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SEARCHROOM

April 10, 1956 R. GOETHERT 2,741,157

ANTI-REFLECTIVE COATING FOR COLOR FILTERS

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FIG. 1.

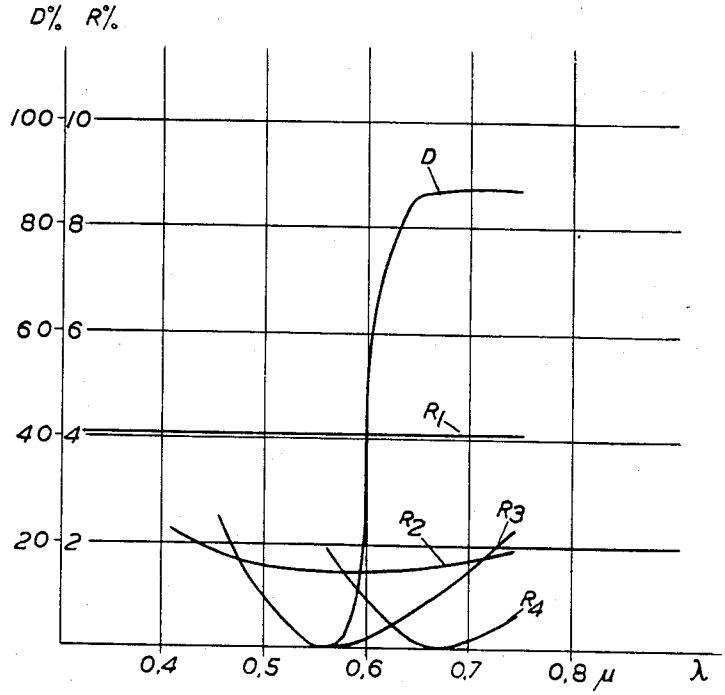
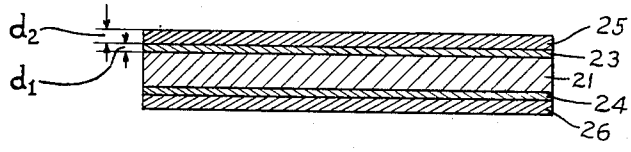


FIG. 10.



Rudolf Goethert
INVENTOR,

BY Charles Shepard
ATTORNEY

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FIG. 2.

