Identifying Taxonomic Belonging of Animal Hair Using Instrumental and Microscopic Methods

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DOI: 10.32353/khrife.2.2022.04 UDC 343.98:636.09
Received: 6 June 2022 / Reviewed: 14 June 2022 / Approved for Print: 17 June 2022 / Available Online: 30 June 2022

Urgent need to develop a methodology for identifying taxonomic belonging of animal hair using modern research methods (identification of additional objective criteria in the case of a comparative research on material evidence, namely: animal hair) is considered that contributes to solving a larger range of issues raised while appointment forensic biological examination. Authors aimed to substantiate possibility of identifying the taxonomic affiliation of animal hair using instrumental and microscopic methods, in particular, scanning electron microscope, allowing forensic biologists to study the surfaces of objects of animal origin, both of significant linear dimensions, and of microparticles in a wide range of magnifications (from 10× to more than 200,000×), providing a resolution of up to 10^{-9} m. Obtaining a general image of the surface and selecting appropriate areas for detailing (at the maximum possible magnifications) does not require significant reconfiguration of the device. A significant depth of focus provides detailed images of various surfaces with developed relief (cracks; traces of mechanical damage; morphological specifics of periodically reproduced surface

This article is translation of the original Ukrainian content, which source is available at the link: *https://khrife-journal.org/index.php/journal* (translated by Andriy Bublikov). The author acknowledges translation as corresponding to the original.

structures). Contrast is the detection result of reflected electrons (depending on the distribution of phase components differing in chemical composition the studied sample surface). The proposed method of researching animal hair will significantly expand possibilities of examination of these objects: it will reduce the time and increase the accuracy of conducting such research, as well as make it possible to supplement illustrative material (for example, microphotographs of hair cuticles of frequently encountered animal species).

Keywords: *animal hair; elemental composition of hair; objects of animal origin; scanning electron microscopy; forensic biological examination.*

Research Problem Formulation

Specific expertise application from various fields of science for the forensic science needs is of great importance in solving issues of strengthening law and order in Ukraine. One of the prominent places among the types of forensic examination is occupied by research in the field of forensic biology, in particular, research on animal hair as objects of animal origin.

Hair research is an independent evidence base for law enforcement agencies contributing to identification of crime tool, the persons committed the crime, as well as to the investigation of other circumstances. Hair is the most common biological material and is often the only physical evidence recovered at crime scene.

Currently, domestic experts: medical examiners and biologists have a number of techniques and methods for researching animal hair.

Development of science and technology contributes to the steady enrichment of methods and means of researching physical evidence. Purposeful, scientifically based study of the signs and properties of these objects, based on the achievements of various scientific fields, increases reliability of conclusions and quality of forensic research.

Laboratory research on physical evidence using modern methods and tools provides detectives and investigators with important information about crime and criminals that is essential for the search and detection of the latter, prevention and detection of crimes.

Analysis of Essential Researches and Publications

Formation of forensic examination on animal hair is connected with research papers of medical examiners and biologists of different countries. Professionals who study its morphology play a leading role in development of animal hair research.

The important forensic significance of hair was also highlighted by forensic scientists and forensic physicians of the 19th century. Thus, at the I. Pirogov Congress of Physicians [1], held in St. Petersburg in 1885, the participants heard and discussed the report of the assistant prosector at the Department of Forensic

1 Верхратський С. А., Заблудовський П. Ю. Історія медицини : навч. посіб. 4-те вид., випр. і допов. Київ, 1991. 431 с.

Medicine of the Kharkiv University M. O. Obolonsky "On hair in forensic medical terms" according to which a year later he defended his doctoral dissertation [2], and in 1894 another prominent physician, P. A. Minakov, defended his doctoral dissertation on the same topic that has not lost its importance [3].

Forensic significance of hair was highlighted by such well-known scientists as: L. P. Bulyha, L. K. Bulysheva, Yu. I. Buraho, O. Yu. Kaniuka, M. V. Kisin, O. V. Lukomska, M. L. Mamotiuk, V. S. Mytrychev, O. I. Razorenova and others. [4]

However, the issues of identifying taxonomic affiliation of animal hair using instrumental and microscopic methods has not been sufficiently investigated by domestic forensic science.

