typically an aluminum that has been deposited on the PET, for example by printing or etching, or by deposition on an adhesive, followed by die cut or laser cutting. The precise placement of the adhesive, and of the antenna on the PET support is extremely important for the proper functioning of the wireless device. The dimensional stability and heat stability of PET ensures that the PET support will not stretch or shrink, ensuring that the antenna, and if present, the adhesive, will remain precisely oriented during their deposition on the PET support. Further, PET is non-toxic, and is a good barrier material, which is makes it suitable for use for food applications.

[0006] Some have used foam or heat shrinkable films as RFID supports. However, foam suffers from the disadvantages of having a lower dimensional stability, a higher cost, and greater processing difficulty than PET. Further, foam supports typically have a thickness of at least 500 µm, which is larger than PET supports, making them too bulky for many applications, such as labels. Additionally, the size of heat shrinkable carriers is limited with regard to the size of antenna that can be used with the specific carrier, and if one departs from these limitations, the performance of the antenna will be negatively affected.

[0007] Accordingly, there remains a need for alternative wireless inlays that are recyclable. Also desired are such device inlays that can at least one of, meet performance requirements, pass the metal detection test, and avoid lost aluminum areas. The constructions and methods of the present invention are directed toward these, as well as other, important ends.

SUMMARY OF THE INVENTION

[0008] The invention relates generally to compositions and methods for removing labels from articles to be recycled.

[0009] In one aspect, the invention is directed to a recyclable construction comprising: a first carrier having a first surface and a second surface, wherein the first carrier comprises a heat stable polymeric film having a density of less than 1 g/cubic centimeter; a wireless identification device, having

a first surface and a second surface, disposed on at least a portion of one of the first surface and the second surface of the first carrier; and a pressure sensitive adhesive, having a first surface and a second surface, wherein the pressure sensitive adhesive is capable of bonding the recyclable construction to a substrate, and capable of debonding from the substrate.

[0010] In another aspect, the invention is directed to a method of making the recyclable construction of the first aspect comprising the steps of: providing the first carrier, disposing the wireless identification device on at least a portion of one of the first surface and the second surface of the first carrier, and disposing the pressure sensitive adhesive on an outer layer of the recyclable construction.

[0011] In a further aspect, the invention is directed to a method of recycling the recyclable construction of the first aspect, comprising the steps of: providing the recyclable construction bonded to the substrate of an article; subjecting the article to mechanical recycling conditions, thereby debonding the pressure sensitive adhesive from the article; and recovering the debonded recyclable construction.

[0012] The summary of the invention is provided as a general introduction to some of the embodiments of the invention, and is not intended to be limiting. Additional example embodiments, including variations and alternative configurations, of the invention are provided herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention, and together with the description, serve to explain the principles of the invention. In the drawings:

[0014] FIG. 1 illustrates an exemplary embodiment of a side view of a recyclable construction according to aspects of the disclosure.

[0015] FIG. 2 illustrates an exemplary embodiment of a side view of a recyclable construction according to aspects of the disclosure.

[0016] FIG. 3 illustrates an exemplary embodiment of a side view of a recyclable construction according to aspects of the disclosure.

[0017] FIG. 4 illustrates a side view of a recyclable construction according to aspects of the disclosure.

[0018] FIG. 5 illustrates a side view of a recyclable construction according to aspects of the disclosure.

[0019] FIG. 6 illustrates a side view of a recyclable construction according to aspects of the disclosure.

[0020] FIG. 7 illustrates a side view of a recyclable construction according to aspects of the disclosure.

[0021] FIG. 8 illustrates a side view of a recyclable construction according to aspects of the disclosure.

[0022] FIG. 9 illustrates a side view of a recyclable construction according to aspects of the disclosure.

[0023] FIG. 10 illustrates a side view of a recyclable construction according to aspects of the disclosure.

[0024] FIG. 11 illustrates a side view of a recyclable construction according to aspects of the disclosure.

[0025] FIG. 12 illustrates a side view of a recyclable construction according to aspects of the disclosure.

[0026] FIG. 13 illustrates a side view of a recyclable construction according to aspects of the disclosure.

[0027] FIG. 14a illustrates a side view of a recyclable construction according to aspects of the disclosure.

[0028] FIG. 14b illustrates a side view of a recyclable construction according to aspects of the disclosure.

[0029] FIG. 14c illustrates a side view of a recyclable construction according to aspects of the disclosure.

It will be noted that the recyclable constructions, and their respective parts in the figures are for illustrative purposes only, and are not drawn to scale.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Definitions

[0030] As employed above and throughout the disclosure, the following terms, unless otherwise indicated, shall be understood to have the following meanings.

[0031] As used herein, the terms “comprises,” “comprising,” “includes,” “including,” “has,” “having” or any other variation thereof, are intended as open-ended and cover a non-exclusive inclusion. For example, a process, method, article, or apparatus that comprises a list of elements is not necessarily limited to only those elements but may include other elements not expressly listed or inherent to such

process, method, article, or apparatus. Also, use of "a" or "an" is employed to describe elements and components described herein. This is done merely for convenience and to give a general sense of the scope of the invention. This description should be read to include "one" or "at least one" and the singular also includes the plural, unless it is obvious that it is meant otherwise by the context. As used herein, the term "about," when referring to a measurable value such as an amount, a temporal duration, and the like, is meant to encompass variations of ±10%, preferably, ±8%, more preferably, ±5%, even more preferably, ±1%, and yet even more preferably, ±0.1% from the specified value, as such variations are appropriate to perform the disclosed methods.

[0032] As used herein, "article" means an item or object. Suitable examples of articles used in the context of this invention include, but are not limited to packaging articles, such as for example containers, bottles, clam shell containers, flexible packaging containers, food containers, and non-food containers.

[0033] As used herein, "wireless identification device" means a device that utilizes wireless technology to communicate with another device. Examples include ultra-high frequency (UHF), near field communication (NFC), bluetooth low energy (BLE), long term evolution (LTE), and electronic article surveillance (EAS) inlays. Wireless identification devices can be passive or active. Passive devices do not include an internal power source, and are powered by electromagnetic energy transmitted from a reader. Different types of passive tags operate on different frequencies. Active devices include an internal power source, and continuously broadcast their own signal.

[0034] As used herein, "integrated circuit" or "chip" means a piece of hardware that is designed to implement one or more functions. Integrated circuits or chip can form, for example, a sensor or a transmission-reception device, have a data or memory processing capacity, and other functions. Integrated circuits or chips typically have a planar structure (whose overall shape is usually that of a small plate), include one or more semiconductor materials (as well as other materials, in particular metallic materials and/or electrically insulating oxides), and can integrate various components, active or passive (for example transistor, diode, resistor, radiating or guiding structure).

[0035] As used herein, "conductive" means able to conduct electricity or induce electrical currents.

[0036] "Conductive materials" as used herein means materials that are able to conduct electricity or induce electrical currents.

[0037] As used herein, the term "antenna" means a structure used to transmit or receive electromagnetic waves.

[0038] As used herein, the term "carrier" means a layer of polymeric film material optionally containing a release coating, to which a wireless identification device can be attached. The carrier has

two sides, including a side that is outward facing and that can receive a wireless identification device directly or by adhesion, and the other side that can receive a pressure sensitive adhesive. The thickness of the carrier typically ranges from 12 μm to 200 μm. In some embodiments, the carrier has a thickness of 12 μm to 150 μm, 12 μm to 100 μm, 12 μm to 50 μm, no more than 200 μm, no more than 150 μm, no more than 100 μm, or no more than 50 μm.

[0039] As used herein, "pressure sensitive adhesive" or "PSA" refers to a material that may be identified by the Dahlquist criterion, which defines a pressure sensitive adhesive as an adhesive having a one second creep compliance of greater than $1x10^{-6}$ cm^2/dyne as described in *Handbook of PSA Technology,* Donatas Satas (Ed.), 2nd Edition, page 172, Van Nostrand Reinhold, New York, N.Y., 1989. Since modulus is, to a first approximation, the inverse of creep compliance, pressure sensitive adhesives may also be defined as adhesives having a Young's modulus of less than $1x10^6$ dynes/cm^2. Another well-known means of identifying a pressure sensitive adhesive is an adhesive that is aggressively and permanently tacky at room temperature and firmly adheres to a variety of dissimilar surfaces upon mere contact, without the need of more than finger or hand pressure, and which may be removed from smooth surfaces without leaving a residue, as described in *Glossary of Terms Used in the Pressure Sensitive Tape Industry* provided by the Pressure Sensitive Tape Council, 1996. Another suitable definition of a suitable pressure sensitive adhesive is that it preferably has a room temperature storage modulus within the area defined by the following points as plotted on a graph of modulus versus frequency at 25°C: a range of moduli from about $2x10^5$ to $4x10^5$ dynes/cm^2 at a frequency of about 0.1 radians/sec (0.017 Hz), and a range of moduli from about $2x10^6$ to $8x10^6$ dynes/cm^2 at a frequency of approximately 100 radians/sec (17 Hz). See, for example, *Handbook of PSA Technology* (Donatas Satas, Ed.), 2nd Edition, page 173, Van Nostrand Rheinhold, N.Y., 1989.

[0040] As used herein, "permanent adhesive" refers to an adhesive that is not easily removable without total or partial destruction of the construction of which it is a part. Permanent adhesives present adhesion values greater than 230 N/m, based on FINAT (Féderation Internationale des fabricants et transformateurs d'Adhésifs et Thermocollants sur papiers et autres supports (International Federation of Manufacturers and Converters of Adhesives and Iron-Ons on Paper and Other Supports)) Test Method 1 - Peel adhesion (180°) at 300 mm/minute. Any suitable permanent adhesive can be used, such as for example an acrylic emulsion based, acrylic solvent based, acrylic hot melt, acrylic UV based or rubber hot melt adhesive. Examples of commercially available permanent adhesives are Fasson™ S7000, Fasson™ S692N, Multicycle™ M7500, Fasson™ S8029, and Truecut™ S2550 adhesive, each of which is available from Avery Dennison Corporation (located in Ohio, USA), and Aquence AV 7595 (available from Henkel Corporation, located in Connecticut, USA).

[0041] As used herein, a "wash-off adhesive" (also "washoff adhesive" or "wash off adhesive" means an adhesive having a chemistry that enables the adhesive to dissolve, dissociate, or release from an underlying polymer, or plastic, surface under typical mechanical recycling conditions (e.g., a caustic wash utilizing NaOH) without the need for further processing steps to render the underlying polymer, or plastic, packaging article suitable for a circular recycling stream that does not downgrade the material. Any suitable wash-off adhesive may be used, such as for example a synthetic polymer based adhesive (for example an acrylic or rubber hotmelt adhesive), or a bioderived adhesive. Examples of commercially available wash-off adhesives include the Henkel Re adhesives, such as for example Loctite Liofol LA 4220 RE/Loctite Liofol LA 3180 RE, a two-component adhesive system, and Aquence PS 3682 (each commercially available from Henkel Corporation, located in Connecticut, USA), the Cleanflake™ adhesives, such as for example S3010, S7000 ER, S7400 ER and S692N ER (commercially available from Avery Dennison Corporation, located in Ohio, USA), and Flexcryl™ ClearCycle 1000 (commercially available from Bostik, located in France).

[0042] As used herein, a "dissolvable coating" means a coating composition that is capable of being dissolved in a solute. In other words, a dissolvable coating is capable of becoming incorporated into a liquid (such as for example water or water-based liquids) so as to form a solution. The dissolvable coating may be tacky (such as a dissolvable adhesive as described herein-below), or it may be inherently non-tacky and/or non-pressure sensitive. Any suitable dissolvable coating may be used, such as for example water soluble coatings such as polyvinyl alcohols. Examples of commercially available dissolvable polyvinyl alcohol coating include the S1500 Series polyvinyl alcohols (available from SNP, Inc., located in North Carolina, USA).

[0043] As used herein, a "dissolvable adhesive" means a tacky or pressure sensitive composition that is capable of being dissolved in a solute. The dissolvable adhesive is a type of dissolvable coating. In other words, a dissolvable adhesive is capable of becoming incorporated into a liquid so as to form a solution. Any suitable dissolvable adhesive may be used, such as for example a synthetic polymer based (for example an acrylic adhesive), or a bioderived adhesive. Examples of commercially available dissolvable adhesives include Herma Adhesive 62P adhesives, such as for example product codes 16820, 16822, 16889, 16909 and 16958 and the 62RPW and 52W adhesives (available from Herma Company, located in Germany), and WX6030, WW2031 and WW4031 adhesives (available from Henkel Corporation, located in Ohio, USA).

[0044] As used herein, "debonding" as related to an adhesive, means no longer adhering or sticking to an adherend or substrate material to which an adhesive was attached, while "debondable" means capable of no longer adhering or sticking to an adherend or substrate material to which an adhesive was attached. An "adhesive that is capable of debonding" or "configured for debonding" can be capable

of debonding by any suitable means. For example, it may be a wash-off adhesive that debonds due to being washed off, or it may be a dissolvable adhesive that debonds due to dissolving in a solution.

[0045] As used herein, the term "bioderived" refers to derived from biological sources, such as for example animal protein, such as for example casein.

