US 20120017521A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2012/0017521 A1

(43) Pub. Date: Jan. 26, 2012

Botke

(54) VARIABLE PERFORMANCE BUILDING CLADDING ACCORDING TO VIEW ANGLE

(76) Inventor: Matthew Murray Botke, Moorpark, CA (US)

(21) Appl. No.: 13/136,252

(22) Filed: Jul. 25, 2011

Related U.S. Application Data

(60) Provisional application No. 61/367,477, filed on Jul. 26, 2010.

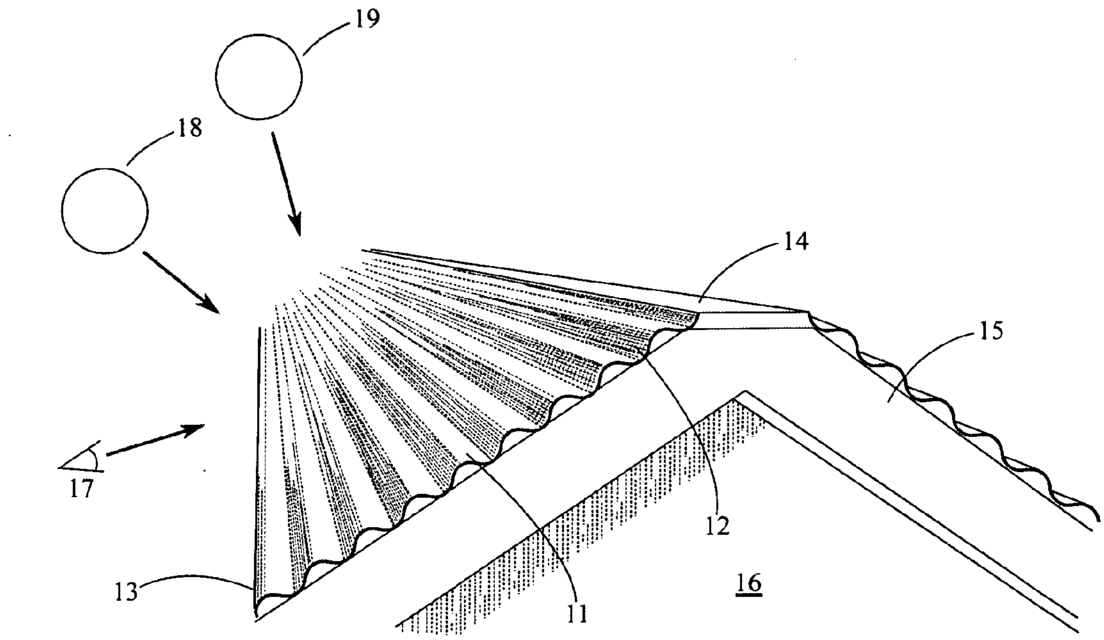
Publication Classification

(51) Int. Cl.
E04B 7/02 (2006.01)

(52) U.S. Cl. 52/90.1

(57) ABSTRACT

This invention relates to inclined outer building surfaces such as roofs reflectively responsive to sun elevation angle and predominantly ornamental when viewed from common viewing positions. More specifically, this invention relates to methods of sizing, shaping, surface characteristics, and coating resulting in improved performance, increased ornamental quality, improved economy of roofing of this class using human eye contrast sensitivity and visual perception.



