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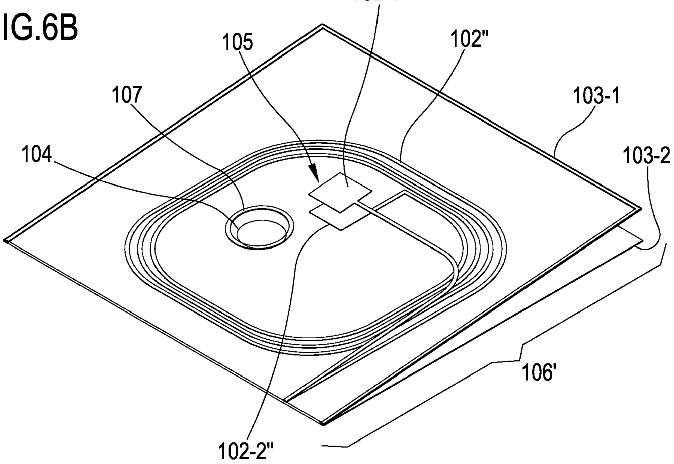
(54) LEAK DETECTION SYSTEM

(57) A leak detection system, process, and package are disclosed. The vacuum package comprises a package wall and a radio frequency circuit configured for emitting a status signal, the status signal changing based on whether the package is in a first sealed condition or in a second non-sealed condition, the radio frequency circuit comprising at least one deformable portion. At least a portion of the package wall is configured to act upon the deformable portion and to move the deformable portion from a first configuration, corresponding to the package being in said first sealed condition, to a second configuration, corresponding to the package being in said second non-sealed condition. The leak detection system comprises a vacuum package and a reader configured for emitting a radio frequency activation signal and for receiving a status signal from the package. The process comprises relatively arranging a package and an interrogation zone of a reader; controlling the reader to emit a radio frequency activation signal configured to supply energy to a radio frequency circuit comprised in/on the package; controlling the reader to receive a status signal from the radio frequency circuit; comparing the status signal to an expected signal; and generating a package state signal indicative of the integrity of the package based on the comparison.

FIG.6B



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Description

Technical Field

[0001] The present invention relates to leak detection in vacuum packages. The leak detection system comprises a vacuum package having a radio frequency circuit. The leak detection process comprises determining the integrity of the vacuum package based on a signal generated by the radio frequency circuit.

Background Art

[0002] A variety of products can be packaged in a package created by bonding plastic film. The storage properties of the packaged goods often depend on the presence of a vacuum or a controlled atmosphere in the package. More precisely, some substances (e.g. oxygen or moisture), if contained in the package, can be detrimental to the quality of the packaged goods. Providing the package with a vacuum, optionally preceded by flushing the inside of the package with an inert atmosphere, can remove most or all of unwanted substances from inside the package, thereby preventing deterioration of the properties of the packaged product. In food packaging, maintaining the properties of packaged goods is vitally important during the entire product life. In all stages of product life, for example packaging, shipping, and storage, up to unpacking of the goods by a consumer, there is a need to ensure the integrity of the package. Further, it must be possible to check whether the package contents have been compromised in any way in a simple and reliable manner.

[0003] The integrity of the package can be compromised by an imperfect or damaged seal such that substances present in the environment can contaminate or impair the contents of the package and/or the packaged goods can exit the package. While larger leaks causing packaged goods to exit from the package can be visually detected quite easily in most environments by checking the integrity of the package (e.g. checking for traces of goods on an outside surface of the package), the same is not true for very small leaks (e.g. micro leaks), causing only very small amounts of packaged goods to leak, or none at all. Further, contamination of the contents of the package cannot easily be detected without special equipment and/or substantial effort. Depending on the packaging requirements (e.g. medical products or food), neither a leak nor a contamination - however small - might be acceptable and must be detectable with a high reliability.

[0004] In some applications, the controlled atmosphere can consist in the package being evacuated (e.g. a vacuum being present inside the package or residual air being expelled as much as possible). A leak or micro leak occurring in such packages typically results in contamination of the package contents and/or in the storage capabilities being substantially compromised, due to substances present in the environment being drawn through the micro leak and into the package as a result of the pressure difference. However, leaks or micro-leaks can be difficult to detect, both after packaging and during shipping and storage, as well as before opening of the package.

[0005] Radio frequency identification (RFID) technology has seen widespread use for a number of purposes, including tracking the state of products and packages. The presence of a package associated with an RFID tag can be detected by remote interrogation of the RFID tag by means of an RFID tag reader. In some examples, the RFID tag contains a numerical code used to identify the package and/or the product contained therein. Triggered by the interrogation, the RFID tag wirelessly transmits the numerical code to the reader.

[0006] RFID tags can either include an individual power source (e.g. in so-called active RFID tags), for example a battery, or receive power required for operation from the signal transmitted by the reader (e.g. in passive RFID tags). Advantages of passive RFID tags typically include small size, low complexity, and low cost of manufacture.

[0007] A very simple type of RFID tag (also referred to as a transponder) does not have any data storage capabilities (e.g. for storing a numerical code). Such RFID tags also include a transponder circuit for remote access, as their counterparts with data storage capabilities do, but are instead designed to electrically resonate at a predetermined frequency. When a reader emits an electromagnetic signal at or near the resonant frequency of the RFID tag within a certain range, the RFID circuit can absorb and/or reflect energy from the emitted electromagnetic field, for example based on capacitive or inductive coupling. The absorbed or reflected energy induces can be detected by the reader, thus indicating the presence of the resonating RFID tag. Corresponding actions, for example activating an alarm signal in anti theft systems, can be triggered accordingly.

[0008] Some applications require more complex RFID tags with extensive data acquisition and/or storage capabilities. In such applications, remote access capabilities of RFID tags are be combined with complex sensor technology in order to provide the tag with sensing capabilities. Typical examples include sensing particular properties of the package and/or its contents, such as moisture content, composition of the atmosphere, temperature, or other parameters. The use of complex active RFID tags is typically not economical in connection with bulk products and products having a low cost per unit, for example in food packaging.

[0009] Therefore, there exists a need for an inexpensive and efficient way to check the integrity of a vacuumized package. Also, there exist a need for a package facilitating an inexpensive and efficient check of its integrity.

[0010] EP 2619106 B1 discloses a reclosable vacuum storage bag with an RFID tag positioned collinearly with a one-time-use sealing means such that the sealing means intersects a portion of the RFID tag. Upon tearing of the sealing means, a portion of the RFID tag antenna is removed, thereby altering the operating frequency of the RFID tag. An RFID reader can be used to pick up on the different frequencies emitted by unopened and opened vacuum storage bags, thereby allowing assessment whether the one-time-use seal on each of the vacuum storage bags has been opened.

[0011] WO 2013/103649 discloses an apparatus for detecting leaks in a flexible package containing an electrically conductive material. A leak can be detected by an electrical current occurring between electrically conductive portions of the device when the current flows through electrically conductive material leaking from the package.

[0012] WO 03/044521 discloses a disposable sensor adapted to be locatable inside a foodstuff package so as to be remotely readable by RF techniques for indication of quality of a packaged foodstuff in a sealed air-filled package, protective atmosphere package or vacuum package. The indication is based on the sensor directly reacting with compounds generated in the atmosphere of the foodstuff package due to the microbiological decay of the foodstuff, for example hydrogen sulfide (or other compounds capable of changing the resistance of a silver thin film). The sensor may also be responsive to increased oxygen content present within the package. The electrical properties of the sensor change cumulatively as a direct function of the degree of product spoilage either due to a reaction related to product spoilage or under the effect of oxygen or other undesirable gas or liquid.

[0013] WO 2008/025779 discloses an RFID-transponder that can be positioned in a radio field of a reading device in an environment having at least one ambient condition. The reading speed is increased in an effective manner and the amount of data is reduced and unauthorized reading out is prevented. Mutual interference of the transponder is reduced and a large number of transponders can be processed. The transponder is combined with an electronic sensor element that detects the ambient condition enabling specific transponders to be read in a targeted manner from a plurality of transponders.

[0014] WO 2005/059859 discloses a sensor arrangement remotely readable by radio frequencies. The sensor arrangement comprises an LC resonator, which comprises a capacitor and a coil, and a sensor element coupled to the LC resonator whose properties change as a function of a measurable quantity. The sensor element does not form a direct galvanic contact with the LC resonator; rather the coupling is implemented not galvanically but capacitively or inductively. The sensor element can be manufactured for example of silver or copper. The thickness of the planar metal layer is typically 30 nm, wherein for example already a small concentration of hydrogen sulphide (less than 1 microgram/liter) inside the package will cause a relatively significant reduction in the average thickness of the element within a few hours.

[0015] US 7,492,164 B2 discloses a product sensor provided with at least one measuring means, whose at least one electrical property is affected by at least one condition, including external conditions of products or product packages (ambient conditions), such as temperature, air pressure, and internal conditions, such as moisture, gas content (protective atmosphere, air), etc. The product sensor is formed of at least two modules connected to each other, in which one module contains at least a part of an antenna circuit and the other module contains a measuring means, which reacts to the condition.

[0016] US 7,456,744 B2 discloses a remote sensing device comprising a sensor and reference circuit. The sensor comprises a resonant circuit having a resonant characteristic modifiable by exposure to an external condition, for example, an environmental condition, such as moisture, humidity, and/or other environmental conditions. Exposure to the external condition alters a material property of the sensor. The modifiable resonant characteristic may comprise at least one of resonant frequency, Q factor, bandwidth, and frequency response characteristic. The sensing system also includes a reference circuit having a reference resonant characteristic. The reference circuit has a resonant characteristic that is relatively immune to changes caused by the external condition. The sensor circuit is configured to be exposed to the external condition and the reference circuit is configured to be protected from the external condition. The receiver is configured to normalize and/or correct the sensor signal based on the reference signal.

[0017] Known devices as described above can entail one or more of the following disadvantages. Complex circuits, for example, passive or active RFID tags comprising sensors configured to control (e.g. track and store) product or package characteristics over time are typically expensive. Other circuits may include redundant elements and/or reference elements or require packaged goods to be of a particular type (e.g. electrically conductive), thereby increasing cost and complexity or restricting the range of possible applications. Equipment for reading information provided by such circuits may be complex to handle and/or maintain with high reliability. In some applications, reading information from a large number of packages simultaneously or in quick succession may be difficult or infeasible.

[0018] An aim of the present invention is to provide a package facilitating an inexpensive and efficient check of its integrity. Another aim of the present invention is to provide an inexpensive and efficient method for checking the integrity of a vacuumized package. A system for checking the integrity of a vacuumized package is also provided.