[0046] As used herein, the term "film" refers to an object that has one dimension (thickness) that is relatively small compared to the other two dimension (length and width). The surface of a film defined by its length and width is also known as the "face" of the film (or as a first face and second face).

[0047] As used herein, "heat stable film" means a film meets the ASTM Standard D1204 for dimensional stability, and under the ASTM Standard D1204 test conditions, experiences a shrinkage of no more than 0.5% in the machine direction, and no more than 0.5% in the cross direction.

[0048] As used herein, "heat shrinkable film" means a film that is stretched and, or oriented during production, and shrinks or reduces in size, thereby losing its structure, upon exposure to heat at or above a certain shrink inducing temperature. Built in stresses in the heat shrinkable film remain stable until a certain level of heat energy is applied. Upon application of this thermal energy, the in-built stresses are released, causing the transitioning of the film from a stretched state, to an unstretched state. Heat shrinkable films will shrink when exposed to heat during the recycling wash process, and thereby detach from an article to which they are attached.

[0049] As used herein, "polymeric film" means a film including at least one of polymers, copolymers (e.g., polymers formed using two or more different monomers), oligomers, and combinations thereof.

[0050] As used herein, "copolymer" is used herein to refer to polymers containing copolymerized units of at least two different monomers (e.g., a dipolymer).

[0051] As used herein, the expression "biaxially oriented polypropylene" or "BOPP" means a film or laminate that has been stretched in both the machine direction (MD), and cross (CD) or traverse direction (TD).

[0052] As used herein, the prefix "(meth)acryl-" refers to both "methacryl-" and "acryl-", such as in "(meth)acrylic" (meaning both methacrylic and acrylic), "(meth)acrylate" (meaning both methacrylate and acrylate), and "(meth)acrylonitrile" (meaning both methacrylonitrile and acrylonitrile). The term "(meth)acrylate" refers to monomeric acrylic or methacrylic esters of alcohols. Acrylate and methacrylate monomers are referred to collectively herein as "(meth)acrylate" monomers. Polymers prepared from (meth)acrylate monomers are referred to as (meth)acrylate polymers.

[0053] As used herein, the term "acrylic polymer" refers to at least one (meth)acrylate homopolymer or copolymer and may include a blend of different (meth)acrylate polymers and copolymers.

[0054] As used herein, the phrase “densified” means made more dense, for example, by the addition of a material having a density greater than that of the substance to which it is added.

[0055] As used herein, the phrase “de-densified” means made less dense, for example, by the addition of a material having a density less than that of the substance to which it is added, or by the introduction of voids within a material.

[0056] By “filler” is meant herein refers to particles or fibers added to polymeric compositions to improve or change properties (such as density, tensile strength, toughness, heat resistance, color, and clarity), provide a cost advantage, or a combination thereof. Fillers can be more dense or less dense than the materials to which they are added, depending on the filler. Typical fillers include, but are not limited to, calcium carbonate (ground or precipitated), kaolin, talc, carbon black, and the like.

[0057] By “pigment” is meant herein an organic, inorganic or synthetic substance that imparts whiteness or color, especially a powdered substance that can be mixed with a liquid in which it is relatively insoluble and that is typically used to impart color to coating materials (such as paints) or to polymers, inks, plastics, and rubber.

[0058] As used herein, the phrase “liner” means a film sheet (typically paper such as kraft or glassine, or polymeric film such as PET or polyolefin, usually applied during the manufacturing process, used to prevent a sticky surface from prematurely adhering to a substrate. It is coated on one or both sides with a release agent, which provides a release effect against any type of a sticky material, such as an adhesive or a mastic. The release agent may be applied at a coating level of 0.5-3 gsm.

[0059] As used herein, “gsm” means grams per square meter.

[0060] As used herein, a “caustic” means a highly basic or alkali compound. Examples include alkali metal hydroxides (such as for example a NaOH, KOH, and LiOH).

[0061] As used herein, a “surfactant” means a substance having both hydrophilic and hydrophobic characteristics, and which, when added to a liquid, reduces the surface tension of that liquid.

[0062] As noted herein-above, conventional wireless inlays are typically not recyclable. When a wireless inlay is placed on an article having the same or a similar density, the wireless inlay cannot be separated from the article to which it is attached during the recycling process. PET, the conventionally preferred wireless inlay support, is often used on wireless inlays that will be attached to an article that is also made of PET. For example, RFIDs, which conventionally have a PET support, are often adhered to articles that are also made of PET. During the recycling process, the article to be recycled is ground into flakes, which are then placed in a heated washwater, typically including a caustic or surfactant. The heavier flakes will sink, while the lighter flakes will float in the washwater. If both the flakes of the inlay support and the flakes of the article to which the inlay is attached are made of the same material, then all

of the flakes will sink or float, depending on their density, making their separation by a sink-float method impossible. For example, if both the flakes of the inlay support and the flakes of the article to which the inlay is attached are made of the PET, then all of the flakes will float, making their separation by sink-float impossible. Accordingly, it is not possible to separate the flakes having an antenna attached to their surface from the flakes that are antenna-free. This is disadvantageous, as a key requirement of the process of recycling articles is sorting materials by type, and recovering clean article flakes for processing into a new article. Thus, the wireless inlay should be able to be separated from the article to which the inlay is attached.

[0063] The present invention generally relates to recyclable wireless inlay constructions, and methods of making and methods of using the recyclable constructions. The recyclable construction includes a first carrier, a wireless identification device, and a pressure sensitive adhesive. The first carrier has a first surface and a second, oppositely directed surface. The first carrier is a heat stable polymeric film. In some embodiments, the first carrier is not a heat shrinkable film.

[0064] In some embodiments, the heat stable polymeric film has a density of less than 1 g/cubic centimeter. The polymeric film having a density of less than 1 g/cubic centimeter can be separated, in a recycling sink-float process, from an article to which the construction is attached, having a density of greater than 1 g/cubic centimeter, as the less dense polymeric film will float in the washwater, while the more dense article will sink. The polymeric material having a density of less than 1 g/cubic centimeter can be made of any suitable material. In some embodiments, the polymeric film having a density of less than 1 g/cubic centimeter is a polyolefin. In some embodiments, the polyolefin is at least one of a polypropylene and a polyethylene. In some embodiments, the polypropylene is a biaxially oriented polypropylene (BOPP). In some embodiments, the polymeric material is not a foam.

[0065] In some embodiments, the heat stable polymeric film has a density of greater than 1 g/cubic centimeter. The polymeric film having a density of greater than 1 g/cubic centimeter can be separated, in a recycling sink-float process, from an article to which the construction is attached, having a density of less than 1 g/cubic centimeter, as the more dense polymeric film will sink in the washwater, while the less dense article will float. The polymeric material having a density of less than 1 g/cubic centimeter can be made of any suitable material, as is described herein-below. In some embodiment, the polymeric film is not a polyester. In some embodiment, the polymeric film is not a polyethylene terephthalate.

[0066] The recyclable construction may include any suitable wireless identification device, several of which are readily commercially available. The wireless identification device has a first surface and an oppositely directed second surface, disposed on at least a portion of the first surface of the first carrier. Wireless identification devices are well known in the art. They include a conductive material that

serves as an antenna for the device. In some embodiments, the conductive material is a conductive ink. Any suitable conductive ink can be used. Many conductive inks are readily commercially available. After being laid down or printed, the conductive ink forms a printed object that is capable of conducting electricity. In some embodiments, the wireless identification device is formed by printing a conductive ink onto the carrier, in the shape of an antenna. The conductive ink can include any suitable conductive material, for example, in some embodiments, the conductive ink includes at least one of a copper, silver, carbon, platinum, gold, palladium, ruthenium, nickel, zinc, an alloy of any of the foregoing, graphene or carbon nanotubes. In some embodiments, the conductive material is etched onto the carrier. In some embodiments, the conductive material is adhered to the carrier. In some embodiments, the wireless identification device is adhered to the carrier by a first permanent adhesive. Any suitable permanent adhesive can be used, such as for example an acrylic emulsion based, acrylic solvent based, acrylic hot melt, acrylic UV based or rubber hot melt adhesive. Examples of commercially available permanent adhesives are Fasson™ S7000, Fasson™ S692N, Multicycle™ M7500, Fasson™ S8029, and Truecut™ S2550 adhesive, each of which is available from Avery Dennison Corporation (located in Ohio, USA), and , Aquence AV 7595 (available from Henkel Corporation, located in Connecticut, USA). In some embodiments, the first permanent adhesive is an acrylic emulsion based adhesive. In some embodiments, the first permanent adhesive is not a hot melt adhesive. In some embodiments, the first permanent adhesive is deposited on at least a portion of the carrier in the shape of an antenna. In some embodiments, the conductive material is deposited onto at least a portion of the surface of the first permanent adhesive. In some embodiments, the conductive material that is deposited onto at least a portion of the surface of the first permanent adhesive has the same, or substantially the same shape and size as the first permanent adhesive. In some embodiments, the conductive material that is deposited onto at least a portion of the surface of the first permanent adhesive has a larger size than the first permanent adhesive. In some embodiments, the conductive material that is deposited onto at least a portion of the surface of the first permanent adhesive has a larger area than the first permanent adhesive. In some embodiments the conductive material is then die cut or laser cut, or both, so that the resulting conductive material has the same, or substantially the same shape and size as the underlying first permanent adhesive. In some embodiments the conductive material is die cut. In some embodiments the conductive material is laser cut.

[0067] In some embodiments, the wireless identification device includes only a conductive material that functions as an antenna. In some embodiments, the wireless identification device includes a conductive material connected to an integrated circuit or chip. In some embodiments, the integrated circuit is directly attached to the conductive material. In some embodiments, the wireless identification device further includes a strap, also known as an interposer. When a strap is used, rather than being

coupled directly with the conductive material, the integrated circuit is coupled to strap leads (also known as interposer leads), forming a strap that is then coupled to the conductive material, as is described, for example in US6940408B2 and US8072333B2, herein incorporated by reference. These leads provide a larger effective electrical contact area than integrated circuits precisely aligned for direct placement without a strap. The larger area reduces the accuracy required for placement of integrated circuits during manufacture, while still providing effective electrical connection. This is advantageous, as integrated circuit placement and mounting are serious limitations for high-speed manufacture. In some embodiments, the strapincludes a polymeric film having a density of less than 1 g/cubic centimeter. In some embodiments, the polymeric film having a density of less than 1 g/cubic centimeter is a polyolefin. In some embodiments, the polyolefin is at least one of a polypropylene and a polyethylene. In some embodiments, the polypropylene is a biaxially oriented polypropylene (BOPP). In some embodiments, the polymeric film of the strap is a cavitated film. In some embodiments, the strap is a film that has been cavitated by at least one cavitating agent in the film. By "cavitating agent" is meant herein at least one particle that induces micro-voids in a material. The presence of the cavitating agent in the carrier during the orientation of the film induces micro-voids. With a high degree of voiding, the film density can be reduced accordingly. Any suitable cavitating agent can be used. In some embodiments, the cavitating agent is a void-initiating particle including at least one of an organic polymer or an inorganic material. In some embodiments, the cavitating agent is a void-initiating particle including an organic polymer, such as for example, a polyamide, (such as for example, nylon-6), a polyester (such as for example polybutylene terephthalate (PBT)), an acrylic resin, or combinations thereof. In some embodiments, the cavitating agent is a void-initiating particle including an organic polymer, such as for example cyclic olefin polymers, cyclic olefin copolymers, ethylene norbornene copolymers, or combinations thereof. In some embodiments, the cavitating agent is a void-initiating particle including an inorganic polymer, such as for example, a glass, metal, ceramic, silica, calcium carbonate (CaCO3), clay, talc, or combinations thereof. In some embodiments, at least a portion of the film layer is an oriented polypropylene (PP) film, and the cavitating agent is a beta-nucleating PP. In some embodiments, at least one non-cavitated skin is disposed on at least one face of the cavitated film. In some embodiments, the cavitated film is sandwiched between two non-cavitated skins. The non-cavitated film provides support to the cavitated film. In some embodiments the cavitated film is a cavitatated PET film.

[0068] Any suitable wireless identification device can be used. In some embodiments, the wireless identification device is an RFID device. In general, RFID tags can retain and transmit enough information to uniquely identify individuals, packages, inventory and the like. RFID tags and labels also can be characterized as those to which information is written only once (although the information may be read repeatedly), and those to which information may be written during use. In some embodiments,

the wireless identification device is a RFID passive device that does not include a power source. In the case of passive tags, in order to retrieve the information from the chip, a “base station” or “reader” sends an excitation signal to the wireless identification device to wake up the device. The excitation signal energizes the wireless identification device, and the RFID circuitry transmits the stored information back to the reader. The “reader” receives and decodes the information from the wireless identification device. In some embodiments, the wireless identification device is an active RFID device that does include a power source.

