The NANODAK Research and Development Project

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Abstract

The research and development project titled: 'The detection of fingerprint traces with nanoparticles generated using high pressure technology', also known as NANODAK, involved the development of a new generation of formulations for the detection of fingerprint traces: NANODAK 30, NANODAK 40 and NANODAK 1. Nanodetectors are safe for people and for the environment and are just as effective as dactyloscopic powder, which in practice has the form of argentorate. The new formulations do not demonstrate any negative effects on other methods of fingerprinting or genetic testing. Nanodetectors, which represent a new generation of fingerprint detection methods, can be implemented in the target environment in order to improve the detecting potential of law enforcement authorities and improve the working conditions of forensic experts and technicians. The funding for this project was provided by the National Centre for Research and Development.

Key words: nanodetectors, nanoparticles, fingerprint marks

Introduction

Nanoparticles are very small particles of the size of one to one hundred nanometres, i.e. one billionth of a metre. They are too small to be seen by the human eye. Most nanoparticles consist of only several hundred atoms. Nanoparticles can demonstrate very different physical and chemical properties than their bigger material equivalents. This difference in properties is the result of the relatively large surface of nanoparticles in comparison to their volume. This characteristic provides nanoparticles with unexpected optical, physical or chemical properties, such as luminescent characteristics. These properties were utilised in the course of the research and development project titled: 'The detection of fingerprint marks with nanoparticles generated using high pressure technology' a.k.a. NANODAK. The project has also been provided with a logo (fig. 1) and a specially created website (fig. 2).

Fig. 1. NANODAK project logo

Fig. 2. NANODAK project website

The funding for the project was provided by the National Centre for Research and Development, under the terms of the 9th Competition for National Security and Defence. The consortium responsible for the delivery of the project composed of the Central Forensic Laboratory of the Police (CFLP) , as the consortium leader, and its partners: The High Pressure Institute of the Polish Academy of Sciences (HPI PAS) and the TOMSAD Tomasz Sadowski company (fig. 3).

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Projekt „Ujawnianie śladów linii papilarnych nanocząsteczkami wytwarzanymi przy użyciu technologii wysokich ciśnień” został sfinansowany przez Narodowe Centrum Badań i Rozwoju

Fig. 3. The logos of the NANODAK project financing institutions and contractors

The project goal

The main aim of the project was to develop new methods of the visualisation of fingerprints with the utilisation of nanoparticles. The first phase of the project involved the selection of nanoparticles for fingerprinting. These were mainly nanoparticles that demonstrated luminescent properties, because they offered better fingerprint contrast with the surface during the identification of fingerprints on a surface, e.g. on a multicolour surface. In addition to contrast, they offered better visibility.An ergonomic and efficient source of light energy also had to be developed to induce the fluorescence of nanoparticles. This task was undertaken by the TOMSAD company. The works began with the preliminary, experimental definition of the scope and properties of light that would be useful for the inducement of the selected nanoparticles. After the initial testing of samples in the full spectrum of ultraviolet and visible light, it was observed that further works should concentrate on ultraviolet light of the wavelength of 360 nm and on blue light of the wavelength of 410 nm, because the tested nanoparticles were subject to inducement in these scopes.

Ultimately, a set of LED 360 nm, 410 nm and white light illuminators was developed, having a high output level with two-stage regulation (fig. 4÷9). The white light illuminator was constructed using COB-type LED radiators (Chip On Board), which provided a very uniform light beam and a relatively high output with the use of small radiators. Each of the developed illuminators was equipped with an integrated switch of the operating range of 0%–50%–100% providing two-stage output selection, a 240 V main power supply unit and a battery for remote operation. The illuminators were designed with light, ergonomic covers, capable of holding radiators, electronic control devices, which ensured sufficient cooling through specially designed vents. Black covers were used to minimise the effect of light reflection. The whole set of illuminators and auxiliary equipment was installed in a robust transport case that provided sufficient protection against mechanical impact and vibrations. The case was designed to hold the entire set of illuminators together with auxiliary equipment, with additional space reserved for small tools (tweezers, brushes, etc.), depending on the individual user’s needs.

Fig. 4÷9. FA set of LED illuminators with auxiliary equipment

Alongside their work on the development of LED illuminators, the CFLP and HPI PAS design teams were also working on the form and composition of nanoparticle formulations for the detection of fingerprints. They decided to contain the luminescent nanoparticles in liquid suspensions, which allowed them to be directly applied to the tested surfaces and prevented their unnecessary spreading in the atmosphere (fig. 10÷12). The research of nanoparticles in the form of powder was also continued (fig. 13, 14).