While forensic biological research on animal hair, research objects can be: specific animal; specific set of animals; specific item containing treatment product of fur of one or more animals (product made of animal skins and fur: a collar, coat, fur coat, floor covering, etc.); specific volume of animal wool; specific collection of animal skins, etc.

Prevalence of domestic and wild animals, the use of their skins, fur, and wool for the manufacture of clothing and other items of daily use, etc., necessitates the use of this type of objects as carriers of probative information.

Obtaining such information is based on the need to find out correlation between

2 Chisnikov V. Ukrainian professor N. A. Obolonsky – prime propagandist of anthropometric systems A. Bertilion in the Russian empire. *Criminalistics and Forensics*. 2016. Vol. 61. Pp. 576—582. URL: http://nbuv.gov.ua/UJRN/krise_2016_61_63 (date accessed: 03.06.2022).

3 Рейсс Р. А. Научная техника расследования преступлений : курс лекц. / под ред. проф. С. Н. Трегубова. Санкт-Петербург, 1912. С. 83 ; Авдеева И. А., Васильева О. О. П. А. Минаков и развитие судебно-медицинской экспертизы волос в России. *Здоровье и образование в XXI веке* : электрон. науч.-образоват. вестн. 2006. № 1. Т. 8. С. 15. URL: https://cyberleninka.ru/article/n/p-a-minakov-i-razvitie-sudebno-meditsinskoy-ekspertizy-volos-v-rossii (date accessed: 03.06.2022).

4 E.g.: Булыга Л. П. Исследование волос животных близких родов в практике судебной экспертизы : пособ. для эксперт. Москва, 1979. 108 с. ; Eadem. Методика дифференциальной диагностики волос животных близких родов. Криминалистика и судебная экспертиза. 1972. Вып. 9. С. 361—365 ; Бураго Ю. И. К особенностям некоторых физико-химических свойств морфологически сходных волос животных при судебно-медицинской экспертизе их видовой принадлежности (комплексное микрофотометрическое, спектрофотометрическое, абсорбционно-спектрографическое экспериментальное исследование) : дис. ... канд. мед. наук. Барнаул, 1977. 168 с. ; Канюка О. Ю. Методичні особливості дослідження перехідного волосся пса свійського. *Теорія та практика судової експертизи і криміналістики.* 2020. № 22. С. 340—347. DOI: 10.32353/khrife.2.2020.27 (date accessed: 03.06.2022) ; Кисин М. В., Булышева Л. К., Мамотюк М. Л., Разоренова О. И. Волосы животных как объект судебно-биологической экспертизы : учеб. пособ. Москва, 1984. 115 с. ; Лукомська О. В. Морфологічні особливості волосся собак порід Yorkshire Terrier, West Highland White Terrier, Airedale Terrier та Australian Terrier / *Біологічні дослідження — 2021* : зб. наук. пр. Житомир, 2021. С. 93—96 ; Wandhare P. P., Bhosale M. S. Trichology: a Science of Hair Examination in Identification of Dog Breeds. *International Journal of Applied and Pure Science and Agriculture (IJAPSA).* 2017. Vol. 03. Is. 6. Pp. 61—66. DOI: 10.22623/IJAPSA.2017.3055.FZ1ES (date accessed: 03.06.2022) ; Tridico S. R. Examination, Analysis, and Application of Hair in Forensic Science — Animal Hair. *Forensic science review*. 01 Jan, 2005. Vol. 17. Is. 1. P. 17—28.

the facts of the presence or condition of animal hair and the circumstances of availability to be established. Determining the information essence and value of information generated from the results of hair research is the result of comparing research data with other circums\tances established in the case [5].

Article Purpose

Justify possibilities of identifying taxonomic affiliation of animal hair using instrumental and microscopic methods, in particular, scanning electron microscope.

Main Content Presentation

The main tasks of the research on objects of biological origin are diagnostic and identification.

Diagnostic tasks (in the case when the carrier of information is the animal hair) are, in particular, determination of whether the hair belongs to a certain animal within a specific classification system (family, genus, species). The basis of most diagnostic studies are natural or artificial classification systems.

Identification tasks are to establish identity of compared objects (a hair belongs to a certain animal, a fragment of fur is separated from a certain collar, etc.); determination of the belonging of the compared objects to an animal of the same taxon, so-called common generic belonging; clarification of the general group belonging of the compared objects.

