# Detection of Fingerprints on Firearms and Cartridges

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**Abstract**
One of the most epochal duties of the defence establishments is to safeguard the weaponry under their control. As a security measure, a tracing protocol should be in place so that if any piece of weapon goes missing, it can be tracked back to the armory. Such a protocol relies on the identification marks on arms and armaments, including mainly, make, model, caliber, manufacturer and serial number. However, if the missing weapon has been used to commit a crime, then the integrated regulatory strategy mandates not only its tracking, but also institution of forensic leads to pin down the criminal. The most important forensic tool under these circumstances is to detect fingerprints on the recovered firearm, on the cartridges collected from the scene of crime and the unfired cartridges which the suspect loaded into the weapon. The chemical methods which have the potential to lift fingerprints on firearms and cartridges are reviewed in this communication.

***Keywords:*** Cartridges; Cyanoacrylate method; Electrochemical method; Electropolymerization method; Fingerprints; Firearms; Gun bluing; Redox method

**Graphical Abstract**

## 1. Introduction

A firearm is a barreled weapon which serves as a means of aiming and discharging a projectile, generally a bullet. The latter is usually enclosed in a metal casing along with a propellant and a primer. The metal covering is also referred to as the cartridge case. Normally the firearms and the cartridges are kept under guard at the defence arsenals, but should a weapon be found missing, it becomes the de rigueur to identify the subject who embezzled it to commit a crime. The most infallible means of identification is to develop the fingerprints of the suspect on the stolen items.

Fingerprints are formed by the sweat secreted by the glands embedded beneath the ridges on the fingertips [1]. The sweat deposition leaves a latent (or hidden) impression on the object which the finger touches. Sweat contains about

99% water, about 0.5% inorganic ions and about 0.5% organic molecules [2]. The latent print is visualized by a chemical developing reagent which tags one or more components of sweat to produce a colored derivative. Although there are lot many methods to detect fingerprints on crime evidence [3], but when it comes to firearms and cartridges, the choice becomes limited [4-5].

There are several factors which preclude the detection of fingerprints on firearms: The weapon may have been recovered several days after the commission of crime and the constituents of sweat may have been degraded by sunlight, washed out by humidity and/or contaminated by wind action. The finishing of the firearm may have been rough because of which the sweat deposition may have become distorted. Multiple handling may have impinged overlapping impressions [6]. The possibility of detecting fingerprints on fired cartridges too is quite low. This may be attributed to such factors as the friction between the cartridge and the barrel, high temperatures and pressures generated at the moment of firing and the gaseous blowback residue which becomes coated on the bullet as it oozes out of the firearm [7]. Even on unfired cartridges it is difficult to detect fingerprints due to their small and curved surface area [8]. Moreover, while loading the cartridge into the magazine, chances of pressure distortion of the sweat residue are quite high [9].

## 2. Detection of fingerprints on firearms

### *2.1. Powder method*

The most simple and commonly used technique to detect fingerprints on metallic and polished wood items (the materials used in manufacturing the firearms) is to apply a powdered formulation on the latent impressions by gentle brushing. The powder, in turn, is composed of two broad chemicals: an adhesive and a colorant [10]. The adhesive gets adsorbed on the moisture and oily components (low-boiling organic compounds) of sweat by pressure deficit mechanism [1]. The colorant gets adsorbed on the adhesive. The double layer adsorption phenomena is symbolically shown in Fig. 1. The magnetic powder works on the same phenomena except that firstly, it contains a sprinkling magnetite in addition to adhesive and colorant and secondly, it is applied with a magnetized want, rather than a brush.

