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(54) A projection screen having high resolution and good mechanical stability.

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(73) Proprietor: **N.V. Philips' Gloeilampenfabrieken**
Groenewoudseweg 1
NL-5621 BA Eindhoven(NL)

(72) Inventor: **Mc Kechnie, Thomas Stewart**
c/o INT. OCTROOIBUREAU B.V.
Prof. Holstlaan 6
NL-5656 AA Eindhoven(NL)
Inventor: **Goldenberg, Jill Forer**
c/o INT. OCTROOIBUREAU B.V.
Prof. Holstlaan 6
NL-5656 AA Eindhoven(NL)

(74) Representative: **Peters, Rudolf Johannes et al**
INTERNATIONAAL OCTROOIBUREAU B.V.
Prof. Holstlaan 6
NL-5656 AA Eindhoven (NL)

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Description

BACKGROUND OF THE DISCLOSURE

1. Field of the Invention

The present invention relates to a projection screen for displaying a picture in an audience room, comprising the following elements: a front plate having a front side facing the audience room and an opposite rear side the front side being provided with a plurality of lenticules, light-diffusing means within the screen, and a mechanically stable substrate plate, having a rear side and a front side facing the rear side of the front plate.

2. Description of the Prior Art

A projection television screen having moderately high resolution and good mechanical stability is described in the paper "Ultra-wide Viewing Angle Rear Projection TV Screen" by R. Bradley, J. Goldenberg, and T.S. McKechnie, Proceedings IEEE Transactions on Consumer Electronics, Vol 31, pp. 185-193, August 1985. Fig. 1 is reproduced from this article. It will be noted that the front element is quite thick, the thickness being expressly chosen to resist warp caused by temperature and/or humidity variations. Spheres are incorporated throughout the front element to diffuse the light. A relatively thin Fresnel lens has an active surface which lies nearest to the viewing audience. The front lenticular portion of the screen is laminated to the bulk diffusing portions to create optical contact between the two and thus minimize reflections from the interface.

In the article "Diffraction Analysis of Bulk Diffusers for Projection Screen Applications" Journal of the Optical Society of America Volume 2. Number 12, December 1985, the inventors of the present invention analyze bulk diffusers by scalar diffraction theory. This article is hereby incorporated by reference into the present application to constitute a part thereof.

SUMMARY OF THE INVENTION

It is an object of the present invention to improve the known designs of projection screens to increase the resolution of the screens while maintaining their mechanical stability.

It is a further object of the present invention to accomplish the above stated goals while, in some cases, reducing the cost of manufacture of the screens.

Thereto the projection screen according to the invention is characterized in that the diffusing means is concentrated in the half portion of the screen facing the audience room.. The diffusing means can be a bulk diffusion zone or a surface diffusing interface. In a particularly preferred embodiment the diffusing means are diffusing particles actually dispersed within the lenticules.

It is remarked, that the abstract of the Japanese patent application no. JP-A 55-12980 discloses a single element projection screen wherein diffusion of the light is achieved with small diffuser particles suspended in the material of the screen and distributed all over the thickness of the screen. The density of the particles decreases exponentially from one side of the screen to the other side. However, the abstract does not disclose concentrating the diffuser particles in a discrete screen portion at the front side of the screen.

If the screen has two elements, the mechanically stable substrate may be part of either the front or the rear element. When the mechanically stable substrate is in the rear element, close proximity of the lenticular element to the substrate may be maintained by giving the lenticular element an inward curvature. The curvature must be sufficient to counteract the outward curvature created in the lenticular element at the most extreme temperature/humidity condition. Alternatively, the lenticular element may be adhered to the substrate at a limited number of points.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a horizontal section through a prior art screen;

Fig. 2 is a schematic diagram of a screen having a three-piece front element with diffuser close to the lenticular surface;

Fig. 3 is a schematic diagram of a screen having a two-piece front element with diffusion elements close to the lenticular surface;

Fig. 4 is a schematic diagram of a screen having a two-piece front element with diffuser inside the lenticules;

Fig. 5 is a schematic diagram of a screen having a two-piece front element with surface diffusion;

Fig. 6 is a schematic diagram of a screen having a one-piece front element with diffuser within the lenticular surface, and a thick rear element;

Fig. 7 is a schematic diagram of a screen having a one-piece front element with surface diffusion and a thick rear element with Fresnel lens;

Fig. 8 is a schematic diagram of a screen having a thick rear element with Fresnel lens and a two-piece front element having a rear surface touching the Fresnel surface; and

Fig. 9 is a schematic diagram of a screen having a front lenticular element touching a rear Fresnel lens element, the rear Fresnel lens ele-

ment having surface diffusion.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiments of the present invention will be discussed with regard to a rear projection screen having the construction shown specifically in U.S. Patent 4,573,764. The invention is, however, in no way limited to the particular construction of the lenticules in that patent or to a screen having a lenticular surface and a Fresnel lens surface. Diffusion will enhance the vertical light distribution in any screen. In the particular screen which is the subject of the '764 patent, diffusion is necessary to achieve minimum color shift.

