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Microtraces in forensic examinations in the past and today as demonstrated by the example of paint coatings and fibres

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Abstract

The article presents the development of methods for examining microtraces such as paints and fibers, in Polish forensic since 1970s to the present day. It describes the transition from classical optical microscopy, based on visual observation, to advanced structural analysis. The application of digital, comparison and electron microscopy, as well as spectroscopic techniques is discussed. The combination of these methods enables comprehensive physicochemical identification of the collected material, increasing the accuracy and evidential value of mictrotraces analysis and making them an essential component of modern forensic examination.

Keywords: microtraces, paints, fibers, microscopy, spectroscopy

Forensic evidence examination has been practised since at least the late 19th century. A type of forensic evidence, microtraces are defined as par ticles of matter which are invisible or barely visible to the naked eye that the perpetrator leaves at the crime scene. As microtraces cannot be avoided or removed, they are a valuable source of information about an incident, its course and persons involved that can help in apprehending the perpetrator [1, 2]. Chemical microtraces include mainly fibres, paint coat particles, plastic particles and micro-shards of glass, metals and metal alloys. Microtraces became particularly important in forensics with the introduction of new sensitive and non-destructive analytical techniques and the development of the measuring instruments used in examinations.

Microscopic methods are among the oldest non-destructive methods of observing microtraces. The use of microscopic observation of specimens with various techniques made it possible to determine a number of physical parameters based on the microscopic images obtained, albeit in a subjective manner and without the aid of result recording equipment.

However, microscopic methods were used in an objective manner as early as in the 1970s. Among those was the interference-polarisation method, used for determining the refractive index and birefringence in synthetic fibres. The method used the MPI-5 microscope (Fig. 1) as the measuring instrument. A combination of the MB-30 biological microscope and the MPI-3 polarisation-interference device, the instrument opened up a range of examination and measurement possibilities, including for anisotropic bodies.

The MPI-5 microscope consisted of the following key components:

- a slit condenser with a rotating polariser,
- an MPI-3 polarisation-interference device,
- a set of lenses with birefringent prisms,
- an OK 15 KM measuring eyepiece.

During examination, measurements of the optical path difference were taken in an interference fringe field, given the known thickness of the object. The data made it possible to calculate the birefringence value and the refractive index [12].

The method for determining the refractive index and birefringence of synthetic fibres had a number of advantages, including the ease of measurement and the ability to examine minute quantities of material and identify fibres without having to destroy them. These advantages enabled widespread use of that method for comparison and group identification of synthetic fibres [12].

Presented below are examples of cases from the 1970s in which polarisation-interference method was applied to determine the refractive index.

The Forensic Department of the then Voivodship Police Headquarters (KW MO) carried out micro-trace analysis for a 1973 preliminary investigation into a burglary of a flat. The perpetrators entered the living quarters through the roof. Evidence in the form of multicoloured fibres was secured from a plank near the manhole cover on the roof of the building. Fibres from a jumper belonging to the suspect were secured for the investigation as reference material. The authority conducting the criminal proceedings requested determination of: "Do the fibres recovered at the scene of the burglary come from the suspect's jumper?"

Fig. 1. A polarisation-interference microscope

It was established in the course of the examination that the jumper was made of polyacrylonitrile fibres. Detailed examinations of the evidence and reference fibres were carried out using, among others, the polarisation-interference microscopy method, and the refractive index of the fibres was determined. In addition, a microspectrophotometer was used for comparing the dyes used to colour the fibres during the manufacturing process. Based on the examinations carried out, it was found that the green and light brown evidence fibres showed resemblance to the polyacrylonitrile fibres from which the jumper had been made and that they probably came from it [5].

In another case from 1974 concerning a fatal road traffic accident in which a lorry hit two women, the polarisation-interference method was also applied. Evidence material in the form of red and beige fibres, which were found and secured during the inspection of the vehicle, was submitted for examination.

The following question was asked in the order: "Could the red fibres found on the vehicle have come from the deceased's scarf, and the beige fibres from her tights?"

