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(54) **INDICATOR DEVICES AND ARTICLES  
COMPRISING THE INDICATOR DEVICE**

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(57) **ABSTRACT**

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**Related U.S. Application Data**

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01181, filed on Aug. 11, 2004.

An indicator device comprising a first carrier material; a first pigment disposed in the first carrier material, the first pigment capable of being degraded by exposure to UV radiation; and wherein the first carrier material is configured so as to have a varying thickness such that upon exposure to UV radiation, a visible change in the pigment will occur which will result in a varying visible change over a first surface of the first carrier material.

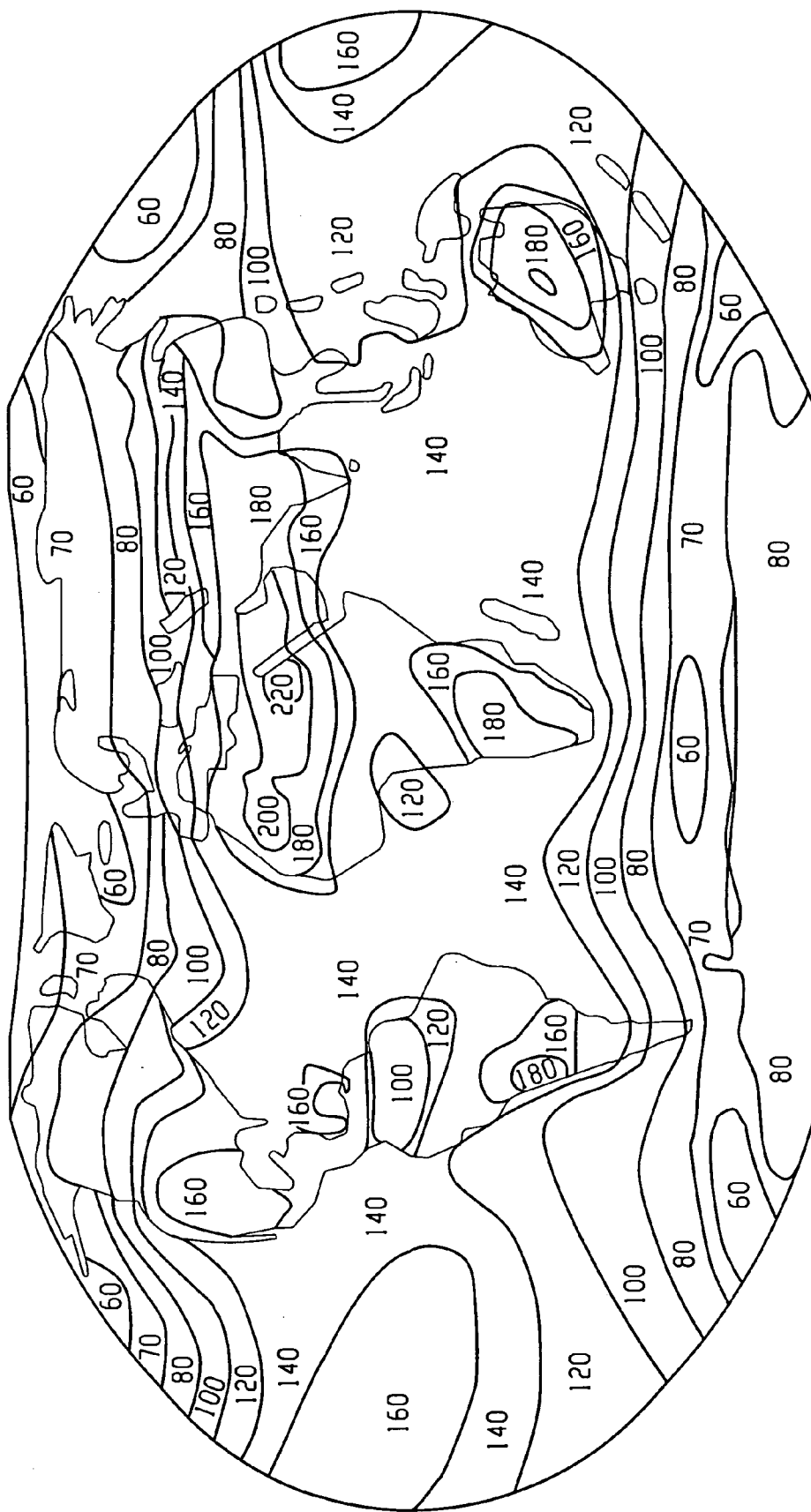


Fig. 1

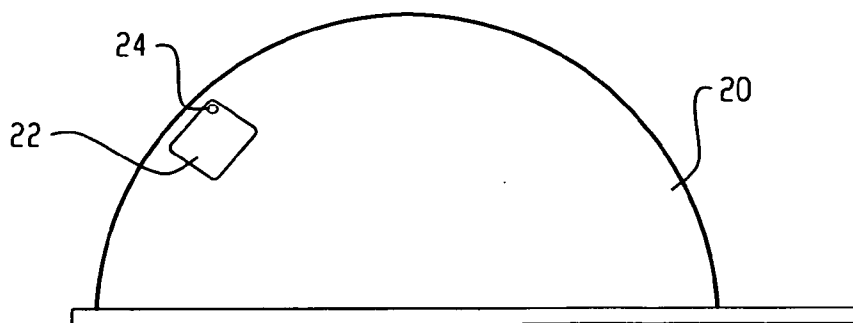


Fig. 2

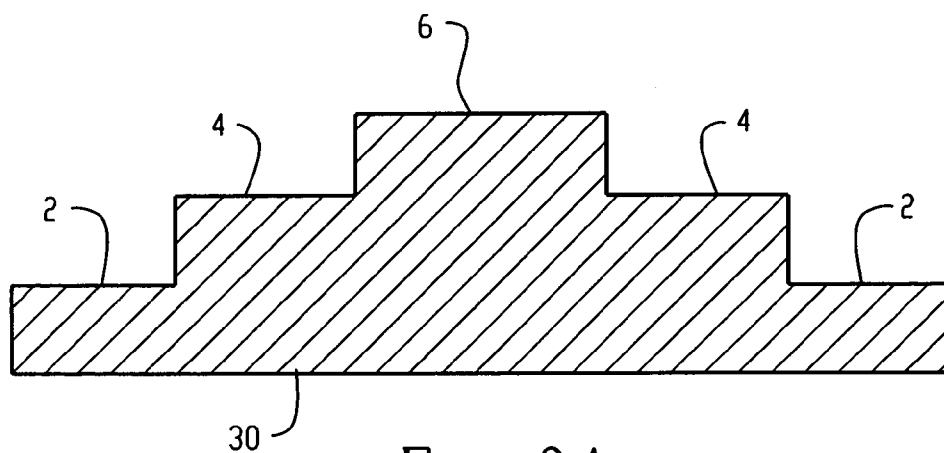


Fig. 3A

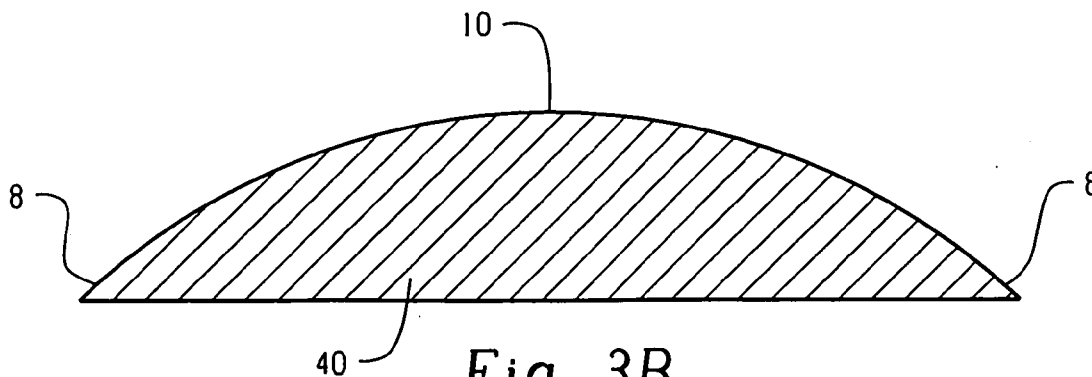


Fig. 3B

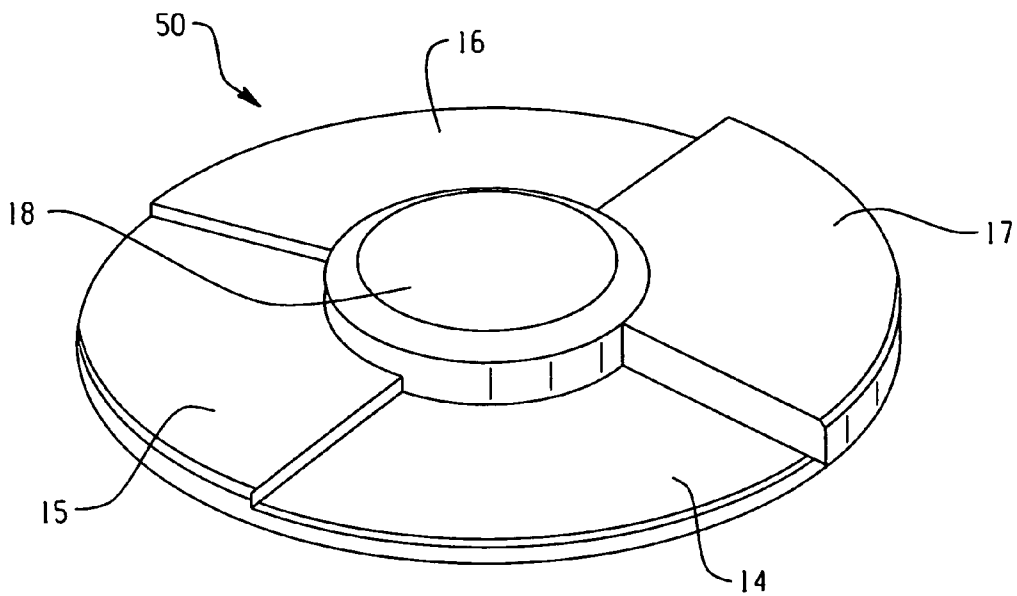


Fig. 4

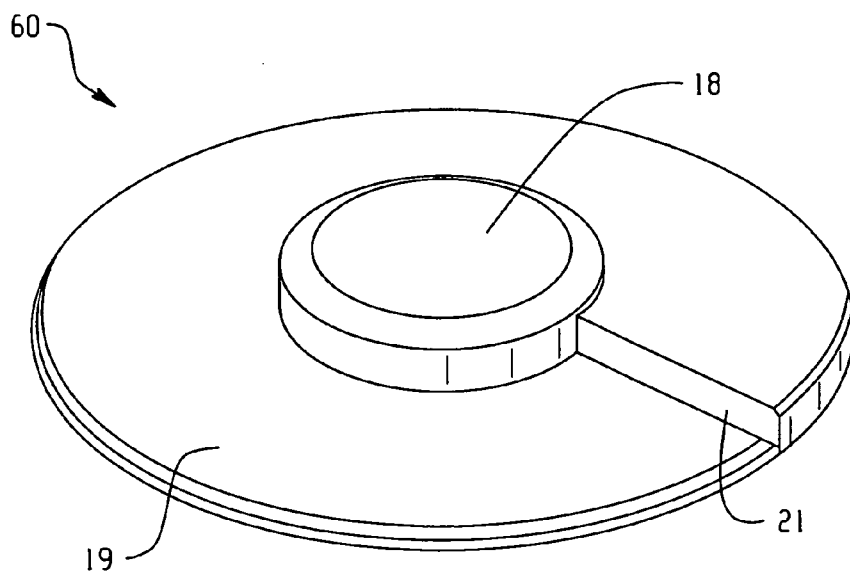


Fig. 5

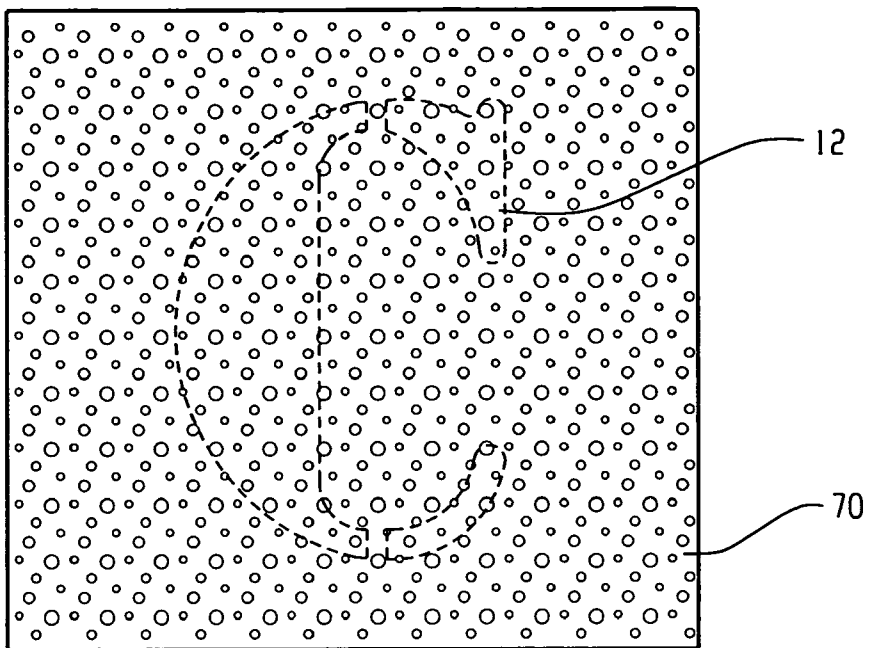


Fig. 6A

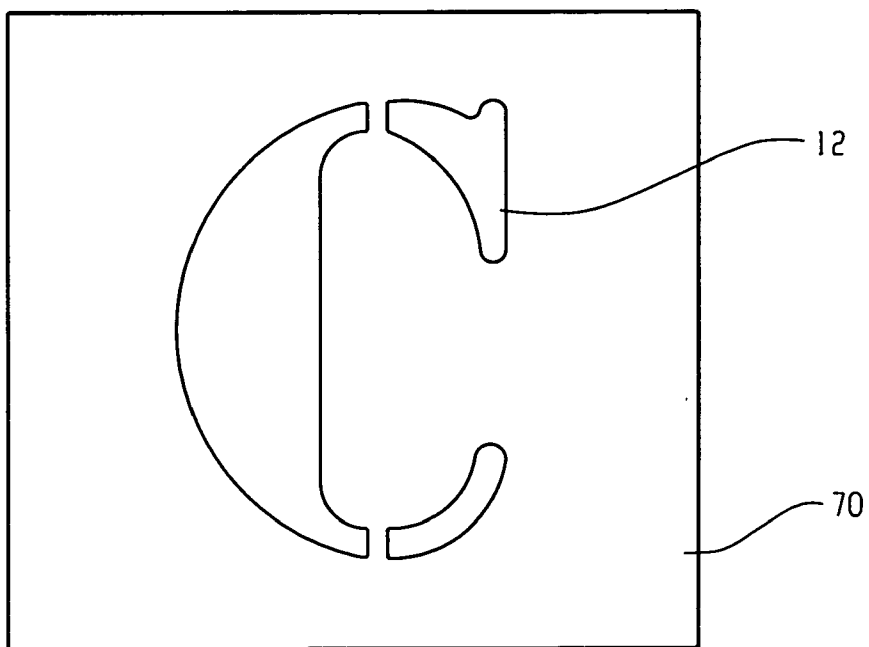


Fig. 6B

