Biological Contamination Detection System

Field of the Invention

[0001] The present invention relates to biological contamination detection system. In particular, the invention relates to a RF-based biological contamination detection system for food packaging.

Background

[0002] For years, many countries around the world have implemented comprehensive food quality control policies for processed and perishable food and beverage products ("the food products"). These policies protect consumers' health and promote safty practices. One of the most common requirements required by these policies is to provide information relating to the food products on the packaging, and amongst the information, shelf life and/or expiry date of the food products.

[0003] Expiry date indicates a cut-off date after which the food product must not be consumed. It is often referred to as "use by (date)". The shelf life, on the other hand, is a length of time that corresponds to a tolerable loss in quality of the food products. It is often referred to as "sell by (date)" or "best before (date)". Generally, the former has a later date than the latter. The food product that has passed the shelf life date, but is still within its expiry date is edible, whilst there is a health risk for consuming the food product after the expiry date expired. For whatever reasons, nevertheless, these dates provide the consumers a guide as to quality/usability conditions of the food products before purchasing it.

[0004] In packaging processes, the labels indicating the shelf life and expiry date are often pre-printed on the package of the food products. In most cases, these dates are pre-determined based on some statistical models, and food products sampling under pre-determined conditions. With certain quality control, measures are taken to make sure that the expiry dates are set well before the food products are spoiled.

[0005] These dates, however, may only be effective provided that the food products are properly packed and stored. Improper handling of the food products, tampering or puncturing of the food products' seal and etc. may cause the food products to decompose prematurely, hence the shelf life and the expiry date may be shortened. Further, ambient conditions changes from place to place and time to time. The change of these conditions may vary decomposition rate of the food products.

[0006] For some food products, for example, medicines begin to deteriorate (e.g. in potency) or begin to accumulate toxic breakdown products immediately after manufacture or packaging. Depending on the material involved, this may be dangerous. Bacterial contaminants are ubiquitous; any food products left unused for too long will often acquire substantial amounts of bacterial colonies and become dangerous to eat. Therefore, it is always recommended that the food be consumed within the shelf life indicated by manufacturers.

[0007] Barcode has been used on every item purchased from a grocery store, department store, and mass merchandiser. This greatly helps in keeping track of the large number of items in a store as the information required to be included within the food packaging can be included within the barcode, which is readable a barcode scanning machine. Since the adoption of barcodes, both consumers and retailers have profited from the savings generated. However, going through the checkout line involves the processes of scanning each bar code on each item. Further, barcode is a read-only technology, meaning that it cannot send out any information.

[0008] Radio frequency identification, or RFID, is a relatively inexpensive means with read and write capabilities for product tracking and monitoring. The application of RFID technology in packaging industry servers not only as identification tags for product tracking, but also a theft detector. The trend is towards replacing barcode with RFID in the near future.

[0009] US patent publication no. US2002/0072079 discloses a barcode-type contamination detection system. The food contamination detector associated with a double bar code what includes coded indicia used to identify the presence of conditions indicative of microbial contamination in food, including toxic contaminants, bacterial

metabolites, and other microbial secretions. It provides means of changing the appearance of indicator which results in a change in barcode symbol for identifying whether the food is contaminated.

[0010] PCT patent application publication no. WO03/044521 and US patent publication no. US6,642,016 disclose an RFID based food quality detection system. Both systems detect the food quality by measuring changes of electrical properties as a direct function of the degree of product spoilage.

[0011] PCT patent application publication no. WO2004/034208 discloses a food safety system and method for providing a consumer risk distribution model. It evaluates consumer risk based on the amount of contaminated food present at each stage of the food distribution process according to consumer risk distribution model, allowing determinations of the efficacy of a trace recall effort. The system is used to model a food contamination event by tracing food production from harvest through consumption in order to estimate the consumer exposure to the food event.

Summary

[0012] In accordance with one embodiment of the present invention, there is provided an RF-based chip for detecting a level of decomposition, the RF-chip chip may comprise an IC die encapsulated by a biodegradable material for environmentally protecting the IC die, wherein when the IC die is exposed without protection of the biodegradable material due to a degradation of the biodegradable material, the IC die is damaged which causes said chip to malfunction, thereby indicating the level of decomposition is reached.

