Final Summary Overview

Special Report: Condition #44 Grant Products

RE: 2016-DN BX-0153

Goals, Summary and Conclusion drawn from the Research Project

A. Major goals of the project

The National Research Council has recommended the determination of the underlying scientific basis of forensic testing procedures. Identification failures, particularly of suspects, occur for a variety of reasons. Both fingerprints and DNA evidence degrade due to environmental insults such as temperature and humidity. Fingerprints from both the victim and a person of interest are often left on various substrates and these prints are routinely retrieved from crime scenes or places frequented by these individuals. These prints maybe exposed to various diverse elements before collection and can be degraded prior to analysis, due to environmental insults, resulting in the destruction of not just the fingerprints but also DNA which are found in nucleated cells embedded in fingerprints.

Conformal deposition of a nanoscale columnar thin film (CTF) on latent and partial bloody fingerprints on several types of forensically relevant substrates is an effective visualization method for identification of individuals. Short tandem repeat (STR) profiles are routinely generated from body fluids in forensic laboratories. Massively parallel sequencing (MPS) technology utilizing single-nucleotide polymorphisms (SNPs) can help identify DNA profiles from fingerprints.

All goals, except the manuscripts in prints, have been completed.

B. Summary and Conclusions drawn from the Research Results:

We demonstrate that columnar thin film (CTF) deposition showed no inhibition after CTF treatment of latent prints and massively parallel sequencing (MPS) of single nucleotide polymorphism (SNP) from DNA obtained from the same fingerprints. We also determined

that fingerprints can be visualized using CTF and then extracted for SNP analysis. In addition, STR and SNP analysis performed on partial bloody fingerprints were accomplished.

The value of both of CTF and SNP technologies in obtaining more information when the DNA is of poor quality and is present in these types of evidence in less than optimal quantity was confirmed in this research. Sequencing of SNPs using the Precision ID Identity Panel was also employed, in which genetic information was obtained with SNPs even when DNA was of poor quality. Various sample types (i.e. pristine, low quality and contaminated) utilized in this project demonstrated the acceptable performance of the Precision ID Identity Panel. Environmental insult and CTF development were found not to be detrimental to obtaining SNP genotypes. The amount of DNA obtained from each fingerprint varied; however, it was possible to obtain both STR (from partial bloody prints) and SNP profiles from both CTF-developed and undeveloped fingerprints. DNA extracted from some of the partial bloody prints yielded SNP genotypes even when STR analysis did not generate any profile.

This study confirms that CTF nanotechnology can be used to individualize humans using both fingerprint geometry and DNA retrieved from CTF-entombed fingerprints, thus strengthening the probative value of CTF-developed fingerprints, whether environmentally insulted or partial bloody. The conclusion derives from this research is that SNP genotypes can be obtained from DNA samples even when it is not possible to generate STR profiles from the same DNA extract. Thus, minute amounts of degraded DNA, obtained from environmentally insulted evidence such as fingerprints, are extremely valuable when used in conjunction with MPS technology. This research demonstrates that the combination of CTF-assisted visualization and analysis of DNA retrieved from CTF-entombed fingerprints would be a very useful tool for criminal justice system and in the forensic community since it combines two different disciplines, fingerprint visualization and DNA analysis, to determine individuality and identity. Our research also will be a valuable tool for law enforcement community in general, in that if the DNA is of poor quality and present in less than optimal amount, SNP technology can yield information when STR analysis, currently the method of choice, do not yield complete or even partial profile.

Five types of substrates commonly found at crime scenes were used to collect fingerprints. Some of these samples were developed with CTF technology. Four different evaporant materials were used in the development. This is highly significant in the forensic community as they can be used in the criminal justice system to convict a perpetrator or to help exonerate an innocent person. Minimal training is required for operating the CTF instruments. The results of CTF indicate that this method can potentially replace the traditional method for fingerprints. DNA sequencing and STR data indicate that CTF and DNA sequencing can be used in crime laboratories from one item of evidence, thus strengthening the weight of the evidence. MPS can be used in conjunction with STR analysis. When STR analysis fails due to degradation or low quality of DNA, MPS can be used in order to detect SNPs. Results also indicate that CTF development does not inhibit DNA analysis; neither STR nor SNP detection was inhibited due to any of the evaporant material or the technology used in developing the prints.

Application of the CTF technique for visualization of samples harvested in real-world conditions was determined to be efficient and useable in forensic laboratories. It was also determined that SNP data can be generated from degraded fingerprint samples. Concordance and identity from sequence data from EIL fingerprints that have been either treated for CTF-assisted visualization or not, are being evaluated and will be submitted for publication.

Accomplishment

In this pilot study, 100 partial bloody fingerprints were collected from two donors and deposited on five different crime scene substrates, in which half were enhanced with CTFs and were graded for quality by an IAI-certified latent fingerprint examiner. CTF-developed fingerprints, on average, had higher grades compared to non-developed partial bloody fingerprints. STR analysis using Fusion 6C was performed to assess inhibition from the evaporant materials, in which no inhibition was observed. Sequencing of SNPs using the Precision ID Identity Panel was also employed, in which genetic information that could not be obtained from STRs was achieved with SNPs. Various sample types (i.e. pristine, low quality and

contaminated) utilized in this project demonstrated the acceptable performance of the Precision ID Identity Panel.

Analysis of partial bloody fingerprints has been completed. Data analysis was achieved with the help of a researcher, Dr. Jennifer Churchill-Cihlar, who is knowledgeable with this sequencing system. DNA has been sequenced and a paper has been submitted to Forensic Science International: Genetics (FSIG), a peer-reviewed journal, for publication. This paper has come back within a very short time, with the comments from two reviewers. We are currently revising and modifying this paper for resubmission in the same journal. As noted in the appendix this paper contains data from STR and SNP analysis.