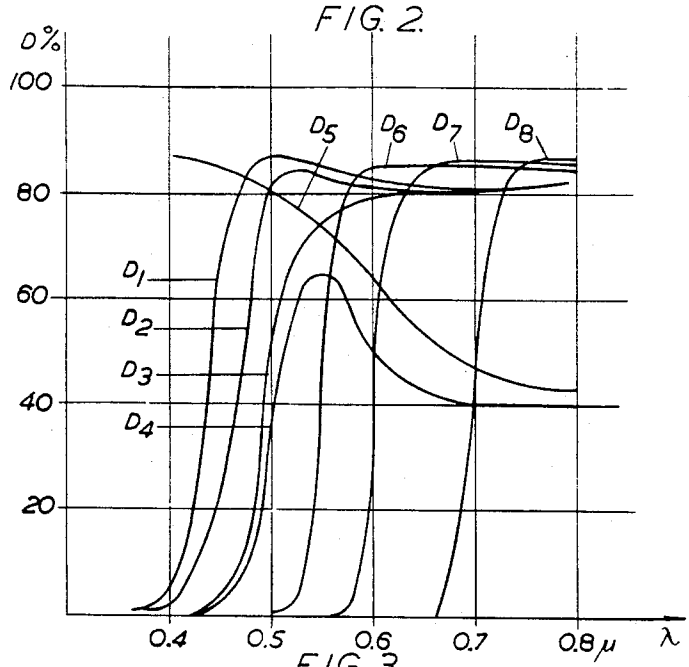
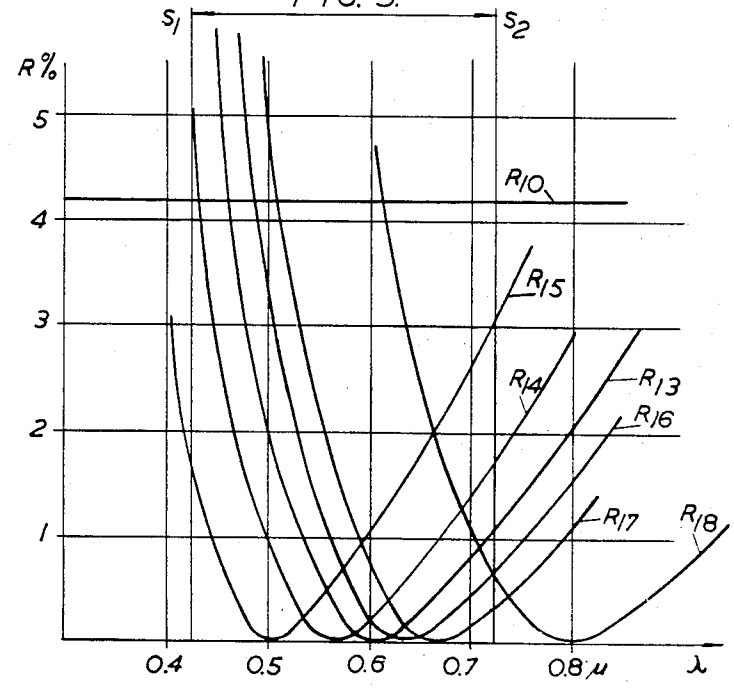


FIG. 3.



INVENTOR,
Rudolf Goethert
BY Charles Shepard
ATTORNEY

April 10, 1956 R. GOETHERT 2,741,157

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FIG. 4.

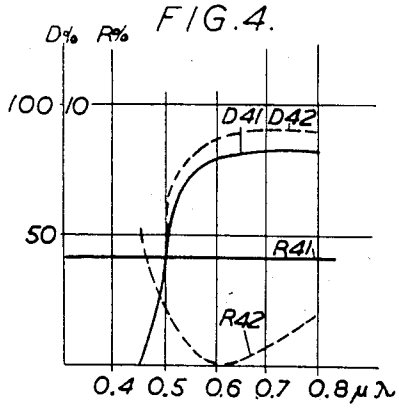


FIG. 5.

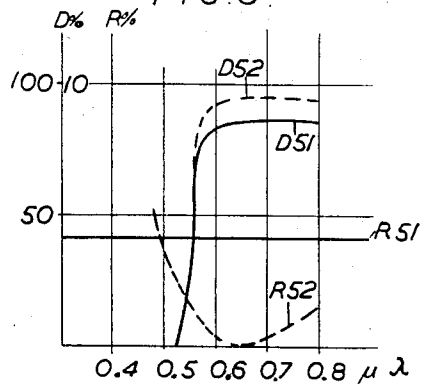


FIG. 6.

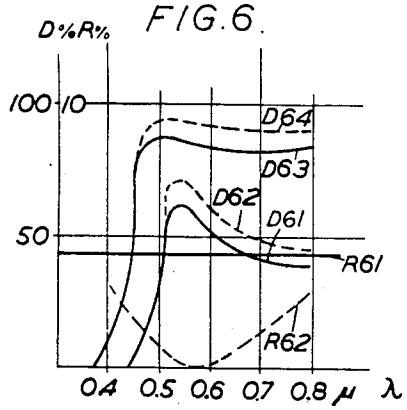


FIG. 7.

