PROPERTIES OF GAS DISCHARGE AROUND HUMAN HAIR UNDER THE INFLUENCE OF EXTERNAL STIMULUS

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I. INTRODUCTION

This work continues a research line of study of gas discharge properties around objects of different nature initiated by strong impulse electromagnetic fields [1,2]. The aim of this work was to study the time dynamics and behavioral response of human hair to different external stimulus.

Hair provides no vital function for humans, but its psychological effect is nearly immeasurable. Luxurious scalp hair expresses femininity for women and masculinity for men. The lack of scalp hair or the presence of excessive facial or body hair is often as distressing to females as the loss of beard and body hair is to males. Study of hair and its response to different treatment and stimulus is of tremendous importance for the humankind.

Each type of hair undergoes repeated cycles of active growth and rest. The relative duration of each cycle varies with the age of the individual and the region of the body where the hair grows. The length of the cycle is often modified by a variety of physiologic and pathologic factors. The cyclic phase of the hair follicle is identified by an active growth period, known as anagen; an intermediate period, catagen; and a resting stage, telogen. Of the 100,000 to 150,000 scalp hairs on a human adult (regardless of sex), 90% are in the growing, or anagen, phase, which lasts from 4 to 8 years[3]. The remaining 10% are in the resting (telogen) phase, which lasts from 2 to 4 months. Approximately 50 to 100 clubbed hairs are shed each day. All of this, of course, differs among individuals. On the scalp, human hair grows at a rate of 0.44 mm/day at the vertex and 0.39 mm/day at the temples, and scalp hair grows slightly faster in women than in men.

At the same time hair has traditionally been considered to be an inert tissue. While the hair root is vital, its product, the hair shaft, is primarily dead keratinized cells[4]. The aim of this work was to demonstrate the presence of time dynamics of hair parameters after cutting from the scalp and to study the influence of different physical stimulus to this process. Results of this study allow to treat fresh hair as a live biological tissue that opens up a new perspective in a hair study.

II. METHODS OF RESEARCH

A swatch of hair about 4 inches long was cut from the back of a live model's head at the distance about 2 inches from the scalp. The swatch was immediately placed inside a Teflon tube with 3 mm of hair protruding from the bottom. The end cross-section cut was performed using a microtome to ensure uniformity. The holder positioned the swatch perpendicular to the glass electrode with the cut ends of the individual hair touching the glass electrode which had the transparent electro-conductive layer at the bottom of the glass. This setup allowed studying the hair still attached to the head of live model sitting nearby the experimental table. All experimental setup was placed in a plexiglass sealed container that allowed control of air pressure, humidity and temperature.

Over 100 swatches, mannequin heads and other control samples were used as hair controls. Swatches were single-sourced, assembled by International Hair Importers and Products, New York USA from hair that was collected during the tests.

The panel of subjects consisted of 14 adults ages 18-55. They represented a variety of hair types; with damage levels ranging from virgin hair, to hair that had been treated or styled extensively. Test subjects sat near the camera so that their hair could pass completely across the electrode. An initial ten-second reading was taken with their hair on the electrode. A few minutes later, a 30 second reading was taken; at the 15-second mark the hair was cut between the electrode and the subject, detaching the hair from the subject. The cut was made in a manner to ensure that the sample did not move on the electrode.

For the first group of test subjects, a varying schedule was used for taking readings of the hair. In some cases, tests concluded after 24 hours of testing; in others, a schedule of readings over 3 days was followed. Due to trends seen in the results for the first group, additional subjects were tested using the same protocol, but with readings taken over a 7-day period.

Using this setup, hair was tested at specific humidity levels using a sealed chamber specially designed for the purpose. Temperature and barometric pressure and were kept constant. Humidity in the chamber was increased from by blowing water vapor into the chamber or decreased by pumping out humid air and drying the chamber with a hygroscopic silica-gel compound. The diapason of humidity change was 0 – 100%. Humidity was measured with a calibrated hygrometer.

Temperature of hair swatch was changed by heating with in-focused intensive light beam for the particular time with control by hromel-copel thermocouple with electronic transducer. Temperature was changed from 20 C^0 to 80 C^0.

