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STRUCTURAL MODELING OPHTHALMIC LENSES SUBJECTED TO CONTROLLED PHYSIC-CHEMICAL AGGRESSIONS

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Abstract: *The paper describes a research stage for manufacturing of some sort of ophthalmic lenses used to recover the eye dysfunctions like myopic, hyperopic and astigmatic eye. In this sense, the research developed within this paper presents an overview of technologies for ophthalmic lenses and microscopic analysis of the layers deposited on the surfaces of the lens. Modular analysis structure of ophthalmic lenses subjected to physic-chemical controlled aggression behavior allows an analysis of any set of lenses (single vision or progressive), of any material ophthalmic and of any sizes. These images are analyzed by image processing procedures and the effect of aggressions is measured accurately.*

Key words: *modeling, ophthalmic lens, layers.*

1. Introduction

In practice correction and recovery of visual function, using the ophthalmic lenses is the best solution especially for people who have already used this system or for those where the refractive begins. Ophthalmic lenses are made from lightweight materials with high optical characteristics and special surface treatments to obtain a final superior image quality offer to visual system. Any producer in optical technology field of these systems try constantly improve the quality and optical material in order to obtain a value of quality-cost more convenient for the customer. Therefore "spectacles are a common, cheap and easy method of prescribing corrective lenses in patients with refractive errors and presbyopia" [2].

To achieve these requirements is important to know the types of materials used in the construction of the lens that can adapt to each client, materials for frames and also the compatibility between them and the needs of the patient.

At present, the most common materials used for the lenses are optical glass and plastic. Special materials such as polycarbonate, high refractive index materials or TRIVEX are most commonly used when must satisfy a number of parameters and special requirements. "Crown glass with refraction index of 1.5223 is used mostly. Abbe value of this material is 58.5. They are highly transparent, scratch resistant and low cost but they are thick, heavy and can break easily. Flint glass has high refraction index of 1.62. Due to high specific gravity and low Abbe value, flint glass has the

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disadvantage of being heavier and has high chromatic aberration” [2].

Another common material in the construction of the lens is CR39 (chemically it is diallyl glycol carbonate) having refraction index 1.498, 1.58, 1.6 or 1.74. “As it is a thermosetting material it can be ground and polished after manufacturing without risk of deformity” [2].

In terms of advantages we can list the following: good optics and chemical resistance; comfortable due to light weight; safer than glass lenses; unlimited designs, coating and tinting, and the major disadvantages are: poor structural integrity; unstable at high temperature; scratches more easily; more expensive; not suitable for rimless frame as they can wreck; difficult to drill without cracking; photo chromatic options available.

Polycarbonate lenses are made with amorphous materials most used especially when the need for protection is the main requirement. Due to slightly higher refractive index (1.586) this material has a number of qualities such as thickness less the center of the lens; weight reduced by approximately 26% compared to other materials; possibility of construction for protection against UV radiation; high impact resistance; bullet proof. Due to the quality of the material (low density) polycarbonate lenses scratch presents a low resistance requiring special layer deposition and optical parameters are degraded by the existence of large peripheral chromatic aberration. However, this type of lens can be used to construct correction glasses for children, sports or persons performing work that requires protection of visual function. Lenses with high refractive index (ranging 1.6 to 1.9) are made of denser materials such as resins MR8, MR10, MR11 or optical glass. In terms of disadvantages of this type of material requires the deposition of surface treatments and has a low Abbe value.

The material quality is considered the best in this moment TRIVEX, a material as an alternative to polycarbonate lenses due to its qualities both mechanical and optical cit. In this type of material can be deposited antireflection coatings, hardness (resistance to scratches) can be tinted, is impact resistant and combined aggression (mechanical and chemical). Also, due to variation of the refractive index or density and Abbe value, shows the lowest weight per unit volume and the best transparency of all ophthalmic materials [6].

Protection of visual function is provided primarily by natural anatomical ocular structures itself, but powerful light beam radiation’s, especially in the UV range (near and far) require additional protection that can be achieved by using filtering characteristics of the deposited layers on the lens.