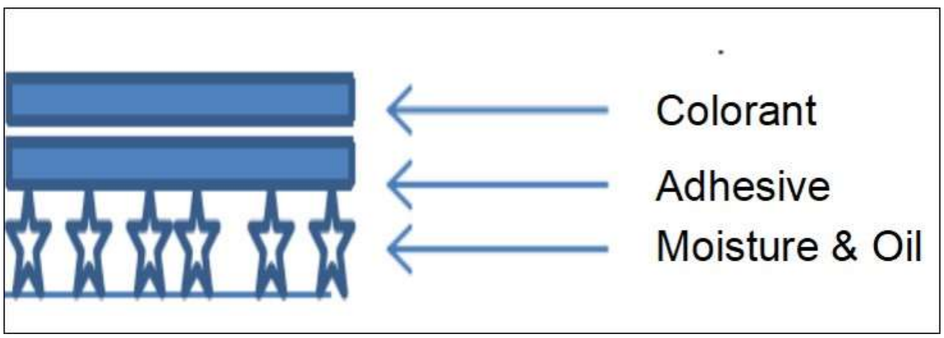


**Fig. 1.** Mechanism of powder method.

Freeman [11] used both the non-magnetic and the magnetic powders to detect fingermarks on firearms, the latter giving better results. In fact, the magnetic compositions could develop latent impressions with ease even on the metallic parts of the firearms. The black, gray, red and green varieties of magnetic powders developed the most clear and sharp fingerprints. Likewise, Matov and Zazulya [12] applied three varieties of non-magnetic powders based on silica gel, polystyrene and aluminosilicate adhesives to detect latent impressions on firearms. The best results were achieved by the silica gel powder.

### *2.2. Cyanoacrylate method*

A fuming procedure, the cyanoacrylate method is based on the premise that when the monomer, ethyl 2-cyanoacrylate is allowed to vaporize in air, it polymerizes into a white product which, in turn, gets deposited on the sweat residue [13]. The polymerization reaction is initiated by a Lewis base, such as ammonia or water vapors. The mechanism of polymerization is displayed in Fig. 2. The development time may be curtailed by installing a battery-operated fan within the fuming chamber, so as to disperse the vapors at a fast pace [14]. The white deposition is difficult to discern on pale colored surfaces. For this reason, the cyanoacrylate-developed fingerprints are generally post-treated with a luminescent dye, such as gentian violet or basic yellow 40, followed by illumination under long-wavelength ultraviolet light [15].

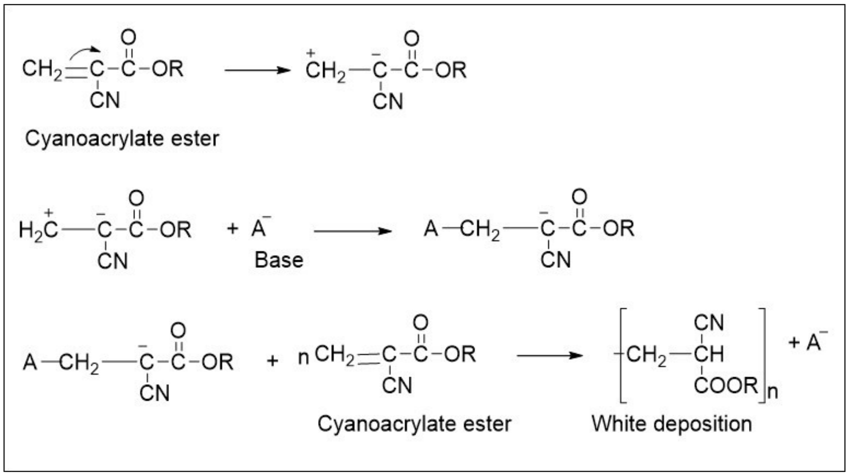


**Fig. 2.** Mechanism of cyanoacrylate polymerization.

By this method it has been possible to develop fingerprints even on a trigger of a firearm [16]. The possibility of this venture is quite low firstly, because there are chances of finding multiple fingerprints on trigger, superimposed one on the other, and secondly, because the surface area in question is so small that only a portion of fingertip will come into contact with it. Klasey and Barnum [17] carried out detection of latent impressions on a set of nine firearms using vacuum and atmospheric cyanoacrylate methods, after a gap of 24 hours from the time the test prints were impinged on the weapons. With vacuum technique, the developed prints were not as white as expected, but the over-development, which usually occurs with atmospheric technique, was averted. The vacuum cyanoacrylate method worked well with blue-steel firearms. For firearms polished with pale colors, the vacuum cyanoacrylate fuming, followed by atmospheric cyanoacrylate fuming, enhanced the fingerprints to an optimum level.

*2.3. Electropolymerization method*

Fingerprints may be detected by electrochemically controlled deposition of conducting polymers on the metallic components of the firearms. The electropolymerization proceeds with the oxidation of monomer to yield a radical cation. The latter reacts with the monomer, propagating the polymer chain by an electron transfer process. The electron transfer is, however, inhibited by the segments containing the ridge details [18]. The sweat lining along the ridges acts as an insulating area. The covalent, organic constituents of sweat – mainly fatty acids and lipids – prohibit the transfer of electrons from one species to the other. As a consequence, the polymer gets selectively deposited *in between* the ridges, and not *on* the ridges, producing negative fingerprints. However, the negative prints have as much potential to individualization as the positive prints. By varying the applied potential, the contrast of the fingerprints may be enhanced [19]. The commonly used conducting polymers used in this endeavor are, polypyrrole [20], polyaniline [21] and poly(3, 4-ethylenedioxythiophene [22]. The structures of these polymers are displayed in Fig. 3.

