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(54) **RELEASABLE SEAL ASSEMBLIES AND METHODS OF USE**

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(57) **ABSTRACT**

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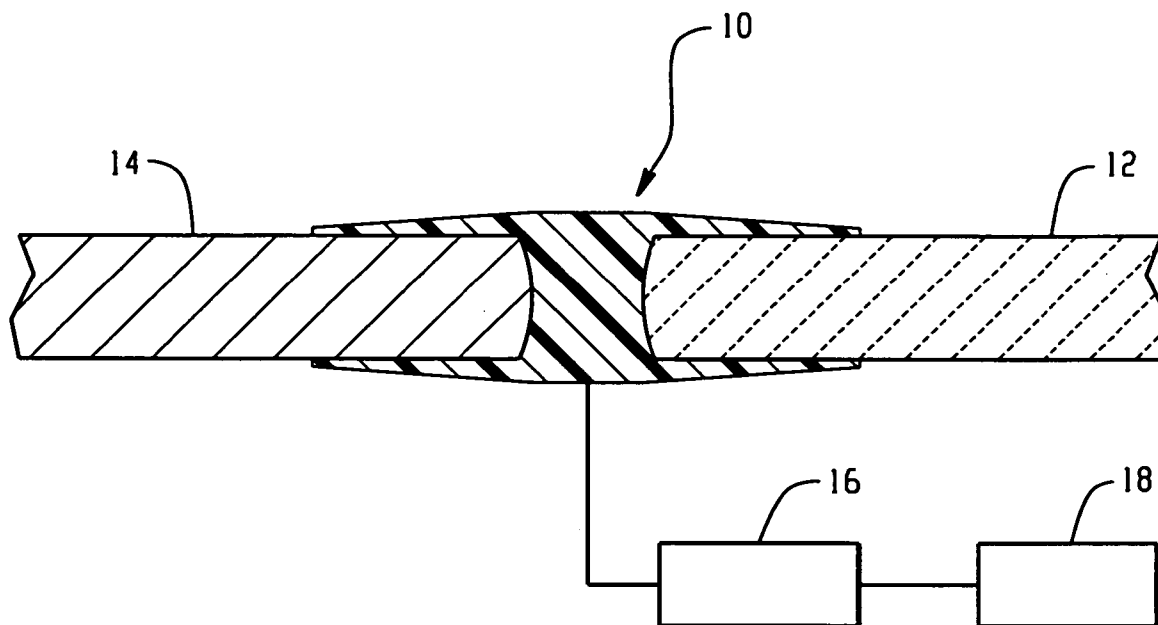
A releasable seal assembly for selectively removing a component from an other component, wherein the component and the other component are in sealing engagement with the releasable seal assembly. The releasable seal assembly includes a seal structure comprising an active material, wherein the active material is effective to undergo a change in at least one attribute in response to an activation signal, wherein the change in the at least one attribute changes a shape and/or modulus property of the seal structure; an activation device adapted to provide the activation signal in operative communication with the active material; and a controller in operative communication with the activation device. Also disclosed herein are methods for the releasable seal assembly.

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Related U.S. Application Data

(60) Provisional application No. 60/552,781, filed on Mar. 12, 2004.



