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Analysis of the Anti-Reflection Coated Eyeglass Used in Turkey

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Abstract

Worldwide, organic anti-reflective (AR) coated glasses constitute one of the largest areas in the industrial market. In our study, the analysis of the stages of anti-reflective glasses produced in our country and offered to eyeglass wearers was examined. Among the anti-reflective coating stages, the characterizations of hard coating, single surface and double surface coated glasses were investigated. High resolution Scanning Electron Microscope device (FESEM) was taken for the surface quality of the AR coatings of glasses, and absorption-transmittance measurements were taken for the optical quality of the glasses. The structure of the glass was analyzed with the X-ray diffraction device (XRD). Maximum light transmittance reaches 98.54% at 464 nm in double-sided AR coated glasses. Our study with the analysis of eyeglasses, which often have an important place in health and commercial areas in our country and in the world, will constitute an important reference for the manufacturer and consumer and will contribute to further studies.

Keywords: Anti-reflective coating, Eyeglass, FESEM, XRD, Absorption-Transmittance Spectrum.

Türkiye'de Kullanılan Antirefle Kaplamalı Gözlük Camlarının Analizi

Özet

Dünya çapında organik antirefle (AR) kaplamalı camlar, endüstriyel pazarın en büyük alanlarından birini oluşturmaktadır. Çalışmamızda ülkemizde üretilen ve gözlük kullanıcılarına sunulan antirefle kaplamalı camların aşamalarının analizleri incelenmiştir. Antirefle kaplama aşamalarından sert kaplama, tek yüzey ve çift yüzey kaplamalı *camların karakterizasyonları incelenmiştir. Camların AR kaplamalarının yüzey kalitesi için yüksek çözünürlüklü Taramalı Elektron Mikroskobu cihazı (FESEM), camların optiksel kalitesi için soğurma-geçirgenlik ölçümleri yapıldı. Camın yapısı X-Işını kırınım cihazı (XRD) ile analiz edildi. Çift tarafi AR kaplı camlarda maksimum ışık geçirgenliği 464 nm'de % 98,54'e ulaşmaktadır. Ülkemizde ve dünyada sıklıkla sağlık ve ticari alanlarda önemli yer tutan gözlük camlarının analizleri ile çalışmamız üretici ve tüketici için önemli bir referans oluşturacak ve daha ileri ki çalışmalara katkı sağlayacaktır.*

Anahtar Kelimeler: *Antirefle kaplama, Gözlük camı, FESEM, XRD, Soğurma-Geçirgenlik Spektrumu.*

1. Introduction

Considering that the rate of visual impairment is increasing day by day and users are becoming conscious (Gifford et al., 2019; Tadokoro et al., 2012), the industrial quality of eyeglasses remains in a great competition. Vision quality depends on the reflection, transmittance and surface quality of the lens (Flaxman et al., 2017; Wang et al., 2020; Wu et al., 2019).

In the ophthalmic industry, ophthalmic lenses are manufactured from glass or resin material. Resin lenses consist of small molecular units called monomers that are linked together to form a long chain known as polymers, and the process of linking monomers together is known as polymerization. Most high index resin lenses are made by a heat curing process. CR39 is a good example of a resin lens that allows superior optical properties. The refractive index of CR39 is 1.498 and its abbe value is 58 and it has started to replace mineral glasses in industry (Bhootra, 2009; Buyukyıldız, 2010)

CR39 lenses are optimized to provide material durability and excellent transmittance in the visible range from 400 to 800 nm. However, in CR39 lenses, abrasion-resistant hard coating and anti-reflection (AR) coatings are required to increase the surface and optical quality (Fardo et al., 2020; Samson, 1996; Schott, 2005). With AR coating, light transmittance is aimed by minimizing factors such as reflection and glare on the surface of the glass.

The aim of the study is to analyze the eyeglasses used in the field, which are the building blocks of the optical industry in our country and in the world, to create a reference for the manufacturer and the consumer, and to contribute to further studies. Accordingly, for the industrial quality analysis of CR39 glass in optical stores, characterizations were made at the AR uncoated and coating stages. Transmittance – absorption measurements, high resolution Scanning Electron Microscope (FESEM) and X-Ray diffraction device (XRD) analyzes were performed.

2. Materials and Methods

The surface images of the coated eyeglasses offered to eyeglass wearers in the optic store were taken with the Zeiss Ultra Plus model FESEM. The surface analysis of eyeglass lenses which were hard coated at 100°C for 3 hours, one side and two sides anti-reflective coated lenses were examined by FESEM. In order to obtain FESEM images, eyeglasses were coated with 30 nm gold (Au) at 50 mA for 2 minutes.

