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(54) **COLOR CHANGING SYSTEM FOR STRUCTURES AND METHOD THEREFOR**

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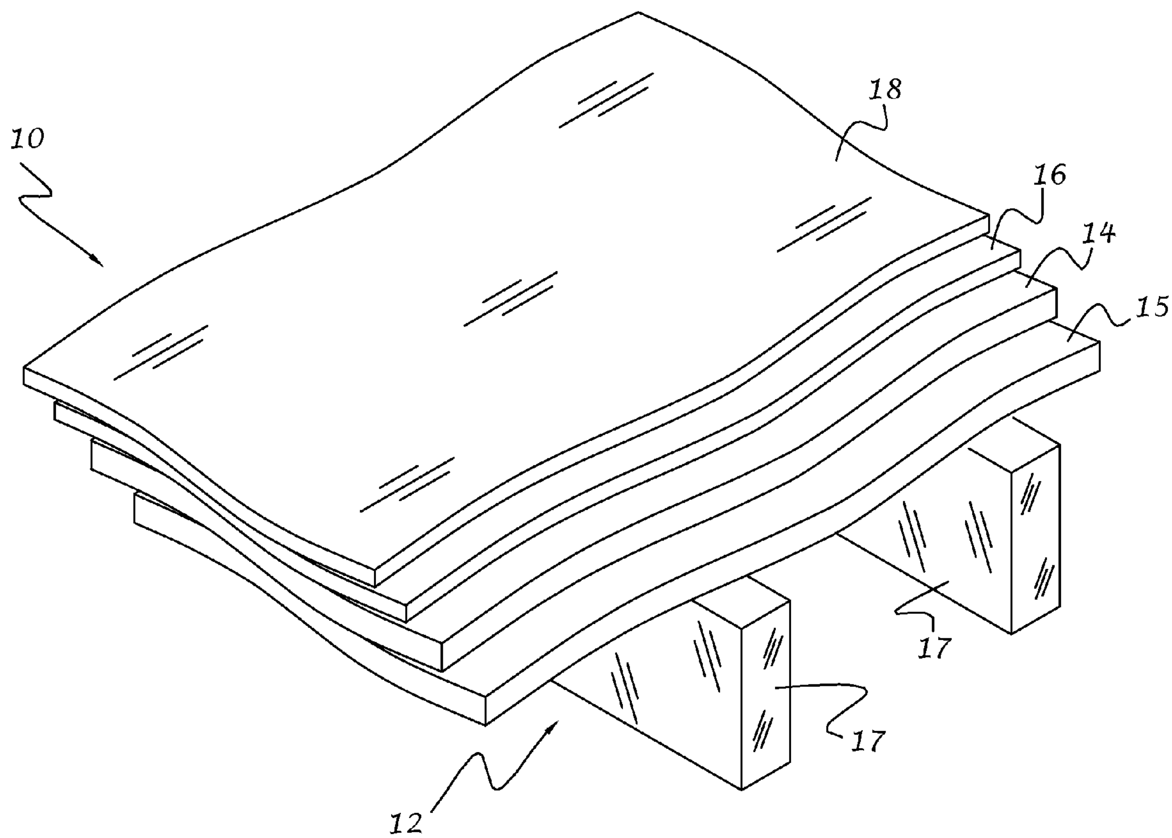
(57) **ABSTRACT**

A coating system and method for assisting in the heating or cooling of an underlying structure includes applying a first seamless, elastic solar reflective membrane over the structure, applying a second seamless, elastic thermochromic membrane over the first membrane, and applying a third seamless protective membrane over the second membrane. The second membrane has a color changing material with a clear state above a first transition temperature to permit transmission of solar radiation to the first membrane to reduce structure cooling requirements, and an opaque state below a second transition temperature to absorb radiant energy and reduce structure heating requirements. In addition, a method of detecting defects in a structure includes applying a layer of thermochromic material to the structure, observing a localized area of non-uniform color associated with the thermochromic layer, and ascertaining whether a defect is associated with the localized area.



