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Effectiveness Of Microstamping Technology For Tracing Firearms

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ABSTRACT
The mounting prevalence of gun-related crimes has intensified the need for innovative forensic techniques that augment firearm traceability; Microstamping technology an innovative method encompassing the microscopic engravings on the firing pin to record make, model, and serial number data on the cartridge primer, useful when matching gun casings found at a crime scene [1]. Thus it offers a promising solution by imprinting unique codes onto cartridge cases each time a gun is fired. This review explores the effectiveness of microstamping in forensic firearm tracing, its operational mechanisms, benefits, challenges, and legal considerations. The technology allows for rapid identification of firearms used in crimes by matching cartridge case imprints to registered gun manufacturers or owners; thus it significantly assistances law enforcement agencies in narrowing down suspects and identifying the actual source. The paper highlights key technical components such as firing pin and breech face micro-engraving, emphasizing their roles in marking cartridges without requiring firearm recovery. In spite of its potential, microstamping faces several obstacles including wear and tear of engraved parts, potential for tampering or purposeful damage, and lack of worldwide legislation mandating its use. Moreover, debates persist over execution costs, manufacturing challenges, and privacy concerns. Case studies and pilot programs conducted in California and other regions are examined to assess real-world applicability and law enforcement perspectives. The study concludes that while microstamping is not an independent solution, it serves as a valuable complement to prevailing ballistic identification systems like the National Integrated Ballistic Information Network (NIBIN). Its adoption could modernize firearm tracking if supported by robust legislation, standardization, and technological developments. Eventually, microstamping offers a proactive tool for deterring crimes related with guns and improving public safety through enhanced traceability.

KEYWORDS
- *Microstamping*
- *Ballistic fingerprinting*
- *Alphanumeric*
- *Firing pin*
- *Breech face*
- *Engrave*
- *Laser*
- *Etchings*
- *Micromachined*

INTRODUCTION

Ballistic fingerprints refer to the unique marks left on the bullets as they are fired through the barrel of a firearm, specifically the striations created by the rifling inside the barrel. This process is part of internal ballistics, which examines the events from the moment a bullet is propelled until it exits the firearm. Ballistic fingerprinting plays a crucial role in criminal investigations, as forensic experts analyze these markings to match bullets to specific firearms, aiding in solving crimes [2]. The concept dates back to the early 20th century, with significant advancements over the years, including the development of digitized databases that allow law enforcement to compare ballistic fingerprints from crime scenes. While ballistic fingerprinting is effective for identifying firearms in many cases, it is not applicable to shotgun pellets due

to their smooth bores. The process can be labor-intensive, often requiring hours of microscopic comparison. Since the early 1900s, firearm identification methods have relied on the analysis of unintentional marks like scratches and indentations that are transferred from the weapon to the surfaces of the cartridge and the bullet. These irregularities are caused by the machining processes utilized in firearms manufacturing. This means that unintentional microstamped features are nondescript, have little readily resolvable repeatability and rely on the recovery of its matching firearm to make them useful during the traditional tool mark forensic identification process. By utilizing intentional tool marks like microstamping, firearm identification technology would be greatly improved; the technology provides consistency and certainty when looking for the connection between firearm evidence and a specific firearm source [3]. Microstamping technology has emerged as a proactive measure, imprinting firearms with unique codes to aid in tracing bullets back to their source. Microstamping is a laser based micromachining process that forms microscopic "intentional structures and marks" on components within a firearm. Thus when the firearm is fired, these microstamp structures transfer an identifying tracking code onto the expended cartridge ejected from the firearm. Microstamped structures are laser micromachined alpha numeric and encoded geometric tracking numbers, linked to the serial number of the firearm. A goal of searching a ballistic image database is to generate an investigative link from ballistics evidence to the point of sale of the weapon or ammunition used in a crime. Similarly, a firearms examiner's opinion that two pieces of ballistics evidence match suggest a link between the ballistics evidence to the point of sale of the weapon or ammunition used in a crime. An entirely different approach, microstamping, could achieve that same goal. This alternative approach is to place a known, unique, and unalterable identifier on gun parts, cartridge cases, or bullets at the time of manufacture [4].

