Surface wettability regulation for prosthetic applications

L. Lancere[1], Y. Dekhtyar[1]
[1]*Institute of Biomedical Engineering and Nanotechnologies, Riga Technical University, Latvia*
E-mail: [1]linda.lancere@rtu.lv

Introduction. In present times, in eye prosthetics and eye lenses production mostly poly methyl metha acrylate (PMMA) is used because this material excellently fulfills biomedical, aesthetic and psychological demands which are essential for patients who need eye supplementary aids. Despite this, peculiarities of PMMA material determines that under of influence of mechanical impact (wind, sand, eye lid movements) and degradation in time, surface properties alter and wetting between supplementary aid and eye lid declines. Reduced biocompatibility follows, discomfort and inflammations in the eye socket region occur. Therefore the aim of this research is to decrease/avoid complications by regulating wettability according to patient's needs. It is presumed that applying small enough energy, will influence properties at surface level without changing bulk properties. For that reason Ultra Violet radiation is used in range 200-400 nm, also there is little knowledge, how wettability is influenced in the mentioned range.

Surface properties depend on material's surface energy which is related to the electrical charge, deposited on to the surface. Electrical charge can be evaluated by material's electron work function. Surface energy level changes allow to judge about surface structure alterations, interactions of chemical/ physical couples (crosslinking,stretching or other processes) and distribution of electrical charge.

Materials and methods. Samples were obtained first by heat polymerization using Ctoma material (Ukraine). Further, mechanical treatment – slipping and polishing – was applied. Finally 96% ethanol was used to wash/clean the specimens. The specimens were irradiated with the Hg - Xe discharge lamp (Hamamatsu). The intensity of irradiation was 3.5 W/cm2. The specimens were positioned at the distance 1.5 m from the light guide output of the lamp and the temperature of the specimens was + $20^{o} \pm 2^{o}$C. Irradiation was provided in different durations: 15, 30, 90, etc. minutes.

Wettability was tested using Axisymmetric Drop Shape Analysis-Profile (ADSAP) method. This method was adjusted to use with custom made assembly made of optical microscope MMI-2 and CCD camera (Imaging Source) to record drop image to the PC. Specimen surface was cleaned with 96% ethanol. Physiological solution was used to form a drop on the clean specimen's surface and the side view of the drop was photographed. The image was used to measure the contact angle using image-processing software (Image analyser, NT - MDT). This measurement was repeated 15 times, average and SD was calculated.

The photoelectron spectrometer was used to measure the electron work function (φ) that an alteration due to UV irradiation was taken as a measure of the surface charge modification. The custom – made spectrometer [1] ensured registration of near-threshold photoelectrons from PMMA. Photo stimulation was provided by weak UV light in the range of 200 – 270 nm. Resulted photoemission current dependence on the wavelength was used to evaluate red boundary and calculate electron work function. Alteration of the latter was noticed.

To reveal possible reconstruction of the chemical couples, PMMA optical absorption was measured as well. The measurements were made in the range 200 – 400 nm with step 0.5 nm by Helios - Gamma spectrophotometer. Spectra was recorded by VISIONlite (Scan Version 2.1) software, digital data was exported to MS Excel for further calculations. Before each series of measurements, a baseline spectrum was recorded to ensure high reliability of results. PMMA spectra were obtained before and directly after each irradiation session. The absorbance spectra A(λ) were attributed with the minimum of the derivation dA/dλ at the wavelength ~ 380 nm. To characterize the number of electron states, corresponding to this peculiarity of the spectra, integral over the peak area (Eq.1) was used:

$$S = \int_{\lambda} \frac{dA}{d\lambda} d\lambda. \tag{1}$$

Results. In the Fig. 1 non-linear tendency of electron work function alterations can be noticed with increase till 45 min of exposure.

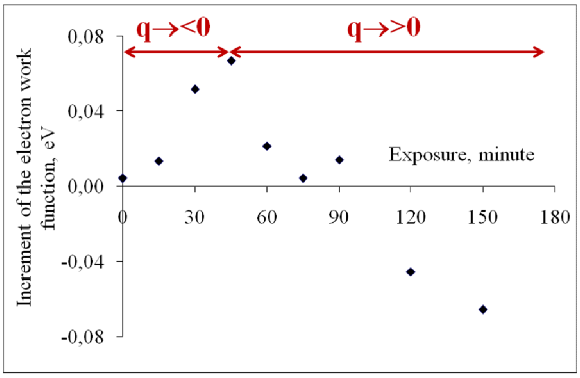

Fig. 1. Electron work function increment depending on exposure time

Further surface charge becomes more positive and electrons do not repel from surface as till 45 min – electron work function decreases.