[0069] In some embodiments, the wireless identification device is selected from a ultra-high frequency device (UHF), a near field communication device (NFC), a bluetooth low energy device (BLE) a long term evolution device (LTE) and an electronic article surveillance (EAS) device. In some embodiments, the wireless identification device is a UHF device. UHF devices are passive RFID devices that use a frequency ranging of about 865 MHz to 928 MHz. This frequency range provides long read distances. In some embodiments, the wireless identification device is not an RFID device. In some embodiments, the wireless identification device is an NFC device. NFC devices are passive devices that typically use a smartphone or tablet that has NFC capabilities. Read ranges for NFC devices are short, typically no more than 1.6 inches. In some embodiments, the wireless identification device is a BLE device. BLE devices are passive devices that use the same radio wavebands as Bluetooth (about 2.402GHz to 2.48GHz) and provide a read range of about 100 meters. In some embodiments, the wireless identification device is an LTE device, also known as a 4G device. LTE devices are used in devices for communication with a wireless cellular networks (uses 450 MHz – 3.8 GHz).

[0070] The recyclable construction further includes a pressure sensitive adhesive. The PSA has a first surface and an oppositely directed second surface. In some embodiments, the PSA is disposed on at least a portion of the wireless identification device. In some embodiments, the PSA is disposed on at least a portion of at least one of the first surface and second surface of the wireless identification device. In some embodiments, the PSA is disposed on all or substantially all of the first surface of the wireless identification device. In some embodiments, the PSA is disposed on all or substantially all of the second surface of the wireless identification device. In some embodiments, the pressure sensitive adhesive is capable of bonding the recyclable construction to a substrate. Further, in some embodiments, the PSA is capable of debonding from the substrate. In some embodiments, the PSA is capable of debonding from the substrate to which the recyclable construction has been applied, upon subjection to mechanical recycling conditions. In some embodiments, the pressure sensitive adhesive is configured to bond the recyclable construction to a substrate. Further, in some embodiments, the PSA is configured to debond from the substrate. In some embodiments, the PSA is configured to debond from the substrate to which the recyclable construction has been applied, upon subjection to mechanical recycling conditions. As

noted herein-above, adhesives that are capable of debonding under recycling conditions can be any suitable adhesive, such as for example wash-off adhesives or dissolvable adhesives. In some embodiments, the pressure sensitive adhesive is capable of remaining attached to the recyclable construction upon debonding of the pressure sensitive adhesive from the substrate. In some embodiments, the pressure sensitive adhesive is capable of removal from the recyclable construction upon debonding of the pressure sensitive adhesive from the substrate. In some embodiments, the pressure sensitive adhesive is configured to remain attached to the recyclable construction upon debonding of the pressure sensitive adhesive from the substrate. In some embodiments, the pressure sensitive adhesive is configured to remove from the recyclable construction upon debonding of the pressure sensitive adhesive from the substrate.

[0071] Any suitable PSA that will debond from the substrate under mechanical recycling conditions, can be used, such as for example wash-off adhesives and dissolvable adhesives. Suitable wash-off PSAs are well known in the art, such as for example, synthetic polymer based adhesive (for example rubber hotmelt adhesives or acrylic adhesives (for example, those described in European Patent 0618947 to Bernard, US Patent 10590315 to Mueller, and U.S. Patent 5508367, all of which are herein incorporated by reference, among others)), and bioderived adhesives. Examples of suitable commercially available wash-off adhesives include the Henkel Re adhesives, such as for example Loctite Liofol LA 4220 RE/Loctite Liofol LA 3180 RE, a two-component adhesive system, and Aquence PS 3682 (each commercially available from Henkel Corporation, located in Connecticut, USA), the Cleanflake™ adhesives, such as for example S3010, S7000 ER, S7400 ER and S692N ER (commercially available from Avery Dennison Corporation, located in Ohio, USA), and Flexcryl™ ClearCycle 1000 (commercially available from Bostik, located in France). Any suitable dissolvable adhesive may be used, such as for example a synthetic polymer based (for example an acrylic adhesive), or a bioderived adhesive. Examples of commercially available dissolvable adhesives include Herma Adhesive 62P adhesives, such as for example product codes 16820, 16822, 16889, 16909 and 16958 and the 62RPW and 52W adhesives (commercially available from Herma Company, located in Germany), and WX6030, WW2031 and WW4031 adhesives (commercially available from Henkel Corporation, located in Ohio, USA). In some embodiments, the pressure sensitive adhesive is an acrylic based adhesive. In some embodiments, the pressure sensitive adhesive selected from an acrylic emulsion based, acrylic hot melt, or rubber-based hot melt adhesive. In some embodiments, the adhesive is an acrylic emulsion based.

[0072] In some embodiments, the pressure sensitive adhesive is not capable of debonding from a substrate or not configured to debond from a substrate, in other words it is a non-debondable adhesive. In some embodiments, a dissolvable coating is disposed on a surface of the non-debondable adhesive. In some embodiments, the dissolvable coating separates the pressure sensitive adhesive from

the wireless communication device. Any suitable pressure sensitive adhesive that is not capable of debonding from a substrate may be used. Examples of suitable pressure sensitive adhesives include acrylic, and rubber-based pressure sensitive adhesive. Examples of commercially available pressure sensitive adhesives include Fasson™ S2550 and Fasson™ Z3000 (available from Avery Dennison Corporation, located in Ohio, USA), or Aquence™ AV7590 (available from Henkel Corporation, located in Germany).

[0073] In some embodiments, the recyclable construction includes at least one additional layer having a first surface and a second surface. Any suitable additional layers can be included in the recyclable construction, such as for example one or more additional carriers, one or more permanent adhesives, one or more dissolvable coatings (such as for example dissolvable adhesives). In some embodiments, the at least one additional layer is selected from the group of a second carrier, a third carrier, a first permanent adhesive, a second permanent adhesive, a dissolvable adhesive, a dissolvable coating, and any combination thereof. It will be understood that the recyclable construction can include one or more carriers. The first carrier can have a composition that is the same as or different from the additional carriers. In some embodiments, the first carrier has the same composition as at least one of the second carrier and the third carrier. In some embodiments, the first carrier has a different composition from the composition of at least one of the second and third carrier. The dissolvable coating may be dissolvable in any suitable material. In some embodiments, the dissolvable coating is dissolvable under conditions that will cause aluminum to dissolve. In some embodiments, the dissolvable coating is dissolvable in a wash composition having a pH of greater than 9. Any suitable dissolvable coating can be used, such as for example water soluble coatings such as polyvinyl alcohols. Examples of commercially available dissolvable polyvinyl alcohol coating include the S1500 Series polyvinyl alcohols (commercially available from SNP, Inc., located in North Carolina, USA).The dissolvable adhesive may be dissolvable in any suitable material. In some embodiments, the dissolvable adhesive is dissolvable under conditions that will cause aluminum to dissolve. In some embodiments, the dissolvable adhesive is dissolvable in a wash composition having a pH of greater than 9. Any suitable dissolvable adhesive can be used, such as for example a synthetic polymer based (for example an acrylic adhesive), or a bioderived adhesive. Examples of commercially available dissolvable adhesives include Herma Adhesive 62P adhesives, such as for example product codes 16820, 16822, 16889, 16909 and 16958 (commercially available from Herma Company, located in Germany), and WX6030, WW2031 and WW4031 adhesives (commercially available from Henkel Corporation, located in Ohio, USA).

[0074] The first carrier can have any suitable shape. The outer edges of that shape define the perimeter of the first carrier. In some embodiments, the first carrier has a length and width defining the perimeter of the first carrier. In some embodiments, the pressure sensitive adhesive is coextensive with

the first carrier. By "coextensive" is meant herein having the same or substantially the same sized perimeter, for example, having the same or substantially the same length and width. Accordingly, in some embodiments, the dimensions of the perimeter of the pressure sensitive adhesive are the same or substantially the same as the dimensions perimeter of the first carrier. This enables the full surface of the first carrier to be attached to an article to which the recyclable construction is to be applied. In some embodiments, the pressure sensitive adhesive extends beyond the perimeter of the first carrier. Accordingly, in some embodiments, the dimensions of the perimeter of the pressure sensitive adhesive is larger than the dimensions perimeter of the first carrier. In some embodiments, the pressure sensitive adhesive has a length that is greater than the length of the first carrier and a width that is greater than the width of the first carrier. In some embodiments, the pressure sensitive adhesive has at least one of a length that is greater than the length of the first carrier, and a width that is greater than the width of the first carrier. In some embodiments, the pressure sensitive adhesive has a length that is greater than a length of the first carrier. In some embodiments, the pressure sensitive adhesive has an area that is greater than the area of the first carrier. In some embodiments, at least one of the length, width, perimeter, area and circumference of the pressure sensitive adhesive extends beyond the corresponding length, width, perimeter, area and/or circumference of the first carrier. When the pressure sensitive adhesive extends beyond the perimeter of the first carrier, this advantageously enables the pressure sensitive adhesive to secure the wireless identification device to the substrate to which the recyclable construction is to be attached, without the need to use an adhesive to adhere the wireless identification device directly to the substrate. As noted hereinabove, during the recycling process, articles are typically sorted, shredded into flakes, washed, and dried. During the shredding process, a majority of the portions of the first carrier that are adhered, via the PSA, to the substrate, will become detached from the portions of the first carrier that are adhered, via the PSA, to the wireless identification device. In some embodiments the pressure sensitive adhesive is a dissolvable adhesive. The dissolvable adhesive releases into the wash composition during the washing process. This enables the recovery of the adhesive-free wireless identification device during the recycling process. In some embodiments a dissolvable coating is disposed between the pressure sensitive adhesive and the wireless identification device. The dissolvable coating releases into the wash composition during the washing process, releasing the wireless identification device from the pressure sensitive adhesive. This enables the recovery of the adhesive-free wireless identification device during the recycling process. Any suitable dissolvable coating may be used, such as for example water soluble coatings such as polyvinyl alcohols. Examples of commercially available dissolvable polyvinyl alcohol coating include the S1500 Series polyvinyl alcohols (commercially available from SNP, Inc., located in North Carolina, USA).

[0075] In some embodiments, the recyclable construction further includes a first permanent adhesive. In some embodiments, the recyclable construction includes a first permanent adhesive disposed between the first carrier and the wireless identification device. This permanent adhesive serves to secure the wireless identification device to the first carrier. In some embodiments, the permanent adhesive has the same or substantially the same shape as the conductive material. In some embodiments, this enables the conductive material, where it is deposited in the shape and configuration of an antenna, to be deposited on the adhesive, where it will function as an antenna. In some embodiments, it enables a conductive material having dimensions that are larger than the deposited first permanent adhesive to be deposited onto the first permanent adhesive, and then be laser cut, die cut, or both, into the dimensions of the underlying first permanent adhesive, where it will function as an antenna.

[0076] FIG. 1 illustrates an exemplary embodiment of a side view of a recyclable construction 100 according to embodiments of the disclosure. The recyclable construction 100 includes a first carrier 110, a wireless identification device 120, and a pressure sensitive adhesive 130. The first carrier 110 has a first surface 111 and a second, oppositely directed surface 112. The wireless identification device 120 has a first surface 121 and a second, oppositely directed surface 122. The pressure sensitive adhesive 130 has a first surface 131 and a second, oppositely directed surface 132.The wireless identification device 120 is disposed on at least a portion of the first surface 111 of the first carrier 110. The pressure sensitive adhesive 130 is disposed on at least a portion of the first surface 121 of the wireless identification device 120.

[0077] FIG. 2 illustrates an exemplary embodiment of a side view of a recyclable construction 200 according to embodiments of the disclosure. The recyclable construction 200 includes a first carrier 210, a wireless identification device 220, a first permanent adhesive 240, and a pressure sensitive adhesive 230. The first carrier 210 has a first surface 211 and a second, oppositely directed surface 212. The wireless identification device 220 has a first surface 221 and a second, oppositely directed surface 222. The pressure sensitive adhesive 230 has a first surface 231 and a second, oppositely directed surface 232. The first permanent adhesive 240 is disposed between the first carrier 210 and the wireless identification device 220. Accordingly, the wireless identification device 220 is adhered to the first surface 211 of the first carrier 210 by the first permanent adhesive 240. The pressure sensitive adhesive 230 is disposed on at least a portion of the first surface 221 of the wireless identification device 220.

[0078] In some embodiments, the recyclable construction further includes a liner. When present, the liner is disposed on at least a portion of the first surface of the pressure sensitive adhesive. FIG. 3 illustrates an exemplary embodiment of a side view of a recyclable construction according to embodiments of the disclosure. The recyclable construction 300 includes a first carrier 310, a wireless identification device 320, a pressure sensitive adhesive 330, and a liner 350. The first carrier has a first

surface 311 and a second, oppositely directed surface 312. The wireless identification device 320 has a first surface 321 and a second, oppositely directed surface 322. The pressure sensitive adhesive 330 has a first surface 331 and a second, oppositely directed surface 332.The wireless identification device 320 is disposed on at least a portion of the first surface 311 of the first carrier 310. The pressure sensitive adhesive 330 is disposed on at least a portion of the first surface 321 of the wireless identification device 320. The liner 350 is disposed on at least a portion of the first surface 331 of the pressure sensitive adhesive 330.