Another publication, manuscript prepared by Dr. Akhlesh Lakhtakia, the Co-PI in this project, on grading of fingerprints using CTF-developed EIL fingerprints, was submitted for publication on November 1, 2019, and reviewers' comments came back several months later. We resubmitted the paper with revision and additional revisions were requested by the reviewers. We are revising the manuscript accordingly and send it back before the end of this month. This manuscript is currently under review in Canadian Society of Forensic Science Journal. Results of the study on the fingerprint samples indicate that environmental insult may degrade the quality of fingerprints but CTF deposition thereafter can considerably enhance the degraded fingermarks for visualization.

SNP genotypes using MPS has been completed on all extracted DNA from all EIL samples. Manuscript of the samples Teresa Tiedge sequenced has been prepared and we submitted this this third manuscript in the journal Science and Justice. Teresa had presented two posters on this part of the project at the International Society for Applied Biological Sciences (ISABS) and her presentation was very well received.

Results of this grant-funded projects are being disseminated to forensic community in the form of publications and presentations. Please see below the list of publications and presentations. During the duration of this grant, part of the results has been disseminated to forensic and law enforcement communities in the form of presentations. As mentioned above, two papers, one on fingerprint grading and the other in DNA sequencing have been submitted in peer reviewed

journals, a third one is in preparation to be submitted in peer-reviewed journal very shortly. It was expected that there will be at least three manuscripts resulting from this project, and although none are in print yet, we have achieved this goal.

Products

PUBLICATIONS UNDER REVIEW

1. N. Nagachar, T.M. Tiedge, A. Lakhtakia, M.N. McCormick & R. Roy, 'Development of environmentally insulted fingerprints on nonporous forensically relevant substrates with conformal columnar thin films,' Canadian Society of Forensic Science Journal. This paper has been reviewed by two reviewers and has come back twice with comments for revisions. It is being revised per the reviewers' comments, as necessary, and has been resubmitted.

ABSTRACT: A systematic study was undertaken on the influence of environmental insult on the efficacy of developing a latent fingermark on a nonporous substrate by the deposition of conformal nanoscale columnar thin film (CTF) on it. Four warm-weather and one cold-weather environmental conditions were chosen as representative for Pennsylvania. Three durations of environmental insult were selected: a day, seven days, and 30 days. Fingermarks were collected from one male donor and one female donor on five different types of substrates. The evaporant material for the deposition of a columnar thin film on a specific fingermark sample was specifically chosen based on a prior study. Photographs of every fingermark were graded for quality after collection, after enduring the chosen environmental insult for a particular duration, and after CTF development. The results of the study on 750 fingermark samples indicate that environmental insult does not always degrade and can even improve the quality of fingermarks but CTF deposition thereafter can considerably enhance the degraded fingermarks for visualization.

2. T. M. Tiedge, P. D. McAtee, M. N. McCormick, A. Lakhtakia & R. Roy, 'Massively parallel sequencing and STR analysis from partial bloody fingerprints enhanced with columnar thin films,' Forensic Science International: Genetics. This paper was reviewed by two reviewers and has come back within a very short period of time, with suggestions for

revisions. It will be revised per the reviewers' comments, as necessary, and resubmitted within a few weeks.

ABSTRACT: Fingerprint enhancement often includes either physical or chemical approaches, such as fingerprint powder or cyanoacrylate fuming, to improve the quality of a fingerprint for visualization and analysis. However, these methods become more complex when fingerprints are partial bloody, and these procedures may interfere with downstream DNA analysis. Columnar thin film (CTF) deposition is a type of nanotechnology that utilizes an evaporant material to enhance a fingerprint under low-pressure conditions. Short tandem repeat (STR) analysis is the traditional method employed in crime laboratories. When DNA is of poor quality and quantity, like that often obtained from fingerprints, little to no genetic information may be obtained. Single nucleotide polymorphisms (SNPs) may be used to glean additional information when STR analysis fails. In this pilot study, 100 partial bloody fingerprints were collected from two donors and deposited on five different crime scene substrates, in which half were enhanced with CTFs and were graded for quality by an IAI-certified latent fingerprint examiner. CTF-developed fingerprints, on average, had higher grades compared to non-developed partial bloody fingerprints. STR analysis using Fusion 6C was performed to assess inhibition from the evaporant materials, in which no inhibition was observed. Sequencing of SNPs using the Precision ID Identity Panel was also employed, in which genetic information that could not be obtained from STRs was acquired with SNPs. Various sample types (i.e. pristine, low quality and contaminated) utilized in this project demonstrated the acceptable performance of the Precision ID Identity Panel.

3. T. M. Tiedge, A. Lakhtakia, N. Nagachar & R. Roy, 'High-throughput DNA sequencing of environmentally insulted latent fingerprints after visualization with the nanoscale columnar-thin-film technique,' (Manuscript submitted for peer-review in Science and Justice). Since this paper was submitted very recently, abstract and data from this manuscript is not included in this report.
4. The PI and the Co-PI are considering submission of a fourth manuscript. Should this

additional manuscript be prepared and submitted, it will be mentioned in the Special Condition #23 report (September 30, 2020).

CONFERENCE PRESENTATIONS

Dr. Nagachar did not attend any conference even though the Co-PI offered to pay for all her expenses. Reena Roy attended ISABS conference at her personal expense and attended ISHI conference which was supported by the forensic science program at The Pennsylvania State University. Teresa Tiedge was supported by the PI (her personal research fund) and the Co-PI to attend ISABS conference. Forensic program at The Pennsylvania State University supported her attendance at the ISHI and GRS conference. Reena Roy and Akhlesh Lakhtakia presented some of the results in various academic institutions. She paid her expenses, personally. None of the funding for presentations or attendance by anyone came from the grant.