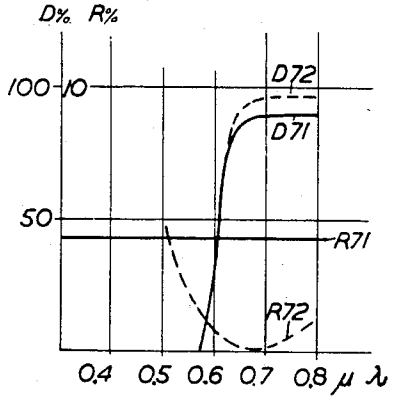


FIG. 8.

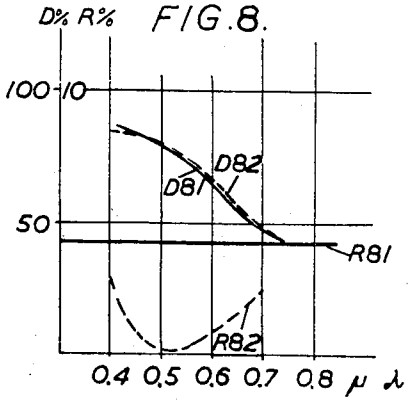
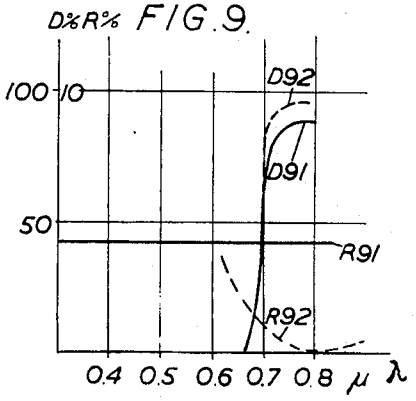


FIG. 9.



INVENTOR,
Rudolf Goethert
BY Charles Shepard
ATTORNEY

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ANTI-REFLECTIVE COATING FOR COLOR FILTERS

Rudolf Goethert, Braunschweig-Mascherode, Germany, assignor to Franke & Heidecke, Fabrik Photographischer Prazisions-Apparate, Braunschweig, Germany, a firm of Germany

Application December 5, 1952, Serial No. 324,211

Claims priority, application Germany December 8, 1951

2 Claims. (Cl. 88—112)

The present invention relates to anti-reflective coatings on color filters for photographic and similar purposes, and to the method of applying such coating. An object of the invention is the provision of improved coatings of this character, and an improved method for applying such coatings.

Another object is the provision of coatings which will provide greater transmission and less reflection of light in the desired wave lengths, than prior coatings.

These and other desirable objects may be attained in the manner disclosed as an illustrative embodiment of the invention in the following description and in the accompanying drawings forming a part hereof, in which:

Fig. 1 is a graph illustrating certain reflection characteristics and transmission characteristics of red filters when uncoated, coated according to prior practice, and coated according to the present invention;

Fig. 2 is a graph showing the transmission characteristics of various commercial color filters when treated according to the present invention;

Fig. 3 is a graph showing the reflection characteristics of some of the filters referred to in Fig. 2;

Fig. 4 to 9, inclusive, are graphs illustrating the improvements attainable in transmission and reflection characteristics of various color filters when treated according to the prior art and according to the present invention, respectively; and

Fig. 10 is an enlarged diagrammatic section through a color filter in accordance with the invention.

The same reference numerals throughout the several views indicate the same parts.

The coating of glass surfaces of lenses and color filters for photographic and similar purposes, by cathode sputtering and by vaporization, are already known. However, according to the present invention, by the selection of the proper materials for the coatings and the selection of certain thicknesses for the coatings, the results heretofore attained are much improved.

