

***MFRC***

**Midwest Forensics Resource Center**

Research and Development  
Program Summary

September 2007

## Acknowledgement

These research projects were funded by the U.S. Department of Justice COPS Program under contract number 2005 CKWX0466, and by the National Institute of Justice, through the Midwest Forensics Resource Center at Ames Laboratory under interagency agreement number 2002-LP-R-083. The Ames Laboratory is operated for the US Department of Energy by Iowa State University, under contract No. W-7405-Eng-82.

# **Midwest Forensics Resource Center (MFRC) Research and Development Program**

## **Introduction**

The mission of the MFRC Research and Development Program, is to provide technological advances in forensic science for the benefit of our regional partners as well as the forensic community at large. Key areas of forensic science need are identified through our interactions with our Midwest partners and our R&D advisory group, as well as through our participation in national meetings in forensic science. Under the sponsorship of the National Institute of Justice and the U.S. Department of Justice COPS Program, the MFRC solicits proposals for the development of practical and useful technology, instrumentation, and methodology that address needs in areas related to forensic science and its application to operational crime laboratories. The MFRC facilitates proposal development by working to establish partnerships between researchers and our regional partners. The MFRC administers a peer-review of the proposals and then funds the selected projects at a cost of approximately \$55,000 each, with a 12-month period of performance.

The process for selection of these projects includes the following steps: 1) drafting of a call for proposals by MFRC staff, 2) review of the draft call by members of the R&D advisory committee, 3) review and approval of the call by NIJ, 4) issuance of the call to ISU, Ames Laboratory, regional partners, and research organizations, 5) receipt of proposals, 6) review of proposals by R&D advisory committee, 7) ranking and selection by MFRC staff using advisory committee reviews, with concurrence by NIJ, 8) notification of proposers, 9) receipt and review of progress reports by MFRC, 10) receipt and review of final reports by MFRC, R&D advisory committee, and NIJ.

The decision to fund any specific project is based upon a peer-reviewed call-for-proposal system administered by the MFRC. The reviewers are crime laboratory specialists and scientists who are asked to rate the proposals on four criteria areas including: 1) relevance to the mission of the MFRC, 2) technical approach and procedures, 3) capabilities, teaming, and leveraging, and 4) implementation plan. A successful proposal demonstrates knowledge of the background for the research and related work in the field and includes a research plan with a defined plan to implement the technology to benefit our partners at the crime laboratories.

## **Program Summary Technical Sheets**

The following project summaries, while not a complete summary of all research areas, are meant to demonstrate the range of research funded by the MFRC. The project summaries describe the forensic need the projects serve as well as the benefits derived from the technology. The summaries provide a brief description of the technology and the accomplishments to date. In addition, the collaboration with regional partners and the status of the implementation of the technology are highlighted. These technical summaries represent the development and implementation of practical and useful technology for crime laboratories that the MFRC hopes to accomplish.

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## Abstracts of Funded Projects

### CHEMISTRY

- ***Analysis of Automotive Clear Coat Paints by Micro-Laser Raman Spectroscopy.*** Jay Siegel, School of Science, Indiana University – Purdue University, Indianapolis (IUPUI), Indianapolis, Indiana.

This project partially funds the purchase of a micro-laser Raman spectrometer to evaluate the feasibility and discriminating power of Raman spectrometry in the characterization and analysis of automotive clear coat paints. This represents one phase of an ongoing project in the analysis of clear coats undertaken by the Forensic and Investigative Sciences Program at IUPUI. The methods used include micro-laser Raman spectroscopy, Fourier transform infrared spectrophotometry and UV-visible-near infrared spectrophotometry. The Raman phase of the project is conducted in partnership with the Indiana State Police Forensic Science Lab.

- ***Analysis of Forensic Soil Samples via High Performance Liquid Chromatography (HPLC) and Ion Chromatography (IC).*** Christopher Bommarito, Micro-Chemistry Subunit, State of Michigan, Department of State Police, Lansing, Michigan.

The purpose of this study is to evaluate the discriminatory power of HPLC and IC in forensic soil comparisons. Traditionally, forensic soil comparisons have been performed via analysis of color, texture, and mineralogical content. Chromatographic methods can provide additional discrimination as the compounds examined by these methods (humic materials, organic and inorganic contaminants) are typically not examined in traditional mineralogical methods. As such, chromatography can be useful screening tools for soils, providing quick methods for eliminating soils from different sources before beginning mineralogical analyses.

- ***Determination of Heavy Metals in Whole Blood Using Inductively Coupled Plasma – Mass Spectrometry.*** Joseph Wermeling, Wisconsin State Crime Laboratory-Madison, Madison, Wisconsin and Charles Cornett, Department of Chemistry and Engineering Physics, University of Wisconsin – Platteville, Platteville, Wisconsin.

The forensic investigation of toxicological cases involving acute intoxication, poisoning, and death is heavily focused on the analysis of organic and pharmaceutical analytes of interest. The determination of inorganic analytes, especially heavy metals, is often limited to a few metals. Tools used include relatively insensitive wet chemical techniques or single-element methods employing atomic absorption or graphite furnace methods. This project addresses the need for the development of rapid, sensitive, multi-elemental methods for the analysis of metal toxins in whole blood, thereby expanding the range of inorganic analysis in toxicological investigations.

- **Development of Rapid, HPLC-Based Intoxicant Screening Approach.** Peter Carr, Department of Chemistry, University of Minnesota, Minneapolis, Minnesota.

High performance liquid chromatography (HPLC) has become the dominant analytical methodology in forensic drug analysis. The overall objective of this work is to develop an ultra-fast, highly reliable gradient elution HPLC screening method for detecting and identifying drugs of abuse. The availability of such a screening method reduces the burden placed on the much slower, more expensive, and harder to maintain liquid chromatography-mass spectrometer method.