Thus, while examination of objects of biological origin, it is often necessary to compare animal hair found at the crime scene with samples taken from persons suspected of murder, rape, theft of animals, wool or fur products, etc.

In the practice of morphological research on animal hair, it is often necessary to establish its belonging to a certain species or a larger taxonomic unit (kind, family). Despite a significant number of works covering this field of knowledge, forensic scientists and biologists still experience some difficulties while relevant examinations.

Currently, morphological methods of animal hair research are the main ones while forensic examination of such objects. Analysis of specifics of hair structure remains crucial for identifying their taxonomic and group affiliation.

For identifying taxon of animal hair, available methods are used, that involve (along with the rest of the research) treating the hair with a hot lye solution in order to obtain core discs, by which taxon of the animal can be identified.

Unfortunately, it is sometimes quite difficult to determine taxonomic affiliation of hair using this method, since similarity of morphological structure of the hair of some animals makes it difficult to differentiate them. In addition, for the study of downy hair, which is often found in expert practice, the morphological method is not enough, because it is common knowledge that core itself most often has a specific composition for a specific taxon. It is necessary to note clear inadequacy of using in expert practice only morphological tests of modified animal hair that was subject to certain technological processing (fur).

Therefore, it is not always possible to use generally accepted methods of analysis to solve the problems of forensic biological research of animal hair that is why development of new methods of research of biological materials is urgent. One of these methods is determining content of elements in biological objects.

5 Кисин М. В., Митричев В. С. Судебно-биологическая экспертиза волос животных: методическое пособие для экспертов, следователей и судей. Москва, 1996. 136 с.

Recently, we have observed an increase in interest in the study of the content of macro- and microelements in the human body in normal conditions and in the presence of pathological conditions. They are necessary for almost all the most important life processes, as well as for the normal course of many metabolic reactions and the implementation of physiological functions [6]. However, in forensic biology (in contrast to medicine), the study and use of this knowledge remains limited and not in sufficient demand. According to modern concepts, the elemental composition of hair reflects the condition of humans and animals better than other bioindicator systems. In addition, the use of special hair research methods makes it possible to detect elements and substances a long time later (after days, weeks, years). A valuable characteristic of hair as an object of research is its resistance to influence of natural factors. In connection with the above, there is a need to apply new methods of animal hair research in order to reveal additional identification and diagnostic signs.

Following issues may be asked for forensic biological examination:

- "Does presented object-carrier contain objects of animal origin, in particular hair?";
- «Are the detected objects animal hair?»;
- "If detected objects are animal hair, what is its taxonomic affiliation?";
- "Does detected animal hair come from the animal hair or from a fur product?";
- "Is the object exposed to specific factors of the external environment?";
- "Do hair found on the carrier object and hair of a certain animal (animal hair product) have a common generic (taxonomic) or group affiliation?";
- "To what breed of animal does the detected hair belong? Is it the same as the hair taken as a sample?";
- "From what part of the animal body does the detected hair come from?";
- "Does detected hair belong to this particular person?" etc.[7]

One of the traditional methods of hair research is the macroscopic method. In addition, the color, shape and length of the hair are determined. To determine

6 Медична біологія : підручник / за ред. В. П. Пішака, Ю. І. Бажори. Вінниця, 2004. 656 с. ; М'ясоєдов В. В. Вміст макро- і мікроелементів в органах та тканинах щурів, токсикованих синтезованими поверхнево-активними речовинами. *Буковинський медичний вісник*. 2000. Т. 4. № 3. С. 206—212 ; Шахбазов В. Г., Григорова И. А., Носатенко П. Е. Оценка состояния здоровья населения с использованием новых биофизических интегральных методов. *Медицинская экология, гигиена производственной и окружающей среды* : регион. науч.-практ. конф. Харьков, 1995. Т. 2. С. 136—138 ; Aggett P. J. Physiology and metabolism of essential trace elements: An outline. *Clinics in Endocrinology and Metabolism*. 1985. Vol. 14. Is. 3. Pp. 513—543. DOI: 10.1016/s0300-595x(85)80005-0 (date accessed: 03.06.2022) ; Frieden E. A. Survey of the Essential Biochemical Elements / Biochemistry of the Essential Ultratrace Elements. N. Y. ; L., 1984. Pp. 1—16 ; Matsumoto K., Inagaki T., Hirunuma R., Enomoto S., Endo K. Contents and uptake rates of Mn, Fe, Co, Zn, and Se in Se-deficient rat liver cell fractions. *Analytical Sciences*. 2001. Vol. 17. Is. 5. Pp. 587—591. DOI: 10.2116/analsci.17.587 (date accessed: 03.06.2022).