For the optical characterization of eyeglasses, absorption-transmittance measurements were taken by using 4802 UV/ VIS Dual Ray Spectrophotometer, the data were plotted in origin Pro 8 and graphics were created. For absorption and transmittance measurements, spectacle glass with hard coating at 100°C for 3 hours, uncoated eyeglass, one side AR coated eyeglass, two sides AR coated eyeglass analyzes were performed. XRD analyzes of the CR39 lenses were performed with a Bruker D8 Advance X-Ray diffraction device.

3. Findings and Discussion

The preliminary stage of AR coated CR39 glasses is hard coating at 100˚C. FESEM images of the hard coated CR39 glass are given in Figure 1.

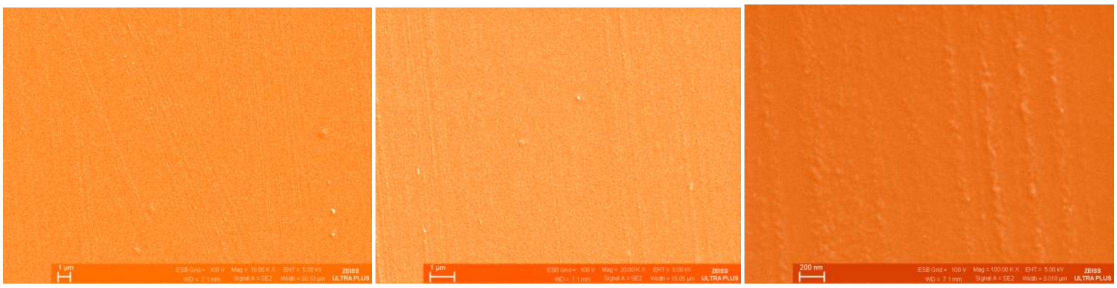
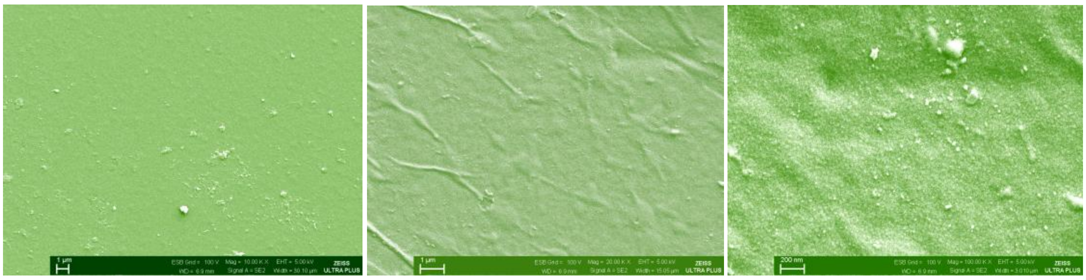


Figure 1. FESEM images of the hard-coated eyeglasses at 100˚C at 10,000; 20,000 and 100,000 magnifications respectively

When the FESEM images of the eyeglasses are examined at 10,000 and 20,000 magnifications (Figure 1), it is seen that the surfaces are quite smooth. At 100,000 magnifications, on the surface of the glass, parallel ridges are seen, originating from baking. The second stage of the eyeglass is to apply an AR coating to one surface. The FESEM images of the eyeglass with one surface coated with AR coating are shown in Figure 2.



(a) (b) (c)

Figure 2. FESEM image of an eyeglass with one side AR coating at (a) 10,000; (b) 20,000 and (c) 100,000 magnifications

When the surface of a single-surface AR coating eyeglass is examined (Figure 2a), it is seen that the surface is quite smooth, but contamination occurs on the surface. These impurities are caused by the cutter during the creation of small sized FESEM samples for glass analysis. When the FESEM image of the lens at 20,000 magnification is examined (Figure 2b), it is seen that there are spatial lines on the surface. When the surface image of the lens is increased to 100,000 magnifications (Figure 2c), it is seen that the lines on the surface are ruffles. It is seen that the parallel ridges in the hard-coated lenses at 100°C are replaced by ridges in clumps.

The third stage in AR eyeglass is the AR coating on the second surface of the glass. FESEM images of eyeglasses coated with antireflection on both sides are given in Figure 3.