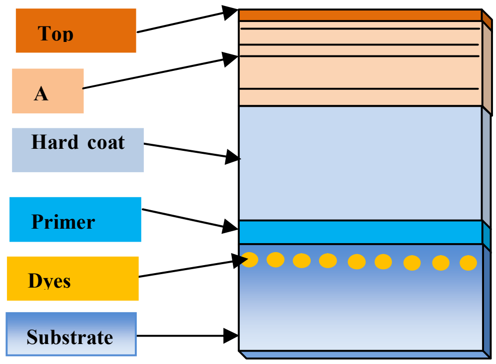


Fig. 1. *The lens as a system* [4]

Filter lenses allow obtaining two fundamental characteristics important: reducing radiation intensity light entering the eye and removing dangerous neutron radiation absorption phenomenon thereof. These lenses can have permanent color shades (uniform or gradual) or color variations (photo-chromic effect).

At present, the market for manufacturing ophthalmic lenses are efforts to develop new products based on superior quality materials (ex. Hybride sol-gel, organic material etc.) to correct visual function, especially for getting a durability and a decorative cosmetic appearance and custom.

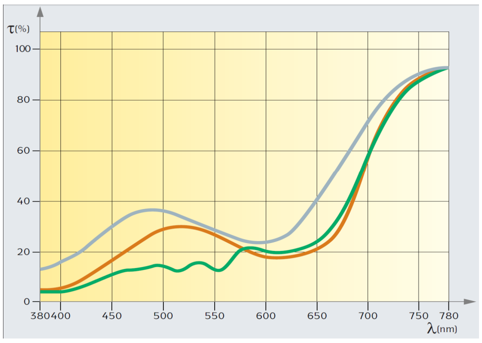


Fig. 2. *Transmission curves for different tints* (*grey, brown, green*) [4]

As shown in [5] "The commercial success of hybrid sol-gel derived coatings in the ophthalmic industries was mainly due to the outstanding mechanical properties of inorganic-organic networks in comparison to purely organic coatings.

To assure comparable mechanical properties, the hybrid network has to be designed to maximize the density and degree of condensation of the inorganic part of the final coating and reduce the space demanding size of the organic substituents" (Figure 2).

In terms of using antireflection coatings (AR) on the surface of the lens there are a number of variants that may apply depending on the support base of the lens or the patient requests. Coatings of anti-reflection layer in general is done with magnesium fluoride material and look how getting a percentage higher transmissibility (about 99.9%).

This material allows a maximum interference in yellow-green color spectrum, unlike red and blue radiation spectrum that is not fully removed. In this case this lens reflex appears slightly purple surface. Most modern technology used an AR layer deposition process their place by alternating refractive index materials more different between them in order to eliminate the reflected radiation from extended spectral bands. [5] In terms of optical layers would provide a coefficient of reflectance on one side between 4% for CR39 plastic material until 6.2% for plastic high index (1.66) material.

If it calculated reflectance for both surfaces then values increase from 7.7% to 11.7%. As shown in [5] "specular surface reflections and ghost images produce visual noise, which degrades retinal image quality without contributing useful visual information" This type of decay is obtained by the expression of two phenomena of propagation of optical radiation, namely reduced visual discrimination and visual disturbance.

Another important layer deposited on the lens is the necessary protection against scratches or damage to the surface. This type of coating is deposited mostly on plastic lenses to increase their abrasion resistance. The material used for hardness coating contains a resin (polysilixane) in which is particles of silica and organic polymers [5].

