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INFLUENCE OF CONTACT LENSES MATERIAL ON AQUEOUS SOLUTIONS

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Abstract: In this paper we present the investigation of influence of new nanophotonic materials for contact lenses on aqueous solutions. The contact lenses that we used were made of standard siloxane acrylate material with incorporated molecules C_{60} and another with fullerol $C_{60}(OH)_{24}$. The aim of the investigation was to compare the influences of these materials on different solutions, such as aqua purificata, saline and drops for dry eyes. Optomagnetic spectroscopy was used to analyze different solutions. The obtained spectrums were commented on and compared with the standard contact lens material, which was analyzed by using the same method, in order to show the differences in influence of this standard and new nanophotonic material. This research contributes to a better understanding of biocompatibility of new contact lens materials.
Keywords: contact lenses, fullerene, fullerol, biocompatibility.

1. INTRODUCTION

Biomaterial is any material, natural or artificial, which is a part of or the entire living structure, or a biomedical device that performs, amplifies or replaces its natural function. Clinical applications of biomaterials are not supposed to cause any unwanted reactions in the organism or to compromise the patient's life; therefore, every material must be biocompatible. Biocompatibility is the ability of the materials to show positive response in specific applications. In order to prevent unqualified and unauthorized selling and applications of materials that are not tested, different regulations and standards have been made.

There are a number of things to be considered when designing a contact lens, but probably the most important one is biocompatibility. A biocompatible contact lens is the one that does not damage the surrounding ocular tissue during contact. The term ”ophthalmic compatibility” is more suitable for the biocompatibility of contact lenses. The contact lens should permit oxygen from air to the cornea because the cornea does not get any oxygen from the blood vessels, like other tissues. Not enough oxygen reaching the cornea causes its swelling and becoming infected. Another important property is wettability because the lens is in contact with tear film which consists of proteins, lipids, enzymes and other molecules that could be deposited on the contact lens surface.

In this paper we present the investigation of influence of three sorts of contact lenses on different aqueous solutions. The analysis of influence on different solutions were made for standard contact lenses and contact lenses with fullerene C_{60} and fullerol $C_{60}(OH)_{24}$. The solutions that we used were sterilized water (aqua purificata), saline and drops for dry eyes. We used opto-magnetic spectroscopy method for characterizing the samples.

2. MATERIALS

Fullerenes are a big family of super-atomic three-dimensional molecules. They were discovered by H. W. Kroto, R. F. Curl and R. E. Smalley in 1985, but the gram quantities became available in 1990 when Krätschmer and Huffman set the procedure for their production. Fullerenes consist of sp^2 hybridized carbon atoms distributed in hexagons and pentagons. Geodesic dome in Montreal made by Richard Buckminster Fuller was an inspiration for the name of these molecules, because this dome has the same structure as a fullerene cage. The most popular fullerene is C_{60} also known as the *Buckyball* (Figure 1), [1] .

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Fullerenes show strong affinity to electrons and act like ”radical sponges”, because they easily enter addition reactions with nucleophiles. Spectroscopic characteristics of fullerenes are in strong relation with their symmetry. Structural information can be acquired from the number of bonds, for example, in IR spectra. C_{60} is a good optical limiter but has low solubility and poor transparency. Fullerene materials are a group of new optical filters with such remarkable attributes as easy fabrication, predictable wavelength tuning, and excellent performance stability. [2]

One of the main disadvantages in fullerene applications is its low solubility in water. In order to make them soluble, they must be functionalized with polar groups such as –OH and –COOH. From all the water soluble fullerenes the most important ones are those with –OH groups attached, named fullerols or fullerenols (Figure 1). They are free radicals scavengers and have anti-oxidative properties. Modified fullerenes are water soluble because they interact with water through hydrogen bonds. These fullerenes are unstable and can be degraded in contact with chemical agents from the environment. Modified fullerenes can be stabilized in the process of harmonization. [4]