In any screen, as has been shown in the article "Diffraction Analysis of Bulk Diffusers for Projection Screen Applications", J. of Optical Soc. of America, J. Goldenberg and T.S. McKechnie, December 1985, the same diffusion angle can be achieved with a thin as with a thick bulk diffuser, where bulk diffuser is defined as a host medium with a minute colloidal particles suspended therein.

Referring now to Fig. 1, the prior art screen, the front element of the screen is denoted by reference numeral 10. It will be noted that the element is quite thick and has diffusion particles suspended throughout the width. A lenticular surface consisting of a plurality of parallel lenticules 12, having a length dimension extending in a direction perpendicular to the surface of the paper, faces the audience viewing the display. The spaces or grooves between adjacent lenticules are filled in part with a blackening material 14. The structure and composition of the lenticules and blackening material are, for example, described in U.S. Patent 4,573,764 and will not be further described here. What is to be noted is that the thickness of the front element causes it to resist warp caused by temperature and humidity variations. Further, the bulk diffusion increases the resolution of the screen to some extent relative to surface diffusion on the rear surface of the front element.

The prior art projection screen also includes a thin rear element 16 whose surface facing front element 10 is constituted by a Fresnel lens structure. According to the '764 patent, by introducing diffusion between the light collimating Fresnel lens and the light spreading lenticular lens elements, the red, blue and green light rays are sufficiently diffused so that a substan t ially even horizontal dispersion of the respective light rays results, thereby substantially decreasing any color shift phenomena. While the possibility of texturizing one of the surfaces other than the front lenticular surface in order to create surface diffusion is discussed, nothing in the '764 patent points to moving the diffuser particles as closely as possible to the front of the screen, preferably to a location within the lenticules.

Referring now to Fig. 2, locating the diffuser particles closer to the front while maintaining the mechanical stability of the projection screen is accomplished by a front element having a clear substrate 20 to assure mechanical stability. This substrate, in the embodiment illustrated in Fig. 2, is 2 millimeters thick. A bulk diffuser element 24, having a thickness of only 1 millimeter, has a rear surface 22 mechanically affixed to the front surface of substrate 20. Specifically, the two surfaces may be glued together or laminated. Similarly, the front surface 26 of the bulk diffuser portion 24 is laminated to the lenticular portion 28 of the front element. Blackening of the screen is omitted in Fig. 2, since it is not essential for the understanding of the present invention. The thickness of the lenticular portion is also 1 millimeter. The dimensions given in Fig. 2 are illustrative only and are not to be taken as limiting. It will be noted that the Fresnel lens element, namely rear element 29, is relatively thin and is not, therefore, mechanically stable. Because the stability of this element is not critical to the screen performance, no effort need be made to constrain this element or attach it to the front, stable element other than to clamp it by its edge to the other element as is customary in screen manufacture. As an option, the Fresnel lens could be adhered to the stable front element using a small amount of adhesive at the optical center of the Fresnel lens. An absorptive disc 27 may then be used to equalize the brightness at the optical center with that at the remainder of the interface. The latter is decreased by approximately 8% due to reflection.

The overall thickness of the front element and the proximity of the diffusion region to the front lenticular surface gives rise to a screen which has high resolution and good mechanical stability.

In Fig. 3, the bulk diffusion spheres are in the front part of the clear substrate which , as in Fig. 2, is, for example, a thick sheet of clear acrylic. This sheet may be manufactured, for example, by compression molding in such a way that the diffusion spheres which have been introduced as specified, e.g. in "Ultra-Wide Viewing Angle Rear Projection Screen" by Ralph Bradley and the present inventors, IEEE Transactions on Consumer Electronics; V. 31; (3); Aug. 1985, are allowed to settle under gravity towards one surface of the sheet. The settling takes place during the time taken for the sheet to cool. The lenticular portion is then laminated to the side of the bulk diffusion sheet which contains the diffusion spheres. In the example illustrated in Fig. 3, the substrate with diffusion 30 has a thickness of 3 millimeters. Laminated

thereto is the lenticular element which, in Fig. 3, has a thickness of 1 millimeter. Again, the front surface 31 of element 30 may be glued to the rear surface of lenticular element 32. The thickness of Fresnel lens 34, which may be identical to Fresnel lens 29 of Fig. 2, is 1 millimeter. Again, the overall thickness of the front element together with the location of the diffusion region in proximity to the front lenticular surface yields a screen having high resolution and good mechanical stability.