- **Elemental Characterization of Automobile Body Fillers, Putties, and Caulk by Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry for Matching and Evidence.** R. S. Houk and Stan Bajic, Ames Laboratory, Iowa State University, Ames, Iowa.

Fillers, putties, and caulks are common materials in automobiles. Yet, in the literature, very little information is available regarding the analytical characterization of these materials. This project utilizes laser ablation - inductively coupled plasma - mass spectrometry as an analytical technique to differentiate between samples of similar composition. Using unique trace element signatures and multivariate analysis techniques sample comparisons can be made and discrimination criteria for the material types can be provided.

- **Evaluation of a Portable Raman Analyzer for Testing Drugs.** Susan Gross, Minnesota Department of Public Safety, Bureau of Criminal Apprehension, St. Paul, Minnesota.

Large case backlogs can cause slowdowns and delays in the judicial system. Speedy trial demands by the defendant are difficult to maintain with these backlogs. This project evaluates a portable drug identification system, using laser-based Raman technology, to ease some of the backlog problems. The evaluation of the Raman StreetLab® is performed in the laboratory and in the field. By implementing a plan to analyze controlled substances in the field, the laboratory case backlog can be alleviated and the prosecution of controlled substance cases can continue in a timely manner.

- **Fast Gas Chromatography Capabilities in Arson Debris Analysis.** Charles Cornett, Department of Chemistry and Engineering Physics, University of Wisconsin – Platteville, Platteville, Wisconsin.

This project assesses the potentially large impact that fast gas chromatography (Fast GC) may have on the determination of ignitable liquids. *Forensic Sciences: Review of Status and Needs* clearly defines a need for further advances in this field. In addition, current analytical literature appears to support Fast GC as a separation technique capable of comparable resolution to conventional GC in less time per sample. This research compares resolution capabilities of the two techniques in separating a wide range of ignitable liquids in an array of matrices. With sufficient resolution, Fast GC may help clear casework in a more timely manner.

- ***Forensic Evaluation of Soils for Presence of Decaying Flesh.*** William Buttner, Sensor Research Group, Illinois Institute of Technology, Chicago, Illinois.

Human decomposition produces a range of chemical by-products which can serve as chemical signatures to the presence of human remains. Traditionally, detection of such a broad range of chemicals is performed in a laboratory using complicated bench-top instruments like gas chromatography - mass spectrometry. This project focuses on the development of a portable chemical analyzer which uses pyrolysis, low power portable sensors, and/or pattern recognition to detect and identify chemical signatures associated with decaying flesh.

- ***Identifying Co-ops and Farmers as Illicit Sources of Anhydrous Ammonia for Meth Makers.*** John Verkade and George Kraus, Department of Chemistry, Iowa State University, Ames, Iowa.

The theft of liquid ammonia for illicit use in the manufacture of methamphetamine (meth) is common. At this point in time, the majority of thieves steal anhydrous ammonia directly from co-op facilities or nurse tanks in the fields of farmers. If anhydrous ammonia were to contain an effective detection compound, which rendered the meth traceable, then the theft could be significantly diminished. The objectives of this project are to develop salts that make detection compounds when lithium, a key component of the illicit meth synthesis, is added; are harmless to humans and crop fields; and can be detected using High Performance Liquid Chromatography.

- ***Long-Term Stability Studies of Liquid Samples from Clandestine Methamphetamine Laboratories.*** Jeremiah Morris, Johnson County Sheriff's Office Criminalistics Laboratory, Mission, Kansas.

Maintaining evidence integrity is a pillar principle of any forensic laboratory. At the current time, very few long-term stability studies have been performed for controlled substances evidence outside of biological fluids. There is a lack of data and knowledge regarding the stability of methamphetamine and its precursors in solutions from clandestine laboratories. This study evaluates if the original levels of precursors and methamphetamine remain stable or convert over time while in storage. The results will answer questions whether or not collected solutions require specialized storage or expedited analysis.

- ***Micromechanical Cantilever (MC)-Based Sensors for Chemical Species Detection.*** Pranav Shrotriya, Department of Mechanical Engineering, Iowa State University and Marit Nilsen-Hamilton, Department of Biochemistry, Biophysics and Molecular Biology, Iowa State University, Ames, Iowa.

The merging of silicon microfabrication techniques with surface functionalization biochemistry offers opportunities for developing microscopic analytical devices with unique characteristics. This project develops a proof-of-concept for high specificity and sensitivity micromechanical cantilever-based (MC) sensors. Successful completion of the research may help the development of portable sensors capable of detecting chemical species at

concentrations of parts-per-billion. Such sensitivity will revolutionize forensic analysis of controlled substances, explosives, biological molecules, and DNA required for crime-scene investigation.

- ***Optimization of Headspace - Solid Phase Microextraction (HS-SPME) for Organic Impurity Profiling of Illicit MDMA Tablets.*** Ruth Waddell, Department of Chemistry, Michigan State University, East Lansing, Michigan.

Organic impurity profiling of illicit synthetic drug tablets aims to identify similarities among tablets. Similar impurity profiles indicate a common production method, and similar levels of the same impurities potentially indicate common production laboratories. In this research project, headspace solid phase micro-extraction (HS-SPME) procedures for the extraction of organic impurities from illicit MDMA ('ecstasy') tablets are developed and compared with conventional liquid-liquid extraction procedures, in terms of the number and level of impurities extracted. HS-SPME is rapid, requiring no solvent and yielding selective extraction of impurities. Hence, HS-SPME is a promising extraction procedure that offers attractive advantages over conventional procedures.

