

[54] **LIGHT-TRANSMISSIVE
RETROREFLECTIVE SHEETING**

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40/132 R, 161/4, 161/83, 161/92, 161/410,
161/DIG. 5

[51] **Int. Cl.** **G09f 13/16**, G09f 13/06

[58] **Field of Search** ... 40/130 B, 130 J, 132 R, 134;
161/3.5, 4, 83, 92, 408-410, DIG. 5

[56] **References Cited**

UNITED STATES PATENTS

1,998,054	4/1935	McBurney	161/3.5 X
2,130,704	9/1938	Patzwaldt.....	161/3.5 X
2,354,018	7/1944	Heltzer et al.	161/DIG. 5

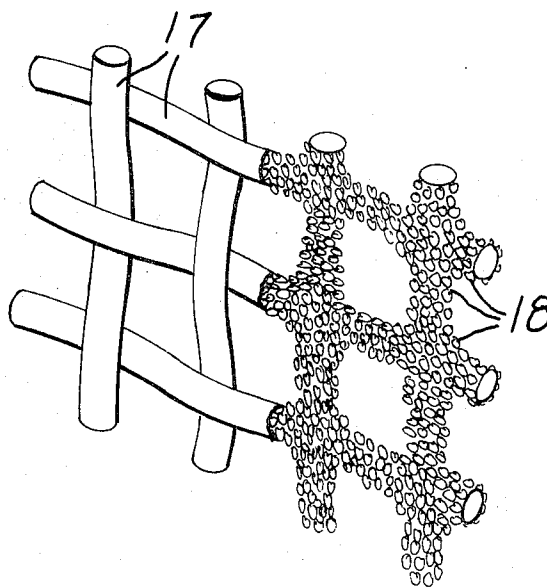
3,155,764	11/1964	Gill	350/106
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Primary Examiner—Harold Ansher
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Steldt & Delahunt

[57] **ABSTRACT**

Light-transmissive retroreflective sheeting comprising an open web of filaments that are encased around their whole circumference at least over those parts of their length that define open spaces of the web by a monolayer of minute retroreflective microspheres. One use of the sheeting is in internally illuminated signs, where the light-transmissive retroreflective sheeting is incorporated between the internal illumination source and the sign face so as to retroreflect light beamed against the sign face and make the signs retroreflective.