[0079] In some embodiments, the recyclable construction further includes an additional, or second carrier. The second carrier has a first surface and a second surface. In some embodiments, the second carrier is disposed over the wireless identification device, so that is resides between the pressure sensitive adhesive and the wireless identification device. In some embodiments, the second permanent adhesive adheres at least a portion of the surface of the second carrier to at least a portion of the surface of the wireless identification device. In some embodiments, the second permanent adhesive adheres at least a portion of the surface of the second carrier to the entire, or substantially entire surface of the wireless identification device. In some embodiments, the second permanent adhesive adheres at least a portion of the second surface of the second carrier to at least a portion of the first surface of the wireless identification device. In some embodiments, the second carrier is a heat stable polymeric film. In some embodiments, the heat stable polymeric film includes a polyolefin. In some embodiments, the polyolefin is selected from a polypropylene, a polyethylene, or any combination thereof. In some embodiments, the polypropylene is a biaxially oriented polypropylene (BOPP). In some embodiments, the polymeric film is not a polyester. In some embodiments, the polymeric film is not a PET. In some embodiments, the polymeric film is not a foam. In some embodiments, the presence of the first and second carrier serves to sandwich, and thereby protect the wireless identification device. This diminishes or prevents the opportunity for the conductive material to separate from the first carrier during the wash-off process. In some embodiments, a second permanent adhesive adheres at least a portion of the surface of the second carrier to at least a portion of the surface of the wireless identification device.

[0080] FIG. 4 illustrates an exemplary embodiment of a side view of a recyclable construction according to embodiments of the disclosure. The recyclable construction 400 includes a first carrier 410, a first permanent adhesive 440, a wireless identification device 420, a second permanent adhesive 460, a second carrier 470, and a pressure sensitive adhesive 430. The first carrier 410 has a first surface 411 and a second, oppositely directed surface 412. The wireless identification device 420 has a first surface 421 and a second, oppositely directed surface 422. The pressure sensitive adhesive 430 has a first surface 431 and a second, oppositely directed surface 432. A first permanent adhesive 440 is disposed between the first carrier 410 and the wireless identification device 420. Accordingly, the first permanent adhesive 440

adheres the second surface 422 of the wireless identification device 420 to at least a portion of the first surface 411 of the first carrier 410. The second carrier 470 has a first surface 471 and a second surface 472. A second permanent adhesive 460 adheres the second surface 472 of the second carrier 470 to the first surface 421 of the wireless identification device 420, so that the second carrier 470 resides between the pressure sensitive adhesive 430 and the wireless identification device 420. The second surface 432 of the pressure sensitive adhesive 430 is disposed on at least a portion of the first surface 471 of the second carrier 470.

[0081] The recyclable construction has a bulk density selected so as to make the construction sink or float during the recycling wash-off process. By "bulk density" is meant herein the overall density of the recyclable construction. This overall density determines whether the construction will sink or float during the wash-off process.

[0082] In some embodiments, the recyclable construction has a bulk density of less than 1 g/cubic centimeter. These low bulk density constructions will float during the wash-off process, while, articles to which they are attached, having a density of greater than 1 g/cubic meter, such as for example PET, will sink. This low bulk density can be inherent to the materials incorporated in the construction. For example, in some embodiments, the first carrier includes a material that inherently has a density of less than 1 g/cubic centimeter, such as for example, a polyolefin. In some embodiments, at least one of the first carrier, the second carrier and the third carrier includes a material that inherently has a density of less than 1 g/cubic centimeter. In some embodiments, the low density can be achieved by using a film that has been de-densified, thereby decreasing its density in some way. For example, the first carrier, and/or the second carrier, and/or the third carrier, can be films that have been de-densified by cavitation or incorporation of low density materials. In some embodiments, the first carrier is a de-densified film. In some embodiments, at least one of the first carrier, the second carrier and the third carrier is a de-densified film. In some embodiments, the first carrier is a cavitated film. In some embodiments, at least one of the first carrier, the second carrier and the third carrier is a cavitated film. The film may have been cavitated by any suitable means. In some embodiments, the first carrier is a film that has been cavitated by at least one cavitating agent the film. By "cavitating agent" is meant herein at least one particle that induces micro-voids in a material. The presence of the cavitating agent in the carrier during the orientation of the film induces micro-voids. With a high degree of voiding, the film density can be reduced accordingly. Any suitable cavitating agent can be used. In some embodiments, the cavitating agent is a void-initiating particle including at least one of an organic polymer or an inorganic material. In some embodiments, the cavitating agent is a void-initiating particle including an organic polymer, such as for example, a polyamide, (such as for example, nylon-6), a polyester (such as for example polybutylene terephthalate (PBT)), an acrylic resin, or combinations thereof. In some embodiments, the cavitating agent is a void-initiating

particle including an organic polymer, such as for example cyclic olefin polymers, cyclic olefin copolymers, ethylene norbornene copolymers, or combinations thereof. In some embodiments, the cavitating agent is a void-initiating particle including an inorganic polymer, such as for example, a glass, metal, ceramic, silica, calcium carbonate (CaCO3), clay, talc, or combinations thereof. In some embodiments, at least a portion of the film layer is an oriented polypropylene (PP) film, and the cavitating agent is a beta-nucleating PP. In some embodiments, at least one non-cavitated skin is disposed on at least one face of the cavitated film. In some embodiments, the cavitated film is sandwiched between two non-cavitated skins. The non-cavitated film provides support to the cavitated film. In some embodiments, the first carrier of the recyclable construction has a density of less than 1 g/cubic centimeter. In some embodiments, the first carrier of the recyclable construction includes a low density material having a density of less than 1 g/cubic centimeter. In some embodiments, the first carrier of the recyclable construction includes a low density material having a density sufficiently low that the recyclable construction has a bulk density of less than 1 g/cubic centimeter. In some embodiments, the low density material has a density of no more than 0.91 g/cubic meter. In some embodiments, the low density material has a density of no more than 0.88 g/cubic meter, no more than 0.8 g/cubic meter, no more than 0.7 g/cubic meter, no more than 0.6 g/cubic meter, or no more than 0.5 g/cubic meter. Any suitable low density material can be used. In some embodiments, the low density material is selected from a filler, hollow glass spheres, a foaming agent, expanding cells, or any combination thereof. In some embodiments, the recyclable construction has been de-densified by at least one of cavitation or addition of a low density material. It will be understood that materials that inherently have a density of greater than 1 g/cubic centimeter can be de-densified so that they provide a carrier having a density of less than 1 g/cubic centimeter. In some embodiments, the first carrier and/or the second carrier, and/or the third carrier include a de-densified polyolefin, polyethylene terephthalate, polycarbonate, acrylic, polyurethane, or any combination thereof.

[0083] In some embodiments, the recyclable construction includes a second carrier. In some embodiments, the recyclable construction includes a second carrier that is a de-densified film. In some embodiments, the second carrier is a cavitated film. The film may have been cavitated by any suitable means. In some embodiments, the second carrier is a film that has been cavitated by at least one cavitating agent the film, such as those described herein-above for the first carrier. In some embodiments, the second carrier of the recyclable construction has a density of less than 1 g/cubic centimeter. In some embodiments, the second carrier of the recyclable construction includes a low density material having a density of less than 1 g/cubic centimeter. In some embodiments, the second carrier of the recyclable construction includes a low density material having a density sufficiently low that the recyclable construction has a bulk density of less than 1 g/cubic centimeter. In some embodiments, the low density

material has a density of no more than 0.91 g/cubic meter. In some embodiments, the low density material has a density of no more than 0.88 g/cubic meter, no more than 0.8 g/cubic meter, no more than 0.7 g/cubic meter, no more than 0.6 g/cubic meter, or no more than 0.5 g/cubic meter. In some embodiments, the recyclable construction has been de-densified by at least one of cavitation or addition of a low density material.

[0084] In some embodiments, the recyclable construction includes a third carrier. In some embodiments, the recyclable construction includes a third carrier that is a de-densified film. In some embodiments, the third carrier is a cavitated film. The film may have been cavitated by any suitable means. In some embodiments, the second carrier is a film that has been cavitated by at least one cavitating agent the film, such as those described herein-above for the first carrier. In some embodiments, the third carrier of the recyclable construction has a density of less than 1 g/cubic centimeter. In some embodiments, the third carrier of the recyclable construction includes a low density material having a density of less than 1 g/cubic centimeter. In some embodiments, the third carrier of the recyclable construction includes a low density material having a density sufficiently low that the recyclable construction has a bulk density of less than 1 g/cubic centimeter. In some embodiments, the low density material has a density of no more than 0.91 g/cubic meter. In some embodiments, the low density material has a density of no more than 0.88 g/cubic meter, no more than 0.8 g/cubic meter, no more than 0.7 g/cubic meter, no more than 0.6 g/cubic meter, or no more than 0.5 g/cubic meter. In some embodiments, the recyclable construction has been de-densified by at least one of cavitation or addition of a low density material.

[0085] As previously noted, the first carrier, the second carrier, and the third carrier can have the same or a different composition. In some embodiments, at least one of the first carrier, the second carrier, and the third carrier is de-densified. In some embodiments, at least one of the first carrier, the second carrier, and the third carrier is not de-densified. In some embodiments, at least one of the first carrier, the second carrier, and the third carrier is cavitated. In some embodiments, at least of the first carrier, the second carrier, and the third carrier is not cavitated. In some embodiments, at least one of the first carrier, the second carrier, and the third carrier further includes a de-densified material. In some embodiments, at least one of the first carrier, the second carrier, and the third carrier does not include a de-densified material.

[0086] FIG. 5 illustrates an exemplary embodiment of a side view of a recyclable construction 500 according to embodiments of the disclosure, having a density of less than 1g/cubic centimeter. The recyclable construction 500 includes a first carrier 510, a second carrier 570, a wireless identification device 520, and a pressure sensitive adhesive 530. The first carrier 510 has a first surface 511 and a second, oppositely directed surface 512. The second carrier 570 has a first surface 571 and a second, oppositely

directed surface 572.The wireless identification device 520 has a first surface 521 and a second, oppositely directed surface 522. The pressure sensitive adhesive 530 has a first surface 531 and a second, oppositely directed surface 532.The wireless identification device 520 is disposed on at least a portion of the first surface 512 of the first carrier 510. The pressure sensitive adhesive 530 is disposed on at least a portion of the first surface 521 of the first carrier 510, and the second carrier 570 is disposed on at least a portion of the second surface of 522 the wireless identification device 520. The pressure sensitive adhesive 530 is co-extensive with the first carrier 510.

[0087] FIG. 6 illustrates an exemplary embodiment of a side view of a recyclable construction 600 according to embodiments of the disclosure, having a density of less than 1g/cubic centimeter. The recyclable construction 600 includes a first carrier 610, a second carrier 670, a wireless identification device 620, a pressure sensitive adhesive 630, and a dissolvable adhesive 680. The first carrier 610 has a first surface 611 and a second, oppositely directed surface 612. The second carrier 670 has a first surface 671 and a second, oppositely directed surface 672.The wireless identification device 620 has a first surface 621 and a second, oppositely directed surface 622.The wireless identification device 620 is disposed on at least a portion of the first surface 612 of the first carrier 610. The pressure sensitive adhesive 630 is disposed on at least a portion of the first surface 621 of the first carrier 610, and the second carrier 670 is disposed on at least a portion of the second surface of 622 the wireless identification device 620. The dissolvable adhesive 680 is disposed between the first carrier 610 and the wireless identification device 620. The pressure sensitive adhesive 630 is co-extensive with the first carrier 610.

[0088] FIG. 7 illustrates an exemplary embodiment of a side view of a recyclable construction 700 according to embodiments of the disclosure, having a density of less than 1g/cubic centimeter. The recyclable construction 700 includes a first carrier 710, a second carrier 770, a wireless identification device 720, a pressure sensitive adhesive 730, and a dissolvable adhesive 780. The first carrier 710 has a first surface 711 and a second, oppositely directed surface 712. The second carrier 770 has a first surface 771 and a second, oppositely directed surface 772.The wireless identification device 720 has a first surface 721 and a second, oppositely directed surface 722.The wireless identification device 720 is disposed on at least a portion of the first surface 712 of the first carrier 710. The pressure sensitive adhesive 730 is disposed on at least a portion of the first surface 721 of the first carrier 710, and the second carrier 770 is disposed on at least a portion of the second surface of 722 the wireless identification device 720. The dissolvable adhesive 780 is disposed between the second carrier 770 and the wireless identification device 720. The pressure sensitive adhesive 730 is co-extensive with the first carrier 710.

[0089] FIG. 8 illustrates an exemplary embodiment of a side view of a recyclable construction 800 according to embodiments of the disclosure, having a density of less than 1g/cubic centimeter. The recyclable construction 800 includes a first carrier 810, a second carrier 870, a wireless identification

device 820, and a pressure sensitive adhesive 830. The first carrier 810 has a first surface 811 and a second, oppositely directed surface 812. The second carrier 870 has a first surface 871 and a second, oppositely directed surface 872.The wireless identification device 820 has a first surface 821 and a second, oppositely directed surface 822. The pressure sensitive adhesive 830 has a first surface 831 and a second, oppositely directed surface 832. The wireless identification device 820 is disposed on at least a portion of the second surface 812 of the first carrier 810. The pressure sensitive adhesive 830 is disposed on at least a portion of the second surface 822 of the wireless identification 820, and the second carrier 870 is disposed on at least a portion of the second surface of 832 the pressure sensitive adhesive 830. The pressure sensitive adhesive 830 has a length that is greater than the length of the first carrier 810. Accordingly, the pressure sensitive 830 adhesive extends beyond the perimeter of the first carrier 810.