- ***The Temporal Fate of Drugs in Decomposing Tissues.*** John Wyman, Franklin County Coroner's Office, Columbus, Ohio.

Interpreting drug concentrations found in decomposed remains is always difficult. Postmortem tissues that are routinely collected and analyzed (blood, urine, vitreous humor), and therefore provide the largest comparative database for interpretation, are frequently lost in the early stages of putrefaction. Consequently, when drugs are found in weathered tissues, there is currently little or no information available to help guide the toxicologist, and subsequently the pathologist, in evaluating whether a drug(s) played any significant role in causing the death. This study follows the fate of sixteen drugs, which commonly cause intoxications, in seven different tissues collected from decomposing pigs.

- ***Trace Metal Analysis of Ecstasy by Microwave-Assisted Digestion and Inductively Coupled Plasma - Optical Emission Spectroscopy (ICP-OES).*** Philip Crawford and James McGill, Department of Chemistry, Southeast Missouri State University, Cape Girardeau, Missouri and Pam Johnson, Crime Laboratory Division, Missouri State Highway Patrol, Cape Girardeau, Missouri.

A common technique among drug enforcement officials is signature profiling, that is, using analytical methods to determine the composition of certain characteristic impurities in a seized drug sample. One illicit drug for which this method holds promise is ecstasy. Using acidic media and inductively coupled plasma - optical emission spectroscopy, trace metal impurities or signatures are profiled for the purpose of comparing and differentiating between ecstasy samples. In doing so, trace metal profiling can provide the link between seized ecstasy samples and the origin (manufacturer or dealer) of the drug.

- ***Ultra-Fast Gradient Elution HPLC as a High Throughput, High Information Content Screening Tool for Drugs of Abuse.*** Peter Carr, Department of Chemistry, University of Minnesota, Minneapolis, MN.

This project is a continuation of previously funded work titled “Ultra-Fast Gradient Elution Reverse-Phased HPLC with Diode-Array Detection.” That activity improved both the speed and selectivity of older HPLC methods through a combination of precise retention measurements and chemometric analysis of the spectro-chromatograms. In the currently funded project, two other potential improvements are examined: error rate and chromatographic resolution. For the first, to reduce error rates and facilitate chemometric analysis, both a unique commercial phase and a novel hydrophobically-assisted cation exchange phase (currently under development) is tested. For the second improvement, a newly developed general purpose optimization scheme is used.

## **DIGITAL EVIDENCE**

- ***Development of Forensic Imaging Technique for Fast Analysis of Magnetic Tapes with High Speed Resolution.*** Seong-Jae Lee, Center for Nondestructive Evaluation, Iowa State University, Ames, Iowa and Robert Sanders, Forensic Imaging Unit, Wisconsin State Crime Laboratory, Wausau, Wisconsin.

Video cameras are widely used as tools for recording criminal acts. Due to recent advances in editing technologies, digital editing or fabrication of videotape evidence has become possible. This project develops a new forensic imaging technique that allows fast and accurate visualization of magnetic patterns of magnetic tapes using a transparent magneto-optic film indicator. The technique, if successful, can be used for investigating any recording patterns on magnetic tapes quickly and non-destructively.

## **PATTERNED EVIDENCE**

- ***Application of Crystal Orientation Method to Forensic Physical Matching of Metal Surfaces along a Fracture Line.*** Barbara Lograsso, School of Technology, Michigan Technological University, Houghton, Michigan; Thomas Lograsso, Ames Laboratory, Iowa State University, Ames, Iowa; and James Kreiser, Springfield, Illinois.

A physical match between two surfaces is routinely viewed as definitive proof that the fracture surfaces were generated from the same part. The practice of fracture matching has recently been challenged in court. Therefore, there is a need for a method to measure the nature and characteristics of materials with a known error rate that can be applied to performing physical matches. This study examines the feasibility of using surface crystal orientation to associate or differentiate metal fracture fragments found at crime scenes.

- ***High Speed Digital Video Analysis of Bloodstain Pattern Formation from Common Bloodletting Mechanisms.*** Terry Laber, Minnesota Department of Public Safety, Bureau of Criminal Apprehension, St. Paul, Minnesota; Bart Epstein, Edina, Minnesota; and Michael Taylor, Institute of Environmental Science and Research, Christchurch, New Zealand.

The analysis of bloodstain patterns is used by criminal investigators to draw inferences about the events that led to the formation of the pattern. An understanding of the dynamics of a blood transfer event is therefore critical to the sound interpretation of the resultant bloodstain pattern. This project studies the formation of some common bloodstain patterns by using a high-speed digital video camera to record the blood transfer as it occurs. The outcome of the research will strengthen the science behind bloodstain pattern analysis (BPA).

- ***Proposed CD-ROM Based Digital Information Database on Pipe and Tubing Utilized in Improvised Explosive Devices.*** Jamie Crippin, Western Forensic Law Enforcement Training Center, Pueblo, Colorado; David Green, Lake County Crime Laboratory, Painesville, Ohio; and William Randle, Missouri State Highway Patrol Laboratory, Jefferson City, Missouri.

The rise in terrorist bombings has made the identification of bomb materials a priority for the forensic scientist. The volume of evidence to be analyzed and the importance of such testing for preventive and investigative purposes have created a need for reliable, fast, and cost-effective tools that can help identify specific tubing material used for bombs. The objective of this project is to collect data on all known types of pipes and tubing and to store the information in a searchable CD-ROM-based database. Such a database greatly reduces the amount of time and effort spent by forensic scientists to process bomb samples.

- ***Quantification of the Individual Characteristics of Human Dentition.*** Thomas Johnson, School of Dentistry, Marquette University, Milwaukee, Wisconsin.