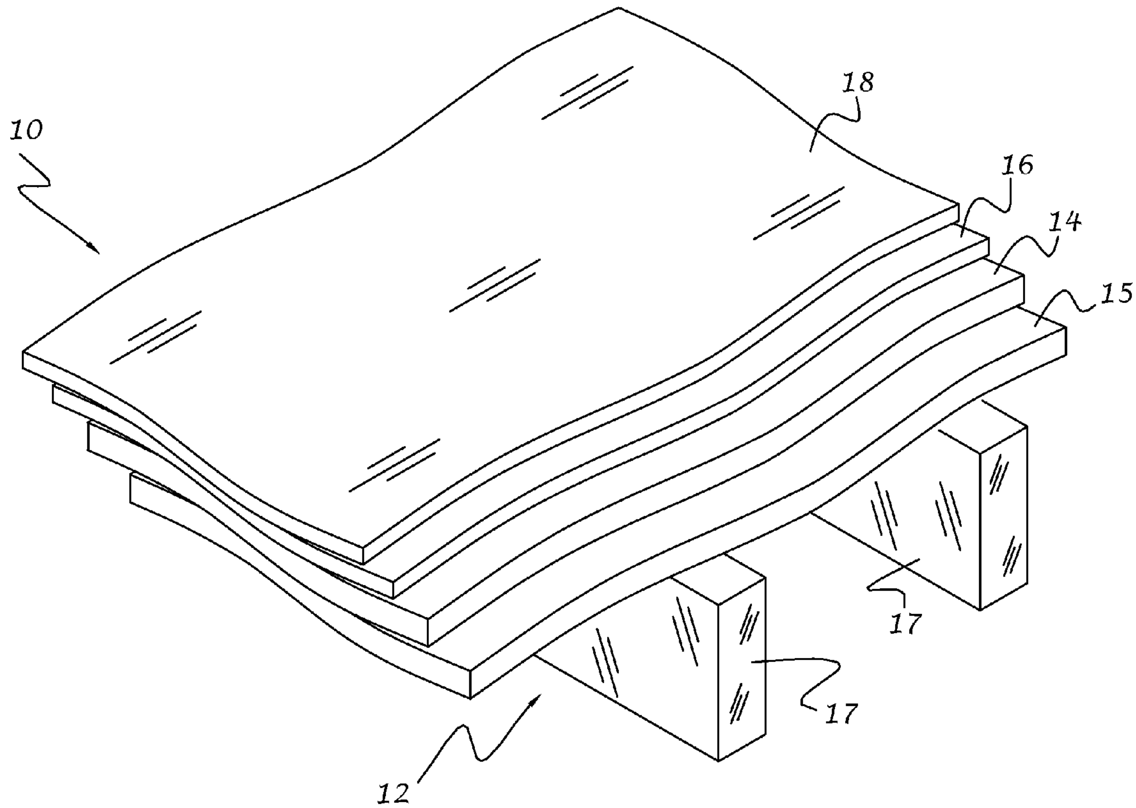


FIG. 1

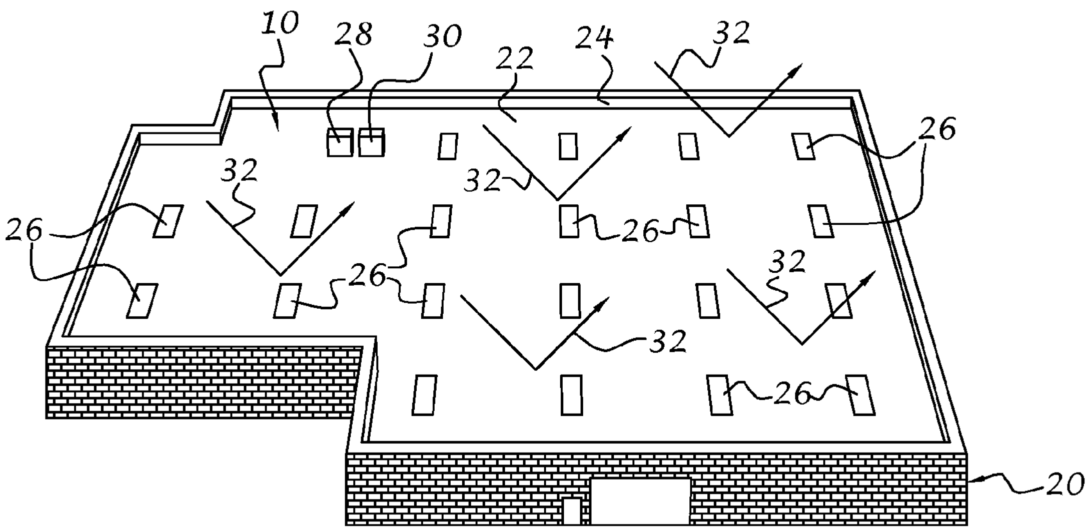


FIG. 2

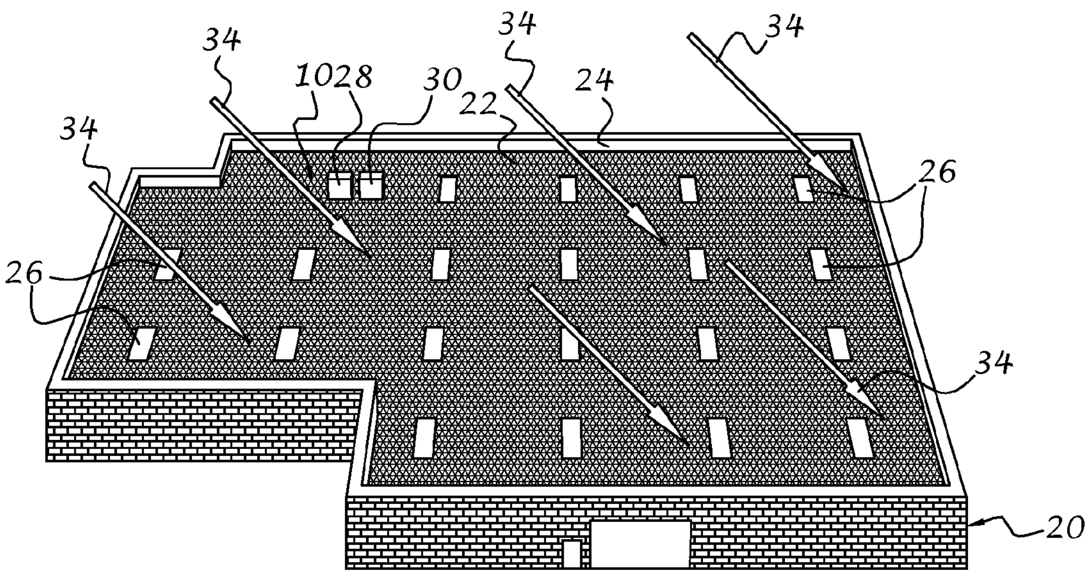


FIG. 3

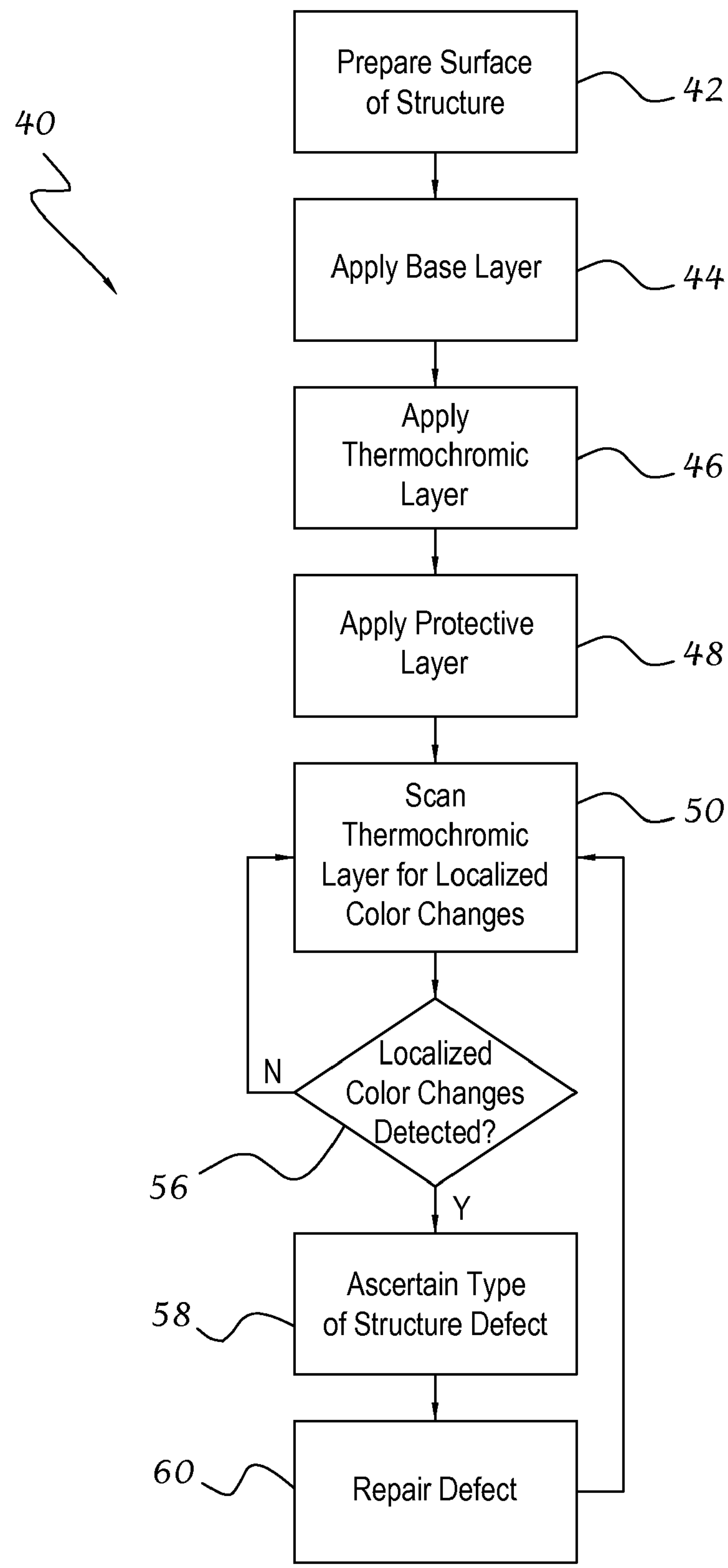

40
Prepare Surface of Structure
42
Apply Base Layer
44
Apply Thermochromic Layer
46
Apply Protective Layer
48
Scan Thermochromic Layer for Localized Color Changes
50