MICROSTAMPING TECHNOLOGY

Microstamping is a proprietary ballistics identification technology where, the microscopic markings are engraved onto the tip of the firing pin and onto the breech face of a firearm with a laser, which are then stamped onto expended cartridge cases each time the firearm is fired [5]. The etchings are transferred to the primer by the firing pin and to the cartridge case head by the breech face, using the pressure created when a round is fired. Microstamping marks bullet cartridge casings with codes as they are fired from the firearm and is incorporated onto optimum surfaces with the firearm mechanism [6]. Microstamping uses lasers to engrave alphanumeric and geometric codes on a gun's firing pin; when a firing pin is micro stamped, it imprints its unique code on the cartridge. This code is tiny, but when viewed under a microscope provides a unique identifier that can link a spent casing to a gun. This code can include numbers letters or geometric shapes [7]. Basically, it deals with the cartridge casings that hold bullets before they're fired, not the actual bullets. In most models of guns, the casings are ejected after they're fired. After being fired, if the cases are recovered by police, the microscopic markings imprinted on the cartridges can then be examined by forensic ballistics experts to help trace the firearm to the last registered owner. Microstamping uses UV lasers to engrave microscopic characters onto the firing pin and other internal surfaces. The etching process used a 1.5-W diode-pumped solid-state ultraviolet laser from Coherent at 266 and 355 nm, coupled with a holographic-mask technology to rapidly produce two-dimensional bar codes or alphanumeric characters [8]. The laser system etched the surface of the micro-stamp to create the raised characters. Smith & Wesson M&P M2.0 and Ruger LCP II are the two models of handguns were modified to comply with California's microstamping laws.

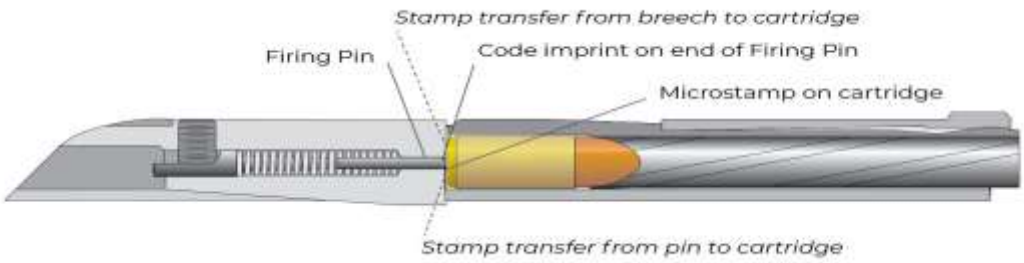

Figure 1: Working of Microstamping technology [9].

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Figure 2: Firing pin showing the alphanumeric identification code which will microstamped into the cartridge case while firing [10].

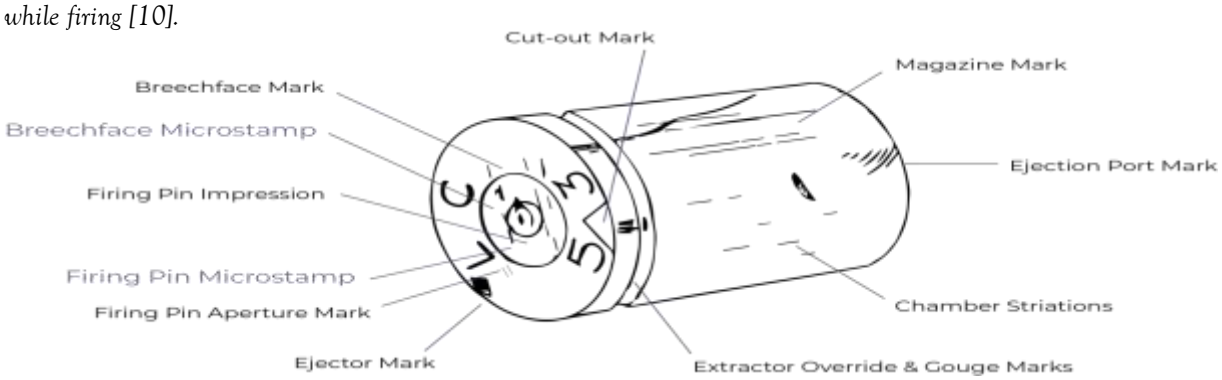

Figure 3: Cartridge case which bearing different types of marks that formed during firing from a gun [9].