Summary of invention

[0019] According to the invention, in a 1^{st} aspect there is provided a vacuum package, comprising a package wall; and a radio frequency circuit configured for emitting a status signal, the status signal changing based on whether the package is in a first sealed condition or in a second non-sealed condition, the radio frequency circuit comprising at least one deformable portion; wherein at least a portion of the package wall is configured to act upon the deformable portion and to move the deformable portion from a first configuration, corresponding to the package being in said first sealed condition, to a second configuration, corresponding to the package being in said second non-sealed condition.

[0020] In a 2nd aspect according to the 1st aspect, the deformable portion, when moving to the second configuration, is designed for modifying an electric configuration or an electrical property of the radio frequency circuit and for allowing or preventing emission of the status signal.

[0021] In a 3rd aspect according to any one of aspects 1 and 2, the deformable portion is elastically mounted into the radio frequency circuit and is configured to elastically move to the second configuration when the package is in said non-sealed condition.

[0022] In a 4th aspect according to any one of aspects 1 to 3, the portion of the package wall is provided in superposition to the radio frequency circuit.

[0023] In a 5th aspect according to any one of aspects 1 to 4, the radio frequency circuit is arranged within the package.

[0024] In a 6th aspect according to the 5th aspect, the radio frequency circuit is positioned between a packaged product and the package wall.

[0025] In a 7th aspect according to the 5th or 6th aspect, the portion of the package wall further comprises an isolation layer, isolating the radio frequency circuit towards the inside of the package, optionally the isolation layer being made from an inert material, the inert material being inert to the packaged product.

[0026] In an 8th aspect according to any one of aspects 5 to 7, the isolation layer comprises an aperture configured to put opposite sides of the isolation layer into fluid communication.

[0027] In a 9th aspect according to any one of aspects 1 to 8, the portion of the package wall is configured for deforming the deformable portion against a packaged product, optionally by transferring the external pressure onto the deformable portion and against the packaged product.

[0028] In a 10th aspect according to any one of aspects 1 to 4, the radio frequency circuit is arranged on an outer surface of the package.

[0029] In an 11th aspect according to the 10th aspect, the portion of the package wall further comprises an isolation layer and wherein the radio frequency circuit is positioned between the isolation layer and the portion of the package wall, the isolation layer being configured to sealingly isolate the radio frequency circuit from an outside atmosphere.

[0030] In a 12th aspect according to any one of aspects 10 and 11, the package wall comprises an aperture configured to put opposite sides of the package wall in fluid communication.

[0031] In a 13th aspect according to any one of aspects 8 or 12, the radio frequency circuit comprises an opening, the radio frequency circuit being positioned so that the opening is in superposition with the aperture.

[0032] In a 14th aspect according to the 13th aspect, the radio frequency circuit further comprises a gasket in superposition with the opening and configured to substantially seal a remaining portion of radio frequency circuit from the opening when the pressure difference is greater than the pre-determined threshold value.

[0033] In a 15th aspect according to the 13th aspect, the radio frequency circuit further comprises a plurality of openings and the package comprises a plurality of corresponding apertures, optionally the radio frequency circuit further comprising a plurality of corresponding gaskets, each gasket of the plurality of gaskets being in superposition with a corresponding opening and being configured to substantially seal a remaining portion of radio frequency circuit from the corresponding opening when the pressure difference is greater than the pre-determined threshold value.

[0034] In a 16th aspect according to aspect 2 and any one of aspects 1 to 15, the electrical property comprises one of: an operating frequency of the radio frequency circuit; an impedance of a resistor integrated into the radio frequency circuit, optionally wherein the resistor is a piezoelectric resistor and wherein the deformable portion comprises the piezoelectric resistor; a switch configured to render the radio frequency circuit operable and inoperable; and a switch configured to electrically bypass or short-circuit a component of the radio frequency circuit, optionally the component of the radio frequency circuit comprising a capacitor.

[0035] In a 17th aspect according to any one of aspects 1 to 16, the radio frequency circuit is a resonant electrical circuit.

[0036] In an 18th aspect according to the 17th aspect, the resonant electrical circuit is configured to generate the status signal in form of resonating at a pre-determined resonant frequency, the resonating being detectable by a reader (30), optionally the resonant frequency being in the range of between 865 MHz to 868 MHz and/or between 902 MHz to 928 MHz.

[0037] In a 19th aspect according to any one of aspects 1 to 16, the radio frequency circuit is a radio frequency identification circuit.

[0038] In a 20th aspect according to the 19th aspect, the radio frequency identification circuit is configured generate the status signal in form of generating a radio frequency identification signal, optionally the radio frequency identification signal containing an identification code indicative of the integrity of the package.

[0039] In a 21st aspect according to any one of aspects 1 to 20, the radio frequency circuit includes at least one capacitor, wherein the deformable portion comprises first and second plates of the capacitor and an elastic suspension placed between the first and second plates, wherein the first and/or second plates of the capacitor are configured to relatively move into a proximal configuration in which the first and second plates are substantially in contact with one another when the package is in the first sealed condition and to move into a distal configuration in which the first and second plates are substantially spaced apart from one another when the package is in the second non-sealed condition

[0040] According to the invention, in a 22nd aspect there is provided a leak detection system, comprising a vacuum package according to any one of the preceding aspects; and a reader (30) configured for emitting a radio frequency activation signal and for receiving the status signal.

[0041] In a 23rd aspect according to the 22nd aspect, the leak detection system further comprises a control unit configured to control the reader to emit the radio frequency activation signal and/or to receive the status signal.

[0042] According to the invention, in a 24th aspect there is provided a process for leak detection in a vacuum package, the process comprising the steps of relatively arranging a package and an interrogation zone of a reader; controlling the reader to emit a radio frequency activation signal configured to supply energy to a radio frequency circuit, the package comprising the radio frequency circuit; controlling the reader to receive a status signal from the radio frequency circuit; comparing the status signal to an expected signal; and generating a package state signal indicative of the integrity of the package based on the comparison.

[0043] In a 25th aspect according to the 24th aspect, the expected signal is a voltage drop generated in a circuitry of the reader by a resonant circuit comprised in the radio frequency circuit.

[0044] In a 26th aspect according to the 24th aspect, the expected signal corresponds to a lack of a status signal from the radio frequency circuit.

[0045] In a 27th aspect according to any one of aspects 25 and 26, generating the package state signal comprises generating a signal indicative of an intact package when the status signal and the expected signal correspond to one another.

[0046] According to the invention, in a 28th aspect there is provided a process for leak detection in a vacuum package, the process comprising the steps of providing a vacuum package, comprising a package wall; and a radio frequency circuit configured for emitting a status signal, the status signal changing based on whether the package is in a first sealed condition or in a second non-sealed condition, the radio frequency circuit comprising at least one deformable portion; relatively arranging the deformable portion and a portion of a package wall of the package so that the portion of the package wall acts upon the deformable portion, thereby biasing the deformable portion in a first biased configuration when the package is in the first sealed condition, and so that, when the package transitions from the sealed condition into the non-sealed condition, the portion of the package wall ceases to act upon the deformable portion, thereby allowing the deformable portion to assume a second unbiased configuration.

[0047] In a 29th aspect according to the 28th aspect, the deformable portion, when moving to the second unbiased configuration, is designed for modifying an electric configuration or an electrical property of the radio frequency circuit and for allowing or preventing emission of the status signal indicative of the condition of the package.

[0048] Advantages of the package, the leak detection system, and the process include easy detection of packages in which the vacuumization has been compromised due to a puncture, leak, perforation, or any other defect occurring before, during or after packaging.

[0049] The presence of an inexpensive radio frequency circuit facilitates contactless and quick detection of a package state, for example faulty or intact, sealed or non-sealed, vacuumized or not vacuumized. The radio frequency circuit is inexpensive as compared to more complex solutions that require complex and/or expensive sensors, circuits, transceivers, and/or processors.

[0050] The radio frequency circuit can be applied during different stages of packaging, for example, the packaging film can be provided with radio frequency circuits at regular intervals (e.g. spaced accordingly) so that after forming and sealing the package around a product, the radio frequency circuit is already positioned as desired.

[0051] In other applications, the radio frequency circuit can be applied, as a separate component (fixedly attached - or not - to the packaging material), to the product itself or to the inside of the packaging material during packaging. In this manner, the radio frequency circuit can be positioned and applied in a flexible manner and depending upon the individual requirements of the product to be packaged and/or the packaging process.

[0052] In still other applications, the radio frequency circuit can be affixed on an outer surface of the package during or after packaging. This allows for flexible adaptation to the packaging process and easy integration into existing processes.

[0053] In another example, detection in bulk of a number of packages in parallel or substantially at the same time (e.g. a number of packages packed in a box for shipping, storage, etc.) can be achieved due to the contactless and quick detection by a suitable reader.

[0054] Further advantages are described in more detail below.

Brief description of drawings

[0055] The present invention will become clearer by reading the following detailed description, given by way of example and not of limitation, to be read with reference to the accompanying drawings, wherein:

FIG. 1 shows general components and basic operation of an RFID system;

FIG. 2 shows an example of a simple RFID transponder and its basic operation;

FIGs. 3A and 3B show first and second embodiments of an RFID transponder and their basic operation in accordance with the present invention;

FIGs. 4A and 4B illustrate the operation of an RFID tag in accordance with the first embodiment of the present invention;

FIG. 4C shows an example of a package suitable for use with embodiments of an RFID in accordance with the present invention;

FIG. 5 shows an example process for checking the integrity of a package in accordance with the present invention;

FIG. 6A and 6B illustrate the operation of an RFID tag in accordance with a third embodiment of the present invention;

FIG. 7A and 7B show details of an application of an RFID tag in accordance with a third embodiment of the present invention, where the tag is placed inside a package;

FIG. 8 shows details of an application of an RFID tag in accordance with a third embodiment of the present invention, where the tag is placed outside on a package;

FIG. 9A and 9B illustrate a deformable portion in accordance with a fourth embodiment of the present invention in respective first and second operating configurations; and

FIG. 10A and 10B illustrate alternative embodiments of deformable portions in accordance with the present invention.