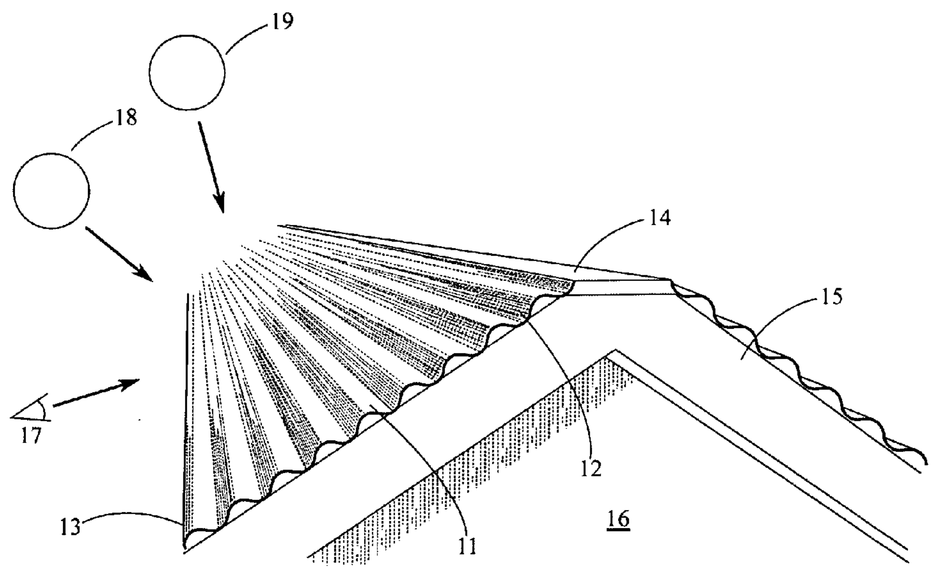


FIG. 1

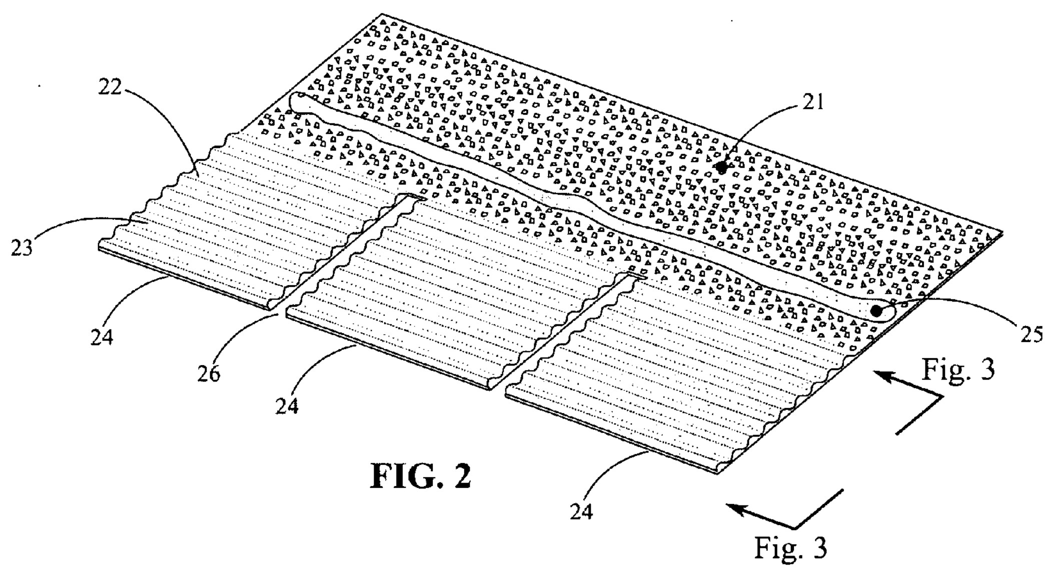


FIG. 2

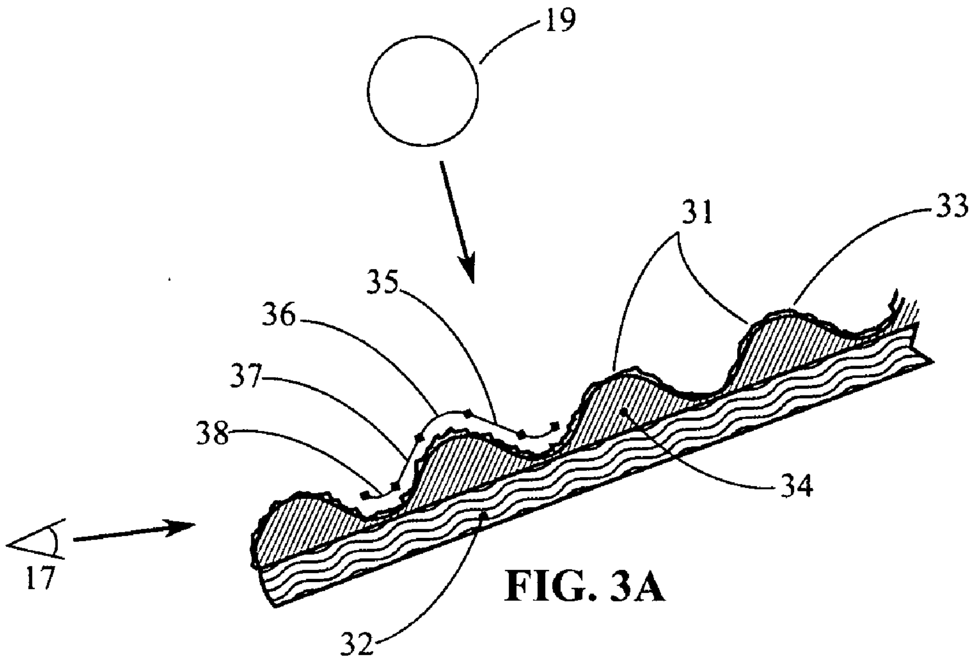


FIG. 3A

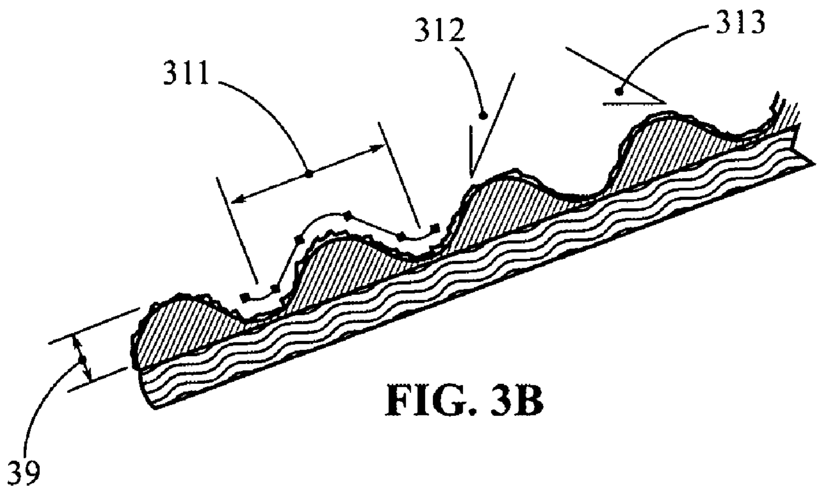


FIG. 3B

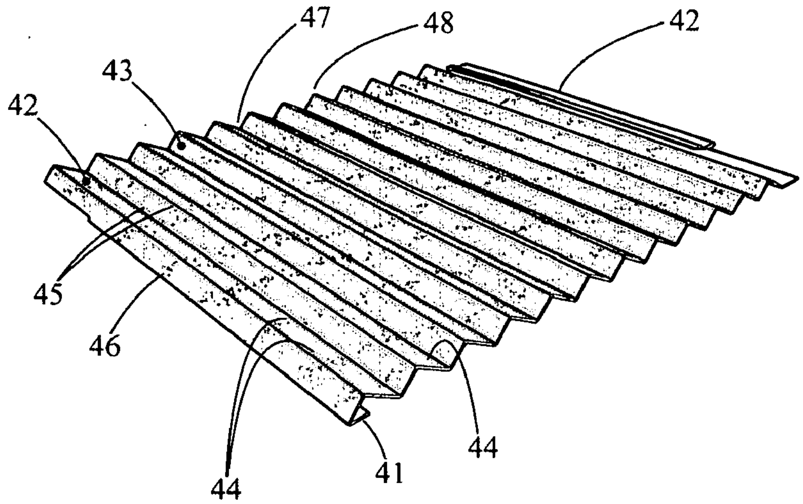


FIG. 4

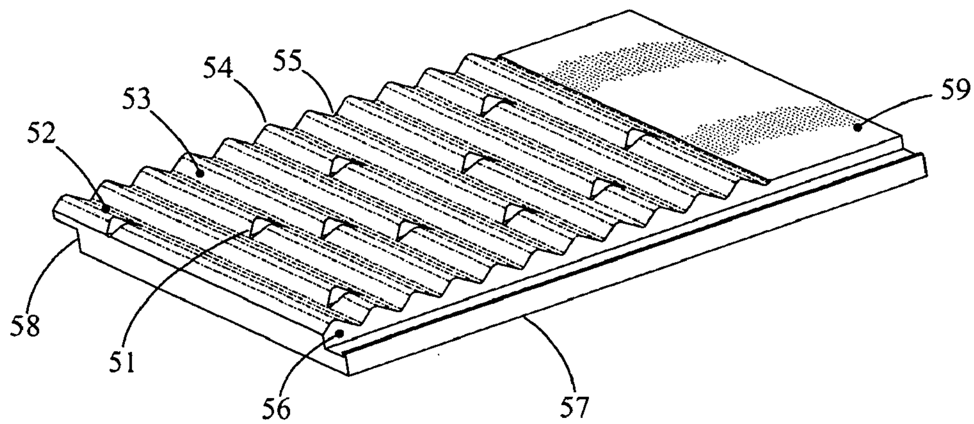


FIG. 5