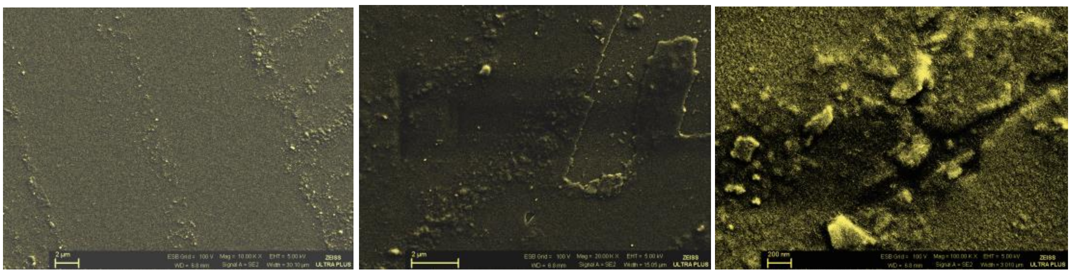


Figure 3. FESEM image of double-sided AR eyeglasses at (a) 10,000; (b) 20,000; (c) 100,000 magnifications

When the surface of double-sided AR lens are examined (Figure 3a,b), it can be said that the surface of double-sided AR coated lens is smoother than the surface of one-side AR-coated lens. However, it is seen that there are defects of 200-250 nm size on the surface that disrupt the homogeneity. When the FESEM image of these defects is examined at 100,000 magnifications (Figure 3c), it is seen that the embossments (Figure 2c) on the glasses with one-sided AR coating disappear and are replaced by defects of different sizes. In the study of Yao and He (Yao & He, 2014), many cracks were observed in AR coated glasses made by etching, 10 nm due to abrasion, and 20 nm width by dipping method. The eyeglass we examined is quite smooth according to the study of Yao and He (Yao & He, 2014; Yuan,YanZhang, 2020), and defects were rarely seen on the surface. The presence of the reliefs seen in Figure 3 on certain parts of the surface is important for the smoothness of the surface.

When Mahadik et al. (Mahadik et al., 2015) examined the FESEM image of antireflective coated glasses, they stated that nano pores would be seen in 500 nm scaled images and that the FESEM image of the examined glass was smooth and homogeneous. In our study, although the surface image of our glass appeared homogeneous in 1µm scale images, when better magnifications were used, defects in 200 nm (at 100,000 magnifications) were found.

Absorption and transmittance measurements of the AR eyeglasses were taken with Spectrophotometer device, the data were plotted in Origin Pro 8 and the graphics are shown in Figure 4. For absorption and transmittance measurements, an eyeglass with a hard coating for 3 hours at 100 °C, an uncoated eyeglass, an AR coating lens on one side, and AR coating lens on both sides were used.

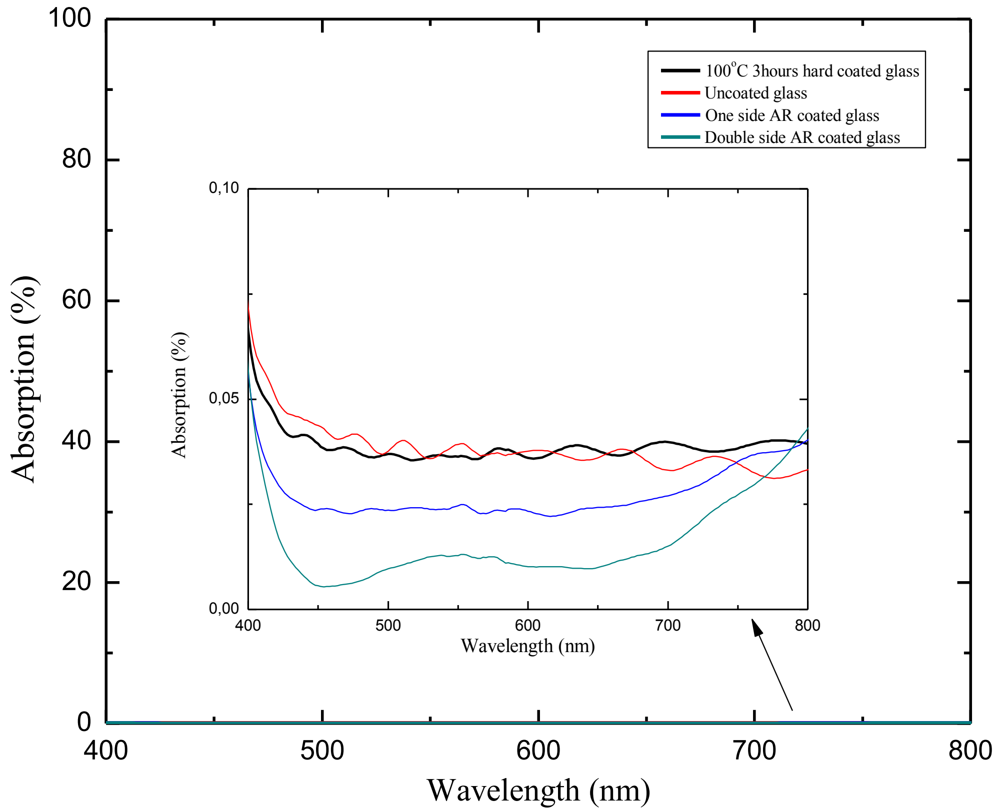


Figure 4. Absorption graphs of lenses

The hard- coated eyeglass and uncoated eyeglass absorption values are approximately 0.03 %. When AR coating is applied on one and both sides, the absorption values decreased to 0.02 % and 0.01 %, respectively (Figure 4).

