

PATENT SPECIFICATION

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(54) MANUFACTURE OF MASTERS FOR RADIATION REDISTRIBUTING DEVICES, AND FABRICATION OF SUCH DEVICES THEREFROM

(71) We, EASTMAN KODAK COMPANY, a Company organized under the laws of the State of New Jersey, United States of America of 343 State Street, Rochester, New York 14650, United States of America do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to the manufacture of masters for radiation redistributive devices such as projection screens of the type which comprise a plurality of optical microelements, each of which is specially contoured for redistributing image flux into a predefined field of observation, and to the fabrication of such devices therefrom.

Heretofore, a wide variety of projection screen surfaces has been proposed to achieve such features as a definitely controllable field of observation, constant image luminance throughout such field of observation, high efficiency due to a definite separation of the field of observation from the environmental field and due to minimum absorption of image light at the screen surface, and a favourable rejection of light impinging on the screen from extraneous sources.

To provide a definitely controllable field of observation, screen surfaces have been proposed which comprise a plurality of contiguous optical microelements, each being precisely contoured to redistribute image flux incident thereon only throughout a pre-defined solid audience angle.

To fabricate projection screen surfaces of the above type economically, it is common to first produce a screen master from which other screens can be subsequently replicated, such as by stamping, pressing, injection moulding, etc.. Cutting of the de-

sired contours in the master is facilitated by selecting a readily workable material, such as plastics material, for use as the master surface wherein the contours are initially cut. Normally, during the master cutting operation, the cutting edge or profile of the cutting tool gradually deteriorates, accumulating minute nicks and burrs as it cuts. The results of such deterioration are striations and other imperfections in the master surface which are reproduced in all screens replicated from such master. These imperfections, of course, have an adverse effect on screen efficiency, scattering image flux outside the field of observation through which the optical microelements were designed to redistribute image flux. Moreover, in cutting the screen master by conventional techniques, the master surface commonly exhibits a streaky appearance and undesirable colour banding due to the orderly arrangement of microelements in rectilinear parallel rows which resemble the appearance of, as well as produce the effect of, a diffraction grating.

Now, by means of the present invention, there is provided a method for treating projection screen masters, prior to use in a projection screen replication process, so as to remove or otherwise minimize the effect of imperfections in the master, and to substantially enhance the aesthetic value of projection screen surfaces replicated from such master. It has been found that by subjecting the screen master to a solvent in which the master surface is soluble, for a time and at a temperature sufficient to liquify its surface only, scatter-producing imperfections will be blended into the master surface and thereby be substantially eliminated, and cusp lines will be smoothed out or rounded off, thereby enhancing the appearance of the screen surface. Also, it has been found that this treatment can be used in a controlled man-

ner to alter the surface contour of the microelements, rendering the microelements more directional and, hence, efficient.

In accordance with one aspect of the present invention there is provided; in the manufacture of a master for a radiation redistributive device having a series of equally spaced rectilinear grooves defining a plurality of optical micro-elements of a size that is beyond the resolution of the closest intended viewer of the device, the micro-elements being contoured to redistribute incident radiation throughout a predetermined solid angle, and the device-forming surface of the master being of plastics material and having been formed by cutting appropriate grooves therein; the step of subjecting the said cut surface of the master to an ambient temperature and pressure atmosphere containing a vapour of a solvent for the said surface for a predetermined time just to liquify the said surface so as to reduce surface blemishes and other minute light-scattering imperfections on the surface of the grooves in a device reproduced from the master without undesirably impairing the radiation redistributing properties of these grooves.

The method of the invention can also include the step of cutting with a stylus the said grooves in the master before subjecting this surface to the said atmosphere.

The said appropriate grooves in the master may be cut so that the microelements of the device produced therefrom are contoured to redistribute incident light into a first predetermined audience angle, the subjecting of the cut surface to the said atmosphere modifying the said appropriate grooves so that a device reproduced from the modified master redistributes similar incident light into a second predetermined audience angle which is smaller than the said first predetermined audience angle.