1. T.M. Tiedge, N. Nagachar, A. Lakhtakia & R. Roy, 'Massively parallel sequencing and short tandem repeat analysis from DNA from partial bloody fingerprints developed with nanotechnology,' 29th International Symposium on Human Identification, Phoenix, AZ, USA, September 29–27, 2018 (Poster).
2. T.M. Tiedge, N. Nagachar, A. Lakhtakia & R. Roy, 'Massively parallel sequencing (MPS) and short tandem repeat (STR) analysis of human DNA from partial bloody fingerprints enhanced with columnar thin films (CTF),' 71st Annual Scientific Meeting of American Academy of Forensic Sciences, Baltimore, MD, USA, February 18–23, 2019 (Oral presentation).
3. T.M. Tiedge, M. McCormick, P.D. McAtee, N. Nagachar, A. Lakhtakia & R. Roy, 'Massively parallel sequencing of DNA obtained from partial bloody fingerprints enhanced with CTF nanotechnology,' 11th ISABS Conference on Forensic and Anthropological Genetics, Split, Croatia, June 17–22, 2019 (Poster and short presentation).
4. T.M. Tiedge, M. McCormick, A. Lakhtakia & R. Roy, 'High-throughput DNA sequencing of cold-weather-insulted fingerprints after visualization with the nanoscale

columnar-thin-film technique,' 11th ISABS Conference on Forensic and Anthropological Genetics, Split, Croatia, June 17–22, 2019 (Poster and Short Presentation).

5. T.M. Tiedge, N. Nagachar, A. Lakhtakia, & R. Roy, 'Sequencing DNA from partially bloody fingerprints using CTF and Non-CTF techniques,' Gordon Research Seminar on the Forensic Analysis of Human DNA, June 2018 (Poster).
6. R. Roy, 'High-throughput DNA sequencing of environmentally insulted latent and partial bloody fingerprints after visualization with the nanoscale columnar-thin-film technique', Northeastern Association of Forensic Scientists (NEAFS) 2018 (Oral).
7. A. Lakhtakia, 'The nanoscale in science and nature,' Center for Nanotechnology Education and Utilization, Department of Engineering Science and Mechanics, Pennsylvania State University, University Park, PA (USA), July 23, 2018.
8. A. Lakhtakia, 'The nanoscale in science and nature,' Nanotechnology Professional Development Partnership, Center for Nanotechnology Education and Utilization, Department of Engineering Science and Mechanics, Pennsylvania State University, University Park, PA (USA), February 22, 2019.
9. R. Roy, 'Nanotechnology, CTF, Fingerprints, Mosquitoes and Human Identity using MPS', Üsküdar University, Institute of Addiction and Forensic Sciences, Istanbul, Turkey, May 2019 (Seminar).
10. R. Roy, 'Mosquitoes, Fingerprints and Nanotechnology to Identify Humans', Yeni Yuzyil Universitesi, Institute of Health Sciences, May 2019 (Seminar).

In addition to the above abstracts and presentations, abstracts were submitted to Kristin Escobar (OJP) for presentation at the NIJ Forensic Science R&D Symposium at AAFS. None of the abstracts were accepted for presentation at this forum at AAFS . If OJP contacts us again about presentations, we will submit an abstract for 2021 presentation at the AAFS conference.

Appendix for Presentations:

Abstracts presented by Teresa Tiedge at various conferences;

1. Presented at Conference on Forensic and Anthropological Genetics, Split, Croatia (ISABS Conference)

HIGH-THROUGHPUT DNA SEQUENCING OF COLD-WEATHER-INSULTED LATENT FINGERPRINTS AFTER VISUALIZATION WITH THE NANOSCALE COLUMNAR-THIN-FILM TECHNIQUE

Tiedge T[1], McCormick M[3], Lakhtakia A[2], Roy R[1],

This research was supported by the National Institute of Justice (NIJ) Award#: 2016-DN-BX-0153
Fingerprints deposited on various substrates from victims and perpetrators are routinely retrieved from crime scenes. These prints are often exposed to various environmental insults resulting in the degradation of fingerprints and DNA. The columnar thin film (CTF) technique employs the evaporation of materials of diverse types, allowing for the substance to adhere and grow from the fingerprints. Massively parallel sequencing (MPS) technologies have made significant progress towards detection of single nucleotide polymorphisms (SNPs), which are suitable for analyzing degraded DNA due their small amplicon size. MPS technology, that utilizes SNPs, may be helpful in identifying DNA profiles from low-quality samples such as fingerprints submitted to forensic crime laboratories. This project utilized (i) CTF nanotechnology to develop cold-weather-insulted latent (EIL) fingerprints on five substrates commonly found at crime scenes and (ii) MPS technology for DNA sequencing. Fingerprints were subjected to -15ºC and 63% relative humidity for one day, one week or one month. Five fingerprints were collected for each substrate and insult duration. Half of the collected prints were developed by deposition of CTFs of Alq3, gold, nickel, or chalcogenide glass. CTF fingerprints were photographed before and after cold-weather insult, and after CTF deposition. Manual library preparation was employed to generate libraries, the libraries were then templated onto Ion 530™ chips via the Ion Chef™. Sequencing was performed with the Ion S5™ which utilizes semiconductor sequencing. An IAI-certified fingerprint examiner from the U.S. Secret Service is involved in grading 450 photographs of fingerprints for quality. SNP genotypes have been generated from all samples, whether CTF

developed or not, thus indicating that semiconductor sequencing can be used to detect genetic information from degraded fingerprints.