It was established in the course of the examination that the scarf was made from a blend of red wool and polyacrylonitrile fibres, while the tights were made from beige polyamide fibres. It was further established that the red fibres recovered from the vehicle were also a blend of wool and polyacrylonitrile fibres, while the beige fibres were polyamide fibres.

Measurements of the refractive indices of the polyacrylonitrile and polyamide fibres, both evidence and reference ones, carried out using the polarisation-interference method, demonstrated a match. In addition, the dyes used for colouring the fibres were compared. The findings constituted the main evidence in the criminal proceedings and led to a guilty verdict and the conviction of the perpetrator [5].

In recent years, advances in microscopy have expanded the microtrace examination capability, including for fibres and paint coatings, while the design and parameters of microscopes have also evolved. Microscopes were connected to a computer, which made it possible to capture images, save the results and compile them into catalogues for use in comparative examinations.

The Chemical Examination Department of the Central Forensic Laboratory of the Police (CLKP) is currently equipped with microscopes that enable a more detailed analysis of evidence and reference material. In addition to stereomicroscopes using reflection and

transmission techniques, which determine the subsequent examinations, their types and sequence, there are also: comparative microscopes, examination microscopes, digital imaging microscopes and scanning electron microscopes (Fig. 2-5, Fig. 10).

Using an examination or digital microscope, one can observe the morphological details of fibres under various lighting conditions, such as white transmitted light (BF), phase contrast (PH), polarised light (PO) and ultraviolet light (UV). In the case of paint coatings, examinations are carried out in white (BF) and dark (DF) fields of reflected light.

By analysing paint coatings, it is possible to determine shape and type of pigments used and the number of layers, and to measure the thickness of individual layers of the paint coating under examination. In fibre examinations, one can determine the shape and size of the cross-section and analyse the longitudinal view, which, in the case of natural fibres, enables identification of the fibre type.

When conducting examinations under polarised light, it is possible to observe the distribution of crystalline and amorphous areas within the fibres. On this basis, an initial identification can be made of the most common types of fibres, particularly synthetic chemical fibres such as polyamide, polyester or polyacrylonitrile fibres [6].

The CLKP's Chemical Examination Department uses a Keyence VHX-6000 digital microscope. Used for high-resolution observation and analysis of samples, the device combines top-quality optics with digital image processing. It enables detailed observation of very small objects and their morphology. The microscope has a large depth of field, enabling observation of uneven surfaces from any angle. It is fitted with an automatic lens system, providing for smooth switching between magnifications ranging from 20x to 2000x. The device facilitates measurements, fast image capturing and report generation. In addition, the microscope enables 3D imaging [7].

Photographs of the microscopes used by the CLKP's Chemical Examination Department are shown below.