Detailed Description

[0056] FIG. 1 shows general components and basic operation of an RFID system. A typical RFID system 20 comprises an RFID tag or transponder 10 and a reader 30. The reader includes an antenna 32 as shown in FIG. 1 as a separate antenna or in an integrated fashion. The RFID tag 10 also includes an antenna (not shown as a separate component in FIG. 1 for clarity). Further, the system may comprise a control unit 40 configured for controlling reader 30 and for processing data provided by reader 30. Within the scope of this document, when a tag is referred to, the term is understood to pertain to RFID tags and transponders, both passive and active, including tags having different capabilities (e.g. data storage, sensory, or other), unless otherwise specified. Also, for brevity, tags, transponders, systems, readers, and other components are generally referred to without the prefix "RFID" as it is understood that RFID tags, transponders, systems, readers, etc. are discussed here.

[0057] Further with respect to FIG. 1, tags 10 are associated with objects 50 (e.g. packages, articles, items), for example for identification purposes. Reader 30 is capable of transmitting and receiving radio waves using antenna 32. The capabilities of reader 30 typically include providing energy to the tag, and reading data from and/or writing data to the tag. Radio waves 202, generated by reader 30 using antenna 32, form an interrogation zone 206 made up of an electromagnetic field. A tag 10 located within interrogation zone 206 receives energy through the electromagnetic field in order to power its functions, for example exciting the resonant circuit or exchanging data with reader 30. In some applications, tag 10 is configured to transmit an ID code upon being subjected to activating radio waves 202. In other applications, merely the resonant circuit is excited to resonate at a predetermined frequency. Control unit 40 controls the transmission of radio waves by reader 30 and processes signals provided by reader 30 upon receipt of signals emitted by tags 10.

[0058] In general, packages 50 have an internal pressure inside the package and an external pressure outside the package. During packaging, typically, the inside of the package is filled with an inert gas or mixture of gases or vacuumized. In both cases a pressure difference between the inside of the package and the outside can be present. In case of substantially complete evacuation or vacuumization of the package, the internal pressure during evacuation is typically substantially lower than an external or ambient pressure (e.g. outside an evacuation chamber), the external or ambient pressure being typically equal to about 101.325 kPa or about ambient pressure. The internal pressure can vary, depending upon the type of vacuumization performed and/or the type of package used. In rigid packages, which can withstand substantial pressure and contain a vacuum for an extended period of time, the pressure difference is typically between 81.6 kPa and 100.8 kPa of relative pressure (preferably between 96.3 kPa and 100.3 kPa of relative pressure), that is, the internal pressure is between 81.6 kPa and 100.8 kPa lower (or, preferably, between 96.3 kPa and 100.3 kPa lower) than the external pressure or the ambient pressure. The same pressure difference can be expressed in absolute values instead of relative values in that the same pressure difference is between 0.5 kPa and 20 kPa of absolute pressure (preferably between 1 kPa and 5 kPa of absolute pressure), whereas the external pressure is equal to about 101.325 kPa or about ambient pressure in both cases. The term "relative pressure" is understood to correspond to a value of pressure difference. For example, if a package is vacuumized to an (absolute) internal pressure of about 5 kPa, and the (absolute) external pressure is about 100 kPa, then the relative pressure difference between both values is about 95 kPa or about 95%.

[0059] In packages made of flexible material (e.g. one or more layers of film, typically shrinkable), a substantial vacuum inside the package typically cannot be sustained after vacuumization as the film material will closely follow the shape or contour of the packaged product. In case of food packaging (e.g. meat, cheese, other non-liquid products), the result is a package having almost the exact shape of the packaged product (e.g. a block of cheese) with a film sealingly surrounding the entire product and closely adhering to its contours. In such cases, the internal pressure within the package is typically not significantly lower than an external pressure. In case the packaged product is semi rigid (e.g. a loaf of meat), the internal pressure within the package will typically be identical to the external pressure, due to the compliant product structure allowing the pressure to reach an equilibrium in which the (flexible) film and the compliant product accommodate some deformation. In any of these cases, the film is forced to closely adhere to the product shape because of the effects of the vacuum process.

[0060] If the product facilitates the creation or preservation of cavities within the package (e.g. blocks of chees having holes, tricklable solid product such as coffee beans), then the internal pressure within a package consisting of plastic film can be significantly lower than an external pressure. The structure of the product allows for the preservation of one or more cavities that substantially contain a vacuum (e.g. 5 to 20 kPa, see above). In such cases, the packaging film cannot easily be lifted off from the product surface or shape, because of the sustained presence of the vacuum within the package. The pressure differential between the internal and external pressures keeps the film to closely adhere to the product.

[0061] If, however, the product does not facilitate the creation or preservation of cavities within the package (e.g. in case of a solid block of cheese without holes or cavities, or a loaf of meat), then the internal pressure within a package consisting of plastic film cannot be significantly lower than an external pressure, as described above. In this case, too, it is not easy to lift off the film from the product, due to the lack of expandable fluid (e.g. gas or air) within the package. Since there is no volume present, that could be expanded, the film is also kept in a position to closely adhere to the product. In these cases, trying to lift the film off the product would instantly and correspondingly create a significant pressure differential that counteracts this action and keeps the film in place.

[0062] FIG. 2 shows an example of a simple RFID transponder and its basic operation. Transponder (or tag) 10 comprises an LC resonant circuit and generally corresponds to a 1-bit transponder device similar to transponders used in anti-theft application or in electronic article surveillance (EAS). A 1-bit transponder typically conveys two states of operation, namely the presence of a transponder within the interrogation zone 206, or its absence. The system 20 shown in FIG. 2 operates as follows. Reader 30 generates a magnetic alternating field 202 in the radio frequency range. Once transponder 10, i.e. the LC resonant circuit, is moved into the interrogation zone (i.e. into the vicinity of the magnetic alternating field), energy 208 from the alternating field is induced in the resonant circuit via its coil. If the frequency of the alternating field corresponds to the resonant frequency of transponder 10, a sympathetic oscillation occurs. The current that flows in the resonant circuit of transponder 10 as a result of the oscillation acts against the external magnetic alternating field generating the energy supplied to transponder 10. This effect can be measured as a voltage drop across the reader's generator coil. A change in the induced voltage can alternatively be detected using an optional sensor coil (not shown).

[0063] The relative magnitude of the change depends on the spatial configuration between the two coils L (or antennae). In order to ensure that a tag 10 is reliably detected in the interrogation zone, the frequency of the magnetic field generated by reader 30 is not constant. Instead, the so-called generator frequency continuously crosses the range between a minimum and a maximum frequency, between which the resonant frequency of tag 10 is enclosed. Each time the generator frequency corresponds to the resonant frequency of the resonant circuit of tag 10, the transponder begins to oscillate, thereby creating the voltage change at the generator coil (and, optionally, at the sensor coil; see above). In such a "scanning" operating mode, in which reader 30 continuously scans a predetermined frequency range, detection of tags 10 can be reliably performed, regardless of most interference and without requiring any particular spatial configuration between reader 30 and tag 10.

[0064] FIGs. 3A and 3B show first and second embodiments of an RFID transponder and their basic operation in accordance with the present invention. Transponders 10 of FIGs. 3A and 3B comprise, similar to transponder 10 as shown in FIG. 2, a coil L and a capacitor C. Further, transponders 10 have a deformable portion 106 configured to modify an electrical property of the LC resonant circuit of each transponder 10. In some embodiments, deformable portion 106 comprises a switch 105, for example a mechanical switch or similar element, which is configured to connect or disconnect portions of the circuitry. In other embodiments (not shown), deformable portion 106 comprises a resistor (e.g. piezoelectric resistor) configured to modify an electrical resistance depending upon the deformation.

[0065] In the first embodiment shown in FIG. 3A, the electrical property of the resonant circuit modified by deformable portion 106 comprises a switch 105 configured to open and close the LC resonant circuit of transponder 10. Depending upon a physical or mechanical deformation of deformable portion 106, thus, the LC resonant circuit of transponder 10 is closed (e.g. switch 105 is closed and the circuit is operational) or opened (e.g. switch 105 is opened and the circuit is not operational). This can be achieved, for example, by providing the resonant circuit with a spring-loaded conductor configured to close an electrical connection upon compression of the spring and to open the electrical connection in a relaxed state of the spring, effectively defining a compression-triggered switch.

[0066] In the second embodiment shown in FIG. 3B, the electrical property of the resonant circuit modified by deformable portion 106 comprises a switch 105 configured to short-circuit capacitor C of the LC resonant circuit of transponder 10. Depending upon a physical or mechanical deformation of deformable portion 106, thus, capacitor C of the LC resonant circuit of transponder 10 is operational (e.g. if the capacitor is not short-circuited; i.e. switch 105 is open) or not operational (e.g. if the capacitor is short-circuited; i.e. switch 105 is closed). This can be achieved, for example, by embedding a compressible dielectric material between the two plates of the capacitor. Upon sufficient compression of the compressible dielectric material, an electrical connection (e.g. facilitated by a small pin or projection in at least one of the plates) is established, thereby electrically short-circuiting the two plates. In this state, the capacitor cannot store any electrical energy due to the electrical connection between the plates and, thus, the resonant circuit cannot function.

[0067] In both embodiments, the operational states of transponder 10 are extended, namely including presence and absence of transponder 10 (within the interrogation zone) and the state of the deformable portion 106. It is noted that deformable portion 106 can comprise different structural features (e.g. spring, coil, foam) and be configured to modify different electrical properties of the circuit (e.g. impedance incl. opening and closing the circuit, switching between portions of the circuit, short-circuiting components of the circuit). Some embodiments are discussed further below.

[0068] FIGs. 4A and 4B illustrate the operation of an RFID tag 10 in accordance with the first embodiment of the present invention. FIG. 4A shows tag 10 in a first state of operation in which deformable portion 106' comprises a switch 105. As shown, deformable portion 106' is in a biased or deformed configuration, such that respective ends 102-1' and 102-2' of resonant circuit 102', overlapping in correspondence of deformable portion 106' and defining switch 105, are in contact with one another. In this configuration (corresponding to the circuit shown in FIG. 3A having switch 105 closed), the resonant circuit 102' of tag 10 is operational in the sense that it can be detected within an interrogation zone 206 of a suitable reader 30. Deformable portion 106' is brought into its biased or deformed configuration by opposite layers (e.g. an upper and a lower outer layer) of a main body 100' of tag 10 being compressed towards one another, thereby bringing respective ends 102-1' and 102-2' of resonant circuit 102', overlapping in correspondence of deformable portion 106' and defining switch 105, into contact with one another. This compression can be achieved, for example, by tag 10 being arranged within a vacuumized package, between the packaged product and the packaging film of the vacuum package. This compression can also be achieved by tag 10 being arranged on a vacuumized package, where tag 10 is placed, for example, as a label on the packaging film of the vacuum package, covering a perforation or aperture configured to put tag 10 into fluid communication with the inside of the package. Both embodiments of application of tag 10 are described in further detail below.