When using a glass of the kind customarily used in making a photographic color filter, that is, a glass having a low refractive index of about 1.52, it is found that for each glass-air separation surface there will be a reflection factor of about 4.2%, which is substantially independent of the wave length of the light. When such surfaces are improved according to the prior art by a vaporized single coating having sufficient resistance to rubbing or abrasion, there are still residual reflections of about 1.5% to 2%, the dependence on wave length of the light being comparatively small. These relationships are illustrated in part in the graph constituting Fig. 1, in which the horizontal scale indicates wave lengths and one of the vertical scales indicates percent of transmission D, while the other vertical scale indicates percent of reflection R. The line R_1 shows the approximately 4.2% reflection at the surface of untreated filter glass. The curve R_2 shows the reflection characteristics of a normal red filter treated with a single coating according to the prior art. The curve R_3 shows the reflection

characteristics for the same normal red filter treated with a double coating according to the prior art. The curve R_4 shows the reflection characteristics of the same red filter treated according to the present invention and indicates clearly that the wave length of the light band having minimum reflection has been shifted to the right, that is, to a higher wave length in the optimum range where a red filter should have its best transmission. The curve D shows the transmission characteristics of the red filter in accordance with the present invention.

This improved result is attained, according to the present invention, by applying to the glass two coatings, first an undercoating of tantalum oxide, and over it a second coating of magnesium fluoride, both coatings being applied in a vacuum by the known processes of vaporization or cathode sputtering, with thicknesses varying according to the wave length which corresponds approximately to the center of the range of the visible or photographically active light which is to be transmitted by the color filter in question. The first or tantalum oxide coating should have a thickness of $\frac{5}{64}$ of the wave length in question divided by the index of refraction of tantalum oxide. The second or magnesium fluoride coating should have a thickness of approximately $\frac{5}{16}$ of the wave length in question divided by the index of refraction of magnesium fluoride.

Expressing these relationships by means of a formula, it may be written as

$$d_1=\frac{5}{64}\cdot\frac{\lambda}{n_1}$$

and

$$d_2=\frac{5}{16}\cdot\frac{\lambda}{n_2}$$

where d_1 is the thickness of the first or tantalum oxide coating and n_1 is the index of refraction thereof, d_2 is the thickness of the second or magnesium fluoride coating and n_2 is the index of refraction thereof, and λ is the wave-length which corresponds to approximately the center of the range of the visible or photographically active spectral range intended to be transmitted by the color filter in question. This range may be hereafter referred to for convenience as the "desired range" or "desired spectral range" of the light.

A diagrammatic enlarged cross-section through a filter in accordance with the present invention is shown in Fig. 10, wherein **21** is the filter glass, **23** and **24** are the first or tantalum oxide coatings on the opposite faces of the filter glass, each having a thickness of d_1, and **25** and **26** are the second or overlying coatings of magnesium fluoride on opposite faces of the filter, each having a thickness of d_2.

The externally visible color of coatings applied according to the present invention, is somewhat different from filters coated according to the prior art. For example, when a blue filter is treated according to the present invention the coating gives the appearance of yellow-brown. A green filter treated according to the present invention has a coating which appears to be of a violet color. A red filter according to the present invention has a coating which has a blue-green appearance.

Referring now to Fig. 2, there are here illustrated the transmission characteristics of various commercial color filters when treated according to the present invention. The horizontal scale indicates wave lengths. The vertical scale indicates percent of transmission or D. The individual curves respectively indicate the percent transmission at different wave lengths of the different filters.

Fig. 3 is a somewhat similar graph in which the horizontal scale again indicates wave length, while the vertical scale indicates percent of reflection or R. The indi-

vidual curves again indicate the reflection characteristics of various commercial color filters treated according to the present invention, with respect to reflection of light waves of different wave lengths. The curves in Fig. 2 are each indicated by the letter D followed by an identifying number, while the curves in Fig. 3 are each indicated by the letter R followed by an identifying number. These identifying numbers following the letters D or R in Figs. 2 and 3 are used to indicate the following:

1	Ultra violet filter.
2	Light yellow filter.
3 and 13	Medium yellow filter.
4 and 14	Green filter.
5 and 15	Blue filter.
6 and 16	Orange filter.
7 and 17	Red filter.
8 and 18	Infra-red filter.
10	Uncoated glass.