In Fig. 4, the diffusion is incorporated into the front lenticular portion 40. The front lenticular portion is then laminated to a thick sheet of acrylic or other suitable material. Again, the thickness of the lenticular element is 1 millimeter, while that of clear substrate 42 is 3 millimeters. A Fresnel lens 44 identical to the previously illustrated Fresnel lens completes the rear projection screen.

In Fig. 5, a front lenticular portion 50 is glued to a thick transparent substrate 52. Surface roughness is used on one or both of the contacting surfaces between clear substrate 52 and lenticular element 50 to effect the light diffusion. The surface roughness and the refractive indices of the materials are chosen to yield the desired diffusion angle. Typically, the index of refraction of the substrate is 1.5, while that of the lenticular portion is 1.6. The substrate is preferably a polymer such as polymethyl methacrylate, or it may be glass.Roughness could be produced by grinding the surface with a rough (e.g. grade 100) carborundum powder. The lenticular portion is preferably made of an ultraviolet cured polymer. The greater the difference between the refractive indices of the two parts, the less roughness is required.

All of the above examples have in common that the diffusion elements are as close to the front of the screen as possible and that front element is sufficiently thick to assure mechanical stability.

A second approach to creating a mechanically stable screen are the embodiments to be described below and illustrated in Figs. 6-8, wherein a thin front element contains diffusion, while mechanical stability is provided by a thick rear Fresnel lens element.

Referring first to Fig. 6, the front element 60 contains the lenticules in which diffusion particles are dispersed. This element is 1 millimetre thick in the example shown in the figure. However, ranges of from 1/2 millimetre to 1-1/2 millimetres can readily be accommodated. On the other hand, rear element 62 is a thick, mechanically stable element. The illustrated thickness is 3 millimetres, but typically a range of from 2 to 5 millimetres may be used. The maximum thickness is limited solely by the cost of material.

It should be noted that for this embodiment the front element is manufactured in such a way as to have an inward curvature. This can be accomplished by hot sagging the front element over a mould which possesses the desired curvature. Alternatively, if the blackening elements (not illustrated) in the grooves between adjacent lenticules are black strings, the correct amount of string tension induces stresses to causes the correct amount of curvature.

For a screen with a 1 meter (40 inch) diagonal, the front element should have a natural bow depth of between 5 millimetres and 25 millimetres. This would require a radius of curvature of between 5 meters and 20 meters. For larger or smaller screen sizes, the bow depth would have to be adjusted accordingly. In general, it depends upon the temperature and humidity conditions anticipated in the screen's working environment. The temperature effects are less important than the humidity effects, since temperature equilibrium between the inner and outer surfaces of the screen is established more rapidly than equilibrium in the humidity. For increasing temperature and increasing humidity, the outer skin expands resulting in the tendency of the screen to bow outwards. The bow depth created in the manufacture by either of the above mentioned techniques would thus have to compensate for the maximum bowing to be expected under the particular temperature and/or humidity conditions to which the screen will be exposed. An overall tendency to curve inwards should be preserved for the maximum bowing to be expected. This slight curvature would cause the screen to continue pressing against the thick and therefore stable Fresnel element.

The above method can be combined with use of a small amount of transparent adhesive between the Fresnel lens and the lenticular element. This small amount of transparent adhesive should be applied at the optical center, where the Fresnel lens has zero optical power and the faceted surface is substantially flat. The amount of adhesive and its manner of distribution is chosen so as not to degrade the optical or cosmetic properties of the screen. In addition, an absorptive disc, such as the one illustrated in Fig. 2, may be used to decrease the brightness at the optical center of the lens.

Although surface diffusion is not always consistent with high resolution, the resolution effected by the screen of Fig. 7 will be entirely adequate for most purposes. In Fig. 7, front element 70 has surface diffusion on its rear surface. The rear surface in the final assembled screen abuts a Fresnel lens surface of rear element 72. Rear element 72, as in Fig. 6, is a thick, mechanically stable element.

Figs. 8 and 9 show other variations of the type of embodiment having a thick rear element. In Fig. 8, as in Fig. 6, the rear element illustrated has a

thickness of approximately 3 mm. In the finished screen its Fresnel surface abuts a bulk diffusion layer 82, which is part of front element 84. The bulk diffusion layer is one millimeter thick, while the rear element is 3mm thick. Again, the latter may typically lie in the range of between 2 to 5 mm, mechanical stability being the main consideration since loss of light is minimal. Close contact is maintained between the front and rear elements by inducing stress in the front element and/or by adhesion.

The embodiment illustrated in Fig. 9 is similar to that in Fig. 7, except that the surface diffusion is introduced on the surface of the Fresnel lens 92, rather than on the back surface of the front element 90.