## INDICATOR DEVICES AND ARTICLES COMPRISING THE INDICATOR DEVICE

### CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a continuation-in-part application of International Application No. PCT/SE2004/001181, with an international filing date of Aug. 11, 2004, which claims priority from Swedish Patent Application No. SE0302216-7 filed Aug. 13, 2003, which are each hereby incorporated by reference in their entirety.

### BACKGROUND

[0002] The present disclosure relates to indicator devices for determining the ageing of articles (e.g., plastic articles), which are degradable by ultraviolet (UV) radiation.

[0003] Plastic is a material that can be used in many contexts. For example, plastic is employed in the manufacture of different consumer related products. More particularly, since plastic withstands impact and is readily/cost effectively formed into different shapes, plastic is suited for use in safety and personal protection articles (e.g., helmets (e.g., construction helmets, bike helmets, ski helmets, and the like), car and bicycle seats for children, and the like).

[0004] One drawback of plastic is that it degrades under the action of UV radiation. For example, the presence of UV radiation leads to cracks in plastics of all different types. Further, it is noted that degradation of the plastic article in the absence of UV radiation can be minimal (e.g., when the plastic article is packed and stored in boxes/containers). Differences in the speed of ageing are also observed depending on whether the plastic article is used indoors or outdoors and whether the plastic article is used in northerly or southerly latitudes. In other words, the UV radiation exposure of the plastic article can be a decisive factor in the speed of aging of the plastic article.

[0005] Referring to **FIG. 1**, a graphical representation of generalized isolines of global radiation is illustrated. The global UV radiation per year is measured according to ASTM D1435. The intensity of UV radiation illustrated in **FIG. 1** is measured in kLy (kilo-Langley), which represents how much UV radiation energy falls on a centimeter square area (cm<sup>2</sup>) per year. **FIG. 1** illustrates that the intensity of UV radiation varies depending on geographical location. For example, the intensity of UV radiation is more intense in the deserts of Africa compared to a city in Western Europe. As such, the useful lifetime of a plastic article varies depending on the geographical location of its use, since some areas receive a greater intensity of UV radiation than other areas.

[0006] Presently, a "date marking" is disposed on a plastic article to provide a consumer with an estimated lifetime of the article. When a date marking is employed, considerable safety margins are employed in order to be certain that an aged article whose mechanical strength is defective is no longer used. For example, the date marking is set based on an assumed time limit for the product to reach maximum UV exposure. As such, this date marking might not adequately reflect the useful life of the article (e.g., in the above example, a plastic article ages faster than the date marking in some areas, particularly in the deserts of Africa). Further, date marking can, in many cases, lead to usable articles,

which have not been exposed to UV radiation and have not aged, becoming unsellable when their date marking has expired. However, in order to avoid injury to a person or damage to property, the date marking is honored. By erring on the side of caution by respecting the date marking, considerable economic losses are suffered by manufactures, retailers, end-users, and the like, who might have stored large quantities of the dated marked articles.