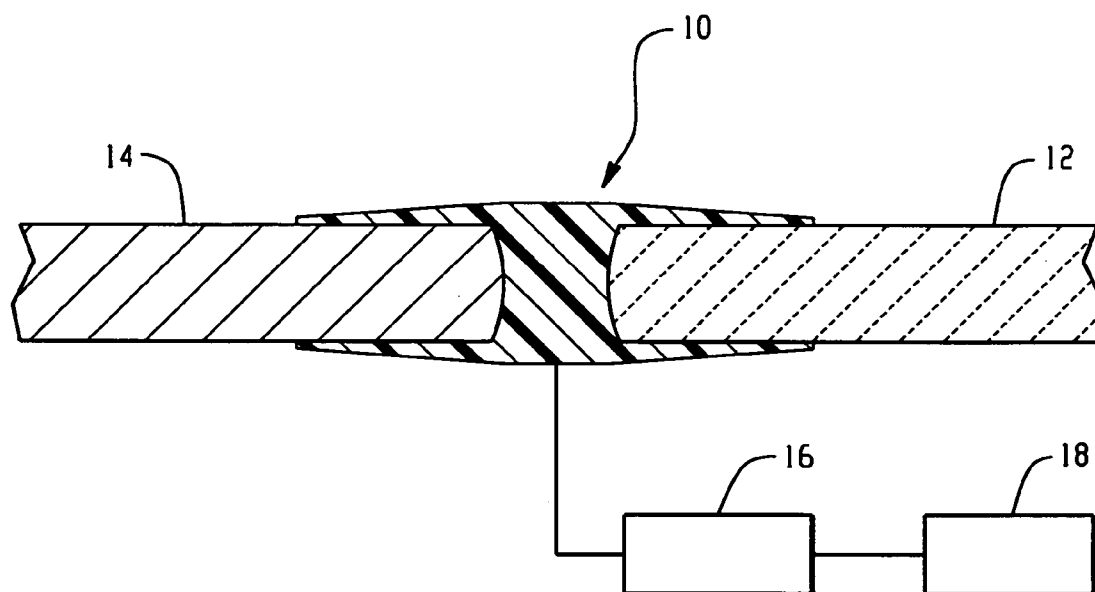


Fig. 1

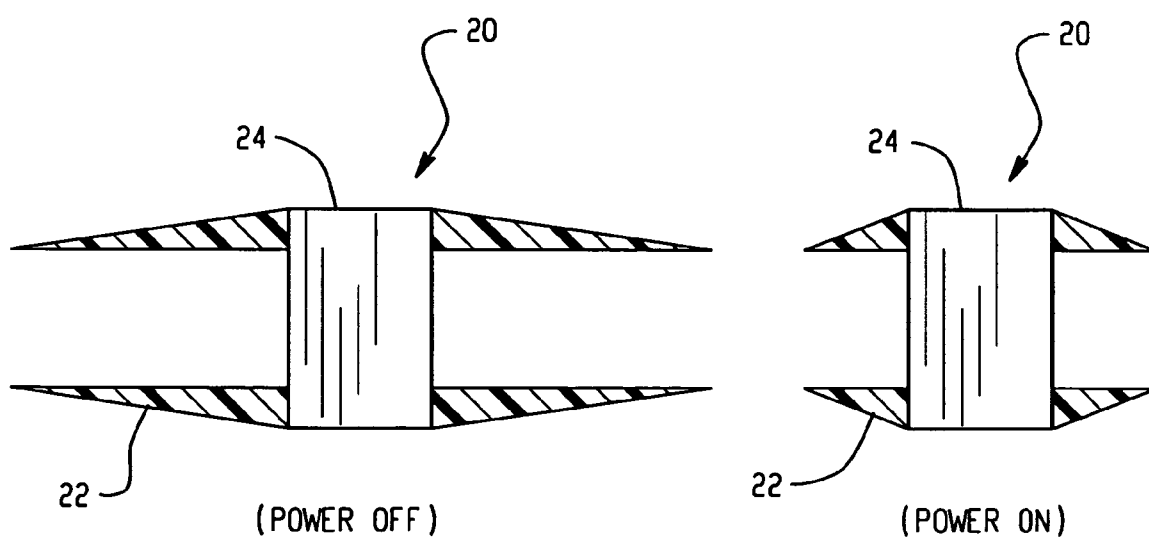


Fig. 2

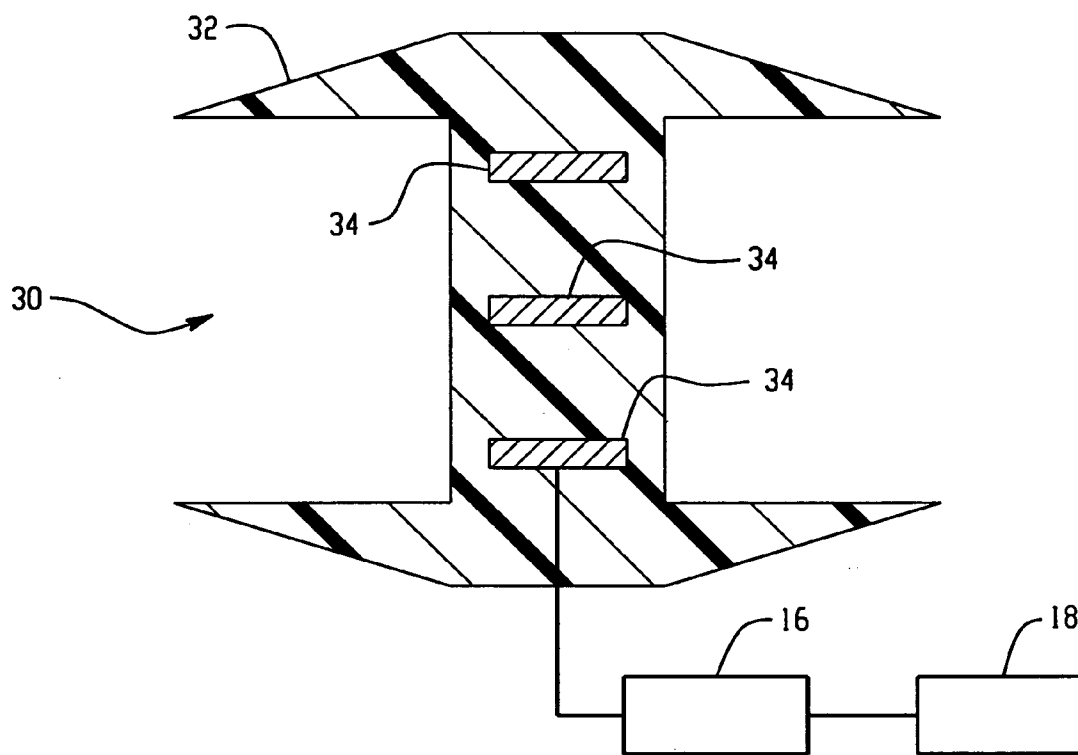


Fig. 3

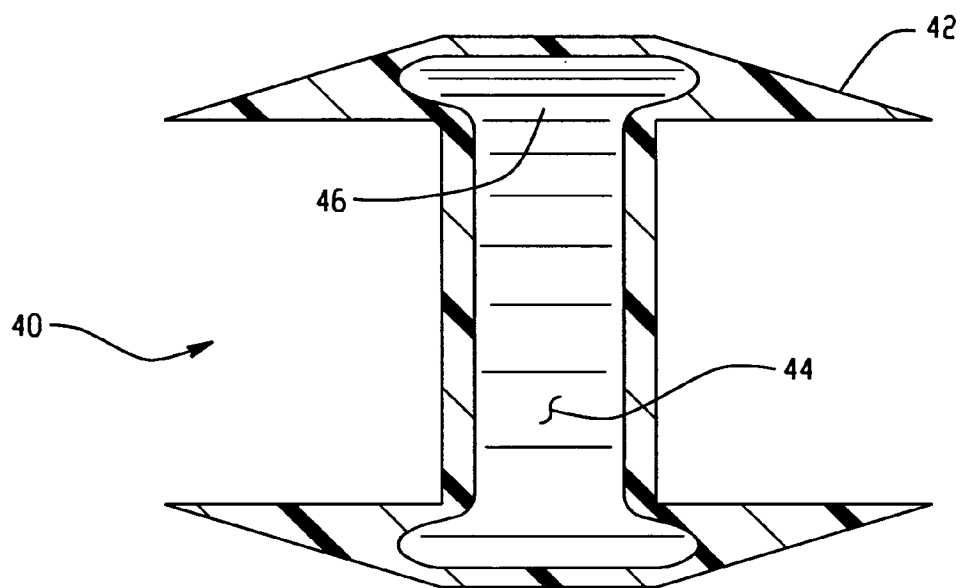


Fig. 4

RELEASABLE SEAL ASSEMBLIES AND METHODS OF USE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application relates to and claims priority to U.S. Provisional Application No. 60/552,781 entitled, "Active Seal Assemblies" filed on Mar. 12, 2004, the disclosure of which is incorporated by reference herein in its entirety.

BACKGROUND

[0002] The present disclosure generally relates to seals, and more particularly, to seal assemblies utilizing active materials for releasing and/or separating sealed opposing surfaces in response to an activation signal.

[0003] Motor vehicles generally employ passive seals to provide sealing engagement between two opposing surfaces, e.g., a passive seal disposed between a windshield and a windshield frame. The resulting seal is generally resistant to forces. A limitation resulting from the use of passive seals in this manner occurs during repairs of one or both of the opposing surfaces or the seal itself. Very often, reuse of the seal is not possible since the repair or seal replacement generally requires separating one surface from the other surface.