[0069] FIG. 4B shows tag 10 in a second state of operation in which deformable portion 106' also comprises switch 105. As shown, deformable portion 106" is not in a biased or deformed configuration, but in an unbiased or relaxed configuration, such that opposite ends 102-1" and 102-2" of resonant circuit 102", overlapping in correspondence of deformable portion 106" and defining switch 105, are not in contact with one another. In this configuration (corresponding to the circuit shown in FIG. 3A having switch 105 opened), the resonant circuit 102" is not operational in the sense that (due to the circuit not being closed) it cannot be detected within an interrogation zone 206 of a suitable reader 30. Deformable portion 106" returns to its unbiased or relaxed configuration if tag 10 does not receive any external pressure forcing opposite layers (e.g. upper and lower outer layers) of a main body 100" of tag 10 towards one another. This state can occur, for example, when tag 10 is arranged within a vacuumized package as described above (e.g. between the packaged product and the packaging film of the vacuum package or placed on the film), in cases where the integrity of the package is compromised and the vacuum can no longer be maintained. In such cases, the ambient atmosphere entering the package enables the packaging material to expand and to relieve pressure from tag 10. Thus, opposite layers of main body 100" of tag 10 can separate from one another. This provides enough space for deformable portion 106" to return to its unbiased or relaxed configuration, thereby separating respective ends 102-1" and 102-2" of resonant circuit 102", overlapping in correspondence of deformable portion 106" and defining switch 105, and, thus, opening the resonant circuit 102" of tag 10. With resonant circuit 102" of tag 10 being open, tag 10 cannot be detected within an interrogation zone of reader 30. Similar functionality can be achieved with a deformable portion and a switch as described above with respect to FIG. 3B.

[0070] FIG. 4C shows an example of a package 50 for use with embodiments of an RFID tag 10 in accordance with the present invention. Package 50 is a vacuumized package containing a product 52 within a package comprising film 54. Product 50 can be packaged and vacuumized in any manner known in the art, for example using bag packing or a horizontal form fill and seal (HFFS) machine. Before or during packaging, and before vacuumization, tag 10 is arranged within package 50 in a manner that allows film 54 to hold tag 10 against packaged product 52 such that deformable portion 106 (not shown in FIG. 4C) of tag 10 is brought into its biased or deformed configuration before or during vacuumization. This can be achieved as mentioned above by placing tag 10 against the inside of film 54 or, for example, by attaching tag 10 in a label-type configuration against film 54 or product 52. This latter is described in more detail further below.

[0071] A configuration of package 50 and tag 10 as described enables checking the integrity of package 50 using a reader 30 by trying to read tag 10 during any stage subsequent to packaging (e.g. storage, shipping). In the manner described above with respect to FIGs. 3A, 4A, and 4B, reader 30 can be activated when package 50 is within the interrogation zone of the reader. If the integrity of package 50 is not compromised (i.e. the package is properly sealed and vacuumized), the resonant circuit of tag 10 is operational and will respond to the reader being activated. Based on receiving a response signal from tag 10, the integrity of package 50 can be confirmed due to the fact that only in the presence of a vacuum inside package 50, tag 10 is operational. In the alternative, should the presence of a package 50 within the interrogation zone 206 of a reader not result in tag 10 providing a response signal, it can be quickly confirmed that the vacuum within the package has been compromised.

[0072] It is noted that tag 10 not providing a return signal can also have other reasons (e.g. malfunction of the tag). In such cases, the system can be modified in order to prevent unwanted results. For example in food packaging it is typically desired to avoid false negatives (e.g. compromised packages not being detected as such), while false positives (e.g. intact packages being detected as compromised packages) are more acceptable, if error rates remain low.

[0073] FIG. 5 shows an example process for checking the integrity of a package in accordance with the present invention. The described process is applicable to all different types of tags and applications in accordance with the present invention, regardless of the mode of application (e.g. internal or external to the package, or the individual type of tag employed). In step 500, the process starts. In step 502, a package 50 and a reader 30 are relatively positioned so that package 50 is within the interrogation zone 206 of reader 30. It is noted that this can be achieved by package 50 being transported, for example using a conveyor belt, into the vicinity of reader 30 (e.g. in a production, processing, or packaging setting). In such cases, reader 30 can be fixedly integrated into a component of a packaging machine (e.g. in correspondence of an exit belt). Alternatively, reader 30 can be a mobile device, manually operated by a user sampling individual packages at random (e.g. after packaging, before and/or during storage and shipping, etc.). In step 504 reader 30 is controlled to activate tag 10 of package 50. This can be achieved as described above, by transmitting electromagnetic waves towards tag 10, thereby inducing an electric current into the resonant circuit of tag 10. Other ways of supplying energy to tag 10 in order to activate it can be employed as known in the art. A control unit can be provided separately from reader 30 or reader 30 can have an integrated control unit. Since package 50 and, thus, tag 10 is positioned within interrogation zone 206 of reader 30, energy is supplied to tag 10, activating its resonant circuit. In step 506, reader 30 is controlled to detect a return signal from tag 10. The return signal can consist of, as described above, a voltage drop being induced into the circuitry of reader 30 or of radio waves emitted by the resonant circuit and received at reader 30. This is typically the case with passive tags comprising a resonant circuit. Other passive or active tags can provide different return signals, including digital data encoded in electromagnetic waves transmitted in response to the tag being activated. In step 508 the return signal detected by reader 30 is compared with an expected return signal.

[0074] In the first embodiment (see, e.g., FIG. 3A, 4A, 4B), tag 10 is configured to provide, upon being supplied with energy from a reader 30, a return signal as long as package 50 remains vacuumized. If the integrity of package 50 is not compromised, switch 105 formed by deformable region 106 (see, e.g. FIG. 3A) remains closed and the resonant circuit can be excited due to energy being supplied. Therefore, the expected signal for checking the integrity of package 50 is the presence of a return signal (e.g. a voltage drop or detected resonant frequency; see above). This configuration is particularly useful in applications, where packages 50 are checked in a sequential manner, for example, at an exit belt of a packaging machine. Here, the presence of a package can be verified (e.g. by optical means) and a corresponding return signal can be detected. The above is also applicable to other embodiments that function substantially analogous to the first embodiment (see, e.g., FIGs. 6A, 6B, 7A, 7B, 8).

[0075] In the second embodiment (see, e.g. FIG. 3B), tag 10 is configured not to provide a return signal as long as package 50 remains vacuumized. As long as the integrity of package 50 is not compromised, switch 150 formed by deformable region 106 (see, e.g. FIG. 3B) remains open and the resonant circuit cannot be excited due to energy being supplied by reader 30. In this second embodiment, the expected signal for checking the integrity of package 50 is the absence of a return signal (e.g. a voltage drop or detected resonant frequency; see above). This configuration is particularly useful in applications, where packages 50 are checked in bulk, for example, after having been packaged in multiple units (e.g. 50 pieces in a shipping container). Here, the presence of (at least) a single defective package 50 among a number of intact packages can easily be verified when the bulk package is placed within the interrogation zone of a reader. It is noted that both embodiments can be combined in that both types of tags be placed in the same package, one actively (i.e. by means of a signal and not lack thereof) indicating a defective or non-sealed package, one actively indicating an intact or sealed package, preferably on different frequency bands. In this manner, bulk checking of a large number of packages can easily be effected while also facilitating the tracking of individual package numbers (e.g. intact, defective, overall).

[0076] In step 510, a corresponding signal (e.g. indicating the integrity state of a single package or that of a bulk shipment of packages) is generated based on the comparison of the detected return signal and the expected signal. For example, in the first embodiment, an alarm signal can be generated if no return signal is detected and, thus, the expected signal (e.g. presence of a voltage drop) does not correspond to the detected signal (e.g. no voltage drop detected), thus indicating a defective package the vacuum of which has been compromised. In the second embodiment, for example, an alarm signal can be generated if a return signal is detected and, thus, the expected signal (e.g. absence of a voltage drop) does not correspond to the detected signal (e.g. a voltage drop was detected), thus indicating at least one defective package 50 (the vacuum of which has been compromised) among a number of packages 50 in a bulk shipment. The process 500 ends at step 512, where further actions can be performed based on the package state signal generated at step 510. In some applications, a defective package 50 can be collected in a separate container and be discarded accordingly. In other applications, defective packages can be removed from a bulk shipment and replaced with intact packages.

[0077] FIG. 6A and 6B illustrate an example structure and operation of an RFID tag in accordance with a third embodiment of the present invention. Tag 10 in accordance with the third embodiment comprises a deformable portion (see different operating configurations of the deformable portion denoted as 106' and 106", respectively), formed by two superimposed layers of film 103-1 and 103-2, which is configured to return to and/or maintain, a relaxed configuration (see FIG. 6B) where layers 103-1 and 103-2 are in a spaced-apart configuration. Layers 103-1 and 103-2 can be formed from a single layer of film folded over to form superimposed layers 103-1 and 103-2. Alternatively, layers 103-1 and 103-2 can be formed as individual layers suitably bonded together (e.g. along one common edge thereof) in superimposition using any one of the known techniques (e.g. heat-bonding, application of glue, crimping, or other). Upon external action on tag 10 (e.g. compression against a product or film), the deformable portion will assume its operating configuration 106', denoting a biased or deformed configuration. This external action can be achieved, for example, by tag 10 being confined between a product 52 and film 54 within a vacuumized package 50 (see, e.g., FIG. 4C). It is understood that layers 103-1 and 103-2 can be made of any suitably stiff or rigid film material which provides sufficient resilience (e.g. to return to the relaxed operating configuration) and sufficient flexibility (e.g. also allowing layers 103-1 and 103-2 to assume the biased operating configuration, in which the layers are compressed against one another).

[0078] Tag 10 further comprises one or more openings (e.g. punctures, apertures) 104. Depending upon the individual form of application, the one or more openings 104 are configured to put the region between layers 103-1 and 103-2 into fluid communication with the vacuumized inside of package 50, thereby allowing fluid to flow from outside layers 103-1 and 103-2 (e.g. above tag 10 or below tag 10) into and out of the region and/or volume between layers 103-1 and 103-2. It is understood that "region" denotes any spatial configuration between the two layers 103-1 and 103-2. For example, as long as package 50 remains vacuumized, layers 103-1 and 103-2 remain in superimposition and in contact with one another, so that there is substantially no significant volume present between the two layers of film. The one or more openings 104, however, are arranged and configured to facilitate ingress of gas or air into the region between the two layers 103-1 and 103-2, such that, upon failure of the vacuum (e.g. due to a leak or puncture), said air or gas can enter into the region between the two layers, thereby allowing the layers 103-1 and 103-2 to gradually separate and form/increase a volume between the layers. The ingress of air or gas facilitates forming and/or increasing an internal volume between layers 103-1 and 103-2, resulting in the deformable portion 106 (e.g. by means of switch 105) modifying the electrical property of the circuit.