[0007] Further, a time period for use of an article can be set by mandate, for example, by a legislative restriction set by a given country, which can differ from country to country. Again, the actual durability (lifetime) of a plastic article can exceed a given time period set by a legislature. As such, removing an article from use prematurely (i.e., before its useful life has expired) can further cause economic losses to be suffered, since the article would be replaced more frequently compared to replacing the article when its useful lifetime has expired.

[0008] Accordingly, what is needed in the art are indicator devices that can measure the ageing of articles that degrade with UV radiation exposure.

### SUMMARY

[0009] Disclosed herein are indicator devices and articles comprising the indicator device.

[0010] One embodiment of an indicator device comprises a first carrier material; a first pigment disposed in the first carrier material, the first pigment capable of being degraded by exposure to UV radiation; and wherein the first carrier material is configured so as to have a varying thickness such that upon exposure to UV radiation, a visible change in the pigment will occur which will result in a varying visible change over a first surface of the first carrier material.

[0011] Another embodiment of an indicator device comprises a first carrier material; a first pigment disposed in the first carrier material, the first pigment capable of being degraded by exposure to UV radiation; a second carrier material disposed in contact with the first carrier material; and a second pigment disposed in the second carrier material, the second pigment capable of being degraded by exposure to UV radiation, wherein the second pigment has a different fastness to light than the first pigment such that a visible change in indicator device occurs from the first carrier material to the second carrier material.

[0012] A third embodiment of an indicator device comprises a carrier material; a first pigment disposed in the carrier material, the first pigment capable of being degraded by exposure to UV radiation; and a marking concealed by the first pigment, the marking capable of being visible upon degradation of the first pigment.

[0013] One embodiment of an article comprises a surface; an indicator device disposed in physical communication with the surface, the indicator device comprising a first carrier material; a first pigment disposed in the first carrier material, the first pigment capable of being degraded by exposure to UV radiation; and wherein the first carrier material is configured so as to have a varying thickness such that upon exposure to UV radiation, a visible change in the pigment will occur which will result in a varying visible change over a first surface of the first carrier material.

[0014] The above-described and other features will be appreciated and understood by those skilled in the art from the following detailed description, drawings, and appended claims.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Referring now to the figures, which are exemplary embodiments, and wherein the like elements are numbered alike:

[0016] FIG. 1 is a graphical representation of generalized isolines of global radiation;

[0017] FIG. 2 is a side view of a helmet comprising an embodiment of an indicator device;

[0018] FIG. 3A is a cross sectional view of an embodiment of an indicator device;

[0019] FIG. 3B is a cross sectional view of another embodiment of an indicator device;

[0020] FIG. 4 is a perspective view of a third embodiment of an indicator device;

[0021] FIG. 5 is a perspective view of a fourth embodiment of an indicator device;

[0022] FIG. 6A is a plain view of a third embodiment of an indicator device in a pristine state; and

[0023] FIG. 6B is a plain view of the embodiment of FIG. 6A in an aged state.

#### DETAILED DESCRIPTION

[0024] Disclosed herein are indicator devices for determining the ageing of articles that are degradable by UV radiation exposure. More particularly, as will be explained in greater detail throughout this disclosure, it has been discovered that a formulation comprising a pigment capable of degrading when exposed to UV radiation can be employed in an UV indicator device to measure the UV exposure of an article to provide a visible indication of the useful life of the article to the end user of the article. Reference is made to articles comprising plastic (hereinafter referred to as plastic articles) for ease in discussion, with the understanding that any article comprising a material that degrades when exposed to UV radiation is within the scope of this disclosure.

[0025] The terms “first,” “second,” and the like herein do not denote any order or importance, but rather are used to distinguish one element from another, and the terms “a” and “an” herein do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced items. The modifier “about” used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (e.g., includes the degree of error associated with measurement of the particular quantity). Unless defined otherwise herein, all percentages herein mean weight percent (“wt. %”). Furthermore, all ranges disclosed herein are inclusive and combinable (e.g., ranges of “up to about 25 weight percent (wt. %), with about 5 wt. % to about 20 wt. % desired, and about 10 wt. % to about 15 wt. % more desired,” are inclusive of the endpoints and all intermediate values of the ranges, e.g., “about 5 wt. % to about 25 wt. %, about 5 wt. % to about 15 wt. %”, etc.).