13 Claims, 3 Drawing Figures



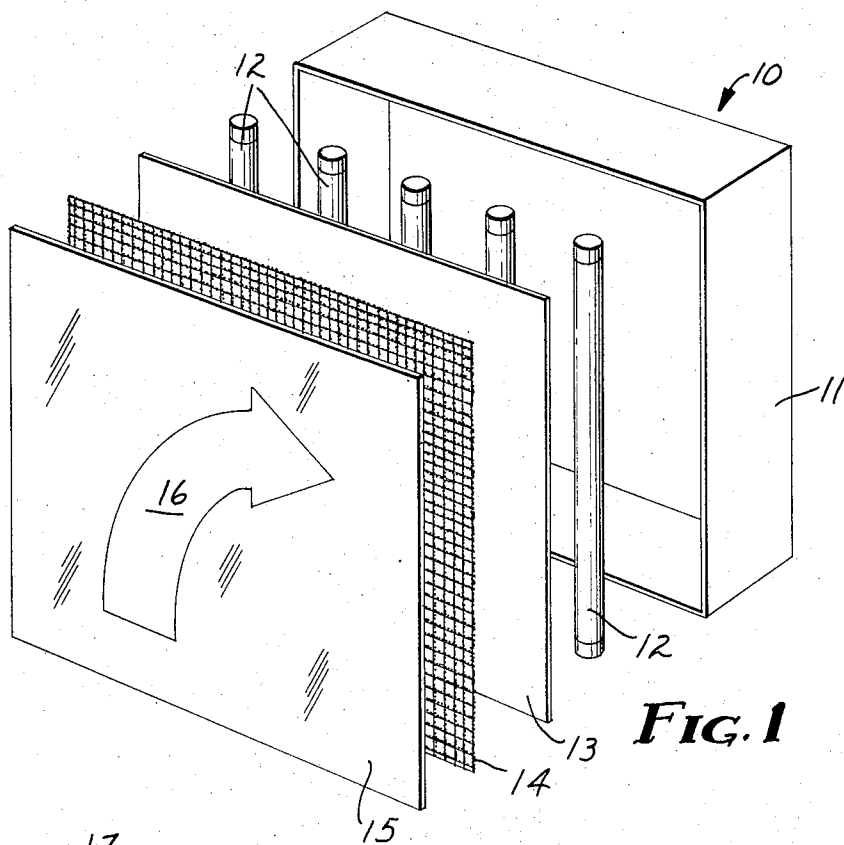


FIG. 1

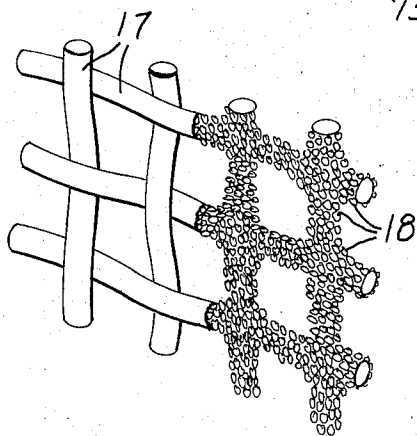


FIG. 2

LIGHT-TRANSMISSIVE RETROREFLECTIVE SHEETING

BACKGROUND OF THE INVENTION

A principal advantage asserted for internally illuminated roadway signs is that they can be seen at night even when out of reach of headlights of approaching vehicles. But this internal illumination also becomes a serious disadvantage when the light source within the sign fails or when there is a general electric power failure. Under such circumstances the sign may become partially or wholly illegible or inconspicuous, especially to motorists traveling at highway speeds at night.

Others have suggested ways for imparting retroreflectivity to internally illuminated signs. For example, in U.S. Pat. No. 3,510,976, it is suggested that a sign face be formed by partially embedding, as a monolayer in an adhesive layer coated on a transparent plate, a mixture of metallized glass microspheres and non-metallized microspheres. The metal on the protruding portions of the metallized microspheres is then removed, a clear material coated over the microspheres, and an opaque sign image painted over the clear layer. The non-metallized microspheres are said to transmit light from the internal source, while the metallized microspheres retroreflect light beamed against the front of the sign.

A major difficulty with a sign as described in U.S. Pat. No. 3,510,976 is that light is poorly transmitted through the non-metallized microspheres, and thus the internal illumination of the sign is greatly reduced. Further, it would be expensive to make existing signs retroreflective using the technique taught in the patent, since that would require replacement of the sign faces. Insofar as is known, signs such as taught in U.S. Pat. No. 3,510,976 have never become commercial.

SUMMARY OF THE INVENTION

The present invention provides retroreflective internally illuminated signs that permit good transmission of internal illumination, and that can be easily made from existing internally illuminated signs. Briefly, a sign of the invention comprises a light source, a sign image supported in front of the light source so as to be readable from the front of the sign when back-lighted by the light source, and a light-transmissive retroreflective sheeting between the sign image and the light source, said sheeting comprising an array of retroreflective microspheres carried on a base support in a non-uniform pattern comprising areas densely packed with microspheres separated by light-transmissive spaces through which the light source illuminates the sign image. The sign is normally illuminated by the light source, but in the event that the light source wholly or partially fails, the sign can still be read by light beamed at the front of the sign and retroreflected by the retroreflective sheeting that is behind the sign image.

A preferred light-transmissive retroreflective sheeting for use in a sign of the invention comprises an open web of filaments encased by minute retroreflective microspheres ("open" means that the filaments are separated from one another so that there are significant light-transmitting spaces between the encased filaments). Typically, the web of filaments is a fabric of interwoven filaments. Such open webs provide good light transmission, and in addition, they have good "angular-

ity," meaning that they will retroreflect light striking them on a line that forms a substantial angle with a line normal to the web. Signs of the invention have especially good brightness, both when illuminated only by the internal illumination and when additionally illuminated by the headlights of approaching vehicles.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is an "exploded" schematic perspective view of a representative sign of the invention;

FIG. 2 is a greatly enlarged perspective view of a light-transmissive retroreflective fabric of the invention, shown with the layer of microspheres broken away to reveal the base fabric; and

FIG. 3 is a plan view of a different light-transmissive retroreflective sheeting of the invention.

