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The influence of Polyquaternium-7 on the hair properties

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Abstract
The influence of UV-light with the wavelength 254 nm on the hair properties was detected. Hair was also treated by the Polyquaternium-7 which is commonly used in cosmetic preparations as conditioning agent. Mechanical properties were measured and the surface of hair was examined by atomic force microscope.

1. Introduction

Characteristic feature of all mammals is hairy body. Human hair is an important social factor, nevertheless it also protects head against the sunburn and other external factors [1].

Several studies on the influence of UV-irradiation on human hair had been already made [2-4]. Cuticle layer in hair is an outer layer and it is exposed to the environmental influence in greater extent than the cortex of hair. Melanin molecules in human hair play very important role due to the protection against the absorption of UV light especially in lower wavelength [4]. Irradiation of hair with UV light can lead to the detachment of scales in the cuticle, what can be observed by the scanning electron microscope and/or atomic force microscope [5,6]. It is commonly known that radiation may also change the visual appearance of human hair [7,8]. Besides the degradation of hair, UV-irradiation can cause also forming new transverse bonds, between carbonyl and amino groups [9].

Degradation of hair can be observed by several techniques. One of them is measurement of mechanical properties of hair [10]. Using simple mechanical test a few parameters can be characterized. The extension of the sample is expressed as a percentage of the sample elongation from the original length. The linear region of the stress extension curve gives the Young's modulus. The stress needed to break the sample is called as a breaking force (F_{max}). Tensile strength (σ_m) was calculated the equation:

$$\sigma = \frac{F_{\max}}{A_0} \qquad (1)$$

where F_{max} is a breaking force, A_0 is an initial cross-sectional area of the specimen in cylinder shape [11].

Polyquaternium-7 (Figure 1) is an example of quaternary anionic surfactant, which is commonly used as a main compound of hair conditioners. It has a positively charged nitrogen atom in the structure. This positively charged nitrogen atom is responsible for the interaction of Polyquaternium-7 with the hair, where it interacts with negatively charged parts of damaged hair. Moreover, van der Waals interactions are also present between the Polyquaternium-7 and the hair surface.

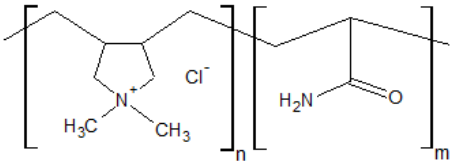


Figure 1. Chemical structure of Polyquaternium-7 [7].

The aim of this study was to determine the influence of UV-irradiation on structure and properties of human hair. For the study of damage of hair induced by UV-irradiation the Atomic Force Microscopy and the measurements of mechanical properties were used. Moreover, the influence of Polyquaternium-7 on the human hair properties before and after exposure to UV light was investigated.

2. Materials and methods

2.1. Materials

Natural dark brown straight hair was taken from 24 years old volunteer. The length of sample was 7 cm. Two kinds of samples were prepared – from the head side (root) and from the end side of hair. Hair was immersed in 5% solution of Polyquaternium-7 for 1 h, then washed with distillate water and dried in air conditions. Samples were irradiated by UV-C light (254 nm) for 2, 6 and 18 hours by using UV lamp Philips TUV-30 with the intensity 27.4 μJ/cm^2 (measured by IL 1400A Radiometer).

2.2. Methods

Mechanical properties were measured by testing machine Z.05 Zwick/Roell, Germany. Stretching rate was 200 mm/min. All measurements were made in room temperature and dry conditions. Atomic force microscope (AFM) images were made by MultiMode Scanning Probe Microscope Nanoscope Illa (Digital Instruments Veeco Metrology Group, CA) with resolution 5 μm. Roughness of hair was measured by Nanoscope program.

3. Results

3.1. Mechanical properties

Mechanical parameter, such as Young Modulus (E_{mod}), breaking force (F_{max}), ultimate tensile strength (σ), elongation at break (dl) were determined for samples after 2, 6 and 18 hours of exposure to UV-irradiation (Table 1) and for irradiated samples treated later by Polyquaternium-7 solution (Table 2).

