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Review Article

AN OVERVIEW OF SOME CONVENTIONAL AND MODERN FINGERPRINT TECHNIQUES

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Abstract
Fingerprints are the most infallible means of identification. Latent print development from crime scenes is a challenging task. Fingerprint composition, Surface type and the technique used govern the success of development. A wide range of physical, chemical and optical techniques are available. However their application demands a complete understanding of the working and their compatibility with the other two factors. The present communication provides an overview of various conventional and modern fingerprint techniques.

Keywords: Fingerprints, Development, Techniques

Introduction

Characteristic alternating strips of ridges and furrows, forming a variety of patterns are present on the palmar and the plantar surface is called the friction skin. The elements and characteristics are used to identify and individualize the print. These impressions from the terminal phalanx are termed as fingerprints. Fingerprints are a type of evidence which are often found at a crime scene. They are not only one of the most crutial evidence but also the only one which may be used to establish individuality[1]. The most common and problematic type are the latent prints owing to their apparent invisibility to the naked eye. A wide array of physical, chemical and optical techniques is available for their development[2]. Numerous substances found in the fingerprint may originate from five different sources, which are, eccrine gland secretions, apocrine gland secretions, sebaceous gland secretions, epidermic substances and external contaminants from the environment. Table 1.1 summarizes composition of fingerprint residue produced from the sweat glands [(4,5)].

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After coming in contact with the surface, the latent deposit undergoes reactions, oxidation, bacterial attack, drying out and ultimately gets dissipated. Due to evaporation of water, Crystals of inorganic compounds are found soon after the deposition. Bacteria continue to decompose the print. Lipids undergo oxidation and hydrolysis. Urea migrates from the deposit. The volatile constituents evaporate and other constituents solidify. As the print ages, the viscosity increases and ultimately dries, hardens and dissipates[3].Thus this ageing is a slow process and if a suitable development technique is employed in the time phase, positive results are obtained. The present communication provides a review of various conventional and modern fingerprint development techniques.

Table 1.1: A summary of fingermark residue composition as contributed by the sweat glands

Source	**Constituents**	
	Inorganic	Organic
Eccrine glands	Chlorides Metal ions (Na^+, K^+, Ca^{2+}) Sulphates Phosphates Fluoride Bromide Iodide Bicarbonate Ammonia (>98%) Trace Metals	Amino acids Proteins Glucose Urea Uric acid Lactic acid Pyruvate Creatinine Choline Glycogen Vitamins Sterols Enzymes Immunoglobulins Fatty acids
Apocrine glands	Iron Water (>98%)	Proteins Carbohydrates Cholestrol Sterols
Sebaceous glands		Glycerides (30-40%) Fatty acid (15-25%) Wax esters (20-25%) Squalene (10-12%) Cholesterol esters (2-3%) Cholesterols (1-3%)
Miscellaneous contaminants	Drugs Cosmetics	Drugs Cosmetics Epidermal skin Nicotine Blood

2. Some conventional and modern development techniques

Each technique of fingerprint development targets a particular component or the complete latent fingermark residue. The understanding of the composition has led to the emergence of better and novel techniques. Various factors affect the success and optimization of a particular technique. Variables may be classified as: Pre- deposition factors like age, gender, diet, lifestyle etc. of donors, mid-deposition factors which refer to the substrate properties and contact dynamics and post-deposition factors which imply the environmental conditions and surface chemistry and porosity. These factors should be considered for attaining prolific results by using the most suitable development technique[6].