[0026] The indicator device comprises a formulation comprising a carrier material and a pigment capable of degrading when exposed to UV radiation. The carrier material is any material that acts as a matrix for the pigment. For example, suitable carrier materials include plastics, textiles, ceramics, and the like. For ease in discussion, reference is made hereinafter to a carrier material comprising plastic, with the understanding that the disclosure can readily be adapted for use with other materials. When the carrier material comprises plastic, the indicator device further comprises an UV stabilizer. Without wanting to be bound by theory, by UV stabilizing the plastic, the fading function of the pigment of the plastic is primarily (e.g., greater than 50%) related to visual light (e.g., light having a wavelength of about 400 nanometers (nm) to about 800 nm). Various optional additives can be added to the formulation depending on the desired application.

[0027] Further, the carrier material comprises a material that has a useful life greater than or equal to the useful life of the article that is to be measured when exposed to UV radiation. The carrier material is selected such that it is compatible with the pigment. While embodiments are envisioned where the carrier material of the indicator device comprises the same material as the plastic article, the indicator device can comprise materials other than those employed in the plastic article. In one embodiment, the carrier material comprises a plastic (e.g., polycarbonate, polyethylene, polypropylene, and the like, and combinations comprising at least one of the foregoing). For example, the carrier material can comprise polyethylene, which is economical, environmentally friendly, capable of being molded (e.g., injection molded), easily UV stabilized, and easily colored with the pigment.

[0028] The carrier material is present in a sufficient amount to act as a matrix for the pigment. For example, the carrier material is present in an amount of greater than or equal to about 90 wt. %, particularly greater than or equal to about 95 wt. %, wherein weight percents are based on a total weight of the formulation. In other embodiments, the carrier material is present in an amount of about 95 wt. % to about 99 wt. %.

[0029] The properties of the pigment and the material thickness of the indicator device are selected such that the color degradation of the indicator device occurs at a rate sufficient to track the useful life of the plastic article. Stated another way, degradation of the pigment under the action of UV radiation corresponds to the degradation (e.g., crack formation) of the plastic article. Without wanting to be bound by theory, factors to consider in designing the indicator device to correspond to the degradation of the plastic article include, but are not limited to, the choice of pigment, the concentration of the pigment in the formulation, the fastness to light, and the material thickness of the indicator.

[0030] In other embodiments, the indicator device is designed such that the pigment and the thickness are selected in such a manner that the degradation of the pigment corresponds to a maximum permitted UV exposure of the article for a given market or regulations. For example, an indicator device can be obtained which indicates when an active use (i.e., exposure to UV radiation) during a predetermined period of time has been achieved. Stated another way, the indicator device indicates the life of an article based

on UV radiation exposure. As such, when an article is not being exposed to UV radiation, the degradation of the pigment is mitigated or eliminated (e.g., when the article is stored indoors) corresponding to a reduction or discontinuation in the ageing of the article.

**[0031]** The fastness to light of the pigment indicates the speed of degradation under the action of light, in particular UV light. Fastness to light is graded on a scale from 1 to 8 as indicated in International Organization for Standards (ISO) 105 B02 wherein a lower number on the scale corresponds to a pigment that degrades more rapidly compared to a pigment with a higher number on the scale. The fastness to light of the pigment can vary depending on the estimated life of the plastic article that is being measured and the carrier material that is employed in the formulation. Stated another way, the pigment can be selected based on the fastness to light such that the pigment degrades at a rate less than or equal to the rate of the plastic article to be measured.

**[0032]** While the choice of pigment can vary depending on the application and carrier material, the pigment can be selected to follow the degradation of the plastic article, can follow a time interval that is predetermined by legislation or other regulation, and the like. For example, it is possible to realize color shifts from violet to white or red to transparent under the action of a suitable predetermined quantity of UV radiation. In one embodiment, a suitable pigment includes Color Index (C.I.) Pigment red 48:30.

**[0033]** In one embodiment, the indicator device comprises a homogeneous mixture of two or more different pigments, each having a different fastness to light such that the indicator device displays different colors as it is exposed to UV radiation. For example, it is possible to mix red and yellow pigment, wherein the yellow pigment is faster to light than the red pigment. Initially, the indicator device appears as red, but as the red pigment disappears, the indicator device changes to yellow. In due course, the yellow colored pigment also disappears and the indicator device changes to white. This color change gives the end user a forewarning that the service life of the article to which the indicator device corresponds is approaching its end. As a result, new objects can be ordered in good time, which is an advantage on planned purchasing and stock-keeping.