The invention also comprises a radiation redistributive device fabricated using such a master, and a master manufactured by the method described.

A description of a preferred embodiment will now be given by way of example, reference being made to the accompanying drawing which presents goniophotometric graphs characteristic of two projection screen surfaces, one screen being replicated from a plastic master prior to treatment in accordance with the present invention, the other screen being replicated from the master subsequent to such treatment.

A method for fabricating a master from which projection screens and other radiation redistributive devices can be replicated is disclosed and claimed in the

Patent Application No. 22242/75 (Serial

No. 1,421,139). Briefly, such a method comprises the steps of moving a workpiece, such as a cellulose acetate-coated aluminium plate at a constant linear velocity, past the cutting stylus of a conventional sound recording head in a series of equally-spaced parallel traverses so as to cut a series of contiguous rectilinear grooves in the acetate coating of the workpiece. The cutting profile of the stylus is contoured to produce a desired transverse cross-section of cut, such cross-section being such as to control the redistribution of projected image light throughout a predefined viewing angle in the transverse plane. During the cutting operation, an electrical signal is applied to the recording head whereby the cutting position of the stylus is modulated in a direction perpendicular to the acetate coating. In this manner, periodic undulations in the groove depth are produced, such undulations having a profile proportional to the wave-form of the modulating signal. As the groove depth undulates along the groove length, a row of optical microelements is defined, the microelements alternating from convex to concave in shape. Redistribution of image light in the longitudinal plane (i.e., a plane perpendicular to the transverse plane) is controlled by the longitudinal cross-section of the grooves or individual microelements, such cross section depending, of course, upon the wave-form of the modulating signal.

To replicate positive projection screens from the screen master, it is first necessary to produce a negative matrix of the master. This may be done by simply affixing side walls about the periphery of the acetate coating of the master and pouring a mixture of silicone rubber (such as that identified by Type RTV 60 and sold by General Electric Company, U.S.A.) and a catalyst over the acetate coating. After the mixture has cured, a silicone rubber negative matrix of the master is formed which, upon being separated from the acetate coating of the master, can be used to cast positive projection screens in a resinous material or the like. To produce front projection screens, the resinous casting is simply aluminium-plated.

In a typical projection screen of this kind, the width of the microelements (i.e., the groove width) is approximately 0.002 inch. The length of each microelement (i.e., one-half of the spacial frequency of groove depth undulation) is comparable to the microelement width. By design, each microelement on the projection screen surface is sufficiently small as to be beyond the resolution limit of the closest intended viewer.

Screens manufactured in accordance with

the above process may exhibit a streaky appearance due to the visible groove structure. Also, it is common for such screens to exhibit so-called "beauty defects" which, in the case of the photographed sample, are manifested in the form of a series of unequally-spaced light streaks which extend parallel to the grooves. Such streaks are commonly the result of uncontrollable variations in the groove-cutting rate, the spacing between adjacent grooves, the signal used to modulate the cutting stylus, etc.

The grooves of such screens contain striations and other light scattering imperfections which adversely affect the efficiency and directionality of the screen. Such imperfections are present in the surface of the acetate master, being reproduced in all screens replicated from such master. It is believed that these imperfections result from the gradual deterioration of the cutting stylus during the cutting of the master.

In the drawing, to which reference should now be made, curve A represents a photometric evaluation of the screen discussed above, illustrating the screen luminance as a function of audience or viewing angle. As is apparent, considerable energy is redistributed by the screen surface at high angles. Assuming the intended viewing audience normally occupies a region bounded by viewing angles of less than ± 20 degrees (measured from a normal to the screen surface), image light which is redistributed outside these audience angles represents optical losses.