Localized Color Changes Detected?
N
Y
56
Ascertain Type of Structure Defect
58
Repair Defect
60

FIG. 4

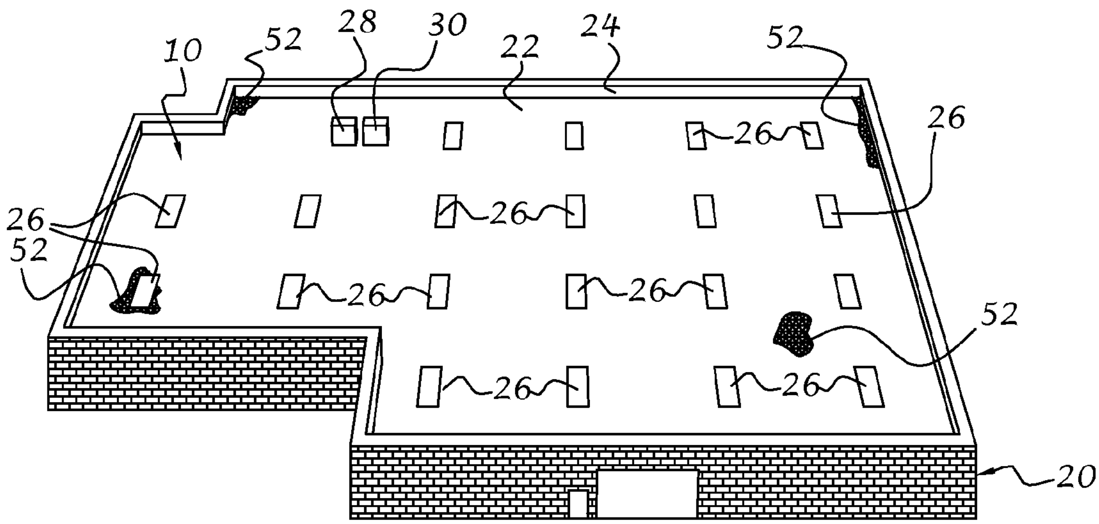

10
52
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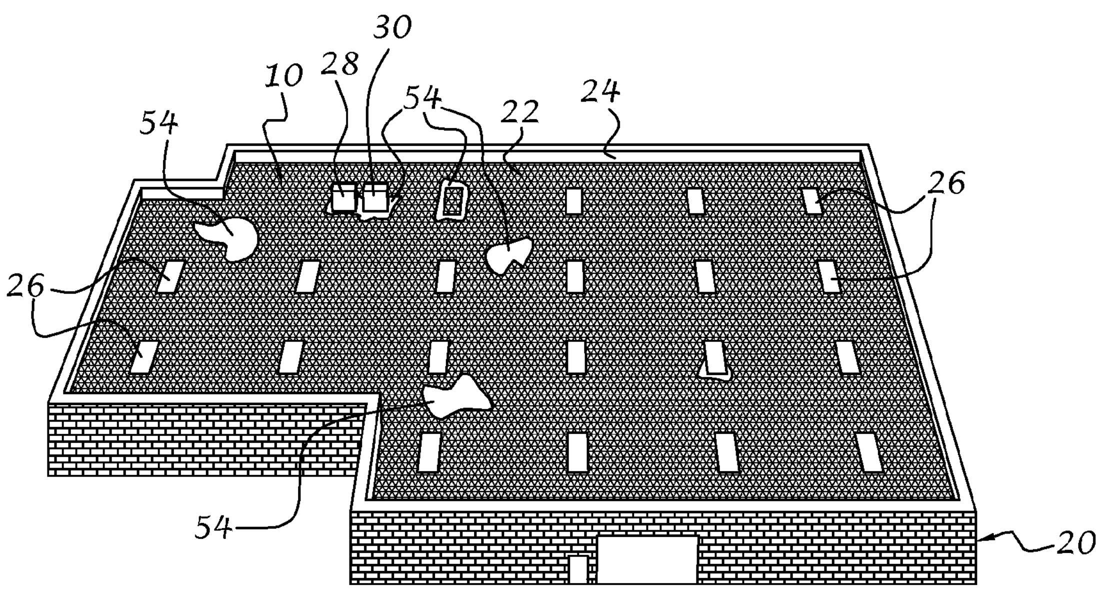
FIG. 5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22
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FIG. 6