7 Основи судової експертизи: навчальний посібник для фахівців, які мають намір отримати або підтвердити кваліфікацію судового експерта / авт.-уклад.: Л. М. Головченко, А. І. Лозовий, Е. Б. Сімакова-Єфремян та ін. Харків, 2016. 928 с.

the hair color, it is washed in warm water with soap and degrease with ether. For measuring the length, a ruler is placed on the hair and carefully straightened. By shape, hair is divided into straight, arc-shaped, wavy, curly. The shape of the hair is determined by studying each individual hair.

One of the main methods for solving issues of forensic biological examination is microscopic examination. Hair is an epidermal keratinized formation containing a root part, fixed in the skin at an angle to the surface and a stem part (shaft). The root of the hair ends with a thickening (hair follicle) and the peripheral end (shaft) ends with a tip of various shapes (needle-shaped, in the form of a broom, etc.).

There are three layers in hair:

1) core, or brain substance that is located in the central part of the hair and contains one or more rows of cells. The core of the hair is made up of cells, which size and shape of differ in different animals. In thin hair, the core can be missing;
2) cortical substance containing cells stretched along the hair. They contain a pigment that determines hair color;
3) cuticle that is surface layer of thin cells located in the form of scales (tiles) along the entire hair shaft. Cuticle scales can vary in size, shape, and location in the hair in different animal species. Furthermore, the shape, size and location of the cuticle scales can vary according to the length of the hair.

For example, the hair of mammals is divided into several types: guides of the 1st-3rd order, spiny hair of the 1st-4th order, downy hair of the 1st-4th order, vibrissae.

Currently, methods of microscopic analysis of hair based on the features of the cuticle and core have been developed, which make it possible to determine whether an animal belongs to a specific group, for which specialists use catalogs of photos of the hair of these animals (standards). However, these methods are not applicable when the required standard is missing from the catalog.

Recently, researchers often turn to highly informative methods [8] (for example,

8 E.g.: Баланюк Ю. В., Педан А. Д., Шклярський В. І. Сканувальний телевізійний оптичний ультрафіолетовий мікроскоп для дослідження біологічних мікрооб’єктів. *Вісник Національного університету «Львівська політехніка»*. 2009. № 645 : Радіоелектроніка та телекомунікації. С. 243—252. URL: https://ena.lpnu.ua/bitstream/ntb/2513/1/38.pdf (date accessed: 03.06.2022) ; ДСТУ Б А.1.1-9-94. Метод електронної мікроскопії матеріалів. Терміни та визначення : затв. наказом Мінбудархітектури України від 12.04.1994 р. № 83. Чинний від 01.10.1994. URL: http://online.budstandart.com/ua/catalog/doc-page.html?id_doc=5031 (date accessed: 03.06.2022) ; Кофанов А. В., Кобилянський О. Л., Давидова О. О. Криміналістичне дослідження біологічних об’єктів : метод. рек. Київ, 2011. 48 с. (Серія «Криміналістичне забезпечення») ; Черепин В. Т., Васильев М. А. Методы и приборы для анализа поверхности материалов : справочник. Киев, 1982. 400 с. ; Ayache J., Beaunier L., Boumendil J., Ehret G., Laub D. Sample Preparation. Handbook for Transmission Electron Microscopy : Methodology. New York, 2010. 338 p. DOI: 10.1007/978-0-387-98182-6 (date accessed: 03.06.2022) ; Дубровська Г. М., Бутенко Т. І., Григор’єва Г. В. Переваги і можливості атомно-абсорбційної спектрофотометрії та лазерної мас-спектрометрії при контролі елементного складу порошкових матеріалів. *Вісник Черкаського державного технологічного університету*. 2004. № 2. С. 96—100 ; Зайцев Д. М., Приступа В. В. Можливості та перспективи застосування електронної мікроскопії з рентгенофлуоресцентним енергодисперсійним мікроаналізом в судовій експертизі. *Криміналістика і судова експертиза* : міжвідом. наук.-метод. зб., присвяч. 105-річ. заснув. суд. експерт. В Україні. 2018. Вип. 63. Ч. 1. С. 357—371. URL: https://digest.kndise.gov.ua/wp-content/uploads/2019/03/40.pdf (date accessed: 03.06.2022) ; Прудиус І. Н.,