Now, in accordance with the present invention it has been found that by subjecting the plastics surface of a projection screen master to a saturated atmosphere of solvent vapour (i.e., the vapour of a material wherein the plastics surface is soluble) for a time sufficient just to liquify the master surface, the light-distributing properties of the master surface, as well as all projection screens replicated therefrom, can be controllably enhanced. Moreover, it has been found that such vapour treatment tends to eliminate beauty defects in the master surface and convert its originally streaky appearance to a substantially unstructured and lustrous surface which exhibits substantially no colour-banding.

A portion of a front projection screen replicated from a master which underwent a vapour treatment in accordance with the invention prior to being used in a projection screen replication process will now be described. A substantial reduction is apparent in the appearance of groove structure and the virtual elimination of the aforementioned "beauty defects". A photometric evaluation of this screen is re-

presented by the goniophotometric curve B in the drawing. As is apparent from this curve, high angle light scattering is markedly reduced, and the peak luminance of the screen is substantially enhanced. It is also apparent that the audience angle throughout which the screen luminance is relatively high is reduced by the vapour treatment of the invention. Thus, if an ultimate audience angle of say ± 20 degrees were desired, then it would be necessary to design the cutting profile of the cutting stylus (or the wave-form of the stylus-modulating signal) such as to produce microelements which would redistribute incident light throughout a greater audience angle, thereby allowing for shrinkage by the subsequent vapour treatment of the master.

The invention is further described by the following examples which relate respectively to the unimproved master and to the improved master.

Example 1

A projection screen master was produced from an acetate-coated workpiece in the manner set forth hereinabove. The workpiece was circular in shape, having a 12-inch diameter. A negative matrix of the master was prepared by surrounding the periphery of the workpiece with a plastics sidewall, thereby forming a mould. Two pounds of General Electric Company, U.S.A. RTV-60 silicone rubber was mixed with a catalyst. Upon degassing this mixture, it was poured into the mould. A heavy plate was placed on the mould to squeeze out the excess silicone rubber mixture. After standing for 20 hours under the heat provided by a 100 watt lamp positioned six inches above the silicone rubber mixture, the cured silicone rubber was removed from the mould and trimmed to form a negative matrix of the master. Upon affixing a sidewall about the negative matrix, a clear mixture of 100 grams of Maraglas Epoxy Resin No. 655 (manufactured by Marblette Corporation, U.S.A.), and 7 grams of hardener, was poured over the negative matrix. Upon curing, the resinous casting was removed and aluminium plated to form a front projection screen. Goniophotometric tests of such screen conducted in a plane perpendicular to the groove length resulted in curve A of the drawing.

Example 2

The projection screen master of Example 1 was placed in an airtight chamber approximately 12.25 inches in diameter and 3.25 inches in depth. Liquid acetone was placed in a beaker in the upper part of the chamber. This beaker was arranged so that the vapour from the acetone could flow freely and saturate the unoccupied space in

the chamber. After approximately two hours, the master was removed from the chamber and allowed to stand for approximately 19 hours in an area with forced ventilation. A negative matrix was then produced therefrom by the procedure set forth in Example 1. A resinous projection screen having an aluminized front surface was then replicated from the negative matrix by the same procedure as described in Example 1.

A photometric evaluation of this surface in a plane perpendicular to the groove length resulted in the goniophotometric curve B in the drawing.

From the foregoing it is apparent that a relatively simple and economical method has been provided for improving the aesthetic appearance of plastic projection screen masters (as well as the screens replicated therefrom) and for controllably altering the light-redistribution pattern thereof.

By simply increasing the vapour treatment time, the audience angle throughout which incident light is redistributed can be reduced, the peak luminance of the screen increased, and the fall-off of luminance with increasing audience angle made sharper or steeper. Moreover, increasing the vapour treatment time results in less noticeable groove structure in the master (and screen) surface, as well as fewer "beauty defects".