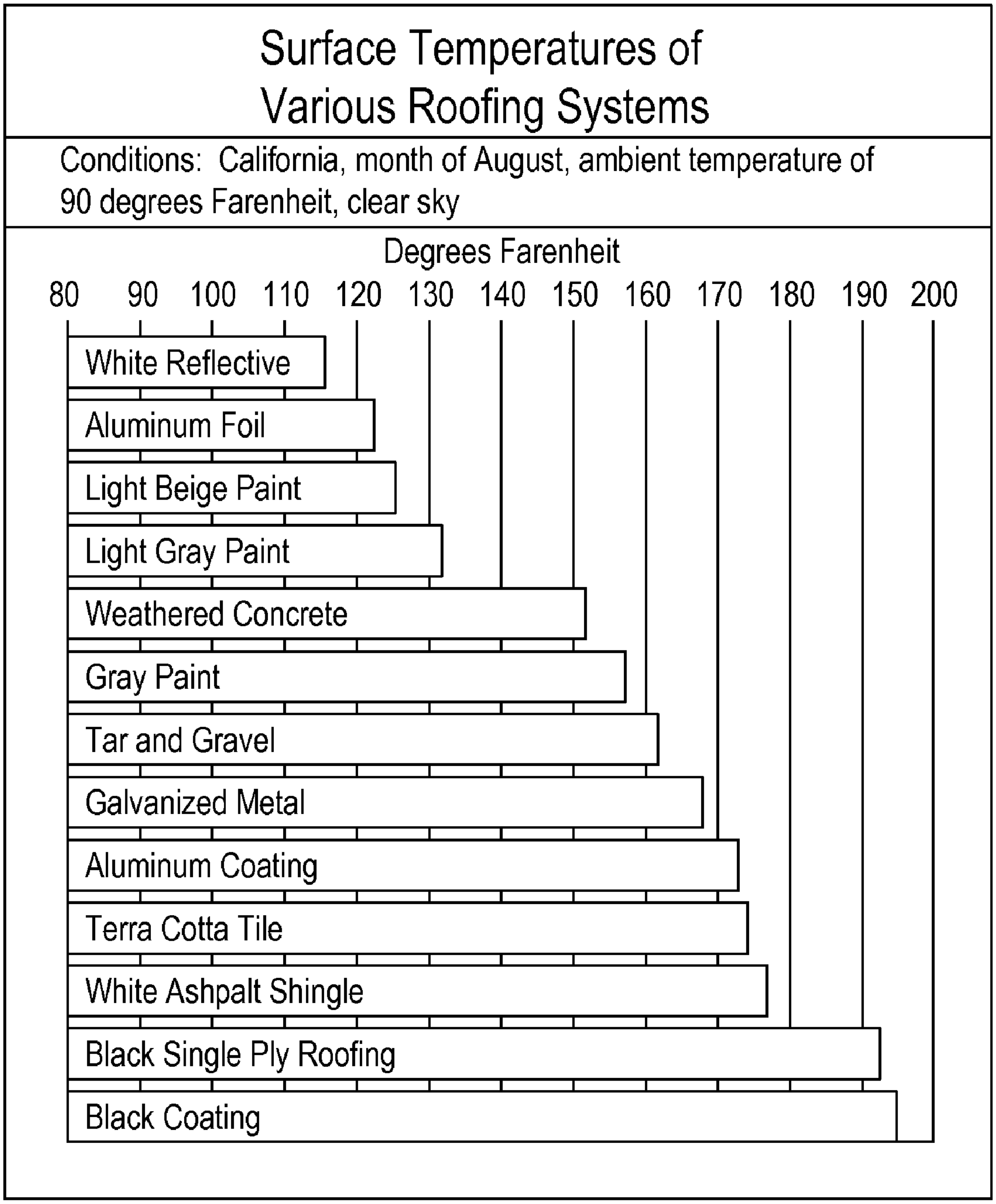
Surface Temperatures of
Various Roofing Systems
Conditions: California, month of August, ambient temperature of
90 degrees Farenheit, clear sky
Degrees Farenheit
80
90
100
110
120
130
140
150
160
170
180
190
200
White Reflective
Aluminum Foil
Light Beige Paint
Light Gray Paint
Weathered Concrete
Gray Paint
Tar and Gravel
Galvanized Metal
Aluminum Coating
Terra Cotta Tile
White Ashpalt Shingle
Black Single Ply Roofing
Black Coating

FIG. 7

COLOR CHANGING SYSTEM FOR STRUCTURES AND METHOD THEREFOR

BACKGROUND OF THE INVENTION

[0001] This invention relates generally to waterproof coating systems, and more particularly to a coating system that changes color in response to ambient temperature changes to assist in the heating or cooling of underlying structures as well as ascertaining defects in the underlying structures.

[0002] Exterior coatings are exposed to the vicissitudes of weather from the very moment they are applied to protect an exterior surface. Water-based coatings are favored over solvent borne coatings for a number of well known reasons. They offer ease of application, reduced toxic solvent emission, lower raw material and application costs, and easy cleanup of site and equipment.