[0013] In the present embodiment, it may be preferred that the biodegradable material consists of biopolymer. The biopolymer may consist of pectin and agar. In other example, the biodegradable material may be a poly(3-hydroxybutyrate). It is also desired that the RF-based chip has pre-determined lifespan which may be configured based on the thickness of the biodegradable material encapsulating the IC die. The RF-based chip may be capable of detecting a state of contamination based on an actual

lifespan when comparing with the pre-determined lifespan. Further the state of contamination may be identified when the actual lifespan is relatively shorter than the pre-determined lifespan.

[0014] In accordance with another embodiment, there is an RFID tag detectable by an RFID reader comprises an antenna for transmitting signals between the RFID tag and the RFID reader; and an RF-based chip for detecting a level of decomposition, the RF-based chip may comprise an IC die encapsulated by a biodegradable material for environmentally protecting the IC die, RF-based chip is electrically connecting to the antenna. When the IC die is exposed without protection of the biodegradable material due to a degradation of the biodegradable material, the IC die may be damaged which causes said tag to malfunction and not detectable by the RFID reader, thereby indicating the level of decomposition is reached.

[0015] In the aforesaid embodiment, the biodegradable material may consist of biopolymer. The biopolymer may consist of pectin and agar. Further, the biodegradable material may consist of poly(3-hydroxybutyrate). It is also desired that the RF-based chip has a pre-determined lifespan which may be configured based on the thickness of the biodegradable material encapsulating the IC die. The RF-based chip may be capable of detecting a state of contamination based on an actual lifespan when comparing with the pre-determined lifespan. Further, the state of contamination may be identified when the actual lifespan may be relatively shorter than the pre-determined lifespan. Further, it may be desired that the antenna is a planar coil antenna.

[0016] In accordance with yet another embodiment, it is provided that a method of determining a level of decomposition, the method may comprise detecting present of an RFID tag having an RFID chip comprising an IC die encapsulated by a biodegradable material for environmentally protecting the IC die; and identifying the level of decomposition is reached when no RFID tag is detected as a result of malfunctioned RFID chip due to an exposure of the IC die without protection of the biodegradable material due to a degradation of the biodegradable material.

[0017] The aforesaid method may further comprise comparing a pre-determined lifespan of the RFID chip with an actual lifespan of the RFID chip for detecting a state of contamination. Also, the method may also comprise identifying the state contamination when the actual lifespan is relatively shorter than the pre-determined lifespan.

Brief Description of the Drawings

[0018] This invention will be described by way of non-limiting embodiments of the present invention, with reference to the accompanying drawings, in which:

[0019] FIG.1a illustrates a cross sectional view of an RF-based chip in accordance with an embodiment of the present invention;

[0020] FIG. 1b illustrates a cross sectional view of the RF-based chip of FIG. 1a, with the biodegradable seal etched;

[0021] FIG. 2a illustrates an RFID tag in accordance with one embodiment of the present invention;

[0022] FIG. 2b illustrates a food product embodied with the RFID tag of FIG. 2a and a RFID reader for detecting the RFID tag in accordance with one embodiment of the present invention;

[0023] FIG. 2c illustrates an RFID tag in accordance with another embodiment of the present invention;

[0024] FIG. 3 illustrates a flowchart of a process of purchasing food product packed with the RFID tag in accordance with one embodiment of the present invention; and

[0025] FIG. 4 illustrates a flowchart of a process of a periodic food products stock checking in accordance with one embodiment of the present invention.

Detailed Description

[0026] In line with the above summary, the following description of a number of specific and alternative embodiments are provided to understand the inventive features of the present invention. It shall be apparent to one skilled in the art, however that this invention may be practiced without such specific details. Some of the details may not be described at length so as not to obscure the invention. For ease of reference, common reference numerals will be used throughout the figures when referring to the same or similar features common to the figures.