[0079] In some embodiments, each of the one or more openings 104 is provided with a gasket 107 arranged opposite thereto, such that in the biased or deformed configuration, the gasket 107 can prevent inflow of any fluids or liquids into the region between layers 103-1 and 103-2. It is noted that the presence of one or more gaskets is optional and that the one or more openings can be arranged on either or both layers 103-1 and 103-2, in order to facilitate ingress of fluid into the region between the layers upon the failure of the vacuum and the subsequent transition of the deformable portion from the biased or deformed configuration into the relaxed configuration.

[0080] In FIG. 6A, switch 105, here formed by superimposed ends 102-1' and 102-2' (not shown for clarity; see FIG. 6B for corresponding superimposed ends 102-1" and 102-2" denoting a spaced-apart configuration), is shown as closed, thereby rendering tag 10 in an operable configuration. Superimposed ends 102-1' and 102-2' are in contact with one another due to layers 103-1 and 103-2 being in superimposition and arranged against one another. Layer 103-1 carries end 102-1' and layer 103-2 carries end 102-2', such that upon contact between layer 103-1 and 103-2, ends 102-1' and 102-2' also make mechanical and, thus, electric contact, closing switch 105.

[0081] In FIG. 6B, switch 105, here formed by superimposed ends 102-1" and 102-2", is shown as opened, thereby rendering tag 10 in an inoperable configuration. Due to the presence of an internal volume of air or gas (or any non-conductive fluid) between layers 103-1 and 103-2, superimposed ends 102-1' and 102-2' are not in contact with one another. Layers 103-1 and 103-2 are still arranged in superimposition but, due to the internal volume between the layers, are no longer arranged against one another. Layer 103-1 carries end 102-1' and layer 103-2 carries end 102-2', such that upon contact between layers 103-1 and 103-2 substantially ceasing to exist, ends 102-1' and 102-2' are also no longer in mechanical and electrical contact, opening switch 105.

[0082] FIG. 7A and 7B show details of an application of an RFID tag in accordance with a third embodiment of the present invention, where the tag is placed inside a package. The detailed view shows a cross section of an outer section of package 50, showing film 54, tag 10 applied inside the package, and part of product 52 in cross section.

[0083] FIG. 7A shows a cross section of tag 10 arranged between film 54 of package 50 and product 52, in a state in which package 50 is intact (e.g. having no leak or puncture) and a vacuum is present inside the package. Due to tag 10 being arranged on the inside of film 54, tag 10 is compressed between film 54 and product 52 such that superimposed layers 103-1 and 103-2 are held in contact with each other. The presence of the vacuum prevents any gas or air from getting between layers 103-1 and 103-2, such that the corresponding deformable portion remains in the biased or deformed configuration and such that the RFID circuit remains operable). It is noted that tag 10 can simply be placed on the product 52 or against the inside of film 54 during or before packaging. Further, tag 10 can be positioned using a label or similar portion of film or without using any additional material, in which case the tag is placed directly on product 52 or against film 54. Depending upon the individual application (e.g. type of product packaged, type of film used, shape/size/type of package, etc.) different modes of placing tag 10 can be employed.

[0084] FIG. 7B illustrates the same tag 10 in the same package 50 upon occurrence of a leak or puncture of film 54. When, due to the leak or puncture (or any other defect in the packaging material allowing for fluid to enter the package), air or gas enters package 50, the air or gas enters also the region between layer 103-1 and 103-2, due to the biased or deformed configuration of the deformable portion, which causes the opposing layers 103-1 and 103-2 to separate and, thus, causes suction of the air or gas into the newly created volume between the two layers through the opening(s) 104. The bias of the deformable portion can be the result of the two layers 103-1 and 103-2 being biased in a spaced-apart configuration. In addition, or as an alternative, biased elements can (further) bias the two layers 103-1 and 103-2, for example springs or similar elements (not shown in FIG. 7B; see FIGs. 10A and 10B for examples as described further below).

[0085] FIG. 8 shows details of an application of an RFID tag in accordance with a third embodiment of the present invention, where the tag is placed on an outside surface of a package, e.g. placed using a label affixed outside on the package. In contrast to FIGs. 7A and 7B, tag 10 is arranged on an outside surface of film 54 of package 50, covering an aperture (not shown for clarity) in film 54 in superimposition with opening 104. An outer film 55 (e.g. an adhesive label or a label having an adhesive peripheral portion along a perimeter thereof) covers the entire tag 10 and keeps it in position with respect to the aperture. Outer film 55 sealingly attaches tag 10 on film 54 and keeps it in position with respect to package 50 and relative to the aperture. It is understood that tag 10 can be affixed to package 50 before or during packaging. Further, tag 10 can be pre-positioned on the film material used for packaging. In some examples, tags 10 are pre-placed at spatial intervals corresponding to the products 52 to be packaged, such that, after forming the packaging film and packaging product 52, each package 50 containing a product 52 also comprises a tag 10 placed thereon.

[0086] Upon occurrence of a leak or puncture of film 54, air or gas can enter package 50 and, thus, in a similar manner as described above with respect to FIGs. 7B, can also enter the region between layers 103-1 and 103-2 of tag 10 through the aperture and opening(s) 104. As the volume between the layers 103-1 and 103-2 fills with air or gas, the two layers separate and tag 10 is, thus, rendered inoperable as described above.

[0087] FIG. 9A and 9B illustrate a deformable portion in accordance with a fourth embodiment of the present invention in respective first and second operating configurations. In this embodiment, tag 10 comprises a resistor (e.g. a piezoelectric resistor) instead of a switch, such as switch 105 described above. A tag 10 having a resistor operates based on a change of resistance in the deformable element. FIG. 9A illustrates a piezoelectric resistor configured for use in a deformable element as described above, which is maintained in a biased configuration by outside air or gas pressure (shown as arrows acting upon the piezoelectric element. FIG. 9A shows the deformable portion in a biased configuration 106', where the piezoelectric element is kept substantially planar due to external pressure.

[0088] FIG. 9B illustrates a relaxed configuration 106" of the deformable portion, where the piezoelectric element is shown in cross section, revealing its default convex shape when not biased by external pressure. Due to the change in shape of the piezoelectric element, the overall resistance of the deformable portion changes. This change in resistance can be detected by the circuitry of tag 10 in any manner known in the art. Upon detection of the change in resistance, the circuitry integrated into tag 10 can generate a signal indicative of the change (i.e. the deformation) and detectable by means of a reader.

[0089] FIG. 10A and 10B illustrate alternative embodiments of deformable portions in accordance with the present invention. As mentioned above, the force separating layers 103-1 and 103-2 can be the result of opposing layers of film being biased towards a spaced-apart configuration. The superimposed layers 103-1 and 103-2 can be manufactured such that without external pressure, the layers are configured to separate. Alternatively, or in addition, spring elements as shown in FIGs. 10A and 10B can be arranged between layers 103-1 and 103-2, in order to facilitate or support the separation of layers 103-1 and 103-2. The depicted elements 106" (unbiased, relaxed) and 106' (biased, deformed) can be made from materials such as PA6 or PA66.

[0090] While the invention has been described in connection with what is presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not to be limited to the disclosed embodiments, but on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and the scope of the appended claims.

Claims

1. A vacuum package (50), comprising:

a package wall (54); and
a radio frequency circuit (10) configured for emitting a status signal, the status signal changing based on whether the package (50) is in a first sealed condition or in a second non-sealed condition, the radio frequency circuit (10) comprising at least one deformable portion (106); wherein
at least a portion of the package wall (54) is configured to act upon the deformable portion (106) and to move the deformable portion (106) from a first configuration, corresponding to the package being in said first sealed condition,
to a second configuration, corresponding to the package being in said second non-sealed condition.

2. The package of the preceding claim, wherein the deformable portion (106), when moving to the second configuration, is designed for modifying an electric configuration or an electrical property of the radio frequency circuit (10) and for allowing or preventing emission of the status signal.

3. The package of any one of the preceding claims, wherein the portion of the package wall (54) is provided in superposition to the radio frequency circuit (10).

4. The package of any one of the preceding claims, wherein
the radio frequency circuit (10) is arranged within the package (50), optionally wherein
the radio frequency circuit (10) is positioned between a packaged product (52) and the package wall (54).

5. The package of the preceding claim, wherein the portion of the package wall (54) further comprises an isolation layer (55), isolating the radio frequency circuit (10) towards the inside of the package, optionally the isolation layer being made from an inert material, the inert material being inert to the packaged product (52).

6. The package of any one of the two preceding claims, wherein the isolation layer (55) comprises an aperture configured to put opposite sides of the isolation layer (55) into fluid communication.

7. The package of any one of the preceding claims, wherein the portion of the package wall (54) is configured for deforming the deformable portion (106) against a packaged product (52), optionally by transferring the external pressure onto the deformable portion (106) and against the packaged product (52).

8. The package of any one of the claims 1 to 3, wherein the radio frequency circuit (10) is arranged on an outer surface of the package (50), optionally wherein the portion of the package wall (54) further comprises an isolation layer (55) and wherein the radio frequency circuit (10) is positioned between the isolation layer (55) and the portion of the package wall (54), the isolation layer (55) being configured to sealingly isolate the radio frequency circuit (10) from an outside atmosphere.

9. The package of the preceding claim, wherein the package wall (54) comprises an aperture configured to put opposite sides of the package wall (54) in fluid communication.

10. The package of claim 6 or 9, wherein the radio frequency circuit (10) comprises an opening (104), the radio frequency circuit (10) being positioned so that the opening (104) is in superposition with the aperture.

11. The package of the preceding claim, wherein
the radio frequency circuit (10) further comprises a gasket (107) in superposition with the opening (104) and configured to substantially seal a remaining portion of radio frequency circuit (10) from the opening (104) when the pressure difference is greater than the pre-determined threshold value; or wherein
the radio frequency circuit further comprises a plurality of openings and the package (50) comprises a plurality of corresponding apertures, optionally the radio frequency circuit (10) further comprising a plurality of corresponding gaskets (107), each gasket (107) of the plurality of gaskets being in superposition with a corresponding opening (104) and being configured to substantially seal a remaining portion of radio frequency circuit (10) from the corresponding opening (104) when the pressure difference is greater than the pre-determined threshold value.