The train of triangular bipolar 10 microsecond electrical impulses of amplitude 3 kV, at a steep rate of 10^6 V/s and a repetition frequency of 10^3 Hz, was applied to the conductive layer, thus generating an electromagnetic field (EMF) around the hair. Under the influence of this field, the hair produced a burst of electron-ion emission and optical radiation light quanta in the visual and ultraviolet light regions of the electromagnetic spectrum. These particles and photons initiated electron-ion avalanches, which gave rise to the sliding gas discharge along the dielectric surface[5,6]. A spatial distribution of discharge channels was registered via glass plate by the optical system with the Charge Coupled Device TV Camera, and then it was digitized in the computer. Hair were exposed to an EMF for 10 seconds, and short "films" were recorded in the computer as "AVI" files. The frame rate (frequency of record) was set at 30 images per second, as dictated by the speed of the camera/ computer interface. All "AVI" files were converted into a series of "BMP" files, and the area (the number of light-struck pixels) and averaged intensity (ranked from "0" for absolute black to "255" for absolute white) parameters for every image were calculated by the software. The time series was averaged on 10 measurements that provided the statistical reliability at the confidence level of 0.95 with an experimental sensitivity of 75%.

III. RESULTS

The reproducibility of the method was verified by measuring the time dynamics of the gas discharge around a metal cylinder that was 10 mm in diameter, and was placed in the center of the optical lens. Thirty subsequent measurements provided statistical reliability at the confidence level of 0.95 with an experimental sensitivity of 95%. Deviation at every point of the time series was less than 5%. The same level of deviation was obtained for most of the studied samples of hair.

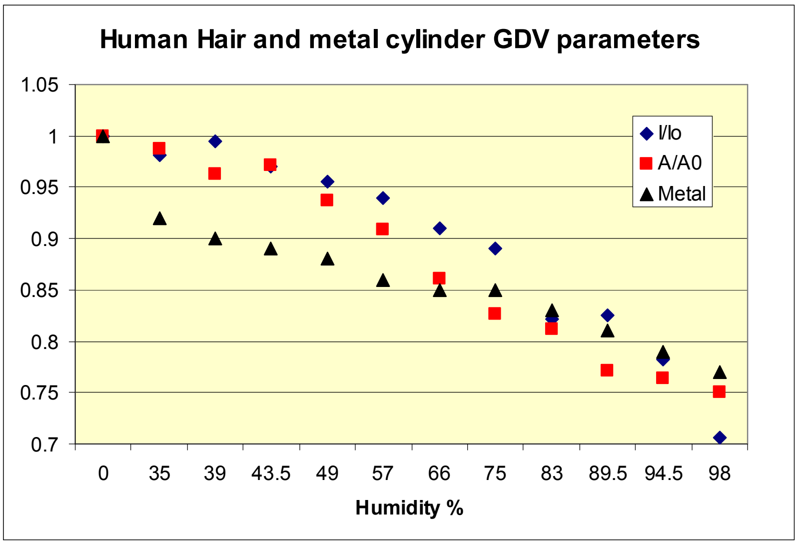

Fig. 1. Humidity dependence of Area and Intensity of gas discharge images of swatch of fresh human hair and metal cylinder expressed as a proportion – value of the parameter at 0% is the divisor.

Hair response to the change of humidity and temperature was studied both for fresh and dry hair. Change of image parameters with humidity was found to be independent from hair freshness and similar to the humidity dependence of the discharge images of a metal cylinder. This reduction of corona discharge is most likely due to decrease of ionization rate caused by absorption of electrons by water molecules[7,8]. At the same time it is known that hair fibers have a moisture regain of approximately 31%, which varies depending on the relative humidity and duration of exposure to that environment. The time required for equilibrium is generally recognized as 18 – 24 hours[9]. In our experiments equilibrium time was from 10 minutes to 72 hours and no dependence from this time was found. Especially noteworthy is the similarity between the readings at 0% and at normal ambient conditions (30-70%); a signal was still detectable in the absence of bound water. The similarity between the readings for the titanium cylinder and the hair samples indicates that the effect of humidity on the tested material is largely independent of the substrate and dictated only by the behavior of gas discharge. In addition, the effect that humidity has on the tested material in the normal range of humidity (30-70%) is minimal.

Temperature dependence was different for hair and metal reference cylinder. For the GDV image of metal cylinder the Area increased by 6% with heating from 20 C° to 80 C°, while the Intensity stayed constant. For hair strong increase both of Area and Intensity was detected (Fig. 2, 3). The level of increase depended on the subject: for woman's, man's and dried hair the level of increase was different. At the moment we do not have enough data for any correlation between temperature dependence of hair and its properties.

The most interesting data was found for the time dependence of hair gas discharge parameters. While for metal cylinder and dried hair neither intensity nor area of the image changed over time, for fresh hair thesee parameters decreased from day-to-day during 5-7 days. The level of decrease from the moment of cut was different for different subjects but this effect was reproducible in numerous experiments conducted independently both in the USA and Russia. Detailed measurements conducted every hour revealed oscillation behavior of the parameters (fig. 4, 5).