[0090] FIG. 9 illustrates an exemplary embodiment of a side view of a recyclable construction 900 according to embodiments of the disclosure, having a density of less than 1g/cubic centimeter. The recyclable construction 900 includes a first carrier 910, a second carrier 970, a third carrier 990, a wireless identification device 920, and a pressure sensitive adhesive 930. The first carrier 910 has a first surface 911 and a second, oppositely directed surface 912. The second carrier 970 has a first surface 971 and a second, oppositely directed surface 972. The third carrier 990 has a first surface 991 and a second, oppositely directed surface 992. The wireless identification device 920 has a first surface 921 and a second, oppositely directed surface 922. The pressure sensitive adhesive 930 has a first surface 931 and a second, oppositely directed surface 932. The wireless identification device 920 is disposed on at least a portion of the second surface 912 of the first carrier 910. The pressure sensitive adhesive 930 is disposed on at least a portion of the second surface 922 of the wireless identification 920, and the second carrier 970 is disposed on at least a portion of the second surface of 932 the pressure sensitive adhesive 930. The third carrier 990 is disposed between the wireless identification device 920 and the pressure sensitive adhesive 930. The pressure sensitive adhesive 930 has a length that is greater than the length of the first carrier 910. Accordingly, the pressure sensitive adhesive 930 extends beyond the perimeter of the first carrier 910. In some embodiments, the pressure sensitive adhesive is a dissolvable adhesive. This enables the second carrier to be separated from the wireless identification deice and the second carrier during recycling.

[0091] FIG. 10 illustrates an exemplary embodiment of a side view of a recyclable construction 1000 according to embodiments of the disclosure, having a density of less than 1g/cubic centimeter. The recyclable construction 1000 includes a first carrier 1010, a second carrier 1070, a third carrier 1090, a wireless identification device 1020, a pressure sensitive adhesive 1030, and a dissolvable adhesive 1080. The first carrier 1010 has a first surface 1011 and a second, oppositely directed surface 1012. The second carrier 1070 has a first surface 1071 and a second, oppositely directed surface 1072.

The third carrier 1090 has a first surface 1091 and a second, oppositely directed surface 1092. The wireless identification device 1020 has a first surface 1021 and a second, oppositely directed surface 1022. The pressure sensitive adhesive 1030 has a first surface 1031 and a second, oppositely directed surface 1032. The wireless identification device 1020 is disposed on at least a portion of the second surface 1012 of the first carrier 1010. The pressure sensitive adhesive 1030 is disposed on at least a portion of the second surface 1022 of the wireless identification 1020, and the second carrier 1070 is disposed on at least a portion of the second surface of 1032 the pressure sensitive adhesive 1030. The third carrier 1090 is disposed between the wireless identification device 1020 and the pressure sensitive adhesive 1030, and the dissolvable adhesive 1080 adheres the wireless identification device 1020 to the third carrier 1090. The pressure sensitive adhesive 1030 has a length that is greater than the length of the first carrier 1010. Accordingly, the pressure sensitive adhesive 1030 extends beyond the perimeter of the first carrier 1010. In some embodiments, the pressure sensitive adhesive is a dissolvable adhesive. This enables the second carrier to be separated from the wireless identification deice and the second carrier during recycling.

[0092] FIG. 11 illustrates an exemplary embodiment of a side view of a recyclable construction 1100 according to embodiments of the disclosure, having a density of less than 1g/cubic centimeter. The recyclable construction 1100 includes a first carrier 1110, a second carrier 1170, a third carrier 1190, a wireless identification device 1120, a pressure sensitive adhesive 1130, and a dissolvable adhesive 1180. The first carrier 1110 has a first surface 1111 and a second, oppositely directed surface 1112. The second carrier 1170 has a first surface 1171 and a second, oppositely directed surface 1172. The third carrier 1190 has a first surface 1191 and a second, oppositely directed surface 1192. The wireless identification device 1120 has a first surface 1121 and a second, oppositely directed surface 1122. The pressure sensitive adhesive 1130 has a first surface 1131 and a second, oppositely directed surface 1132. The wireless identification device 1120 is disposed on at least a portion of the first surface 1111 of the first carrier 1111. The pressure sensitive adhesive 1130 is disposed on at least a portion of the second surface 1132 of the pressure sensitive adhesive 1130, and the third carrier 1190 is disposed on at least a portion of the second surface of 1121 the wireless identification device 1120. The dissolvable adhesive 1180 adheres the wireless identification device 1120 and the third carrier 1190. The pressure sensitive adhesive 1130 has a length that is greater than the length of the first carrier 1110. Accordingly, the pressure sensitive adhesive 1130 extends beyond the perimeter of the first carrier 1110. In some embodiments, the pressure sensitive adhesive is a dissolvable adhesive. This enables the second carrier to be separated from the wireless identification deice and the second carrier during recycling.

[0093] In some embodiments, the recyclable construction has a bulk density of greater than 1 g/cubic centimeter. These high bulk density constructions will sink during the wash-off process, while, articles to which they are attached, having a density of less than 1 g/cubic meter, such as for example

polypropylene (PP) or high density polyethylene (HDPE), will float. This high bulk density can be inherent to the materials incorporated in the construction. For example, in some embodiments, the first carrier and/or the second carrier, and/or the third carrier include a material that inherently has a density of greater than 1 g/cubic centimeter, such as for example, a polycarbonate, polymethylmethacrylate (PMMA), polylactic acid, polystyrene, acrylonitrile butadiene styrene, rigid polyvinyl chloride, polyetheretherketone (PEEK), polyethersulfone (PES), polyamide, polyimide, and any combination thereof.

[0094] In some embodiments, the high density can be achieved by using a film that has been densified, thereby decreasing its density in some way. For example, at least one of the first carrier, the second carrier, and the third carrier, can be films that have been densified by incorporation of high density materials. In some embodiments, the first carrier of the recyclable construction has a density of greater than 1 g/cubic centimeter. In some embodiments, the first carrier is a densified film. In some embodiments, the first carrier of the recyclable construction includes a high density material having a density sufficiently high that the recyclable construction has a bulk density of greater than 1 g/cubic centimeter. In some embodiments, the high density material has a density of greater than 1 g/cubic centimeter. In some embodiments, the high density material has a density of at least 2 g/cubic centimeter, at least 3 g/cubic centimeter, or at least 4 g/cubic centimeter. Any suitable high density material can be used. In some embodiments, the high density material is at least one of a filler or pigment. In some embodiments, at least one of the first carrier, the second carrier, and the third carrier include a densified polyolefin, polyethylene terephthalate, polycarbonate, acrylic, polyurethane, or any combination thereof. In some embodiments, at least one of the first carrier, the second carrier, and the third carrier include at least one of a densified polypropylene and a polyethylene.

[0095] In some embodiments, the second carrier of the recyclable construction has a density of greater than 1 g/cubic centimeter. In some embodiments, the second carrier is a densified film. In some embodiments, the second carrier of the recyclable construction includes a high density material having a density sufficiently high that the recyclable construction has a bulk density of greater than 1 g/cubic centimeter. In some embodiments, the high density material has a density of greater than 1 g/cubic centimeter. In some embodiments, the high density material has a density of at least 2 g/cubic centimeter, at least 3 g/cubic centimeter, or at least 4 g/cubic centimeter. Any suitable high density material can be used. In some embodiments, the high density material is at least one of a filler or pigment.

[0096] In some embodiments, the third carrier of the recyclable construction has a density of greater than 1 g/cubic centimeter. In some embodiments, the third carrier is a densified film. In some embodiments, the third carrier of the recyclable construction includes a high density material having a density sufficiently high that the recyclable construction has a bulk density of greater than 1 g/cubic

centimeter. In some embodiments, the high density material has a density of greater than 1 g/cubic centimeter. In some embodiments, the high density material has a density of at least 2 g/cubic centimeter, at least 3 g/cubic centimeter, or at least 4 g/cubic centimeter. Any suitable high density material can be used. In some embodiments, the high density material is at least one of a filler or pigment.

[0097] As previously noted, the first carrier, the second carrier, and the third carrier can have the same or different composition. In some embodiments, at least one of the first carrier, the second carrier, and the third carrier is densified. In some embodiments, at least one of the first carrier, the second carrier, and the third carrier is not densified. In some embodiments, at least one of the first carrier, the second carrier, and the third carrier further includes a densified material. In some embodiments, at least one of the first carrier, the second carrier, and the third carrier does not include a densified material.

[0098] Other components in the recyclable construction can also be densified. In some embodiments, the pressure sensitive adhesive is densified. In some embodiments, the pressure sensitive adhesive includes a high density material having a density of greater than 1 g/cubic centimeter. In some embodiments, the high density material has a density of at least 2 g/cubic centimeter, at least 3 g/cubic centimeter, or at least 4 g/cubic centimeter. In some embodiments the densified adhesive includes at least one of a filler or pigment.

[0099] FIG. 12 illustrates an exemplary embodiment of a side view of a recyclable construction 1200 according to embodiments of the disclosure, having a density of greater than 1g/cubic centimeter. The recyclable construction 1200 includes a first carrier 1210, a second carrier 1270, a wireless identification device 1220, a pressure sensitive adhesive 1230, and a permanent adhesive 1240. The first carrier 1210 has a first surface 1211 and a second, oppositely directed surface 1212. The second carrier 1270 has a first surface 1271 and a second, oppositely directed surface 1272.The wireless identification device 1220 has a first surface 1221 and a second, oppositely directed surface 1222.The wireless identification device 1220 is disposed on at least a portion of the first surface 1212 of the first carrier 1210. The pressure sensitive adhesive 1230 is disposed on at least a portion of the first surface 1221 of the first carrier 1210, and the second carrier 1270 is disposed on at least a portion of the second surface 1222 of the wireless identification device 1220. The permanent adhesive 1240 is disposed between the first carrier 1210 and the wireless identification device 1220. The pressure sensitive adhesive 1230 has a length that is greater than the length of the first carrier 1210. Accordingly, the pressure sensitive adhesive 1230 extends beyond the perimeter of the first carrier 1210.

[0100] FIG. 13 illustrates an exemplary embodiment of a side view of a recyclable construction 700 according to embodiments of the disclosure, having a density of greater than 1g/cubic centimeter. The recyclable construction 1300 includes a first carrier 1310, a second carrier 1370, a wireless identification device 1320, a pressure sensitive adhesive 1330, and a permanent adhesive 1340. The first

carrier 1310 has a first surface 1311 and a second, oppositely directed surface 1312. The second carrier 1370 has a first surface 1371 and a second, oppositely directed surface 1372.The wireless identification device 1320 has a first surface 1321 and a second, oppositely directed surface 1322.The wireless identification device 1320 is disposed on at least a portion of the first surface 1312 of the first carrier 1310. The pressure sensitive adhesive 1330 is disposed on at least a portion of the first surface 1321 of the first carrier 1310, and the second carrier 1370 is disposed on at least a portion of the second surface of 1322 the wireless identification device 1320. The permanent adhesive 1340 is disposed between the second carrier 1370 and the wireless identification device 1320. The pressure sensitive adhesive 1330 is co-extensive with the first carrier 1310. The pressure sensitive adhesive 1330 has a length that is greater than the length of the first carrier 1310. Accordingly, the pressure sensitive adhesive 1330 extends beyond the perimeter of the first carrier 1310.

[0101] FIG. 14 illustrates an exemplary embodiment of a side view of a recyclable construction 1400 according to embodiments of the disclosure, having a density of greater than 1g/cubic centimeter. As noted hereinabove, during the recycling process, articles are typically sorted, shredded into flakes, washed, and dried. FIG. 14a illustrates the recyclable construction 1400 in an intact state, prior to the commencement of recycling. The recyclable construction 1400 includes a first carrier 1410, a second carrier 1470, a dissolvable coating 14100, a wireless identification device 1420, and a pressure sensitive adhesive 1430. The first carrier 1410 has a first surface 1411 and a second, oppositely directed surface 1412. The second carrier 1470 has a first surface 1471 and a second, oppositely directed surface 1472. The dissolvable coating 14100 has a first surface 14101 and a second, oppositely directed surface 14102. The wireless identification device 1420 has a first surface 1421 and a second, oppositely directed surface 1422. The pressure sensitive adhesive 1430 has a first surface 1431 and a second, oppositely directed surface 1432. The wireless identification device 1420 is disposed on at least a portion of the second surface 1412 of the first carrier 1410. The pressure sensitive adhesive 1430 is disposed on at least a portion of the second surface 1422 of the wireless identification 1420, and the second carrier 1470 is disposed on at least a portion of the second surface of 1432 the pressure sensitive adhesive 1430. The dissolvable coating 14100 is disposed between the wireless identification device 1420 and the pressure sensitive adhesive 1430. The pressure sensitive adhesive 1430 has a length that is greater than the length of the first carrier 1410. Accordingly, the pressure sensitive adhesive 1430 extends beyond the perimeter of the first carrier 1410. The portions of the pressure sensitive adhesive that extend beyond the perimeter of the first carrier 1433 are attached to a substrate of an article (not shown). The portions of the pressure sensitive adhesive that do not extend beyond the perimeter of the first carrier 1434 are attached to the dissolvable coating 14100. In some embodiments, the pressure sensitive adhesive is capable of debonding from a substrate. In some embodiments, the pressure sensitive adhesive is not capable of debonding from

a substrate. FIG. 14b illustrates the recyclable construction 1400 after the shredding stage. The portions of the first carrier that are adhered, via the pressure sensitive adhesive, to the substrate (not shown) 1473, have become mechanically detached from the portions of the first carrier that are adhered, via the pressure sensitive adhesive, to the wireless identification device 1474. FIG. 14c illustrates the recyclable construction 1400 after the washing step of a recycling process. The dissolvable coating 14100 that was disposed between the pressure sensitive adhesive 1430 and the wireless identification device 1420 has released into the wash composition (not shown) during the washing process, thereby releasing the wireless identification device 1420 from the pressure sensitive adhesive 1430. This enables the recovery of the adhesive-free wireless identification device during the recycling process. In some embodiments, instead of a pressure sensitive adhesive in combination with a dissolvable coating, a dissolvable pressure sensitive adhesive can be used.