[0003] In more recent years, white water-based coatings have become extremely popular and in some areas are required due to their ability to protect a roof against excessive temperatures by reflecting solar radiation, to thereby significantly reduce cooling costs of the underlying building. The temperature of the roof surface is dependent on its ability to reflect solar energy (solar reflectance), absorb solar energy (solar absorbance) and to release absorbed energy in the form of infrared radiation (emissivity). The peak surface temperature of the roof strongly depends on the peak solar radiation and the solar reflectance of the surface, and the ability to remove heat from the roof depends on its emissivity. On a sunny day in August in California, with an ambient temperature of 90° as shown in FIG. **7**, a black roof surface (solar reflectance less than 0.1) may reach peak temperatures exceeding 190° F. (88° C.). Under the same conditions, a highly reflective white roof surface (solar reflectance greater than 0.8) could be less than 120° F. (49° C.). Other roofing surfaces, such as tar and gravel, aluminum coatings and white asphalt shingles, exhibit higher temperatures under the same conditions. In tests conducted by the Lawrence Berkeley National Laboratory and other energy-conscious organizations, it has been determined that white reflective roof coatings can save up to 50% or more in energy costs. These savings become especially significant with large building structures such as manufacturing facilities, warehouses, malls, supermarkets, and so on.

[0004] Although white reflective roof coatings are ideal for summer conditions, they also block much desired solar radiation during cooler periods. In some areas, relatively hot daytime temperatures are replaced by relatively cool night-time temperatures. Although it may be desirous to seasonably or even daily replace the roof surface from reflective white to absorptive black depending on the ambient temperature, such a practice would be impractical to implement and extremely expensive.

[0005] In an effort to provide a color-changing roof surface, U.S. Pat. No. 6,500,555 to Khaldi and Japanese Laid-Open Application No. 08-226211 to Sumiko disclose laminates of thermochromic material that can be adhered to the roof of a building. Such laminates become light in color to stop absorption of solar heat as the temperature rises and become dark in color to absorb more solar heat as the temperature falls. However, the inelastic nature of such laminates (the Khaldi patent for example discloses an aluminum foil base) do not lend well to large roof areas where expansion and contraction of the underlying structure due to extreme temperature fluctuations, wind or other weather conditions may occur. In addition, the provision of separate laminates are not only difficult to store, transport and lift to the roof surface, they also must be manually installed with roof-penetrating mechanical fasteners and/or adhesives and joined together at their seams through appropriate sealers, thus increasing the amount of material, time and labor for installing such laminates. Such systems are also prone to leakage and separation, especially during extreme weather conditions. It would therefore be desirable to provide a seamless, stretchable color changing membrane that can be directly applied to the roof surface, including any pre-existing roof materials and roof-related equipment or features, without the use of mechanical fasteners, adhesives or joints.

[0006] Another challenge associated with thermochromic materials is their normally quick deterioration when exposed to ultraviolet (UV) rays. Although a clear top layer would be desirable to maximize the effectiveness of the lower thermochromic layer, many materials with UV blocking or absorbing additives are unfortunately too opaque to allow effective use of the thermochromic layer.

[0007] In order to further minimize costs for heating and cooling buildings or other structures, an infrared scanner can be used to determine underlying areas where moisture may accumulate, since such areas are typically at a lower temperature than the surrounding roof surface, as well as areas of missing or inadequate insulation. However, such scanners can be expensive, have a limited field of view, and require significant labor to operate, especially over large area roofs on manufacturing buildings or the like. It would therefore be desirable to readily detect, without the aid of infrared scanners or the like, one or more defects in an underlying structure.

BRIEF SUMMARY OF THE INVENTION

[0008] According to one aspect of the invention, a method of passively heating or cooling an underlying structure includes applying a solar reflective base layer over the underlying structure to form a first seamless membrane; applying a color changing layer over the base layer to form a second seamless membrane that is contiguous with the first seamless membrane, the color changing layer having a clear state above a first transition temperature and an opaque state below a second transition temperature; reflecting radiant energy from the base layer by exposing the color changing layer to a temperature above the first transition temperature to thereby prevent absorption of heat into the underlying structure; and absorbing radiant energy into the base layer by exposing the color changing layer to a temperature below the second transition temperature to thereby heat the underlying structure.

[0009] According to a further aspect of the invention, a coating system for assisting in the heating or cooling of an underlying structure includes a first seamless, elastic membrane comprising a solar reflective material and a second seamless, elastic membrane that is contiguous with the first membrane. The second membrane has a color changing material with a clear state above a first transition temperature to thereby permit transmission of solar radiation to the first membrane and an opaque state below a second transition temperature to thereby absorb radiant energy.

[0010] According to yet a further aspect of the invention, a method of detecting defects in a structure includes applying a layer of thermochromic material to the structure; observing a localized area of non-uniform color associated with the thermochromic layer; and ascertaining whether a defect is associated with the localized area.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The foregoing summary as well as the following detailed description of the preferred embodiments of the present invention will be best understood when considered in conjunction with the accompanying drawings, wherein like designations denote like elements throughout the drawings, and wherein:

[0012] FIG. **1** is a perspective view of a coating system applied to a structure in accordance with the present invention;

[0013] FIG. **2** is a flow chart illustrating a method of ascertaining defects in the underlying structure;

[0014] FIG. **3** is a perspective view of a building and defect-free roof structure with the applied coating system showing reflection of solar radiation from the roof structure above a first temperature with no roofing defects;

[0015] FIG. **4** is a perspective view of a building and defect-free roof structure with the applied coating system showing absorption of solar radiation into the roof structure below the first temperature;

[0016] FIG. **5** is a perspective view of the building and roof structure with the applied coating system revealing defects above the first temperature;

[0017] FIG. **6** is a perspective view of the building and roof structure with the applied coating system below the first temperature; and

[0018] FIG. **7** is a chart showing surface temperatures of various roofing systems during a hot summer day in California.

[0019] It is noted that the drawings are not necessarily to scale and are only intended to depict typical embodiments of the invention. Accordingly, the drawings should not be considered as limiting the scope of the invention. The invention will now be described in greater detail with reference to the accompanying drawings.