Although the present invention has been illustrated in preferred embodiments, it is not to be limited thereto. Many variations and changes will occur to one skilled in the art and are intended to be encompassed in the accompanying claims.

Claims

1. A projection screen for displaying a picture in an audience room, comprising the following elements:

   a front plate (28, 32, 50, 60, 70, 84, 90) having a front side facing the audience room and an opposite rear side, the front side being provided with a plurality of lenticules,

   light-diffusing means within the screen,

   and a mechanically stable substrate plate (20, 30, 42, 52, 62, 72, 80, 92), having a rear side and a front side facing the rear side of the front plate,

   characterized in that the diffusing means is concentrated in the half portion of the screen facing the audience room.

2. A projection screen as claimed in claim 1, characterized in that the diffusing means is included in the front plate.

3. A projection screen as claimed in claim 2, characterized in that the diffusing means is constituted by a plurality of diffuser particles dispersed in a separate bulk diffuser section (24) adjacent to said lenticules, and that the thickness of the section is less than the distance between the section and the front side of the front plate (28).

4. A projection screen as claimed in claim 2, characterized in that the diffusing means is constituted by a plurality of diffuser particles dispersed in the lenticules (40).

5. A projection screen as claimed in claim 2, characterized in that the diffusing means is constituted by a rough surface on the rear side of the front plate (50).

6. A projection screen as claimed in claim 1, characterized in that the diffusing means is included in the substrate plate.

7. A projection screen as claimed in claim 6, characterized in that the diffusing means is constituted by a plurality of diffuser particles dispersed in a distinct bulk diffuser section (24), affixed to the front side of the substrate plate (20).

8. A projection screen as claimed in claim 6, characterized in that the diffusing means is constituted by a plurality of diffuser particles dispersed in the bulk of the substrate plate (30), near its front side.

9. A projection screen as claimed in claim 6, characterized in that the diffusing means is constituted by a rough surface at the front side of the substrate plate (52).

10. A projection screen as claimed in claims 3, 4, 7 or 8, characterized in that said diffuser particles are colloidal particles.

11. A projection screen as claimed in claim 1, characterized in that the front plate (40) and the substrate plate (42) are mechanically and optically connected.

12. A projection screen as claimed in claim 11, characterized by an additional plate (29, 34, 44, 54) with a lens structure thereon which faces the rear side of the substrate plate.

13. A projection screen as claimed in claim 1, characterized in that one side of the substrate plate (62, 72, 80, 92) has a lens structure.

14. A projection screen as claimed in claims 12 or 13, characterized in that the constituent plates are in mechanical contact.

15. A projection screen as claimed in claim 1, characterized in that the front plate (60, 70, 84, 90) has a curvature such that the front plate presses against the substrate plate (62, 72, 80, 92), thereby providing mechanical stability for the front plate.

16. A projection screen as claimed in claim 12 or 13, characterized in that said lens structure is

a Fresnel lens.

17. A projection screen as claimed in claim 13, wherein said Fresnel lens is provided on the front side of said substrate (62, 72, 80, 92), characterized in that said substrate plate and the front plate (60,70,84,90) are bonded at the optical centre of the lens, thereby preventing movement between the two plates.

Patentansprüche

1. Projektionsschirm zum Wiedergeben eines Bildes in einem Zuschauerraum, mit folgenden Elementen:
einer Vorderplatte (28, 32, 50, 60, 70, 84, 90), deren Vorderseite dem Zuschauerraum zugewandt ist, und einer gegenüberliegenden Rückseite, wobei die Vorderseite mit einer Vielzahl von Linsen versehen ist,
Lichtstreumitteln im Schirm,
und einer mechanisch stabilen Substratplatte (20, 30, 42, 52, 62, 72, 80, 92) mit einer Rückseite und einer der Rückseite der Vorderplatte zugewandten Vorderseite,
dadurch gekennzeichnet, daß das Lichtstreumittel in dem dem Zuschauerraum zugewandten halben Schirmanteil konzentriert ist.

2. Projektionsschirm nach Anspruch 1, dadurch gekennzeichnet, daß das Streumittel in die Vorderplatte aufgenommen ist.

3. Projektionsschirm nach Anspruch 2, dadurch gekennzeichnet, daß das Streumittel aus einer Anzahl von Streupartikeln zusammengesetzt ist, die in einem getrennten Hauptstreuabschnitt (24) neben den Linsen verteilt sind, und daß die Dicke des Abschnitts weniger ist als der Abstand zwischen dem Abschnitt und der Vorderseite der Vorderplatte (28).

4. Projektionsschirm nach Anspruch 2, dadurch gekennzeichnet, daß das Streumittel aus einer Anzahl von Streupartikeln zusammengesetzt ist, die in den Linsen (40) verstreut sind.