Although DNA can be associated with a human bite, it is not always recovered. In those cases, comparative forensic sciences are under attack for lacking a scientific basis. This project studies the ability to scientifically quantify the occurrence of special dental characteristics and error rates in the analysis of bite marks. Using six measurements and 400 samples, a database is created that may provide the criminal justice system with the beginning of a tool and the hard science for objective statement of probability, in either exculpating or incriminating a suspect from patterned injuries caused by human teeth.

- ***Spectral Analysis of the 3D Fracture Surfaces for Enhanced Matching.*** Ashraf Bastawros, Department of Aerospace Engineering, Iowa State University, Ames, Iowa; Barbara Lograsso, School of Technology, Michigan Technological University, Houghton, Michigan; and Jeremiah Morris, Johnson County, Sheriff's Office Criminalistics Laboratory, Mission, Kansas.

A fractal surface carries sets of unique signatures dictated by the intrinsic material microstructure and the external loading conditions. This project combines the basic

understanding of fracture mechanics with the practical applications of forensic science to develop testing protocols for improved matching of fractured surfaces. A 3D spectral analysis of the fracture surface is developed to identify these fracture signatures and to show their uniqueness for each fractured specimen. Fracture of metal coupon specimens are used to generate proof-of-concept and to establish the feasibility of the approach. The matching ability is then compared against the techniques currently used in forensic labs.

- ***Statistical Validation Study of Toolmark Uniqueness.*** David Baldwin, Max Morris, and Stan Bajic, Ames Laboratory, Iowa State University, Ames, Iowa.

The recovery and comparison of toolmarks connected to a crime scene are of great importance in forensic science. It is generally accepted that particular manufacturing methods produce marks on tools that are substantially different from tool to tool. The overall objective of this study is to conduct a numerical validation of that proposition. Such a validation of tool uniqueness is particularly important in light of some recent court challenges.

- ***Testing for Potential Contextual Bias during the Verification Stage of the ACE-V Methodology when Conducting Latent Print Examinations.*** Glenn Langenburg, Minnesota Bureau of Criminal Apprehension, St. Paul, Minnesota.

Recent Daubert challenges to fingerprint evidence and the ACE-V methodology have questioned the reliability of the methodology as it is currently applied by experts. This project studies the potential effect of contextual bias on expert opinion. Experiments were conducted at an International Association for Identification conference in Boston, MA, and at a local community college where the principal investigator teaches an introductory course in forensic science. The results of the experiments provide valuable insight on the effects of potentially-biasing context information, when present, during the verification of latent print examinations.

## **BIOLOGY / DNA**

- ***Testing DNA Samples for Population of Origin.*** Raymond Miller, School of Medicine, Washington University, St. Louis, Missouri.

This activity funds the development and implementation of a forensic test to help field investigators with unidentified DNA samples and to provide information about the population of origin of the donor of the DNA sample. The test uses available equipments to genotype ancestry informative single nucleotide polymorphisms (SNPs). The results will be compared with known population frequencies of self-described ethnic groups to narrow the possible ancestry of the sample.



# Analysis of Automotive Clear Coat Paints by Micro-Laser Raman Spectroscopy

## FORENSIC TECHNOLOGY NEED

Little attention to date has been paid to clear coats. This may be due, in part, to the lack of inorganics in clear coats, which are almost always present in color or base coats. Recent advances in micro-laser Raman instrumentation make it easier to obtain high quality spectra of small materials, like the cross section of a chip of automotive paint.

## TECHNOLOGY DESCRIPTION

The main objective of this research is to evaluate the effectiveness of micro-laser Raman spectroscopy in discriminating among automobile clear coat paints.

A secondary objective is to evaluate micro-laser Raman spectroscopy as part of a scheme to analyze automotive clear coats. Other techniques that are used in such a scheme are also evaluated. They include Fourier transform infrared (FTIR) spectrophotometry and ultraviolet (UV)-visible-near infrared (IR) spectrophotometry.

## METHODOLOGY

To achieve these objectives, the project plans to purchase a micro-laser Raman spectrometer that will evaluate the feasibility and discriminating power of Raman spectrometry in the characterization and analysis of clear coats.

Specific activities include:

- Evaluation of micro-laser Raman spectroscopy and optimization of sampling and analysis techniques.

- Partial validation of the techniques and proposed scheme.
- Use of the scheme that is developed.

## ACCOMPLISHMENTS AND ONGOING WORK

The procurement of the micro-laser Raman has been delayed by the manufacturer until late August 2007. More than 200 samples of automobile paint chips with make and model information have been obtained, and a method for sectioning the chips using a microtome has been developed. Currently, we are in the process of obtaining FTIR spectra of the clear coats of all of the paints are being obtained. This will continue until the Micro-Laser Raman instrument arrives.

## TECHNOLOGY BENEFITS

Clear coats on automobile paints are very common now but have not been analyzed forensically to any degree. This project will develop this area of forensic analysis by providing multi-instrumental data about this evidence type. Laser Raman spectroscopy is not a widely used technique in forensic chemistry and this project will show how valuable this technique can be when applied to the analysis of trace evidence. Use of this instrument will improve the scientific value of paint evidence and increase the association value of paint evidence to a suspect source.

## COLLABORATION

The research will be conducted by the Forensic and Investigative Sciences Program at Indiana University, Purdue University, Indianapolis (IUPUI). The Raman phase of the project will be conducted in partnership with

the Indiana State Police Forensic Science Laboratory.

Using IUPUI blind samples and samples from previous casework, forensic scientists from the Indiana State Police (ISP) will use their own FTIR and UV-visible-near IR instrument as well as the Raman instrument to evaluate paint chips. They will also determine the effectiveness of the scheme and of Micro-Laser Raman, in particular, to characterize and compare known and unknown paint chips.