Table 1

Mechanical properties of hair after 2, 6 and 18 hours of UV-irradiation

Time of irradiation [h]	Emod [GPa]	Fmax [N]	σ [MPa]	dl [%]
0	5.42±0.56	0.943±0.089	362±63	59.8±1.7
2	5.04±0.69	0.877±0.136	297±38	56.8±4.8
6	4.94±0.79	0.861±0.192	256±42	55.4±3.0
18	3.11±0.28	0.681±0.055	231±25	48.5±5.1

Table 2

Mechanical properties of hair after 2, 6 and 18 hours of UV-irradiation and then treated by Polyquaternium-7

Time of irradiation [h]	Emod [GPa]	Fmax [N]	σ [MPa]	dl [%]
0	4.71±0.82	0.768±0.088	301±25	53.4±2.9
2	5.27±0.89	0.888±0.124	324±32	58.1±6.0
6	5.16±0.95	0.822±0.143	311±34	63.7±4.0
18	4.63±0.53	0.761±0.100	288±75	56.5±3.1

3.2. Atomic force microscope

Atomic force microscope (AFM) images of hair surface are shown in Figure 1 and 2.

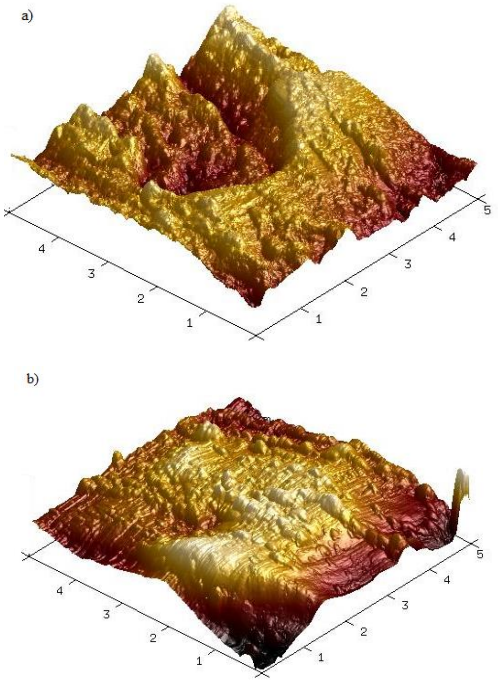
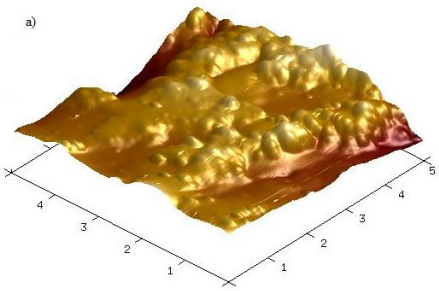


Figure 1. AFM images of the surface of: a) hair b) hair after Polyquaternium-7 treatment.



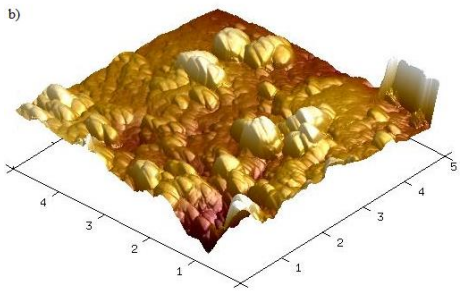


Figure 2. AFM images of a surface of: a) hair after 6 h of UV-irradiation b) hair after 6 h of UV-irradiation and Polyquaternium-7 treatment.

The atomic force microscope images show that after UV-irradiation hair scales have been degraded. Application of Polyquaternium-7 on the surface of hair results that it becomes to be more smooth and much less symptoms of hair scales degradation can be observed.

4. Discussion and conclusion

UV-irradiation leads to the degradation of hair. The degradation is observed as reduced mechanical parameters with the increasing time of irradiation. Hair which was not irradiated by UV light, but treated with the Polyquaternium-7 had worse mechanical properties than irradiated one, probably due to overloading of the surface by the layer of conditioner. When hair is irradiated, cortex is unveiled and Polyquaternium-7 can get into the hair shaft. New interactions, between amine and carboxylic groups, can be then formed what improve the mechanical properties of hair. Images made by atomic force microscope shows that Polyquaternium-7 causes adhesion of hair scales. It is observed also for hair after the UV light damage.

5. References

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