**[0034]** In another embodiment, the indicator device comprises multiple layers or sections, wherein each layer or section comprises a different pigment. For example, multiple layers are disposed in contact with each other, wherein each layer has a pigment with a different fastness to light than the respective pigment(s) employed in each other layer. As each layer is exposed to UV radiation, the pigment in each respective layer begins to degrade. Over time, the pigment in the outer most layer degrades completely exposing the pigment of the next layer, which provides a visual indication of the aging of the article. It is briefly noted that the multiple layers can be formed by any suitable method (e.g., injection molding, coextrusion, lamination, and the like).

**[0035]** As briefly mentioned, the indicator device can comprise multiple sections disposed adjacent to each other in the same planar direction. For example, in one embodiment, the indicator device comprises a disc-like shape, which is formed by joining multiple wedge-like shapes (sections) together to form the disc-like shape. Each section comprises a different pigment having a different fastness to

light. Stated another way, the pigment of each section degrades at a different rate, which provides a visual indication of the aging of the article. For example, an indication that the useful life of the article has been depleted occurs when the color of all the sections are the same color.

**[0036]** The degradation of the pigment, and thereby the color of the indicator device, can also be affected by the material thickness of the carrier material of the indicator device. More particularly, pigment that lays most proximal to the surface of the indicator device is affected first and to the greatest extent when compared to the pigment laying deeper, which is affected only when the surface pigment has been broken down. Thus, the color tends to disappear first in the relatively thinnest part of the indicator device, while areas of greater material thickness can maintain the pristine color longer than the thinnest part.

**[0037]** Further, while the amount of pigment degradation can vary with the thickness of the indicator device, the pigment is present in an amount sufficient to allow the pigment to degrade at a time greater than or equal to a time in which the plastic article degrades. For example, the formulation comprises about 0.5 wt. % to about 10 wt. % pigment, more particularly about 1 wt. % to about 5wt. %, even more particularly 1 wt. % to about 3 wt. %, wherein the weight percents are based on a total weight of the formulation.

**[0038]** It is noted that by varying the material thickness of the indicator device, a multi-stage (e.g., stepwise) indication is obtained, which indicates the remaining life of the article. For example, each stage can represent a fraction of useful life of the article, such that a color change at each step indicates to the end user of the article that remaining fraction of useful life remaining or the fraction of life depleted.

**[0039]** In various embodiments, the formulation further comprises an UV stabilizer, which is compatible with the carrier material and the pigment. The UV stabilizer employed is selected to maintain the properties of the pigment (e.g., does not affect the manner in which the pigment degrades when exposed to UV light). Suitable UV stabilizers include hindered amine light stabilizers (Hals), UV absorbers, and the like. In one embodiment, the UV stabilizer is present in an amount up to about 1 wt. %, particularly about 0.2 wt. % to about 0.5 wt. %, wherein the weight percents are based on a total weight of the formulation.

**[0040]** The carrier material, the pigment, the optional UV stabilizer, and any other additive(s) can be mixed together by any suitable method to form the formulation employed in the indicator device. Suitable methods include blending (e.g., melt blending), mixing (e.g., admixing), and the like. For example, the components of the formulation can be disposed in a hopper and extruded into sheets, which can be employed in the indicator device. Suitable methods of forming the indicator device include, but are not limited to, extrusion (including coextrusion), molding, and the like, with molding being particularly beneficial in some applications where a relatively low cost indicator device is desired. Further, in various embodiments, an adhesive (e.g., a pressure sensitive adhesive (PSA) can be disposed on a surface of the indicator device by any suitable method (e.g., spraying, coating (e.g. cast coating), and the like).

**[0041]** The indicator device comprises any shape or size that is compatible with the plastic article. Further, the indicator device is affixed to the plastic article or disposed





TABLE 1-continued

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
30% Pigment red 48:3; Sr salt of a monoazo acid dye (MB 4111 Röd Polystatic)	1.0	0.6	0.3	0.5	0	0	0	0
Fluorescent pigment (12-2030-LMP5)	0	0	0	3.0	1.0	3.0	1.0	3.0

\*Chimassorb is a product designation of Ciba Specialty Chemicals.

[0050] The indicator devices disclosed herein are used to measure the life of any article that degrades upon exposure to UV radiation. Suitable articles include articles made of plastic. For example, plastic articles include, but are not limited to, helmets (e.g. bicycle helmets, construction helmets, and the like), car seats, bicycle seats, earmuffs, face shields, box carrier, chairs, and boat hulls. Non-plastic articles that employ the indicator device include, but are not limited to foods, clothes, and the like.

[0051] It is advantageously noted that the indicator device disclosed herein provides an indication of the lifetime of an article that degrades upon UV exposure. The visual indication provided by the indicator device allows the article to be replaced as needed, rather than for example by some arbitrary date marking. As such, new articles can be ordered in good time, which is an advantage on planned purchasing and stock-keeping. Further, as noted above, considerable economic losses can be suffered by manufactures, retailers, end-users, and the like, who might have stored large quantities of the dated marked articles, this indicator allows the same large quantity of articles to be stored with the benefit of an indication of the UV exposure of each article, thereby providing the indication of remaining useful life of the article.