Fig. 2. Stereoscopic microscope

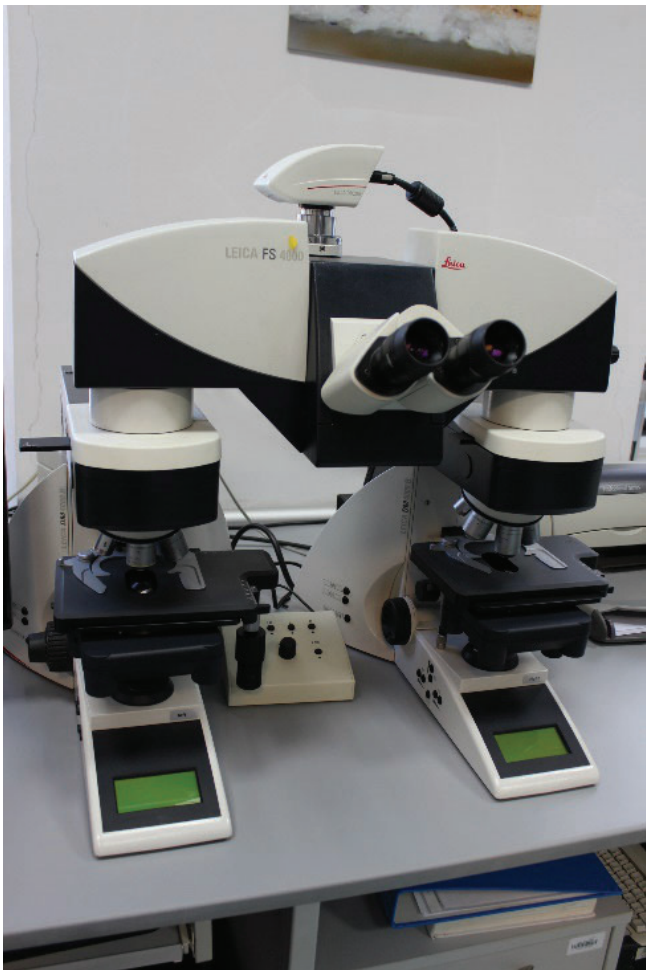


Fig. 3. A comparative microscope

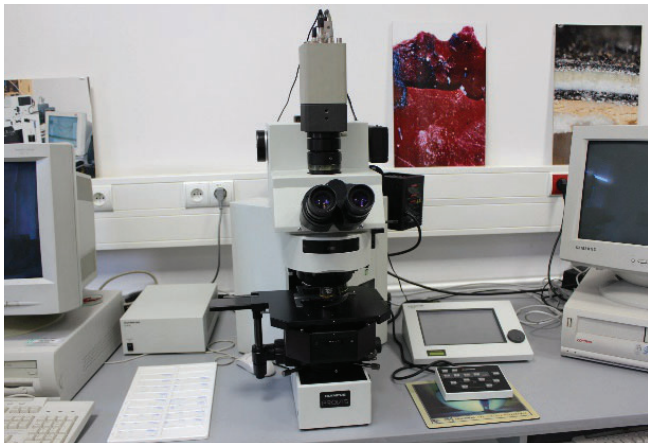


Fig. 4. An examination microscope

Fig. 5. A digital microscope

A microscopic image of bicoloured, colourless-red, synthetic fibres under white light (BF) and ultraviolet light (UV) (Fig. 6, 7), and of a black pearlescent paint coating and its cross-section (Fig. 8, 9) obtained with a digital microscope (Fig. 5)

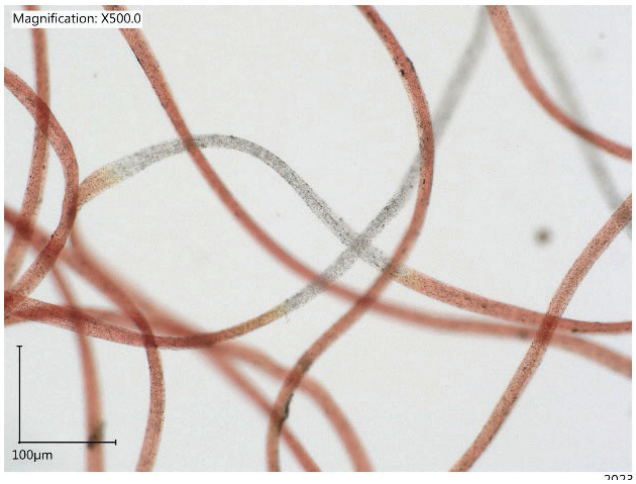


Fig. 6. A microscopic image of fibres under white light (BF)

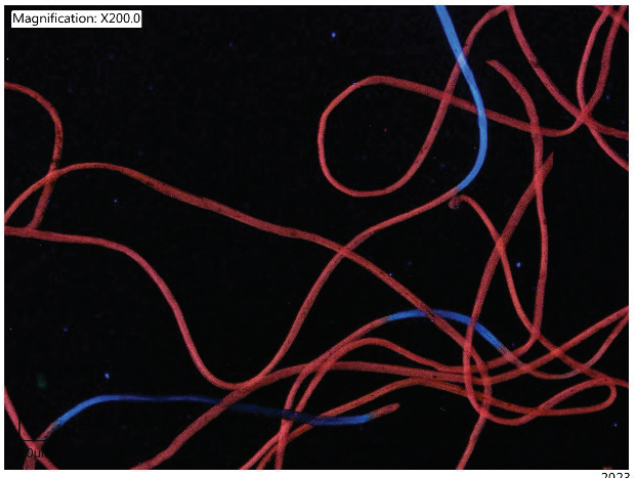
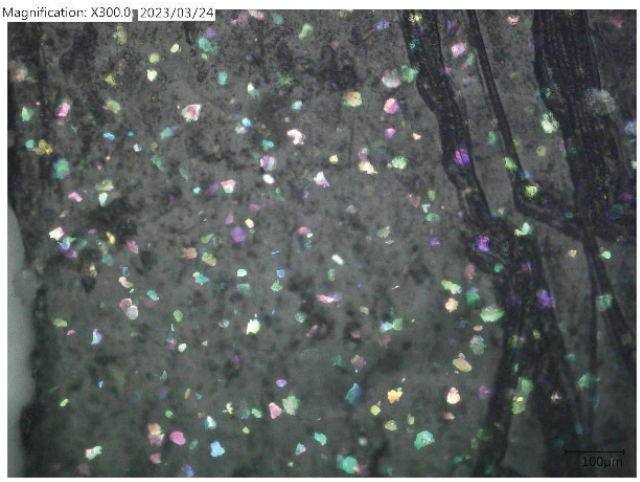