Powder Method

The application of finely divided material and the subsequent removal of the excess powder by brushing, blowing or tapping has been a recognized method since the 19th century. The powder composition mechanically adheres with the moisture and the oily fingerprint residue. The frictional charges results in the electrostatic attraction between the residue and the powder, which forms the principle of adherence. The size and shape of the powder particles govern the effectiveness of adherence[7]. Particle size ranges from 1 µm to 10 µm in diameter[8]. The powder is optimum if it bears no affinity for the surface and provides maximum contrast[9]. The powders are classified as regular, metallic and luminescent. Regular powders comprise of a resinous polymer for adhesion, which may be starch, kaolin, silica gel or rosin. Apart from the polymer it contains a colorant. Though both organic as well inorganic colorants can be used, the health hazards associated with the inorganic compositions have made the former more popular. To enhance the efficiency the powder is sometimes further coated on to fine quartz or plastic particulates. Organic dyes which exhibit fluorescence or are laser active are commonly employed for the same. Rhodamine B and fluorescin are examples of widely used dyes. A recent modern advancement is the use of sublimable powders[7]. Metallic powders are advantageous with respect to their shelf lives but impose toxic effects to the users. Fine Powders generally range from 1 to 50 µm[10]. Aluminum, zinc, copper and iron powders are used prevalently. Luminiscent fingerprint powders impose severe health hazards and are toxic in nature. These cause severe occupational hazards such as chronic disorders of the skin and vision. Morbidity cases have also been reported[7].

Ninhydrin method

In 1910 Siegfried Ruhemann first synthesized ninhydrin (2, 2- dihydroxy-1,3-indanedione) and discovered its reaction with amino acids. The reaction results in a non fluorescent, purple colored compound which was subsequently named Ruhemann's purple[11]. In spite of being used for many years in amino acid chromatography, ninhydrin was first employed in developing latent fingerprints in 1954, when Oden developed latent fingerprints on paper[12]. Ninhydrin is the most popular method to develop latent prints on porous surfaces The reagent had been prepared using ethanol, petroleum ether or acetone containing ninhydrin in the concentration range of 0.2 -1.5 %. But these Reagents imposed serious drawbacks of being inflammable and also affected the ink on the paper bearing the print[13]. These disadvantages were not exhibited by a non flammable composition called non flammable ninhydrin (NFN). This reagent was prepared by dissolving ninhydrin in ethanol and acetic acid followed by subsequent dilution with florosil (1,1,2-trichloro 1,2,2 –trifluorethane) [14]. Since all amino acids give the same purple color, it was opiniated that the nitrogen of the amine group is responsible for the reaction[15]. Inspite of the successful development rates, there was a serious limitation in terms of contrast. Herod and Menzel, 1982 revealed that a post treatment with zinc chloride is an advantageous modification of the conventional method. It was found that Ruhemanns purple forms a coordination complex after treatment with metal salts. This effect is further enhanced on cooling with liquid nitrogen[11]. Another breakthrough was the post treatment with lasers and alternative light sources[15]. Because of the slow reaction rate, application of heat has been recommended but it cannot be done on all types of surfaces. Also, temperature, humidity and pH must be controlled for optimization. Hence inspite of being the most popular method for developing latent prints on porous surfaces, ninhydrin analogues have been discovered that offer operational advantages, enhanced quality and more sensitivity than ninhydrin[16]. 1,8-Diazafluorene-9-one (DFO) and 1,2-indanedione are the most acknowledged analogues since they produce luminescence and intense color without any further treatment[11].

Cyanoacrylate method

In the cyanoacrylate method or the superglue fuming technique, alkyl 2-cyanoacrylate reagent is allowed to vaporize. On vaporizing it undergoes anionic polymerization. Adsorption takes place between the polymerized ester and the fingerprint residue resulting in a white colored deposition[17]. The latent print bearing specimen is kept in a fumigation chamber under 80 % relative humidity and the cyanoacrylate vapors are generated on heating. Effective results are obtained on both non porous and semi porous surfaces. Due to the white deposition produced, the technique fails to produce a sharp contrast. Post treatments such as powder dusting and dye staining have been suggested as a means to overcome this drawback[18]. Basic yellow 40 and Rhodamine 6G were suggested as effective dyes for post staining[19]. In an another study, sublimation of the dye for post treatment was advocated but it requires high temperatures[20]. In a recent study, Lumicyano™ technique was investigated. The technique utilized a liquid composed of 99% cyanoacrylate and 1% fluorophore and the fingermarks were subsequently enhanced with basic yellow 40 dye solution[18].