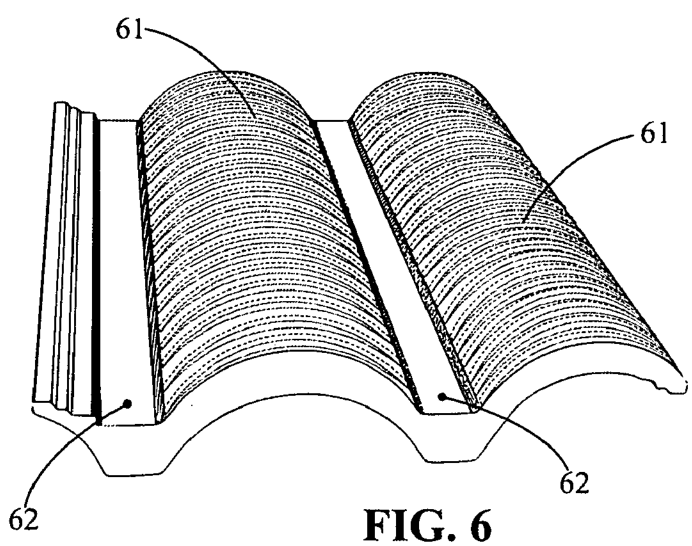


FIG. 6

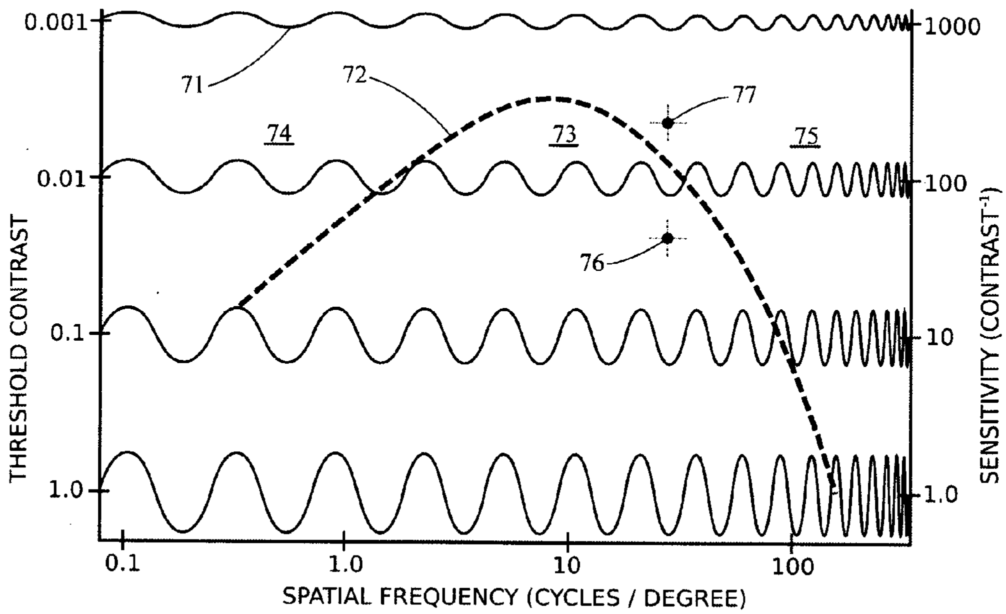

0.001
0.01
0.1
1.0
THRESHOLD CONTRAST
1000
100
10
1.0
SENSITIVITY (CONTRAST-1)
0.1
1.0
10
100
SPATIAL FREQUENCY (CYCLES / DEGREE)
71
72
74
73
75
76
77

FIG. 7

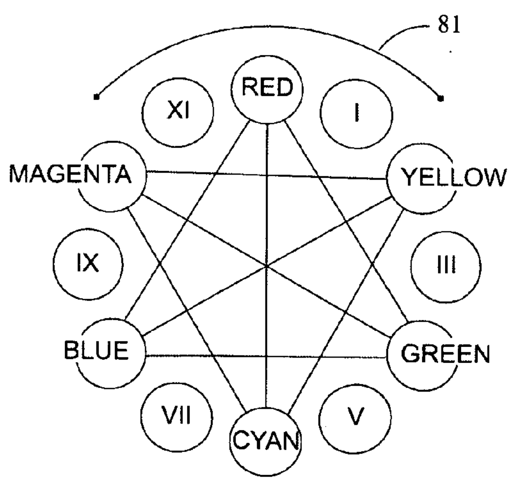
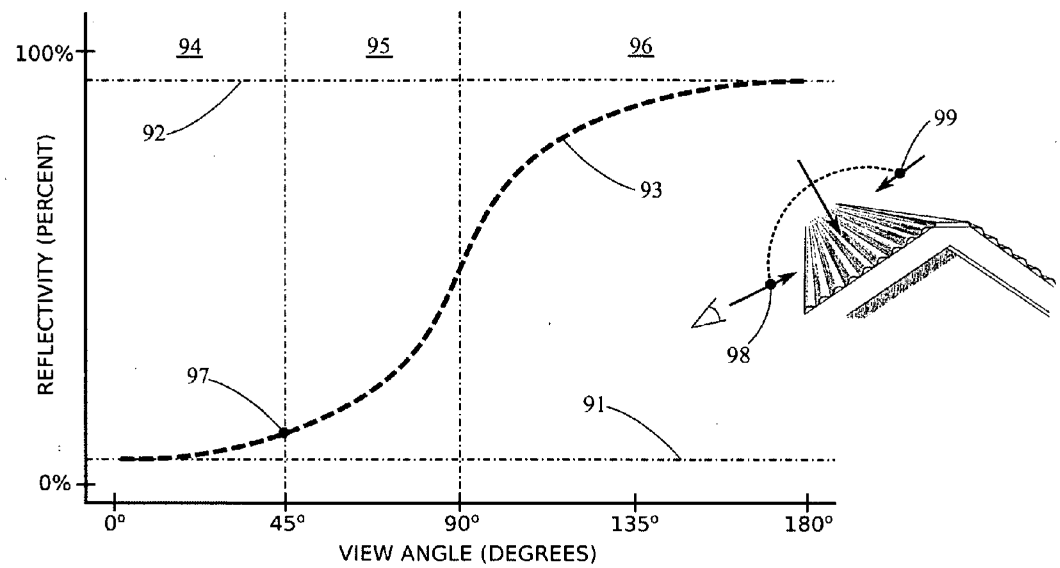