[0004] Accordingly, it is desirable to have releasable seal assemblies that can be controlled to selectively release and/or separate the seal upon demand. It would be particularly advantageous if such releasing assemblies result in minimal removal efforts, and provide reuse.

BRIEF SUMMARY

[0005] Disclosed herein are releasable seal assemblies and methods of use. In one embodiment, a releasable seal assembly for selectively removing a component from an other component, wherein the component and the other component are in sealing engagement with the releasable seal assembly comprises a seal structure comprising an active material, wherein the active material is effective to undergo a change in at least one attribute in response to an activation signal, wherein the change in the at least one attribute changes a shape and/or modulus property of the seal structure; an activation device adapted to provide the activation signal in operative communication with the active material; and a controller in operative communication with the activation device.

[0006] A method for selectively removing a component from an other component, wherein the component and the other component are in sealing engagement with a releasable seal assembly comprises activating the releasable seal assembly, wherein the releasable seal assembly comprises an active material in operative communication with a seal structure, wherein activating the releasable seal assembly comprises providing an activation signal to the active material to effect a change in at least one attribute in response to the activation signal, wherein the change in the at least one attribute changes a modulus property and/or shape of the seal structure; and removing the component from the other component.

[0007] The above described and other features are exemplified by the following figures and detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Referring now to the figures, which are exemplary embodiments and wherein like elements are numbered alike:

[0009] FIG. 1 is a cross section view of a releasable seal assembly in accordance with one embodiment, wherein the releasable seal assembly provides sealing engagement between two components;

[0010] FIG. 2 is the cross section view of the releasable seal assembly in accordance with another embodiment, wherein the illustrated releasable seal assembly depicts a power-off configuration and a power-on configuration;

[0011] FIG. 3 is a cross section view of a releasable seal assembly in accordance with another embodiment; and

[0012] FIG. 4 is the cross section view of the releasable seal assembly in accordance with another embodiment.

DETAILED DESCRIPTION

[0013] Disclosed herein are releasable seal assemblies and methods of use. The releasable seal assemblies generally includes a seal structure comprising an active material, wherein the active material changes at least one attribute in response to an activation signal to effect release and/or separation of at least one component disposed in a sealing engagement with another component.

[0014] Although reference will be made herein to automotive applications, it is contemplated that the releasable seal assemblies can be employed for releasing and/or separating components that define various seal interfaces in consumer related products, trucks, airplanes, trains, recreational vehicles, ships and the like. For automotive applications, the releasable sealing assemblies are preferably utilized in selectively releasing one component from another component such as a windshield from a windshield frame, fixed-in-place glazing from its frame, a trunk door from a trunk door frame, a removable hard top from a vehicle body, a sunroof from a sunroof frame, a tail gate from a tail gate frame, a lift gate from a lift gate frame, a light fixture from a light fixture frame, and the like. By way of example, a releasable seal assembly can be selectively activated to release the seal structure disposed between the windshield and the window frame on the vehicle to provide ease of removal and efficient replacement of a new windshield part. Upon deactivation of the signal, the seal structure sealingly engages the windshield and the window frame.

[0015] The active releasable sealing assemblies generally include a seal structure comprising an active material, and controller for providing an activation signal to the active material, wherein the active material changes at least one attribute in response to the activation signal. The term "active material" as used herein refers to several different classes of materials all of which exhibit a change in at least one attribute such as dimension, shape, and/or flexural modulus when subjected to at least one of many different types of applied activation signals, examples of such signals being thermal, electrical, magnetic, mechanical, pneumatic, and the like. One class of active materials is shape memory materials. These materials exhibit a shape memory effect. Specifically, after being deformed pseudoplastically, they can be restored to their original shape in response to the activation signal. Suitable shape memory materials include,

without limitation, shape memory alloys (SMA), ferromagnetic SMAs, magnetic SMAs, and shape memory polymers (SMP). A second class of active materials can be considered as those that exhibit a change in at least one attribute when subjected to an applied field but revert back to their original state upon removal of the applied field. Active materials in this category include, but are not limited to, piezoelectric materials, chemically active polymers, electroactive polymers (EAP), magnetorheological fluids and elastomers (MR), electrorheological fluids (ER), composites of one or more of the foregoing materials with non-active materials, combinations comprising at least one of the foregoing materials, and the like.

[0016] The active material may be integrated within a seal structure, define the complete active seal structure, or may be physically linked with the seal structure. Moreover, the active materials in various embodiments can be used to fabricate the entire seal structure; can be configured to externally actively control the seal structure, e.g., provide actuator means, provide an exoskeleton of the seal structure; and/or can be configured to internally actively control the seal structure, e.g., provide the skeletal structure of the seal structure. Still further, controlled release and/or separation of two components can be effected by means of flexural modulus changes, shape changes, geometry changes, and the like to the seal structure. Of the above noted materials, SMAs and SMPs based releasable sealing assemblies may further include a return mechanism in some embodiments to restore the original geometry of the sealing assembly. The return mechanism can be mechanical, pneumatic, hydraulic, or based on one of the aforementioned active materials. For example, the return mechanism can be a conventional spring biased to the seal structure to provide a restoring force upon deactivation of the active material.

[0017] In those applications where the active materials are integrated into the seal structure, the materials integrated with the active materials are preferably those materials already utilized for the manufacture of seals. For example, various rubbers, foams, elastomers, and the like can be utilized in combination with the active material to provide a releasable sealing assembly. As such, suitable seal materials include, but are not intended to be limited to, styrene butadiene rubber, polyurethane, polyisoprene, neoprene, chlorosulfonated polystyrene, natural rubber, synthetic polyisoprene rubber, epoxylated natural rubber, styrene-butadiene rubber, polybutadiene rubber, nitrile-butadiene rubber, ethylene propylene rubber, butyl rubber, various elastomers, and the like.