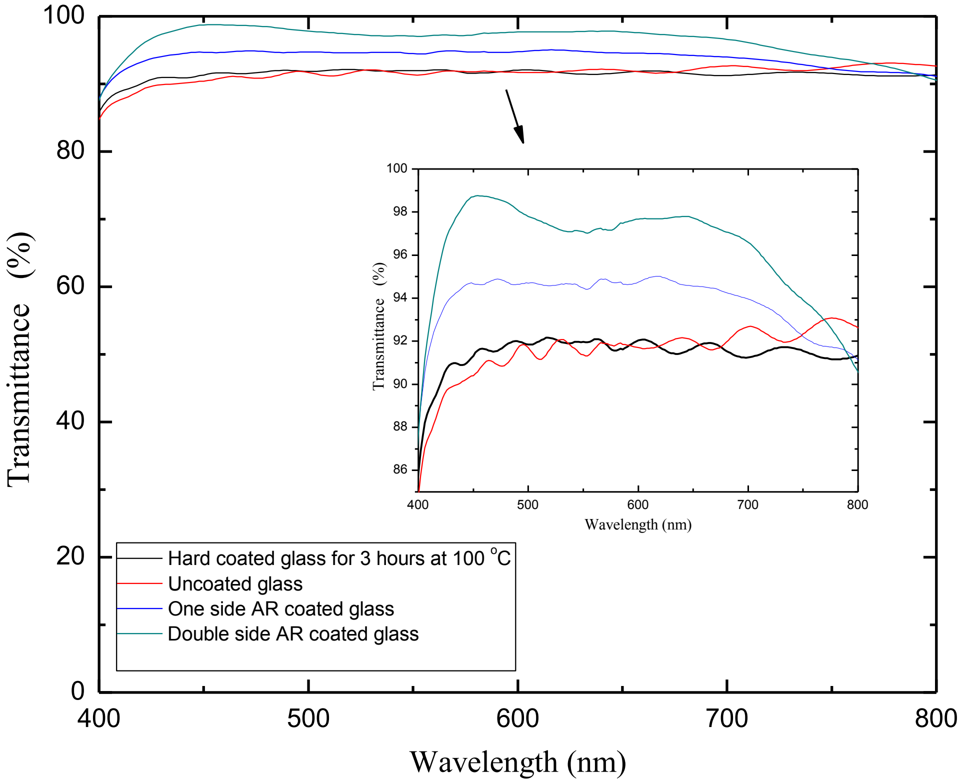


Figure 5. Transmittance graphs of lenses

It is seen that the hard-coated eyeglass transmits 91,93% light at 550 nm, and the uncoated eyeglass transmits approximately 91,32 % light at 550 nm. This ratio reaches 94,41 % and 97,05 % light transmittance for 550 nm, respectively, for single and double side AR coated glasses. Maximum light transmittances reach 98,54 % at 464 nm in double-sided AR coated eyeglasses (Figure 5).

In a study on the transmittance of AR coated lenses (Yao & He, 2014), the AR effect of the lens increased as a result of the etching method, but the transmittance increased as a sharp peak at a certain wavelength. In the glasses we examined, the increase of the data in all waves in the transmission spectrum as a result of the anti-reflective coating and the fact that the data is close to the constant value show that AR coating is very efficient. In another study (Sun,Tu, et al., 2020) on AR coatings, it is seen that they reaches 93.6 % transmittance in the 400-800 nm range. In yet another study (Mahadik et al., 2015), 97.5 % transmittance of lens was obtained at 500 nm. The transmittance at 500 nm wavelength is 97.83 % in double-sided AR coated eyeglasses that we have examined, and it is approximately the same. However, the spectra of the coated glass are examined (Mahadik et al., 2015), it seen that their spectrums show sudden decreases up to 92 % and they do not perform very well at every wavelength in the visible region.