2. Presented at Conference on Forensic and Anthropological Genetics, Split, Croatia (ISABS Conference)

MASSIVELY PARALLEL SEQUENCING OF DNA OBTAINED FROM PARTIAL BLOODY FINGERPRINTS ENHANCED WITH CTF NANOTECHNOLOGY

Tiedge T[1], McCormick M[2], McAtee P[3], Nagachar N[4], Lakhtakia A[3], Roy R[1],

This research was supported by the National Institute of Justice (NIJ) Award#: 2016-DN-BX-0153
Fingerprints are often found on various objects at crime scenes. Cyanoacrylate fuming in conjunction with a dye stain is a traditional method used to enhance fingerprints in crime laboratories. Partial bloody fingerprints are more challenging to develop, as they contain both a latent and a patent component, which requires different methods of enhancement. Previous research has demonstrated that nanotechnology utilizing columnar thin film (CTF) deposition on partial bloody fingerprints is effective on certain types of substrates. Single nucleotide polymorphisms (SNPs) are valuable for analyzing low-quality or degraded samples because the amplicon size is smaller than that of STRs. Massively parallel sequencing (MPS) technology can be beneficial in identifying SNPs from degraded or low template samples such as DNA obtained from fingerprints. A combination of nanotechnology to enhance fingerprints, and DNA analysis with MPS gives scientists an opportunity for dual identification of an individual, which strengthens the weight of the evidence. In this project, partial bloody fingerprints were collected on five forensically relevant substrates. CTF enhancement was performed using four different evaporant materials. DNA was extracted from undeveloped and CTF-developed fingerprints. Libraries were prepared both manually and with the Ion Chef™. Libraries were templated onto Ion 530™ chips via the Ion Chef™ and then sequenced on the Ion S5™ platform. The Precision ID Identity Panel was used in this study. STR analysis was also utilized in this research to determine if the evaporant materials were inhibitory to DNA analysis. This study demonstrated that CTF nanotechnology can be used to enhance partial bloody fingerprints.

Additionally, MPS can be used as an alternative technique when STR analysis fails due to low quantity DNA. Results indicate that the evaporant materials used in this project are not inhibitory to either STR analysis or sequencing.

3. Presented at International Symposium on Human Identification: Arizona, USA

MASSIVELY PARALLEL SEQUENCING AND SHORT TANDEM REPEAT ANALYSIS OF DNA FROM PARTIAL BLOODY FINGERPRINTS DEVELOPED WITH NANOTECHNOLOGY

Teresa M. Tiedge, B.S., Nivedita Nagachar, Ph.D., Akhlesh Lakhtakia, Ph.D., D. Sc., and Reena Roy, Ph.D.

Fingerprints are commonplace on various substrates at crime scenes. Traditional methods of enhancing latent fingerprints include cyanoacrylate fuming and dusting with carbon-based, fluorescent and magnetic, or other powders. Enhancement of partial bloody fingerprints is challenging because the latent and the patent parts require different methods that may be difficult to cascade. Deposition of a columnar thin film (CTF) on partial bloody fingerprints has been shown to be effective for some types of forensically relevant substrates. Prior research with deposition of CTFs of Alq_3 on partial bloody fingerprints on brass has established that CTF deposition preserves DNA for short tandem repeat (STR) DNA analysis.

Recent advances in massively parallel sequencing (MPS) have made sequencing more economical and faster compared to earlier technologies. Single nucleotide polymorphisms (SNPs) are advantageous to use for low-quality samples because their amplicon size is smaller than that of STRs. MPS technology, in combination with SNPs, can be helpful in identifying DNA profiles from low-quality samples such as fingerprints. Combining fingerprint enhancement with CTFs and DNA analysis with MPS allows for dual identification of an individual, thereby strengthening evidentiary value.

Partial bloody fingerprints collected on glass, brass, cherry wood, black garbage bags, and clear sandwich bags were considered in this project. CTFs of Alq_3, gold, $Eu(tta)_3phen$, or GeSbSe chalcogenide glass, as appropriate, were deposited on the samples. DNA was extracted from

undeveloped as well as CTF-developed fingerprints. Quantification using qPCR was performed to determine the degradation index of every sample. In addition to STR testing, DNA extracts were also sequenced on the Ion S5™ to determine SNP genotypes. The Precision ID Identity Panel contains primers for 124 SNPs and consists of 90 autosomal and 34 Y-clade SNPs. The Ion Chef™ was used to prepare the libraries via automation, as well as to template the libraries onto the semi-conducting chip for sequencing. This study demonstrated that CTF nanotechnology can be used to individualize humans using both STR and MPS techniques.

5. Presented (platform presentation) at American Academy of Forensic Sciences: Maryland, USA

MASSIVELY PARALLEL SEQUENCING AND STR ANALYSIS OF HUMAN DNA FROM PARTIAL BLOODY FINGERPRINTS ENHANCED WITH COLUMNAR THIN FILMS

Teresa M. Tiedge, B.S.[*1], Nivedita Nagachar, Ph.D.[1], Akhlesh Lakhtakia, Ph.D., D. Sc.[2], and Reena Roy, Ph.D.[1]

Fingerprints are commonplace on various substrates at crime scenes. Traditional methods of enhancing latent fingerprints include cyanoacrylate fuming and dusting with carbon-based, fluorescent, magnetic, or other powders. Enhancement of partial bloody fingerprints is challenging because the latent and the patent components require different methods that may be difficult to cascade. Deposition of a columnar thin film (CTF) on partial bloody fingerprints has been shown to be effective for some types of forensically relevant substrates. CTF deposition requires the use of the conformal-evaporated-film-by-rotation (CEFR) method, allowing for conformal growth of CTFs from the fingerprint. Prior research with deposition of CTFs of Alq_3 on partial bloody fingerprints on brass has established that CTF deposition preserves DNA for short tandem repeat (STR) DNA analysis.

Recent advances in massively parallel sequencing (MPS) have made sequencing more economical and faster compared to earlier technologies. Single nucleotide polymorphisms (SNPs) are advantageous for use with low-quality samples because their amplicon size is smaller

than that of STRs. MPS technology, in combination with SNPs, can be helpful in identifying DNA profiles from low-quality samples such as fingerprints. The primary goal of this research is to combine fingerprint enhancement with CTFs, and DNA analysis with MPS allowing for dual identification of an individual, thereby strengthening evidentiary value. Additionally, MPS libraries may be prepared manually or through automation. A secondary goal of this research was to compare sequencing data between the two library preparation methods.