[0018] By utilizing the active material in the releasable seal assembly, the seal assembly can reversibly change its modulus and/or dimensional properties to provide release and/or separation between components, provide minimal effort to remove one or both components, as well as provide effective sealing engagement. Applying an activation signal to the active material can effect the reversible change. Suitable activation signals will depend on the type of active material. As mentioned, the activation signal provided for reversibly changing the dimensional and/or modulus properties of the releasable seal structure may include a thermal signal, an electrical signal, a magnetic signal, a pneumatic signal, a mechanical load, and combinations comprising at least one of the foregoing signals, and the like. The particular activation signal is generally dependent on the materials

and/or configuration of the active material within the seal structure. For example, a magnetic and/or an electrical signal may be applied for changing the property of the active material fabricated from magnetostrictive materials. A heat signal may be applied for changing the property of the active material fabricated from shape memory alloys and/or shape memory polymers. For example, the heat signal may be applied via resistive, conductive, or convective heating particularly to SMA and SMP materials. An electrical signal may be applied for changing the property of the active material fabricated from electroactive materials, piezoelectrics, electrostatics, and/or ionic polymer metal composite materials.

[0019] Referring now to FIG. 1, there is shown an exemplary releasable seal assembly generally designated by reference numeral 10 in a sealing engagement prior to activation. The present disclosure is not intended to be limited to the particular configuration of the seal assembly or location. For example, the illustrated releasable seal assembly can be employed to provide releasable sealing engagement between a front windshield and a windshield frame. The releasable seal assemblies in this and other embodiments described herein are generally desirable for automotive applications where at least one component needs to be replaced from the vehicle for regular maintenance and/or replacement and the at least one component is desirably disposed in sealing engagement with a seal structure. The releasable seal assemblies as described herein can be re-used or recycled as may be desired to minimize costs associated with repair, replacement and/or maintenance.

[0020] In FIG. 1, the active material based seal assembly 10 is illustrated as sealing an interface defined by components 12, 14, e.g., a window and a window frame. At least a portion or all of the seal assembly 10 comprises the active material, which is in operative communication with a controller 16. The controller 16 selectively provides a suitable activation signal to the active material. Once the active material is activated, the seal assembly 10 is adapted to reversibly change at least one attribute, e.g., modulus, shape, and the like, so as to permit removal of one or both components 12, 14 from the seal assembly 10, i.e., a reduction in the seal forces or seal surface area against one or both components 12, 14.

[0021] By way of example, electroactive polymers could be used either directly as all or part of the seal assembly 10 or alternatively, as an intermediate layer between the vehicle surface and an adhesive that is used to bond/attach the part in question. Applying voltage to the electroactive polymer can cause compression of the EAP in a direction parallel to the applied field and expansion of the EAP in the plane perpendicular to the applied field. Preferably, the electroactive polymer would be incorporated into the seal assembly so that the directions of compression and expansion would be properly aligned to distort the seal assembly geometry so as to assist in freeing the part.

[0022] As another example, shape memory alloys can be embedded within the seal assembly itself or connected externally (in communication with) its external surface. Heating the SMA through either resistive, conductive, and/or convective heating would cause it to return to a memorized shape, the shape memory alloy being aligned so that this return action would distort the seal/gasket geometry in a manner that would assist in release of the part.

[0023] Likewise, shape memory polymers could be used either directly as all or part of the seal assembly or as an intermediate layer between the vehicle surface and an adhesive that is used to bond/attach the part in question. As will be described in greater detail below, shape memory polymers can have their shape set by first heating them above the glass transition temperature of the lower temperature phase, then applying an external force to deform the shape memory polymer to a desired shape while in this high temperature soft phase, and then cooling the shape memory polymer to a temperature below that of the glass transition temperature of the lower temperature phase while still under the external force which force can then be removed after cooling is complete with the SMP keeping the deformed shape. The original shape can be reset by reheating the SMP while unloaded (with external forces removed) above the glass transition temperature of the lower temperature phase.

[0024] By way of example, the shape memory polymer can be configured to have a memorized high temperature shape such as a flat strip that would be consistent with easy removal of the part. The shape memory polymer would then be held against the part and heated so as to deform the seal into a channel shape, suitable for retention of the part. This "good hold" shape would then be set in the shape memory polymer by lowering the temperature while maintaining the shape. The part with shape memory polymer retainer could then be mounted using for example an adhesive bond between the SMP and the vehicle. Simple heating of the SMP channel would revert it to its memorized flat shape that would ease part removal, for example.

[0025] It should be understood that the following embodiments of active material based seal assemblies would include the controller 16 for selectively providing a suitable activation signal to the active material unless otherwise noted.

[0026] In another embodiment as shown in FIG. 2, an active material based seal assembly 20 includes one or more flange portions 22 that extend from a seal body 24. The flange portion 22 is in sealing contact with surfaces of the component 12, 14 and is formed of the active material. Upon activation, as shown more clearly in FIG. 2, the modulus properties and/or the shape of the flange changes to provide a decrease in the sealing forces exerted by the seal assembly and/or surface area of the seal assembly against the components 12, 14. In this embodiment, the shape can change and cause the seal assembly to retract away from the components 12, 14 to permit removal of one or both components 12, 14. Although the flange portion 20 may be in the removal path of the desired component to be removed, the change in modulus properties and/or shape permits removal or installation to easily occur. Optionally, the entire seal assembly 20 is formed of the active material. In this embodiment, the seal body undergoes a change in modulus and/or shape change to provide similar advantages described above.

[0027] Although reference has been made to the seal assemblies 10, 20 as shown, it should be apparent to those skilled in the art that the specific shape of the seal assembly is not limited. Various seal assembly configurations are contemplated, the shape of which will generally be dependent on the intended application. Preferably, the seal assembly shape is selected to conform substantially to the passive seal structure in which it is intended to replace.

[0028] FIG. 3 illustrates another exemplary active material based seal assembly 30. The seal assembly includes a seal body 32 and one or more active 34 materials embedded with the seal body 32. For example, wires or strips of a shape memory alloy are embedded with the seal body such that activation of the shape memory alloy causes the shape or modulus change in the seal body. The seal body 32 can be solid or may include a wall structure defining an interior region, as may be desired for some applications.

[0029] In yet another embodiment as shown in FIG. 4, the active material based seal assembly 40 includes a seal body 42 defining an interior region 44. Disposed within the interior region is an active material fluid 46. Activation of the active material changes the shape or modulus properties. For example, an electroactive polymer gel may be disposed within the interior region. Activation of the electroactive polymer gel causes seal body to expand.