[0027] FIG. 1a exemplifies a cross-sectional view of a radio frequency chip (RF-chip) **100** in accordance with one embodiment of the present invention. The RF-chip **100** includes a IC die **150** having delicate circuitry, a chip body **160** having a molded body **120** and a biodegradable seal **110** for encapsulating the IC die **150**, and leads **130** extended from inner parts of the chip body **160**. The RF-chip **100** is fabricated using a pre-plated lead frame in a form of stripes defining the leads **130**. The leads **130** are usually made of a copper alloy, but other materials suitably used for semiconductor leads are also desired. The lead frame is then transfer molded, or injection molded to form the molded body **120** defining a cavity, of which, one end of the leads **130** sticks out from the molded body **120** and the other end extends into the cavity of the molded body. The molded body **120** is made of any packaging materials, such as ceramic, plastic, and etc. The IC die **150** is mounted within the cavity and wire bonding is performed to connect the leads **130** with the IC die **150** with bond wires **140**. The hollow space of the cavity is then filled-up with biodegradable encapsulant to form the biodegradable seal **110**, thus environmentally protecting the IC die **150** within the cavity.

[0028] When the RF-chip **100** is exposed to the ambient, the moisture and contaminant in the ambient air decomposes the biodegradable seal **110**. In time, the biodegradable seal **110** is etched (shown in by arrows **180**) until the IC die **150** exposes to the ambient as shown in FIG. 1b. Without protection by the biodegradable seal **110**,

the IC die **150** is susceptible/vulnerable to moisture and contaminant in the ambient, which will result in damage to the IC die **150**. A damaged RF-chip **100** serves as a gauge for detecting decomposition level. The length of period it takes before the RF-chip malfunctions depends on the thickness of the biodegradable seal **110** and/or the materials of the biodegradable seal **110**. Therefore, it is preferred that the RF-chips **100** are provided with variety thicknesses and/or materials of the biodegradable seal **110** to cater for different requirements. Further, as the biodegradable seal **110** decomposes as soon as it is exposed to the environment, it is further preferred that the RF-chip **100** is stored in clean room, or sealed with a layer of temporary protecting shield (not shown) to avoid unnecessary decomposition before it is packed into food products.

[0029] Referring back to FIG. 1a, the RF-chip **100** is a RF-based integrated circuit (IC) and with its package made based on molded plastic technology. It is shown by way of illustration only, and not limitation. It is understood that the present invention may be implemented in any integrated circuit technology for detecting decomposition level. It is also understood that the integrated circuit embodied the present invention may be made by any manufacturing methods and processes known in the art.

[0030] FIG. 2a exemplifies an RFID tag **200** in accordance with one embodiment of the present invention. The RFID tag **200** is a passive type RFID tag with the RF-chip **100** of FIG. 1a mounted thereon. The RFID tag **200** has a planar antenna **210** fabricated on a polymer laminate **220** in a form of planar coils. The RF-chip **100** is electrically connected to planar electrodes **215** of the planar antenna **210**. The RF-chip **100** is mounted on the polymer laminate **220** and connected to the planar electrodes **215** with the biodegradable seal **110** of the RF-chip **100** facing outward.

[0031] Still referring to FIG. 2a, the RFID tag **200** is made in planar label form by way of illustration only, not limitation. It is understood that the present invention may be embodied in other forms of RFID tags existing in market depending on requirements.

[0032] FIG. 2b illustrates a food product **250** packed with the RFID tag **200** in accordance with one embodiment of the present invention. The food product **250** is

packed with one RFID tag **200** having the biodegradable seal **110** exposes to the inner space of the food product packaging.

[0033] While the RFID tag **200** is still functioning, it can be detected within the food product **250** via an RFID reader **290**. In operation, the RFID reader **290** sends out radio frequency signal within a detection range to detect for RFID tags **200**. The detection range is configured in accordance with the industrial standards. When the food product **250** is brought within the detection range, the radio frequency signal induces electrical current in the planar antenna **210** and power is supplied to the RFID tag **200** and the RF-chip **100** is powered up. In response to the RFID reader **290**, the RFID tag **200** (or the RF-chip **100**) transmits outbound backscatter signal to the RFID reader **290** via the planar antenna **210**. The RFID reader **290** may then display the acquired information on a display **295**, such the expiry date and manufacturing date of the food product.