81
RED
I
YELLOW
III
GREEN
V
CYAN
VII
BLUE
IX
MAGENTA
XI

FIG. 8



100%
0%
REFLECTIVITY (PERCENT)
94
95
96
92
93
99
98
97
91
0°
45°
90°
135°
180°
VIEW ANGLE (DEGREES)

FIG. 9

VARIABLE PERFORMANCE BUILDING CLADDING ACCORDING TO VIEW ANGLE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 61/367,477 filed on Jul. 26, 2010.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable

THE NAMES OF THE PARTIES TO A JOINT RESEARCH AGREEMENT

[0003] Not Applicable

REFERENCE TO SEQUENCE LISTING, A TABLE OR A COMPUTER PROGRAM LISTING COMPACT DISC APPENDIX

[0004] Not Applicable

BACKGROUND OF THE INVENTION

[0005] Heat energy transfer through the building envelope changes the temperature of the interior space and can therefore become uncomfortable. Energy must be expended to maintain the desired temperature if this space is conditioned in order to offset energy transfer to or from the environment. Therefore, minimal energy transfer across the envelope is desirable. The rate of energy transfer across the building envelope becomes significant when large temperature differences exist between the ambient environment and the interior space. A primary source of heat energy loading on the envelope is due to the absorption of direct solar radiation. Characteristics by which the outer surface interacts with incident solar radiation have significant affect on the heat transfer between the interior space and the outside environment. Traditionally, the energy required to cool a conditioned space is more expensive than the equivalent energy required for heating the same space due to the type of energy required for each application. Therefore, buildings located in regions with hot summers benefit from methods to reject solar heat gain.

[0006] Elevation and azimuth sun angles vary according to date, time, and the latitude on the earth from which the angles are measured. Daily peak heating occurs in the hours surrounding solar noon when the elevation angle of the sun is at or near the daily maximum. Yearly peak heating occurs at summer solstice when solar noon sun elevation angle reaches annual maximum. For example, during summer solstice at 34-deg N latitude, the sun elevation angle remains above 40-deg for over seven hours. By comparison, during winter solstice the sun reaches a maximum of only approximately 35-deg elevation angle at solar noon. Energy used to cool a conditioned space in the summer most often reaches a maximum in the early afternoon as a result of the energy absorbed into the active thermal mass of the envelope throughout the day and especially during the solar noon hours.

[0007] Energy transfer across the building envelope is affected by the outer building surface properties. Some relevant properties are;

[0008] a. reflectivity, which herein describes the non-wavelength dependent total fraction of incident solar radiation reflected and is measured on a scale of 0 to 1, whereas 1 is a perfect reflector, and

[0009] b. absorptivity, which herein describes the non-wavelength dependent fraction of incident solar radiation absorbed and is measured on a scale of 0 to 1, whereas 1 is a perfect absorber, and

[0010] c. emissivity, which herein describes the non-wavelength dependent effectiveness of emitting or radiating absorbed energy to the surroundings for a given temperature difference between the cladding and surroundings assuming optically thick materials and is measured on a scale of 0 to 1, whereas 1 is a perfect blackbody emitter, and

[0011] d. thermal capacitance per unit mass which herein describes the temperature rise of the materials for a given unit of energy input, and

[0012] e. thermal conductivity, which herein describes the time rate of heat energy conducted through materials and into or out of surroundings in physical contact, and

[0013] f. surface orientation and latitude with respect to the earth.

[0014] Absorbed heat energy raises the outer surface temperature of a building surface in proportion to thermal capacity and thermal mass of the material in thermal proximity. The absorbed energy is then typically transferred through conduction and radiation into the building substrate, re-radiated into the surroundings, and or transferred through convection to the air. Roofs comprised of low reflectivity and low emissivity surfaces exposed to solar radiation will reach a higher peak temperature compared to a similar roof with higher reflectivity and emissivity resulting in increased local air temperature. The effects of local air heating in regions with a high proportion of absorbing surfaces such as in developed areas is known as the Heat Island Effect. In the past, most high reflectivity building surfaces have been incorporated into flat roofs, which typically comprise a large area fraction exposed to the sun and are not commonly visible. These types of roofs are not limited by ornamental requirements and most often are white. Buildings with inclined roofs such as residential structures also typically benefit from high reflectivity. Since darker colors are preferred for visible roofs, high reflectivity roofing has not been widely adopted in residential buildings.

[0015] Building materials and coatings have been developed that selectively reflect in the near-infrared portion of the spectrum thereby preserving a traditional appearance while reflecting approximately 52% of the direct incident solar energy. This method is effective but limited in efficiency. The visible portion of the solar spectrum contains approximately 43% of the incident solar energy and significantly contributes to solar heat gain. Building performance is substantially improved when integrated with broad-spectrum reflective surfaces. Since roofs represent the largest exposed surface to the sun on low-rise buildings, reflective roofs have a large impact on energy use in conditioned interior spaces. Building surface incline angles vary from approximately flat to nearly vertical. Sloped roof incline angles are generally described as the ratio of vertical rise to 12 units of horizontal run. Steep slope roofing typically is classified as between 2:12 and 12:12. The majority of roofs are typically sloped at between 4:12 and 8:12. What is needed is a method of economically integrating broad-spectrum reflective surfaces into roofing applicable to a wide range of slope angles while preserving traditional appearance.