The ISP will further prepare a number of proficiency tests to use for further validation of the Raman technique and of the scheme.

## **IMPLEMENTATION**

ISP will use the scheme (developed from this research) in the analysis of case samples of paint as they come into the lab, and as a supplement to their normal analysis protocols. They will have use of the Raman instrument and microtome for their case work.

## **PUBLICATIONS AND PRESENTATIONS**

This is a new project with no publications or presentations to date.

## **CONTACTS**

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# Analysis of Forensic Soil Samples via High Performance Liquid Chromatography (HPLC) and Ion Chromatography (IC)

## FORENSIC TECHNOLOGY NEED

Forensic soil comparison has traditionally been performed via analysis of color, texture, and mineralogical content, including an analysis of particle distribution by polarized light microscopy (PLM) and mineral identification by spectroscopy. Although these are useful methods for discrimination, they primarily target inorganic minerals in the soil while the organic and water soluble constituents are largely neglected.

Chromatographic methods could provide additional discrimination as the compounds examined by these methods (humic materials, organic, and inorganic contaminants) are independent variables that are not examined in traditional mineralogical methods. Also, analyses of this type could be useful screening tools for soils, providing a quick method for eliminating soils from different sources before beginning any mineralogical analysis.

## TECHNOLOGY DESCRIPTION

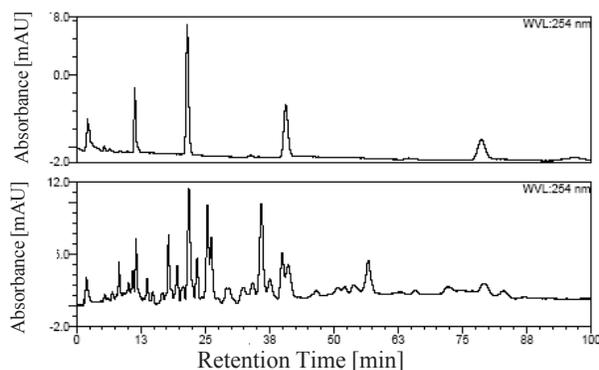


Figure 1. HPLC chromatograms of two samples showing qualitative differences in the number and location of components.

Methods for high performance liquid chromatography (HPLC) analysis of organic and humic materials in soil have been

developed but there is some variation in the forensic literature as to whether this type of analysis effectively discriminates soil samples. While the humic substances themselves may not discriminate soil samples, environmental contaminants can be detected by these methods and may prove to be an effective discriminator (Figure 1).

Ion chromatography (IC) has been widely utilized for the analysis of water soluble inorganic ions in forensic explosive analysis but the application of this technique to forensic soil samples has not been explored (Figure 2).

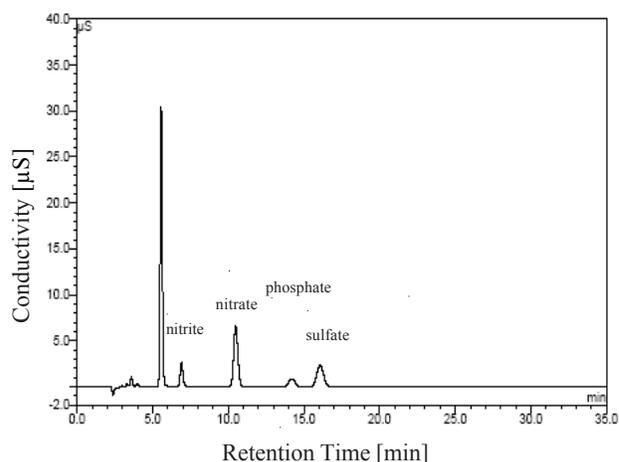


Figure 2. IC chromatogram of one sample showing detectable amounts of nitrite, nitrate, phosphate, and sulfate.

## METHODOLOGY

The purpose of this study is to evaluate the discriminatory power of HPLC and IC in forensic soil comparisons. Qualitative HPLC and IC analyses of soils from 120 different locations allow for an assessment of the evidentiary value of any similarities and/or differences in the organic and inorganic fractions of soils encountered during forensic analyses. Quantitative IC analysis will help

determine baseline levels of anions (e.g. nitrate, chlorate, and perchlorate) in soils from various locations. Samples from six locations were collected and analyzed over ten weeks to examine the temporal variation of organic and inorganic content in soils and the spatial variation of these constituents were examined via grid sampling of these same six locations.

## **ACCOMPLISHMENTS AND ONGOING WORK**

All samples were collected using a #9 soil plug five times to a depth of about 1 inch and stored in brown paper bags. Each sample was placed in a glass petri dish, dried in a 60°C oven for 2 hours, and sieved through a 60/250 µm mesh Tyler-certified brass sieve. The fraction that passed through the sieve was stored in a vial for analysis by the HPLC system consisting of an automatic sampler and diode array detector and an ion chromatograph with autosampler and electrochemical detector.

Qualitative and quantitative analysis of the resultant chromatograms showed that using HPLC and IC to analyze organic- and water-soluble fractions of soil can successfully discriminate samples. Including quantitative analysis of the results eliminates some false inclusions by providing further differentiation of samples. To demonstrate that the variation observed via HPLC and IC analysis is an independent variable from the inorganic composition, 10 samples that were differentiated by these methods were also examined via X-Ray Fluorescence (XRF). The resulting data indicated that additional discrimination is possible when HPLC and IC analysis are added to traditional forensic soil analysis schemes.