It will be noted from Fig. 3 that near the ends of the curves the coatings of the present invention give very strong reflections, even exceeding those of untreated glass. However, this is not detrimental because these strong reflections occur outside of the desired spectral range which is intended to be transmitted by these particular filters to which the curves relate. Therefore, these strong reflections do not exist in practice.

Referring now to Figs. 4 to 9, there are here shown the improvements attainable in practice in the transmission and reflection characteristics of various color filters treated according to the present invention, as compared with uncoated filters. Fig. 4 shows the characteristics for yellow filters, Fig. 5 for orange filters, Fig. 6 for ultra-violet and green filters, Fig. 7 for red filters, Fig. 8 for blue filters, and Fig. 9 for infra-red filters. In each of these figures, the horizontal scale indicates wave length, the vertical scale indicates percent of transmission D and percent of reflection R, and the heavy horizontal line R41, R51, R61, etc., indicates the normal reflection of approximately 4.2% occurring at the glass-air surface of normal uncoated filter glass. The heavy line curves D41, D51, D61, etc., indicate the normal transmission characteristics of the color filters of the respective kinds above indicated, when uncoated, while the corresponding broken line curves D42, D52, D62, etc., indicate the transmission characteristics when the same filters are coated according to the present invention.

In Fig. 6, which includes the transmission characteristics of two filters in a single graph, the curves D61 and D62 refer to green filters, while the curves D63 and D64 refer to ultra-violet filters.

The broken line curves R42, R52, R62, etc., in each case refer to the reflection characteristics of the respective filters, when the glass surfaces thereof are treated according to the present invention. In Fig. 6, the curve R62 refers to the green filter.

In all of the various graphs, it will be seen that a very considerable improvement in transmission is attained when the filters are treated according to the present invention. The data for drawing the various curves have been obtained from measurements made with a Pulfrich photometer or with interference filters and photoelectric cells. The optimum thickness of the coatings as above disclosed was ascertained by theoretical calculations and confirmed by systematic series of experiments.

As mentioned above, the preferred material for the

first or undercoating layer is tantalum oxide, and the preferred material for the second or overlying layer is magnesium fluoride. Although these are the preferred materials, according to the present invention, other materials can be used, and it is within the scope of the invention to use other materials. It is preferred that the first coating (next to the glass) shall have a higher index of refraction and the second or outer coating a lower index of refraction. The formulas above given include the index of refraction of each coating, and so will indicate the proper thickness of coatings of any material known in the art as a suitable glass coating material.

It is seen from the foregoing disclosure that the above mentioned objects of the invention are well fulfilled. It is to be understood that the foregoing disclosure is given by way of illustrative example only, rather than by way of limitation, and that without departing from the invention, the details may be varied within the scope of the appended claims.

What is claimed is:

1. As a new article of manufacture, an anti-reflective color filter for photographic purposes comprising a glass plate color filter having on an air-exposed surface thereof an anti-reflection coating of two layers, the layer next to the glass being composed essentially of tantalum oxide having approximately the thickness indicated by the expression

$$d_1=\frac{5}{64}\cdot\frac{\lambda}{n_1}$$

and the layer farther from the glass being composed essentially of magnesium fluoride having approximately the thickness indicated by the expression

$$d_2=\frac{5}{16}\cdot\frac{\lambda}{n_2}$$

wherein

d_1=thickness of the tantalum oxide layer
d_2=thickness of the magnesium fluoride layer
n_1=index of refraction of the tantalum oxide layer
n_2=index of refraction of the magnesium fluoride layer
λ=wave length which corresponds approximately to the center of the range of the visible or photographically active spectral range intended to be transmitted by the filter, the curve of reflection of said color filter having a low point of substantially zero reflection substantially in the center of the range of light intended to be transmitted by the filter.

2. A filter as defined in claim 1, having an anti-reflective coating of the same kind on the opposite side of the glass plate color filter.

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