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POSITRON ANNIHILATION LIFETIME SPECTROSCOPY ANALYSIS OF UV IRRADIATED CONTACT LENSES (OCUFILCON D)

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Abstract. We have analyzed, soft contact lenses (CL), made of 45% polymer (ocufilcon D) and 55% water, that are used in vision correction treatments. The purpose of our analysis was to see the evolution of this type of lenses, under UV irradiation, as in treatments the contact lenses can be used daily and are exposed for 8-10 hours per day to the Sun and the UV light can affect them. We irradiated the lenses using a UV lamp of irradiance 12 mW/cm^2. Another goal was to see if the recommended seven days use of one pair is fair. The analysis of the contact lenses was made using positron annihilation lifetime spectroscopy, as it can give us an insight on how the free volume present in the polymer evolves.

Key words: positron, annihilation, lifetime, contact lenses, UV light, irradiance, polymer, free volume.

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1. INTRODUCTION

In the past decade biomaterials have become more and more important in medicine and medical treatments and the technology for producing or using them has evolved so that the risks that existed in the past have been minimized. Contact lenses are used in similar treatments in which glasses are used, mainly in treatments for vision correction but they can also play an aesthetic role. In the case of contact lenses, the biomaterials used have reached the point in which they have the necessary properties for every day use without affecting the bearer too much and making their wear be and feel as natural as possible. Although, in the past contact lenses were used, they were made from hard materials that in time inflicted injuries, infections or other eye problems; nowadays, the use of hydrophilic polymers (hydrogel), not only that confers much more comfort to the eye but also reduces the chance of other types of complications. The free volumes and properties of the polymer material allows a good oxygen transfer between the eye and the outside media.

2. CONTACT LENSES

Contact lenses (CL) are of different types: soft contact lenses, rigid gas permeable contact lenses (RGP) and hard plastic lenses [2], [3]. Each of the types have certain characteristics. RGP CL are more durable, offer a very good oxygen transfer but they are not comfortable and can give certain medical complications. Hard plastic lenses are not used anymore as they do not have oxygen permeability and being made from hard plastic they could inflict injuries to the eye, but in the past were a good alternative to glass contact lenses. The soft CL are being used in treatments that include daily replacement of the pair or scheduled replacement, that can have a time span of 7 days to 30 days. Soft lenses are the most used contact lenses nowadays as they have some advantages compared to the other types. Having almost the same optical characteristics as RGP, they give more comfort and have a good oxygen permeability, with a very low risk of complications to the eye.

Soft disposable (scheduled replacement) CL are usually made from a hydrophilic polymer and water. The two components can be found in different concentrations, depending on the use and type of the contact lens. The water content can range from 38 % to 80 % [4], depending on the type of lens and the bearer. These bio-materials are called hydrogels.

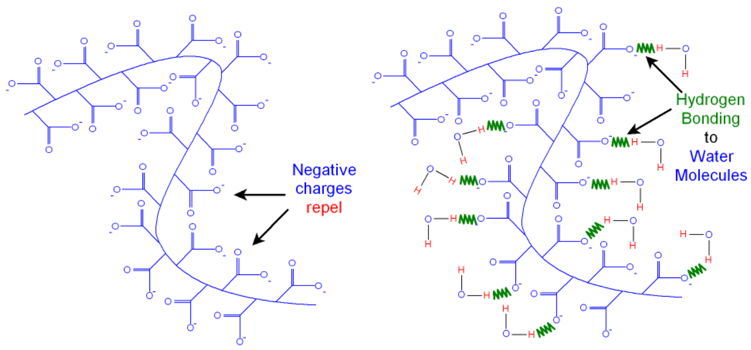

Fig. 1 – Hydrogel schematic view. Hydrogen bonding in hydrogel [http://www.gcsescience.com/o70.htm].

Hydrogels (figure 1), are three-dimensional hydrophilic polymer networks made up of water-soluble polymers, crosslinked to form a water-insoluble hydrogel [1]. Water in these type of polymers can be found in at least 20% and a maximum of 99% [1]. For this they make a good choice for producing contact lenses, thus being highly biocompatible and also having a good oxygen permeability. We chose for our experiment to use contact lenses generically named ocufilcon D, the name being the name of the polymer used. The composition is 55 % water and 45 % ocufilcon D, that is a random copolymer of 2-hydroxyethylmethacrylate and methacrylic acid [5].

3. POSITRON ANNIHILATION LIFETIME SPECTROSCOPY (PALS)

Positron annihilation spectroscopy (PAS) is a sensitive method of investigating materials that have free volumes, vacancies, defect holes, that go down to the nanometric scale. The method is based on the annihilation of the positron inside the material; as the positron has an affinity for free volumes inside the material, it gives good information on the volume.