The methods used in this study were also able to detect both qualitative and quantitative variations in soil over a relatively small geographic area. This demonstration of soil

heterogeneity underscores the importance of the collection of a representative known sample population when assessing a forensic soil comparison. Significant temporal variation was also demonstrated over the course of 10 weeks of sampling. However, samples were found to be consistent over shorter periods of time only. Finally, baseline levels of inorganic anions were determined by IC. These levels may be useful in assessing the significance of anions detected in soil from cases involving low explosives.

## **TECHNOLOGY BENEFITS**

Quantitative IC analysis will help determine baseline levels of anions in soils from various locations and therefore aid in the forensic analysis of soils from cases involving low explosives. Many of which contain some of the same anions detected by this method.

Any increased discrimination of soil samples via these methods will improve the analytical scheme for soil analysis by eliminating Type II errors (false inclusions). In cases where an inclusion is inferred, the improved discrimination will reduce the size of the class to which the samples belong and add significance to the association.

## **COLLABORATION**

Graduate students from Michigan State University collaborated with Christopher Bommarito, Michigan State Police Forensic Science Division.

## **IMPLEMENTATION**

The results of the research were disseminated through presentation at forensic meetings of the MFRC and the Midwestern Association of Forensic Scientists. The research was published in the January 2007 issue of the Journal of Forensic Sciences. PDF Reprints of the article are available through the author at

bommaric@michigan.gov. A number of paper reprints were forwarded to the MFRC for distribution.

The 2007 publication was recommended as suggested reading material in forensic geoscience courses at Oxford University and the University College in London, England. The publication also formed the basis for recommending ion chromatography as a comparative tool for forensic geoscience work in Switzerland.

## **PUBLICATIONS AND PRESENTATIONS**

- Bommarito, C.R., “Analysis of Forensic Soil Samples via High Performance Liquid Chromatography (HPLC) and Ion Chromatography (IC).” Presented at the Midwest Forensics Resource Center Annual Meeting, April 2006, St. Louis, MO.
- Bommarito, C.R., Sturdevant, A.B., Szymanski, D.W., “Analysis of Forensic Soil Samples Via High-Performance Liquid Chromatography and Ion Chromatography.” *Journal of Forensic Sciences*, Vol. 52, No. 1, January 2007.
- Bommarito, C.R., Sturdevant, A.B., Szymanski, D.W., “Analysis of Forensic Soil Samples Via High-Performance Liquid Chromatography and Ion Chromatography.” Presented at the Midwestern Association of Forensic Scientists meeting, 2006, Indianapolis, IN.

## **CONTACTS**

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# Determination of Heavy Metals in Whole Blood Using Inductively Coupled Plasma - Mass Spectrometry

## FORENSIC TECHNOLOGY NEED

The forensic investigation of toxicological cases involving acute intoxication, poisoning, and death investigations is heavily focused on the analysis of organic and pharmaceutical analytes of interest. The determination of inorganic analytes, especially heavy metals, is often limited to a few metals, using relatively insensitive wet chemical techniques or single-element methods employing atomic absorption or graphite furnace methods. Because these methods are limited and time-consuming, testing for toxic metals in blood samples often goes undone.

This project addresses the need for the development of rapid, sensitive, multi-elemental methods for the analyzing metal toxins in whole blood. This expands the range of inorganic analysis in toxicological investigations.

## TECHNOLOGY DESCRIPTION

The primary objective of this project is to employ the sensitivity, wide dynamic range, and multi-element capabilities of inductively coupled plasma mass spectrometry (ICP-MS) to the elemental analysis of samples related to forensic toxicology. In principle, nearly 70 elements can be determined by ICP-MS. The goals of the project are to develop a rapid screening method for heavy metal toxins using the semi-quantitative features of ICP-MS, to develop and validate a quantitative method for arsenic, cadmium, mercury, and lead in whole blood, and to assess the use of microwave assisted digestion of whole blood samples in addition to currently used dilution protocols.

## METHODOLOGY

Existing methods for heavy metals in whole blood are generally concerned with the analysis of samples of clinical or environmental interest. As such, they focus on biomonitoring, i.e., the monitoring of levels of metals related to chronic exposure to elevated yet relatively low levels of heavy metals.

The concern of the forensic toxicologist is more often related to determining acute exposure to very elevated levels of a metal toxin. This requires calibration of a method across a wide analytical range. In addition, the screening procedures for biomonitoring of metals are usually limited to well-established suites of metals that are analyzed on a routine basis in large batches. The needs of the forensic toxicologist are therefore for methods that can rapidly detect analytes ranging from the most common to those that are rare. The "semi-quantitative" capability of the inductively coupled plasma (ICP) would allow this determination.

Two different approaches will be used in establishing the procedure. First, the diluents for several well-established biomonitoring procedures will be evaluated for both semi-quantitative and quantitative analyses. Second, the use of microwave-assisted acid digestion of whole blood samples will be evaluated. Such digestion procedures have been shown to remove effects from dissolved solids and the carbonaceous components of biological samples. Optimization of both dilution and digestion will be carried out in an interactive fashion.

## **ACCOMPLISHMENTS AND ONGOING WORK**

This is a new project. Work to date has focused on developing the necessary ICP-MS methodology using primary standards and certified reference materials. Current work has been directed at comparing sample dilution and microwave digestion pre-treatment techniques.

## **TECHNOLOGY BENEFITS**

With this procedure, it is conceivable that all toxicology samples could be screened for common heavy metals and for a suite of toxic elements in a single analysis. This ability to routinely test biological samples for a broad spectrum of elemental toxins would add a valuable dimension to forensic toxicological analysis.

Since this project represents collaboration between the toxicology and trace evidence units at the crime laboratory, this work also anticipates the expansion of ICP-MS capabilities to other disciplines in the forensic sciences, particularly in trace evidence. The use of ICP-MS for glass analysis as referenced in the literature is one example.