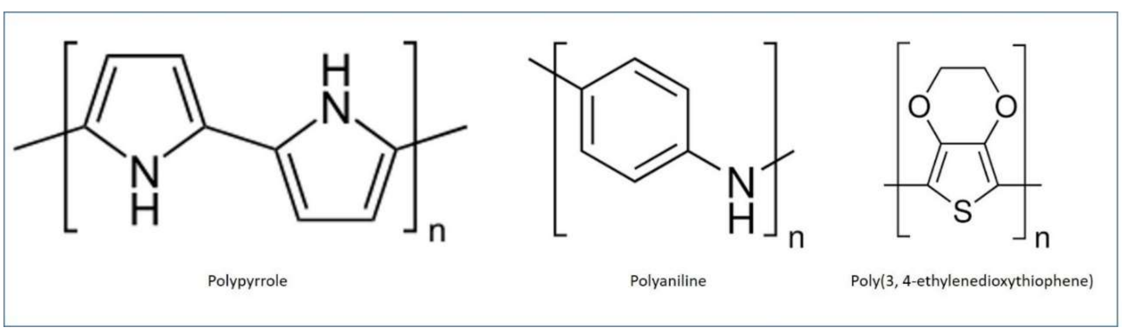


**Fig. 3.** Conducting polymers used for detecting fingerprints on metallic surfaces.

Sapstead et al [23] carried out the simultaneous oxidation of pyrrole and 3, 4-ethylenedioxythiophene to produce a copolymer, the deposition of which produced negative fingerprints on stainless steel surface. The developed fingerprints had a sharp contrast vis-à-vis the background. By this method it was possible to detect aged fingerprints, as well as those exposed to elevated temperatures and water.

## 3. Detection of fingerprints on cartridges

### *3.1. Electrochemical method*

Fingerprints on cartridges may be visualized electrochemically with the aid of scanning Kelvin probe. This technique is based on potentiometric measurements and is non-contact, as well as non-destructive in nature [24]. It elucidates the potential difference between a wire probe and the metallic surface of the cartridge. The potential difference, in turn, is attributed to the reaction between the ionic constituents of latent sweat and the cartridge. The fact that the ionic compounds are non-volatile makes it possible to develop the fingermarks even at elevated temperatures. This implies that fingerprints may be detected on fired cartridges as well by Kelvin probe method [25]. Moreover, the reaction between sweat deposition and the metal initiates as soon as the finger touches the cartridge. Therefore, fingerprints may be developed even on unfired cartridges. Rubbing the cartridge with a tissue or a towel does not impede visualization [26].

Bond [27] advocated that the reaction between the ionic compounds in the sweat and the cartridge causes corrosion at the surface, thereby revealing the ridge details. The rate of corrosion, and hence the clarity of fingerprints increases with temperature. The clarity is also dependent on the composition of the casing: If the proportion of copper is greater than 40%, the ridges that are visualized are more clear and sharp [28]. The corrosion reaction is initiated by anions, generally chloride ions. Their reaction with copper content of cartridge may be depicted as follows.

$Cu + 2Cl^- \rightarrow CuCl_2 + 2e^-$] x2
$2H_2O + O_2 + 4e^- \rightarrow 4OH^-$
Net reaction: $2Cu + 4Cl^- + 2H_2O + O_2 \rightarrow 2CuCl_2 + 4OH^-$

In an extension of this technique, Bond and Heidel [29] heated the cartridge to 700°C (so as to imitate a fired cartridge) to increase the rate of corrosion and thereafter applied a potential of 2.5 kV. Subsequently, a conducting carbon powder was applied, which enhanced the contrast of the fingerprint against the background.

### *3.2. Redox method*

As stated in the previous section, the reaction between the inorganic ions present in sweat and the active metals in cartridge results in a corrosion pattern on the casing, which is a replica of the fingerprints of the shooter. This pattern can be seen both on unfired and fired cartridges, although it is more prominent in the latter due to elevated temperatures. The ridge details may be enhances with the aid of a potentiometric probe. In redox method, the enhancement is brought about not by an instrumental technique, but by a strong oxidant. The oxidizing agent dissolves the active metal(s) from the outer surface of the casing and exposes the paler underneath coating. However, it leaves out the ridges since the sweat coating thereon resists oxidation. By default, the ridge pattern becomes pronounced.