[0034] Under the normal conditions, and the food product **250** is properly sealed and handled the contents of the food product **250**, including the biodegradable seal **110** of the RF-chip **100**, decomposes gradually within the food product **250** package. The RFID tag **200** is made to have a lifespan at about the same time as the pre-determined expiry date of the food product **250**. Should premature decomposition occurs within the food product **250** due to improper handling of the package for example, foreign substances contaminate the contents of the food product and cause the biodegradable seal **110** to etch at a higher rate. As soon as the IC die **150** exposes within the food package without protection of the biodegradable seal **110**, the IC die **150** malfunctions and the RFID tag **200** is no longer detectable by the RFID reader **290**, which indicates that the food product **250** may no longer suitable for consumption.

[0035] FIG. 2c is an alternative embodiment of an RFID tag **280**, which includes three individual planar antennas **285** fabricated on a polymer laminate **282**. Each of planar antennas **285** has an RF-chip **100** (also denoted as **100a**, **100b** and **100c** respectively) connected to form a gauge for detecting usability condition. The RF-chip **100a** is made with a lifespan of about the pre-determined expiry date, RF-chip **100b** is made with a lifespan of about two third of the pre-determined expiry date, and RF-chip **100c** is made with a lifespan of about one third of the pre-determined expiry date. To

achieve that, each RF-chip **100a**, **100b** and **100c** is made with a biodegradable seal **110** of different thickness from each other, for detecting usability condition in four stages, i.e. all chips working stage, one malfunctioned chip stage, two malfunctioned chips stage, all chips failed stage. The all chips working stage shows that the product having the RFID tag **280** embedded thereto are in fresh to good condition stage. The one malfunctioned chip stage shows that the product is not new but still in good condition. The two malfunctioned chips stage shows that the product is in still useable condition, but use with care. The all chips failed stage shows that the product is not suitable for further usage. The RFID reader **290** is able to show the decomposition in the above-mentioned stages as the RF-chips **100c**, **100b** and **100a** malfunction consecutively. Further, when the reader detects that the RF-chips **100a**, **100b** and/or **100c** malfunction at an early stage relative to the pre-determined expiry date, it may show that the food product is contaminated.

[0036] FIG. 3 is process flow chart illustrating the steps a shopper go through in shopping for a food product packed with the RFID tag **200** in accordance with one embodiment of the present invention. The flow chart includes the shopper picking up a food product at step **310**; reader detects presence of RFID tag **200** at step **320**; a conditional step **330** is performed depending on the detection result; a display shows the detection results at either step **340** or **350**; and the customer proceeds to purchase the food product at step **360**.

[0037] Still in FIG. 3, the shopper picks up a food product from a shopping shelf at the step **310**. The food product is packed with the RFID tag **200**. To make sure that the food product is still safe for consumption, the shopper brings the food product to scan for usability condition at a checking station at step **320**. The checking station may be a casher counter of the store, or a stand-alone device provided at a designated location within the store. The checking station provides an RFID reader, suitable for detecting the existence of the RFID tag **200**. Step **330** is a conditional operation to produce a result of "yes" or "true", which means the RFID tag **200** detection result is present; or "no" or "false", which means no RFID tag **200** can be detected. If the RFID tag **200** is detected, step **340** is performed. If no RFID tag **200** is detected, step **350** is performed. At step **340**, a display at the checking station displays that the RFID tag

200 is present, and thus, the food product is safe for consumption. Preferably, the reader may further acquire information stored in the RFID tag **200** and display the information on the display. This information may include a pre-determined expiry date, a manufacturing date and the like. The shopper may then continue shopping or proceed to make payment for the food product at step **360**. If, however, at step **330**, the reader could not detect the RFID tag **200**, the display displays a warning message to the shopper that the food product is no longer fit for consumption. The shopper may then go back to the relevant shelf to pick up another pack of the food product as in the step **310** and steps **320** and **330** are repeated until the shopper finishes purchasing the food product.