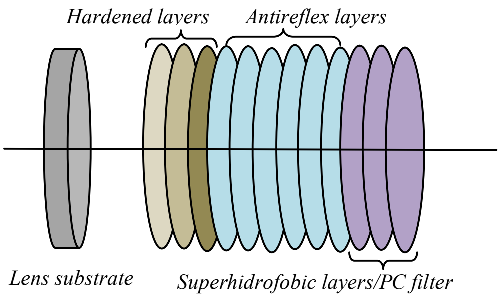
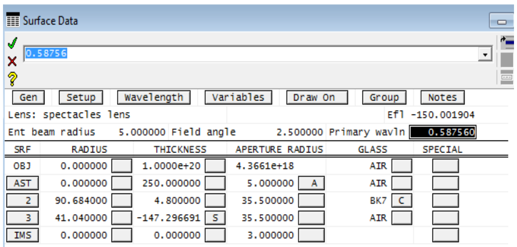


Fig. 3. *The lenses layers*

The settlement of several layers of hardening is to take the internal tensions of transition from a soft base (lens) to a surface tougher and also allows the following layers to be deposited on rough surfaces to increase the degree of adhesion. Submission of multiple AR coatings require a certain degree of adhesion layers roughness ensured through hardening, but attenuates outwards, towards layers hydrophobic, oleophobic, antifog or computer filters (Figure 3) [5], [6].

2. Optical Analyse of Lens

The lenses undergo initial experiment are analyzed theoretically and in terms of optical parameters to identify the basic elements involved in making the final image quality. Such lenses were analyzed by software OSLO EDU-LT ver.6.6 and OpTalix ver.8.39, have been modeled and optical parameters were determined effects on the geometrical and chromatic aberrations. Thus, the following figures are the results of this modeling for a diverging lens with focal length (-150 mm) [7].



Surface Data

0.58756

Gen | Setup | Wavelength | Variables | Draw On | Group | Notes

Lens: spectacles lens — Efl -150.001904

Ent beam radius 5.000000 Field angle 2.500000 Primary wavln 0.587560

SRF	RADIUS		THICKNESS		APERTURE RADIUS		GLASS		SPECIAL
OBJ	0.000000		1.0000e+20		4.3661e+18		AIR		
AST	0.000000		250.000000		5.000000	A	AIR		
2	90.684000		4.800000		35.500000		BK7	C	
3	41.040000		-147.296691	S	35.500000		AIR		
IMS	0.000000		0.000000		3.000000				

Fig. 4. *Lens data*

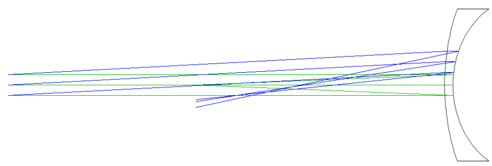


Fig. 5. *Design of lens*

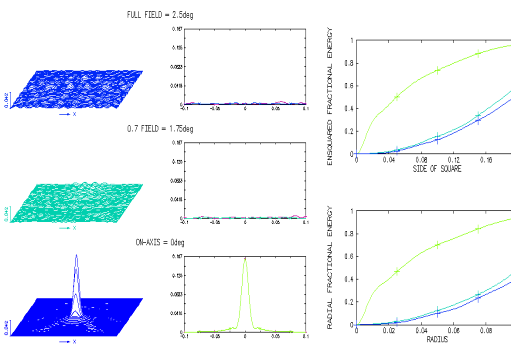


Fig. 6. *Point spread function* (*PSF*) *of lens with f = -150 mm*

Following these modeling found substantial effect caused by layers deposited on the surface of lens aberrations on the level and the quality of their functions.

