ABSTRACT: Durable first surface silver reflector having a layer of silver which is undercoated and overcoated in such a manner as to give the layer excellent adhesion to the substrate and which is also provided with a multilayer dielectric coating to give the coating an ability to withstand high humidity salt spray and the like.
DURABLE FIRST SURFACE SILVER HIGH REFLECTOR

BACKGROUND OF THE INVENTION

Heretofore silver has been utilized as a reflector but it has suffered from severe environmental limitations. For example, the adhesion to the substrate has been very poor and the silver coating was easily scratched so that it was virtually uncleanable. In addition, in a humid atmosphere, such a coating was found to oxidize with a consequent loss in reflectivity. The use of overcoatings in such situations has not been satisfactory because such overcoatings, when thick, have been found to give rise to poor adhesion and when relatively thin, serving to give little protection to oxidation in a humid atmosphere.

There is, therefore, a need for a new and improved silver reflector.

SUMMARY OF THE INVENTION AND OBJECTS

The durable first surface silver high reflector consists of a substrate which has a first surface. An adhesion layer is deposited on the first surface. A layer of silver is deposited on the adhesion layer and is of a sufficient thickness so that it is opaque to visible light. A multilayer dielectric coating is deposited over the silver layer and serves as a protective layer.

In general, it is an object of the present invention to provide a durable first surface silver high reflector which has excellent adhesion to the substrate and which has the ability to withstand abrasion, salt, fog and the like.

Another object of the invention is to provide a silver high reflector of the above character in which the silver layer has excellent adhesion to the substrate wherein the dielectric overcoating has excellent adhesion to the silver layer.

Another object of the invention is to provide a silver high reflector of the above character in which crazing or poor adhesion are not present.

Additional objects and features of the invention will appear from the following description in which the preferred embodiment is set forth in detail in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a cross-sectional view of a silver high reflector incorporating the present invention.

FIG. 2 is a curve showing the reflectivity of a silver high reflector incorporating the present invention.

BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in FIG. 1, the silver high reflector 11 consists of a substrate 12. The substrate 12 can be formed of suitable material such as metal, glass and the like. It is preferably formed of a rigid material. The substrate 12 is provided with a first surface 13. An adhesion layer 14 is deposited on the surface 13 in a conventional manner such as by evaporating the material in a vacuum. One material found to be particularly satisfactory is "Inconel" which is a chromium nickel alloy. Alternatively, it can be a material such as chromium. The principal characteristic for the adhesion layer 14 is that it be one to which silver will readily adhere. The thickness of the layer 14 is not critical and therefore, any desired thickness can be utilized. For example, it has been found that a physical thickness in the order of 50 millimicrons is adequate.

A layer 16 of silver is then deposited upon the adhesion layer 14 in a suitable manner such as by evaporating silver in a vacuum chamber. It has been found to obtain the best adhesion to the layer 14, that is desirable to bond or deposit the silver layer on the layer 14 while the layer 14 is still "fresh." By "fresh" is meant within a period of a few seconds after the coating has been deposited. In fact, it has been found that it is desirable to commence the evaporation of the layer 16 just prior to completion of the layer 14. Thus, in practice, it has been found that it is best to commence evaporation of the silver layer 16 immediately before or immediately upon conclusion of the evaporation of the material for making the layer 14. The silver layer 16 is evaporated to a thickness which is just sufficient to be opaque to visible light. The silver layer is quite soft and, therefore, it is desirable to keep the silver layer as thin as possible and still obtain the desired reflectivity.

It can be seen that the layer 14 serves as an undercoating for the silver layer 16 to secure firm adhesion of the silver layer to the substrate 12. An overcoating in the form of a layer 17 is deposited on the top side of the silver layer 16 and serves to bond a multilayer dielectric coating 18 to the silver layer 16.

The layer 17 is preferably formed of a very thin layer of a metal oxide. One material found to be particularly satisfactory is titanium monoxide evaporated in an oxygen atmosphere. However, other materials can be utilized such as zirconium oxide, cerium oxide, aluminum oxide and magnesium oxide, etc., or mixtures of these oxides. The layer 17 should be as thin as possible consistent with the requirement that it be a continuous layer. When this layer 17 becomes too thick, it absorbs energy and, therefore, causes a loss in reflectivity of the silver layer 16. The layer 17, in addition to serving as a bonding layer, serves as a moisture-resistant layer and, therefore, provides humidity protection to prevent oxidation of the silver layer.

The layer 18 is a multilayer dielectric coating which has been designed to provide a low residual stress. In order to provide such a coating, it has been found desirable to provide a plurality of layers which have a combined physical thickness ranging from 0.2 to 0.15 microns. By way of example, one such multilayer dielectric coating had the following design:

LHLHHL

in which the letter L stands for a layer formed of a low index material, and H stands for a layer formed of a high index material. Magnesium fluoride having an index of refraction of 1.38 was used for the low index material, and fused silica having an index of refraction of 1.46 was used for the high index material. These layers were deposited in a conventional manner in a vacuum chamber. Under normal deposition conditions, the magnesium fluoride layers assume internal tensile stresses and the fused silica layers assume internal compressive stresses. The net stresses of the obtained layers which form the multilayer dielectric coating 18 are sufficiently low so that the multilayer dielectric coating can be supported by the relatively weak silver layer 16.

