Ophthalmic Antireflection Coatings with Same Residual Reflective Colors on the Ophthalmic Optics with Different Refractive Indices

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Abstract

In this paper the design and manufacture of ophthalmic multilayer broadband antireflection coatings with same residual reflective colors on the substrates for different refractive indices have been investigated. Someone need to dispense spectacles in which the two lenses are different optical materials with different refractive indices (e.g. n=1.75, n=1.52),and the residual reflective colors of the two lenses must remain the same. We designed triplelayer anti-reflection coatings on the substrates which have different refractive indices. The residual reflective colors of these coatings have the same color position in the CIE color chart and have almost the same average reflective brightness. Also, we have found that the quartz crystal thickness monitor is a good method for preparing the AR coatings.

1. Introduction

Antireflection (AR) coatings are used today on the surfaces of lenses and windows of almost all optical equipment. AR coatings exhibit characteristic reflection colours which influence the cosmetic appearance of the bearer of the spectacles and thus subject to fashion trends. In China, the most popular residual reflective color is green or green in different shades, the green color is the current fashion in China. Some people need to dispense spectacles that the two lenes are made from different optical glasses with different reflective indices and the residual reflective colors of the two lenses must remain the same green. We investigated different coating designs with three layers of different material combinations with respect to the above mentioned goals.

2. Coating Designs

Triple-layer broadband AR coatings, which are easily manufactured, offer the possibility to adjust the reflective color and reflective brightness of lense. We have designed several coating structures by the fast refining method[1] using personal computer. Figures, from 1 to 9, show the spectral refrectance curves of some kind of structures of three-layer AR coatings on the substrates with different refractive indices of 1.45, 1.52, 1.60 and 1.75, respectively.

The design commonly used for broadband AR coatings is the three-layer structure of $\lambda/4$-$\lambda/4$-$\lambda/4$, the thickness of outside layer one-quarter, middle layer one half and inside layer one-quarter wavelength. For the visibl region, the centre wavelength $\lambda = 520$nm. The coating material, used as the outside layer with low index, is MgF_2, the high-index coating as the middle layer is the composite mixture of TiO_2, ZrO_2[2] and the middle-index coating as the inside layer is Al_2O_3. Fig. 1 gives the theoritical spectralcurve of reflecetance in the region of 400nm—750nm. It waswell known that the designs for the common glass BK7 to reduce the reflectance in the visible region. Nevertheless, according to the computer simulation by statistical method and our experiment, the design has not good ratio of finished product for the spectacle lenses, because it was difficult to manufacture the coated lenses with the stable reflective colour, the slight errors of the layer thickness and refractive indices will change the residual reflective color of the coatings.

We have mentioned the fact that some people dispense the two spectacle lenses which made of different glass material with different refractive indices and they want that the colors and brightness of residual reflective light of these two lenses maintain the same. We also have noted the fact that the different people require the different brigtness of green colour from the reflection. For these purpose, we have designed aother structure triple layer broadbend AR coatings. That is $\lambda/4$-$\lambda/4$-$\lambda/4$, the thickness of every layer is one-quarter wavelength. For the broadband AR coating in visible region, the centre wavelength $\lambda = 520$nm. The coating material of the outside layer with low refractive index is MgF_2, the high-index material as the middle and inside layer is the composite mixtures of ZrO_2, TiO_2, Ta_2O_5, and Al_2O_3[2][3]. It is very convenient adjusting the refractive indices of middle and inside layer to maintain the same residual reflective color and same reflective brightness of coatings on the glasses with different indices.

The requirement of some people who want the appearent color not strong, that means we must make the antireflective effect obviousely. So in these designs, it can be seen that, in green region, the maxmum residual reflectance was controlled at the level arround 0.3—0.4% for all of four triple-layer designs with different substrates of 1.45, 1.52, 1.65 and 1.75 refractive indices, respectively, which was commonly used. Fig.2, 3, 4, 5 show us the theoretically calculated spectral curves of them.

Another group, also including four designs corresponding the substrates with different refractive indices mentioned above, has been designed. These designs fitted the requirements of other people who want the brightness of green colour some stronger. they also have the structure of $\lambda/4$-$\lambda/4$-$\lambda/4$, which can be easily manufactured and of course, the mixtural technique is also needed. Fig.6, 7, 8, 9 give us the calculated spectral curves which show us the residual reflectance is under 0.8% in the region of green.

The color and brightness of residual reflective of these coating have no discrimination. The experiment and computer simulation of these designs appeared that the last four designs (Design 6, 7, 8, 9) have larger manufacturing error tolerances.

3. Thickness Monitoring

In the deposition process of the triple-layer AR coatings, the film thickness was monitored by the quartz crystal oscillator positioned in the centre of the substrate holder The thickness errors were mainly caused by the unstability of the quartz oscillator and the fluctuation of condensed density of films induced by the fluctuation of the temperature, deposition rate and the residual pressure in vacuum chamber.