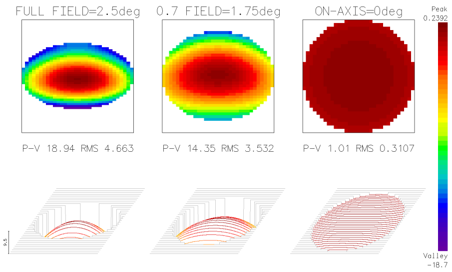


Fig. 7. *Wavefront analysis*

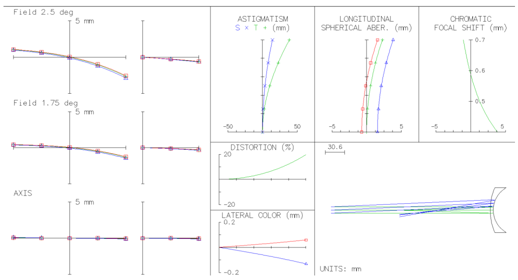


Fig. 8. *Ray trace analysis*

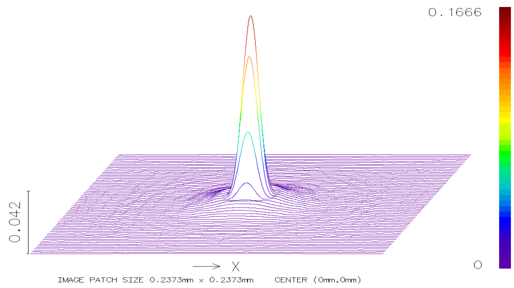


Fig. 9. *Fast Fourier transform* (*FFT*) *based PSF*

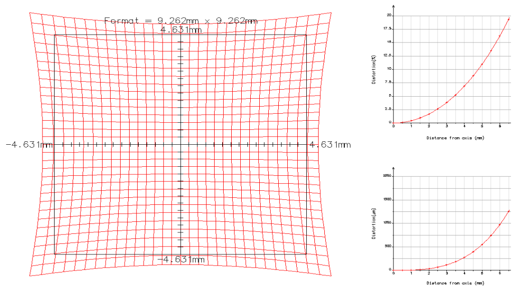


Fig. 10. *Distorsion plot for spectacles lens*

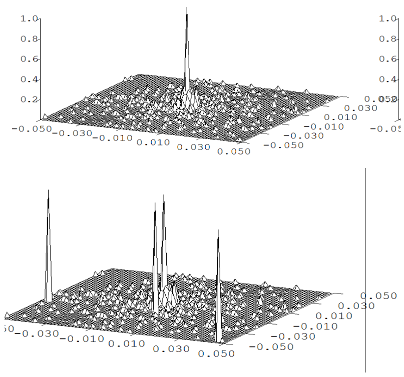


Fig. 11. *Geometric PSF*

Therefore any damage to the layers, any change in structure may induce a decrease in image quality offered to visual system and they cannot be compensated physiologically by the wearer of glasses.

3. Experimental Setup

To analyse the behaviour of the lens assembly at the action of various forms of mechanical or chemical-physical aggression it has developed a rating system unified and consistent of lenses set, forming the analyse sample.

The test sample is composed of a set of lenses made of different materials with similar technology but with different accuracies (called no-name lenses, mark1 mark 2 and mark 3) [3].

This set of lenses has one common feature, namely the sequence of hardening layers, antireflection coatings and special layers (Figure 12).

The types of lenses used in the investigation were: CR39 (simple, hardening, AR, oleophobic, antistatic, super-hardening layers), polycarbonate (simple, AR layer) EYAS (simple, AR, oleophobic, super-hardening layers) EYNOA (simple, AR, oleophobic, super-hardening layers) EYRY (simple, oleophobic, super-hardening layers) and ophthalmic glass (simple, AR).

In the first phase of the study, the lenses were marked with four equal sectors on diopter surface, convex and have undergone a first step of a process for producing a scratch with the following materials: metal, wood, ceramic, plastic.

These materials were chosen because it was observed that the daily use of these lenses, the materials listed above may interact with dioptric surfaces and cause significant scratches.

Also to even scratched how to design a system that would provide the same downforce and if possible, the same size of all scratches (Figure 13).

Fig. 12. *Lenses samples*

In order to a correlative analysis, it was performed unitary scratching of lens types with this mechanical device adapted to drill, that has been modified to these experiments. To scratch the tested lens surface with the same force, to the device adapted were attached different weights and scratching is performed by moving the lens helped by the guide of the drill table.

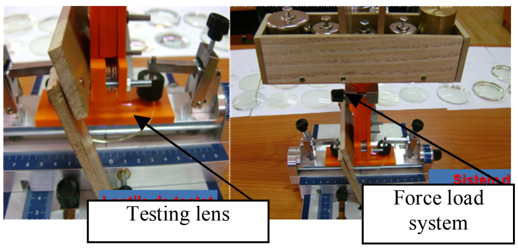


Fig. 13. *Force load system*

The equipment used for microscopic study of surface lens consist into a digital microscope type Keyence, having an objective with 500x-5000x magnification, an image acquisition system based on camera with CCD sensor and a dedicated computer image processing software and analysis of images captured (Figure 14) [1].