Iodine method

Iodine vapors passed over a latent fingerprint, causes the lipids in the print to absorb the vapors turning them orange or brown. The prints fade quickly. Despite the lack of longevity of the iodine treated fingerprints, the method is very commonly used because of its easy operation, its applicability on various types of surfaces and its non destructive nature. Iodine method cannot be used on substrates exposed to water because of the solubility of chlorides in water[13]. Chemical Reagents such as starch[21] and benzoflavone[22] are commonly used to fix iodine developed prints. Pressing a silver foil on the iodine developed prints has also been recommended. It firstly produces a yellow color of silver iodide which subsequently turns black on exposure to light[22].

Phase transfer catalysis (PTC) method

The weak or no development of latent prints may be due to the difference in phases of reagent (aqueous) and the residue (sebaceous). PTC is a heterogenous catalysis, where a catalyst facilitates the migration of a reactant from one phase to another. It comprises of a hydrophilic phase, a hydrophobic phase and an interphase. The ion gets transferred from the aqueous to the organic phase. t-tetrabutylammonim chloride[23] and t-tetrabutylammonium iodide[24] have been reported as efficient phase transfercatalysts. It involves formation of a metal carbanion at the interphase. The method is efficient for both, porous and non porous surfaces. Tetrabutyl ammonium iodide has been incorporated as the precipitating agent to accelerate the reaction between the insoluble calcium ions of the fingerprint residue and an aqueous solution of disodium salt of eosin[23]. Workers have successfully developed latent prints on the sticky side of adhesive tapes using PTC method[25].

Silica particles

Silica based particles have been used to develop latent prints. With the breakthrough of nanotechnology, cadmium sulphide and europium oxide based powders have been used to develop latent prints. They overcome the limitations of conventional powders but are rather expensive. Silica nanoparticles and microparticles with hydrophobic coatings are a recent advancement. These particles have embedded within them macromolecules labeled with fluorescent dyes. The print thus exhibits fluorescence. For stable incorporation of dyes, strong binding interactions between the dye and the backbone of the cross-linked matrix are mandatory[26].

Metal deposition

Saunders in 1989 became the pioneer of multimetal deposition technique. Multi-metal deposition involves immersing the sample in an aqueous gold nanoparticle solution and subsequent treatment with physical developer to improve the contrast[5]. It has been proposed that that amino acid component of the fingerprint residue is protonated and carries a positive charge under acidic conditions. Thus by electrostatic means, the negatively charged gold nanoparticles are deposited preferentially along the fingerprint ridges[27]. The technique is less effective than cyanoacrylate fuming or DFO on dry surfaces[5]. Single metal deposition is a modification of the technique in which the silver developer step is replaced with gold enhancement. Single hydroxylamine or gold chloride bath is used. Gold colloids deposited on the residue act as a catalyst for deposition of metallic gold from the hydroxylamine or gold chloride solution[28]. Vacuum metal deposition is another effective method for non porous surfaces. The method has been substantiated for the development of latent fingermarks on polymer surfaces, including polyethylene bags exposed to harsh environment conditions[29]. The technique involves evaporation and deposition (under vacuum) of gold followed by zinc. Zinc deposition results in the negative print. The characteristic property of zinc (and other group12 metals of periodic table) of not depositing on non metallic surfaces unless the surface temperature is below -100^0C or nucleation sites of another metal are already present is the basis of VMD technique. Gold nucleation sites in the form of agglomerates are considered most suitable and zinc for the second step because of its non toxicity[29]. The thickness and structure of the gold film, determine the binding of the zinc to the surface The technique has been affirmed to be sensitive and suitable for developing older prints and prints exposed to adverse conditions[30]. Using the vacuum evaporation technique, vacuum metal deposition of zinc oxide to develop latent prints on plastic surfaces has been employed. Thermal evaporation of ZnO was conducted to develop latent fingerprints on polyethylene terephthalate without using gold cluster deposition. It was reported that the technique developed clear, sharp prints in cases of fresh samples but failed to develop aged samples[31].