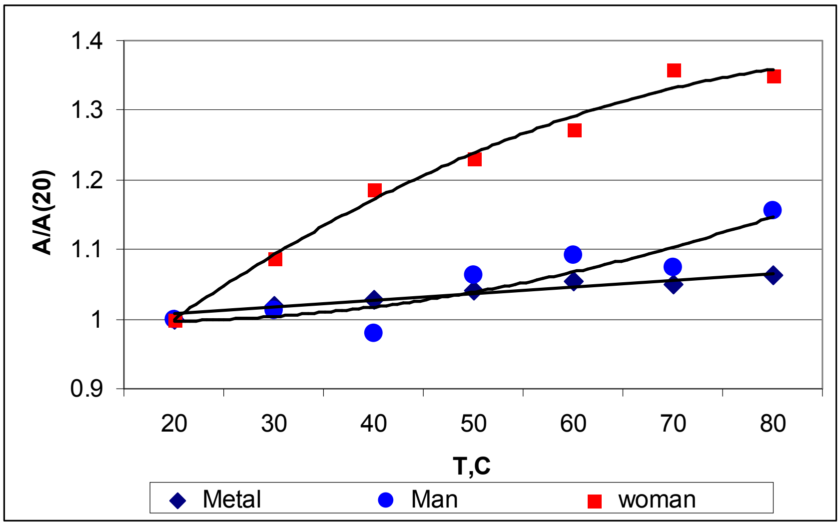

Fig.2. Temperature dependence of Area of gas discharge images of swatch of fresh human hair and metal cylinder expressed as a proportion – value of the parameter at 20 C° is the divisor.

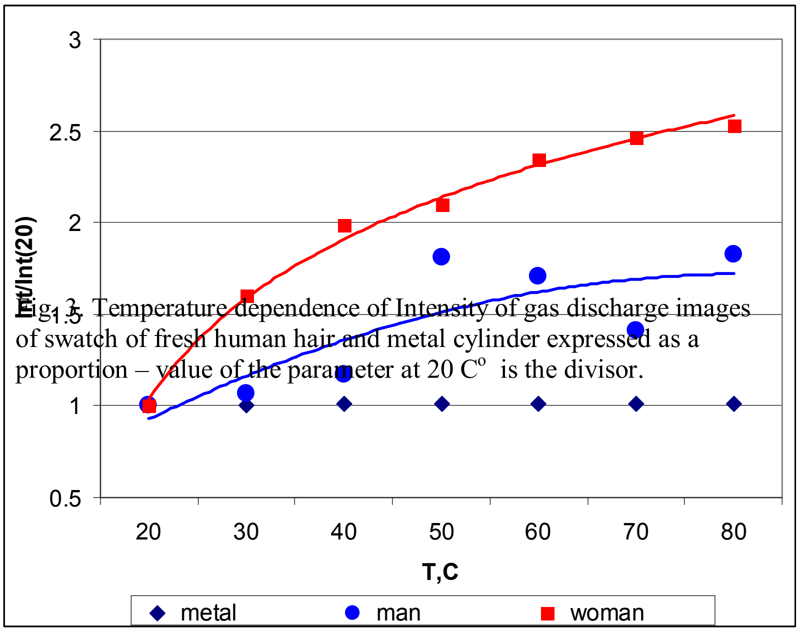

Fig. 3. Temperature dependence of Intensity of gas discharge images of swatch of fresh human hair and metal cylinder expressed as a proportion – value of the parameter at 20 C° is the divisor.

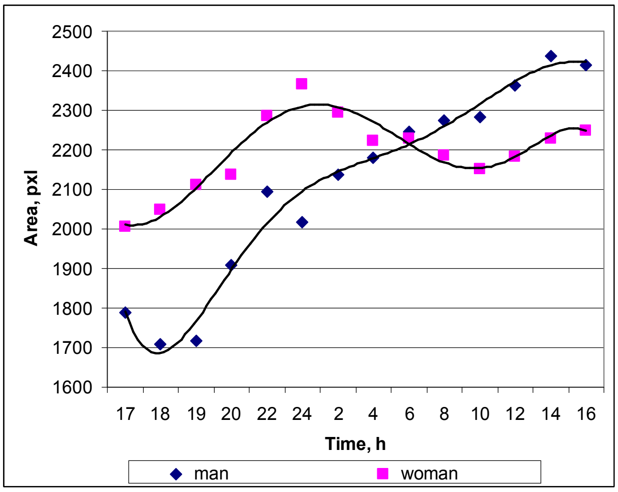

Fig. 4. Time dependence of Area of gas discharge images of swatch of fresh human hair.