[0038] In accordance with an alternative embodiment, a food product is packed with a plurality of RFID tags **200**, such as the RFID tag **290** in FIG. 2c. Each of the RFID tags **200** includes an RFID chip **100** encapsulated by a biodegradable material having different level of tolerance to the contamination from another RFID chip **100**. The number of RFID tags **200** serves as indication of stages of decomposition within the food product package by detecting the number of functional RFID tag(s) **200**. Such tolerance levels may be varied by using different thicknesses of same biodegradable material for encapsulating the RFID chip **100**, or by encapsulating the RFID chips **100** with different biodegradable materials, or the combination thereof. Accordingly, when all the RFID tags **200** packed within the food product are functioning and detected, the food product shall be safe for consumption. When at least one RFID tag **200** is malfunctioned and not detected, it shows that the food product has been decomposed and possibly contaminated. When all the RFID tags **200** are malfunctioned (no RFID tags **200** is detected at all), it indicates that the food product might had already spoilt and not safe for consumption.

[0039] In a non-limiting example of the present embodiment, a food product is packed with two RFID tags **200**, tag A and tag B. The tag A has a lifespan of about the pre-determined expiry date and the tag B has a lifespan of about half of the tag A. Referring back to FIG. 3, a shopper picks up the food product packed with tags A and B in step **310**. Subsequently, the shopper brings the food product to a checking station to scan for the usability condition at step **320**. When the reader at the checking station

detected that both tags A and B are functioning at step **330**, the food product is in good condition. Upon detecting the tags A and B, the reader acquires the relevant information from tag A. The information includes at least the pre-determined expiry date, manufacturing date, and the number of RFID tags **200** packed within the food product package. Accordingly, the reader displays a message that the food product is in good condition and the acquired information may also be displayed by the reader for the shopper's consideration at step **340**. When the reader detects absent of tags A and B at step **330**, the reader displays a warning message to the shopper that the food product may no longer suitable for consumption.

[0040] Still in FIG. 3, when the reader detects tag A but not tag B, the reader further processes the acquired information in step **335** (shown in dashed line) to determine if the food product has been contaminated. The processing at the step **335** is performed based on the date of scanning the food products and the number of functioning and malfunctioned tags. It is known that, the tag B is expected to have a lifespan of about half of the pre-determined expiry date. If the date of scanning occurs after the expected lifespan of the tag B, it is likely that the food package is not being contaminated, and accordingly the pre-determined expiry may well still be applicable. If the date of scanning occurs relatively earlier than the expected lifespan of the tag B, it is likely that the food product is contaminated. It is preferred that the reader also refers to the length of time from the date of manufacturing to the date of scanning as a factor for determining whether the food product has been contaminated. It is further preferred that, the reader also estimates a new expiry date for the food product for the shopper consideration if the food product is suspected to be contaminated. Accordingly, at step **340** the reader displays the processed results on the display. Based on the displayed results, the shopper may consider whether to change to another pack of the same food product at step **345** (shown in dashed line). If the shopper decides not to change to another pack of the food product, he may proceed with payment for that food product at step **360**. Otherwise, the shopper may go back to the relevant shelf to pick up another pack of the food product as in the step **310**, and steps **320-340** are repeated until the shopper finishes purchasing the food product.

[0041] In yet another embodiment, a packaging of a food product may include a plurality of RFID tags **200**, in conjunction with an ordinary RFID tag, tag C, which does not decompose in time. The tag C may store information in relation to the food product and the number of the RFID tags **200** is included in the food product packaging.

[0042] Still referring back to FIG. 3, the shopper picks up the food product of the present embodiment in step **310**. The food product is packed with tag C along with two RFID tags **200**, tag D and tag E. The tag D has a lifespan of about the pre-determined expiry date and the tag E has a lifespan of about half of that of tag D. The shopper brings the food products to a checking station to scan for the usability condition at step **320**. The RFID reader of the checking station acquires information from tag C, and identifies the number of RFID tags **200** are packed within the food product. If the RFID reader detects absence of RFID tags **200** at step **330**, a display of the RFID reader displays a warning message to the shopper that the food product is no longer suitable for consumption at step **350**, and the shopper may pick up another pack of the food product (back to step **310**).