nuclear-physical methods of elemental analysis), which provide information about the content of the most important bioactive macro- and microelements in biological objects of various levels of organization. These methods are characterized by high accuracy.

The main advantages of nuclear physics methods (compared with traditional chemical and biophysical methods):

- high absolute sensitivity (mcg/g), which allows to analyze even a very small amount of substance;
- ability to determine a significant number of elements at the same time;
- high sensitivity to concentration (up to 1 mcg);
- ability to analyze both thin layers of the substance and bulk samples;
- ability to conduct non-destructive analysis;
- speed of obtaining information (up to 10 minutes per target);
- automation of measurements and processing of results.

For carrying out research using the above-mentioned methods, researchers chose animal hair that is most often found in practice of forensic biologists, as well as human hair.

Preparation of hair samples for research using the gamma activation method does not require the use of many chemical reagents, long time, etc. compared to the preparation of these objects for other types of analysis. Thus, for gamma-activation analysis, hair samples were processed according to the P. J. Barlow method: they were washed twice with distilled water, followed by treatment with a mixture of ethanol and diethyl ether (1:1), dried at a temperature of 250 °C, weighed on an analytical balance and packed in aluminum foil. For the gamma activation analysis, the weight of the hair sample was approximately 0.5 g (the weight of the sample may be less). The sample was placed in foil and reweighed. All packages were numbered and placed in a common foil pencil case that was placed under the beam of a linear electron accelerator.

Irradiation was carried out on a linear electron accelerator with a beam of bremsstrahlung gamma rays with an energy of 24 MeV and a current of 700 μA. The sample activation time was 3 days. Upon completion of the activation, the samples were removed from the pencil case and successively transferred to the detector, which registers the given activity. We used a Ge(Li) detector with a volume of 50 cm^3, manufactured at the Kharkiv Physical and National Science Center Kharkiv Institute of Physics and Technology (KIPT), the resolution of which was 2.8 keV (on the 1333 keV line).

The detector was connected to the AI-1024 pulse amplitude analyzer. Calibration of the energy scale of the spectrometer was performed using a set of sample spectrometric sources (OSGI, kit № 69). To measure the activity of the samples, they were sequentially installed on the end of the cover of the cryostat, behind which was the Ge(Li) detector. In the process of measuring the above activity, the stability of the position of the channel (energy) of the gamma spectrometer was monitored. The spectrum acquisition

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Шклярський В. І., Педан А. Д. Скануючий оптичний мікроскоп для клінічної лабораторної діагностики. *Прикладна радіоелектроніка. Стан і перспективи розвитку МРФ'2008* : тези доп. 3-го міжнар. радіоелектр. форуму (Харків, 23—25.10.2008). Харків, 2008. Т. 4. С. 127—131.

time ranged from 10 min to 5 h (depending on the activity of the sample). The resulting spectrum was processed on an amplitude analyzer. The absolute values of concentrations of macro- and microelements were determined using standard samples. The detection limit of the elements was 10^{-4}—10^{-7} % by mass.

As a research result, approximately 30 spectra of hair samples were obtained, in which the following main elements were detected: Ca, Na, Mn, Cr, Zn, Pb, Sr, Ni, Zr, I (Figs. 1-3). It seems possible to detect more elements, provided that the period of start of registration on the detector is reduced.