When looking at all similar studies (Mahadik et al., 2015; Sun,Li, et al., 2020; Sun,Tu, et al., 2020; Yuan,Yan,Xiao, et al., 2020; Yuan,YanZhang, 2020), the spectra of the glass we examined are in very good condition. The fact that the spectrum is in approximately the same order shows that the eyeglass is of very good quality.

When the absorption-transmittance spectra (Mahadik et al., 2015) of glasses are compared, it is seen that their transmittance is quite high and absorption is very low. It can be said that AR coated CR39 eyeglass, which are produced in our country and frequently encountered in optical stores, are of good enough quality and that users can see more clearly. At the same time, many studies and theoretical calculations have shown that an important parameter affecting the anti-reflective performance is the angle of incidence of the incident beam (Camargo et al., 2012; Min et al., 2008; Xi et al., 2007).

XRD is a powerful method to characterize the crystal structure (Mendibide et al., 2005). Measurements made between 30°-60° of uncoated and two-sided AR eyeglass, whose 2α measurements were taken in the XRD device, are shown in Figure 6.

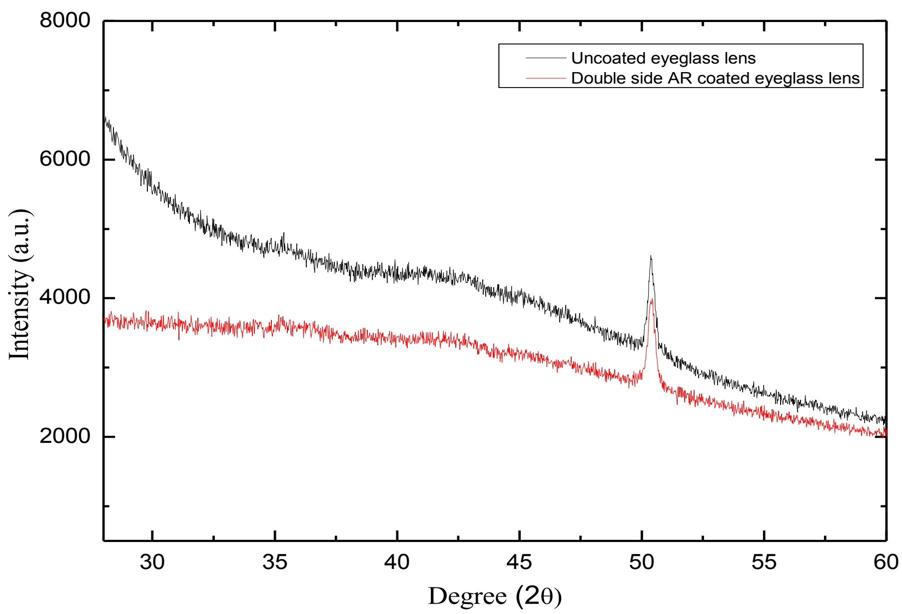


Figure 6. XRD measurement graphs of eyeglasses

In the analysis of uncoated and two-sided AR eyeglass in XRD measurements, no distinguishing material with high concentration was found. The peak where 2Θ corresponds to 50.39° is seen for coated and uncoated lenses and is caused by the device itself. In the direction of the graphic obtained (Figure 6), it is seen that the structures are in amorphous structure(Sun,Xu, et al., 2020), as in the wide peak (Sun,Li, et al., 2020). As light passes through the amorphous lens surface, it moves at the same speed in all directions. In another study on the X-Ray diffraction pattern of AR coated lenses (Mahadik et al., 2015), they obtained a sharp peak from silicon substrate at 2Θ= 55,6° for SiO_2 coating coated on silicon substrate. For a wide peak of about 2Θ being 15°, it was stated that it came from the SiO_2 coating. It is thought that half of the peak in Figure 6 comes from SiO_2 within the peak where it is seen.

4. Results and Recommendations

In our study, the interface analysis and optical characterization of CR39 AR coated eyeglass produced in our country and offered to eyeglass wears were performed. According to the results of FESEM, while the surfaces of hard-coated and single-sided AR-coated eyeglass are quite smooth and homogeneous, 200-250 nm defects were encountered on the surfaces of double-surface AR coated glasses. These defects are thought to occur during cutting due to the geometric structure of the glass. These defects are found on the rare part of the surface and do not cause any problems with vision. When the absorption and transmittance measurements of eyeglass with AR coating on both sides are examined, it is seen that their transmittance is quite high, absorption is very low and has good spectrum transmittance compared to the literature. Analyzing the AR coated eyeglasses produced and used in our country is very important in terms of informing the public, obtaining new products and contributing to many studies.

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Conflicts of interest

The authors declare that we have no conflict of interest.

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