[0102] In some embodiments, the recyclable construction meets at least one of the applicable Association of Plastic Retailers (APR) or the Plastic Recyclers Europe (PRE) recycling guidelines. These guidelines vary by material type, for example, APR PET CG-02 for polyethylene terephthalate, APR HDPE CG-01 for high density polyethylene, APR FPE-CG-01 for low density polyethylene (LDPE), and APR PP CG-01 for polypropylene.

[0103] The invention further includes a method of making the recyclable construction. In some embodiments, the method includes providing the first carrier, disposing the wireless identifications device on at least a portion of the first surface of the first carrier, and disposing the pressure sensitive adhesive on an outer layer of the recyclable construction. As previously noted, the wireless identifications device is disposed on the first carrier by any suitable means, such as for example etching, laser printing, or being disposed on an adhesive and optionally being at least one of laser cut or die cut, as is described herein-above. In some embodiments, the wireless identification device is disposed by printing a conductive ink in the shape of an antenna. In some embodiments, the wireless identification device is disposed by etching. In some embodiments, the wireless identifications device is disposed by depositing the first permanent adhesive on at least a portion of the first surface of the first carrier, and depositing the wireless identification device on at least a portion of the first surface of the first permanent adhesive. The wireless identification device can be deposited such that it has the dimensions of an antenna, or dimensions larger than an antenna and then at least one of laser cut or die cut. In some embodiments, the method further includes coupling an integrated circuit to the wireless identifications device.

[0104] The invention further includes a method of recycling the recyclable construction of the invention. The method includes providing a recyclable construction bonded to the substrate of an article, and subjecting the article to mechanical recycling conditions. Recycling processes and conditions are well known to those in the art. As noted hereinabove, typically, this involves grinding the article to

which the wireless identification device has been attached, and then placing the resulting flakes in a heated washwater, typically under agitation. Usually, the washwater will contain a caustic or a surfactant or both. In some embodiments, the recycling conditions include exposure to a wash composition including at least one of a caustic or a surfactant. In some embodiments, the recycling conditions include exposure to a wash composition having a temperature of from 40°C to 90°C washwater conditions cause the debonding of the pressure sensitive adhesive from the article. The article to which the recyclable construction was attached can then be recovered and later used for other purposes. In some embodiments, the recyclable construction has a bulk density of less than 1 g/cubic centimeter, and the article to which it was attached has a density of greater than 1 g/cubic centimeter. The less dense recyclable construction will float in the washwater, while the more dense article will sink, enabling separate collection of the flakes of the recyclable construction and the article flakes. In some embodiments, the recyclable construction has a bulk density of greater than 1 g/cubic centimeter, and the article has a density of less than 1 g/cubic centimeter. The more dense recyclable construction will sink in the washwater, while the more dense article will sink, enabling separate collection of the flakes of recyclable construction and the article flakes.

Examples

[0105] Tests were performed as described below.

[0106] 1. Preparation of wash media

[0107] A wash-off solution was prepared containing water, and 0.5 wt% sodium hydroxide. Wireless constructions having different carriers were adhered, by an acrylic emulsion based PSA, on several PET or HDPE bottles, where they resided for 72 hours.

[0108] 2. Preparation of flakes

[0109] PET containers to which were attached wireless constructions were ground into flakes, each of which measured 1 cm x 1 cm.

[0110] 3. Sink-Float Process – PET Container

[0111] This test evaluated the ability of a specific package component to float in room temperature water (cold wash), as well as after exposure to hot water as occurs during hot wash of PET flake during recycling. The density of PET flake is 1.37 g/cm3 and so PET sinks in water. It is generally desirable that other package components such as wireless constructions completely float in water so that they can be cleanly separated from the PET container. Sink-float testing was performed according to a modified version of the APR (The Association of Plastic Recycler) test method APR-PET-S-05, titled “PET Packaging Component Sink or Float Evaluation”, as described below:

[0112] For each example, 50 of the wireless construction bearing flakes were placed into a 250 mL beaker containing 100 mL of the wash solution having a temperature of 75°C (hot wash), or 20°C (cold wash). Each of the wireless constructions included a PP carrier. The wash-off solution containing the flakes was agitated by a pitch blade at 1000 rpm for 15 minutes to separate the PET container flakes from the wireless construction.

[0113] The wash water was separated from the PET flakes on a de-watering screen and rinsed with tap water for 30 seconds to remove the wash off solution. The flakes were then transferred completely to a 1 L container containing tap water, stirred with a rod for 10 seconds, and allowed to separate based on density. Any floating materials were skimmed from the surface and the sunken material was drained using a screen. The collected PET flakes were collected on a paper towel to absorb water from the flakes, after which the PET flakes were transferred to an aluminum dish. The number of cleaned PET flakes (with label removal) were counted against the total number, to determine a percent wash-off. These tests were accomplished in triplicate. The percent of the PET bottle flakes that was clean (i.e. PSA and construction free) was observed. A % clean of at least 85% was considered a pass. Test results are shown in Table 1 below.

Table 1 – Sink/float and Separation Results

Example	Container	Carrier Density (g/cm3)	Carrier	Carrier Density (g/cm3)	PSA	Wash	Sink/Float	Separation Pass/Fail
Ex. 1	PET	>1	PP	<1	Acrylic emulsion based PSA 1	Hot (75°C; 0.5% NaOH)	Pass: PET sank; PP floated; some of Al antenna sank while some floated	Pass – no contamination of PET

CLAIMS

What is claimed is:

1. A recyclable construction comprising:

(1) a first carrier having a first surface and a second surface, wherein the first carrier comprises a heat stable polymeric film having a density of less than 1 g/cubic centimeter;

(2) a wireless identification device, having a first surface and a second surface, disposed on at least a portion of one of the first surface and the second surface of the first carrier; and

(3) a pressure sensitive adhesive, having a first surface and a second surface,

wherein the pressure sensitive adhesive is capable of bonding the recyclable construction to a substrate, and capable of debonding from the substrate.

2. The recyclable construction of claim 1, further comprising at least one additional layer having a first surface and a second surface.

3. The recyclable construction of claim 3, wherein the at least one additional layer is selected from the group consisting of a second carrier, a third carrier, a first permanent adhesive, a second permanent adhesive, a dissolvable adhesive, a dissolvable coating, and any combination thereof.

4. The recyclable construction of claim 1, wherein the wireless identification device is disposed on the first surface of the first carrier, and

wherein the pressure sensitive adhesive is disposed on the first surface of the wireless identification device.

5. The recyclable construction of claim 3, wherein the at least one additional layer is a first permanent adhesive, and

wherein the first permanent adhesive is disposed between the first carrier and the wireless identification device.

6. The recyclable construction of claim 5 wherein the at least additional layer further includes a second permanent adhesive,

wherein the second carrier is disposed between the pressure sensitive adhesive and the wireless identification device, and

wherein the second permanent adhesive adheres at least a portion of the second surface of the second carrier to at least a portion of the first surface of the wireless identification device.

7. The recyclable construction of claim 3, wherein the at least one additional layer is a second carrier,

wherein the wireless identification device is disposed on the second surface of the first carrier,

wherein the pressure sensitive adhesive is disposed on the first surface of the first carrier, and

wherein the second carrier is disposed on the second surface of the wireless identification device.

8. The recyclable construction of claim 7, further comprising a dissolvable adhesive, wherein the dissolvable adhesive is disposed between the first carrier and the wireless identification device.

9. The recyclable construction of claim 7, further comprising a dissolvable adhesive, wherein the dissolvable adhesive is disposed between the second carrier and the wireless identification device.

10. The recyclable construction of any one of claim 1 to 9, wherein the pressure sensitive adhesive is coextensive with the first carrier.

11. The recyclable construction of claim 3, wherein the at least one additional layer is a second carrier,

wherein wireless identification device is disposed on the second surface of the first carrier,

wherein the pressure sensitive adhesive is disposed on the second surface of the wireless identification device, and

wherein the second carrier is disposed on the second surface of the pressure sensitive adhesive.

12. The recyclable construction of any claim 11, wherein the pressure sensitive adhesive is a dissolvable adhesive.

13. The recyclable construction of any claim 11, wherein the at least one additional layer further includes a third carrier,

wherein the third carrier is disposed between the wireless identification device and the pressure sensitive adhesive.

14. The recyclable construction of claim 13, wherein the at least one additional layer further includes a dissolvable adhesive,

Wherein the dissolvable adheres the wireless identification device to the third carrier.

15. The recyclable construction of claim 3, wherein the at least one additional layer is a second carrier, a third carrier and a dissolvable adhesive,

wherein the wireless identification device is disposed on the first surface of the first carrier,

wherein the pressure sensitive adhesive is disposed on the second surface of the first carrier,

wherein the second carrier is disposed on the second surface of the pressure sensitive adhesive,

wherein a third carrier is disposed on the first surface of the wireless identification device, and

wherein a dissolvable adhesive adheres the wireless identification device to the third carrier.

16. The recyclable construction of any one of claim 1 to 3, 11 to 15, wherein the perimeter of the pressure sensitive adhesive extends beyond the perimeter of the first carrier.

17. The recyclable construction of any of claim 3, wherein at least one of the dissolvable adhesive and the dissolvable coating is dissolvable under conditions that will cause aluminum to dissolve.

18. The recyclable construction of any of claim 3, wherein at least one of the dissolvable adhesive and the dissolvable coating is dissolvable in a wash composition having a pH of greater than 9.

19. The recyclable construction of any of claim 3, wherein the dissolvable adhesive comprises at least one of a synthetic and a bioderived adhesive.

20. The recyclable construction of any of claim 3, wherein the dissolvable coating comprises a polyvinyl alcohol coating.

21. The recyclable construction of claim 1, having a thickness of no more than 200 µm.

22. The recyclable construction of any of claim 1 to 21, where the pressure sensitive adhesive is capable of debonding from the substrate upon subjection to mechanical recycling conditions.

23. The recyclable construction of claim 3, wherein at least one of the second carrier and the third carrier comprises a heat stable polymeric film.

24. The recyclable construction of any one of claim 1 to 23, wherein the heat stable polymeric film comprises a polyolefin.

25. The recyclable construction of claim 24, wherein the polyolefin is selected from the group consisting of a polypropylene, a polyethylene, and any combination thereof.

26. The recyclable construction of claim 25, wherein the polypropylene is a biaxially oriented polypropylene (BOPP).

27. The recyclable construction of any one of claim 1 to 26, wherein the wireless identification device comprises a conductive material connected to an integrated circuit.

28. The recyclable construction of claim 1 to 27, wherein the wireless identification device further comprises a strap,

wherein the strap is coupled to the conductive material.

29. The recyclable construction of any one of claim 1 to 28, wherein the recyclable construction has a bulk density of less than 1 g/cubic centimeter.

30. The recyclable construction of any one of claim 1 to 29, wherein the first carrier is de-densified.

31. The recyclable construction of any one of claim 1 to 30, wherein the first carrier is cavitated.

32. The recyclable construction of any one of claim 1 to 31, wherein the first carrier further includes a low density material having a density of less than 1 g/cubic centimeter.

33. The recyclable construction of any one of claim 3 to 32, wherein at least one of the first carrier, the second first carrier, and the third carrier is de-densified.

34. The recyclable construction of any one of claim 3 to 32, wherein at least one of the first carrier, the second first carrier, and the third carrier is cavitated.

35. The recyclable construction of any one of claim 3 to 32, wherein at least one of the first carrier, the second carrier, and the third carrier includes a low density material having a density of less than 1 g/cubic centimeter.

36. The recyclable construction of claim 35, wherein the low density material is selected from the group consisting of a filler, hollow glass spheres, a foaming agent, expanding cells, and any combination thereof.

37. The recyclable construction of any one of claim 1 to 36, wherein the first carrier is selected from the group consisting of a polyolefin, polyethylene terephthalate, polycarbonate, acrylic, polyurethane and any combination thereof.