Partial bloody fingerprints collected on glass, brass, cherry wood, black garbage bags, and clear sandwich bags were used in this project. CTFs of Alq_3, gold, $Eu(tta)_3phen$, or GeSbSe chalcogenide glass, as appropriate, were deposited on the samples. DNA was extracted from undeveloped as well as CTF-developed fingerprints. Quantification using qPCR was performed to determine the degradation index of every sample. In addition to STR testing, DNA extracts were also sequenced on the Ion S5™ to determine SNP genotypes. The Precision ID Identity Panel contains primers for 124 SNPs and consists of 90 autosomal and 34 Y-clade SNPs. The Ion Chef™ was used to prepare the libraries via automation, as well as to template the libraries onto the semi-conducting chip for sequencing. This study demonstrated that CTF nanotechnology can be used to individualize humans using both STR and MPS techniques. It was determined that the use of gold, chalcogenide glass, and $Eu(tta)_3phen$ as evaporant materials were not inhibitory to STR analysis. It was concluded that automated and manual library

6. Presented at Gordon Research Seminar on the Forensic Analysis of Human DNA Maine, USA

SEQUENCING DNA FROM PARTIALLY BLOODY FINGERPRINTS DEVELOPED USING CTF AND NON-CTF TECHNIQUES

Teresa M. Tiedge, B.S.[*1], Nivedita Nagachar, Ph.D.[1], Akhlesh Lakhtakia, Ph.D., D. Sc.[2], and Reena Roy, Ph.D.[1]

Fingerprints are often deposited on various substrates at crime scenes. Traditional methods of collecting and enhancing these fingerprints include cyanoacrylate fuming and the use of various powders including carbon-based, fluorescent and magnetic powders. The

difficulty of enhancing fingerprints increases when the prints have been deposited in blood. Prior research with one of the evaporant material Alq_3 has established that columnar thin film (CTF) deposition allows for the enhancement of examination-quality fingerprints while preserving DNA for short tandem repeat (STR) DNA analysis.

In this project partially bloody fingerprints were deposited on five crime scene substrates: glass, brass, cherry wood, black garbage bags and clear sandwich bags. These fingerprints were then subjected to CTF deposition to enhance the fingerprint using various evaporant materials including Alq_3, gold, nickel and chalcogenide glass. One of the goals of this research was to explore the effects of partially bloody fingerprints developed with gold, nickel and chalcogenide glass on STR analysis.

In recent years, advances in massively parallel sequencing (MPS), commonly referred to as next generation sequencing (NGS) have made sequencing more economical and faster compared to earlier technologies. MPS technology can be helpful in identifying DNA profiles from degraded or low quantity samples, such as detected from fingerprints. In addition to STR testing, partially bloody fingerprints subjected to CTF deposition were also sequenced on the Ion S5 using an automated Ion Chef to determine SNP genotypes. Combining fingerprint enhancement with CTF nanotechnology and DNA analysis with MPS allows for dual identification of an individual, which in turn, strengthens the value of the evidence.

1. Below are several photographs that were included in the paper currently under review in the Canadian Society of Forensic Science Journal (under review).

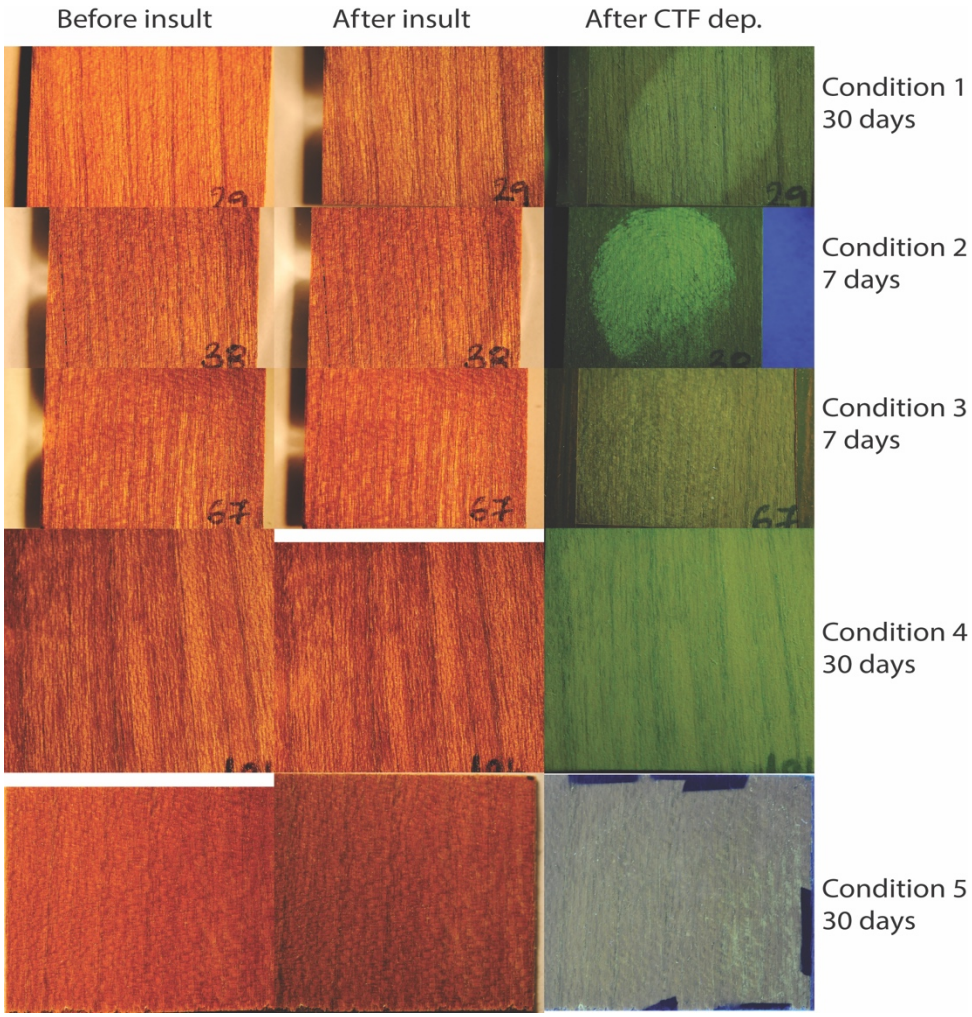

Figure 1. Sequence of three photographs for five randomly chosen samples of fingermarks on cherry wood. Left column: before insult, middle column: after environmental insult for the specified duration, right column: after CTF deposition.