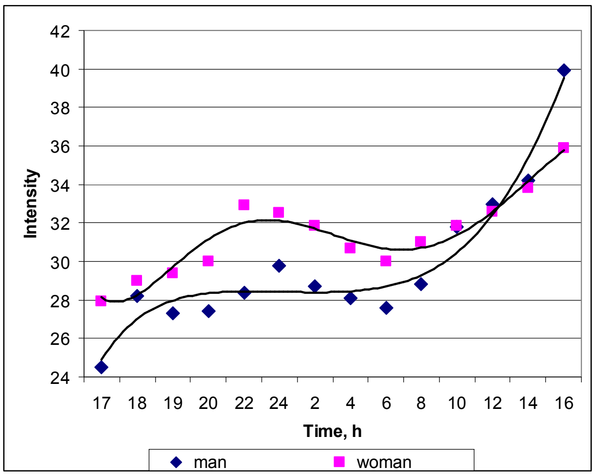

Fig. 5. Time dependence of Intensity of gas discharge images of swatch of fresh human hair.

We pay attention that measurements of fig.5, 6 were conducted during 24 hours immediately after hair cut from the head. After several days of oscillations both Area and Intensity of the images gradually dropped down to a stable level.

The process itself of cutting hair from the scalp reflected at the time series of intensity readings (fig. 6). During this measurement the swatch of hair was positioned on the electrode and care was taken not to disturb this position. The magnitude of drop was different for different subjects but this drop was never registered for dried hair.

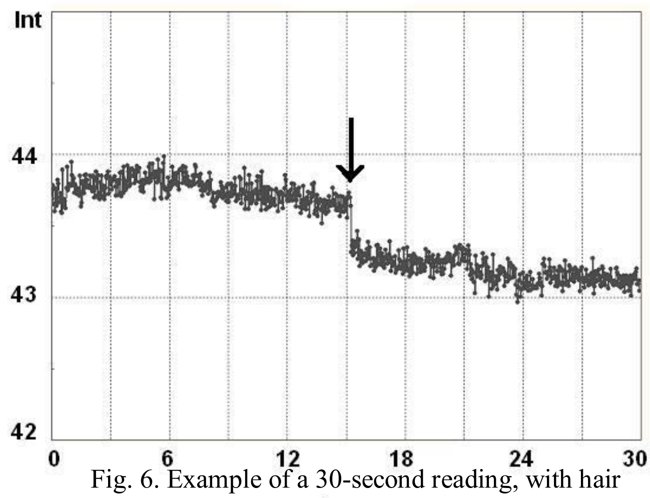

Fig. 6. Example of a 30-second reading, with hair cut from the model midway through the reading (this moment is shown by the arrow).

DISCUSSION AND CONCLUSION

Experiments conducted independently in two laboratories demonstrated the following results:

1. Parameters of gas discharge images around swatch of hair had specific dynamic behavior for freshly cut hair, while no changes of parameters for metal subject and dried hair was found.
2. The live model panel included a diverse array of test subjects: both male and female with ages ranging from 18-55. Additionally, a variety of hair types ranging from undamaged (virgin) to heavily damaged (both mechanically and chemically) were encountered during the study. It should be noted that while the majority of panelists were Caucasian, the panel consisted of a wide range of hair levels (shades). Some panelists exhibited up to 50% gray hair coverage. In every test subject, an immediate reaction to cutting was observed, using the intensity parameter. The parameter of area remained the same during cutting, meaning that the hair did not move during the cutting procedure.
3. In the subsequent measurements after cutting of the hair, fresh samples from the live models showed a decrease in GDV activity with oscillations during the day. While the hair from the dried swatches underwent the same protocol of cutting under identical environmental conditions, the swatches' activity remained at constant levels after cutting.
4. GDV signals were observed even in hair samples kept at 0% humidity for many hours and humidity dependence was the same both for fresh hair and for metal cylinder. That shows that evaporation of bound molecules of water found within the human hair has little or no contribution to the observed phenomena.
5. Temperature dependence of freshly cut hair is different from temperature dependence of metal subject and has nothing to do with thermal enlargement.
6. While further investigation of this phenomenon is needed, this disruption was not dependent on the gross physical characteristics of the freshly cut samples; nor was it observed on the dried single-sourced hair. These results support the hypothesis of the transmission of signals between human hair and body due to the electron jumping with tunneling mechanism, possibly centered on the polypeptide composition of hair[10]. Hair cuticles comprise specific amino acids, notably cysteine, serine, and glutamic acid[9].
7. GDV presents a highly sensitive and reproducible technique for the testing of human hair. It was able to record specific properties of freshly cut hair that are not observed in dried samples. This approach may be used for the study of influence of different treatments like coloring, washing, drying to the human hair.

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