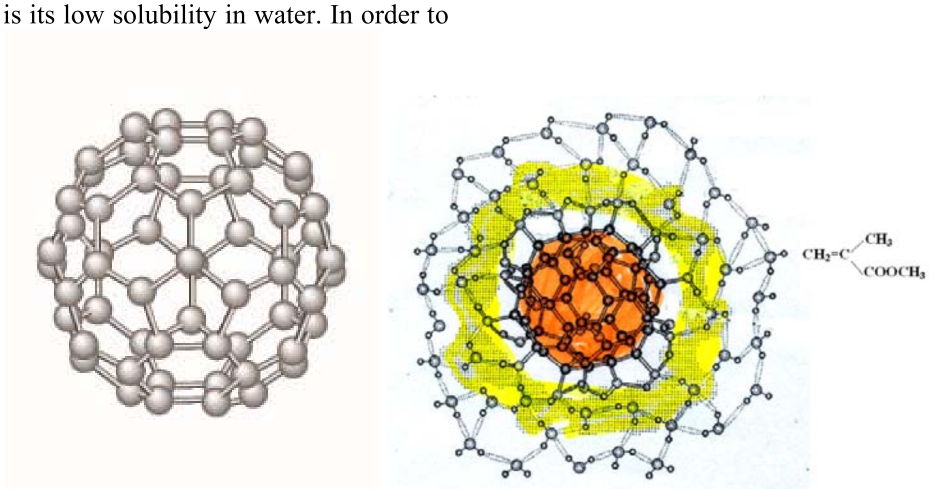

Figure 1. Fullerene C_{60} (on the left) and fullerol $C_{60}(OH)_{24}$ [3,4]

In our investigation of new contact lens materials we used two different sorts of nanomaterials: fullerene C_{60} and fullerol $C_{60}(OH)_{24}$. These nanomaterials, 1 gram of each, were added during the polymerization process to the standard polymethylmethacrylate material, Soleko SP40™. The percentage of nanoparticles was 0.33%, but they were not completely dissolved in methylmethacrylate. Polymerization was homogenous in all samples, so the new nano-photonic Soleko SP40™ material for rigid gas permeable lenses was made. The third polymerization was done without nanomaterials, so the standard Soleko SP40™ RGP material was made and was used as a referent sample.

Three sorts of solutions were used for biocompatibility investigation: aqua purificata, saline and drops for dry eyes. Aqua purificata is a drinking water which is purified by double reverse osmosis. This water is completely demineralized. The saline is Natrii Chloridi infundibile 0.9% (Sodium Chloride solution). The artificial drops were Refresh Contacts drops that consist of sodium-carboxymethylcellulose of 0.5%, as well as PURITE®. This is a unique preservative which breaks down into natural tear components – sodium and chloride ions, oxygen and water. Since these components are also in natural tears, the risk of irritating the eye or damaging cornea is minimized. Carboxymethylcellulose is a polymer which is ideal cytoprotective lubricant for the ocular surface. It provides long-lasting relief and protection from the symptoms of dry eye. This polymer is a mucoadhesive that shares similar protective qualities against harmful agents as natural ocular mucin. Under experimental conditions it binds to epithelial cells of the ocular surface. [5]

3. METHODS

In this research we used three samples of all three types of contact lenses: standard SP40, SP40 with C_{60} incorporated and SP40 with $C_{60}(OH)_{24}$ incorporated. The solutions, aqua purificata, saline and drops, were poured into 20 ml cups and the contact lenses were put inside those solutions. The solutions with contact lenses were left for 72 hours.

After 72 hours, the contact lenses were taken out of the solutions, and the solutions were poured into other cups for taking pictures. Every sample was shot 10 times, with white and reflected polarized light. The pictures of solutions, without influence of contact lenses, were taken as well, for comparison.