12. The package of claim 2 and any one of the preceding claims, wherein the electrical property comprises one of:

- an operating frequency of the radio frequency circuit (10);

- an impedance of a resistor integrated into the radio frequency circuit (10), optionally wherein the resistor is a piezoelectric resistor and wherein the deformable portion (106) comprises the piezoelectric resistor;
- a switch (105) configured to render the radio frequency circuit operable and inoperable; and
- a switch (105) configured to electrically bypass or short-circuit a component of the radio frequency circuit (10), optionally the component of the radio frequency circuit (10) comprising a capacitor (C).

13. The package of any one of the preceding claims, wherein the radio frequency circuit (10) is a resonant electrical circuit, optionally wherein
the resonant electrical circuit is configured to generate the status signal in form of resonating at a predetermined resonant frequency, the resonating being detectable by a reader (30), further optionally wherein
the resonant frequency is in the range of between 865 MHz to 868 MHz and/or between 902 MHz to 928 MHz.

14. The package of any one of claims 1 to 12, wherein the radio frequency circuit (10) is a radio frequency identification circuit, optionally wherein
the radio frequency identification circuit is configured generate the status signal in form of generating a radio frequency identification signal, further optionally wherein
the radio frequency identification signal contains an identification code indicative of the integrity of the package (50).

15. The package of any one of the preceding claims, wherein the deformable portion (106) is elastically mounted into the radio frequency circuit (10) and is configured to elastically move to the second configuration when the package (50) is in said non-sealed condition.

16. The package of any one of the preceding claims, wherein the radio frequency circuit (10) includes at least one capacitor (C), and wherein the deformable portion (106) comprises first and second plates of the capacitor and an elastic suspension placed between the first and second plates, wherein the first and/or second plates of the capacitor (C) are configured to relatively move into a proximal configuration in which the first and second plates are substantially in contact with one another when the package is in the first sealed condition and to move into a distal configuration in which the first and second plates are substantially spaced apart from one another when the package is in the second non-sealed condition.

17. A leak detection system, comprising:

a vacuum package (50) according to any one of the preceding claims;
a reader (30) configured for emitting a radio frequency activation signal and for receiving the status signal; and optionally
a control unit configured to control the reader (30) to emit the radio frequency activation signal and/or to receive the status signal.

18. A process for leak detection in a vacuum package (50), the process comprising the steps of:

relatively arranging a package (50) and an interrogation zone (206) of a reader (30);
controlling the reader (30) to emit a radio frequency activation signal configured to supply energy to a radio frequency circuit (10), the package (50) comprising the radio frequency circuit (10);
controlling the reader (30) to receive a status signal from the radio frequency circuit (10);
comparing the status signal to an expected signal; and
generating a package state signal indicative of the integrity of the package (50) based on the comparison.

19. The process of the preceding claim, wherein
the expected signal is a voltage drop generated in a circuitry of the reader (30) by a resonant circuit comprised in the radio frequency circuit (10); or the expected signal corresponds to a lack of a status signal from the radio frequency circuit (10), and
optionally wherein generating the package state signal comprises generating a signal indicative of an intact package (50) when the status signal and the expected signal correspond to one another.

FIG.1

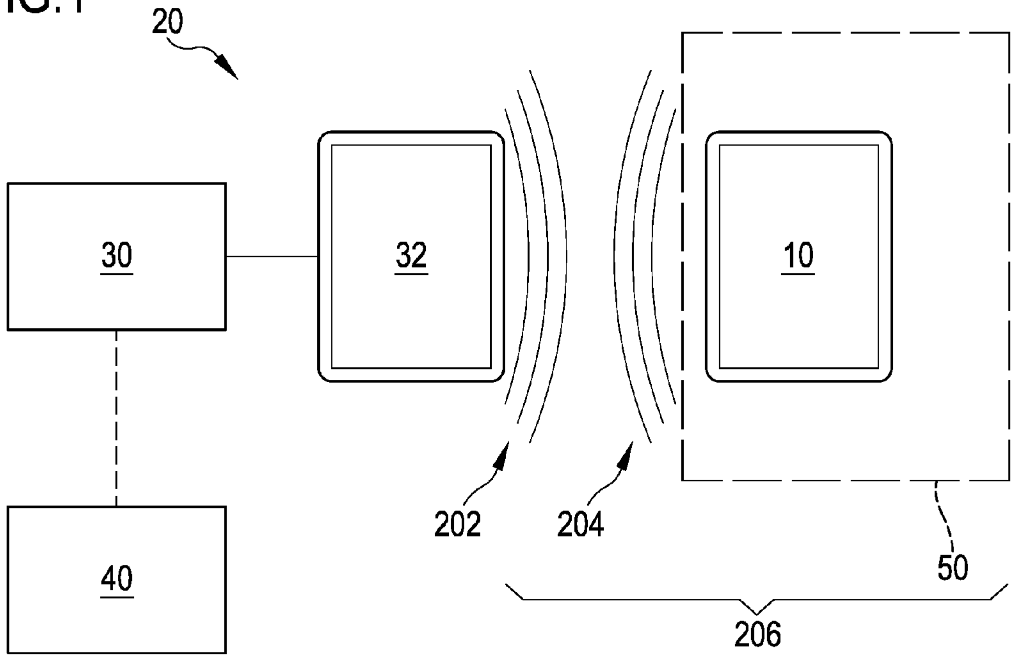


FIG.2

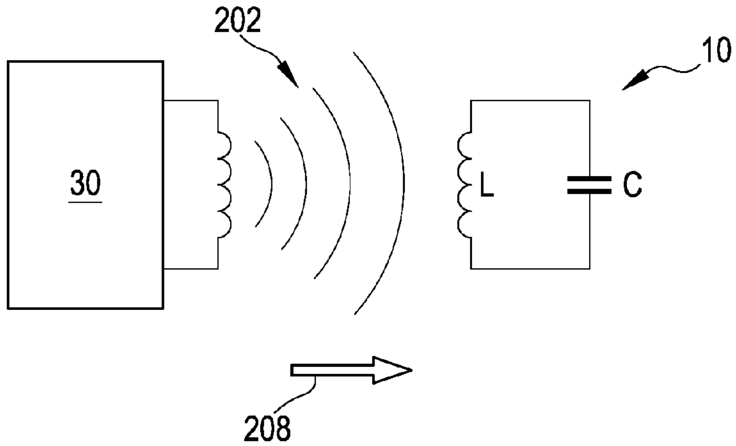


FIG.3A

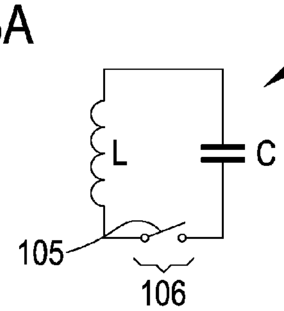


FIG.3B

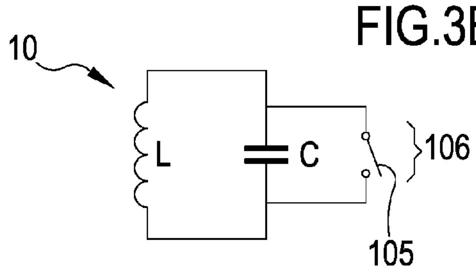
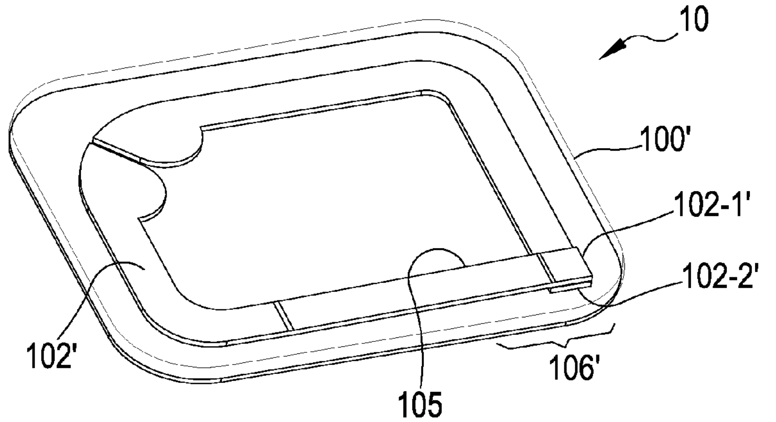