DETAILED DESCRIPTION OF THE INVENTION

[0020] Referring to the drawings, and to FIG. **1** in particular, a coating system **10** in accordance with the present invention for application to an underlying structure **12** is illustrated. By way of example, the underlying structure **12** may include a panel **15** supported by beams **17** as used in many roof and wall constructions. The structure **12** may alternatively be constructed of a wide variety of different building materials architectural features, styles or configurations. When the panel **15** forms part of a roof structure, it may be bare, covered with shingles, gravel, waterproof coatings, laminates, or any other well-known roofing materials. The coating system **10** preferably includes a base layer **14** applied over the panel **15** and any pre-existing panel structures, a color changing layer **16** contiguous with the base layer **14**, and a protective layer **18** contiguous with the color changing layer **16**.

[0021] The base layer **14** preferably comprises a thermally insulative flexible material such as a water-based acrylic elastomer with a relatively high solar reflectivity value and a relatively high heat emittance value for maximum effectiveness. The high solar reflectivity value may be obtained by adding metal oxides to the acrylic elastomer. Preferably, the base layer material is substantially white in color to maximize solar reflectivity. However, it will be understood that the base layer may be of any other color and/or shade with varying degrees of effectiveness. The base layer is also preferably formulated to have a high elasticity to accommodate expansion and contraction of the underlying structure, laminates, coatings and other materials through extreme hot and cold temperature cycles. A suitable single component material with the above-described features is supplied by Neptune Coatings Corp. of Grass Valley, Calif. under the trademark Reflex®. Such a material may be cured at room temperature and is capable of reflecting over 90% of impinging solar radiation when provided in white or beige colors and up to about 50% when provided in darker colors.

[0022] It will be understood that a wide variety of different colors, tints, shades, materials, metal oxides and/or other heat reflecting additives may be used for the base layer **14**. By way of example, and without limitation, water-based or oil-based single or two-part polymers such as epoxies, polyurethanes, silicones, styrene butadiene, polyvinyl acetate, bituminous or polymer-modified bituminous materials, and so on, containing aluminum pigments, ceramic nano-particles, glass, ceramic or polymeric micro-spheres, extender pigments with low conductivity such as calcined clay, radiation reflective metal oxides such as red iron oxide, titanium oxide or silver oxide, various combinations thereof, as well as any other material or combination of materials and additives that assist in reflecting the sun's radiant energy and/or emitting absorbed energy from the base layer **14**.

[0023] The color changing layer **16** preferably comprises a flexible thermochromic material that is located between the source of solar radiation and the base layer **14**. The color changing layer **16** preferably changes color between a substantially clear (translucent or transparent) condition over a predetermined temperature range to thereby passively expose the base layer **14** to solar radiation above a first transition temperature, and an opaque condition at a second transition temperature below the first transition temperature to thereby passively conceal the base layer **14** below the second transition temperature. Depending on the particular formulation of the thermochromic material, it is contemplated that the first and second transition temperatures may be substantially equal. When the base layer **14** is constructed of an acrylic elastomer, the color changing layer **16** preferably comprises a thermochromic ink, such as a micro-encapsulated leuco dye material, in a clear polyvinyl acrylic emulsion polymer. For maximum effectiveness, the color changing layer **16** is preferably substantially black in color below the first temperature and substantially clear above the second temperature so that effective heating and cooling of the structure **12** can be enhanced. As with the base layer **14**, the color changing layer **16** is also preferably formulated to have a high elasticity to accommodate expansion and contraction of the underlying structure, laminates, coatings and other materials through extreme hot and cold temperature cycles.

[0024] By way of example only, when the temperature of the ambient air and/or structure **12** is above approximately 66° F. (19° C.), the layer **16** is substantially clear to expose the base layer **14** to the sun's radiant energy. Likewise, when the temperature of the ambient air and/or structure **12** is below about 52° F. (11° C.), for example, the layer **16** is substantially opaque to absorb the sun's radiant energy. It will be understood that the color changing layer **16** can be formulated for other temperature ranges, such as between 68° F. and 84° F., 72° F. and 88° F., and so on, and/or for shorter or longer temperature ranges, since the ideal temperature or temperature range for one location may be different than the ideal temperature or temperature range for another location due to local seasonal conditions and variations.

[0025] It will be further understood that the color changing layer may be constructed of a wide variety of different formulations and colors. For example, different coating products such as lacquers, enamels, epoxies, acrylics, latexes, polyurethanes, silicones, and so on, may be combined with different colored thermochromic materials such as blue, red, green, brown, orange, and so on, and/or different thermochromic formulations such as micro-encapsulated leuco dye systems, liquid crystals in the nematic mesophase, phase shifting semiconductor materials such as Vanadium dioxide that selectively block or conduct radiation in the infrared range at a predetermined phase change temperature, as well as other phase shifting materials and the like.

[0026] The protective layer **18** preferably comprises a two component, solvent based, high solids fluorinated polyurethane (FPU) material composed of closely packed trifluoromethyl groups, with a 2:1 ratio of base to activator. Preferably, the protective layer **18** is clear so that solar radiation will reach the color changing layer **16**. The FPU material prevents the transmission of UV radiation to the color changing layer **16** and protects the color changing layer against UV degradation, moisture, oxygen permeation, weathering, and other degrading environmental conditions to thereby prolong the useful life of the color changing layer. The FPU material also exhibits a lower surface energy than Polytetrafluoroethylene (PTFE) at about 6 MJ/m^2 for easy cleaning and maintenance, as well as hydrophobic and oleophobic properties to shed water, oils and other contaminants that may be present on its surface.

[0027] It will be understood that the protective layer **18** may be constructed of a wide variety of different materials such as lacquers, enamels, epoxies, acrylics, latex, silicones, and so on, with well-known additives for blocking UV radiation and protecting the color changing layer from direct exposure to environmental conditions.

[0028] Referring now to FIGS. **3** and **4**, and by way of example, the coating system **10** is applied to the roof **22** of a building **20**. The roof **22** may include a safety rim **24**, skylights **26**, HVAC units **28** and **30**, vent pipes (not shown), as well as other well-known devices and accessories that may be mounted on and/or extend through the roof. When the color changing layer **16** is above a first transition temperature, it will be substantially clear to expose the base layer **14** to the sun's radiant energy so that a substantial amount of the radiant energy can be reflected away from the building **20** by the base layer **14**, as shown by arrows **32** in FIG. **2**, to thereby reduce the building's cooling requirements.