The positron, inside the sample material, can annihilate directly with an electron it encounters or can form an atom-like stable structure named Positronium (Ps) with an electron and this structure usually forms inside a free volumes. Ps has two possible states p-Ps (singlet state) and o-Ps (triplet state), each of them having a characteristic lifetime. For p-Ps the lifetime is of 125 ps and for o-Ps is 142 ns, in vacuum. But the o-Ps time, depending on the sample material, can decrease down to a few ns, as it annihilates with an electron (with anti-parallel spin) it picks off from the surrounding media. So keeping in account that the lifetime of the o-Ps can be directly related to the size of the free volume

$$\tau_3^{-1} = 2[1 - \frac{R}{R_0} + \frac{1}{2\pi} sin(\frac{2\pi R}{R_0})] \quad (1)$$

we can investigate solid structures with one PAS method named Positron Annihilation Lifetime Spectroscopy (PALS). The method measures the time between the start signal (given by the production of the positron) and the stop signal (the 511 keV annihilation gamma quanta). And it can give information about the lifetime of the positron in matter. The spectrum can be deconvoluted into lifetime components related to the source and the sample as the spectrum is a sum of these time components

$$N_i = \sum A_i exp(-\lambda_i t_i) + B_i \quad (2)$$

and can give the lifetime of o-Ps.

4. EXPERIMENT

We used for our experiment contact lenses which have 55% water and 45% ocufilcon D as polymer. This hydrogel is a random copolymer of 2-hydroxyethylmethacrylate and methacrylic acid [4]. The lenses are soft lenses than can be used as daily disposable or in scheduled replacement treatments. The producer recomends that the lenses are used in treatments that involve the use of a pair for one week (7 days).

For the experiment we have irradiated the lenses with UV light with the irradiance of 12 mW/cm^2. The lenses were exposed to the UV lamp for 1, 2, 3, 4 and 5 minutes in order to see how the lens would behave under UV light, as the eye is exposed daily to this kind of irradiation. Keeping into account that the maximum value of exposure to UV light for the eye is about 1 mW/cm^2 for exposures bigger than 16 minutes [7] we calculated that 1 minute of irradiation with the lamp is equivalent to approximately 8 days of normal exposure during a wearing time of 8-10 hours.

We used ^{48}V positron source, with an activity of 50 μCi, sandwiched between the sample contact lenses, that have the diameter of 14.2 mm. The lenses were put in a plastic isolated bag in order to keep the lens solution inside so that to prevent them from drying. Each lifetime spectrum, for each irradiation session was taken in 3 days.

5. RESULTS AND DISCUSSIONS

The fitting of the lifetime spectra, which was made using the program LT v10 [14], by Kansy, revealed an increase of the o-Ps lifetime after the irradiation, compared to the normal, non-irradiated CL. The χ^2 for fitting the spectra was 0.98. As it can be seen in figure 2 the o-Ps lifetime increases from 1.8 ns (the lifetime of the non-irradiated lenses) to 2.6 ns after 2 min of irradiation (2.2 ns after 1 minute of irradiation), which is equivalent to the increase of the size of free-volume. After 2 minutes of irradiation the lifetime has a leveling behavior and only at the 5 minutes mark another visible increase is found. We believe the saturation, that occurs between the irradiation marks of 2 and 4 minutes, is due to the fact that the structure of the lenses becomes degraded and the polymer loses its properties and the molecular and chemical bounds are partially destroyed. Also, the increase at 5 minutes irradiation time mark means the total degradation of the lenses. So we can say that the lenses are unusable after 2 minutes of exposure to the UV lamp and that they start to be affected after the first minute of irradiation.

The 2 minutes irradiation time, keeping into account the calculation of the irradiation equivalence, means about 16 days of exposure to the Sun UV light. Considering that when the contact lenses are worn, they are influenced by other factors such as dryness and mechanical wear it can be considered that the lifespan of their use should not exceed the producers recommendations and that they probably should be used in 7 days treatments. The probability that after 7 days of use they lose the necessary characteristics to be used in safe conditions is high enough, so that the recommendation of the producer is correct.

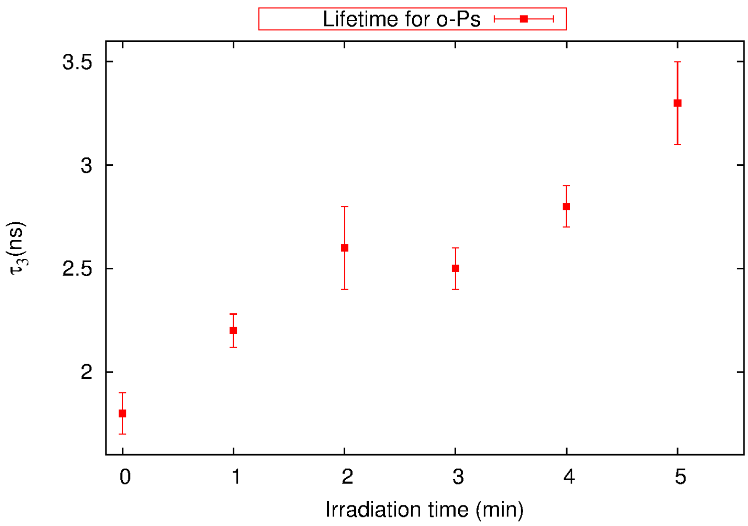

Fig. 2 – o-Ps lifetime for CL normal, irradiated 1,2,3,4,5 minutes.

6. CONCLUSIONS

We have successfully analyzed hydrogel contact lenses using positron annihilation in polymer, through the lifetime spectroscopy method. The positron source we used was a ^{48}V source. The results have shown that under UV light the lenses have a longer lifespan than that recommended by the producer for use in treatments, but by keeping into account other environmental factors, the recommendations are valid and it is not indicated to use this type of contact lenses in treatments that exceed 7 days of use.

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