[0030] Consider next embodiments involving changing the stiffness of the seal structure to assist in part release. Specifically, consider the use of active materials that become more flexible/exhibit reduced modulus when subjected to an applied field, as all or part of the seal structure or as an intermediate layer between the vehicle surface and an adhesive that is used to bond/attach the component. Such use would dramatically reduce the forces and thus mechanical effort required for component removal. Suitable active materials include (but are not limited to) SMP's and MR polymers. In the case of SMP's, the modulus drops significantly (for example by a factor of 30 for polyurethane based SMP's) when heated above the glass transition temperature of their low temperature component. Such a drop in modulus would cause the seal structure to essentially become limp dramatically easing component removal. Similarly, but to a lesser degree, applying a neutralizing field to an MR rubber that contains embedded magnetic particles would reduce the stiffness of the MR rubber in this manner easing part removal.

[0031] It is further contemplated that in addition to field activated morphing, softening, or loss of integrity being individually used to ease component release as described above, that various combinations involving two or more of these field activated attribute changes can be simultaneously co-employed.

[0032] As described above, the present disclosure is generally categorized as using the active material based seal assemblies to replace and/or augment passive seal structures using embedded or integrated active material components. In alternatives, the active material may be partially embedded or completely embedded within the non-active material. In another embodiment, the active material is substantially embedded with the non-active material, which may be completely encased with active or non-active material. The active material or non-active material can be a thin covering.

[0033] Shape memory polymers (SMPs) generally refer to a group of polymeric materials that demonstrate the ability to return to some previously defined shape when subjected to an appropriate thermal stimulus as long as they are under negligible load while the thermal stimulus is operative. The shape memory polymer may be in the form of a solid or a foam as may be desired for some embodiments. Shape memory polymers are capable of undergoing phase transitions in which their shape orientation is altered as a function

of temperature. Generally, SMPs are co-polymers comprised of at least two different units which may be described as defining different segments within the copolymer, each segment contributing differently to the flexural modulus properties and thermal transition temperatures of the material. The term "segment" refers to a block, graft, or sequence of the same or similar monomer or oligomer units that are copolymerized with a different segment to form a continuous crosslinked interpenetrating network of these segments. These segments may be combination of crystalline or amorphous materials and therefore may be generally classified as a hard segment(s) or a soft segment(s), wherein the hard segment generally has a higher glass transition temperature (T_g) or melting point than the soft segment. Each segment then contributes to the overall flexural modulus properties of the SMP and the thermal transitions thereof. When multiple segments are used, multiple thermal transition temperatures may be observed, wherein the thermal transition temperatures of the copolymer may be approximated as weighted averages of the thermal transition temperatures of its comprising segments. With regard to shape memory polymer foams, the structure may be open celled or close celled as desired.

[0034] In practice, the SMPs are alternated between one of at least two shape orientations such that at least one orientation will provide a size/dimension change relative to the other orientation(s) when an appropriate thermal signal is provided. To set a permanent shape, the shape memory polymer must be at about or above its melting point or highest transition temperature (also termed "last" transition temperature). SMP foams are shaped at this temperature by blow molding or shaped with an applied force followed by cooling to set the permanent shape. The temperature necessary to set the permanent shape is generally between about 40° C. to about 200° C. After experiencing an alteration in shape, the permanent shape is regained when the applied force is removed, and the SMP is again brought to or above the highest or last transition temperature of the SMP. The T_g of the SMP can be chosen for a particular application by modifying the structure and composition of the polymer.

[0035] The temperature needed for permanent shape recovery can generally be set at any temperature between about -63° C. and about 160° C. or above. Engineering the composition and structure of the polymer itself can allow for the choice of a particular temperature for a desired application. A preferred temperature for shape recovery is greater than or equal to about -30° C., more preferably greater than or equal to about 40° C., and most preferably a temperature greater than or equal to about 100° C. Also, a preferred temperature for shape recovery is less than or equal to about 250° C., more preferably less than or equal to about 200° C., and most preferably less than or equal to about 180° C.

[0036] Suitable shape memory polymers can be thermoplastics, interpenetrating networks, semi-interpenetrating networks, or mixed networks. The polymers can be a single polymer or a blend of polymers. The polymers can be linear or branched thermoplastic elastomers with side chains or dendritic structural elements. Suitable polymer components to form a shape memory polymer include, but are not limited to, polyphosphazenes, poly(vinyl alcohols), polyamides, polyester amides, poly(amino acids), polyanhydrides, polycarbonates, polyacrylates, polyalkylenes, polyacrylamides, polyalkylene glycols, polyalkylene oxides, polyalkylene

terephthalates, polyortho esters, polyvinyl ethers, polyvinyl esters, polyvinyl halides, polyesters, polylactides, polyglycolides, polysiloxanes, polyurethanes, polyethers, polyether amides, polyether esters, and copolymers thereof. Examples of suitable polyacrylates include poly(methyl methacrylate), poly(ethyl methacrylate), poly(butyl methacrylate), poly(isobutyl methacrylate), poly(hexyl methacrylate), poly(isodecyl methacrylate), poly(lauryl methacrylate), poly(phenyl methacrylate), poly(methyl acrylate), poly(isopropyl acrylate), poly(isobutyl acrylate) and poly(octadecylacrylate). Examples of other suitable polymers include polystyrene, polypropylene, polyvinyl phenol, polyvinylpyrrolidone, chlorinated polybutylene, poly(octadecyl vinyl ether), ethylene vinyl acetate, polyethylene, poly(ethylene oxide)-poly(ethylene terephthalate), polyethylene/nylon (graft copolymer), polycaprolactones-polyamide (block copolymer), poly(caprolactone) diethacrylate-n-butyl acrylate, poly(norbornyl-polyhedral oligomeric silsequioxane), polyvinylchloride, urethane/butadiene copolymers, polyurethane block copolymers, styrene-butadienestyrene block copolymers, and the like.

[0037] Conducting polymerization of different monomer segments with a blowing agent can be used to form the shape memory polymer foam. The blowing agent can be of the decomposition type (evolves a gas upon chemical decomposition) or an evaporation type (which vaporizes without chemical reaction). Exemplary blowing agents of the decomposition type include, but are not intended to be limited to, sodium bicarbonate, azide compounds, ammonium carbonate, ammonium nitrite, light metals which evolve hydrogen upon reaction with water, azodicarbonamide, N,N'-dinitrosopentamethylenetetramine, and the like. Exemplary blowing agents of the evaporation type include, but are not intended to be limited to, trichloromonofluoromethane, trichlorotrifluoroethane, methylene chloride, compressed nitrogen gas, and the like. The material can then be reverted to the permanent shape by heating the material above its T_g but below the highest thermal transition temperature or melting point. Thus, by combining multiple soft segments it is possible to demonstrate multiple temporary shapes and with multiple hard segments it may be possible to demonstrate multiple permanent shapes.