Fig. 7. A microscopic image of fibres under UV light



Ryc. 8. A microscopic image of a black pearlescent paint coating under white light (BF)

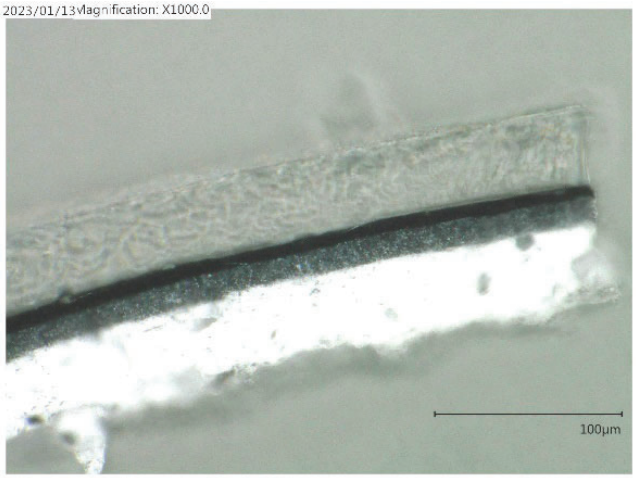


Fig. 9. A microscopic image of a cross-section of a paint coating under white light (BF)

Microtrace imaging is also carried out with a scanning electron microscope coupled with an energy-dispersive X-ray spectrometer (Fig. 10) which enables observation of objects at a magnification of up to tens of thousands of times. It provides for obtaining a large depth of field, and its high resolution facilitates analysis at very high magnifications that cannot be achieved with optical microscopes. Using a scanning electron microscope, one can identify morphological details, areas of degradation and the nature of damage, e.g. charring/melting of fibres, exposure to chemicals, ruptures and cuts that may have been caused by various tools [8, 9]. In the case of paints, it enables detailed observation of the shape and type of pigments used in automotive paint coatings. Using this microscope, one can also determine the elemental composition of microtraces, leading to identification of, among others, inorganic pigments and fillers present in e.g. paint.

A microscopic image of selected fibres and a cross-section of a paint coating (Fig. 11, 12) obtained with a scanning electron microscope (Fig. 10) is shown below.

Fig. 10. An electron microscope

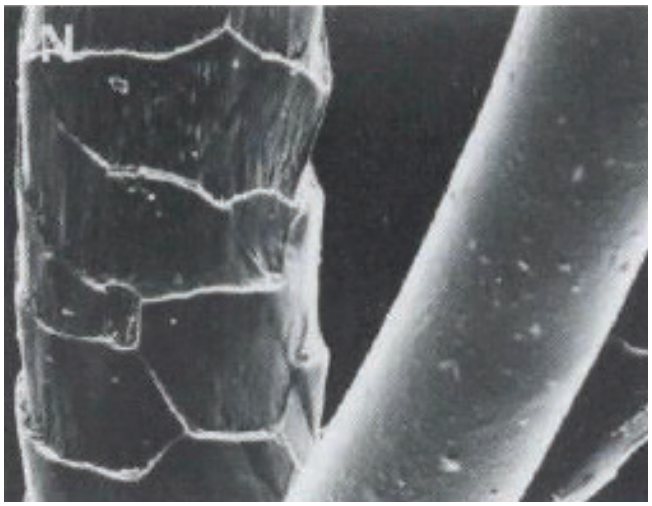


Fig. 11. A microscopic image – a longitudinal view of a wool and polyester fibres