The recording equipment was a Canon digital camera, model IXUS 105, 12.1 MP. The light solution was accomplished by diffuse white diode and a lighting composition at Brewster's angle (three LED set at angle of 53° in regard to vertical axes). The recording region is circular with diameter of about 25 mm. [7]

Each type of matter has special, different, angle value of light polarization. Since reflected polarized light contains electrical component of light-matter interaction, taking the difference between white light (electromagnetic) and reflected polarized light (electrical) yields magnetic properties of matter based on light-matter interaction. Since such measurement can identify the conformational state and change in tissue on molecular level we named this method the opto-magnetic fingerprint of matter or opto-magnetic spectroscopy (OMS). [6]

In addition to customized camera, a software solution is used to analyze obtained images, yielding a characteristic diagram – diagnostic result – which shows the intensities of light in correspondence with wavelength difference. Since this light is polarized by a sample it means that the character of polarization describes the character of the material. In this way, by characterizing the reflected light we can actually characterize the properties of the sample. This method is very sensitive as it detects magnetic properties on the basis of the response to visible light excitation which is relatively low in energy. [6].

4. RESULTS

Analyzing the diagrams we can see the differences and similarities, on the diagrams from the same class, as well as on the diagrams from different classes. From the diagram of average spectrums (Figure 4) of class *aqua purificata* one can see some similarities and differences in peaks. It is obvious that for *aqua purificata* and for *aqua purificata* under influence of SP40 contact lens there are four peaks, two positive and two negative.

For *aqua purificata,* the average wavelengths and amplitudes for the first and the second positive peaks are 111.71/100.728 and 120.71/72.91, respectively, and for the first and the second negative peaks, 110.7/-121.95 and 121.91/-68.49. On the other hand, these peaks under the influence of standard contact lens are at 113.57/85.05 and 119.22/52.91, and negative ones at 112.28/-103.05 and 120.68/-64.69.

For *aqua purificata* under the influence of contact lens with incorporated C_{60} and $C_{60}(OH)_{24}$, there are three peaks, two negative and one positive. The wavelengths are slightly different (approximately 0.6 nm of difference), however the intensities (amplitudes) of the peaks are very different (the differences are up to 77 units). For *aqua purificata* under the influence of contact lens with incorporated C_{60} the wavelength and amplitude of the positive peak are 115.9/164.2, and for the first and the second negative peaks 114.99/-63.54 and 116.73/-131.25, respectively. The same peak for the case with incorporated $C_{60}(OH)_{24}$ the peaks are at 115.29/86.38, and for the negative ones at 114.32/-38.11 and 116.26/-111.81.

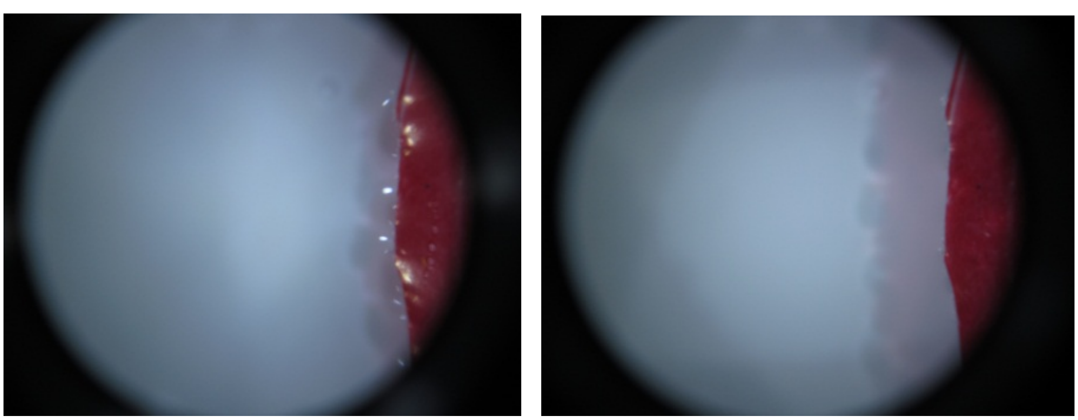

Figure 2. The pictures show aqua purificata, taken with white light (on the left) and reflected polarized light (on the right). The marked part is the region that was cropped and used for further operations. This region size is 250x250 pixels. [7]