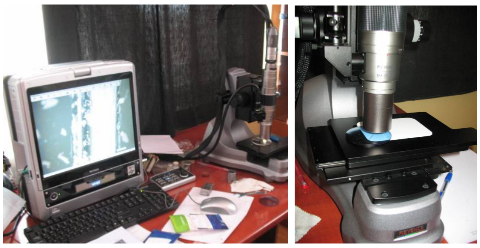


Fig. 14. *Digital microscope system*

As the study involves the same conditions, the same types of mechanical aggression, was chosen for illustration the presentation of a lens surface anti-reflection treatment and hydrophobic-oleophobic coating. The lens base material is CR39. This lens with specified treatments has been subjected to scratching with different materials (wood, metal, plastic, ceramic) (Figures 16, 17).

4. Results

Lens subject to high mechanical stress was analyzed by digital microscopy and have obtained the following results. Scratched lens with wood (soft material in relation to the lens surface) shows small traces (aprox. 330 microns), discontinuous and not very deep (until layer hardening) (lens scratched, wood, 500x - Figure 15).

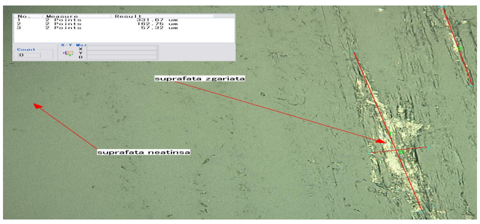


Fig. 15. *Digital image for wood lens scratches* (*500x*)

The same lens scratches with the metal on no. 2 zone (same strength) shows traces very deep, up to the base of the lens, traces of large and damaged coatings on large surfaces (4.45 mm length of trace).

Sector 4 of the lens surface was subjected to scratch with the plastic material. This material damage the lens surface affecting all layers, between them there is a grip needed to obtain a good image quality.

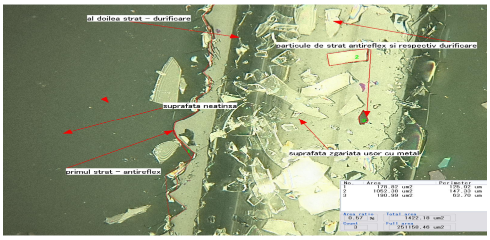


Fig. 16. *Digital image for metal lens scratches* (*500x*)

When using ceramic material for getting scratches on the surface of the lens, it can be seen that the traces obtained are different from those of metal or wood, because the ceramic material is tough but contact lens behaves as a brittle material that scatters ceramic particles on the lens surface.

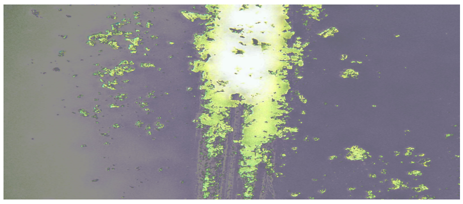


Fig. 17. *Digital image for ceramic lens scratches* (*500x*)

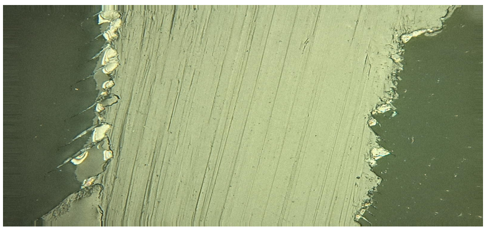


Fig. 18. *Digital image for plastic material lens scratches* (*500x*)

Scratches are high, comparable to those of metal and particles from scratching of these layers are drilled and removed, leaving the lens surface exposed and frosted by friction with plastic material (Figure 18).

There fore all four types of materials that have been used to scratch lens surfaces left important traces on the lens structure and modify the image quality. In addition, if the lenses are in the category no-name then their surface is more sensitive leading to worsening of visual function by reducing transparency and increasing the risk of entering the eyeball parasitic reflected radiation or UV.