5. Projektionsschirm nach Anspruch 2, dadurch gekennzeichnet, daß das Streumittel aus einer rauhen Oberfläche an der Rückseite der Vorderplatte (50) zusammengesetzt ist.

6. Projektionsschirm nach Anspruch 1, dadurch gekennzeichnet, daß das Streumittel in die Substratplatte aufgenommen ist.

7. Projektionsschirm nach Anspruch 6, dadurch gekennzeichnet, daß das Streumittel aus einer Anzahl in einem unterschiedenen Hauptstreuabschnitt (24) verteilten Streupartikeln zusammengesetzt ist, wobei dieser Abschnitt an der Vorderseite der Substratplatte (20) befestigt ist.

8. Projektionsschirm nach Anspruch 6, dadurch gekennzeichnet, daß das Streumittel aus einer Anzahl in der Hauptmasse der Substratplatte (30) nahe bei seiner Vorderseite verteilter Streupartikeln zusammengesetzt ist.

9. Projektionsschirm nach Anspruch 6, dadurch gekennzeichnet, daß das Streumittel aus einer rauhen Oberfläche an der Vorderseite der Substratplatte (52) zusammengesetzt ist.

10. Projektionsschirm nach Anspruch 3, 4, 7 oder 8, dadurch gekennzeichnet, daß die Streupartikeln Kolloidalpartikeln sind.

11. Projektionsschirm nach Anspruch 1, dadurch gekennzeichnet, daß die Frontplatte (40) und die Substratplatte (42) mechanisch und optisch miteinander verbunden sind.

12. Projektionsschirm nach Anspruch 11, dadurch gekennzeichnet, daß eine zusätzliche Platte (29, 34, 44, 54) mit darauf einer Linsenstruktur vorgesehen ist, die der Rückseite der Substratplatte zugewandt ist.

13. Projektionsschirm nach Anspruch 1, dadurch gekennzeichnet, daß eine Seite der Substratplatte (62, 72, 80, 92) eine Linsenstruktur hat.

14. Projektionsschirm nach Anspruch 12 oder 13, dadurch gekennzeichnet, daß die zusammenstellenden Platten in mechanischem Kontakt miteinander sind.

15. Projektionsschirm nach Anspruch 1, dadurch gekennzeichnet, daß die Vorderplatte (60, 70, 84, 90) eine derartige Krümmung hat, daß die Vorderplatte an die Substratplatte (62, 72, 80, 92) drückt, wodurch mechanische Stabilität für die Vorderplatte erhalten wird.

16. Projektionsschirm nach Anspruch 12 oder 13, dadurch gekennzeichnet, daß die Linsenstruktur eine Fresnel-Linse ist.

17. Projektionsschirm nach Anspruch 13, in dem die Fresnel-Linse an der Vorderseite des Substrats (62, 72, 80, 92) vorgesehen ist, dadurch gekennzeichnet, daß die Substratplatte und die Vorderplatte (62, 72, 80, 92) in der optischen Mitte der Linse verklebt sind, wodurch Bewegungen zwischen den beiden Platten verhin-

dert werden.

Revendications

1. Ecran de projection permettant d'afficher une image dans une salle de spectacle, comprenant les éléments suivants :
   - une plaque avant (28, 32, 50, 60, 70, 84, 90) ayant une face avant en regard de la salle de spectacle et une face arrière opposée, la face avant étant dotée d'une pluralité de lenticules,
   - des moyens de diffusion de la lumière, à l'intérieur de l'écran, et
   - une plaque de support mécaniquement stable (20, 30, 42, 52, 62, 72, 80, 92) ayant une face arrière et une face avant tournée vers la face arrière de la plaque avant,

   caractérisé en ce que les moyens de diffusion sont concentrés dans la moitié de l'écran tournée vers la salle de spectacle.

2. Ecran de projection selon la revendication 1, caractérisé en ce que les moyens de diffusion sont inclus dans la plaque avant.

3. Ecran de projection selon la revendication 2, caractérisé en ce que les moyens de diffusion sont constitués par une pluralité de particules de diffusion dispersées dans une section de diffusion volumique séparée (24) au voisinage desdites lenticules, et l'épaisseur de la section est inférieure à la distance entre la section et la face avant de la plaque avant (28).

4. Ecran de projection selon la revendication 2, caractérisé en ce que les moyens de diffusion sont constitués par une pluralité de particules de diffusion dispersées dans les lenticules (40).

5. Ecran de projection selon la revendication 2, caractérisé en ce que les moyens de diffusion sont constitués par une surface rugueuse sur la face arrière de la plaque avant (50).

6. Ecran de projection selon la revendication 1, caractérisé en ce que les moyens de diffusion sont inclus dans la plaque de support.