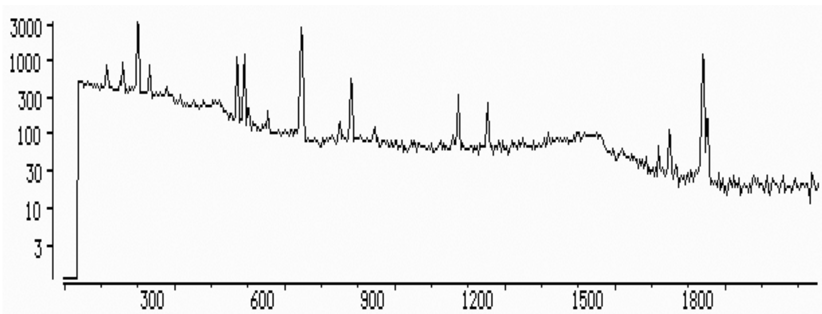

Fig. 1. Spectrum of domestic dog hair

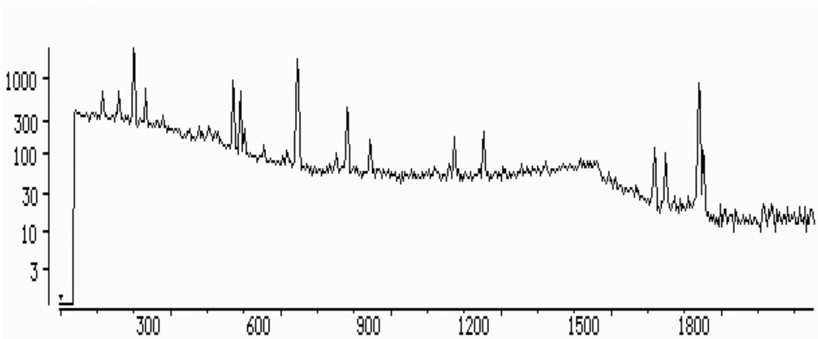

Fig. 2. Spectrum of domestic cat hair

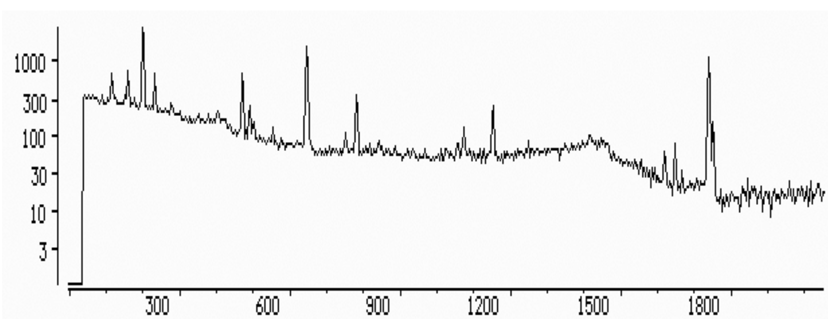

Fig. 3. Spectrum of domestic goat hair

The analysis of obtained results by absolute value, taking into account root mean square deviations, shows that there are certain differences in the content of macro- and microelements between families and genera of animals. Quantitative characteristics of the detected elements in the samples make it possible to detect interfamilial and intergeneric differences using correlation analysis.

In addition to the research on animal hair by the gamma-activation method, a priority and powerful direction is research using scanning electron microscopy that is based on the registration of analytical signals arising from the interaction of a focused beam of accelerated electrons (electron probe) with the object surface under research.

Scanning electron microscopes (hereinafter referred to as SEM) are actively used in various fields of materials science, as they have (due to the physical principles of image formation) a number of significant advantages over any optical microscopes. These advantages include:

- magnification up to 1 000 000×, that is fundamentally unattainable for Bright-field microscopy (BF);
- significant depth of focus making it possible to research relief specifics of volumetric samples (surfaces of fractures, mechanical traces of contact interaction, individual hair samples, microparticles of various morphological structures, etc.);
- ability to receive images with phase contrast of multiphase objects.