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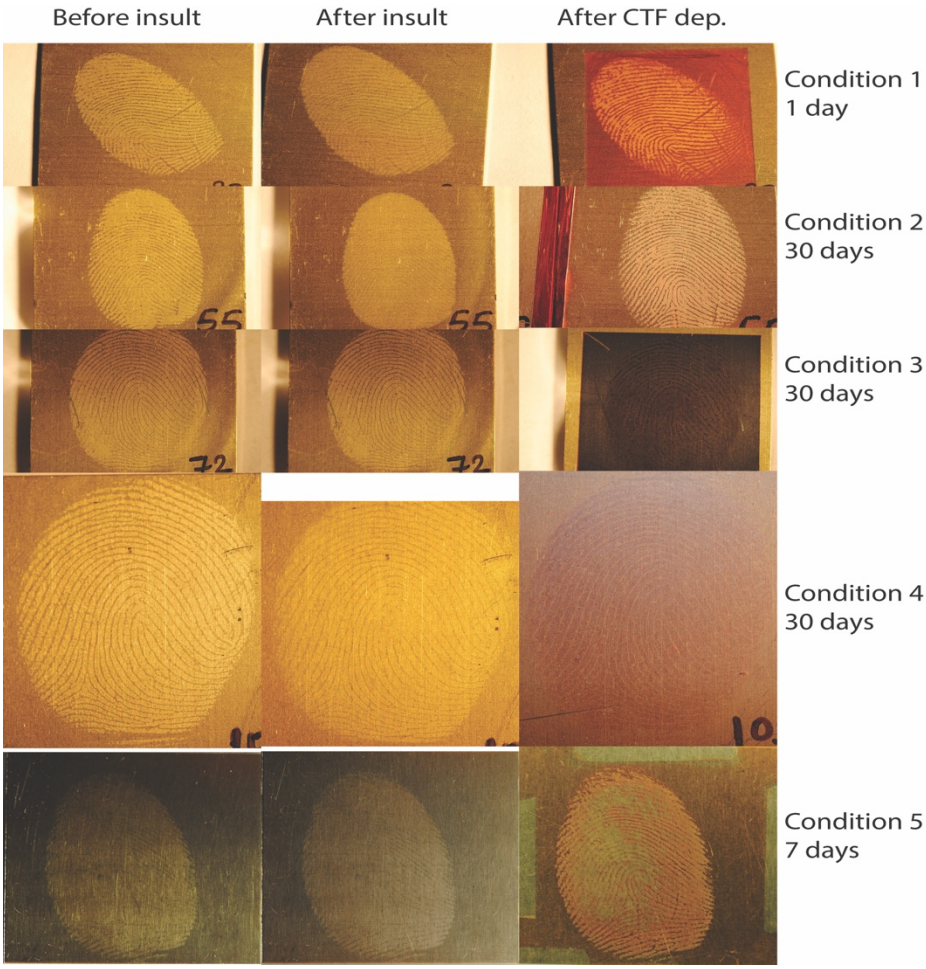


Figure 2. Sequence of three photographs for five randomly chosen samples of fingermarks on brass. Left column: before insult, middle column: after environmental insult for the specified duration, right column: after CTF deposition.

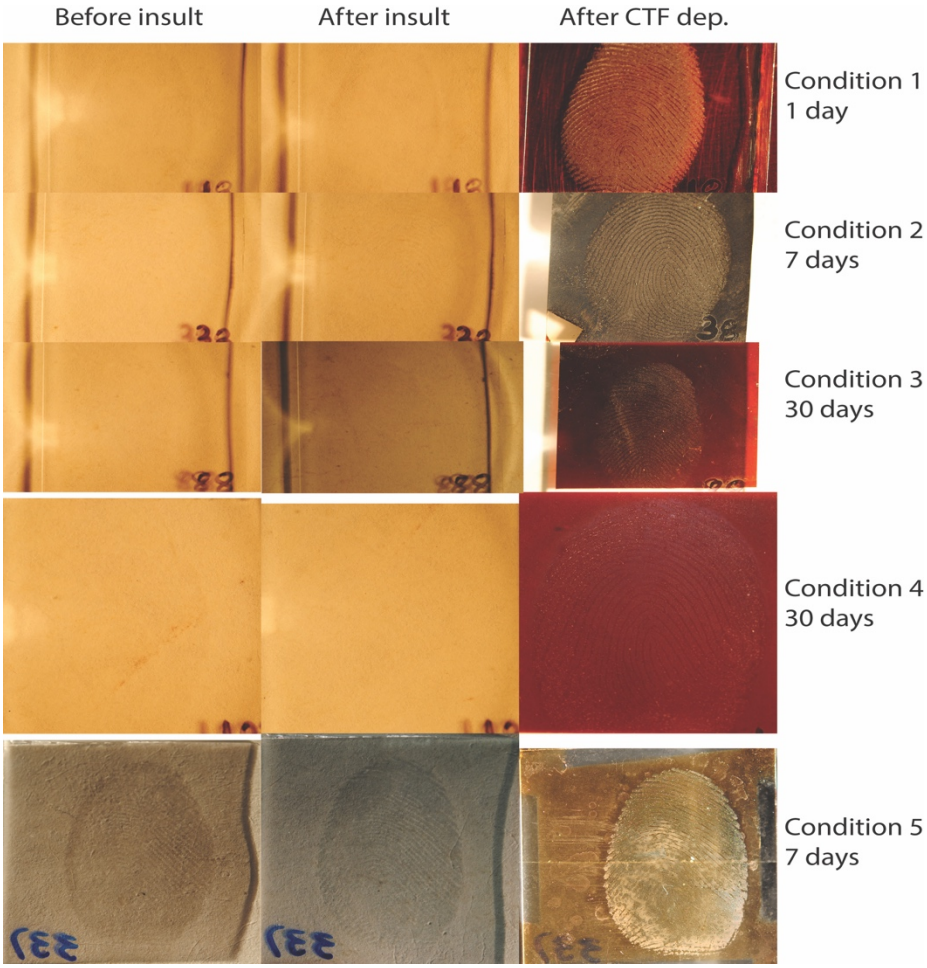


Figure 3. Sequence of three photographs for five randomly chosen samples of fingermarks on glass. Left column: before insult, middle column: after environmental insult for the specified duration, right column: after CTF development. A black sheet of paper was inserted behind the substrate for last photograph in the last row (Condition 5).