## **COLLABORATION**

This project is a collaborative effort between the Wisconsin State Crime Laboratory and the University of Wisconsin-Platteville. It also represents collaboration between the trace evidence and toxicology units within the Wisconsin State Crime Laboratory.

## **IMPLEMENTATION**

The establishment and validation of procedures suitable for inclusion in the Wisconsin State Crime Laboratory Unit Procedure Manual is the first goal. If

successful, the blood metals method will be incorporated into the toxicology unit's routine procedures when the final version is ready.

These results will be presented in the form of oral or poster presentations to the Midwest Association of Forensic Scientists, the Academy of Forensic Science, or at the MFRC annual meeting. The investigators will work with the MFRC to disseminate results to professionals from interested organizations. Publication in relevant journals will also be pursued. The results of this project will be used to assess additional applications of ICP-MS to both toxicology and trace evidence.

## **PUBLICATIONS AND PRESENTATIONS**

- Wermeling, J.R., "Determination of Heavy Metals in Whole Blood Using Inductively-Coupled Plasma-Mass Spectrometry." Abstract submitted to the 59th Annual Pittsburgh Conference and Exposition on Analytical Chemistry and Applied Spectroscopy (Pittcon 2008).

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# Development of a Rapid, HPLC-Based Intoxicant Screening Approach

## FORENSIC TECHNOLOGY NEED

Over the past two decades, high performance liquid chromatography (HPLC) has become the dominant analytical methodology in the pharmaceutical industry and in forensic drug analysis. It is also becoming a common analytical technique in clinical toxicology.

## TECHNOLOGY DESCRIPTION

The overall objective of this work is to develop an ultra-fast, highly reliable gradient elution HPLC *screening* method for detecting and identifying drugs of abuse. To achieve this objective, the long-term reproducibility of retention is studied to develop a chemometrically-based approach to automate analyte identification based on diode-array UV spectra, and to test the methodology by running an extensive series of comparisons on actual positive and negative samples.

## METHODOLOGY

The specific aims of this work are to:

- Develop a rapid, HPLC intoxicant screening method (RLCIS) based upon our earlier ultra-fast gradient elution HPLC (UFGELC) work.
- Identify two or three alternative, highly stable reverse phase HPLC columns with *different selectivity* to be used for analytes that cannot be identified due to incomplete chromatographic resolution from endogenous materials.
- Apply chemometric techniques including various established forms of principal components analysis and multivariate curve resolution alternating least squares

as a means of maximizing the use of the data that will be obtained by the RLCIS approach.

- Evaluate the discriminating power (DP) and mean list length (MLL) provided by the measured retention times of the target analytes, and assess detection limits for the target analytes using the optimized UFGELC method.
- Determine the sensitivity and specificity of the methodology by evaluating real samples whose composition is known based on previous analysis using established techniques [e.g. liquid chromatography-mass spectrometry (LC-MS)].

## ACCOMPLISHMENTS AND ONGOING WORK

The effectiveness of the modified gradient elution HPLC system as a screening technique was demonstrated by comparing the DP and MLL to slower LC methods involving comparable numbers of compounds.

The new technique showed significant improvement in both speed and identification power. In order to choose the most informative (orthogonal) pair of HPLC columns, Snyder's empirical model of reversed-phase column selectivity was applied. Based on the Snyder's column parameters, a set of columns was selected which provides the best orthogonality.

Figure 1 shows the distribution of the gradient retention times for a set of 47 of the most commonly abused regulated intoxicants on a

Discovery HS-FS column (a penta-fluorophenyl phase) versus the gradient retention on an Agilent SB-C18 column. The system enables many pairs of compounds that co-elute on one column to be separated by the alternative column.

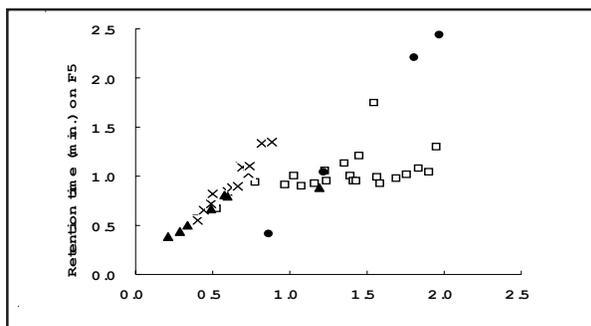


Figure 1. Retention time of the regulated 47 intoxicants on SB-C 18 versus HS-F5; opiates (triangles), amphetamine (cross outs), benzodiazepine (open squares), and other (circles).

Another type of reversed phase (called Hyper Cross-linked Sulfonated phase) synthesized in this laboratory was also studied. This is a unique phase in that it is a hydrophobic cation exchanger and thus should have a selectivity very different for common purely hydrophobic reversed phases. As shown in Figure 2, it has different selectivity from the Agilent SB-C18. The pair of columns also provides poorly correlated retention times especially for the benzodiazepines.

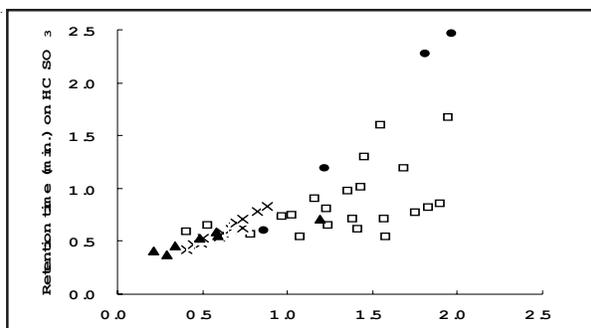


Figure 2. Retention time of the regulated 47 intoxicants on SB-C18 versus Highly Cross-linked  $\text{SO}_3$ ; opiates (triangles), amphetamine (cross-outs), benzodiazepine (open squares), other (circles).