While interaction of accelerated electrons with the substance atoms of the sample under research, we observe the following main physical effects:

- secondary electron emission, i.e., release of electrons beyond the electron shells of the atoms of a substance due to the acquisition of additional energy, exceeding the binding energy, from the electrons of the primary beam. Secondary electrons (hereinafter referred to as *SE*) are low-energy, and the intensity of their formation depends mostly on the angle of contact of the electron probe with the surface of the sample. Therefore, images in secondary electrons have a maximum depth of field;
- elastic reflection of primary electrons by atoms of the substance under study at angles of ≈90° to the surface of the sample. Such electrons are called *backscattered electrons* (hereinafter referred to as *BSE*). Probability of occurrence of elastic reflection is proportional to the atomic density in the area of interaction of the substance of the object with the primary electron beam. Accordingly, their registration makes it possible to obtain phase-contrast images;
- X-ray fluorescence is producing electromagnetic radiation with defined energies (wavelengths) that correspond to energy differences between the internal electron shells of the atoms of the sample substance (due to the transition of electrons to positions on lower shells, released in the process of interaction with the primary beam). Determining the numerical values of these energies (wavelengths) and the intensity of corresponding fluorescence maxima is a tool for

establishing the qualitative and relative quantitative elemental composition of the research object;

- formation of Auger electrons. While ionization of the inner atomic shells, there is a possibility of the atom returning to its ground state without emitting a quantum of energy. In this case, excess energy is transferred to one of the electrons of the atom that as a result, leaves its boundaries. The numerical value of the energy of such an electron does not depend on the energy of the primary electron, but is determined by the structure of the electron shells. This phenomenon is the basis of Auger electron spectroscopy (AES);
- cathodoluminescence is emergence of electromagnetic radiation in the visible, ultraviolet, and infrared ranges due to multiple ionization of target atoms under the action of an electron beam. The study of cathodoluminescence is used in scientific research in the field of solid state physics.

Furthermore, informative analytical signals use the current of absorbed electrons and the current of electrons that have passed through the sample.

Secondary electrons (*SE*) are registered mainly by the Evergarth-Thornley detector, a scintillation type detector. Secondary electrons emitted by the sample surface have negligible energy (< 50 eV), so they are attracted (if they enter the detection zone) by the electric field of the detector, where they are accelerated and collide with the surface of the phosphor, causing a flash of light. The optical signal is registered by a photoelectric multiplier (hereinafter referred to as a photomultiplier). The electrical signal from the photomultiplier is amplified and, after digital processing, converted into a gray level on the electronic image. The process occurs in correlation with the coordinate position of the primary beam at a certain point on the surface of the object, thanks to which a relief image of the scanned surface is formed. Backscattered electrons have a much higher energy, so they are not captured by the detector field and they practically do not affect the formation of the image.

Both scintillation and semiconductor detectors are used to register backscattered electrons: reflected electrons (*BSE*). Semiconductor detectors are usually built according to the scheme of a semiconductor diode, which additionally has, in addition to p- and n-conductivity zones, a zone of its own conductivity (depleted of charge carriers). If an ionizing particle (in particular, electron with sufficient energy) enters this zone, carriers of electric charge are formed in so-called electron-hole pairs that are registered in the form of an electric current pulse.

X-ray fluorescence is registered by two types of detectors — a cooled semiconductor detector, which, in combination with an electronic analytical signal processing circuit, simultaneously registers the characteristic maxima of X-ray fluorescence energies of the atoms of the substance of the object in the full energy range available for registration (Energy Dispersive X-ray Fluorescence (EDXRF).

Detectors by wavelengths use the phenomenon of X-ray diffraction on single crystals.

The use of SEM makes it possible to study the surfaces of both objects of significant linear dimensions and microparticles in a wide range of magnifications (from 10× to more than 200,000×). In addition, it is possible to provide a resolution of up to 10^{-9} m. Therefore, without significant reconfiguration of the device, it is possible to quickly obtain a general overview image of the surface and select the appropriate areas for detailing at the maximum possible magnifications.

Significant depth of focus makes it possible to obtain detailed images of various surfaces with developed relief (namely: cracks, traces of mechanical damage, morphological features of periodically reproduced surface structures).

BSE detection provides the ability to form a contrast depending on the distribution of phase components that vary in chemical composition, on the surface of the test sample.

The corresponding images obtained using the *Tescan Vega3* microscope are indicated in Figures 4 and 5.