DETAILED DESCRIPTION

FIG. 1 shows in an "exploded" schematic representation an illustrative back-lighted sign 10 of the invention, which comprises a box-like enclosure 11; a light source that comprises a set of tubular light bulbs 12 and a diffuser panel 13; a light-transmissive retroreflective sheeting 14 of the invention; and a transparent sign face 15 carrying a sign image 16 visible from the front of the sign when illuminated from the back by the light source. A diffuser panel is not necessary, but is preferred so that light traveling through the sign face is substantially uniform over the whole area of the sign face. The sign image is almost always supported on a transparent sign face, though for special effects it could be supported in some other way (as by suspension on wires) and could be in front of or behind the sign face.

As previously noted, light-transmissive retroreflective sheeting comprising an open web of filaments encased by minute retroreflective microspheres is especially preferred, because such a sheeting provides good light transmission and also has good "angularity." For example, some light-transmissive retro-reflective fabrics of the invention can retroreflect, with 50 percent of original brightness, light striking the sheeting at an angle of 70°-80° to the normal to the sheeting. Open webs are further advantageous in that they permit movement of air within the sign, and light is better transmitted through open spaces than through transparent structure such as a transparent film. Instead of being woven as a fabric, only parallel filaments supported in an exterior frame may be used as a retroreflective sheeting of the invention. And in some embodiments, the base filaments of the sheeting are electrical conductors that generate heat when carrying a current, making the sheeting useful to keep the sign warm and free from condensation.

A light-transmissive retroreflective fabric useful as the light-transmissive sheeting 14 is illustrated in closeup in FIG. 2, and comprises a base fabric of woven filaments 17, a layer of binder material (not shown) coated on the filaments, and a monolayer of microspheres or beads 18 each partially embedded and adhered in the layer of binder material (the layer of microspheres is partially broken away to show the base fabric); the embedded surfaces of the microspheres are preferably covered with a reflective material such as vapor-coated aluminum. A typical method for preparing such a light-transmissive retroreflective fabric includes the steps of coating binder material on a base

fabric having filaments of the desired denier and the desired percentage of open area; applying microspheres completely covered with a reflective material to the coated fabric while the binder material is in a tacky state so that the microspheres become partially embedded in the layer of binder material; drying or curing the binder material to advance it to a non-tacky durable adherent condition; and removing the layer of reflective material that covers the exposed surfaces of the microspheres, as by etching. Light-transmissive retroreflective sheeting can also be prepared by weaving or otherwise grouping into an integral whole a web of filaments that have been previously coated with retroreflective elements, but such a method is much more difficult than preparing the light-transmissive retroreflective fabric from an already prepared base fabric, and such precoated filaments cause substantial wear on weaving equipment.

The filaments in a fabric of the invention are made from a variety of materials, such as natural cellulose-based fibers, synthetic polymeric fibers, or metal filaments. And they are sometimes made of a material that can be heat-formed, whereby the fabric is given a non-planar configuration. Such a configuration is useful, for example, when the sign face is three-dimensional.

The binder material on a light-transmissive retroreflective sheeting of the invention is preferably elastomeric to permit the sheeting to be rolled, as for shipment, and to facilitate an otherwise easy handling of the sheeting. One such useful elastomer-forming binder material comprises a polyether polyamine of high amine functionality, such as poly(tetramethyleneoxide) diamine taught in Hubin et al., U.S. Pat. No. 3,436,359, and diglycidyl ether of bisphenol A. This material cures to form a very strong bond with partially embedded silver- or aluminum-coated glass microspheres. Other useful binder materials include natural rubber, acrylic resins, and polyvinyl butyral resins.

A light-transmissive retroreflective fabric of the invention has other uses besides in an internally illuminated sign. For example, it can be incorporated in a perforate retroreflective traffic or advertising sign for use in situations where it is desired to permit viewers to see in back of the sign or to permit wind to blow through the sign and thus keep it from being blown over, or it can be incorporated in a cool retroreflective over-garment, for example, a retroreflective vest or jacket worn by highway or street crews.