Chemical Imaging

It is a recent breakthrough which relies on digital imaging and molecular spectroscopy. This allows viewing the image as well as the spectral information of the sample analyzed. Molecular chemical imaging utilizes various spectroscopic techniques like UV-Vis absorption, fluorescent emission, photoluminiscent emission, Raman scattering and infrared absorption [32]. Conventional spectroscopic techniques study the behavior and hence composition of samples when they interact with the electromagnetic radiations. Imaging records intensity at each pixel and creates an electronic image. Condor macroscopic chemical imaging system with an imaging spectrometer range of 400-720 nm has been proposed[32]. The imaging optic was a macrzoom lens and CCD camera was used. They used chemical imaging technique on three sets of samples; with no pre treatment, treated with DFO, treated with ninhydrin. Productive outputs were obtained in their study on both porous and non porous surfaces. Attenuated total reflection fourier transform spectroscopic imaging has been used to obtain chemical images of fingerprints. Further the workers studied the amino acid and lipid distribution in the fingerprint residue of various donors[33]. Surface enhanced Raman imaging of latent prints has also been used for enhancement[34].

Quantum dots

A quantum dot is a nanocrystal made of semiconductor material that exhibit quantum mechanical properties. CdS nanocomposite was the first of its kind to be employed in fingerprint detection. It attracted forensic scientist's interests due to its magnificient fluorescence properties. Organic and aqueous syntheses are available and the latter is more suitable because QDs synthesized in the former are not soluble in aqueous phase and hence incompatible with biological systems. The use of CdS, CdSe and CdTe has been reported with CdTe being the most preferred choice[35]. CdSe quantum dots containing thioglycolic acid (TGA) as stabilizer, have been asserted to successfully recover latent prints on adhesives[36]. The major limitation of quantum dots as a fingerprint developing technique was the long developing time. Use of mercaptosuccinic acid as a stabilizer in CdTe QDs enabled fast developing speed and high sensitivity. The mercaptosuccinic acid stabilized CdTe QDs successfully developed latent prints on non porous surfaces such as adhesive tapes, transparent tape, aluminum foil and stainless steel[37].

Small Particle Reagent (SPR)

Small particle reagent method is apparently a potential technique. Goode and Morris were the first to describe this method[38]. In forensic investigations, we often come across the problem of recovering fingerprints exposed to water. SPR is a popular and an advantageous physical development technique to detect latent fingerprints on non porous, wet surfaces[39]. SPR is basically a suspension of very fine insoluble powder in a dilute aqueous solution of a surfactant[25]. It relies on the adhesion between fatty components present in traces and the hydrophobic tails of the reagent. These tails are linked to a hydrophilic head, which adheres to the metal salt to give a precipitate[40]. Suspension is generally applied by immersion or spraying method. Small particle reagent technique, also known as the wet powdering method, is an effective technique for moist surfaces, where other eccrine secretion sensitive reagents fail. Conventionally, molybdenum disulphide based SPR has been used, wherein it adheres to the fatty constituents and forms a grey deposit.

Some other suspension materials include graphite, cobalt oxide, lead oxide and Xerox powder [41]. Fe_3O_4 based suspension has been reported to produce better contrast, clarity and sensitivity[42]. Contradictory results were obtained in another study which proclaimed that iron oxide based suspension lacks sensitivity compared to MOS_2 based SPR[43]. Frank and Almog proposed zinc carbonate based formulation. It produces white precipitate and thus is suitable for dark surfaces[44]. SPR formulation comprising of titanium dioxide has been reported on surfaces namely plastic, glass and metallic surface[40]. Titanium dioxide, tergitol and water containing suspension has also been formulated[45]. Surfactant is an essential component of SPR and over the years, surfactants with varied sensitivities have been used in different studies. The surfactant should be sufficiently soluble and the tail of the surfactant should contain eight carbon atoms. These two conditions are necessary for attaining an optimum working solution[38].

All these SPR formulations are lacking in terms of contrast. The developed prints are either black or white depending on the composition. Hence, using these formulations, poor contrast is obtained on multicolored surfaces. Moreover the quality of prints developed deteriorates with long immersion periods[41]. It has been proposed that fluorescent SPR zinc carbonate compositions are better than molybdenum disulphide since the former does not interfere with the fluorescence[41]. In a study, zinc carbonate based fluorescent SPR formulation containing crystal violet was also proposed. The composition successfully developed clear and sharp fingerprints on various non porous surfaces immersed in water for up to 36 hours. The workers proclaimed the formulation was non hazardous and cost effective [46]. Fluorescent SPR is better than the conventional method since the contrast and visibility are highly improved in the former[41].

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