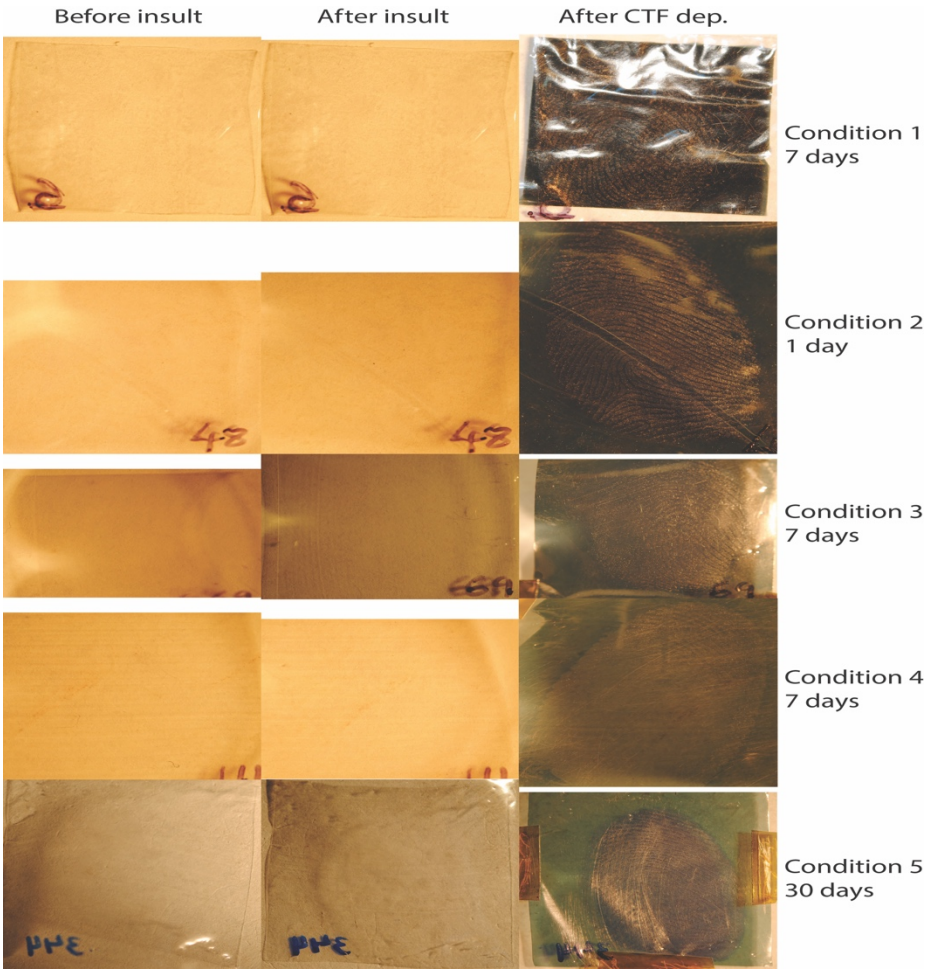


Figure 4. Sequence of three photographs for five randomly chosen samples of fingermarks on clear plastic sandwich bag. Left column: before insult, middle column: after environmental insult for the specified duration, right column: after CTF development.