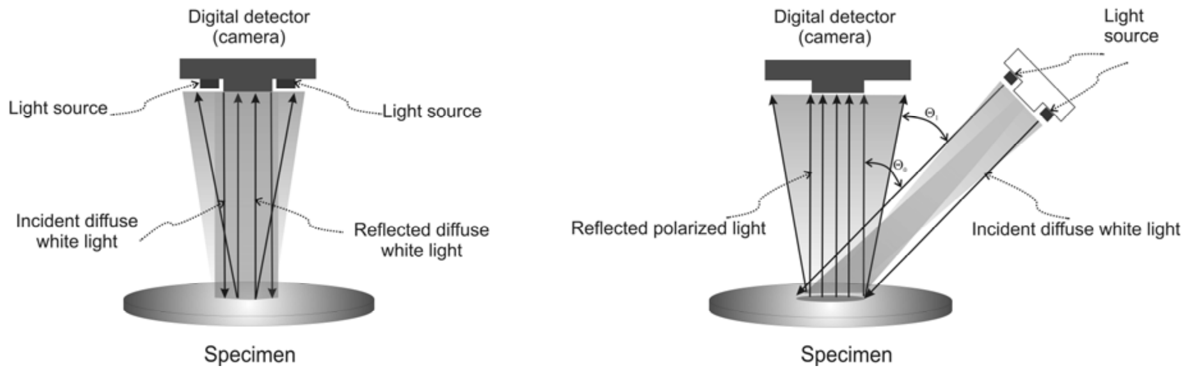

Figure 3. When the incident white light is diffuse, the reflected white light is then composed of electrical and magnetic components, whereas diffuse incident light that is inclined under certain angle will produce reflected light which contains only electrical component of the light. This angle is called Brewster's angle and it represents the magnitude of the angle of incidence under which the sample polarizes the incident light [6]