[0016] Visual perception is a combination of the performance of the human eye and the synthesis of the visual scene by the brain. The eye is able to resolve features as a function of contrast to surroundings and apparent feature size. This contrast sensitivity function is generally characterized as curve (**72**) shown in FIG. **7** plotted against contrast amplitude along the vertical axis and spatial frequency along the horizontal axis. Spatial frequency is the number of contrast cycles in one degree of subtended angle in the visual scene. Variations of both contrast amplitude and special frequency is illustrated as the several sine wave functions (**71**). The eye is typically able to resolve features along and under this curve and with increasing contrast as shown in region (**73**) and is typically unable to resolve features in regions (**74**) and (**75**). Visual sensitivity of the human eye reaches a maximum at about 4 to 10 cycles per degree of subtended angle in the visual field depending on lighting conditions with greater sensitivity associated with brighter lighting conditions. The eye can generally resolve features with the minimum contrast in this range of spatial frequency. Visual sensitivity for a given spatial frequency and contrast is lower for smoothly varying contrast such as a sine wave compared to abrupt contrast changes such as a square wave. Further, the sensitivity curve is not symmetrical around the maximum sensitivity and decreases more rapidly as spatial frequency increases. Therefore for a given contrast, visual sensitivity decreases more rapidly as feature sizes are reduced.

[0017] Achromatic contrast herein is the difference in luminance between any two points along the spectrum from black to white through all the shades of grey and can be measured on a scale of 0 to 1 where 1 is maximum contrast such as between white and black. Chromatic contrast herein generally relates to the contrast between colors as a function of hue, saturation, and luminance. FIG. **8** illustrates a color wheel in a Red-Green-Blue color model. Complimentary colors are considered to have high chromatic contrast amplitude and are located at diametrically opposed points on the color wheel. Analogous colors are located adjacent to each other on the color wheel as indicated by (**81**) and are considered to have lower contrast and therefore lower contrast sensitivity for a given spatial frequency. Traditional analogous colors used on a building surface are typically considered warm colors such as reds. Dark colored roofs are traditionally preferred and are also typically from the warm color group or black.

BRIEF SUMMARY OF THE INVENTION

[0018] Sloped roofs such as those typically found on residential buildings comprise a large fraction of the appearance of the building to users and also present a large exposed surface to the sun. Since the view factor of the roof presented to observers differs from the view factor to the sun essentially throughout the entire day, the roof can be configured to exhibit different properties for each such as reflectivity and apparent color. Sloped roof systems are viewed from below the elevation of the roof from a generally predictable locus of points, herein referred to as common viewing positions and is determined by the typical interaction of people with each particular building. Normal routes of ingress, egress, commonly accessible areas such as driveways, parking lots, and lawn areas, as well as views from proximal transit routes such as streets and sidewalks comprise normal viewing locations from which the roof of the building contributes to the overall aesthetics of the architecture. Generally, architectural aesthetics are most relevant when the observer is in close proximity to the building. More specifically, common viewing positions herein relates primarily to observers standing at ground level within about 60-meters from a building roof. Of course, the observer view of the roof will vary according to observer location relative to the roof surface, building height, and roof pitch. The view factor of the roof to the sun can be determined based on location upon the earth, roof surface orientation, date, and time of day.

[0019] This invention relates to inclined building surfaces such as sloped roofs passively reflective to incident solar radiation according to sun elevation angle having substantially traditional ornamental appearance when viewed from a wide range of common viewing positions and applicable to a wide range of building surface incline angles. A roof according to this invention utilizes treatments to achieve desirable reflectivity and emissivity characteristics while reducing contrast sensitivity and visual impact thereby resulting in a roof that has substantially improved performance, ornamental quality, and manufacturing economy.

[0020] FIG. **1** illustrates a pitched roof according to this invention comprised of predominantly sun-facing surfaces (**11**) and predominantly observer-facing surfaces (**12**), wherein predominantly is taken to mean the orientation of the larger fraction of that portion of the surface. These two sets of surfaces form surface features following the contour of the underlying roof extending generally parallel to the roof ridge (**14**) and repeating in the pitch direction from the fascia (**13**) to the ridge. Sun-facing surfaces comprise the larger fraction of the view factor of the roof to the sun at high sun elevation angles (**19**) such as at a sun elevation angle of about 30 degrees or higher. Observer-facing surfaces comprise the larger fraction of the view factor of the roof to observers at common viewing locations (**17**). The maximum view factor to the sun of substantially high elevation angle sun-facing surfaces increases as the sun elevation angle increases throughout the day and reaches the daily maximum at solar noon. The time rate of change of the view factor to the sun is a function of many parameters including; latitude, roof slope, date of the year, time of day, and surface profile according to this invention. A building surface such as a sloped roof according to the present invention comprising predominantly observer-facing ornamental, typically darker surfaces and high sun elevation angle sun-facing reflective surfaces will exhibit a sun elevation angle responsive composite reflectivity throughout the day with a maximum reflectivity generally at solar noon.

[0021] Aspects of this invention are presented by which predominantly sun-facing, predominantly observer-facing, and transitional interconnecting edge surfaces between sun-facing and observer-facing surfaces are sized, shaped, colored, coated, textured, distributed, and or oriented with respect to the visual perception of observers to achieve applicability to a wide range of building incline angles while maintaining desirable ornamental quality and incident solar energy reflectivity. An inclined building surface according to this invention will exhibit reflectivity to the sun according to incident angle and similarly an apparent visible ornamental view to observers at common viewing locations.

[0022] It is an object of the present invention that gradient contrast transitions are utilized to reduce the contrast sensitivity in the visual scene of observers between the predominantly observer-facing and predominantly sun-facing surfaces at a given surface profile wavelength.

[0023] These reductions are achieved by any combination of a variety of treatments applied in such a way as to lie within the low perception regions of FIG. 7 for an observer at a common viewing position. One method of achieving contrast sensitivity reduction is accomplished for example by printing smoothly gradient patterns, spray coating at an angle, or varying coating thickness at the edges of the coated surface. Another method of achieving contrast gradient is accomplished by smoothly varying the shape of transitional surfaces between sun-facing and observer-facing surfaces such as by relatively large, generally rounded interconnecting edge surfaces resulting in a dithered appearance along the pitch direction of the roof. It is also an aspect of the present invention that both apparent color, luminance, and or hue gradient as well as dithered edges may be combined resulting in gradual contrast transitions and therefore lower visual perception of predominantly sun-facing surfaces for a given surface profile wavelength.