In the quartz crystal thickness monitor, we use a temperature frequency compensation system for stablizing the oscillator[4]. The deposition rate was controled by the quartz crystal monitor. Large area uniformity of temperature distribution was obtained by adjusting the positions of heaters. The temperature of substrates was precisely controled during the process of deposition. The fluctuation of the pressure in the vacuum chamber was reduced to 5% by an automatic valve. So, we can control the deposition process accurately, maintain refractive index of every layer reproductible and obtain the high accuracy of reflective color of AR coatings.

4. Conclusion

We have realized the mass production of the high qulity ophthalmic AR coatings with the same residual green color. Good color reproducibility on the different glasses can be reached with the coating that have higher residual reflectance (Design 6, 7, 8, 9). The quartz crystal thickness monitor method is excellent for preparing the AR coatings on the spectacle lenses. The stability of the vacuum deposition condition is important.

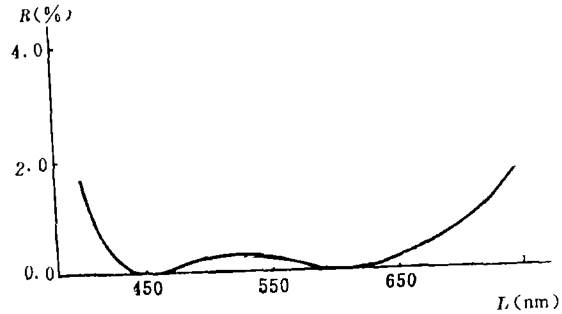

Fig.1 Reflectance vs wavelength of the triple-layer AR coating of(λ/4-λ/2-λ/4) structure

Layers	n	nd
$N_{med}=1$		
1	1.38	130
2	2.05	260
3	1.61	130
$N_{sub}=1.52$		

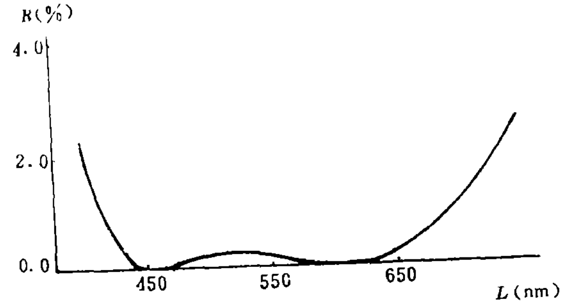

Fig.2 Reflectance vs wavelength of the triple-layer AR coating of (λ/4-λ/4-λ/4) structure

Layers	n	nd
$N_{med}=1$		
1	1.38	130
2	1.95	130
3	1.8	130
$N_{meb}=1.45$		

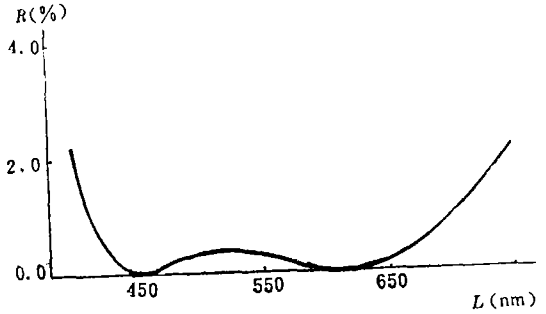

Fig.3 Reflectance vs wavelength of the triple-layer AR coating of (λ/4-λ/4-λ/4) structure

Layers	n	nd
$N_{med}=1$		
1	1.38	130
2	1.95	130
3	1.85	130
$N_{sab}=1.52$		

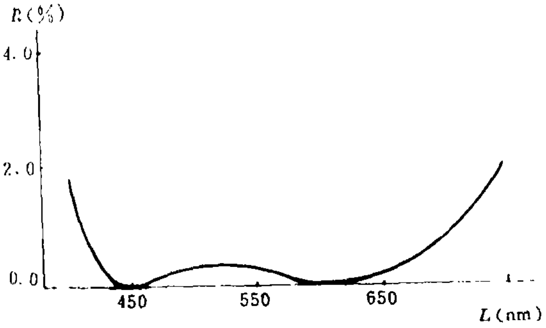

Fig.4 Reflectance vs wavelength of the triple-layer AR coating of (λ/4-λ/4-λ/4) structure.

Layers	n	nd
$N_{med}=1$		
1	1.38	130
2	1.97	130
3	1.92	130
$N_{sub}=1.6$		

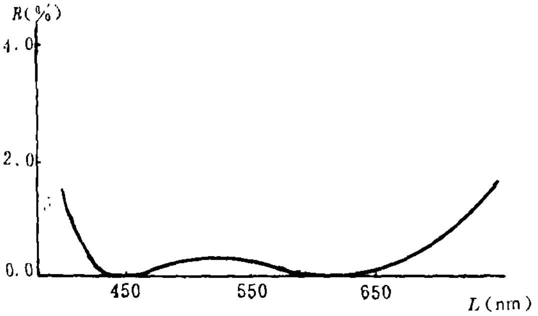

Fig.5 Reflectance vs wavelength of the triple-layer AR coating of (λ/4-λ/4-λ/4) structure