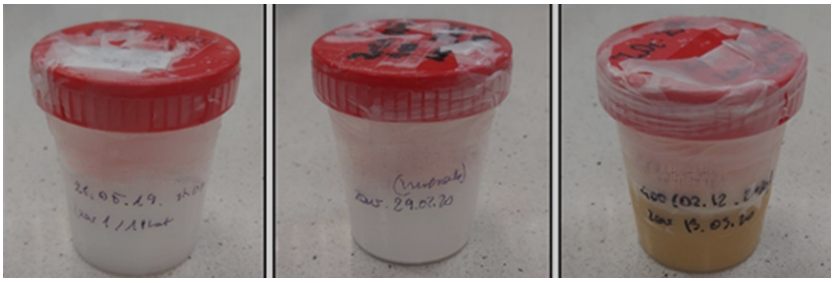


Fig. 10÷12. Luminescent nanodetectors in the form of suspension

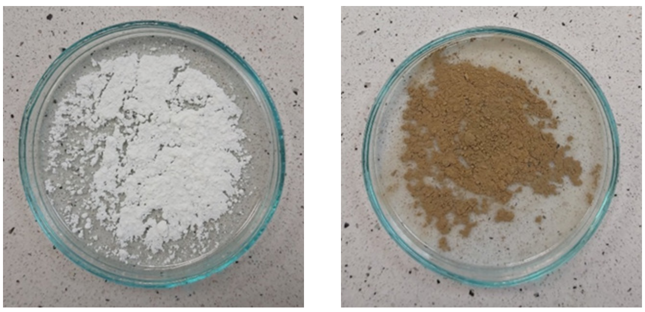


Fig. 13, 14. Nanodetectors in the form of powder

A 'Methodology of verification of nanodetector components' was developed, in order to ensure quality control of the created nanodetectors and to provide an objective assessment of their effectiveness in fingerprinting. In accordance with this developed methodology, during the tests fingerprints were applied in a controlled manner to surfaces with variable properties by different donors. A bank of fingerprint donors was created for the purposes of this research, which categorised the donors into very good (category A), good (category B) and poor (category C) producers of sweaty/oily (fingerprint-generating) substances. The classification of donors allowed the authors to verify the sensitivity of the tested formulations.

Fingerprints were applied to surfaces defined in dactyloscopy as standard, i.e. generally smooth surfaces, such as glass or aluminum film, and to problematic, generally porous surfaces, such as furniture board or artificial leather (fig. 15÷17). This allowed the authors to evaluate the effectiveness of individual formulations, depending on the surface type and texture.