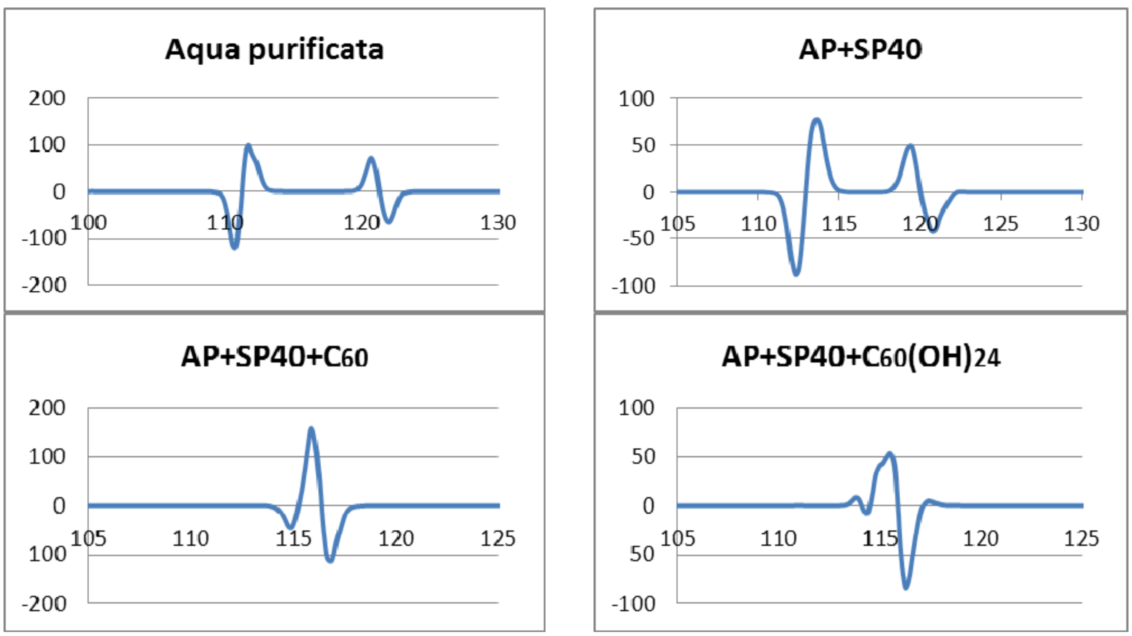

Figure 4. Comparison of Wavelength difference (nm)- Intensity (n.a.u.) diagrams for aqua purificata, aqua purificata with SP40 contact lens (AP+SP40), aqua purificata with contact lens with C_{60} (AP+SP40+C_{60}) and aqua purificata with contact lens with $C_{60}(OH)_{24}$ (AP+SP40+ $C_{60}(OH)_{24}$)

The situation is a little different for the class of *saline*. In case of *saline* there are four peaks, two positive and two negative. Average wavelengths and intensities of the first and the second peaks are 109.14/66.87 and 121.609/58.16, respectively, and the negative ones are 111.196/-37.53 and 119.51/-137.48. However, when this liquid was under the influence of contact lenses the diagrams show two or three peaks. In case of a standard contact lens SP40 and the one with incorporated C_{60} there are two peaks, one negative and one positive, at almost the same average wavelengths, and at slightly different amplitudes.

The positive peak for the *saline* under the influence of SP40 contact lens is at 115.51/78.03, and the negative one is 116.63/-72.89. When *saline* was under the influence of C_{60} the peaks were at 115.73/86.62 and 116.92/-73.73, respectively. The differences in wavelengths are approximately 0.2 nm, and for intensities approximately 0.8 units for the negative peak and 8 units for the positive one. In the case of influence of the contact lens with incorporated $C_{60}(OH)_{24}$ on the *saline* there are three peaks, two positive and one negative. As we can see from the diagram (Figure 5) the wavelengths difference of the peaks are approximately the same as in two previous cases. The first positive peak is at 114.91/99.74, and the negative one is at 116.19/-113.29.