Other types of useful light-transmissive retroreflective sheeting beside open webs of filaments include transparent films such as the film 19 shown in FIG. 3 on which small dots 20 of retroreflective microspheres have been deposited (such a sheeting is prepared, for example, by depositing tacky binder material in a pattern of dots on the film, then cascading metal-coated microspheres over the sheeting, then advancing the binder material to a dry adherent condition, and then etching off the metal from the nonembedded portions of the microspheres), retroreflective sheeting that has been punched to form light-transmissive spaces, tapes of retroreflective material grouped together to form a network of retroreflective areas separated by light-transmissive areas, or fabrics to which retroreflective dots have been laminated.

The light-transmissive retroreflective sheeting in a sign of the invention is chosen so as to provide a desired balance of transmission and reflection. Preferably, the

light-transmissive retroreflective sheeting transmits at least 20 percent, and more preferably at least 40 percent, of the light impinging on the sheeting from the light source. On the other hand, so that the light-transmissive retroreflective sheeting will provide good retroreflection if the light source fails, the light-transmissive retroreflective sheeting preferably transmits no more than 80 percent, and more preferably no more than 60 percent, of the light from the light source (the percent-transmission numbers are assumed to describe the percent open area of the area occupied by the sheeting, and the non-transmitting portions of the sheeting are assumed to be retroreflective). Adequate light-transmission and reflection can also be obtained with sheeting having a percentage of open area outside these ranges; for example, by increasing the brightness of the light bulbs in the sign, a sheeting transmitting as little as 5 percent of the light impinging on it may be used, and sheeting transmitting as much as 90 or 95 percent of light has useful reflection characteristics.

The light-transmissive retroreflective sheeting is usually not in contact with the sign face in the assembled condition of the sign, since the microspheres touching the sign face might not retroreflect. Desirably, the sheeting is spaced far enough from the sign face so that light from the light source transmitted through the sheeting will spread sufficiently to eliminate or minimize any shadow cast by the sheeting on the sign face by the light source.

Also, a light-transmissive retroreflective sheeting is least noticeable in a sign of the invention when the light-transmissive spaces and the densely packed areas of microspheres are very fine or small. Thus, a light-transmissive retroreflective fabric is least noticeable when the diameter of the retroreflective-microsphere-encased filaments is less than 500 microns and preferably less than 250 microns, and the smallest dimension of the spaces between the encased filaments is less than one millimeter, and preferably less than 500 microns. The glass microspheres or beads are of a size such that a dense monolayer of them can be coated on the filament without unduly reducing the size of the spaces between the filaments.

The invention will be further illustrated by the following example. A fabric of 200-micron-diameter nylon filaments woven in a straight "Leno" weave using 20 threads per inch was first roller coated with a primer to fill up all crevices in the filament. The primer material was a 10-weight-percent-solids solution in toluene of the following ingredients:

	Parts by Weight
Poly(tetramethyleneoxide) diamine that has a number-average molecular weight of 10,000, an amine equivalent weight of 4610, and a viscosity at 65°C of 49,500 centipoises, and that was prepared according to the procedures of Examples 1-4 of Hubin et al., U.S. Pat. No. 3,436,359	100
2,4,6-tris-dimethylaminomethylphenyl catalyst (DMP-30)	2.5
Diglycidyl ether of bisphenol A having an epoxide equivalent weight of 180-195 (Epon 828)	50
Stannous octoate catalyst	5

This primer coating was then cured at 150°F for 30 minutes. After the fabric had cooled to room temperature, a binder material of the same ingredients listed above but dissolved at 30-weight-percent solids in toluene

ene was coated on the fabric, after which the coated fabric was exposed to jets of compressed air to remove excess binder material and keep the spaces between filaments open. While the layer of binder material was still wet and tacky, the fabric was passed through a "fluidized bed" of aluminum-vapor-coated glass microspheres 37 to 88 microns in diameter (the fabric passed over a trough containing microspheres that were shot upward by a set of compressed air nozzles at the bottom of the trough, with a canopy above the fabric returning the microspheres toward the fabric), whereupon the filaments of the fabric became individually encased by a densely packed monolayer of microspheres adhered to and partially embedded in the coating of binder material. The layer of binder material was then cured at 150°F for one hour, after which the aluminum on the exposed portions of the microspheres was removed by etching with an alkali solution.