[0038] As previously discussed, other suitable shape memory materials for fabricating the seal assembly also include shape memory alloy compositions. Similar to shape memory polymers, shape memory alloys exist in several different temperature-dependent phases. The most commonly utilized of these phases are the so-called martensite and austenite phases. In the following discussion, the martensite phase generally refers to the more deformable, lower temperature phase whereas the austenite phase generally refers to the more rigid, higher temperature phase. When the shape memory alloy is in the martensite phase and is heated, it begins to change into the austenite phase. The temperature at which this phenomenon starts is often referred to as austenite start temperature (A_s). The temperature at which this phenomenon is complete is called the austenite finish temperature (A_f). When the shape memory alloy is in the austenite phase and is cooled, it begins to change into the martensite phase, and the temperature at which this phenomenon starts is referred to as the martensite start temperature (M_s). The temperature at which austenite finishes transforming to martensite is called the martensite finish temperature (M_f). Generally, the shape memory alloys are

softer and more easily deformable in their martensitic phase and are harder, stiffer, and/or more rigid in the austenitic phase. In view of the foregoing properties, expansion of the shape memory alloy is preferably at or below the austenite transition temperature (at or below A_s). Subsequent heating above the austenite transition temperature causes the expanded shape memory to revert back to its permanent shape. Thus, a suitable activation signal for use with shape memory alloys is a thermal activation signal having a magnitude to cause transformations between the martensite and austenite phases.

[0039] The temperature at which the shape memory alloy remembers its high temperature form when heated can be adjusted by slight changes in the composition of the alloy and through heat treatment. In nickel-titanium shape memory alloys, for instance, it can be changed from above about 100° C. to below about -100° C. The shape recovery process occurs over a range of several degrees and the start or finish of the transformation can be controlled to within a few degrees depending on the desired application and alloy composition. The mechanical properties of the shape memory alloy vary greatly over the temperature range spanning their transformation, typically providing shape memory effects, superelastic effects, and high damping capacity.

[0040] Suitable shape memory alloy materials include, but are not intended to be limited to, nickel-titanium based alloys, indium-titanium based alloys, nickel-aluminum based alloys, nickel-gallium based alloys, copper based alloys (e.g., copper-zinc alloys, copper-aluminum alloys, copper-gold, and copper-tin alloys), gold-cadmium based alloys, silver-cadmium based alloys, indium-cadmium based alloys, manganese-copper based alloys, iron-platinum based alloys, iron-palladium based alloys, and the like. The alloys can be binary, ternary, or any higher order so long as the alloy composition exhibits a shape memory effect, e.g., change in shape orientation, changes in yield strength, and/or flexural modulus properties, damping capacity, superelasticity, and the like. A preferred shape memory alloy is a nickel-titanium based alloy commercially available under the trademark FLEXINOL from Dynalloy, Inc. Selection of a suitable shape memory alloy composition depends on the temperature range where the component will operate.

[0041] Suitable magnetic materials include, but are not intended to be limited to, soft or hard magnets; hematite; magnetite; magnetic material based on iron, nickel, and cobalt, alloys of the foregoing, or combinations comprising at least one of the foregoing, and the like. Alloys of iron, nickel and/or cobalt, can comprise aluminum, silicon, cobalt, nickel, vanadium, molybdenum, chromium, tungsten, manganese and/or copper.

[0042] Polymer means a macromolecular compound prepared by polymerizing monomers of the same or different type. Polymer includes homopolymers, copolymers, terpolymers, interpolymers and the like. Monomer or comonomer refers to any compound with a polymerizable moiety which is added to a reactor in order to produce a polymer. The term "interpolymer" means a polymer prepared by the polymerization of at least two types of monomers or comonomers. It includes, but is not limited to copolymers, polymers prepared from two different types of monomers or comonomers, used interchangeably with interpolymers. Ionic

polymer metal composite means one or more polymer containing a ionic metal composite.

[0043] Suitable magnetorheological fluid materials include, but are not intended to be limited to, ferromagnetic or paramagnetic particles dispersed in a carrier fluid. Suitable particles include iron; iron alloys, such as those including aluminum, silicon, cobalt, nickel, vanadium, molybdenum, chromium, tungsten, manganese and/or copper; iron oxides, including Fe_2O_3 and Fe_3O_4 ; iron nitride; iron carbide; carbonyl iron; nickel and alloys of nickel; cobalt and alloys of cobalt; chromium dioxide; stainless steel; silicon steel; and the like. Examples of suitable particles include straight iron powders, reduced iron powders, iron oxide powder/straight iron powder mixtures and iron oxide powder/reduced iron powder mixtures. A preferred magnetic-responsive particulate is carbonyl iron, more preferably, reduced carbonyl iron.

[0044] The particle size should be selected so that the particles exhibit multi-domain characteristics when subjected to a magnetic field. Diameter sizes for the particles can be less than or equal to about 1,000 micrometers, with less than or equal to about 500 micrometers preferred, and less than or equal to about 100 micrometers more preferred. Also preferred is a particle diameter of greater than or equal to about 0.1 micrometer, with greater than or equal to about 0.5 more preferred, and greater than or equal to about 10 micrometers especially preferred. The particles are preferably present in an amount between about 5.0 to about 50 percent by volume of the total MR fluid composition.

[0045] Suitable carrier fluids include organic liquids, especially non-polar organic liquids. Examples include, but are not limited to, silicone oils; mineral oils; paraffin oils; silicone copolymers; white oils; hydraulic oils; transformer oils; halogenated organic liquids, such as chlorinated hydrocarbons, halogenated paraffins, perfluorinated polyethers and fluorinated hydrocarbons; diesters; polyoxyalkylenes; fluorinated silicones; cyanoalkyl siloxanes; glycols; synthetic hydrocarbon oils, including both unsaturated and saturated; and combinations comprising at least one of the foregoing fluids.

[0046] The viscosity of the carrier component can be less than or equal to about 100,000 centipoise, with less than or equal to about 10,000 centipoise preferred, and less than or equal to about 1,000 centipoise more preferred. Also preferred is a viscosity of greater than or equal to about 1 centipoise, with greater than or equal to about 250 centipoise preferred, and greater than or equal to about 500 centipoise especially preferred.