Also, it should be apparent that the process disclosed herein has considerable utility outside the projection screen manufacturing art. For instance, in the manufacture of masters for reflective signs both for traffic control and for refractive lighting fixtures (e.g., used in street and home lighting), light redistributing optical elements are sometimes formed in a plastics or other soluble material. The vapour treatment of the invention would have utility in enhancing the directionality of such devices or otherwise altering the light-redistribution pattern thereof.

This invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the scope of the appended claims.

WHAT WE CLAIM IS:—

1. In the manufacture of a master for a radiation redistributive device having a series of equally spaced rectilinear grooves defining a plurality of optical micro-elements of a size that is beyond the resolution of the closest intended viewer of the device, the micro-elements being contoured to redistribute incident radiation

throughout a predetermined solid angle, and the device-forming surface of the master being of plastics material and having been formed by cutting appropriate grooves therein; the step of subjecting the said cut surface of the master to an ambient temperature and pressure atmosphere containing a vapour of a solvent for the said surface for a predetermined time just to liquify the said surface and thereby reduce surface blemishes and other minute light-scattering imperfections on the surface of the grooves in a device reproduced from the master without undesirably impairing the radiation redistributing properties of these grooves.

2. In the manufacture of a master as claimed in Claim 1, the step of cutting with a stylus the said appropriate grooves in the device-forming surface of the master before subjecting this surface to the said atmosphere.

3. In the manufacture of a master, as claimed in Claim 2, wherein the said appropriate grooves are cut so that the micro-elements of the device produced therefrom are contoured to redistribute incident light into a first predetermined audience angle, and wherein the subjecting of the cut surface to the said atmosphere modifies the said appropriate grooves so that a device reproduced from the modified master redistributes similar incident light into a second predetermined audience angle which is smaller than the said first predetermined audience angle.

4. In the manufacture of a master as claimed in any preceding claim, the device-forming surface being an acetate coating, the use of acetone as the said solvent.

5. A radiation redistributive device, in the form of a projection screen, fabricated using a master manufactured in accordance with any of Claims 1, 2, 3 and 4.

6. A radiation redistributive device fabricated using a master manufactured in accordance with any one of Claims 1, 2, 3 and 4, a negative matrix having been formed from the master, and the radiating redistributive device being a positive reproduction of the master formed from the negative matrix.

7. The manufacture of a master for a radiation redistributive device, using a modifying treatment for a cut, device-forming, surface of the master, substantially as hereinbefore described.

8. A master for a radiation redistributive device manufactured in accordance with Claim 1, substantially as hereinbefore described.

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the chamber. After approximately two hours, the master was removed from the chamber and allowed to stand for approximately 19 hours in an area with forced ventilation. A negative matrix was then produced therefrom by the procedure set forth in Example 1. A resinous projection screen having an aluminized front surface was then replicated from the negative matrix by the same procedure as described in Example 1.

A photometric evaluation of this surface in a plane perpendicular to the groove length resulted in the goniophotometric curve B in the drawing.

From the foregoing it is apparent that a relatively simple and economical method has been provided for improving the aesthetic appearance of plastic projection screen masters (as well as the screens replicated therefrom) and for controllably altering the light-redistribution pattern thereof.

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Also, it should be apparent that the process disclosed herein has considerable utility outside the projection screen manufacturing art. For instance, in the manufacture of masters for reflective signs both for traffic control and for refractive lighting fixtures (e.g., used in street and home lighting), light redistributing optical elements are sometimes formed in a plastics or other soluble material. The vapour treatment of the invention would have utility in enhancing the directionality of such devices or otherwise altering the light-redistribution pattern thereof.

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3. In the manufacture of a master, as claimed in Claim 2, wherein the said appropriate grooves are cut so that the micro-elements of the device produced therefrom are contoured to redistribute incident light into a first predetermined audience angle, and wherein the subjecting of the cut surface to the said atmosphere modifies the said appropriate grooves so that a device reproduced from the modified master redistributes similar incident light into a second predetermined audience angle which is smaller than the said first predetermined audience angle.

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