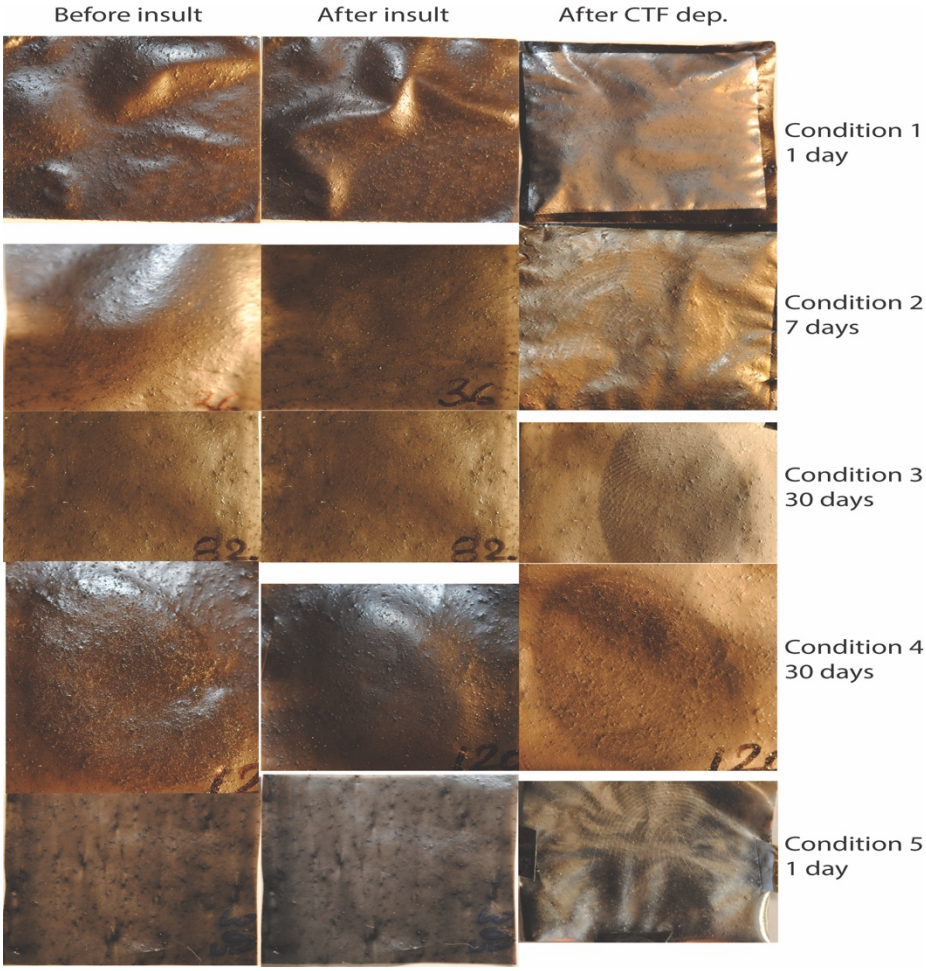


Figure 5. Sequence of three photographs for five randomly chosen samples of fingermarks on black plastic garbage bag. Left column: before insult, middle column: after environmental insult for the specified duration, right column: after CTF deposition.

2. Below are some of the data that were included in the paper currently under review in the Forensic Science International: Genetics

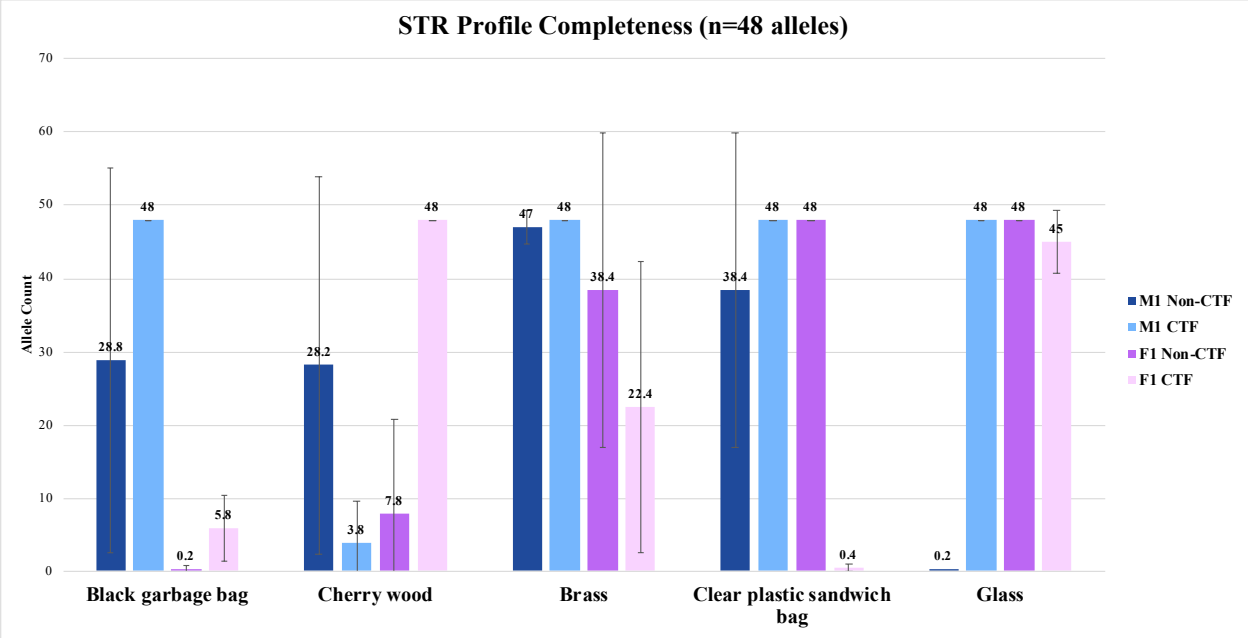
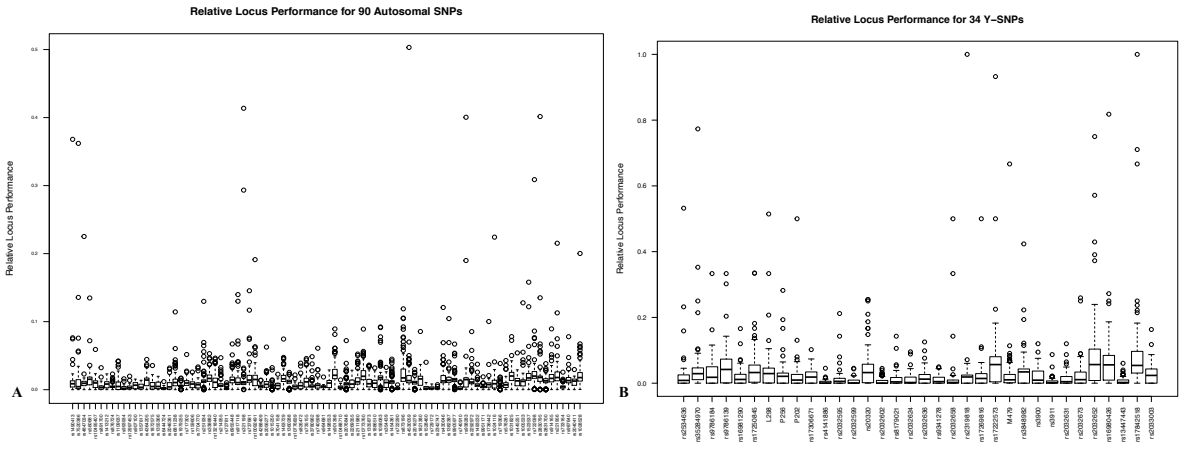


Figure: Average STR profile completeness for all samples



The above two figures are the following; Relative Performance for 90 autosomal SNPs and Relative Locus Performance for 34 Y-SNPs.

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