FIG.4A



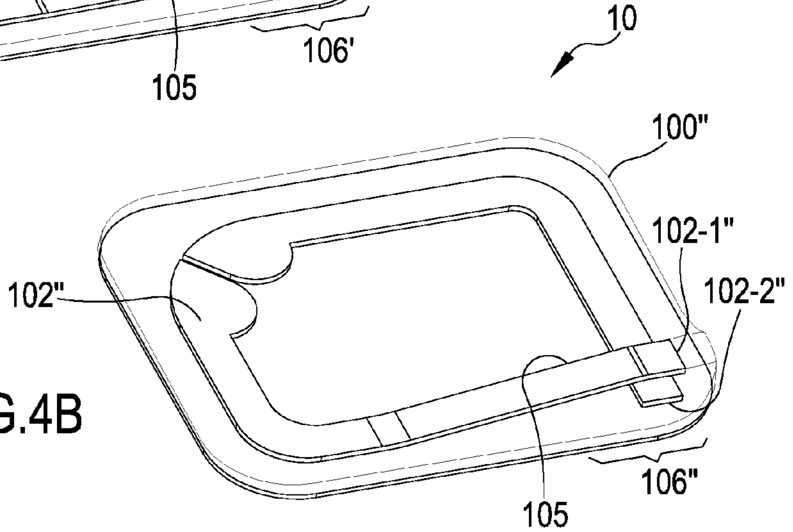


FIG.4B

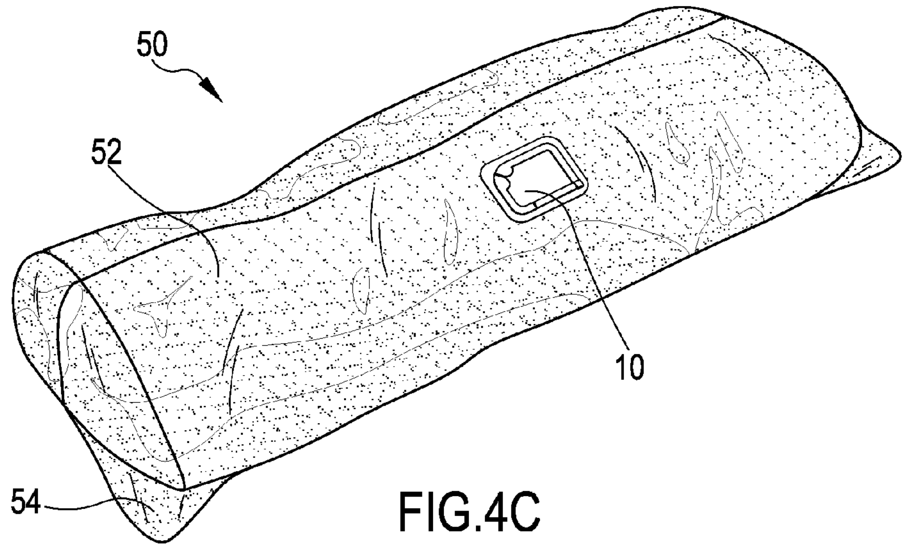


FIG.4C

FIG.5

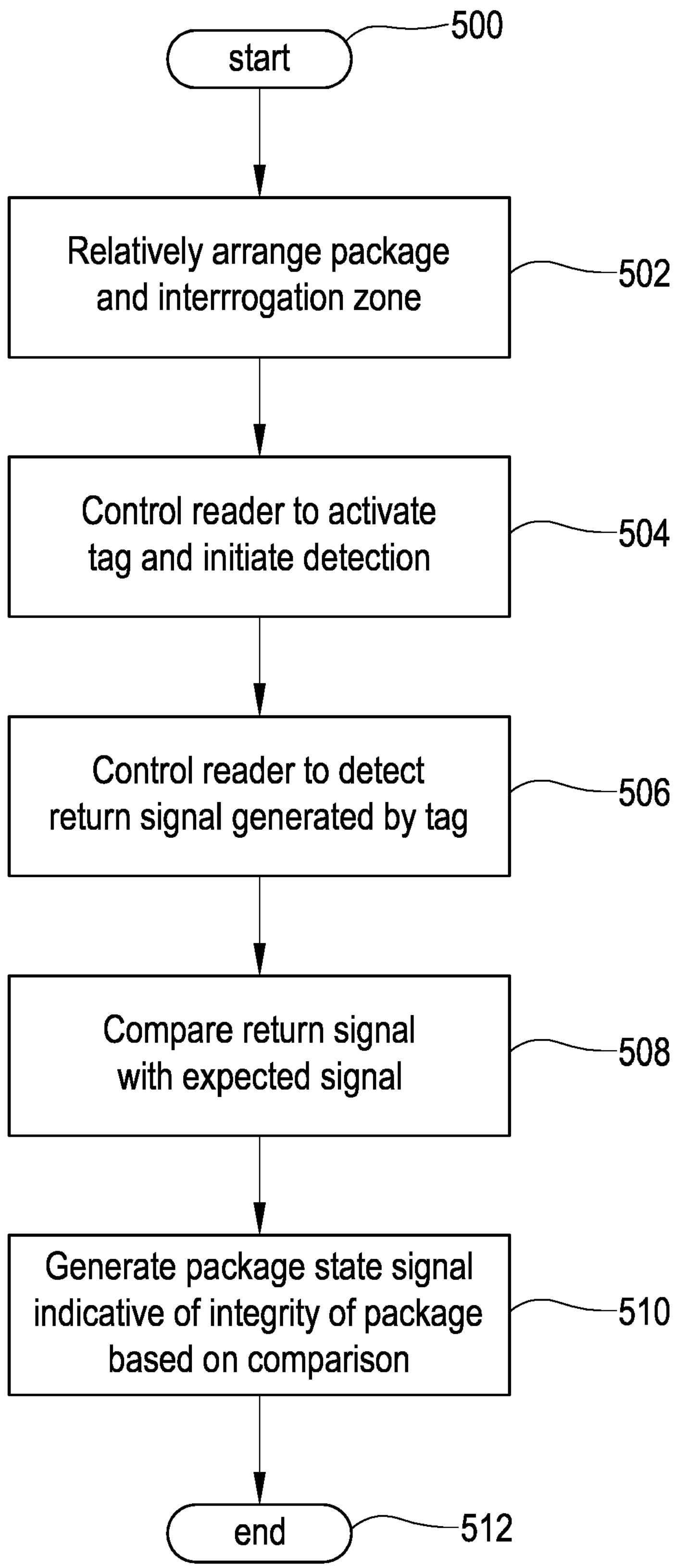

start
500
Relatively arrange package and interrrogation zone
502
Control reader to activate tag and initiate detection
504
Control reader to detect return signal generated by tag
506
Compare return signal with expected signal
508
Generate package state signal indicative of integrity of package based on comparison
510
end
512

FIG.6A

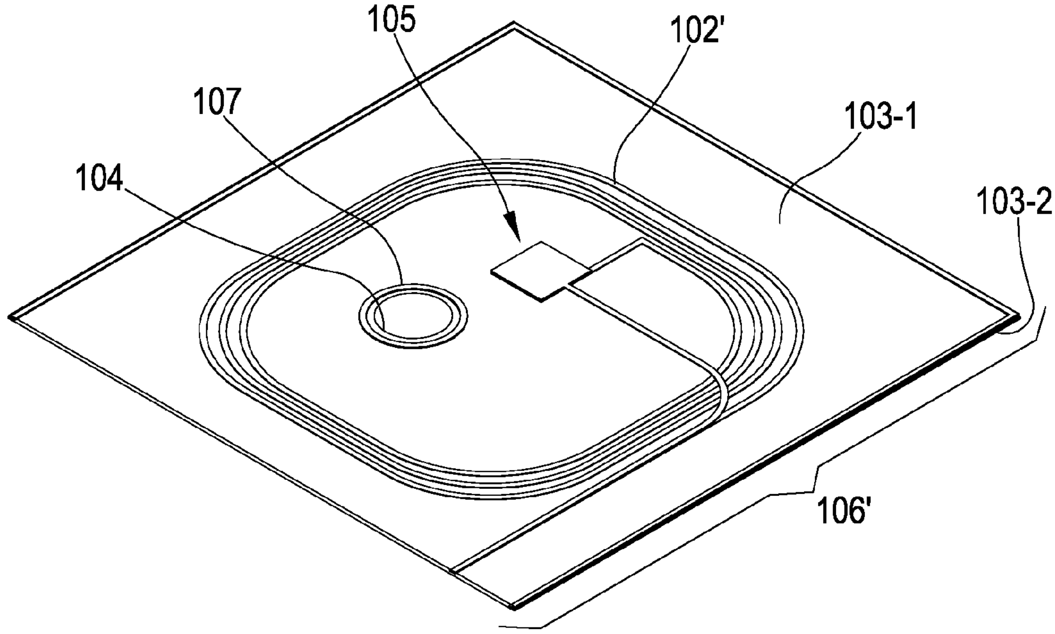
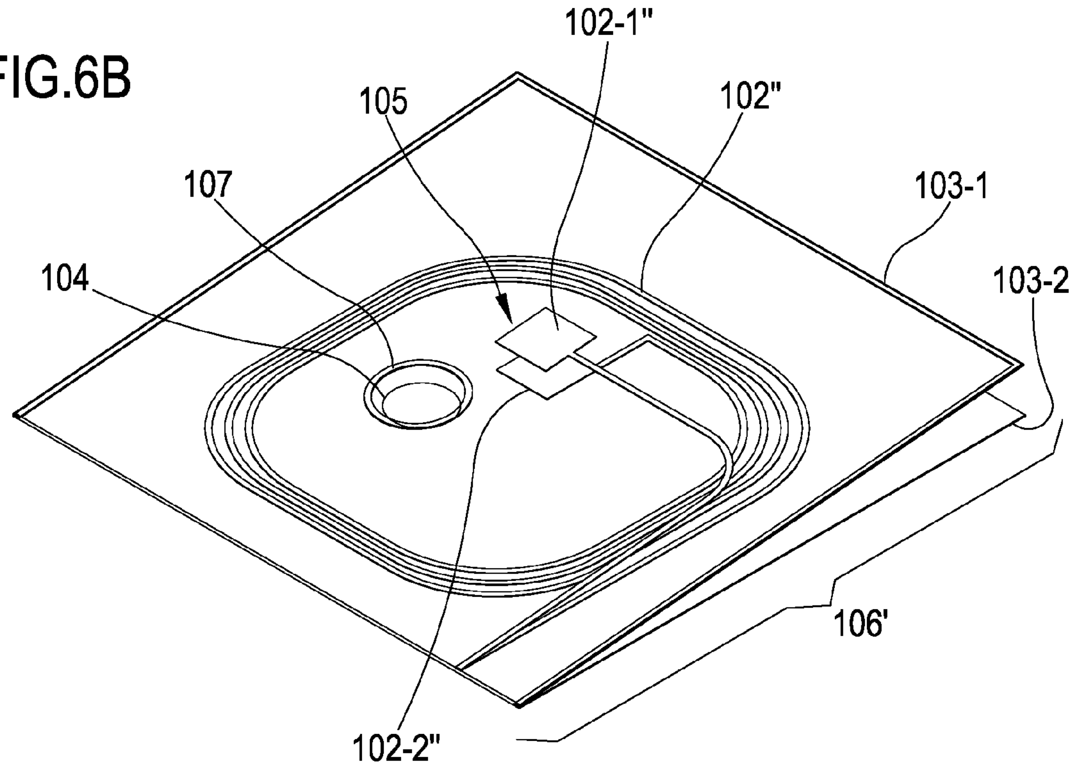

105
102'
107
103-1
104
103-2
106'

FIG.6B


102-1"
105
102"
107
103-1
104
103-2
106'
102-2"