[0024] It is another object of the present invention that contrast amplitude be reduced at a given surface profile wavelength resulting in desirable ornamental quality while still maintaining desirable incident solar energy reflectivity performance. Reduced contrast amplitude is accomplished for example by selecting a suitable apparent contrasting coating treatment for predominantly sun-facing surfaces compared to predominantly observer-facing surfaces. A suitably selected shade of gray coating for predominantly sun-facing surfaces provides perceptibly acceptable low contrast amplitude when compared to dark black predominantly observer-facing surfaces yet still provides increased reflectivity compared to a uniformly dark black roof. Analogous colors as a combination of hue and saturation of approximately equivalent luminance provide perceptibly acceptable contrast sensitivity between predominantly sun-facing and predominantly observer-facing surfaces as a result of lower contrast amplitude. It is also an aspect of the present invention that luminance, hue, and saturation in any combination are utilized to achieve suitably low contrast amplitude between predominantly sun-facing and predominantly observer-facing surfaces resulting in desirable ornamental quality and incident solar energy performance. It is a further aspect of this invention that surface finish such as gloss is also utilized to reduce the apparent contrast amplitude of a roof according to this invention for a given lighting condition. Therefore, a roof according to this invention with low contrast amplitude between sun-facing and observer-facing surfaces may be more economically manufactured at larger surface profile wavelength and still maintain acceptable ornamental quality, solar reflectivity performance, as well as wide building surface incline angle applicability.

[0025] It is a further object of this invention that texture be utilized to reduce contrast sensitivity and add visual variety resulting in increased ornamental quality of a roof reflectively responsive to sun elevation angle. Texture as it relates to physical surface roughness may be utilized in any size range relative to the wavelength of the generally repeating surface profile of a roof according to this invention. A preferred texture size range is from approximately less than 0.010 times the profile wavelength of predominantly sun-facing and surfaces to greater than 10 times the profile wavelength. A more preferred range of texture is from approximately 0.1 times the profile wavelength to 1.0 times the profile wavelength. Roofing granules, sputtered paint textures, and discontinuities in predominantly sun-facing and observer-facing surfaces are but a few examples of texture within the preferred size range.

[0026] It is yet a further object of this invention that patterns of features be utilized in any combination of visually perceptible artifacts such as contrast, color, physical feature characteristics, texture, and or surface finish that are arranged within a surface, on a surface, or extending across more than one surface in any combination of repeating or random spatial relationship to reduce contrast sensitivity of the repeating set of predominantly sun-facing and predominantly observer-facing surfaces. Features and patterns of features provide elements in the visual scene that add architectural interest, simulate natural materials, or provide greater relative visual significance resulting in a reduction of visual perception of the predominantly sun-facing surfaces.

[0027] It is even a further object of this invention that combinations of size, shape, color, surface finish, texture, distribution, and or orientation be used on inclined building surfaces substantially ornamental when viewed from common viewing positions and reflectively responsive to sun elevation angle resulting in desirable incident solar energy reflectivity performance. An example of reduced impact in the visual scene of predominantly sun-facing surfaces results in a generally uniform apparently lighter color than the color of the predominantly observer-facing surfaces alone when viewed from typical viewing positions. A roof according to this invention having perceptually visible delineation between predominantly sun-facing and predominantly observer-facing surfaces remains desirably ornamental by use of texture, pattern, color choice, and contrast gradient typically within an order of magnitude on the contrast sensitivity curve to visible delineation contrast and spatial frequency.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0028] FIG. 1 is a perspective view of a roof system according to this invention

[0029] FIG. 2 is a perspective view of a shingle according to the present invention.

[0030] FIG. 3A and FIG. 3B are sectional views of the shingle illustrated in FIG. 2.

[0031] FIG. 4 is a perspective view of a metal panel according to the present invention.

[0032] FIG. 5 is a perspective view of a flat tile according to the present invention.

[0033] FIG. 6 is a perspective view of an s-curve or Malibu tile according to the present invention.

[0034] FIG. 7 is a chart illustrating the contrast sensitivity function of the human eye.

[0035] FIG. 8 is a chart illustrating a color wheel using the Red-Green-Blue color model.

[0036] FIG. 9 is a chart illustrating a representative reflectivity curve as a function of observation angle according to this invention.

DETAILED DESCRITPION OF THE INVENTION

[0037] An inclined building outer surface reflectively responsive to sun elevation angle is disclosed having high ornamental quality over a wide range of common viewing positions and applicable to a wide range of incline angles. In embodiments according to the present invention, surfaces are adapted to appear with non-constant and perhaps continually varying contrast and or reflectivity across surfaces for a given surface profile wavelength based on the human eye contrast sensitivity function and visual perception. An inclined building outer surface according to this invention therefore has wide applicability to a large range of roof slopes thereby increasing cost-effectiveness, reducing visual impact of surface profiles, and simplifying installation while maintaining acceptable energy performance. Embodiments of the present invention are currently contemplated as tiles, panels, shingles, membranes, granulated roll roofing and other materials known to be suitable for use on inclined building surfaces including and especially materials used for sloped or pitched roofing.

[0038] Methods of accomplishing this invention during or after installation on a building are also contemplated. As but one example is a process by which physical features are embossed and then selectively spray coated resulting in a building surface responsive to sun elevation angle and ornamental when viewed from common viewing positions. Embodiments disclosed herein illustrate many of the various aspects of the invention and are not intended to be scope limiting to specified attributes such as feature sizes or ratios, coating selection, construction, materials and the like. Further, aspects disclosed may be combined in any way and not depart from this invention.