Figure 4 and 5: Cartridge cases showing microstamped identification codes [4].

Microstamping technology was developed in the 1990s by New Hampshire inventor Todd Lizotte, who is also a board member of NanoMark, the company that owns the patent to the ballistic tagging technology. This technology allows gun manufacturers to place an identification mark on each cartridge casing ejected from a properly outfitted firearm at the moment of firing each bullet" and is an alternative to ballistic fingerprinting. Unlike microstamping, with current ballistics [fingerprinting] technology, detectives must recover a weapon to link an owner to a crime scene or must compare markings on shell casings with bullets fired from guns recovered later. Initially, microstamping was utilized in the medical and computer technology fields. After the Beltway sniper attacks in 2002, gun control advocates insisted on implementing this technology inside firearms to match shell casings to their owners. Microstamping technology imprints microscopic identifying information, such as the make, model, and serial number, onto the cartridge casing when a firearm is discharged. Prior to 2007, no state had taken the step of requiring semiautomatic pistols to include microstamping technology. California the first state to require gun manufacturers to develop semiautomatic handguns that leave an identifying mark (e.g., microstamp) on each bullet fired. Prior to this enactment; ballistics experts could match bullets with the corresponding guns only if they had a weapon for comparison. This technology enjoyed tremendous support from various organizations and groups. Perhaps the strongest support came from law enforcement organizations, including support from many city police chiefs and county sheriffs. More than sixty-five police chiefs and sheriffs supported the bill, along with law enforcement associations such as the Peace Officers Research Association of California [8]. Firing pins equipped with microstamping technology

would be difficult to alter as they are nearly as hard as diamonds. Therefore, even if criminal were too successfully filing the pin down, it would effectively prevent the gun from firing. However, at least one independent peer-reviewed study from a professional society of firearm examiners found that microstamp markings could be removed without rendering the firearm inoperable. The studies also found the technology unreliable, concluding that the implementation of the technology will be complicated. But, according to the co-inventor of the technology, the reason that this test produced poor results and markings not 'fully legible' was because the study did not use a more sophisticated method to read the markings known as, Scanning Electron Microscopy. The most recent test conducted by NanoMark Technologies, the manufacturer of the microstamping technology, showed tremendous success and accuracy. The co-inventor of the technology credited the success to several factors, including optimizing the technology to the dynamic behavior of the firearm and the use of appropriate imaging technology to extract the code data off the cartridges [11].In India, there is currently no federal regulation mandating microstamping technology on firearms, and it's not a widespread practice. While microstamping, which marks bullets and cartridge cases with a unique fingerprint, is used in some jurisdictions, like California, to aid in identifying guns used in crimes, it's not a national requirement in India. The Indian government's approach to firearms focuses on licensing, registration, and controlling the types of firearms allowed, rather than mandating specific technologies like microstamping.

EFFECTIVENESS OF MICROSTAMPING TECHNOLOGY IN TRACING FIREARMS

As the firearm is discharged the intentional tooling marks transfer a code to the cartridge casing which is ejected out of the firearm. When recovered at the scene of a firefight or engagement, the technology will provide forensic intelligence allowing the mapping and tracking of small arms traffic patterns within the host nation or identify insurgency force strength and pinpoint firearm sources, such as corrupt or rogue military units or police force. Microstamping is a passive mechanical trace technology that can be outfitted or retrofitted to semiautomatic handguns and military rifles to assist in developing real time intelligence providing a greater level of situational awareness. Proactively Microstamping firearms that are introduced and distributed for security forces, thus it will become easier to track the firearms if they go missing or end up on the black market in the hands of an insurgency [12]. Microstamping provides critical intelligence for use in border security operations and cross border violent drug related crime investigations. The technology assigns each firearm a unique, randomized identifier rather than a sequential number, similar to how DNA provides individual specific markers; thus this system offers a high level of reliability and repeatability, making it an effective tool for tracing firearms [13].Microstamping will provide critical forensic intelligence in regions of conflict by helping to identify patterns, trafficking routes and ultimately shut down illicit arms sources and markets that fuel the violence associated with regional genocide, terrorism and/or insurgency groups within warzones. The technology will provide a rapid and accurate cartridge-to-firearm identification process, enabling law enforcement both national and international to quickly pursue international arms dealers and other illicit firearm markets. As the firearm is discharged the intentional tooling marks transfer a code to the cartridge casing before it is ejected out of the firearm. When recovered at the scene of an incident, the intentional firearm microstamped cartridge can identify a specific firearm, without the need to recover that firearm [14].Microstamping allows investigators to identify and trace ammunition components to guns that have been used in criminal activities even when the guns are not accessible, and also to identify the last retail purchaser of the firearms linked to the ammunition. Reading the codes that are stamped do not require specialized forensic equipment or expertise, the routine use of microstamping would also reduce the workloads of overstretched forensic examiners [15]. These technologies have the potential to improve record-keeping and tracing by enabling investigators to instantly capture, store, and retrieve key data about each firearm in a given storage facility, the authorized users to whom each weapon is issued, and the usage history of each weapon. The widespread use of such systems could have significant implications for tracing lost, seized, and stolen weapons, thereby enhancing the accountability of the end-user [16].Microstamping allows each firearm to be uniquely identified through microscopic codes etched into internal parts like the firing pin or breech face. When a fired cartridge is recovered at a crime scene, the imprinted code can be traced back to the original registered owner through firearms registration databases. Traditional ballistics often requires recovery of the weapon whereas microstamping allows tracing with just the spent