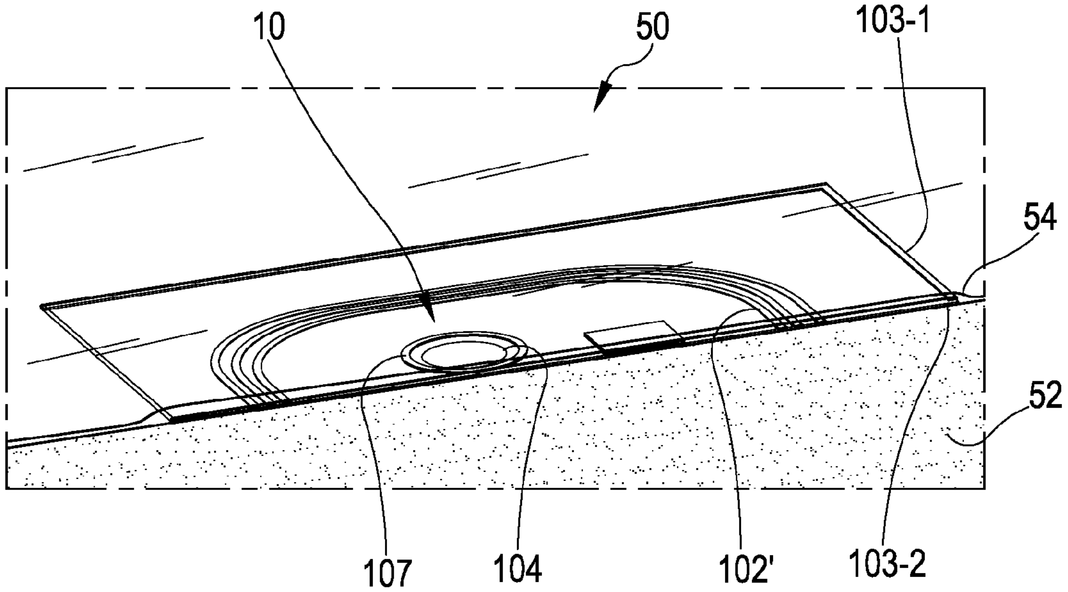

10
50
103-1
54
52
107
104
102'
103-2

FIG.7A

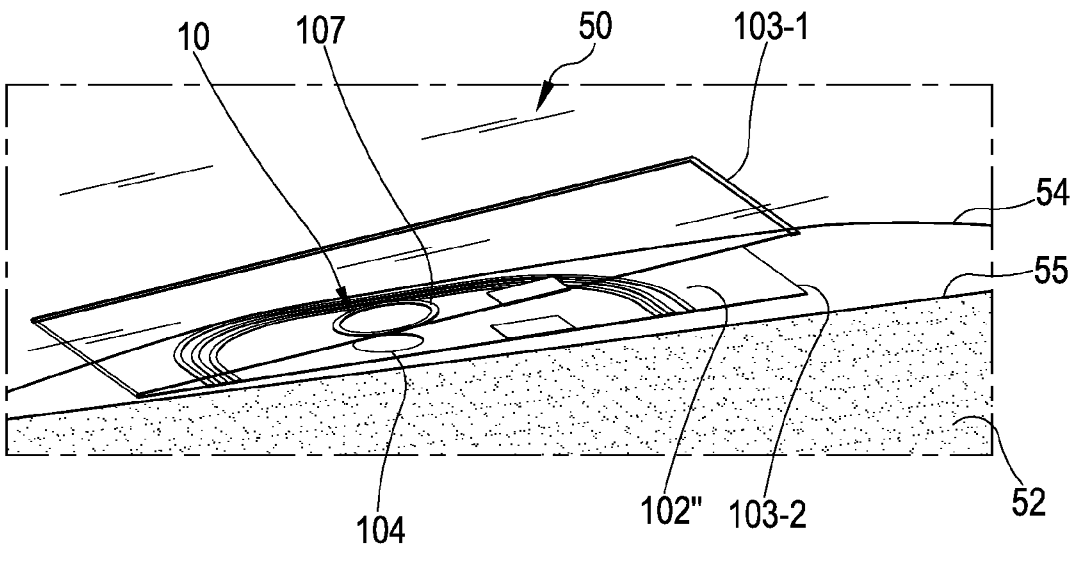

10
107
50
103-1
54
55
52
104
102"
103-2

FIG.7B

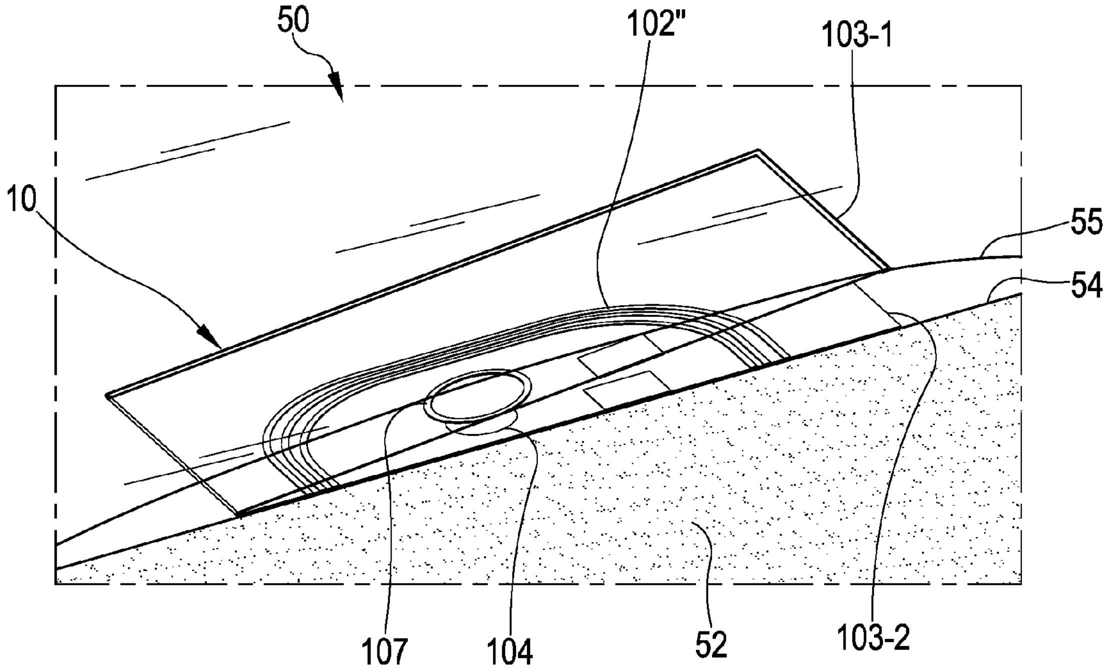


FIG.8

FIG.9A

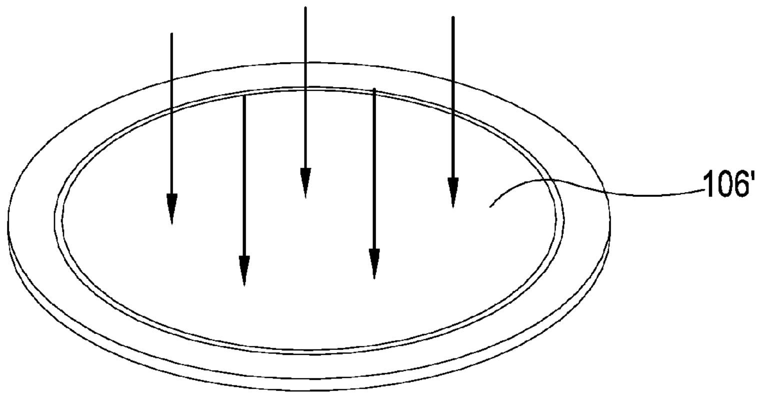
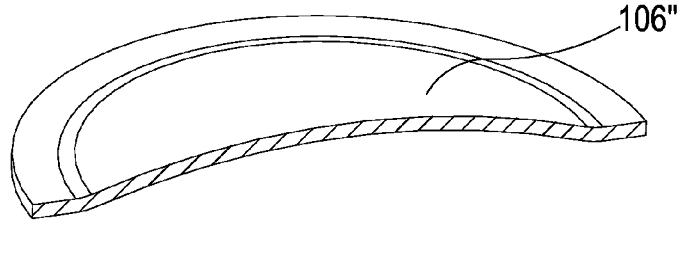


FIG.9B



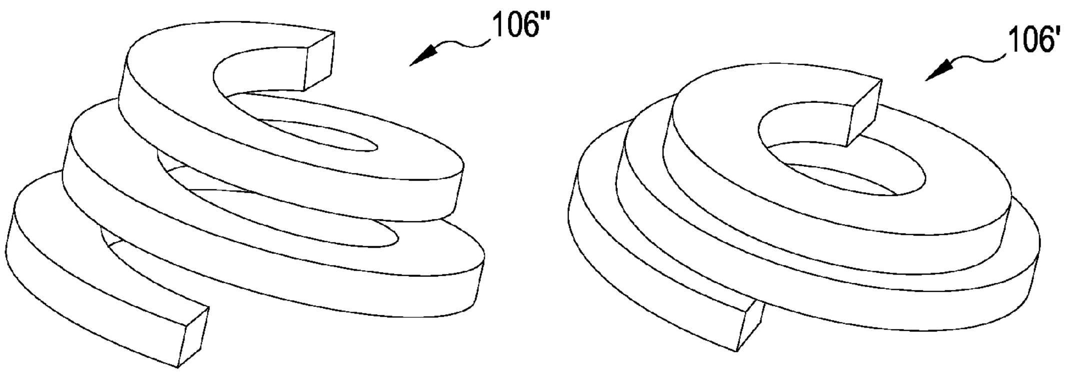


FIG.10A

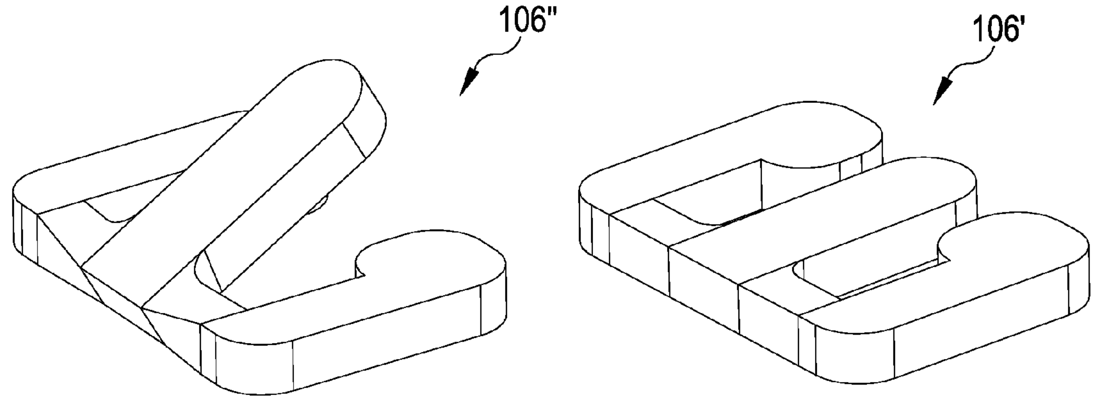


FIG.10B

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EUROPEAN SEARCH REPORT

Application Number
EP 15 17 1609

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			B65D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	13 November 2015	Wimmer, Martin

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