[0043] Still in FIG. 3, when the reader at the checking station detects functioning RFID tag(s) **200**, the number of functioning RFID tag(s) **200** will be determined. When all the RFID tags **200**, tags D and E, are functioning, it shows that the food product is in good conditions. If the reader detects only tag D but tag E, the reader processes the information acquired from the tag C, and in step **335** to determine if the food product has been contaminated. The processing at the step **335** is performed based on the date of scanning the food products and the number of functioning and malfunctioned tags. It is known that, the tag E is expected to have a lifespan of about half of the pre-determined expiry date. If the date of scanning occurs after the expected lifespan of the tag E, it is likely that the food package is not being contaminated, and accordingly the pre-determined expiry may well still be applicable. If the date of scanning occurs earlier than the expected lifespan of the tag E, it is likely that the food product is contaminated. It is preferred that the reader also refers to the length of time between the date of manufacturing and the date of scanning as a factor for determining whether the food product has been contaminated. It is further preferred that, the reader

also estimates a new expiry date for the food product for the shopper consideration if the food product is suspected to be contaminated. Accordingly, at step **340** the reader displays the processed results on the display. Based on the displayed results, the shopper may consider whether to change to another pack of the same food product at step **345** (shown in dashed line). If the shopper decides not to change to another pack of the food product, he may proceed with payment for that food product at step **360**. Otherwise, the shopper may go back to the relevant shelf to pick up another pack of the food product as in the step **310**, and steps **320-340** are repeated until the shopper finishes purchasing the food product.

[0044] FIG. 4 illustrates the operations of a periodic food products stock checking performed by a stock keeper in accordance with yet another embodiment of the present invention. The stock keeper carries a handheld RFID reader for scanning stocks of food products which are packed with the RFID tag(s) **200**. The handheld RFID reader has a trigger, when pressed, the reader sends out radio frequency signal for scanning RFID tags. At step **410**, the stock keeper initiates scanning of each of the food products by pressing the trigger. The RFID tag(s) **200** of each food product, when functioning, responds to the reader with the acquired information at step **420**. The reader then processes the acquired information at step **430**. At step **440**, the processing determines whether the food products are within the storage condition in accordance with the industrial or government standards. If the storage condition is out of the standards' threshold, the reader notifies the stock keeper at step **450** and the stock keeper may pick up the food products for disposal. If the storage condition is within the standards' threshold, the stock keeper may proceed to check the next product item.

[0045] In accordance with one embodiment of the present invention, the biodegradable seal **110** consists of a mixture of two polysaccharides, such as pectin and agar. In this given example, when pectin is cross linked with agar using thermal treatment, the mixture forms an impermeable barrier, which make it a suitable material for environmentally protecting the IC die **150**. For an RFID tag X having an RF-based chip **100** encapsulated by the mixture material above, it is suitably for packing with food products such as fresh milk products. Both the milk products and the polysaccharides mixture are susceptible to at least streptococcus thermophilus. When

the milk product is packed with the RFID tag X, the microbial growth decomposes the milk product as well as the biodegradable seal **110** gradually. In the present example, the RFID tag X is selected to have a lifespan of about the lifespan of the milk product, and therefore, failure to detect the RFID tag X within the milk product package by an RFID reader would indicated that the milk product is no longer suitable for consumption.

[0046] In yet another embodiment, the biodegradable seal **110** may consist of poly(3-hydroxybutyrate) (or P3HB). Such biodegradable material is known to be degradable by more than 290 dominant microbial strains, which makes it a good encapsulant for the IC die **110**

[0047] The aforementioned two embodiments are provided herewith for illustration only, not limitation. It is understood that any materials or the combinations thereof are suitable for further embodiments as long as the encapsulant material used are biologically degradable and it is suitable for packing with the targeted food products available on market. A further example of such encapsulant material is biopolymer. Selections of encapsulant material depending mainly on type of the targeted food products.