[0029] Likewise, when the color changing layer **16** is below a second transition temperature lower than the first transition temperature (depending on the particular thermochromic formulation), it will be substantially opaque so that a substantial amount of radiant energy is absorbed by the layer **16**, as shown by arrows **34** in FIG. **3**. The absorbed radiant energy is transformed into heat energy and will heat the base layer **14** and building **20** first by thermal conduction through the roof structure, such as the panel **15** (FIG. **1**) or other structure, independent of the reflective properties of the base layer **14** to thereby reduce the building's heating requirements. Between the first and second transition temperatures, varying degrees of absorption/reflection will occur as the color changing layer **16** will have varying degrees of clearness, e.g. opacity, translucency or transparency.

[0030] Referring now to FIGS. **1** and **4**, a method **40** of applying the coating system **10** to an underlying surface or panel **15** of the structure **12** (FIG. **1**) and using the coating system **10** for modifying the structure **12** in accordance with the invention is illustrated. As shown at block **42**, the underlying structure **12**, such as the panel **15** and any device or feature located on or extending through the panel, may be prepared for receiving the coating system **10** through different techniques, depending on the type and age of the structure. For example, an older roof structure may require power washing to reduce or eliminate debris and other contaminants that may be present. Depending on the condition of existing roofing materials or the absence of such materials on old or new roof structures, a foundation layer or coating may be applied to the panel and any preexisting roofing materials, features and protuberances. Preferably, the foundation layer is a two-part water-based coating that is substantially immediately cured upon application to the surface of the structure. Such a coating is supplied by Neptune Coatings Corp. of Grass Valley, Calif. under the trademark WetSuit®, and is disclosed in my copending U.S. patent application Ser. No. 11/307,551, the disclosure of which is hereby incorporated by reference.

[0031] Once the underlying surface has been properly prepared, the base layer **14** is applied over the surface as shown at block **44**, preferably through the use of high pressure, airless spray equipment capable of supplying at least one-half gallon per minute (GPM) of the base layer material. Preferably, the thickness of the cured base layer is in the range of about 10 mils to about 40 mils, and more preferably about 20 mils. It will be understood that the base layer **14** can alternatively be applied using brushes, rollers, conventional air atomization equipment, high velocity low pressure (HVLP) systems, and so on. In some instances, it may be desirable to apply two or more coats to build up to the desired layer thickness. Application of the base layer **14** using one or more of the above-described techniques creates a seamless, flexible, highly elastic, weather impenetrable and heat reflective first membrane that eliminates the problems associated with rolled laminates or other roofing systems.

[0032] When the base layer **14** has sufficiently cured, the color changing layer **16** is applied over the base layer as shown at block **46**, preferably through the use of high pressure, airless spray equipment capable of supplying at least one-half GPM. When the atmospheric and/or base layer temperature is above the clear transition temperature, the thermochromic material is preferably cooled through a refrigerated holding tank and insulated delivery hoses (not shown) so that the material can be seen as it is applied over the base layer **14**. In this manner, uniform application of the color changing layer **16** at temperatures above the clear transition temperature can be verified. The thickness of the cured color changing layer is in the range of about 1 to 10 mils, and more preferably in the range of about 2-3 mils. It will be understood that the color changing layer **16** can alternatively be applied using brushes, rollers, conventional air atomization equipment, high velocity low pressure (HVLP) systems, and so on. Application of the color changing layer **14** using one or more of the above-described techniques creates a seamless, flexible, highly elastic, and heat responsive second membrane that eliminates the problems associated with rolled laminates or other roofing systems. When it has been determined that the existing roof structure has a radiant energy reflective surface in good condition, the color changing layer may be directly applied to the reflective surface without applying the base layer.

[0033] When the color changing layer **16** has sufficiently cured, the protective layer **18** is applied over the color changing layer as shown at block **48**. For high volume applications using the afore-mentioned two-component fluorinated polyurethane material, plural component airless spray equipment for mixing the base and activator at the correct ratio during application is preferred. Such a system can be pneumatically or hydraulically driven. The thickness of the cured protective layer **18** is preferably in the range of about two to ten mils, and more preferably about five mils. For low volume applications, the two components may be mixed together and applied over the color changing layer **16** by brush, roller, conventional atomized spray equipment, or HVLP equipment. Application of the protective layer **18** using one or more of the above-described techniques creates a seamless, flexible, highly elastic, weather impenetrable and heat reflective third membrane that eliminates the problems associated with rolled laminates or other roofing systems.

[0034] Once installed, the coating system **10** can be scanned or observed, as shown at block **50**, to determine whether there are localized color changes and thus underlying structural defects, as shown in FIGS. **5** and **6**. Such localized changes may be indicative of heat escaping from the structure due to missing or inadequate insulation and cooler areas of the structure due to the presence of water or moisture. By way of example, when the temperature of the roof **22** is above the transition temperature as shown in FIG. **5**, the white reflective coating of the base layer is exposed through the clear color changing layer. Any localized dark areas **52** of the color changing layer would tend to be cooler than the surrounding white areas and thus may reveal the presence of moisture, liquid or other defects.

[0035] Likewise, when the temperature of the roof is below the transition temperature as shown in FIG. **6**, the dark color changing layer hides the white reflective layer except at localized areas **54** that would tend to be warmer than the surrounding darker areas and thus may reveal missing or inadequate insulation allowing heat to escape from the building, improperly applied roofing materials, weak understructure, and other defects. In addition, application of the coating system **10** around vent stacks and other roof protrusions or openings provides both a water proof seal and gives indication of any breach or weakness at the interface of the roof structure and these protrusions.

[0036] When the base layer **14** is white and the color changing layer is black below the lower transition temperature, the combined layers may exhibit varying shades of gray to indicate varying degrees of structural defects. Since the localized color changes lie within the visible range of the electromagnetic spectrum, the roofing defects may be readily ascertained by the naked eye without relying on the expensive and time consuming thermal imaging equipment of the prior art.