38. The recyclable construction of any one of claim 3 to 36, wherein at least one of the first carrier, the second carrier, and the third carrier is selected from the group consisting of a polyolefin, polyethylene terephthalate, polycarbonate, acrylic, polyurethane, and any combination thereof.

39. The recyclable construction of any one of claim 3 to 38, wherein the strap comprises a polymeric film having a density of less than 1 g/cubic centimeter.

40. The recyclable construction of any one of claim 1 to 39, wherein the substrate is located on an article having a density of greater than 1 g/cubic centimeter.

41. The recyclable construction of any one of claim 1 to 40, wherein the pressure sensitive adhesive is selected from the group consisting of an acrylic emulsion based, acrylic hot melt, and rubber-based hot melt adhesive.

42. The recyclable construction of any one of claim 3 to 40, wherein the permanent adhesive is one of a an acrylic emulsion based, acrylic solvent based, acrylic hot melt, acrylic UV based, and rubber hot melt adhesive.

43. The recyclable construction of any one of claim 1 to 42 wherein the recyclable construction further comprises a liner disposed on the first surface of the pressure sensitive adhesive.

44. The recyclable construction of any one of claim 1 to 43, wherein the wireless identification device is selected from the group consisting of ultra-high frequency device (UHF), a near filed communication device (NFC), a Bluetooth low energy device (BLE) long term evolution device (LTE), and an electronic article surveillance (EAS) device.

45. The recyclable construction of any one of claim 1 to 44, wherein the pressure sensitive adhesive is capable debonding from the substrate upon exposure to mechanical recycling conditions.

46. The recyclable construction of claim 45, wherein the mechanical recycling conditions include exposure to a wash composition including at least one of a caustic and a surfactant.

47. The recyclable construction of any one of claim 1 to 46, wherein the recyclable construction meets at least one of the Association of Plastic Retailers (APR), and the Plastic Recyclers Europe (PRE) recycling guidelines.

48. A method of making the recyclable construction of claim 1 comprising the steps of:

(1) providing the first carrier,

(2) disposing the wireless identifications device on at least a portion of one of the first surface and the second surface of the first carrier, and

(3) disposing the pressure sensitive adhesive, on an outer layer of the recyclable construction.

49. The method of claim 48 wherein the method further comprises the step of disposing at least one additional layer on the recyclable construction.

50. The method of any one of claim 48 to 49 wherein the method further comprises the step of disposing a liner on the pressure sensitive adhesive.

51. The method of any one of claim 48 to 50 wherein the at least one additional layer is selected from the group consisting of a second carrier, a third carrier, a first permanent adhesive, a second permanent adhesive, a dissolvable adhesive, a dissolvable coating, and any combination thereof.

52. A method of recycling the recyclable construction of claim 1 comprising the steps of:

(1) providing the recyclable construction bonded to the substrate of an article;

(2) subjecting the article to mechanical recycling conditions, thereby debonding the pressure sensitive adhesive from the article; and

(3) recovering the debonded recyclable construction.

53. The method of claim 52 wherein the mechanical recycling conditions include exposure to a wash composition comprising at least one of a caustic and a surfactant.

54. The method of any one of claim 52 to 53, wherein the recyclable construction has a bulk density of less than 1 g/cubic centimeter, and the article has a density of greater than 1 g/cubic centimeter.

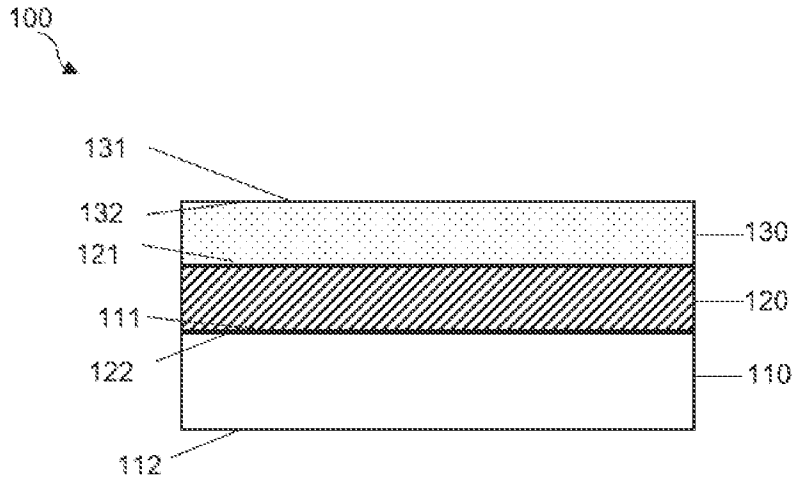
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FIG. 1

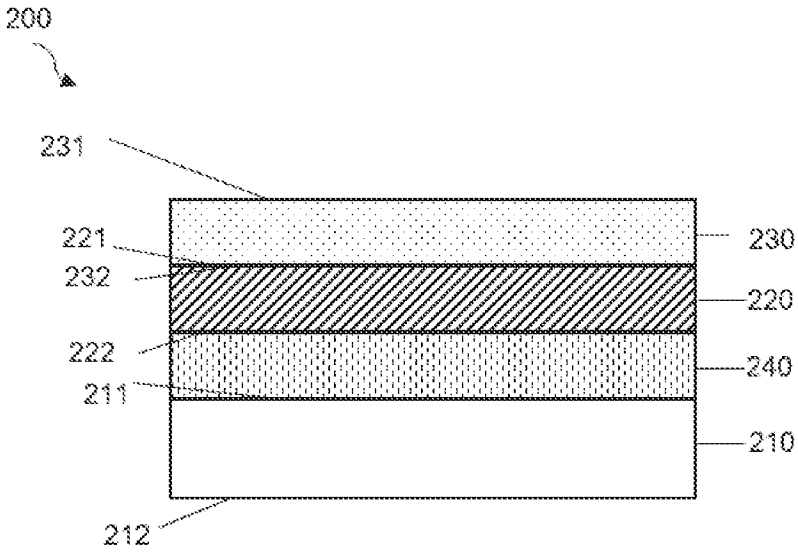
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FIG. 2

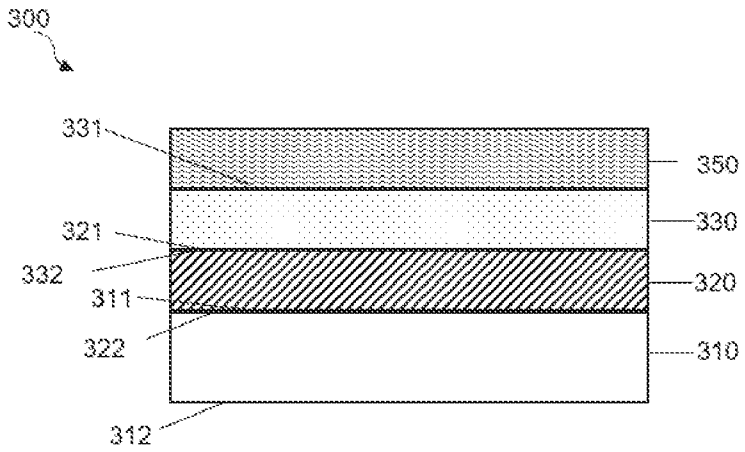
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FIG. 3

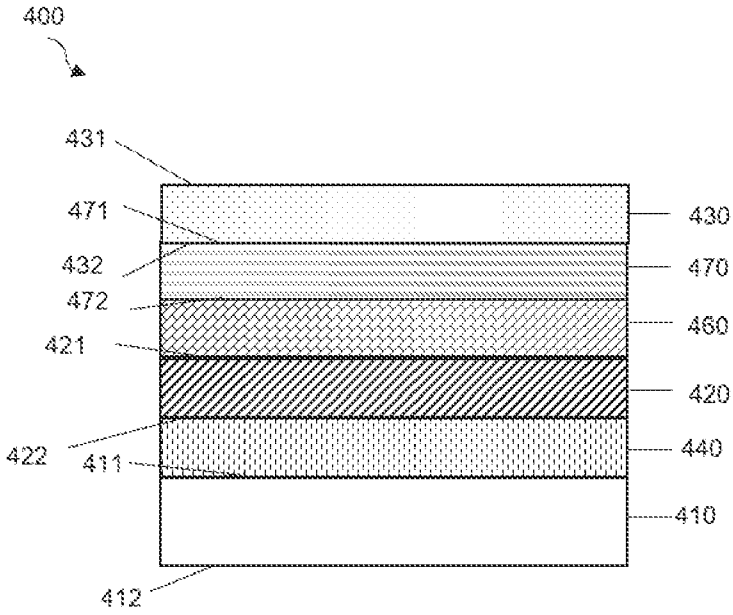
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FIG. 4

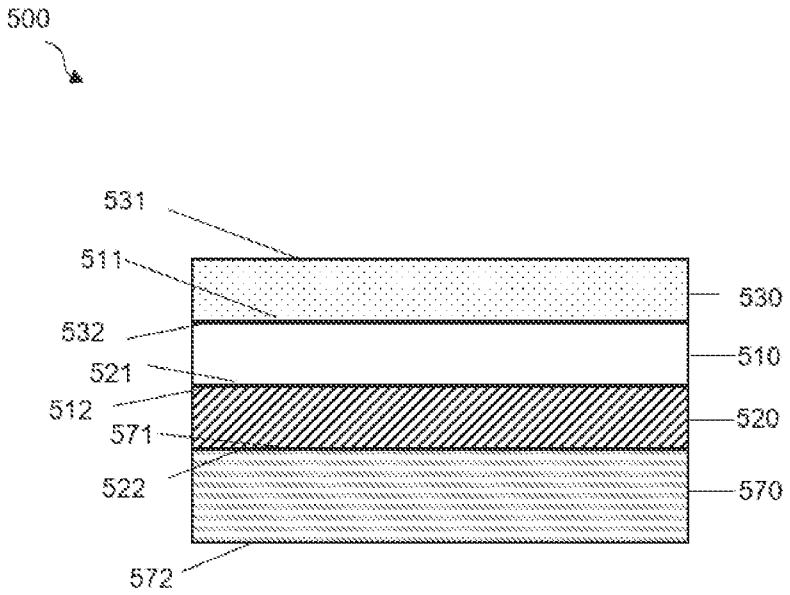
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FIG. 5

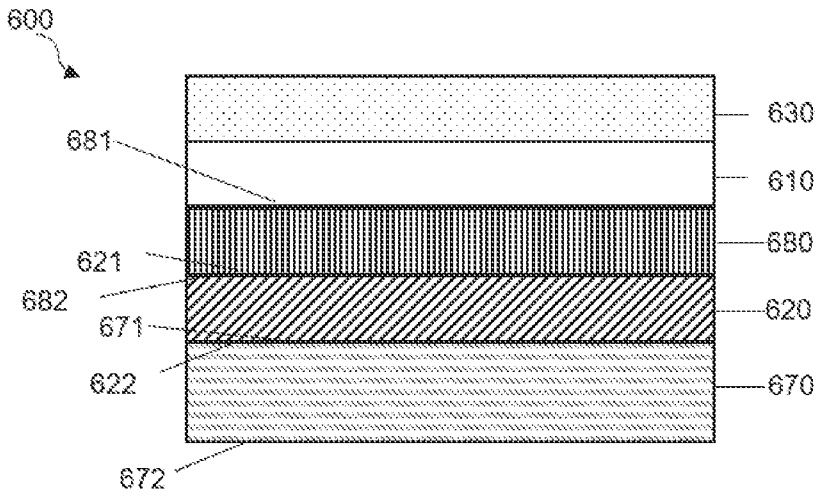
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FIG. 6

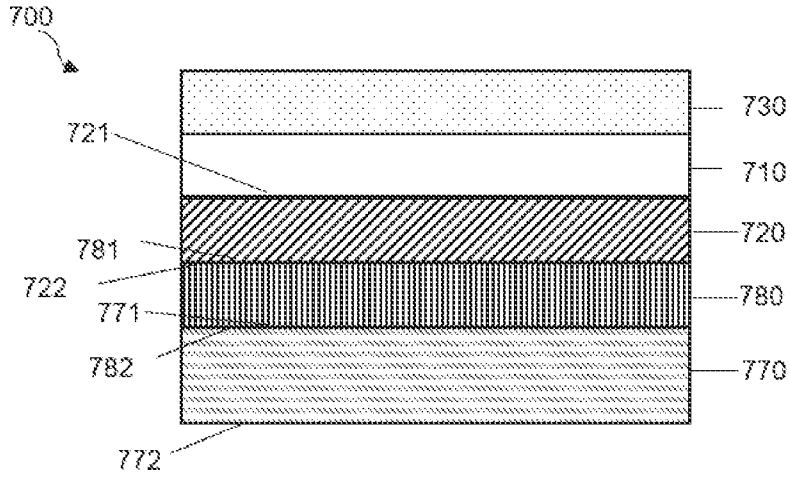
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FIG. 7