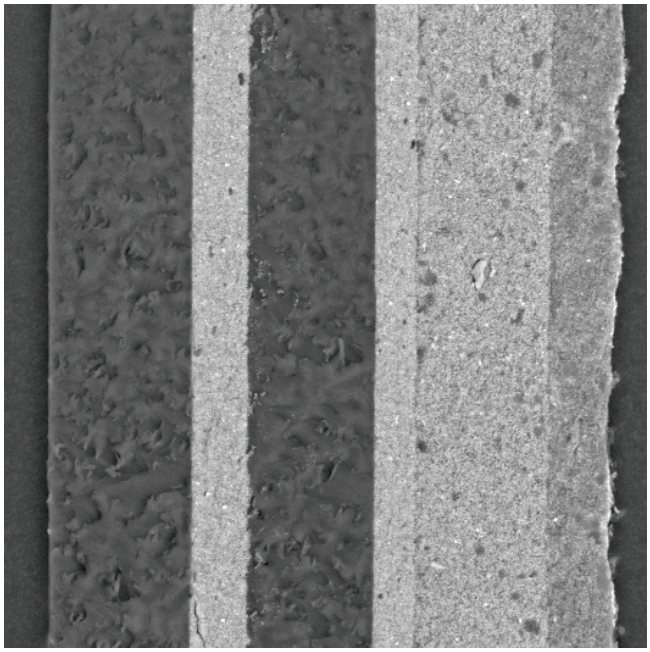


Fig. 12. A microscopic image of a cross-section of a paint coating

Significant progress in examination of paint traces or fibres was made when two or more basic analytical techniques were employed. Microspectrometry, which combines optical microscopy with spectrometry, is currently particularly useful in forensic trace examinations. It provides for comparing colours, morphological structure and chemical composition of minute samples of paint or fibres in a non-destructive manner [1, 3].

Among methods that enable determination of the chemical composition of microtraces is Fourier-transform infrared spectroscopy – FTIR (Fig. 13). It enables identification of the polymer type in fibres and paints with the use of a microscope fitted with a diamond cell (Fig. 14). This tool facilitates measurements and enables analysis and identification of small samples.

Microspectrophotometry is also used in the UV-VIS range for the objective determination of colour. In the 1990s, the CLKP's Chemical Examination Department was equipped with a Leitz MPV-SP (Combi) microspectrophotometer (operating in the 220–780 nm

Fig. 13, 14. Fourier-transform infrared spectroscopy with a diamond cell

range) coupled with a quartz optics examination microscope in a fully automated setup that enables archiving of measurement data. The measurement results are presented in the form of relative and corrected as well as graphical or numerical spectra. The method is used mainly in comparative examinations of forensic traces [10, 11] (Fig. 15). The chemical lab is also equipped with an uSight 2100 series MSP VIS microspectrophotometer with a Nikon Ci Series microscope operating in the visible light range of 380–780 nm (Fig. 16). Microspectrophotometry provides for measuring and comparing colours in even minute samples, such as varnishes, paints, fragments of individual fibres no longer than one millimetre and with a diameter of a few micrometres, and cross-sections of multi-layer paint coatings. It is an analytical method that combines optical microscopy and UV-VIS spectrophotometry. The purpose of the former is to enable observation of an object in transmitted and reflected light. Spectrophotometry, as a measurement method, involves measuring the intensity of radiation transmitted through and/or reflected from the test sample as a function of wavelength [4].