[0047] Aqueous carrier fluids may also be used, especially those comprising hydrophilic mineral clays such as bentonite or hectorite. The aqueous carrier fluid may comprise water or water comprising a small amount of polar, water-miscible organic solvents such as methanol, ethanol, propanol, dimethyl sulfoxide, dimethyl formamide, ethylene carbonate, propylene carbonate, acetone, tetrahydrofuran, diethyl ether, ethylene glycol, propylene glycol, and the like. The amount of polar organic solvents is less than or equal to about 5.0% by volume of the total MR fluid, and preferably less than or equal to about 3.0%. Also, the amount of polar organic solvents is preferably greater than or equal to about 0.1%, and more preferably greater than or equal to about 1.0% by volume of the total MR fluid. The pH of the

aqueous carrier fluid is preferably less than or equal to about 13, and preferably less than or equal to about 9.0. Also, the pH of the aqueous carrier fluid is greater than or equal to about 5.0, and preferably greater than or equal to about 8.0.

[0048] Natural or synthetic bentonite or hectorite may be used. The amount of bentonite or hectorite in the MR fluid is less than or equal to about 10 percent by weight of the total MR fluid, preferably less than or equal to about 8.0 percent by weight, and more preferably less than or equal to about 6.0 percent by weight. Preferably, the bentonite or hectorite is present in greater than or equal to about 0.1 percent by weight, more preferably greater than or equal to about 1.0 percent by weight, and especially preferred greater than or equal to about 2.0 percent by weight of the total MR fluid.

[0049] Optional components in the MR fluid include clays, organoclays, carboxylate soaps, dispersants, corrosion inhibitors, lubricants, extreme pressure anti-wear additives, antioxidants, thixotropic agents and conventional suspension agents. Carboxylate soaps include ferrous oleate, ferrous naphthenate, ferrous stearate, aluminum di- and tri-stearate, lithium stearate, calcium stearate, zinc stearate and sodium stearate, and surfactants such as sulfonates, phosphate esters; stearic acid, glycerol monooleate, sorbitan sesquioleate, laurates, fatty acids, fatty alcohols, fluoro-aliphatic polymeric esters, and titanate, aluminate and zirconate coupling agents and the like. Polyalkylene diols, such as polyethylene glycol, and partially esterified polyols can also be included.

[0050] Suitable MR elastomer materials include, but are not intended to be limited to, an elastic polymer matrix comprising a suspension of ferromagnetic or paramagnetic particles, wherein the particles are described above. Suitable polymer matrices include, but are not limited to, poly- α -olefins, natural rubber, silicone, polybutadiene, polyethylene, polyisoprene, and the like

[0051] Electroactive polymers include those polymeric materials that exhibit piezoelectric, pyroelectric, or electrostrictive properties in response to electrical or mechanical fields. An example of an electrostrictive-grafted elastomer with a piezoelectric poly(vinylidene fluoride-trifluoroethylene) copolymer. This combination has the ability to produce a varied amount of ferroelectric-electrostrictive molecular composite systems. These may be operated as a piezoelectric sensor or even an electrostrictive actuator.

[0052] Materials suitable for use as an electroactive polymer may include any substantially insulating polymer or rubber (or combination thereof) that deforms in response to an electrostatic force or whose deformation results in a change in electric field. Exemplary materials suitable for use as a pre-strained polymer include silicone elastomers, acrylic elastomers, polyurethanes, thermoplastic elastomers, copolymers comprising PVDF, pressure-sensitive adhesives, fluoroelastomers, polymers comprising silicone and acrylic moieties, and the like. Polymers comprising silicone and acrylic moieties may include copolymers comprising silicone and acrylic moieties, polymer blends comprising a silicone elastomer and an acrylic elastomer, for example.

[0053] Materials used as an electroactive polymer may be selected based on one or more material properties such as a high electrical breakdown strength, a low modulus of elasticity—for large or small deformations), a high dielectric

constant, and the like. In one embodiment, the polymer is selected such that it has an elastic modulus at most about 100 MPa. In another embodiment, the polymer is selected such that it has a maximum actuation pressure between about 0.05 MPa and about 10 MPa, and preferably between about 0.3 MPa and about 3 MPa. In another embodiment, the polymer is selected such that it has a dielectric constant between about 2 and about 20, and preferably between about 2.5 and about 12. The present disclosure is not intended to be limited to these ranges. Ideally, materials with a higher dielectric constant than the ranges given above would be desirable if the materials had both a high dielectric constant and a high dielectric strength. In many cases, electroactive polymers may be fabricated and implemented as thin films. Thicknesses suitable for these thin films may be below 50 micrometers.

[0054] As electroactive polymers may deflect at high strains, electrodes attached to the polymers should also deflect without compromising mechanical or electrical performance. Generally, electrodes suitable for use may be of any shape and material provided that they are able to supply a suitable voltage to, or receive a suitable voltage from, an electroactive polymer. The voltage may be either constant or varying over time. In one embodiment, the electrodes adhere to a surface of the polymer. Electrodes adhering to the polymer are preferably compliant and conform to the changing shape of the polymer. Correspondingly, the present disclosure may include compliant electrodes that conform to the shape of an electroactive polymer to which they are attached. The electrodes may be only applied to a portion of an electroactive polymer and define an active area according to their geometry. Various types of electrodes suitable for use with the present disclosure include structured electrodes comprising metal traces and charge distribution layers, textured electrodes comprising varying out of plane dimensions, conductive greases such as carbon greases or silver greases, colloidal suspensions, high aspect ratio conductive materials such as carbon fibrils and carbon nanotubes, and mixtures of ionically conductive materials.

[0055] Materials used for electrodes of the present disclosure may vary. Suitable materials used in an electrode may include graphite, carbon black, colloidal suspensions, thin metals including silver and gold, silver filled and carbon filled gels and polymers, and ionically or electronically conductive polymers. It is understood that certain electrode materials may work well with particular polymers and may not work as well for others. By way of example, carbon fibrils work well with acrylic elastomer polymers while not as well with silicone polymers.

[0056] By way of example, a weatherstrip formed of SMP can be used for a window and a window frame in a sliding door. These windows tend to get damaged upon normal wear and tear. For example, windows are held in place with the weatherstrip formed of SMP in the window frame. The seal is thermally activated to change at least one attribute in the SMP which reduces the forces resulting from the engagement. Thus, the seal is now released and/or separated between the window and window frame.

[0057] In another example, a weatherstrip formed of magnetorheological polymers (MR) rubber contains embedded magnetic particles that would enhance the sealing on a mounting surface such as windshield to window frame.