[0037] Accordingly, it is determined at decision block **56** (FIG. **4**) whether localized color changes have been detected. If one or more localized areas of different color have not been detected, it can be assumed that the underlying structure is free of defects and the roof **22** can be observed again to determine whether new defects may have occurred since the last observation time. However, if one or more localized areas of different color have been detected, the nature of the structural defect is determined at block **58** and appropriate repairs are made as shown at block **60**. Subsequently, the roof **22** can be observed again to determine whether the defects have been properly repaired as well as to locate new defects that may have occurred since the last observation time.

[0038] The coating system **10** of the present invention can thus be advantageously applied as a seamless monolithic membrane over the entire area of a roof, wall or other structure, including structure protuberances, accessories or fixtures that must be sealed to the structure against moisture and other environmental conditions, in a quick and efficient manner without the time consuming, labor intensive, and error prone installation of prior art laminate materials, including the inherently weak seam interface between laminate strips.

[0039] It will be understood that the terms "opaque", "translucent", "transparent" and "clear" as used throughout the specification denote relative, rather than absolute conditions. By way of example, when the color changing layer is "clear" or "transparent", it may allow the transmission of certain wavelengths while inhibiting the transmission of other wavelengths through the layer. Thus, a transparent material may be transparent to certain wavelengths and yet opaque to other wavelengths. In addition, the terms "translucent", "transparent" and "clear" may refer to a colorless condition or a colored condition different from the "opaque" color condition. It will be further understood that the term "preferably" as used throughout the specification refers to one or more exemplary embodiments of the invention and therefore is not to be interpreted in any limiting sense. Also, it will be understood that the term "contiguous" and its various derivatives as may be used throughout the specification refer to components that may be joined together either directly or through one or more intermediate members. Accordingly, intermediate layers of material may be located between or on at least one side of one or more of the layers **14**, **16** and **18** and/or between the underlying structure **12** and the layer **14**. Accordingly, it is not necessary that the structure **12** and layers **14**, **16**, and **18** be in immediate contact with each other to reap the benefits of the present invention.

[0040] It will be appreciated by those skilled in the art that changes could be made to the embodiments described above without departing from the broad inventive concept thereof. For example, although the color changing system of the present invention has been shown and described for use with structures such as walls and roofs of buildings, it will be understood that the system of the invention can be used with other enclosed spaces such as vehicles, trailers, temperature-controlled enclosures, and so on. It will be further understood that the base layer, color changing layer and protective layer, if used, can be formed as single ply roofing membranes during the manufacturing process and installed separately on roof structures or the like. It will be understood, therefore, that this invention is not limited to the particular embodiments disclosed, but is intended to cover modifications within the spirit and scope of the present invention as defined by the appended claims.

I/We claim:

1. A method of passively heating or cooling an underlying structure, the method comprising:

applying a base layer over the underlying structure to form a first seamless membrane, the base layer being adapted to reflect solar radiation;

applying a color changing layer over the base layer to form a second seamless membrane that is contiguous with the first seamless membrane, the color changing layer having a clear state above a first transition temperature and an opaque state below a second transition temperature;

reflecting radiant energy from the base layer by exposing the color changing layer to a temperature above the first transition temperature to thereby prevent absorption of heat into the underlying structure; and

absorbing radiant energy into the base layer by exposing the color changing layer to a temperature below the second transition temperature to thereby heat the underlying structure.

2. A method according to claim **1** and further comprising applying a clear protective layer over the color changing layer to form a third seamless membrane that is contiguous with the second seamless membrane.

3. A method according to claim **2**, wherein the base layer, color changing layer and protective layer are applied by spraying.

4. A method according to claim **3**, wherein the base layer has a thickness in the range of approximately 10 to 40 mils and the color changing layer has a thickness in the range of approximately one to ten mils and the protective layer has a thickness in the range of approximately two to ten mils.

5. A method according to claim **2**, wherein the protective layer comprises a fluorinated polyurethane material.

6. A method according to claim **1**, wherein the base layer and color changing layer are applied by spraying.

7. A method according to claim **1**, and further comprising applying a seamless foundation layer before applying the base layer, the seamless foundation layer comprising a two-part water-based coating that is substantially immediately cured upon application to the underlying structure.

8. A coating system for assisting in the heating or cooling of an underlying structure, the coating system comprising:

a first seamless, elastic membrane comprising a solar reflective material;

a second seamless, elastic membrane contiguous with the first membrane, the second membrane comprising a color changing material with a clear state above a first transition temperature to thereby permit transmission of solar radiation to the first membrane and an opaque state below a second transition temperature to thereby absorb radiant energy.

9. A coating system according to claim **8**, and further comprising a third seamless, flexible membrane contiguous with the second membrane, the third membrane being resistant to weathering.

10. A coating system according to claim **9**, wherein the third membrane is transparent.

11. A coating system according to claim **10**, wherein the third membrane is elastic.

12. A coating system according to claim **10**, wherein the protective layer comprises a fluorinated polyurethane material.

13. A coating system according to claim **9**, wherein the first membrane has a thickness in the range of approximately 10 to 40 mils and the second membrane has a thickness in the range of approximately one to ten mils and the third membrane has a thickness in the range of approximately two to ten mils.

14. A coating system according to claim **13**, wherein the second membrane has a thickness of approximately two mils.

15. A coating system according to claim **8**, and further comprising a fourth seamless, elastic membrane contiguous with the first membrane opposite the second membrane, the fourth membrane including a two-part water-based coating that is substantially immediately cured upon application to the underlying structure.

16. A method of detecting defects in a structure, comprising:

applying a layer of thermochromic material to the structure;

observing a localized area of non-uniform color associated with the thermochromic layer; and

ascertaining whether a defect is associated with the localized area.

17. A method according to claim **16**, and further comprising repairing the detected defect.

18. A method according to claim **16**, and further comprising:

applying a base layer of reflective material between the structure and the thermochromic layer.

19. A method according to claim **18**, wherein the thermochromic layer is substantially clear above a first transition temperature and substantially opaque below a second transition temperature.

20. A method according to claim **19**, and further comprising applying a protective layer to the thermochromic layer to thereby protect the thermochromic layer from weathering.

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