7. Ecran de projection selon la revendication 6, caractérisé en ce que les moyens de diffusion sont constitués par une pluralité de particules de la partie avant de la plaque de support (20).

8. Ecran de projection selon la revendication 6, caractérisé en ce que les moyens de diffusion sont constitués par une pluralité de particules de diffusion dispersées dans la masse de la plaque de support (30), à proximité de sa face avant.

9. Ecran de projection selon la revendication 6, caractérisé en ce que les moyens de diffusion sont constitués par une surface rugueuse sur la face avant de la plaque de support (52).

10. Ecran de projection selon la revendication 3, 4, 7 ou 8, caractérisé en ce que lesdites particules de diffusion sont des particules colloïdales.

11. Ecran de projection selon la revendication 1, caractérisé en ce que la plaque avant (40) et la plaque de support (42) sont reliées mécaniquement et optiquement.

12. Ecran de projection selon la revendication 11, caractérisé par une plaque supplémentaire (29, 34, 44, 54) sur laquelle se trouve une structure de lentille qui fait face à la face arrière de la plaque de support.

13. Ecran de projection selon la revendication 1, caractérisé en ce qu'une face de la plaque de support (62, 72, 80, 92) a une structure de lentille.

14. Ecran de projection selon la revendication 12 ou 13, caractérisé en ce que les plaques constituantes sont en contact mécanique.

15. Ecran de projection selon la revendication 1, caractérisé en ce que la plaque avant (60, 70, 84, 90) a une courbure telle qu'elle se presse contre la plaque de support (62, 72, 80, 92), assurant de la sorte une stabilité mécanique de la plaque avant.

16. Ecran de projection selon la revendication 12 ou 13, caractérisé en ce que ladite structure de lentille est une lentille de Fresnel.

17. Ecran de projection selon la revendication 13, dans lequel ladite lentille de Fresnel est prévue sur la face avant dudit substrat (62, 72, 80, 92), caractérisé en ce que ladite plaque de support et la plaque avant (60, 70, 84, 90) sont unies au centre optique de la lentille, empêchant de la sorte tout mouvement entre les deux plaques.

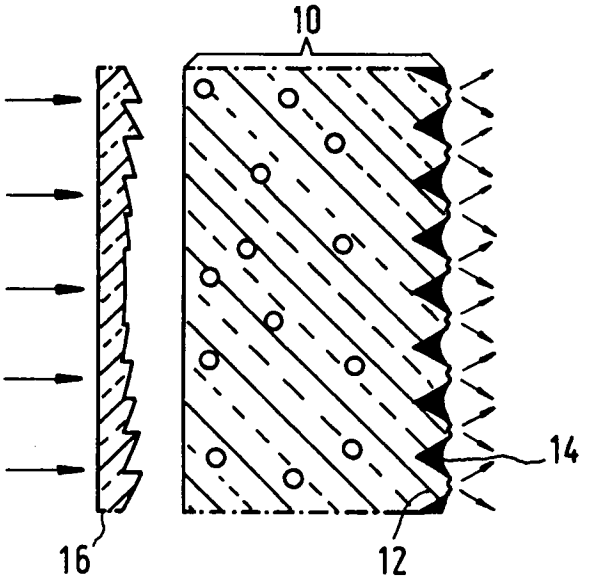

FIG.1 (prior art)