cartridge case. Law enforcement can quickly determine the origin of a firearm used in a crime thus speeding up investigations. Microstamping adds a precise, readable ID that complements traditional ballistic markings like tool marks and rifling patterns thus the examiners categorize these striations looking for matches to be made between the components that created the marks and recovered firearm [17]. If criminals know that a gun can be traced through cartridge casings, they may be less likely to use legally purchased firearms in crimes. Gun owners may be more cautious with their firearms, knowing misuse can be traced back to them. Microstamping aligns with efforts to improve firearms regulation by adding traceability without requiring GPS or electronic components. It also enhances the responsibility of dealers and manufacturers by compliance with lawful manufacturing and distribution practices. Enables collaboration between local, state, and federal agencies in tracking firearms used across state or national borders and also identifies illegal distribution of the firearms by tracing the patterns emerged from traced cartridges. A distinct advantage of microstamping is that the marks could be examined at a crime scene using equipment no more sophisticated than a magnifying glass, vastly simplifying and expediting the process of developing investigative leads. It reduces need for extensive lab analysis for identification of a particular firearm. The ability to visually read or digitally scan codes makes it less resource-intensive than full forensic analysis. The technology enables faster processing of cases, potentially reducing backlog in forensic labs. Microstamping does not alter firing capability, accuracy, or safety of the firearm, making it a non-intrusive tracing method. With broader adoption, microstamped codes can be registered in a national database for instant retrieval and cross-referencing. Centralized data can help law enforcement to identify crime trends, hotspots, and repeat offenders. With this microstamping technology, investigators try to determine whether the bullet came from a single firearm and not from another firearm of the same make or model. This ability reduces the likelihood of punishing an innocent person and greatly enhances the likelihood of identifying and penalizing the perpetrator [18].

CONCLUSIONS

Microstamping technology presents a promising advancement in firearm tracing and law enforcement investigations. By etching microscopic identification codes onto the firing pin and other internal components of a firearm, it enables law enforcement to link spent cartridge cases found at crime scenes to the weapon that fired them. This capability can significantly aid in criminal investigations, improve firearm accountability, and prevent the use of guns in illegal activities. Researches and pilot programs have shown that microstamping can be an effective forensic tool, particularly when integrated with existing databases such as the National Integrated Ballistic Information Network (NIBIN). It enhances the ability of law enforcement to track down suspects and establish links between different crimes involving firearms. Furthermore, by introducing a layer of traceability, microstamping can promote loopholes in firearm trafficking. However, the technology is not without limitations, challenges include the potential for wear and tampering of microstamped components, the firing pin can often be filed down or replaced, rendering the technology useless. Despite these concerns, the potential benefits of microstamping in promoting public safety and improving investigative efficiency are considerable. With further technological refinement, legislative support, and broader implementation, microstamping could become a valuable tool in the fight against gun violence and illegal firearms distribution. In conclusion, while not a standalone solution, microstamping technology represents a forward step in modern forensic science and crime prevention. When used in conjunction with other crime-fighting tools and policies, it holds promise for making our communities safer and our justice system more effective.

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