Layers	n	nd
$N_{med}=1$		
1	1.38	130
2	2	130
3	2.03	130
$N_{sub}=1.75$		

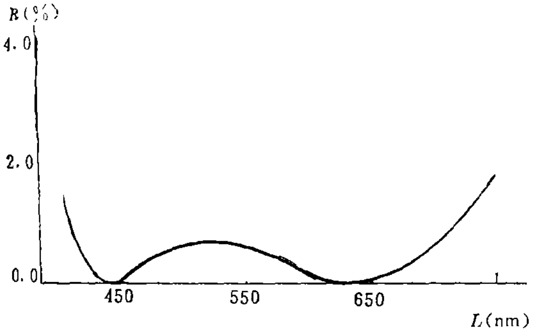

Fig.6 Reflectance vs wavelength of the triple-layer AR coating of (λ/4-λ/4-λ/4) structure

Layers	n	nd
$N_{med}=1$		
1	1.38	130
2	1.9	130
3	1.81	130
$N_{sub}=1.45$		

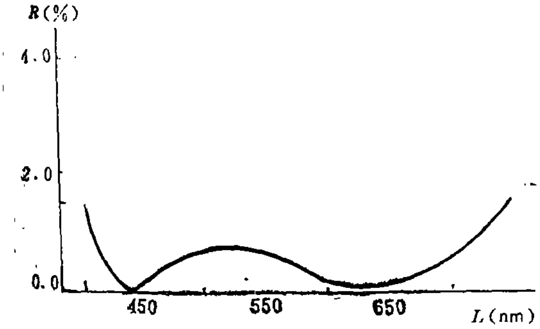

Fig.7 Reflectance vs wavelength of the triple-layer AR coating of (λ/4-λ/4-λ/4) structure

Layers	n	nd
$N_{med}=1$		
1	1.38	130
2	1.9	130
3	1.85	130
$N_{sub}=1.52$		

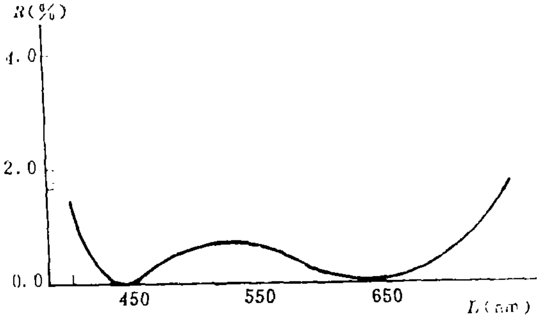

Fig.8 Reflectance vs wavelength of the triple-layer AR coating of (λ/4-λ/4-λ/4) structure

Layers	n	nd
$N_{med}=1$		
1	1.38	130
2	1.95	130
3	1.95	130
$N_{sub}=1.6$		

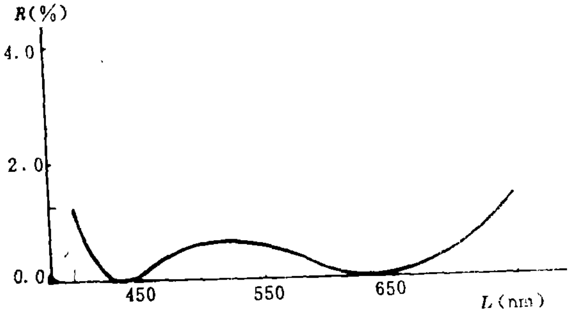

Fig.9 Reflectance vs wavelength of the triple-layer AR coating of (λ/4-λ/4-λ/4) structure

Layers	n	nd
$N_{med}=1$		
1	1.38	130
2	1.99	130
3	2.08	130
$N_{sub}=1.75$		

References

[1] Jin Tianfeng et al.; Chinese Quantum Electronics, 4, No.3, June 1987

[2] Qian Longshen; SPIE,1335,1990

[3] Jin Tianfeng et al.; ZrO_2-Y_2O_3 and HfO_2-Y_2O_3 composite coatings for high power UV laser applications, ISCO 90, Shanghai, China

[4] H.K.Pulker; «Coatings on Glass», Elsevier Science Publishers B.V.,1987

具有相同的残余反射颜色的眼镜片减反射膜

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摘要：针对不同折射率的眼镜片设计和研制备层宽带减反射膜，使其保持相同的残余反射颜色。有些人的双眼的曲光度相差较大，需要配带不同折射率的眼镜片，例如一只眼睛需配高折射率眼镜片$n=1.75$，即超薄片，而另一只眼睛需用普通眼镜片$n=1.52$，以保持两片镜片的曲率相差不太大。但是不同折射率的镜片的反光强弱有明显差别，通过表面镀膜处理使两眼镜片保持相同的残余反光，可以改善眼镜的外观。通过对三层宽带减反射膜结构进行研究，对不同折射率的基片设计相应的减反射膜膜系，保证这些镀层的残余反射光颜色在CIE色图上有相同的位置，残余反射光的强度也几乎相等。文中同时报导了膜层材料和制备方法，发现石英晶体监控是制备这些减反射膜膜厚控制的良好方法。