Application of a neutralizing field to the active material reduces the stiffness of the MR rubber. The change in modulus causes the MR rubber to become more flexible which reduces the forces associated with the engagement. This flexural modulus change allows ease of removal for part replacement.

[0058] In another example, a releasable seal assembly based on SMA springs can be employed in a windshield and window frame. For example, several releasable seal assemblies are placed along the perimeter of the windshield. Inside the releasable seal assembly, the SMA springs are at a slanted configuration to allow compressibility of the seal. This creates the forces to engage the seal. Upon thermal activation, the SMA springs will contract, pulling away from the opposing surface, which reduces the forces in the plane of engagement. Thus, the seal between the windshield and the window frame is released allowing the windshield for part removal and part replacement.

[0059] Other examples include the releasable seal assembly formed of SMA embedded within the seal assembly. The seal assembly is employed to seal and release the window from the window frame of a door in a recreational vehicle. It is desirable to remove the window to allow circulation of air and then re-use the seal for the window. For example, the SMA releasable seal is aligned along the perimeter of the window and frame. Using resistive, conductive, or convective heat would cause the SMA embedded within the seal assembly to distort the seal geometry in such a manner to release the forces from the engagement. As a result, the forces associated with the seal are reduced which releases the seal. Upon deactivation, the SMA releasable seal forms a seal between the window and frame.

[0060] In another example, the releasable seal assembly formed of SMP appendages can be employed in a channel such as a windshield. For example, the SMP would have a memorized high temperature shape such as a flat strip orientation, which would help with ease of removal of the windshield. The SMP would be held against the channel cavity and heated and deformed into an appendage shape that would be adapted to fit the channel cavity. This particular channel shape and appendage shape such as a knob shape would provide good retention of the windshield to the window frame. This knob shape, which is a "good hold" shape would be set in the SMP by lowering its temperature while held in this shape. The part with the SMP knob shape could be mounted using adhesive bond between the SMP and the window frame. Thermal activation of the SMP would revert it to its memorized flat shape, which would reduce the retention and the forces from the engagement. Thus, the seal would be released and/or separated helping with part removal and part replacement.

[0061] The various examples provided herein are merely exemplary and are not intended to be limiting. Other examples may include releasable seal assemblies used to seal and release parts that may be desirable for the appearance or functionality of a vehicle. For example, seals can be formed and released between fender flares and vehicles, fender skirts and vehicles, and mudguards and vehicles.

[0062] While the disclosure has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof

without departing from the scope of the disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the disclosure without departing from the essential scope thereof. Therefore, it is intended that the disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this disclosure, but that the disclosure will include all embodiments falling within the scope of the appended claims.

1. A releasable seal assembly for selectively removing a component from an other component, wherein the component and the other component are in sealing engagement with the releasable seal assembly, the releasable seal assembly comprising:

a seal structure comprising an active material, wherein the active material is effective to undergo a change in at least one attribute in response to an activation signal, wherein the change in the at least one attribute changes a shape and/or modulus property of the seal structure;

an activation device adapted to provide the activation signal in operative communication with the active material; and

a controller in operative communication with the activation device.

2. The releasable seal assembly of claim 1, wherein the active material comprises a shape memory alloy, a ferromagnetic shape memory alloy, a shape memory polymer, a piezoelectric material, a chemically active polymer, an electroactive polymer, a magnetorheological fluid or elastomers, an electrorheological fluids, composites of one or more of the foregoing materials with non-active materials, and combinations comprising at least one of the foregoing materials.

3. The releasable seal assembly of claim 1, wherein the change in the at least attribute is reversible.

4. The releasable seal assembly of claim 1, wherein the active material is an actuator externally disposed relative to and in operative communication with the seal structure.

5. The releasable seal assembly of claim 1, wherein the active material defines a recess, a cavity, a groove, or a channel of the seal structure.

6. The releasable seal assembly of claim 1, wherein the seal structure forms a weatherstrip, a seal, a gasket, or a lace strip between the component and the other component.

7. The releasable seal assembly of claim 1, wherein the component and the other component comprise a windshield and a windshield frame, fixed-in-place glazing and its frame, a trunk door and a trunk door frame, a removable hard top and a vehicle body, a sunroof and a sunroof frame, a tail gate and a tail gate frame, a lift gate and a lift gate frame, a light fixture and a light fixture frame.

8. The releasable seal assembly of claim 1, wherein the seal structure defines an interior region filled with a fluid of the active material.

9. The releasable seal assembly of claim 8, wherein the active material fluid comprises a magnetorheological fluid or an electrorheological fluid.

10. The releasable seal assembly of claim 8, wherein the activation signal comprises an electrical signal, a magnetic signal, a loading or applied stress, a thermal signal, or combinations comprising at least one of the foregoing activation signals.

11. The releasable seal assembly of claim 1, further comprising a spring in biased communication with the seal structure to restore the seal structure in the absence of the activation signal.

12. A method for selectively removing a component from an other component, wherein the component and the other component are in sealing engagement with a releasable seal assembly, the method comprising:

activating the releasable seal assembly, wherein the releasable seal assembly comprises an active material in operative communication with a seal structure, wherein activating the releasable seal assembly comprises providing an activation signal to the active material to effect a change in at least one attribute in response to the activation signal, wherein the change in the at least one attribute changes a modulus property and/or shape of the seal structure; and

removing the component from the other component.

13. The method of claim 12, wherein the active material comprises a shape memory alloy, a ferromagnetic shape memory alloy, a shape memory polymer, a piezoelectric

material, a chemically active polymer, an electroactive polymer, a magnetorheological fluid or elastomers, an electrorheological fluid, composites of one or more of the foregoing materials with non-active materials, and combinations comprising at least one of the foregoing materials.

14. The method of claim 12, further comprising discontinuing the activation signal and restoring the releasable seal assembly to its original properties.

15. The method of claim 12, wherein the component and the other component comprise a windshield and a windshield frame, a fixed-in-place glazing and its frame, a trunk door and a trunk door frame, a removable hard top and a vehicle body, a sunroof and a sunroof frame, a tail gate and a tail gate frame, a lift gate and a lift gate frame, a light fixture and a light fixture frame.

16. The method of claim 12, wherein the activation signal comprises an electrical signal, a magnetic signal, a loading or applied stress, a thermal signal, or combinations comprising at least one of the foregoing activation signals.

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