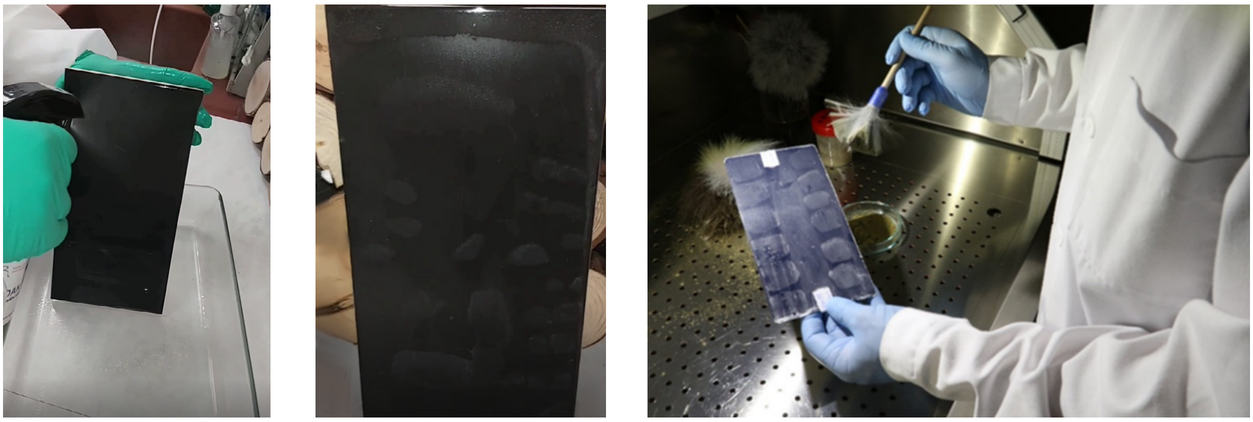


Fig. 15÷17. Application of nanodetectors to surfaces

The tested samples, imprinted with fingerprints, were adequately marked. The fingerprints were detected using the tested formulations and were then subject to macroscopic tests in white and fluorescent light, in the range of UV light and, during the first phase of research, in the range of visible VIS light between 380 and 780 nm. Following the conclusion that nanodetectors demonstrate the best fluorescence in illumination of the range between 360 nm and 410 nm (blue light), further observation was carried out only in this range.

Three parameters of the tested formulations were evaluated:

- the adherence of the formulation to fingerprints (P),
- the uniformity of adherence to fingerprints (R),
- the legibility of detected fingerprints (C).

A binary zero/one assessment system was implemented. With reference to parameter P, the score of 1 indicated that the tested formulation adhered to the fingerprint, in the case of parameter R – the score of 1 indicated that the adherence was uniform, and in the case of legibility designated with the letter C – the score of 1 was given to fingerprints which had at least twelve specific features suitable for identification. The results were recorded in spreadsheets and subsequently analysed.

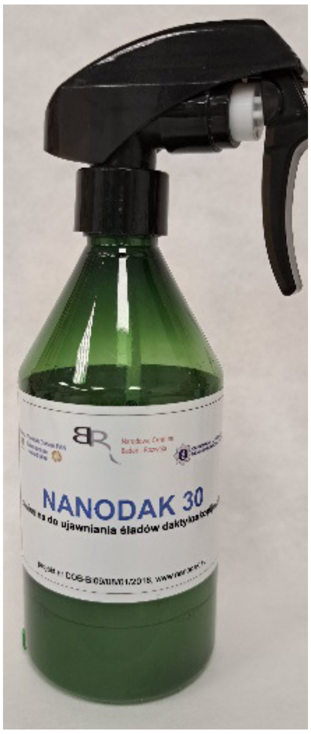
Positive assessment was given to formulations whose three parameters P/R/C simultaneously achieved the score of greater than or equal to 80%.

In the first phase of the project, the CFLP design team tested formulations prepared by HPI PAS with variable parameters such as:

- the concentration of base nanoparticles in a suspension,
- the concentration of nanoparticle luminescence-enhancing additives,
- the size of nanoparticles,
- the supplementation of base nanoparticles with metallic elements.

Out of several dozen of versions of the formulations, three nanodetectors were ultimately selected as prototypes, on the basis of the effectiveness of fingerprint detection, as well as the intensity of their fluorescence (fig. 18÷20), which were designated as:

- NANODAK 30/ND1 (nanodetector in the form of a suspension),
- NANODAK 40/ND2 (nanodetector in the form of a suspension),
- NANODAK 1/NP (nanodetector in the form of powder).



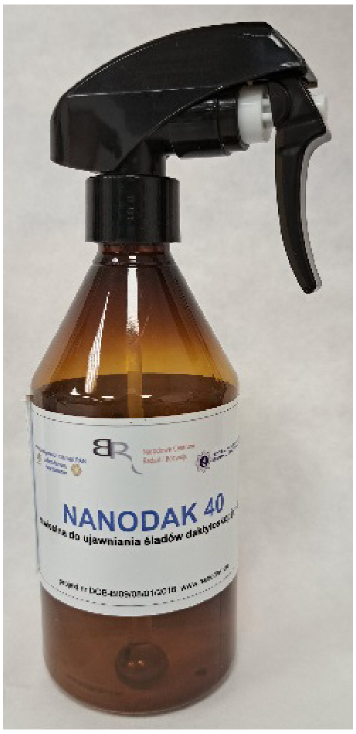


Fig. 18÷20. Prototypes of nanodetectors

The examples of fingerprints revealed using NANODAK 30, NANODAK 40, NANODAK 1 nanodetector prototypes are shown in fig. 21÷43.

Fig. 21. Fingerprint revealed on a ceramic plate using the NANODAK 30 suspension, registered in white light

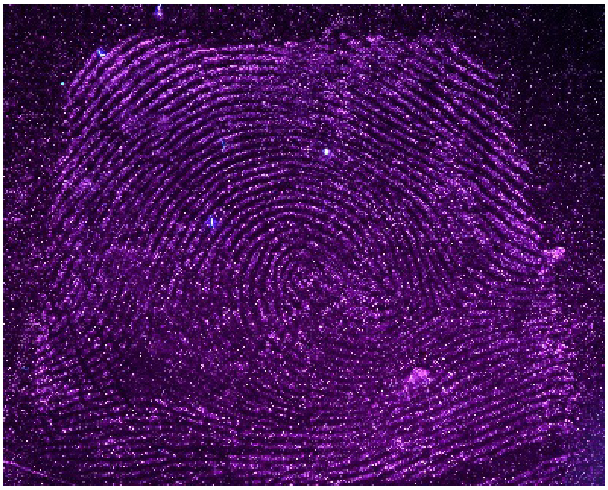


Fig. 22. Fingerprint revealed on a ceramic plate using the NANODAK 30 suspension, registered in UV light of the wavelength of 360 nm, with a colourless filter

Fig. 23. Fingerprint revealed on a ceramic plate using the NANODAK 30 suspension, registered in UV light of the wavelength of 360 nm, with a yellow filter

Fig. 26. Fingerprint revealed on an aluminium foil using the NANODAK 30 suspension, registered in white light

Fig. 24. Fingerprint revealed on a ceramic plate using the NANODAK 30 suspension, registered in blue light of the wavelength of 410 nm, with a yellow filter

Fig. 27. Fingerprint revealed on an aluminium foil using the NANODAK 30 suspension, registered in UV light of the wavelength of 360 nm, with a colourless filter

Fig. 25. Fingerprint revealed on a ceramic plate using the NANODAK 30 suspension, registered in blue light of the wavelength of 410 nm, with an orange filter

Fig. 28. Fingerprint revealed on an aluminium foil using the NANODAK 30 suspension, registered in UV light of the wavelength of 360 nm, with a yellow filter

Fig. 29. Fingerprint revealed on an aluminium foil using the NANODAK 30 suspension, registered in blue light of the wavelength of 410 nm, with a yellow filter

Fig. 30. Fingerprint revealed on a ceramic plate using the NANODAK 30 suspension, registered in blue light of the wavelength of 410 nm, with an orange filter

Fig. 31. Fingerprint revealed on a ceramic plate using the NANODAK 40 suspension, registered in white light

Fig. 32. Fingerprint revealed on a ceramic plate using the NANODAK 40 suspension, registered in UV light of the wavelength of 360 nm, with a colourless filter

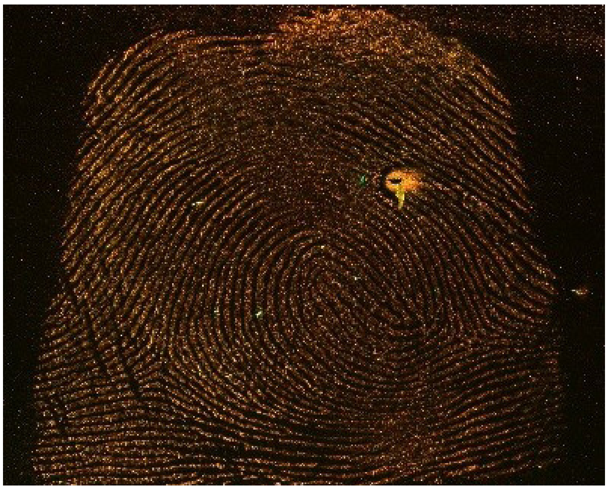


Fig. 33. Fingerprint revealed on a ceramic plate using the NANODAK 40 suspension, registered in UV light of the wavelength of 360 nm, with a yellow filter

Fig. 34. Fingerprint revealed on a ceramic plate using the NANODAK 40 suspension, registered in blue light of the wavelength of 410 nm, with a yellow filter

Fig. 35. Fingerprint revealed on a ceramic plate using the NANODAK 40 suspension, registered in blue light of the wavelength of 410 nm, with an orange filter

Fig. 36. Fingerprint revealed on an aluminium foil using the NANODAK 40 suspension, registered in white light

Fig. 37. Fingerprint revealed on an aluminium foil using the NANODAK 40 suspension, registered in UV light of the wavelength of 360 nm, with a colourless filter

Fig. 38. Fingerprint revealed on an aluminium foil using the NANODAK 40 suspension, registered in UV light of the wavelength of 360 nm, with a yellow filter

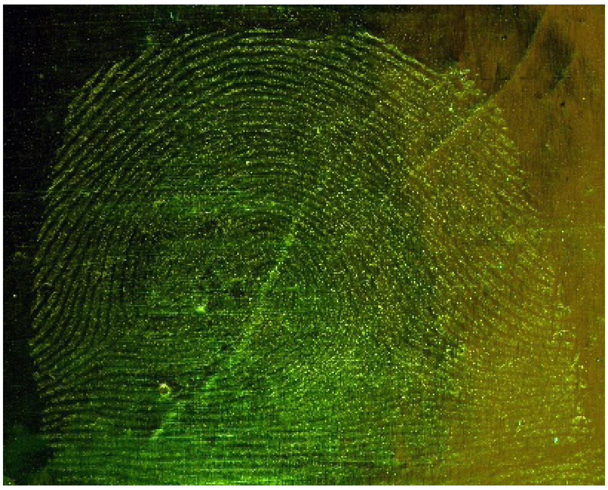


Fig. 39. Fingerprint revealed on an aluminium foil using the NANODAK 40 suspension, registered in blue light of the wavelength of 410 nm, with a yellow filter

Fig. 40. Fingerprint revealed on a ceramic plate using the NANODAK 40 suspension, registered in blue light of the wavelength of 410 nm, with an orange filter

Fig. 41. Fingerprint revealed on a ceramic plate using the NANODAK 1 nanopowder, registered in white light

Fig. 42. Fingerprint revealed on an aluminium foil using the NANODAK 1 nanopowder, registered in white light

Fig. 43. Fingerprint revealed on a cardboard folder using the NANODAK 1 nanopowder, registered in white light

Following a number of tests, optimal applicators were selected for the nanodetectors. The atomiser for suspension-type nanodetectors is made of high-quality plastic and is equipped with a tube, which at its end has a weight in the form of a metal ball. This solution achieves a uniform suspension with the stirring and shaking of the bottle contents. Optimal application of the powdery nanodetector was achieved using a flat squirrel hair brush of the width of 3 cm.

Some design works were also aimed at selecting the best method of protecting fingerprints revealed using the nanodetectors. In the first instance, the authors attempted to transfer fingerprints onto dactyloscopic foils. But even if the fingerprints were successfully secured on the foil, after a short while the nanoparticles penetrated into its gelatine layer. The best recording method was to use the TrasoScan system or a photo camera.

One of the objectives of the project dealt with the safety of working with nanodetectors. Environmental research (fig. 44, 45) on the concentration of nanoparticles in the atmosphere during the application of formulations to surfaces was carried out by the Central Institute for Labour Protection – National Research Institute.

Fig. 44, 45. Environmental research

The average concentration of nanoparticles during spray application was very low in comparison with the threshold limit concentration value (NDS). During the application of nanopowder with a brush, its precipitation was relatively rapid and the range of emissions was limited. The concentration of dactyloscopic powder – argentorate – was also measured. Its measurement revealed high emissions of argentorate and its prolonged presence in the atmosphere.

The confirmation of the safety of working with nanodetectors represented a milestone in the project and allowed the authors to proceed to the task of their validation. Nanodetectors were validated in the basic scope and in terms of their repeatability, reproducibility and sensitivity within two periods: a two-week period and a two-month period. On the basis of the obtained test results it was concluded that nanodetectors fulfilled the necessary requirements in terms of the effective detection of fingerprints.

Visualisation tests are based on the principle of using several complementary methods in a specifically defined sequence. None of the existing methods is known to be able to reveal all possible fingerprints. Even if one of the methods is particularly effective, there is a chance of revealing new fingerprints, or of improving the legibility of those already revealed, using another one. A question therefore arose: is it possible to use other fingerprinting methods following the application of nanodetectors? To answer this question, tests were performed in the following sequence:

- suspension-type nanodetector – polymerisation of cyanoacrylates – Basic Yellow 40,
- powdery nanodetector – polymerisation of cyanoacrylates – Basic Yellow 40,

Tests were carried out in ten batches, which enabled the assessment of the repeatability of the whole process. It was concluded that nanodetectors do not have a negative impact on the possibility of using other fingerprint visualisation techniques in the course of further dactyloscopic tests.

In the case of fingerprint visualisation, an important characteristic of formulations is the maximum age of fingerprints that can be revealed with them. Therefore such tests were also carried out for the newly developed nanodetectors. The fingerprints prepared for testing were stored in ambient conditions and the formulations were applied to the samples in biweekly intervals. The tests were continued for a period of seven months. It was observed that six-month-old fingerprints visualised using nanodetectors demonstrated poor contrast, due to the blurring of the lines.

The users of different formulations pay attention to the period of their validity. Therefore, in the case of nanodetectors, tests were also carried out to determine their stability. It was concluded that the product life of the formulations is at least 12 months.

Due to the current complex approach to the forensic testing of evidence materials, the effect of nanodetectors on the acquisition of genetic material from fingerprints revealed using nanodetectors was also examined. No negative, repeatable effects of nanodetectors on the quality of the results of the testing of DNA obtained from the biological residue was observed. Additionally, the obtained test results indicated that the used nanodetectors have no effect on the analysis of genetic material obtained from single biological traces, even when present in small quantities, or if a given batch contains the DNA of more than one person.

The last project phase involved the testing of nanodetectors in real-life conditions. The new technology (fig. 46÷50) was demonstrated by independent experts in accordance with a predefined scenario. Tests were performed on various objects of everyday use that represented evidence materials most commonly found at the scene or sent to forensic laboratories. Nanodetectors were used to reveal natural sweaty/oily traces left during the handling of everyday objects. Because the study involved the utilisation of objects on which fingerprints were left during their regular use, the age of the individual fingerprints was unknown.

The material for testing was obtained by collecting objects of use from many different sources, without leaving any additional traces. Typical objects with non-absorbent and semi-porous surfaces were collected, such as: bottles, containers, packaging, tapes, etc. The surfaces were treated with suitable nanodetectors and with the currently used dactyloscopic powder – argentorate for reference, wherein macroscopic tests were subsequently performed. A quantitative assessment of the effects of fingerprinting was carried out, which involved the counting of all fingerprints revealed using the individual nanodetectors (assessment criteria: 0 – fingerprint not detected, 1 – fingerprint detected). The numbers of revealed fingerprints shown in tab. 1 represent the total number of fingerprints suitable for identification and fingerprints not suitable for reference testing.

Fig. 46÷50. Testing nanodetectors in real-life conditions

Tab. 1. The summary of results for the tests of formulations in real-life conditions

Name of object	Name of formulation/No. of revealed fingerprints			
	ND1	ND2	NP	Argentorate
Black plate	33	41	30	36
Brown glass bottle	57	59	67	59
CD disc	28	31	33	30
Silver adhesive tape	29	35	41	33
Transparent glass container	33	32	22	17
Black ceramic tile	43	45	39	42
CD case	31	33	28	28
Transparent glass bottle	42	44	39	43
Tray	29	38	30	28
Sprinkler	48	52	48	41
Total	**373**	**410**	**377**	**357**

best formulation   comparable formulations

The traces of fingerprints were revealed on everyday use items that were collected for testing both using nanodetectors, as well as using dactyloscopic powder – argentorate. The highest number of fingerprints was revealed following the application of the NANODAK 40 suspension-based nanodetector. In the case of the NANODAK 30 suspension-based nanodetector, the number of revealed fingerprints was comparable with argentorate. The highest number of fingerprints detected using the NANODAK 1 powdery nanodetector was revealed on glass bottles, CD discs and adhesive tape.

The total number of fingerprints revealed using nanodetectors demonstrates that the new technology achieved the desired effect in real-life conditions.

Summary

The research and development project titled: 'The detection of fingerprint traces with nanoparticles generated using high pressure technology' involved the development of a new generation of formulations for the detection of fingerprints based on nanoparticles with luminescent properties. The luminescence of nanodetectors is induced using dedicated, efficient and ergonomic LED illuminators that were also developed in the course of this project. Environmental research of nanodetectors has revealed that they are harmless to humans and to the environment, as opposed to argentorate. Nanodetectors are just as effective as dactyloscopic powder, which in practice has the form of argentorate. The newly developed formulations do not demonstrate any negative effects on other methods of fingerprinting. They also do not have any negative effect on genetic testing. Nanodetectors are easy to apply and can be removed from the tested surfaces if necessary. Nanodetectors, which represent a new generation of fingerprint detection methods, can be implemented in the target environment in order to improve the detecting potential of law enforcement authorities and improve the working conditions of forensic experts and technicians.

Source of figures and the table: authors