[0048] TABLE 1 exemplifies some micro-organisms commonly associated with food spoilage of the corresponding food products:

Organisms	**Products**
Acetobacter spp.	Fresh cider
Bacillus spp.	Bread dough
Byssochlamys spp.	Canned fruits
Clostridium spp.	Hard cheeses
Flat-sour spores	Canned vegetables
Geotrichum spp.	Fruit cannery sanitation
Lactic acid bacteria	Beers and wines
Lactococcus lactis	Raw refrigerated milk
Leuconostoc mesenteroides	Sugar (during refinery)
Pectinatus cerevisiiphilus	Beers
Pseudomonas putrefaciens	Butter
Yeasts	Fruit juice concentrates
Zygosaccharomyces bailii	Mayonnaise and other salad dressings

[0049] TABLE 2 exemplifies certain metabolites which associated with food quality:

Metabolites	Product
Cadaverine and putrescine	Vacuum-packed beef
Diacetyl	Frozen juice concentrate
Ehtanol	Apple juice and fishery products
Histamine	Canned tuna
Lactic acid	Canned vegetables
Trimethylamine (TMA)	Fish
Total volatile bases (TVB) and total volatile nitrogen (TVN)	Seafoods
Volatile fatty acids	Butter and cream

[0050] TABLE 3 exemplifies some nutritional requirements of micro-organisms which can be commonly found within a food product packages:

Element	Source	Function
1. Macronutrients		
Carbon	Organic compounds or CO_2	Main constituent of cellular material
Oxygen	H_2O organic compounds, CO_2, O_2	Constituent of cell material and cell water; O_2 is electron acceptor in aerobic respiration
Nitrogen	NH_3, NO_3, organic compounds, N_2	Constituent of amino acids, nucleic acids, nucleotides and coenzymes.
Hydrogen	O_2, organic compounds, H_2	Constituent of organic compounds and cell water. Also important in energy generation as protons.
Phosphorus	Inorganic phosphates (PO_4)	Constituent of nucleic acids, nucleotides, phospholipids, LPS and teichoic acids.
2. Micronutrients		
Sulfur	SO4, J2S, S0, organic sulfur compounds	Constituent of cysteine, methionine, glutathione and several coenzymes.
Potassium	Potassium salts	Main cellular inorganic cation and cofactor for certain enzymes.
Magnesium	Magnesium salts	Inorganic cellular cation, cofactor for certain enzymatic reactions
Calcium	Calcium salts	Inorganic cellular cation, cofactor for certain enzymes and a component of endospores.

Iron	Iron salts	Component of cytochromes and other proteins and a cofactor for some enzymatic reactions.

3. Trace Elements

Element	Example of Function
Cobalt	Part of vitamin B12, which is used to carry methyl groups
Zinc	Structural role in many enzymes including DNA polymerase.
Molybdenum	Certain reactions involving nitrogen assimilation. Found in nitrate reductase and nitrogenase.
Copper	Catalytic role in some enzymes that react with oxygen, for example cytochrome oxidase.
Manganese	Required by a number of enzymes in catalytic cistes. Certain photosynthetic enzymes use manganese to split water into oxygen and protons.
Nickel	Several different enzymes including some involved in carbon monoxide metabolism, urea metabolism and methanogenesis.

4. Vitamins and their roles in metabolism

Vitamin	Coenzyme form	Function
Folic acid	Tetrahydrofolate	Transfer of one-carbon units, required for synthesis of thymine, purine bases, serine, methionine and pantothenate.
Biotin	Biotin	Biosynthetic reactions that require CO_2 fixation.
Lipoic acid	Lipoamide	Transfer of acyl groups in oxidation of keto acids.
Mercaptoethane-sulfonic acid	Coenzyme M	CH_4 production by methanogens.
Nicotinic acid	NAD (nicotinamide adenine dinucleotide) and NADP	Electron carrier, oxidation reduction reactions.
Pantothenic acid	Coenzyme A and the Acyl Carrier Protein (ACP)	Oxidation of keto acids and acyl group carriers in metabolism.
Pyridoxine (B6)	Pyridoxal phosphate	Amino acid metabolism
Riboflavin (B2)	FMN (flavin mononucleotide) and FAD (flavin adenine dinucleotide).	Electron carrier, oxidation-reduction reactions.
Thamine (B1)	Thiamine pyrophosphate	Decarboxylation of keto

	(TPP)	acids and transaminase reactions.
Vitamin B12	Cobalamine coupled to adenine nucleoside	Transfer of methyl groups.
Vitamin K	Quinones and napthoquinones	Electron transport processes.