[0039] A first contemplated embodiment is illustrated in FIG. **2** as a tabbed asphalt shingle. Exposed regions of the shingle such as the tabs (**24**) have an exterior profile comprised of predominantly sun-facing surfaces (**22**) and predominantly observer-facing surfaces (**23**). Unexposed surfaces such as the top lap portion of a shingle (**21**) do not require surfaces according to this invention and may be of traditional design including a heat-activated adhesive asphalt strip (**25**). A partial side view of the shingle shown in FIG. **2** is illustrated in FIG. **3**. FIG. **3**A illustrates the typical components of an asphalt shingle according to this invention including an asphalt-saturated base material (**32**), stabilized asphalt weathering layer (**34**), and mineral or ceramic granules (**33**). A series of ridges (**31**) integral to the shingle comprise predominantly sun-facing surfaces (**35**), predominantly observer-facing surfaces (**37**), and interconnecting transitional edge surfaces (**36**) and (**38**). As but two examples of methods of forming the ridges are by embossing or roll forming the weathering asphalt and granulated layers at acceptable temperature and pressure. Transitional surfaces smoothly transition the exposed roof surface from predominantly sun-facing to predominantly observer-facing surfaces.

[0040] FIG. **3**B describes some of the relevant shape characteristics of a roof surface according to this invention. Surfaces exposed to the environment generally repeat along the pitch direction of the inclined building substrate at a profile wavelength (**311**) and amplitude (**39**).

[0041] Predominantly sun-facing (**35**) and predominantly observer-facing (**37**) surfaces are oriented at angles to the horizontal plane (**313**) and vertical plane (**312**) respectively. Predominantly sun-facing surface orientation with respect to the horizontal plane may be tilted for rain shedding either toward or away from the pitch direction of the roof. Reducing the amplitude and also generally proportionately the wavelength of the repeating set of surfaces results in a desirably reduced spatial frequency and therefore the visual perception of the surfaces when viewed from common viewing positions. A preferable range of repeating surface set size is within about the range small enough to be nearly imperceptible to observers at common viewing positions yet large enough for economical manufacture. Feature sizes greater than about 4-mm with rain shedding tilt angles away from the pitch direction of the roof generally require methods of precluding degrading amounts of water pooling and subsequent infiltration. Surface features smaller than about 4-mm and approaching the surface roughness of traditional roofing such as granulated roofing typically shed water acceptably well so as not to degrade the life of the building material. In all size ranges, the length of continuously extending surface ridges especially with predominantly sun-facing surfaces oriented with a tilt angle away from the pitch direction of the roof should be limited to provide the most expedient drainage method for high rates of precipitation. In order to achieve acceptable rain shedding and drainage, surface features such as discontinuities, notches, breaks, the distribution of surfaces, distribution of feature sizes, surface orientation, and surface texture may be utilized in any combination. FIG. **2** illustrates a discontinuity (**26**) in the surface features according to this invention.

[0042] Granulated asphalt roofing materials with a weathering layer of stabilized asphalt have a traditional range of layer thicknesses and distribution of granule sizes, which largely determine the range of amplitude and cycle wavelength resulting in acceptably well-formed surfaces according to this invention. Granulated surfaces at this range of amplitude and profile wavelength result in a textured surface with reduced contrast sensitivity by effectively increasing spatial frequency above or within acceptable proximity to curve (**72**). A preferred amplitude and cycle wavelength is within 1-mm to 8-mm. Even more preferable is an amplitude and cycle wavelength of about 2-mm and 4-mm respectively. Surface features within this size range result in a texture (**33**) including randomly distributed surface notches thereby further reducing contrast sensitivity and enhancing water shedding.

[0043] Another contemplated embodiment of the present invention is illustrated in FIG. **4** as a metal panel. Predominantly sun-facing (**42**), predominantly observer-facing (**43**), and transitional interconnecting edge surfaces (**47**) and (**48**) are formed in sheet metal. Coatings may be applied before and or after forming steps. Methods for assembling the panel into a contiguous weather resistant cladding such as a head-clip (**42**) and a lower tab (**41**) are well known. Similarly, horizontally adjacent panel joining methods are well known for cladding of this class such as by integral vertical side flanges for standing seam systems.

[0044] For either roof type, for a given profile wavelength and amplitude of generally repeating surface features according to this invention, contrast sensitivity is reduced by smoothly transitioning between surfaces of maximum contrast such as by gradients on sun-facing surfaces (**44**), observer-facing surfaces (**45**), and or on transitional interconnecting edge surfaces (**47**) and (**48**). Gradients are typically accomplished by varying luminance and or hue and saturation smoothly through one contrast cycle, which is equivalent to the repeating surface profile wavelength (**311**). Methods of accomplishing gradients include varying the coating opacity by varying coating thickness or dithering the coating edges. Contrast sensitivity is also reduced according to this invention for a given surface profile amplitude and wavelength by reducing the maximum contrast amplitude when viewed from common viewing positions Techniques, which may or not include smoothly varying gradients include applying the treatments to the sun facing and observer facing areas in analogous colors, with small luminance differential or both.

Contrast reduction techniques also include increasing spatial frequency by reducing surface profile amplitude and wavelength treatments to about or more preferably below the spatial resolution of observers at common viewing positions. Or any combination of techniques with and without smoothly varying gradients may be employed. It should be understood that the treatments and surface features disclosed are shown in embodiments but are amenable to any roofing system suitable for use as an inclined roof The aspects of the invention may be combined in any way and may also be effectively utilized individually. Particular combinations of techniques generally depend on manufacturing methods, materials, as well as roofing system design. Detailed examples are presented below. Multiple examples of roof types are shown, all of which as well as others not shown can benefit from the invention

[0045] For example, maximum contrast amplitude may be reduced by using a light gray coating instead of a bright white coating on predominantly sun-facing surfaces. Contrast amplitude using a bright white predominantly sun-facing surface compared to the desired ornamental appearance of predominantly observer-facing surface might be visually perceptible at a given spatial frequency such as at point (**76**) in FIG. **7**. A suitably light gray predominantly sun-facing surface results in an inclined building outer covering appearing significantly more uniform such as represented by point (**77**) in region (**75**) above the contrast threshold sensitivity curve.

[0046] Maximum contrast amplitude can also be reduced by selecting a coating of similar hue and saturation having increased luminance for predominantly sun-facing surfaces compared to predominantly observer-facing surfaces. Similar hue and saturation is preferable within about 45-degrees of arc on the color wheel in FIG. **8** from the hue and saturation of the predominantly observer-facing surfaces with which contrast amplitude is determined such as within arc segment (**81**) for Red.