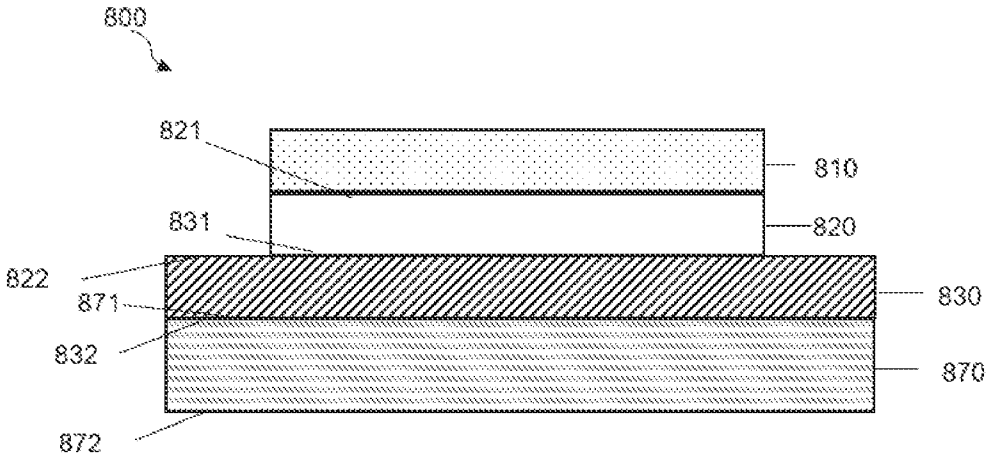
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FIG. 8

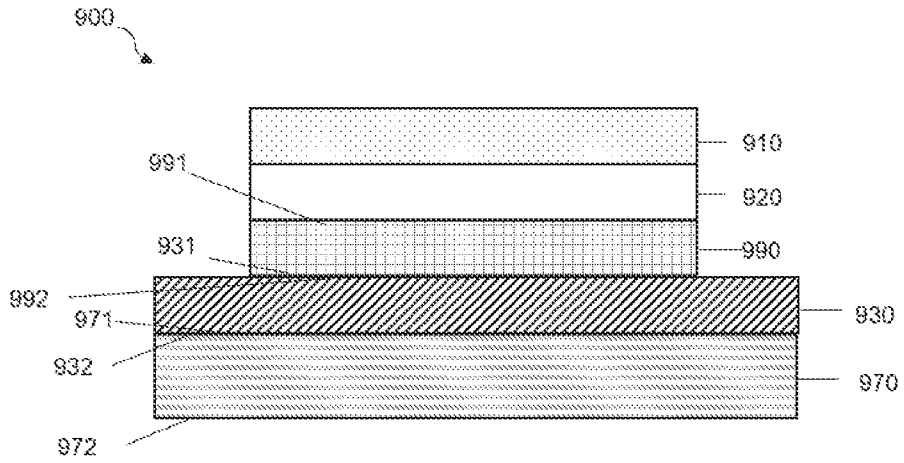
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FIG. 9

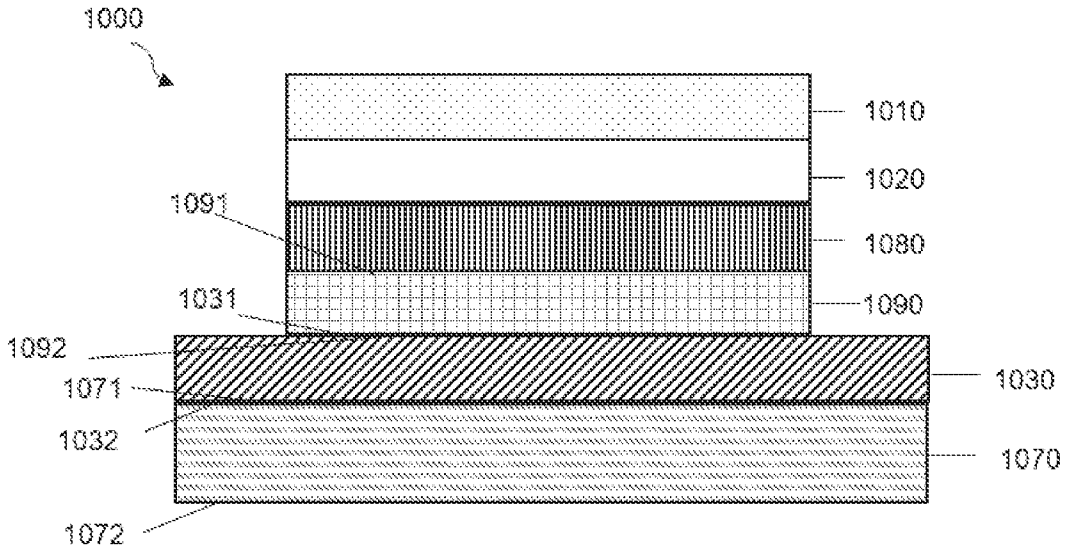
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FIG. 10

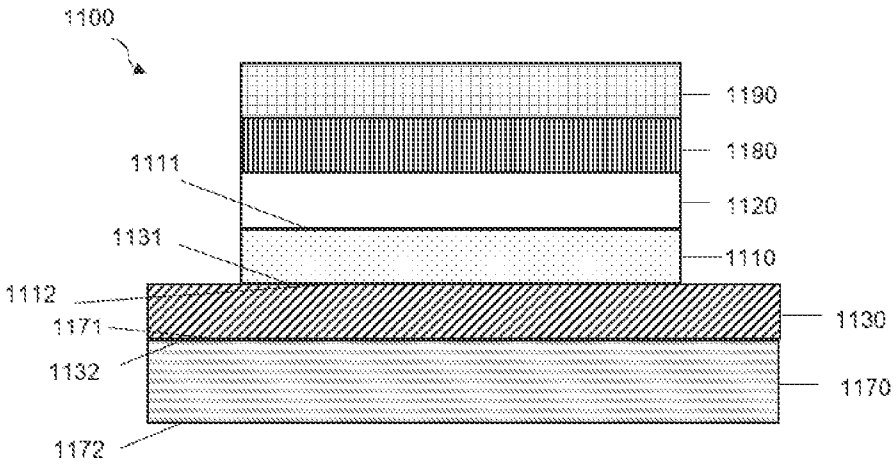
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FIG. 11

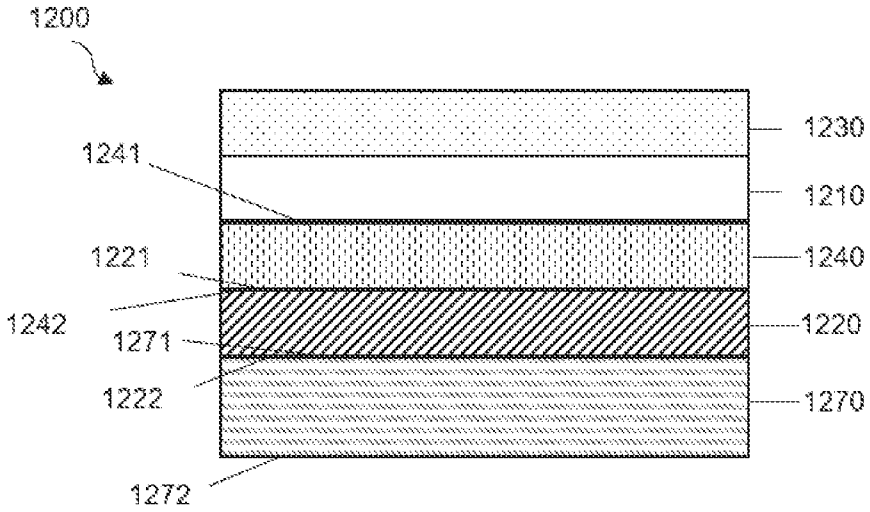
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FIG. 12

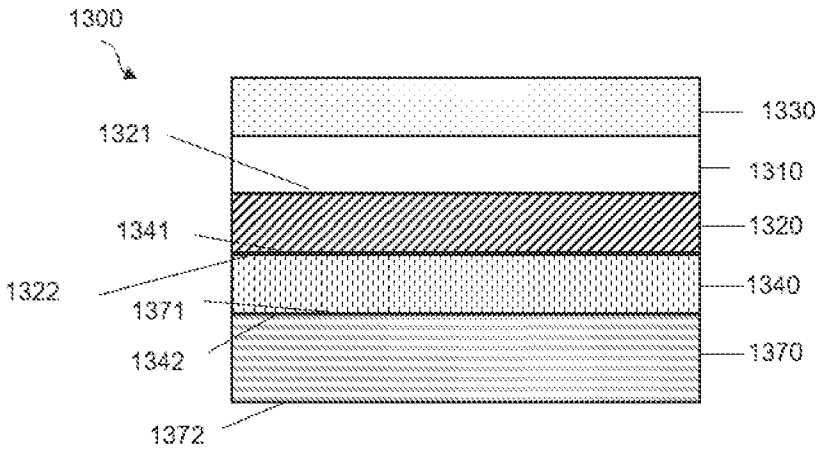

FIG. 13

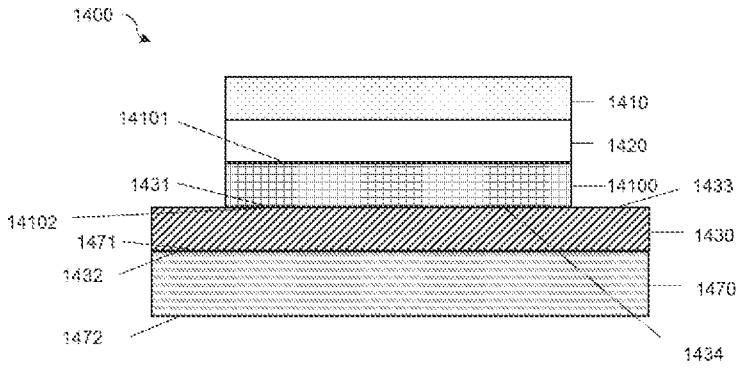

FIG. 14a

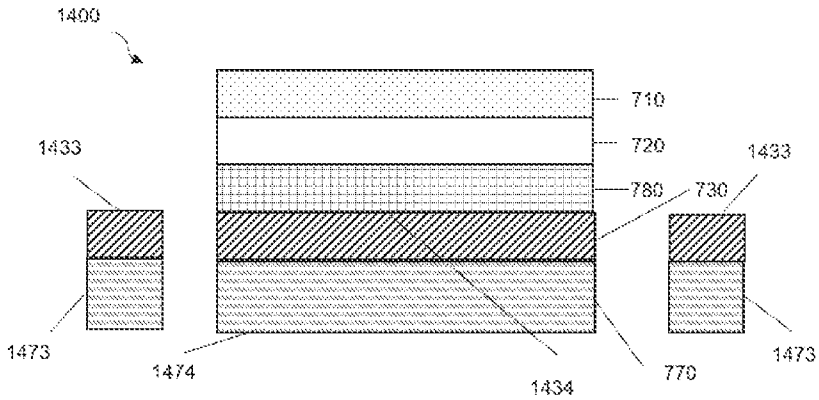

FIG. 14b

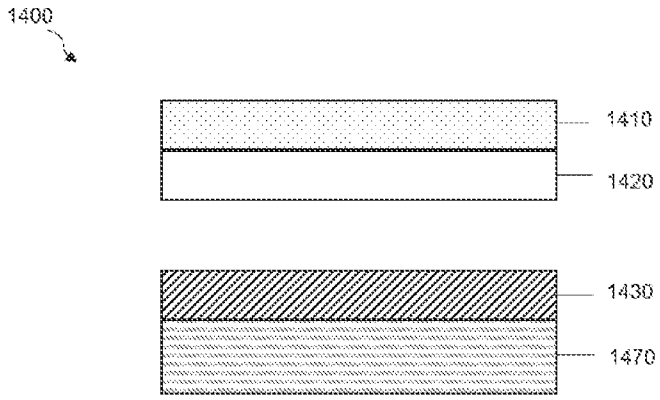

FIG. 14c

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2024/056233

A. CLASSIFICATION OF SUBJECT MATTER

INV. C09J5/00 C09J7/22 C09J7/38 G06K19/00 G09F3/03
G09F3/10
ADD.

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)

C09J G06K G09F

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)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2022/053346 A1 (ETIFIX GMBH [DE]) 17 March 2022 (2022-03-17)	1-51
Y	pages 1-10 - pages 19-22; claims 1-12; figures 5,8,11,14	52-54

X	CN 115 273 646 A (QIKE PODE ELECTRONIC JIANGSU CO LTD) 1 November 2022 (2022-11-01)	1-5, 7-12, 17-19, 22-25, 27,29, 37,38, 40-48, 52-54
Y	paragraphs [0001] - [0027]; claims 1-9; figure 1	52-54

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[X] Further documents are listed in the continuation of Box C.

[X] 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	Date of mailing of the international search report
30 August 2024	16/09/2024

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Alevizopoulou, M

2

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INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2024/056233

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	paragraphs [0026], [0031], [0034], [0066], [0071]; claims 1-3	52-54
A	US 2006/145860 A1 (BROWN KATHERINE A [US] ET AL) 6 July 2006 (2006-07-06) claims 1-23	1-54
A	WO 2017/077184 A1 (UPM RAFLATAC OY [FI]) 11 May 2017 (2017-05-11) claims 1-21	1-54
A	US 2022/356375 A1 (PIETARI ISMO [PL] ET AL) 10 November 2022 (2022-11-10) claims 1-20	1-54

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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