[0051] TABLEs 1-4 has illustrated some information for considering the constituents of the biodegradable seal **110**. They are shown by way of illustration, not limitation. The actual material selection for the biodegradable seal **110** are formulated based on the targeted food product and other factors which are not described herewith.

[0052] While specific embodiments have been described and illustrated, it is understood that many changes, modifications, variations and combinations thereof could be made to the present invention without departing from the scope of the invention. For example, one food product package may consist a plurality of RFID tags, having the respective IC die encapsulated by a encapsulant material different from each other.

Claims

1. An RF-based chip for detecting a level of decomposition, said chip comprising an IC die encapsulated by a biodegradable material for environmentally protecting the IC die,

wherein when the IC die is exposed without protection of the biodegradable material due to a degradation of the biodegradable material, the IC die is damaged which causes said chip to malfunction, thereby indicating the level of decomposition is reached.

2. The RF-based chip according to claim 1, wherein the biodegradable material consists of biopolymer.

3. The RF-based chip according to claim 2, wherein the biopolymer is selected from the group consists of pectin and agar.

4 The RF-based chip accordingly to claim 2, wherein the biodegradable material consists of a poly(3-hydroxybutyrate).

5. The RF-based chip according to claim 1, wherein said chip has a pre-determined lifespan which is configured based on the thickness of the biodegradable material encapsulating the IC die.

6. The RF-based chip according to claim 5, wherein said chip is capable of detecting a state of contamination based on a actual lifespan when comparing with the pre-determined lifespan.

7. The RF-based chip according to claim 6, wherein the state of contamination is identified when the actual lifespan is relatively shorter than the pre-determined lifespan.

8. An RFID tag detectable by an RFID reader comprising:

an antenna for transmitting signals between the RFID tag and the RFID reader;

an RF-based chip for detecting a level of decomposition, said chip comprising an IC die encapsulated by a biodegradable material for environmentally protecting the IC die, said chip is electrically connecting to the antenna;

wherein when the IC die is exposed without protection of the biodegradable material due to a degradation of the biodegradable material, the IC die is damaged which causes said tag to malfunction and not detectable by the RFID reader, thereby indicating the level of decomposition is reached.

9. The RFID tag according to claim 8, wherein in the biodegradable material consists of biopolymer.

10. The RFID tag according to claim 9, wherein the biopolymer is selected from the group consists of pectin and agar.

11 The RF-based chip accordingly to claim 9, wherein the biodegradable material consists of poly(3-hydroxybutyrate).

12. The RFID tag according to claim 8, wherein said chip has a pre-determined lifespan which is configured based on the thickness of the biodegradable material encapsulating the IC die.

13. The RFID tag according to claim 12, wherein said chip is capable of detecting a state of contamination based on an actual lifespan when comparing with the pre-determined lifespan.

14. The RFID tag according to claim 13, wherein the state of contamination is identified when the actual lifespan is relatively shorter than the pre-determined lifespan.

15. The RFID tag according to claim 8, wherein the antenna is a planar coil antenna.

16. A method of determining a level of decomposition, said method comprising:

detecting present of an RFID tag having an RFID chip comprising an IC die encapsulated by a biodegradable material for environmentally protecting the IC die; and

identifying the level of decomposition is reached when no RFID tag is detected as a result of malfunctioned RFID chip due to an exposure of the IC die without protection of the biodegradable material due to a degradation of the biodegradable material.

17. The method according to claim 16, further comprising comparing a pre-determined lifespan of the RFID chip with an actual lifespan of the RFID chip for detecting a state of contamination.

18 The method according to claim 17, further comprising identifying the state contamination when the actual lifespan is relatively shorter than the pre-determined lifespan.