Optik 127 (2016) 2062–2068

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

The evaluation of spectral transmittance of optical eye-lenses

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ARTICLE INFO

Article history:
Received 3 April 2015
Accepted 9 November 2015

Keywords:
Mineral lens
Organic lens
Transmittance
UVR
Visible light
DFT

ABSTRACT

In the present study, the effect of light on mineral (Quartz) and organic lenses (Diethylene glycol bis (allyl carbonate)-CR39, polycarbonate, trivex) is briefly reported. It is essential to choose the right conditions for ophthalmic lenses, such as the lighting environment in order to maintain the eye health.

In this article, to discuss the harmful effects of ultraviolet radiation (UVR) on the lenses and to analyze the results of the visible-light transmittance, the properties of mineral and organic eye-lenses are investigated considering the personal eye-protections, ophthalmic optics, the transmittance requirements standards of scientific researches and the literature studies, by use of coated and uncoated prescriptive ophthalmic plastic concave and convex lenses.

A UV–vis spectrophotometer device is used to determine the spectral transmittance of lenses in different diopters, index numbers and coating characteristics. Additionally, the physical and optical characteristics of eye-lenses, as well as their chemical characteristics and molecular structures are studied in this article. Also, the vibrational frequencies of organic lenses are investigated applying FT-IR device measurements, and the optimized molecular structure of CR-39 monomer by density functional theory (DFT) quantum chemical method is explained using B3LYP method with STO-3G and 6-31G as basis set.
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1. Introduction

The scientific research of all spherical, cylindrical, sphero-cylinder and prismatic optical lenses within the fields of optics and ophthalmic involves both microscopic and macroscopic measurements. These optical and ophthalmic lenses are essential materials used in the correction of refractive errors on ophthalmic health field (personalized Rx ophthalmic lenses, with optical power) and focusing of a light beam in several optical devices. Additionally, these lenses are utilized in optic educational studies, refractive surgery, optical instruments and various industry technologies including mirror, lens prisms, lensmeter, telescope, camera, monocular and binocular vision, magnifier, projector, pinhole effect in optics, interferometer, auto refractor/keratometer, microscope, refractometer, spectrophotometer, periscope, polarimeter, photometer, polychromator, ophthalmic-optical and surveying instruments, etc.

Additionally, the fabricated microlens can be used in the applications that require integration of the optoelectronic devices and the optical communications [1].

As an organ of vision, the human eye is a relatively simple optical system compared to most artificial optical instruments. The parts in the eye structure are cornea and crystalline converging lenses, sclera, conjunctiva, iris, retina, vitreous, macula and the optic nerve [2]. Cornea constitutes the front surface of the eye and has a nearly spherical section with 7.8 mm anterior radius and 6.5 mm posterior radius of curvature and refractive indices of 1.3771. Cornea has an approximate dioptric power of 43 diopters and a focal length of 2.3 cm. The structure of the lens is biconvex with curvature radii of 10.2 mm and −6.00 mm respectively for the anterior and posterior surfaces. The layered internal structure of the lens produces a non-homogenous refractive index of 1.42. The refractive index of the aqueous is 1.3374. The refractive index of vitreous humors is 1.336 [3].

The mineral glasses/organic lenses were processed with automated cutting machinery, diamond tools and then polished with abrasive paste. The edging was performed using lens cutting machines, controlled with diamond wheels [4]. The materials of spectacle lenses are categorized as mineral eye-glasses and

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http://dx.doi.org/10.1016/j.ijleo.2015.11.034
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CR-39, high index, polycarbonate and trivex in plastic/organic lenses group. Shortly, the types of mineral glasses are crown, flint, borosilicate and mineral glasses with high refractive indices (heavy flint glasses). The plastics lenses are classified as CR-39, high index organic, polycarbonate and trivex. The lenses with different focal structure are classified as monofocal, bifocal, trifocal and multifocal [5]. Mono-layer, multi-layer coatings and tints are commonly applied on the spectacle lenses. Multi-coatings are applied on the ophthalmic lenses to enhance the optical view performance of the spectacle lens. The coatings can be classified in seven groups according to the chemical characteristics of eye-lenses [6]: anti-reflection coatings, hard coatings, clean coat, mirror coatings, color tint coating, photochromic coating, and anti-fog coating. Various color tinted and photo-chromatic lenses are also used for sun protection and the absorption of the harmful UVR [7].

Light may be reflected, transmitted or absorbed by an optic lens material. The behavior and the characteristics of light as well as the effect of visible, ultraviolet and infrared light on materials are described in the field of optics. UV is a part of the electromagnetic radiation spectrum with wavelengths ranging from 100 to 400 nm. There are three types of UVR (UVA/near/315–400 nm, UVB/middle/280–315 nm, and UVC/far/100–280 nm) [8].