The resulting light-transmissive retroreflective sheeting had an open area of about 50 percent (determined by measuring the light in photovolt units (PV) returned by an assembly that comprised the sheeting before the aluminum was removed (which is known to have a PV of zero) over a standard sheeting known to have a PV of 57 using a photometer that had been calibrated with the standard 57 PV sheeting; the assembly was measured as having a PV of 30, meaning that the percent open area of the light-transmissive sheeting of this example was 30/57 times 100 percent, or about 50 percent). The sheeting was disposed in a sign having a 24-inch-by-24-inch transparent glass-plate sign face carrying no image; the sign was lighted by a bank of four 40-watt fluorescent light bulbs through a diffuser panel of white translucent plastic sheeting spaced 4 inches in front of the bulbs. The light from the sign was then measured under various combinations of the following conditions: with the light-transmissive retroreflective sheeting ("screen" in the table below) in place and not in place between the sign face and diffuser panel; with the sign illuminated by a headlight (having 3950 candle power at 12.5 feet) and not illuminated; and with the internal lights on and not on. The light was measured through a photocell and galvanometer 50 feet away from the sign, and the headlight was adjacent the photocell. The sign was turned so that the angle of incidence of light on the sign from the headlight was varied between 0° and 60° from the normal of the sign face. The results were as follows, the numbers given being readings on the galvanometer:

Test number	Internal light	Head-light	Screen	Angle of incidence, degrees							
				0	10	20	30	40	50	60	
1	On	Off	Out	29.5	29.1	27.7	25.0	21.5	17.2	12.1	
2	On	Off	In	14.8	13.5	12.6	11.1	9.0	6.8	4.1	
3	Off	On	In	53.0	52.2	50.3	46.3	39.4	29.8	19.4	
4	On	On	In	67.6	66.3	63.5	57.8	48.1	36.0	22.2	
5	Off	On	Out	2.83	.1	.1	.1	.1	.09	.09	

What is claimed is:

1. Light-transmissive retroreflective sheeting com-

prising an open web of filaments that are encased around their whole circumference at least over those parts of their length that define open spaces of the web by a monolayer of minute retroreflective microspheres, the spaces between the encased filaments occupying between 20 and 80 percent of the area covered by the sheeting.

2. Sheetting of claim 1 in which the spaces between the encased filaments occupy between 40 and 60 percent of the area covered by the sheeting.

3. Sheetting of claim 1 in which the encased filaments have a diameter less than 500 microns.

4. Sheetting of claim 1 in which the smallest dimension of the spaces between the encased filaments is less than one millimeter.

5. Sheetting of claim 1 in which the web is a fabric of interwoven filaments.

6. Sheetting of claim 1 in which the retroreflective microspheres are partially embedded in a layer of binder material coated on the filaments and comprise glass microspheres covered over their partially embedded surface with reflective material.

7. Sheetting of claim 1 in which the microspheres are held to the filaments by a layer of elastomeric material.

8. Sheetting of claim 7 in which the elastomeric material comprises epoxy resin and a water-insoluble polyether polyamine of high amine functionality.

9. Light-transmissive retroreflective sheeting comprising an open fabric of interwoven filaments that are encased around their whole circumference over those parts of their length that define open spaces of the fabric by a monolayer of minute retroreflective microspheres, the microspheres being partially embedded in a layer of elastomeric binder material coated on the filaments after the filaments have been woven into a fabric, the encased filaments having a diameter less than 500 microns, the spaces between the encased filaments occupying between 20 and 80 percent of the area covered by the fabric, and the smallest dimension of the spaces being less than one millimeter.

10. Sheetting of claim 9 in which the elastomeric material comprises epoxy resin and a water-insoluble polyether polyamine of high amine functionality.

11. Sheetting of claim 9 in which the retroreflective microspheres comprise glass microspheres covered over their partially embedded surface with reflective material.

12. Sheetting of claim 9 in which the spaces between the encased filaments occupy 40-60 percent of the

area occupied by the sheeting.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,790,431 Dated February 5, 1974
Inventor(s) Chi Fang Tung

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 31, "through" should read -- though --.

Signed and sealed this 8th day of October 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents