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Vacuum metal deposition (VMD) – characteristics of the method

Summary

Vacuum metal deposition was introduced in the process of visualization of latent fingermarks already in the 20th century. However, due to the requirement of using specialist equipment to ensure appropriate conditions for the development process, which would have generated significant costs, the method was not available in Poland. Technological developments, however, made it possible to create compact devices with smaller dimensions and lower parameters, which, nowadays, can be used in virtually every forensic fingerprint identification laboratory. The article describes the theoretical basis of the process of developing fingerprints by means of the vacuum metal deposition method with the use of sequential deposition of gold, zinc and silver on the tested surfaces. The device used for the VMD method is also presented along with sample effects of treating fingerprints on various surfaces, including registration in the range of reflected infrared light and with recovering marks on lifting foils. The final part deals with the issue of accrediting forensic service providers performing fingerprint examinations, including problems related to the implementation of vacuum metal deposition in the range of accredited fingerprint visualization techniques.

Key words: fingermarks, vacuum metal deposition, VMD, infrared

Identification of humans based on the unique nature of skin ridge patterns, i.e. a forensic discipline referred to as dactyloscopy was in its prime in the 20th century. That period is also associated with the rapid development of fingerprint detection methods based on various physical and chemical phenomena, one of them being deposition of metal on examined surfaces in vacuum conditions with an aim to visualize latent fingermarks.

Vacuum deposition was used in the process related to the production of mirrors, lenses, sunglasses or decorative ornaments. The first use of vacuum metal deposition referred to by an abbreviation VMD in the detection of fingerprints dates back to the 1960s (Bleay et al., 2017). Due to the cost of the instrument vacuum metal deposition method had been absent in Polish fingerprint examination until 2018. The first forensic laboratory in Poland to use the VMD method was the Forensic Bureau of the Internal Security Agency. Currently, there are several devices used by various services in the country. The British Centre for Applied Science and Technology (CAST) recommends vacuum metal deposition as one of the most effective methods of developing fingermarks on non-absorbent and semi-porous substrates (while retaining the properties of both absorbent and non-absorbent substrates) (Bandey et al., 2014). The use of VMD in the visualization procedure prior to conventionally applied cyanoacrylate polymerization is, with some exceptions, generally recommended.

The essence of the VMD method is to create appropriate conditions for the evaporation of metals by achieving a significant level of negative pressure. Removal of air particles allows for free movement of the evaporated metal atoms towards the treated surface. Besides, by reducing the pressure the temperature of phase transitions is lowered, and this contributes to decreasing energy demand of the process. The parameters of the visualization procedure include: pressure value $< 3 \times 10^{-4}$ mbar for gold and $3 \times 10^{-4} \div 5 \times 10^{-4}$ mbar for zinc. The mechanism of revealing latent fingermarks by the VMD method consists in deposition of the evaporated metal layer on the tested surface under vacuum conditions. The conventional process is carried out in two steps and involves sequential deposition of two metals: gold and zinc ($VMD_{Au / Zn}$). In the first stage, a thin layer of gold imperceptible to the human eye is deposited; the gold then penetrates the substance fingermarks are made of. The second step involves evaporation and deposition of the zinc layer, which has a greater affinity for surfaces covered with a thin layer of gold, while it does not adhere to the mark substance (Fig. 1). In most cases, developed fingerprints remain transparent, while the background is covered with a zinc layer that creates a contrast between the mark and the substrate (Champod et al., 2016). The $VMD_{Au/Zn}$ process is effective for non-absorbent and semi-porous substrates, as well as natural and artificial fabrics and surfaces exposed to high temperatures, even up to 900°C, after removing the soot layer, as needed (Bandey et al., 2014).

In some cases, the so-called reverse development of fingerprints occurs when zinc demonstrates a greater affinity for the mark substance in the places of contact of the skin ridges with the substrate (Fig. 2). The effect is explained by the processes taking place in the mark-forming substance, including natural drying due to the presence of air or migration of mobile components into the substrate and leaving mainly crystallized inorganic substances (e.g. NaCl) on the surface or presence of various impurities that inhibit the diffusion of gold agglomerates into a mark-forming substance. Additionally, such places are characterized by a higher surface energy in relation to the substrate, which causes the formation of larger gold aggregates on the surface of the mark-forming substance and, as a result, deposition of zinc in these places (Bleay et al., 2017).

In the case of highly plasticized plastics, the $VMD_{Au/Zn}$ process does not give good results.

This is due to the fact that gold agglomerates diffuse into both the mark-forming substance and the substrate. As a result, gold agglomerates are not formed, which form the basis for the deposition of the zinc layer (Fig. 3; Bleay et al., 2017). In such situations, a one-step VMD process is carried out involving the use of thermal evaporation of silver in a vacuum (VMD_{Ag}) – Figure 4. This process is recommended for most plastic substrates, including in particular plasticized polyvinyl chloride, plastic wrapping films, and surfaces coated or contaminated with fat or oil (Champod et al., 2016; Bandey et al., 2014; Bleay et al., 2017). The development mechanism is based on the penetration of silver into both the substrate and the mark-forming substance. The contrast of the revealed marks is caused by the differences in the size of the growing agglomerates of silver atoms forming in the substrate and the mark-forming substance.

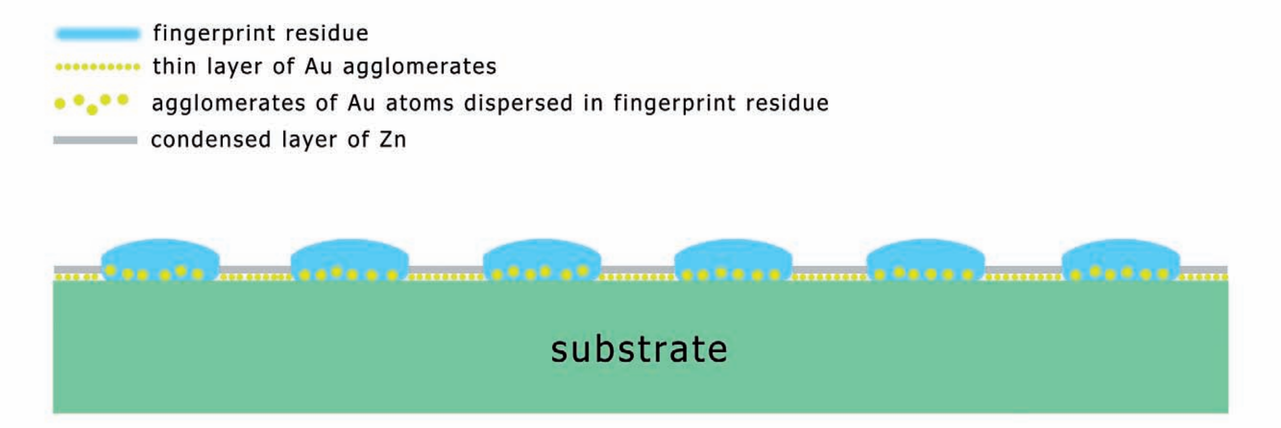

Fig. 1. Mechanism of detecting fingermarks by $VMD_{Au/Zn}$ process.

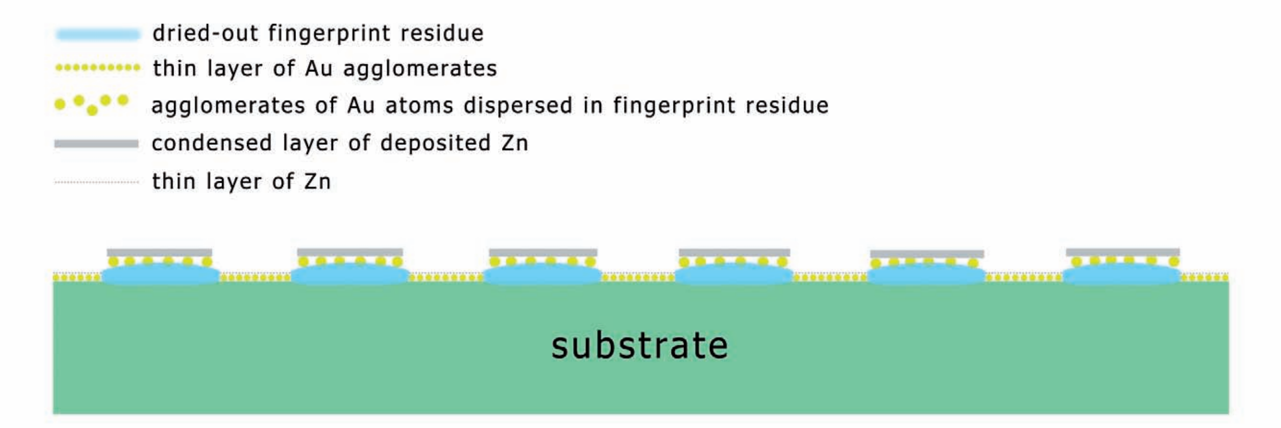

Fig. 2. Mechanism of, so-called, reversed development of fingermarks in $VMD_{Au/Zn}$ process.

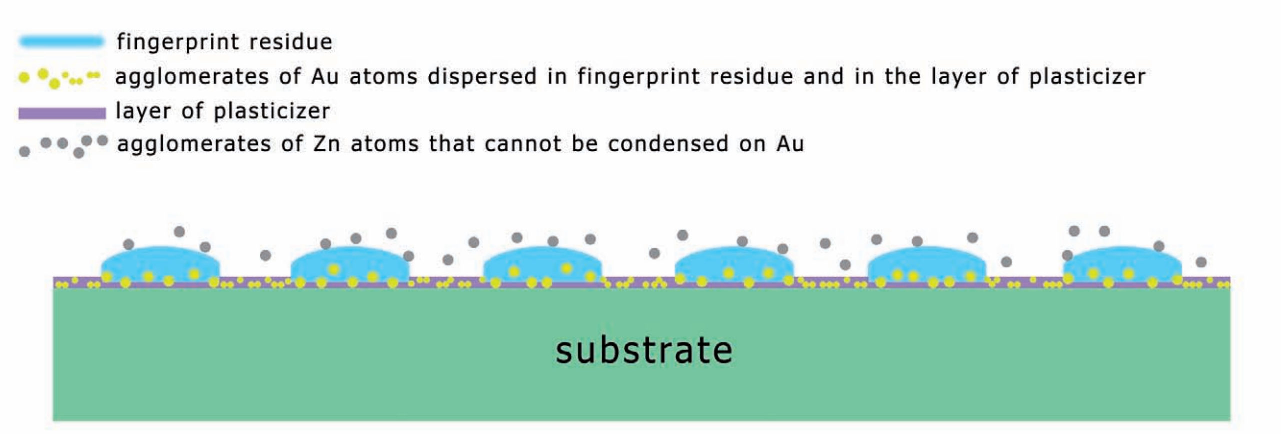

Fig. 3. Mechanism causing ineffective visualisation of fingermarks in $VMD_{Au/Zn}$ process caused by presence of plasticizer.

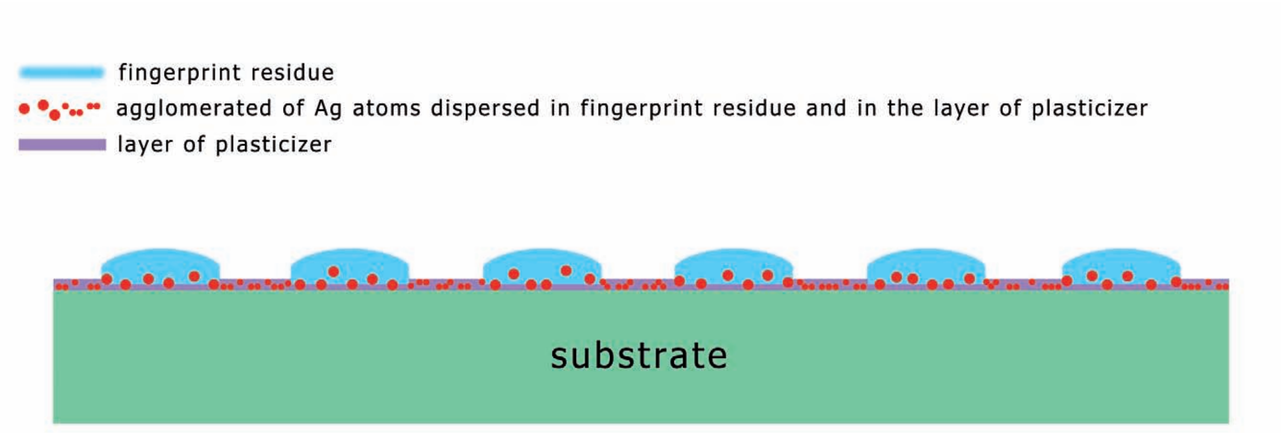

Fig. 4. Mechanism of fingermarks visualization in VMD_{Ag} process.

The VMD method can also be used in the detection of all kinds of contact traces other than marks of skin ridges as it gives effects in form of visible stains and discoloration of the tested surfaces.

The vacuum metal deposition method requires creation of appropriate conditions for the performance of the process, namely: defined negative pressure and metal evaporation temperature. In practice, specially designed devices for latent fingermarks development are used and depending on the manufacturer and model. Currently, VMD chambers with different capacities from several manufacturers are available on the market. The Internal Security Agency (ABW) Forensic Bureau uses a compact device manufactured by West Technology Systems Limited (Great Britain) – VMD360 (Fig. 5). The dimensions of the working chamber are 36 × 36 × 30 cm. The external dimensions of the device allow it to be freely placed in the laboratory; it only requires access to a standard 220 V power supply. Surfaces bearing latents are held on special handles with magnets and placed in the upper part of the working chamber. It should be emphasised that only the surface that is directly exposed to metal vapours is subjected to the deposition process. In order to carry out the process on the opposite side of the object, it is required to flip it and carry out the deposition again (Figs. 6, 7). The evaporated metals are dosed onto special molybdenum boats located on the bottom surface of the chamber (Fig. 8).

Sometimes, when the $VMD_{Au / Zn}$ method is applied, the deposited zinc layer covers the substrate but there is only a stain with no ridges pattern in the place of the latent, forming a, so-called, empty mark. In such cases it is advisable to use another silver evaporation process. In order to obtain the best development effect, it is also possible to carry out the process in the reverse sequence depending on the type of substrate. Examples of resulting images on various substrates are shown in Figures 9–13.

In addition to the gold, zinc and silver deposition techniques discussed in detail above, other metals may be used to visualize latent marks, e.g. copper, sterling silver or aluminium.

Copper is used to reveal fingerprints on polymer banknotes, aluminium foil, CDs / DVDs and credit cards. Interestingly, it allows marks that are invisible or hardly

Fig. 5. VMD360 chamber.

Fig. 6. The inside of VMD360 chamber.

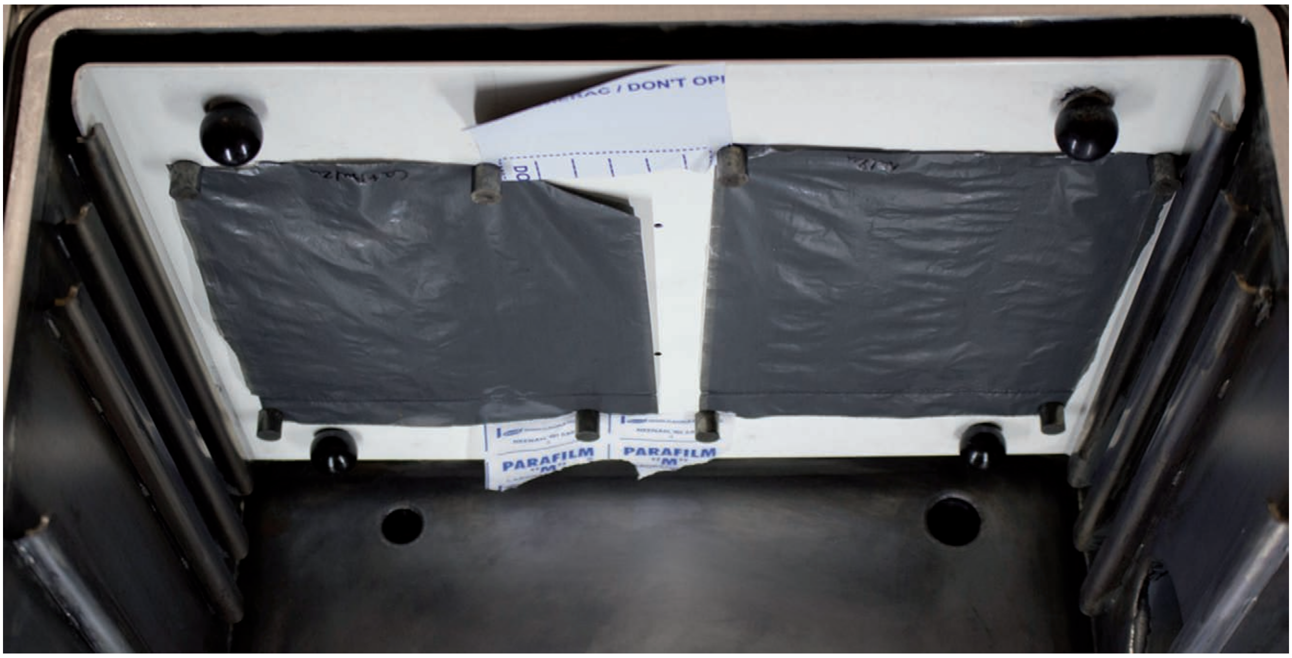

Fig. 7. The manner of mounting exhibits for the visualization process: surfaces to be treated are held with magnets in the upper part of VMD360 chamber in a special mount.

visible in white light in infrared to be observed thanks to the use of appropriate filtration (645 nm).

Sterling silver obtained by combining 92.5% by weight of silver and 7.5% of other metals, most often copper, can be used to develop latents, e.g. on nitrile gloves, plastic ATM cards, reinforced mounting tapes, transparent tapes, condoms, mobile phones or SIM cards. The result of the process is light yellow fingermarks and orange/brown substrate/grooves visible under white light.

The application of copper and sterling silver to reveal fingermarks does not preclude the second stage of examination and the use such metals, as gold and zinc, or silver, with an aim to improve the contrast between the pattern and the substrate.

In many cases, fingermarks developed in the VMD chamber are visible in white light. A problem arises when the substrate and the revealed trace are of similar colours or the tested substrate is multi-coloured. Then it is reasonable to use a forensic light source in order to reduce or eliminate the influence of background colour on the mark. Recording in reflected infrared light is also helpful. This is due to the fact that the metal layer deposited in the places where there are impressions of grooves between skin ridges absorbs radiation in this range and they are visible in the form of dark areas

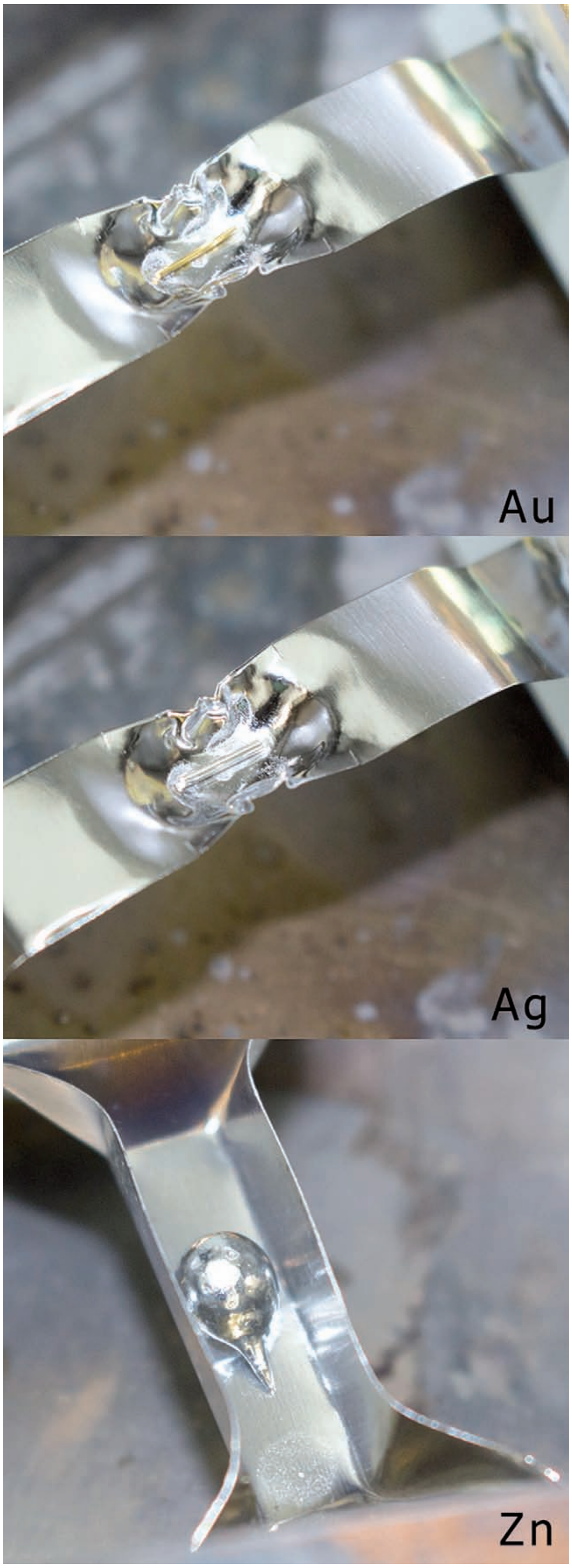

Fig. 8. Administering metals for evaporation on special molybdenum boats in VMD360 chamber.

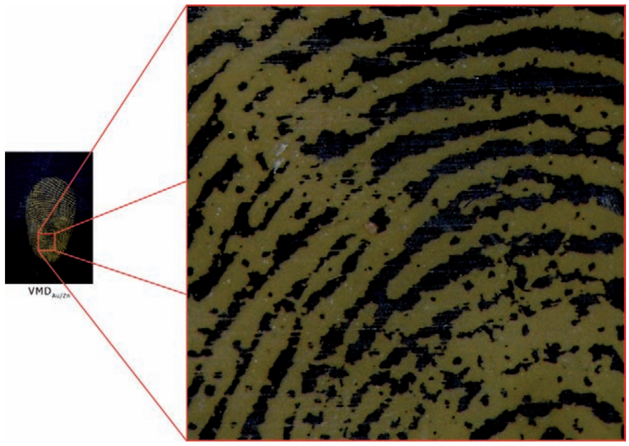

Fig. 9. A latent detected on the outer side of adhesive packaging tape by deposition of gold and zinc; image of pores and papillae grooves covered with a dark layer of zinc can be observed.

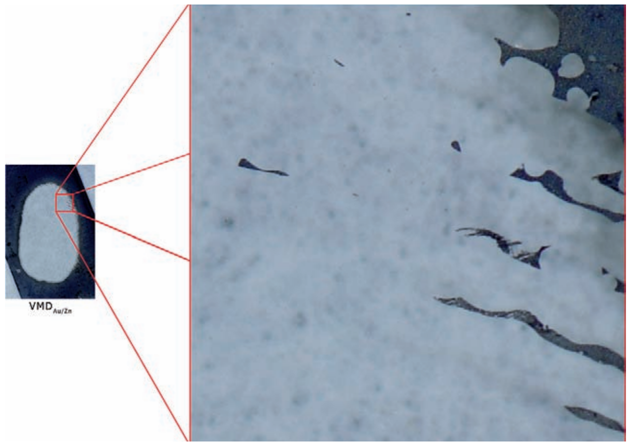

Fig. 10. A so-called, empty mark developed on glass by deposition of zinc and gold; shapes of skin ridges visible under magnification.

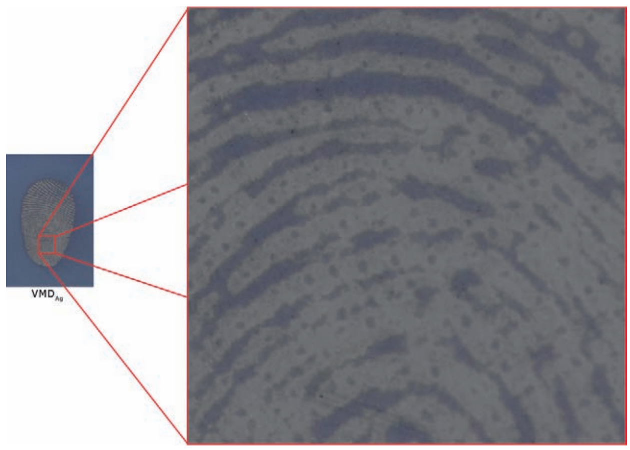

Fig. 11. Fingermark visualized by deposition of silver on plastic: polyvinyl chloride (PVC).

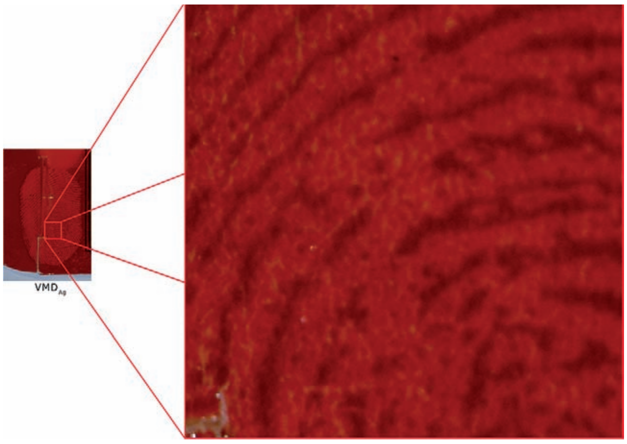

Fig. 12. Fingermark visualized by deposition of silver on semi-porous surface of improved packaging.

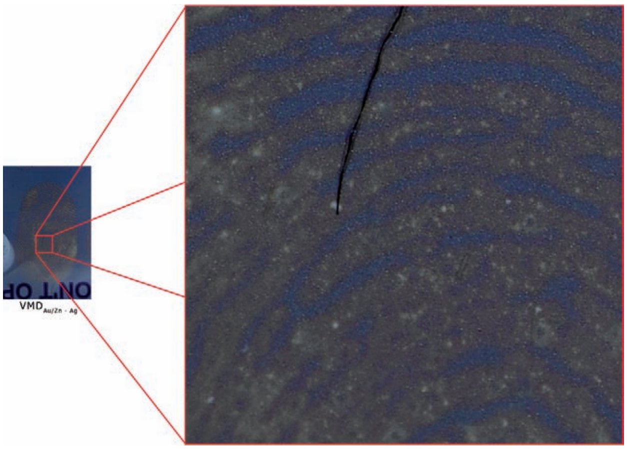

Fig. 13. Fingermark visualized by deposition of gold and zinc on the surface of a tamper-safe envelope.

contrasting with the lighter areas reflecting infrared light in the places of skin ridges impressions where the metal was not deposited (Fig. 14). An interesting issue is the possibility of lifting developed marks on gel foils and then taking a scan or photo (Fig. 15).

In Poland, the forensic laboratories use various research techniques accredited by the Polish Centre for Accreditation. However, vacuum metallization does not belong to this group (as of July 2020), which is due, among others, to the following reasons:

- problems resulting from the need of periodical checking the device's operating parameters using control and measurement equipment (negative pressure value and metal evaporation temperature),
- the need to ensure the assumed reproducibility and repeatability of the obtained results, generating problems with the validation of the technique,
- significant costs of servicing the device and training.

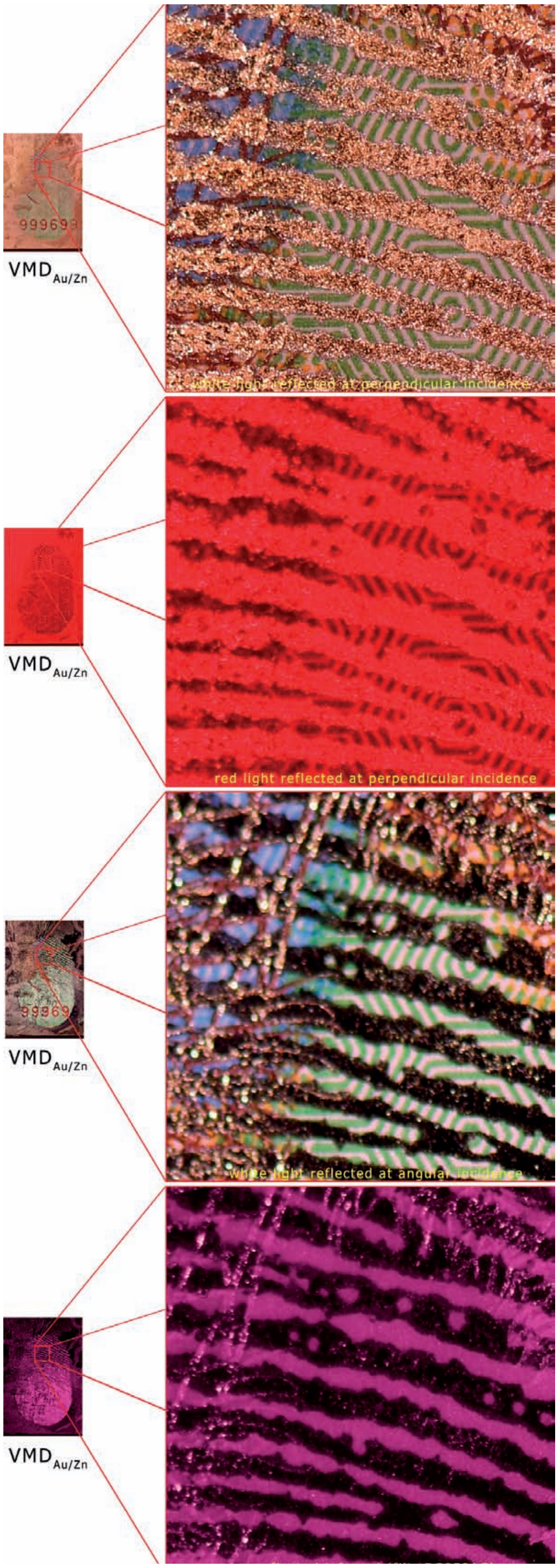

Fig. 14. Latent fingermark visualized by deposition of gold and zinc on a polymer test banknote „Pszczoły" (Polish Security Printing Works JSC) – dark layer of zinc visible on grooves images – viewed in various lights.

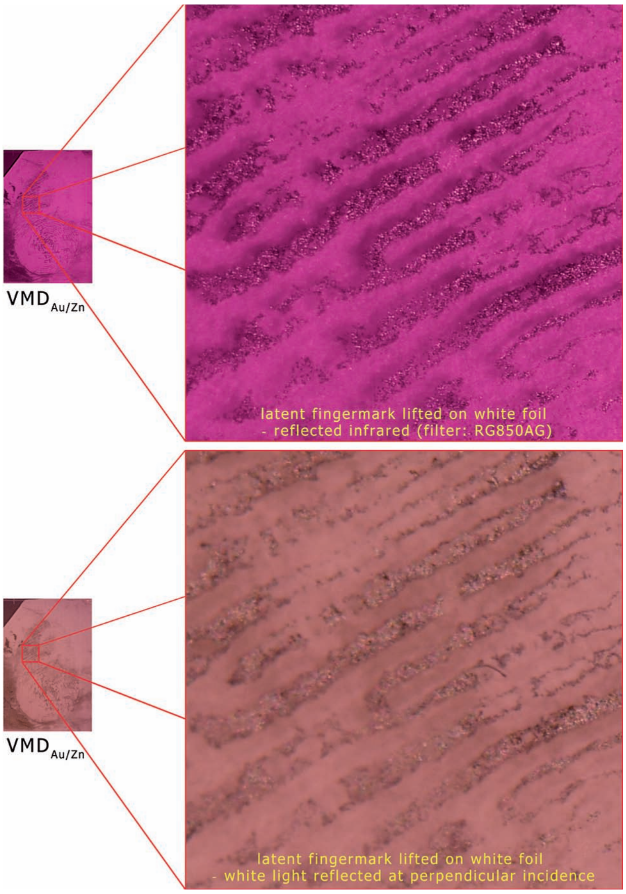

Fig. 15. Latent fingermark visualized by deposition of gold and zinc on polymer test banknote „Pszczoły" (Polish Security Printing Works JSC) transferred to white lifting foil – dark layer of zinc visible on grooves images – viewed in various lights.

Regarding the effectiveness of the vacuum metal deposition method, it is worth quoting the data from the analysis of cases conducted over two years by the Montreal Forensic Identification Section of the Royal Canadian Mounted Police. It showed that thanks to the VMD method, 67 additional fingermarks suitable for identification were revealed, which constituted 14.8% of all the submitted marks. The quality of another 23 fingerprints developed by traditional methods improved after using the VMD method. The quality of only 2 marks deteriorated (Dove, 2017).

To summarise, it needs to be concluded that the vacuum metal deposition is a valuable supplement to the generally used methods of latent fingermarks visualization. High sensitivity, combined with the proper implementation of the VMD to the sequences of visualization methods may increase the effectiveness of examinations. Such a situation will create an opportunity to detect those fingermarks, which would not have become the objects of identification tests after using the traditional sequences of methods.

Sources of Figures

Figures 1–4: Elaborated by the Authors basing on Bleay et al., 2017
Figures 5–15: Authors

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