Fig. 4. Animal down hair (magnification 1190×1190)

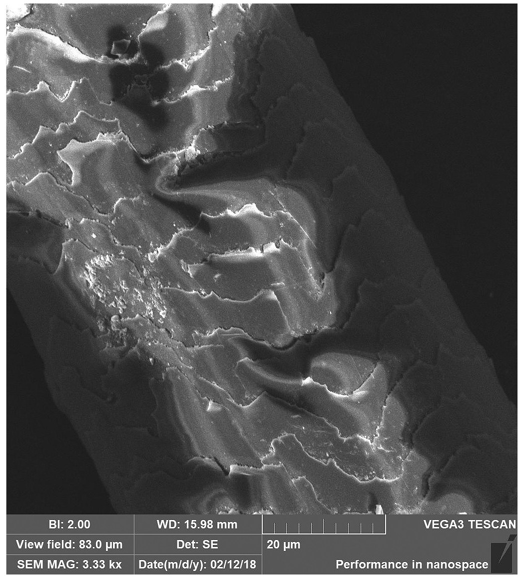

Fig. 5. Detailed image of the figure of the animal's down hair cuticle (magnification 3330×)

Conclusions

Thus, using a scanning electron microscope, biologists can study the surfaces of both objects of animal origin of significant linear dimensions and microparticles in a wide range of magnifications (from 10× to more than 200,000×). In addition, it is possible to provide a resolution of up to 10^{-9} m.

Without major adjustments to the instrument, you can get a general overview of the surface and select the appropriate areas for detailing at the maximum possible magnifications. Significant depth of field makes it possible to obtain detailed images of various surfaces with developed relief (such as: cracks, traces of mechanical damage, morphological specifics of periodically reproduced surface structures).

BSE detection provides the ability to form a contrast depending on the distribution of phase components that vary in chemical composition, on the surface of the test sample.

The proposed methods for researching animal hair will significantly enrich the possibilities of examination of the specified objects: it will make it possible to reduce the time and increase the accuracy of conducting such studies, as well as to supplement illustrative material (for example, microphotographs of hair cuticles of various types of animals, which are often encountered while forensic researches).

Use of modern research methods makes it possible to identify additional objective criteria in the case of a comparative research on animal hair that will contribute to solving a larger range of issues while forensic biological examination.

Встановлення таксономічної належності волосся тварин за допомогою інструментальних і мікроскопічних методів

Лариса Дереча, Олександр Борзов, Флорін Русіторіу

Розглянуто нагальну потребу в розробленні методики для встановлення таксономічної належності волосся тварин за допомогою сучасних методів дослідження (виявлення додаткових об'єктивних критеріїв у разі порівняльного дослідження речових доказів — волосся тварин), що сприяє розв'язанню більшого кола питань, поставлених під час призначення судово-біологічної експертизи. Автори мали на меті обґрунтувати можливість встановлення таксономічної належності волосся тварин за допомогою інструментальних і мікроскопічних методів — зокрема, сканувального електронного мікроскопа, який дає змогу експертам-біологам вивчати поверхні об'єктів тваринного походження як значних лінійних розмірів, так і мікрочастинок у широкому діапазоні прирощень (від 10× до понад 200 000×), забезпечуючи роздільну здатність до 10–9 м. Отримання загального зображення поверхні й вибір відповідних ділянок для деталізації (за максимально можливих збільшень) не потребує істотного переналаштування приладу. Значна глибина різкості дає деталізовані зображення різних поверхонь із розвиненим рельєфом (злами; сліди механічних пошкоджень; морфологічні особливості поверхневих структур, що періодично відтворюються). Контрастність є результатом детектування відбитих електронів (залежно від розподілу поверхнею досліджуваного зразка фазових компонентів, що різняться за хімічним складом). Запропонована методика дослідження волосся тварин суттєво розширить можливості експертизи зазначених об'єктів: зменшить час і збільшить точність проведення таких досліджень, а також дасть змогу поповнити ілюстративний матеріал (наприклад, мікрофотографіями кутикули волосся видів тварин, що часто зустрічаються).

Ключові слова: *волосся тварин; елементний склад волосся; об'єкти тваринного походження; сканувальна електронна мікроскопія; судово-біологічна експертиза.*

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Disclaimer

The funders had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Contributors

The authors contributed solely to the intellectual discussion underlying this paper, case-law exploration, writing and editing, and accept responsibility for the content and interpretation.

Declaration of Competing Interest

The authors state that there is no conflict of interest on this topic, although Larysa Derecha is a member of the journal Advisory Board; she did not take part in decision regarding publication and this article is subject to a full peer review process.

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