Measurements of contact angle show decreased contact angle (Fig.2) till 60min of exposure.

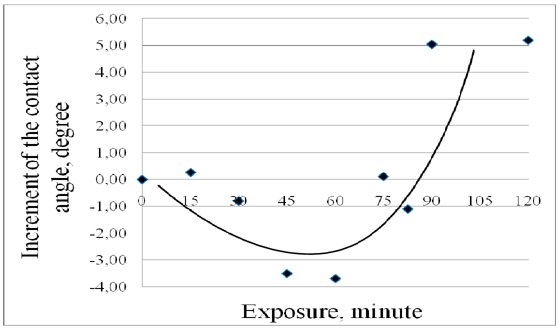

Fig.2. Increment of contact angle depending on exposure time.

Tendency in Fig. 2 confirms that higher surface energy requires lower values of contact angle – material becomes more hydrophilic. Wettability could be influenced by both - redistribution of the electrical charge and to reconstruction of the chemical couples under influence of UV photons.

In the absorbance data spectrum a minimum occurred – this minimum occurs for radiation exposures 0, 15, 30 and 45 min. However, for samples under different exposures (60, 90, 120, etc.) the described extreme was not detected.

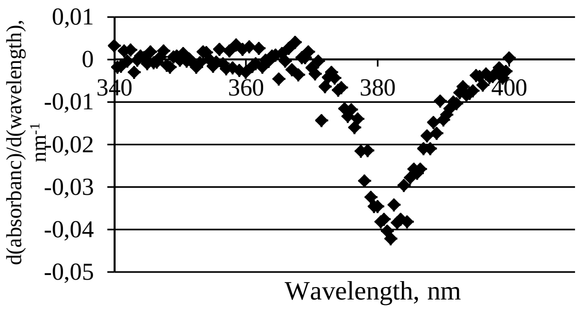

Fig. 3. Absorbance spectra of PMMA for exposure times 0 - 45min

The area of the peak, related to concentration of absorption centers increases at wavelength of 381 nm. Those centers may be responsible for the accumulation of the surface charge. Area of this peak also shows a specific tendency as shown in Fig. 4.

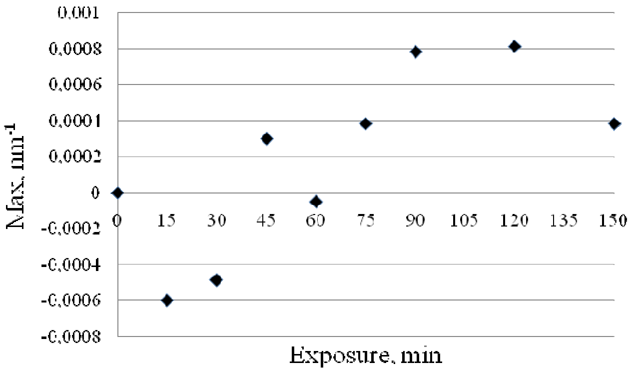

Fig. 4. Area of the maximum peak depending on exposure time

Tendency in Fig. 4 shows that number of absorption centers increases till 60 min of exposure.

Conclusions. UV radiation can be in use to engineer PMMA surface wettability, particularly for eye prostheses and lenses applications.

Alterations in wettability, absorbance spectra, electron work function, all are detected at approx. 45-60 min of exposure. In future work stability in time of the effect should be explored.

References

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Prosthetic poly (methyl methacrylate) is widely used for medical applications like lenses and eye prostheses. For prosthetic products biocompatibility is essential. This article is targeted to describe a possible simple solution how to influence alterations of PMMA wettability by non-ionizing UV radiation in range of 200 - 400nm. Processed material was examined by means of detecting contact angle, electron work function and absorption spectra to find correlation between wettability and other surface properties. Results show non-linear tendency of surface wetting alteration and peculiarities in electron work function and absorption spectras. UV radiation could be used to functionalize PMMA surface by not influencing its structure with UV exposures under 60 minutes.