[0047] Further, visual appearance can be varied within surfaces and across surfaces to establish visual impact and interest thereby reducing the relative visual perception and impact of transitions from predominantly sun-facing and predominantly observer-facing surfaces. Patterns may be comprised of any combination of visible artifacts such as aspects of color, texture, or surface finish. As but one example of accomplishing variable appearance on an inclined building surface according to this invention is by printing patterns (**46**) during the coating process or as a secondary process. Visual perceptible impact of surfaces and coatings according to this invention is more effectively reduced by incorporating patterns using visual contrast having spatial frequency similar to the surface profile wavelength. Patterns may be applied to predominantly observer-facing, predominantly sun-facing, transitional interconnecting surfaces or any combination of surfaces. Patterns that visually extend beyond individual surfaces have visual impact and reduce sensitivity to the generally regular periodicity of surface profiles according to this invention. Apparently random or pseudo random and or repeating patterns are utilized to reduce the visual impact of transitions between predominantly observer-facing and predominantly sun-facing surfaces in the scene of persons viewing the building surface from common viewing positions.

[0048] A third contemplated embodiment of the present invention is illustrated in FIG. **5** as a concrete or clay roof tile. Tiles are generally molded or extruded in various profiles. Methods and features for assembling the tile into a contiguous weather resistant cladding such as a gutter (**57**), side lap (**58**), and head lap (**59**) are well known. Predominantly sun-facing (**52**), predominantly observer-facing (**53**), and transitional interconnecting edge (**54**) and (**55**) surfaces have natural discontinuities for rain shedding at each side of the tile (**56**). Notches or grooves (**51**) in the face of the tile both enhance water shedding and provide visual impact thereby reducing visual sensitivity to surface profiles according to this invention.

[0049] Molded or extruded tiles are typically manufactured with integral color and then coated to inhibit water absorption and environmental fouling. According to the invention, predominantly sun-facing surfaces may be further coated with desirably reflective and emissive coatings. Suitable coatings such as epoxy or urethane paints with suitable pigment can be applied directly on the tile using conventional methods such as by spray coating. Predominantly observer-facing surfaces are suitably functional and acceptably ornamental as molded. Natural or enhanced color and texture variation further enhances ornamental appeal across the cladding. Increasing solar absorptivity of the predominantly observer-facing surfaces to preferably greater than 0.40 enhances wintertime solar gain.

[0050] A fourth contemplated embodiment of the present invention is illustrated in FIG. **6** as an S-shaped tile such as a Malibu tile. Surface features according to this invention are integrated into the tile surface (**61**) following the contours of the tile. Predominantly sun-facing and predominantly observer-facing surfaces of sufficiently small size and contrast amplitude remain sufficiently ornamental. Rain shedding is accommodated by smooth gutter surfaces (**62**) between contours resulting in discontinuities that enhance drainage.

[0051] FIG. **9** illustrates representative reflectivity curves for an inclined building surface according to this invention. Each curve smoothly varies according to viewed angle from a low reflectivity reference (**91**) to a high reflectivity reference (**92**). The low reflectivity reference value is determined by the desired surface properties of the predominantly observer-facing ornamental surfaces (**12**) while the high reflectivity reference value is determined by the desired surface properties of the predominantly sun-facing surfaces. Ornamental quality generally correlates to reflectivity as it relates to darker apparent colors commonly favored for roofing.

[0052] FIG. **9** illustrates a representative reflectivity curve (**93**) according to this invention as a function of the elevation angle from approximately zero degrees (**98**) to approximately 180 degrees (**99**) looking along the pitch direction of the roof. A view angle of 45-degrees represents a view factor to a roof inclined at 12:12 pitch whereby the look angle is parallel to the horizontal plane. This view factor is considered an approximate upper bounding limit within which acceptable ornamental quality should be maintained as shown in FIG. **9**A as point (**97**). The normal viewing angle for roof slopes less that 12:12 and or look angles greater than zero with respect to the horizontal plane result in an elevation angle less than 45-degrees and the visible reflectivity value will be to the left of point (**97**) on curve (**93**) within zone (**94**). Acceptable ornamental quality is desirable within about this range of look angles as well as high reflectivity at approximately 90-degrees and greater as shown as zone (**96**). The shape of the curve within the transitional zone (**95**) may be adapted for climate zones or other factors by varying surface treatments according to the invention. Therefore, a roof according to this invention with slowly changing reflectivity at low elevation angles results in a wide range of viewing positions resulting in high ornamental quality while maintaining acceptable solar energy reflecting performance.

[0053] The foregoing description of the embodiments of the present invention has shown, described and pointed out the fundamental novel features of the invention. It will be understood that various omissions, substitutions, and changes in the form of the detail of the systems and methods as illustrated as well as the uses thereof, may be made by those skilled in the art, without departing from the spirit of the invention. Consequently, the scope of the invention should not be limited to the foregoing discussions, but should be defined by appended claims.

1. An aesthetically pleasing slanted roof reflectively responsive to sun elevation angle, comprising;

a repeating set of surfaces, portions of which are oriented predominantly toward the sun and portions of which are oriented predominantly toward observers at common viewing positions; and,

treatments applied to the surfaces, comprising;

at least one surface treatment that is selected for emissivity and reflectivity properties in the direct sunlight direction; and,

at least one surface treatment that is selected for aesthetically pleasing visual properties in the observer viewing direction, wherein;

the surface treatments are selected and applied to reduce visual perception of the repeating set of surfaces.

2. The roof of claim **1** wherein at least a portion of the surface treatments are smoothly varied between regions of high contrast differential.

3. The roof of claim **1** wherein surface treatments are selected to reduce visible contrast amplitude.

4. The roof of claim **3** wherein at least one surface treatment selectively reflects non-visible sunlight in the direct sunlight direction.

5. The roof of claim **1** wherein the surfaces are textured to increase visible spatial frequency.

6. The roof of claim **1** wherein at least a portion of the surface treatments are applied in a visible pattern.

7. The roof of claim **1** wherein surface treatments are applied at the location of use.

8. The roof of claim **3** wherein the contrast reduction includes at least one of;

applying the treatments to the sun facing and observer facing areas in analogous colors,

applying the treatments to the sun facing and observer facing areas with small luminance differential,

sizing the treatments with dimensions below the spatial resolution of observers at common viewing positions; and,

applying the treatments with smoothly varying gradients between the sun facing and observer facing areas.

* * * * *