The particular multilayer dielectric coating set forth above is also advantageous because it provides interference reinforcement of the silver reflectivity in the blue spectrum region (400-450 millimicrons).

It should be pointed out that use of high and low index materials for the multilayer dielectric coating is not particularly significant in and of itself. The principle characteristic for the two materials is that one material counterbalances the stresses in the other so that there is relatively little net stress placed on the silver coating 16. When the tensile and compressive forces of the two materials equalize each other, there is provided a strong multilayer dielectric coating. Each of the layers of the multilayer dielectric coating 18 has an optical thickness which is one-fourth of the design wavelength, or, in other words, has a thickness of approximately 0.4 microns quarter-wave optical thickness.

In making the multilayer dielectric coating 18, it is desirable that the total physical thickness of the fused silica be equal to or greater than that of magnesium fluoride. This is desirable because the tensile stresses in vacuum evaporated magnesium fluoride tend to be greater than the compressive stresses in fused silica and, therefore, in order to prevent crazing or poor adhesion it is desirable there be at least as much fused silica as magnesium fluoride.

A curve showing the results which can be obtained with a silver high reflector incorporating the present invention is shown in FIG. 2. Curve 21 shows the percent of reflectance
for a silver high reflector made in accordance with the present invention in comparison to a curve 22 for a conventional aluminum reflector with a silicon monoxide overcoat. As can be seen, the reflectivity of the silver high reflector is over 90 percent and consistently higher than the aluminum reflector throughout the entire wavelength range (400 millimicrons to 2½ microns) considered and at certain wavelengths by as much as 20 percent higher. The design wavelength for the silver high reflector shown in FIG. 2 was 400 millimicrons.

Although magnesium fluoride and fused silica have been disclosed as being useful for making the multilayer dielectric coating 18, other materials not quite as satisfactory may be utilized. For example, other forms of silicon dioxide can be used in place of the fused silica. In place of the magnesium fluoride, sapphire and possibly zirconium oxide can be utilized.

Another alternative arrangement for the multilayer dielectric coating 18 is to utilize a layer of magnesium fluoride followed by a thicker layer of silicon dioxide which is followed by another thin layer of magnesium fluoride. Such a coating had a design wavelength of 450 millimicrons and because it was reduced to three layers is of lower cost.

It can be seen that such a silver high reflector has many advantages. It has excellent reflectivity. In addition, it has substantial abrasion resistance. Also, it is capable of withstanding salt, fog and humidity tests without oxidizing the silver layer. The silver high reflector has excellent reflectivity in all regions of the spectrum. The coating is also one which can be produced relatively simply and inexpensively.

I claim:

1. In a durable first surface silver high reflector, a substrate having a first surface, a layer of silver of sufficient thickness so that it is substantially opaque to visible light, an adhesion layer deposited on said surface of said substrate and serving as an undercoat for said layer of silver to secure said layer of silver to said substrate, a multilayer dielectric coating carried by the substrate and overlying the silver layer and a substantially transparent bonding layer serving as an overcoat on said silver layer and serving to bond said multilayer dielectric coating to said silver layer.

2. A reflector as in claim 1 wherein said multilayer dielectric coating is formed of a plurality of layers, certain of said layers being formed of materials which exert compressive forces after they have been evaporated onto a surface and certain of the other layers being formed of a material which exerts tensile forces after it is evaporated onto a surface.

3. A reflector as in claim 3 wherein said multilayer dielectric coating has a thickness ranging from 0.2 to 0.6 microns.

4. A reflector as in claim 2 wherein said multilayer dielectric coating is formed of a plurality of layers arranged as LHLHHL in which the letter L represents a low index material and H represents a high index material, each of said layers having an optical thickness of approximately one-fourth of the design wavelength.

5. A reflector as in claim 2 wherein said multilayer dielectric coating is formed of a plurality of layers arranged as LH in which the letter L represents a low index material and H represents a high index material, each of the layers having an optical thickness approximately one-fourth of the design wavelength.

6. A reflector as in claim 2 wherein said multilayer dielectric coating consists of a plurality of layers designated as LHL in which the letter L represents a low index material and H represents a high index material, each of the layers having an optical thickness of approximately one-fourth of the design wavelength.

7. A reflector as in claim 1 wherein said adhesion layer is formed of a chromium nickel alloy.

8. A reflector as in claim 1 wherein said bonding layer is formed of a metal oxide.

9. A reflector as in claim 4 wherein said low index material is magnesium fluoride and said high index material is fused silica.

10. A reflector as in claim 1 wherein a multilayer dielectric coating is formed of at least two different materials in which one of the materials exerts compressive forces after evaporation and the other of said materials exerts tensile forces after evaporation and in which the layers are arranged so that the net stress is relatively low.

11. A reflector as in claim 10 wherein one of the materials is fused silica and the other material is magnesium fluoride and wherein the layers have a thickness so that the multilayer dielectric coating is formed of more fused silica than magnesium fluoride.

12. A reflector as in claim 11 where the reflectivity is over 90 percent from 400 millimicrons to 2½ microns.

13. A reflector as in claim 1 wherein said bonding layer is as thin as possible so that it absorbs substantially no energy consistent with the requirement that it be a continuous layer.

14. A reflector as in claim 8 wherein said metal oxide is an oxide of titanium which is as thin as possible so that it absorbs substantially no energy consistent with the requirement that it be a continuous layer.