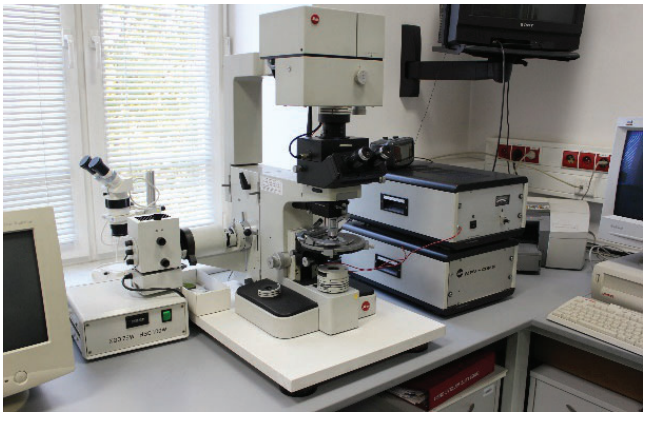


Fig. 15. A UV-VIS microspectrophotometer

Fig. 16. A VIS microspectrophotometer

Over the years, the methodology used in microtrace examination has remained largely unchanged, although there have been significant advances in the equipment used. The miniaturisation of measuring instruments and their connection to computers have provided for automation of examinations. The use of graphics and measurement software has made it possible to record the test results and measure the analysed microtraces.

New methods have expanded examination capabilities, provided information on the structure and composition of the examined trace, enabled faster acquisition of results and provided for detection and identification of minute traces.

Bibliography:

1. Zięba-Palus, J. (2014). Zobaczyć niewidzialne – czyli o mikrośladach kryminalistycznych, Kraków *Problems of Forensic Sciences*, vol. 100, s. 307-317.
2. Śmigiel-Kamińska, D., Wąs-Gubała, J., Kumirska, J. (2025). Potencjał technik chromatograficznych i spektroskopowych w kontekście kryminalistycznych badań włókien tekstylnych, W: D. Semków, K. Bajda (red.), *Kryminalistyka – moja pasja: Księga jubileuszowa dedykowana profesorowi Mieczysławowi Gocowi z okazji 50-lecia pracy naukowej*, (s. 503-515). Rzeszów, Wydawnictwo Uniwersytetu Rzeszowskiego.
3. Zięba-Palus, J. (2020). Rola badań fizykochemicznych w analizie śladów kryminalistycznych, *Analityka*, nr 21(3), s. 36–43.
4. Wąs-Gubała, J. (2018). Badania identyfikacyjno-porównawcze barwnych fragmentów pojedynczych włókien w kryminalistyce. [w:] *Rewolucja przemysłowa 4.0 – wyzwaniem dla przemysłu włókienniczego* (s. 43–52). Łódź, Fundacja Rozwoju Polskiej Kolorystyki.
5. Bodecki R. (1975). Przykłady wykorzystania mikrośladów w praktyce, *Problemy Kryminalistyki*, nr 117(3), s. 596-607.
6. Wąs-Gubała J. (2015). Badania włókien i wyrobów włókienniczych w kryminalistyce, W: J. Zięba-Palus (red.), *Mikroślady i ich znaczenie w postępowaniu przygotowawczym i sądowym*, (s. 51-72), Kraków, Wydawnictwo Instytut Ekspertyz Sądowych.
7. www. Keyence.eu,
8. Wąs-Gubała J. (2009). *Wpływ wybranych czynników na destrukcję włókien i wyrobów włókienniczych w aspekcie ich znaczenia w procesie sądowym*. Kraków, Wydawnictwo Instytutu Ekspertyz Sądowych.
9. Śmigiel-Kamińska D. (2014). Destrukcyjny wpływ środków żrących na wyroby włókiennicze i włókna w aspekcie badań kryminalistycznych. *Problemy Kryminalistyki*, nr 284(2), s. 26-31.
10. Miron, M., Mazurek A. (1994). Mikrospekrtometryczne badania powłok lakierniczych, *Problemy Kryminalistyki*, nr 204, s. 19-25.
11. Miron, M., Mazurek A. (1993). Zastosowanie mikrospektrofotometrii w badaniach mikrośladów, *Biuletyn informacyjny CLK KGP,* nr 89, s. 22-27.
12. Domański, H. (1976). Oznaczanie współczynników załamania światła i dwójłomności we włóknach syntetycznych za pomocą mikroskopu interferencyjno – polaryzacyjnego MPI-5, *Problemy Kryminalistyki,* nr 124(4), s. 784-786.