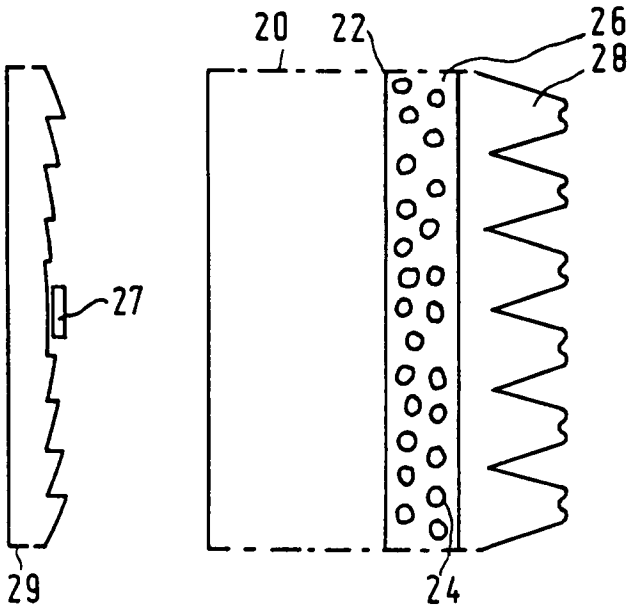

FIG.2

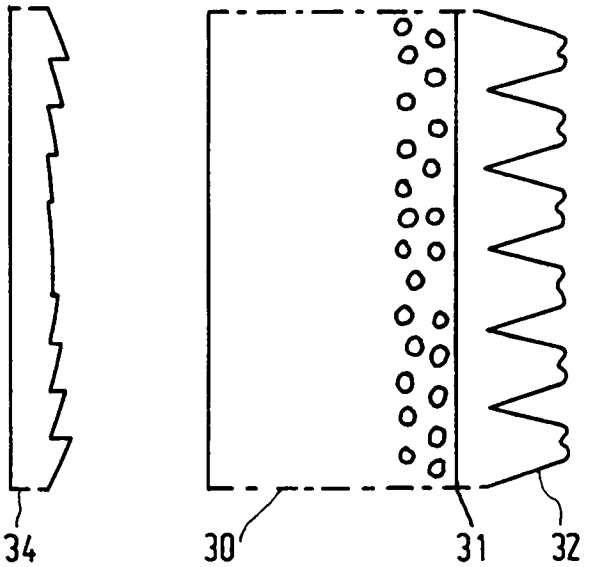

FIG. 3

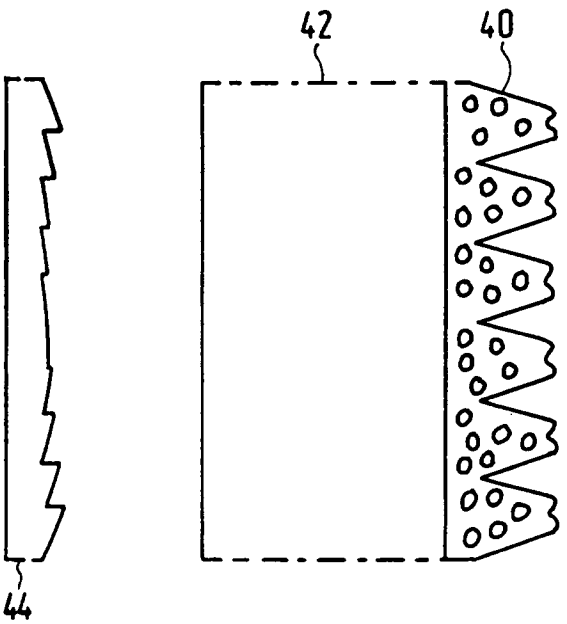

FIG. 4

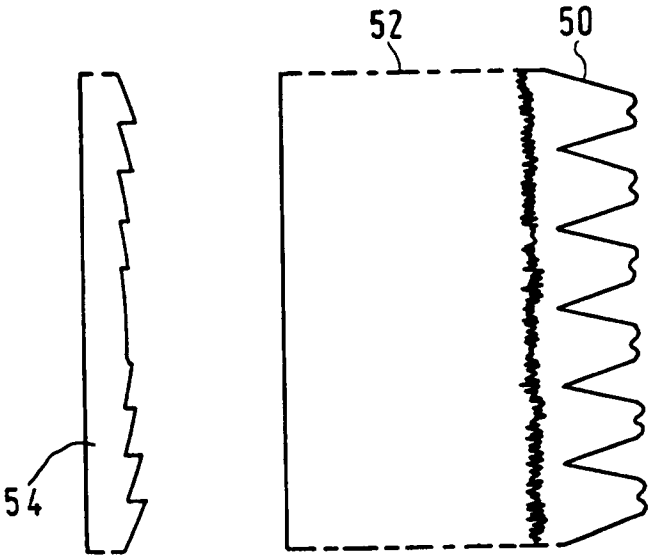

FIG.5

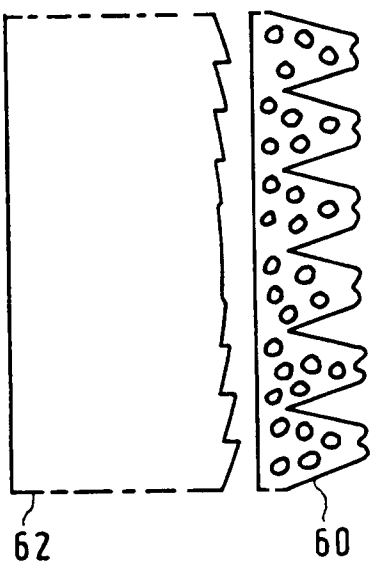

FIG.6

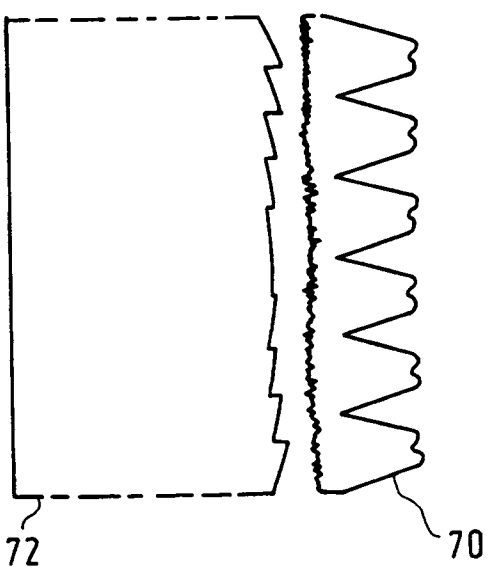

FIG.7

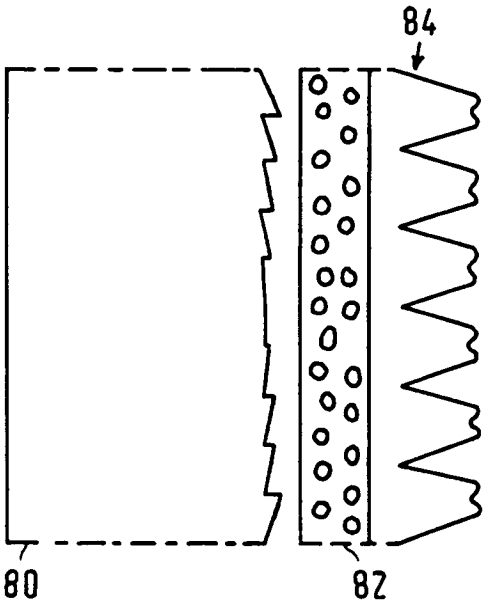

FIG.8

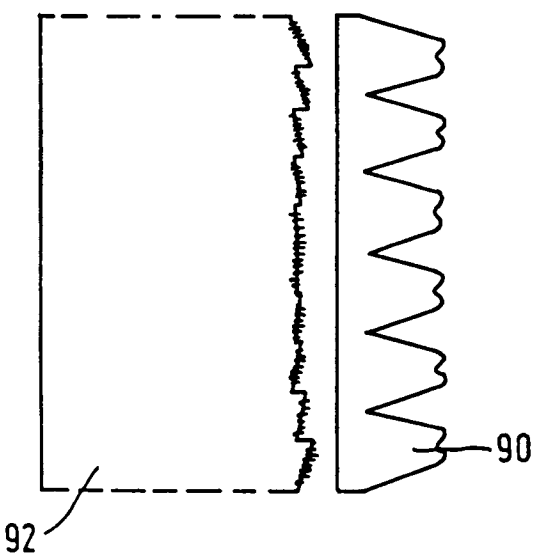

FIG.9

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Title A PROJECTION SCREEN HAVING HIGH RESOLUTION AND GOOD MECHANICAL STABILITY

Applicant/Proprietor
N.V. PHILIPS' GLOEILAMPENFABRIEKEN, Groenewoudseweg 1, NL-5621 BA Eindhoven, Netherlands [ADP No. 50311273001]

Inventors
THOMAS STEWART MC KECHNIE, c/o INT. OCTROOIBUREAU B.V. Prof. Holstlaan 6, NL-5656 AA Eindhoven, Netherlands [ADP No. 56073653001]

JILL FORER GOLDENBERG, c/o INT. OCTROOIBUREAU B.V. Prof. Holstlaan 6, NL-5656 AA Eindhoven, Netherlands [ADP No. 56073661001]

Classified to
G03B

Address for Service
R J BOXALL, PHILIPS ELECTRONICS, Patents and Trade Marks Dept, Philips House, 1-19 Torrington Place, LONDON, WC1E 7HD, United Kingdom [ADP No. 00974790004]

EPO Representative
RUDOLF JOHANNES PETERS, INTERNATIONAAL OCTROOIBUREAU B.V. Prof. Holstlaan 6, NL-5656 AA Eindhoven, Netherlands [ADP No. 50079953001]

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11.04.1994 Notification of change of Address For Service name and address of R J BOXALL, PHILIPS ELECTRONICS, Patents and Trade Marks Dept, Philips House, 1-19 Torrington Place, LONDON, WC1E 7HD, United Kingdom [ADP No. 00974790004]
to
PHILIPS ELECTRONICS, Patents and Trade Marks Department, Cross Oak Lane, REDHILL, Surrey, RH1 5HA, United Kingdom [ADP No. 00658492006]
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N.V. PHILIPS' GLOEILAMPENFABRIEKEN, Groenewoudseweg 1, NL-5621 BA
Eindhoven, Netherlands [ADP No. 50311273001]
to
PHILIPS ELECTRONICS N.V., Incorporated in the Netherlands, Address see ☞
Groenewoudseweg 1, 5621 Ba Eindhoven, Netherlands
[ADP No. 06363782001]
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Philips Electronics N V, Incorporated in the Netherlands,
Groenewoudseweg 1, 5621 Ba Eindhoven, Netherlands

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