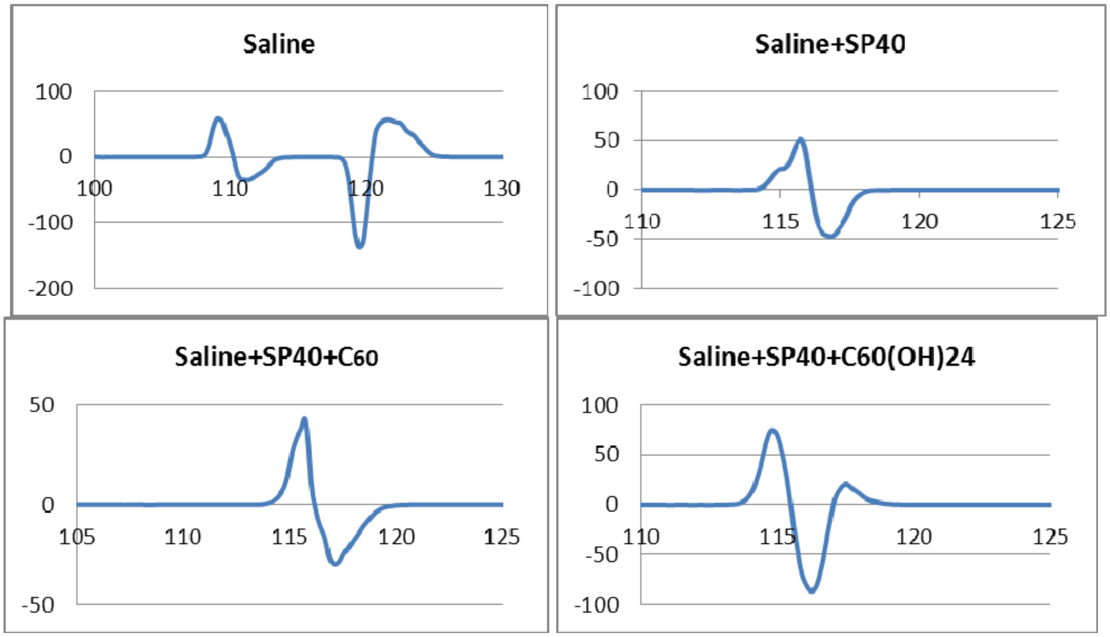

Figure 5. Comparison of Wavelength difference (nm)- Intensity (n.a.u.) diagrams for saline, saline with SP40 contact lens (Saline+SP40), saline with contact lens with C_{60} (Saline+SP40+C_{60}) and saline with contact lens with $C_{60}(OH)_{24}$ (Saline+SP40+ $C_{60}(OH)_{24}$)

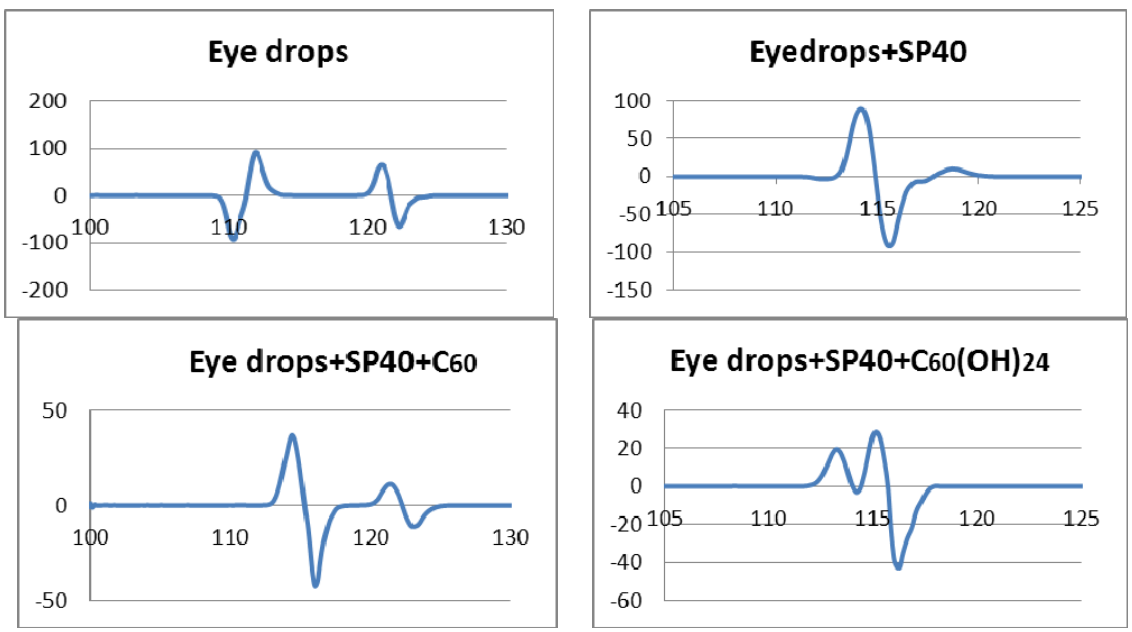

Figure 6. Comparison of Wavelength difference (nm)- Intensity (n.a.u.) diagrams for eye drops, eye drops with SP40 contact lens (Eye drops+SP40) eye drops with contact lens with C_{60} (Eye drops+SP40+C_{60}) and eye drops with contact lens with $C_{60}(OH)_{24}$ (Eye drops+SP40+ $C_{60}(OH)_{24}$)

In the case of *eye drops* the diagrams are similar. For the *eye drops* only we have four peaks, two positive and two negative, like it was with *aqua purificata* and *saline*. The first and the second positive peaks are at 111.94/91.855 and 121.28/69.611, respectively. The negative peaks are at 110.37/-99.73 and 122.34/-81.26. However, in this class we have four peaks in the case of *eye drops* under the influence of contact lens with incorporated C_{60} as well. Here the positive peaks are at 114.87/84.76 and 118.12/50.08, and the negative ones are at 115.372/-74.86 and 118.48/-104.73. When *eye drops* were under the influence of contact lens SP40 and the one with incorporated $C_{60}(OH)_{24}$ there were three peaks.