[0052] While the invention has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

1. An indicator device comprising:

a first carrier material;

a first pigment disposed in the first carrier material, the first pigment capable of being degraded by exposure to UV radiation; and

wherein the first carrier material is configured so as to have a varying thickness such that upon exposure to UV radiation, a visible change in the pigment will occur which will result in a varying visible change over a first surface of the first carrier material.

2. The indicator device of claim 1, wherein the visible change comprises a color change.

3. The indicator device of claim 1, wherein the varying visible change comprises a stepwise visible change.

4. The indicator device of claim 1, further comprising a marking concealed by the first pigment, the marking capable of being visible upon degradation of the first pigment.

5. The indicator device of claim 1, further comprising a second pigment disposed in the first carrier material, the second pigment capable of being degraded by exposure to UV radiation and having a different fastness to light than the first pigment.

6. The indicator device of claim 1, further comprising a second carrier material disposed in contact with the first carrier material; and a second pigment disposed in the second carrier material, the second pigment capable of being degraded by exposure to UV radiation.

7. The indicator device of claim 1, wherein the indicator device further comprises an adhesive disposed on a second surface of the first carrier material opposite the first surface of the first carrier material.

8. The indicator device of claim 1, wherein the first carrier material comprises polyethylene; and the first pigment comprises C.I. Pigment red 48:30.

9. The indicator device of claim 1, wherein the indicator device comprises a formulation comprising greater than or equal to about 90 wt. % of the first carrier material and 0.5 wt. % to about 10 wt. % of the first pigment, wherein weight percents are based on a total weight of the formulation.

10. The indicator device of claim 9, wherein the first pigment is present in an amount of about 1 wt. % to about 3 wt. %.

11. The indicator device of claim 9, wherein the first carrier material comprises polyethylene; the first pigment comprises C.I. Pigment red 48:30, and the formulation further comprises about 0.2 wt. % to about 0.5 wt. % of a UV stabilizer.

12. The indicator device of claim 1, wherein degradation of the first pigment corresponds to degradation of an article, such that the indicator device is capable of providing a visual indication of a remaining life of the article.

13. The indicator device of claim 1, wherein degradation of the first pigment corresponds to a predetermined maximum permitted UV exposure for an article such that the indicator device is capable of providing a visual indication that the article has received the predetermined maximum permitted UV exposure.

14. The indicator device of claim 1, wherein the indicator device is fixedly disposed on or integrated into an article such that degradation of the pigment corresponds to degradation of the article, such that the indicator device is capable of providing a visual indication of a remaining life of the article.

15. The indicator device of claim 1, wherein degradation of the pigment corresponds to a time interval that is predetermined by legislation or other regulations.

16. An indicator device comprising:

a first carrier material;

a first pigment disposed in the first carrier material, the first pigment capable of being degraded by exposure to UV radiation;

a second carrier material disposed in contact with the first carrier material; and

a second pigment disposed in the second carrier material, the second pigment capable of being degraded by exposure to UV radiation, wherein the second pigment has a different fastness to light than the first pigment such that a visible change in indicator device occurs from the first carrier material to the second carrier material.

17. The indicator device of claim 16, wherein the visible change comprises a color change.

18. The indicator device of claim 16, wherein the visible change comprises a stepwise visible change.

19. An indicator device comprising:

a carrier material;

a first pigment disposed in the carrier material, the first pigment capable of being degraded by exposure to UV radiation; and

a marking concealed by the first pigment, the marking capable of being visible upon degradation of the first pigment.

20. The indicator device of claim 19, further comprising a second pigment disposed in the carrier material, the second pigment capable of being degraded by exposure to UV radiation, wherein the second pigment has a different fastness to light than the first pigment.

21. An article comprising:

a surface;

an indicator device disposed in physical communication with the surface, the indicator device comprising

a first carrier material;

a first pigment disposed in the first carrier material, the first pigment capable of being degraded by exposure to UV radiation; and

wherein the first carrier material is configured so as to have a varying thickness such that upon exposure to UV radiation, a visible change in the pigment will occur which will result in a varying visible change over a first surface of the first carrier material.

22. The article of claim 21, wherein the visible change comprises a color change.

23. The article of claim 21, wherein the varying visible change comprises a stepwise visible change.

24. The article of claim 21, wherein degradation of the first pigment corresponds to degradation of the article, such that the indicator device is capable of providing a visual indication of a remaining life of the article.

25. The article of claim 21, wherein the article is a helmet.

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