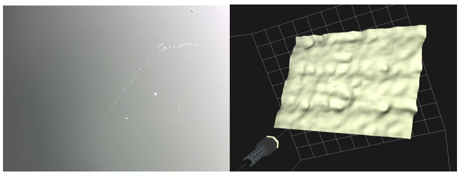


Fig. 19. *CR39 lens without layers (noname) and wiped with paper/cleaning solution after 60 days*

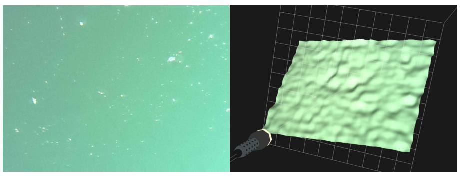


Fig. 20. *CR39 lens with AR, oleofob, hidrofob layers (noname) wiped with microfiber/ water after 60 days*

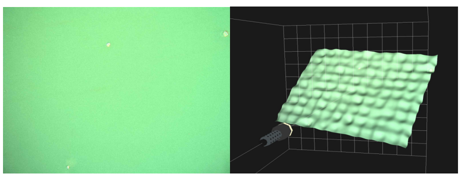


Fig. 21. *CR39 lens with AR, oleofob, hidrofob layers (mark1) wiped with microfiber/cleaning solution after 60 days*

If these lenses are subjected to aggression and process maintenance with different substances, negative effects on the quality of surface or on image quality are amplified to determine that these lenses cannot be used in the visual correction.

The deletions were simulated on the lens surface during 30 and 60 days with different materials and substances maintenance (paper handkerchief, microfiber, water, rubbing alcohol 100%, lens-cleaning solution containing water demineralized ion surfactants, alcohol and preservative) (Figure 19).

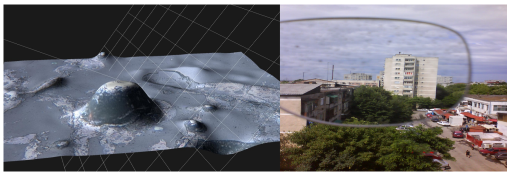


Fig. 22. *Lens improperly maintained (welding drops)*

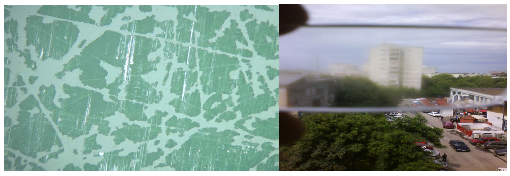


Fig. 23. *Lens improperly maintained (AR layer)*

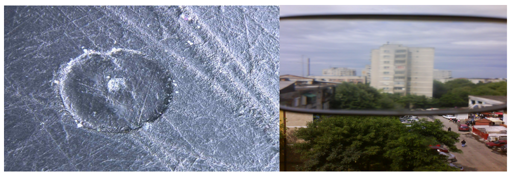


Fig. 24. *Lens improperly used (without any layer)*

Through a simple example we can determine what level of transmissibility (intensity) at a lens refractive index of 1.6 which is deposited a layer with refractive index of 1.5 in the amount of 97.19% compared to 94.67% in value an uncoated lens substrate AR. Thus the reflected intensity is 2.81% for the lens with AR unlike variant uncovered when this value increases to 5.32% [9].

5. Conclusions

It was found from these experiments that lens treatments hardness, AR, hydrophobic, oleophobic have an increased resistance to scratching and erasing (maintenance) if these treatments are right quality and technology meet.

Also, the best materials are cleaning solution used with special microfiber, plus maintaining a normal operating temperature (without prolonged exposure to intense solar radiation and temperatures above 350^0 C).

High operating temperatures associated with poor maintenance and inadequate support lens are frequently causes encountered in everyday practice.

For this reason we recommend installing the frames glasses lens quality, well-structured surface treatments and correctly completed, and the maintenance to be carried out according to the principles defined in the user guide for each type of lens (glasses correction and/or protection).

Also these tests have highlighted the difference between a lens surface quality and a brand noname after being subjected to the same period of harvesting (Figures 20-24), the destruction is visible up to the AR coating.

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