The biological and harmful effects of UVR exposure dosimetry and precautions regarding the protection of the eye against solar ultraviolet radiation have been widely studied [9–11]. As the ocular system is exposed to broadband optical radiation; UVR becomes a threat to the anterior structures of the eye, as it penetrates into the lens [12]. The visible light is required for human vision. Therefore, ideal sunglasses shall adequately reduce the UVR, coming from lateral directions and impairing the function of cornea and the lens [13]. There are several negative biological effects of UV-A, UV-B, and UV-C exposure on eyes. These negative effects include ocular damage, photo-aging, skin cancer and impairment to the immune system. Ultraviolet keratitis, also known as snow blindness or photokeratoconjunctivitis, is inflammation of the corneal epithelium and conjunctiva induced by UVR exposure. Ultraviolet keratitis is characterized by significant ocular pain and decreased visual acuity. A superficial punctate keratitis, usually bilateral, develops in early ages and can lead to a large epithelial defect, severe pain, and excessive tearing [14].

Ophthalmic lenses should have a low-density (d) structure. Also, coated and uncoated lenses should provide UVR-protection, feature the lowest transmittance within UVR wavelength ranges and highest transmittance within visible wavelength ranges, thus provide a good field of vision, and reduce the aberration of lenses and reflection of anti-reflection coated lenses.

This paper aims to test the ophthalmic eye-lenses by adjusting the wavelength ranges of light, compare the transmittance properties of prescriptive clear lens materials, decrease the patient's ocular exposure between UVR ranges and increase the patient's ocular exposure between visible-light ranges taking into account the transmittance values. Providing a useful source for the people working on ophthalmic and optical education is also aimed.

In this study, positive and negative powered dioptric lenses with and without UV-coating were selected as the test lens material. The transmittance spectra for UVR, the visible-region light as well as the chemical structures and the frequency values of mineral and organic lenses were obtained for ophthalmic group lenses. A beam of light passed through the center of each spectacle lens placed inside a spectrophotometer. The spectrophotometry in spectrum mode was conducted over the wavelengths of 200–1000 nm with 5 nm increments, performing the wavelength scan. Spectral graphs were obtained using a Shimadzu UV–vis spectrophotometer (UV-1800 model) in photometric measurements. A lensmeter (SHIN-NIPPON-SLM-6000) device were also used for a single wavelength of 375 nm.

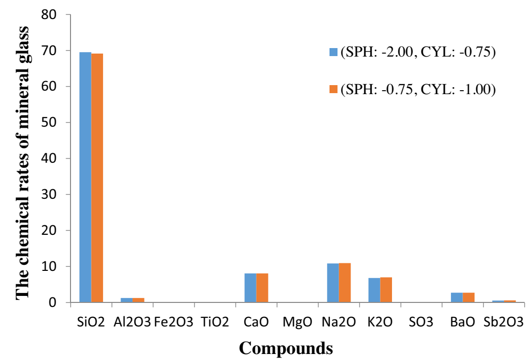

Fig. 1. The chemical rates of mineral glass analyzed by X-ray fluorescence device.

2. Methods and measurements

The physical characteristics/types of the optical lenses are the diameter (*R*), the base curvature (BC), the diopter (*D*), the sagitta (*S*), the spherical (SPH), the surface-type (sphero/cylindrical), flat (plano-convex/concave, bi-convex/concave) and lenses having one convex surface and the other concave (meniscus lenses), the edge thickness, the optical center (OC), the focal point (*F*) and index of refraction (*n*).

In the present paper, index properties of refractive lenses and the characterization of various coatings are essential for the spectral transmittance measurements. The chemical structure of the mineral glass was examined with an X-ray fluorescence device. Fig. 1 shows the chemical rates of mineral glass with 65 mm diameter, SPH: $-2.00D$, CYL: $-0.75D$ and SPH: $-0.75D$, CYL: $-1.00D$ dioptric power.

Fig. 2 shows a graph for the spectral transmittance of mineral glasses and provides a comparison of different diopter lenses to analyze the spectral measurement results. Generally, all eyeglasses should feature a high transmittance value between 400 nm and 800 nm within the total visible range. The transmittance range extends to near UV (ultraviolet) and IR (infrared) regions as shown in Fig. 2.

According to the graphs, average UVR transmittance value decreases with increasing lens thickness and average wavelengths of UVR transmittance shorten with decreasing lens thickness. The marking peak detection values for the 1st sample are determined as %91.742 in 403 nm, %91.838 in 494 nm, %91.553 in 754 nm, %91.524 in 760 nm, %91.502 in 770 nm, %91.425 in 805 nm, %91.434 in 826 nm, %91.444 in 840 nm. The marking valley detection values for the 1st sample are determined as %0.023 in 258 nm, %91.672 in 420 nm, %91.774 in 518 nm, %91.692 in 610 nm, %91.632 in 670 nm, %91.498 in 757 nm, %91.396 in 795 nm, %91.382 in 844 nm.

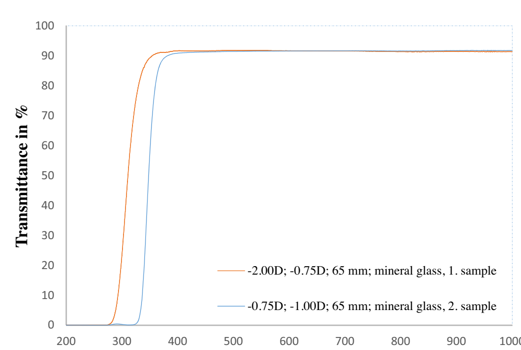

Fig. 2. The spectral transmittance of mineral eye-glasses.

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