Given [30] used fuming nitric acid as an oxidizing agent on brass and nickel plated cartridges. Copper, being more active than nickel, responded better to oxidant treatment and manifested a sharper ridge detail. The redox reaction between copper and fuming nitric acid may be displayed as follows.

$Cu \rightarrow Cu^{2+} + 2e^-$
$NO_3^- + 2H^+ + e^- \rightarrow NO_2 + H_2O$ ] x2
Net reaction: $Cu + 2NO_3^- + 4H^+ \rightarrow Cu^{2+} + 2H_2O + 2NO_2$

A cartridge coated with a thin layer of copper may be treated with an acidified solution of potassium permanganate for 30-60 seconds, whereupon the ridge pattern can be discerned [31].

$Cu \rightarrow Cu^{2+} + 2e^-$] x5
$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ ] x2
Net reaction: $5Cu + 2MnO_4^- + 16H^+ \rightarrow 5Cu^{2+} + 2Mn^{2+} + 8H_2O$

Likewise, a mixture of silver nitrate and sulfuric acid causes oxidation of the outer layer of copper in a brass cartridge.

$Cu + 2Ag^+ \rightarrow 2Ag + Cu^{2+}$

The non-ridge area becomes plated with silver, thus manifesting negative fingerprints [32].

*3.3. Gun bluing method*

Gun bluing is a spray-polish that is applied on the metallic components of firearms to prevent rusting [33]. It comes in several varieties, but its main ingredients are selenious acid and a copper salt. The most important variety is *perma blue* which contains 3% selenious acid and 3% copper sulfate; yet another composition, *super blue* is a mixture of 5% selenious acid and 4% copper nitrate [34].

The gun bluing spray may also be used to visualize fingerprints on fired cartridges. The ingredients of the composition undergo the following sequence of reactions on coming in contact with air.

$$2H_2O \rightarrow 4H^+ + O_2 + 4e^-$$

$$Cu^{2+} + 2e^- \rightarrow Cu$$

$$H_2SeO_3 + 4H^+ + 4e^- \rightarrow Se + 3H_2O$$

$$Cu + Se \rightarrow CuSe$$

The copper selenide, is repelled by latent sweat and therefore it forms a thin layer on non-ridge area, revealing negative fingerprints [35]. Gun bluing compositions can detect fingerprints on a broad spectrum of fired cartridges, including those made of brass, nickled brass, aluminium, copper and lacquered steel [36].

*3.4. Sequential method*

The recovery of fingerprints on cartridges which are cycled through the firearm – irrespective whether these were fired or not fired – depends not only the nature of alloy from which these were originally manufactured, but also on the technique of visualization. Very often a single method may fail to reveal quality marks, and for this reason a sequence of methods may be resorted to so as to have an optimum level of development. For example, Dominick and Laing[37] attempted to lift fingerprints from unfired cartridges of different sizes and found that the sequence which gave the best result was cyanoacrylate fuming, followed by gun bluing reagent, followed by basic yellow 40 staining. On the other hand, Bentsen et al [38] advocated that on fired cartridges, the sequence, cyanoacrylate fuming, followed by basic yellow 40 staining, followed by gun bluing reagent, gave the best results. For cartridges which were loaded in the firearm, but not fired, cyanoacrylate fuming, followed by gun bluing reagent gave optimum level of development of fingerprints; cyanoacrylate fuming, followed by basic yellow 40 staining gave the next best results [39]. Edmiston and Johnson [40] determined an optimal sequence for chemical development of latent prints on fired cartridge casings and fired shotgun shells made of brass and nickel. For brass cartridges, the best sequence proved to be: Cyanoacrylate fuming, black powder, acidified hydrogen peroxide, rhodamine 6G staining. For nickel cartridges, the following sequence gave the most appropriate results: Cyanoacrylate fuming, rhodamine 6G staining, acidified hydrogen peroxide, black powder. In both cases, fluorescence was observed under 515 nm radiation.

## 4. Conclusion

In a criminal cases involving shootouts, an investigator may come across a wide variety of firearms and cartridges. One of the most useful forensic tools which can help solve such crime cases is to develop latent fingerprints on ammunition. Although there are a large number of methods to detect fingermarks on different types of evidence, this venture on firearms and cartridges is problematic. Due to the multiple handling of firearms, small size of casings and surface degradation of cartridges associated with firing process, the number of fingerprint development methods that may be used on arms and ammunition becomes severely limited. These scarce methods are described in this review article.

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