Further, different reaction response times require different types of chemical additives. Also, nitrogen atmospheres or ultraviolet irradiation are required to produce and use the indicator.

Accordingly, there is a need to provide an alternative indicator that overcomes, or at least ameliorates, one or more of the disadvantages described above.

Summary

According to a first aspect, there is provided an irreversible, colorimetric, oxidant-dependent time indicator comprising: a) a porous material substrate; b) one or more redox-active dyes; c) one or more reductants; d) one or more non-alkaline additives; characterized in that the components b) to c) are deposited on the substrate a) substantially in the absence of a polymeric material or thickener in the component matrix and substantially in the absence of an oxidant semipermeable coating layer on the substrate.

According to a second aspect, there is provided a method of using an indicator as disclosed herein to measure the oxidant exposure time wherein the indicator is activated by exposure to a constant oxidant concentration in its environment and its irreversible time dependent change in colour is observed after activation.

According to a third aspect, there is provided a process for making an indicator as disclosed herein, characterized in that a solution of the reductants and additives is added to a solution of a redox-active dye and deposited on the porous material substrate; or solution of the reductants and additives is added to a pre-dried spot of a redox-active dye solution on the porous material substrate.

According to a fourth aspect, there is provided an oxidant exposure time measuring device comprising one or more indicators as disclosed herein.

According to a fifth aspect, there is provided a two or multilayer device according to the fourth aspect, wherein an indicator on one layer of porous material as disclosed herein is covered with another layer of porous material that contains further additives.

According to a sixth aspect, there is provided a kit of parts comprising a device as disclosed herein together with an oxidant impermeable container wherein the device is stored.

Definitions

The following words and terms used herein shall have the meaning indicated:

The term "dye" refers to substances which impart color to a substrate by selective absorption of light. Dyes are retained in the substrate by absorption, solution, mechanical retention, or by ionic or covalent chemical bonds.

The term "redox" refers to a chemical reaction involving a reduction (accepting of an electron(s)) and a corresponding oxidation (donation of an electron(s)). Accordingly, the term "redox-active dye" refers to a dye that is capable of being oxidized or reduced. The term "redox-sensitive" is used interchangeably herein.

Claims

1. An irreversible, colorimetric, oxidant-dependent time indicator comprising

   a) a porous material substrate;

   b) one or more redox-active dyes;

   c) one or more reductants;

   d) one or more non-alkaline additives;

   characterized in that the components b) to c) are deposited on the substrate a) substantially in the absence of a polymeric material or thickener in the component matrix and substantially in the absence of an oxidant semipermeable coating layer on the substrate.

2. The time indicator according to claim 1 wherein at least one the non-alkaline additive is an acidic additive

   selected from water-soluble strong acids.

3. The time indicator according to claim 1, wherein at least one reductant is selected from L-ascorbic acid, D-erythorbic acid and their enantiomers or tris(2-carboxyethyl)phosphine (TCEP) .

4. The time indicator according to claim 1, wherein at least one redox-active dye is methylene blue.

5. The time indicator according to claim 1, wherein the oxidant is oxygen.

6. The time indicator according to claim 1, wherein the porous material substrate is paper or a cellulosic material.

7. The time indicator according to claim 6, wherein components b) to c) are deposited in a hydrophilic detection zone of a wax printed substrate.

8. The time indicator according to claim 1, wherein the molar ratio of the reductant to the redox-active dyes is about 1:1 to 125:1 or

wherein the molar ratio of the acidic additives to the reductants is about 5,000:1 to 1:1.

9. A method of using an indicator according to claim 1 to measure the oxidant exposure time wherein the indicator is activated by exposure to a constant oxidant concentration in its environment and its irreversible time dependent change in colour is observed after activation.

10. The method according to claim 9, wherein several indicators according to claim 1 are used with varied concentration ratios of redox-active dyes to reductants and additives to obtain a colour change at different times of oxidant exposure.

11. The method according to claim 9 or 10 to survey time in an environment with constant oxidant content in the air.

12. A process for making an indicator according to claim 1, characterized in that a solution of the reductants and additives is added to a solution of a redox-active dye and deposited on the porous material substrate; or solution of the reductants and additives is added to a pre-dried spot of a redox-active dye solution on the porous material substrate.

13. The process according to claim 12, wherein the process is run at about 20 to 30 °C without the exclusion of oxygen.

14. The process according to claim 12 or 13 wherein the deposition spot of the redox-active dye on the porous material is an hydrophilic zone separated by hydrophobic barriers from the rest of the porous material or

wherein the pattern of hydrophobic areas

are introduced by wax printing on the substrate.

15. An oxidant exposure time measuring device comprising one or more indicators according to claim 1.

16. A device according to claim 15, wherein several indicators of claim 1 are arranged in form of a single layer of porous material as an array of indicators wherein the concentration ratios of redox-active dyes to reductants and additives are varied among the indicators to obtain a colour change at different times of oxidant exposure.

17. A two or multilayer device according to claim 15, wherein an indicator on one layer of porous material according to claim 1 is covered with another layer of porous material that contains further additives.

18. A two or multilayer device according to claim 17, wherein the covering layer comprises at least one alkaline additive.

19. A two or multilayer device according to claim 18, wherein the indicator layer and the cover layer include areas of hydrophilic spots on the porous material separated by hydrophobic areas created by wax printing; and the layers are bonded to each other in a way that the hydrophilic areas where the redox-active dyes, reductants, non-alkaline and alkaline additives are deposited are in connection with each other.

20. A kit of parts comprising a device according any of claims 15 to 19 together with an oxidant impermeable container wherein the device is stored.