For the SP40 contact lens the peaks are at 114.39/105.89, 115.84/-112.02 and 118.25/22.18, and for the one with $C_{60}(OH)_{24}$ the peaks are at 114.91/79.3, 116.09/-89.03 and 117.08/34.02.

5. CONCLUSION

The obtained Wavelength difference (nm)-Intensity (n.a.u.) diagrams show that all three sorts of contact lenses have almost the same influence on all three used liquids. Therefore, in case of aqua purificata before adding the contact lenses, there are four peaks, two positive and two negative. The diagrams are the same for saline and eye drops as well. Also, it is obvious that the SP40 contact lens did not result in significant changes for aqua purificata, and for saline and eye drops there is a change, as there are three peaks. For the case of contact lenses with incorporated C_{60} and $C_{60}(OH)_{24}$ in aqua purificata the peaks are at approximately the same wavelengths, only with different intensities, which can imply the same influence of both sorts of contact lenses.

In the case of saline under the influence of contact lenses with incorporated C_{60} and $C_{60}(OH)_{24}$ the diagrams are slightly different. It is obvious that these sorts of contact lenses have different influences, because there are two and three peaks, at different wavelengths. It is the same for the eye drops that were under the influence of contact lenses with incorporated C_{60} and $C_{60}(OH)_{24}$, but here we have four and three peaks. Also it was noticed that the peaks appeared at wavelengths in the range of 108 nm to 122 nm, while intensities have bigger variations.

The aim of this paper was to investigate the influence of contact lenses made of different materials, the standard SP40 material and SP40 material with incorporated nanomaterials (C_{60} and C_{60} $(OH)_{24}$)) on liquids that have similar content as tear film (aqua purificata, saline, eye drops). By the method of opto-magnetic spectroscopy we have detected differences in influence, but the meaning of these differences is not known until comparative toxicological investigations are done.

Finally, we can conclude that:

1. It is possible to detect the differences in influences of contact lenses on aqueous solutions with opto-magnetic spectroscopy method. The results obtained are consistent.
2. Opto-magnetic spectroscopy method is a qualitative, and not quantitative method that is used for characterization of surface structures of materials. The depth of a region of interest depends on the transparency of the sample, and it is within a range of few nanometers to few millimeters.
3. According to the diagrams obtained we can conclude that there are differences in peak wavelengths, for the solutions itself and for the solutions with influence of the contact lenses.
4. According to the diagrams obtained there are differences and similarities of influences of different contact lenses.

6. ACKNOWLEDGMENTS

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 УТИЦАЈ МАТЕРИЈАЛА КОНТАКТНИХ СОЧИВА НА ВОДЕНЕ РАСТВОРЕ

Сажетак: У овом раду приказали смо испитивање утицаја нових нанофотонских материјала за контактна сочива на водене растворе. Контактна сочива која смо користили направљена су од стандардног материјала силоксанског акрилата са уграђеним молекулама C_{60} и још једног материјала са фулеролом $C_{60}(OH)_{24}$. Циљ истраживања је био да се упореде утицаји тих материјала на различите растворе, као што је деминерализована (18.2 MΩ) вода, алкална со и капи за сухе очи. За анализу различитих раствора користили смо оптомагнетну спектроскопију. Добијени спектри су коментарисани и упоређени са стандардним материјалом за контактна сочива, који је анализиран истом методом, како би се приказале разлике у утицају овог стандардног и новог нанофотонског материјала. Ово истраживање доприноси бољем разумијевању биокомпатибилности нових материјала за контактна сочива.

Кључне ријечи: контактна сочива, фулерен, фулерол, биокомпатибилност.