## TECHNOLOGY BENEFITS

A major virtue of this optimized UFGELC methodology is that several retention standards can be run repeatedly throughout a day (at very low cost and in time) thereby greatly improving retention and thus identification reliability.

The availability of such a screening technique will significantly reduce the burden placed on the much slower, more expensive, and harder to maintain LC-MS method. It will also provide valuable information to LC-MS operators so that they can set the system parameters to obtain more reliable information.

## COLLABORATION

This project involves collaborative work between the chemistry laboratory at the University of Minnesota and the toxicology group at the Minnesota Bureau of Criminal Apprehension (BCA) Forensic Science Laboratory (St. Paul, MN).

For analysis by the new UFGELC approach, the chemistry laboratory will obtain a minimum of 100 real (but blind) samples. To compare results, these samples will be analyzed by the BCA laboratory using LC-MS or Gas Chromatography-Mass Spectrometry.

## IMPLEMENTATION

Collaborative work will be published in the Journal of Forensic Sciences and in the Journal of Analytical Toxicology. It will also be presented at the American Academy of Forensic Sciences and at the Society of Forensic Toxicologist meetings.

After demonstration of adequate predictive capability, the methodology will be transferred to the BCA Forensic Science Laboratory, where the technique will be used routinely in order to establish performance statistics.

## **PUBLICATIONS AND PRESENTATIONS**

This is a new project with no publications or presentations to date.

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# **Elemental Characterization of Automobile Body Fillers, Putties, and Caulk by Laser Ablation - Inductively Coupled Plasma - Mass Spectrometry for Matching of Evidence**

## **TECHNOLOGY NEED**

Fillers, putties, and caulks are common in everyday lives, yet very little information can be found regarding the analytical characterization of these materials, either organic or inorganic. Automobile body fillers, putties, and caulking-type materials generally are comprised of 60% to 90% organic materials with the balance being inert, inorganic filler. These inorganic fillers may differ from different manufacturers and the composition of the fillers may contain trace inorganic impurities that could provide additional discrimination criteria for these material types.

The presence, absence, and relative abundance of elements in specific association patterns provide a unique means of displaying and comparing the trace elemental signatures for samples. Elemental compositional analysis has frequently been considered as the best approach to classify and differentiate between similar samples. The implementation of laser ablation as a sampling technique prevents destruction of the sample by dissolution and extends this elemental analysis technique to much smaller sizes, typical of trace samples encountered in forensic cases.

## **TECHNOLOGY DESCRIPTION**

This project is an extension of previously funded work, i.e., the development of laser ablation - inductively coupled plasma - mass spectrometry (LA-ICP-MS) as a technique to analyze and discriminate forensic glass fragments. The results of that study were published by the MFRC in 2004 (MFRC/Ames Laboratory Report IS-5163).

This project involves the utilization of LA-ICP-MS as an analytical technique to differentiate between samples of similar composition. Based on the unique trace elemental signatures (or fingerprint), ICP methods have the precision, sensitivity, multi-element detection capability, and dynamic range suited for trace elemental analysis of forensic samples. Coupled with MS, ICP-MS has excellent detection limits and the capability to provide isotopic information for most elements.

## **METHODOLOGY**

Criteria and protocols will be developed for the comparison and differentiation of sample types. Sample comparisons are conducted using multivariate analysis techniques, in particular, principal component analysis (PCA). PCA is a multivariate data reduction method that examines the variance patterns within a multidimensional dataset. In doing so, it reduces the dimensionality of the dataset to a few simple variables while retaining a major portion of the mass spectral information (Figure 1). These new variables are then used for sample comparisons and to derive a statistical significance for the analysis. PCA allows the use of the full mass spectrum without requiring any pre-selection or elimination of elements.

## **ACCOMPLISHMENTS AND ONGOING WORK**

This project established an analysis protocol to characterize and differentiate body fillers and caulks. Studies demonstrated that differentiation between manufacturers and manufacturer product lines is possible for both body fillers and caulk. Differentiation between lots (in caulk) is also possible. Survey studies

showed that the chemical composition is consistent within a can or tube for body filler and caulk, respectively. Additionally, no spatial variability was observed for cured filler or caulk after 8 weeks.

## TECHNOLOGY BENEFITS

Although the majority of crime laboratories do not have the instrumentation used in this study, the results of this study will provide the framework for elemental analysis schemes employing other techniques and fill an apparent void in the literature on the inorganic analysis of these types of materials. Furthermore, this study will demonstrate another type of forensic sample in addition to glass that can be readily analyzed by LA-ICP-MS, further validating the technique in the forensic community.

The analysis protocols developed for this project are based on a previous MFRC project evaluating LA-ICP-MS for glass analysis.

## COLLABORATION

This project is carried out in collaboration with the Wisconsin State Crime Laboratory, Milwaukee, which provided guidance in the development of sampling and analysis protocols for these types of samples.

## IMPLEMENTATION

The developed technique and protocols from the project are available to all MFRC partners for casework assistance and a manuscript outlining the experimental and analysis protocols for glass analysis is planned for submission to a forensic journal.

The results of this research will be disseminated through presentations at regional and national meetings as well as through submission to a forensic journal.

## PUBLICATIONS AND PRESENTATIONS

- Messerly, J., Bajic, S. J., Baldwin, D. P., Houk, R.S., "Elemental Characterization of Automobile Body Fillers and Caulk by Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry for Matching of Evidence." Presented at the Federation of Analytical Chemistry and Spectroscopy Societies Annual Meeting, 2006, Orlando, FL.
- Bajic, S.J., Houk, R.S., "Elemental Characterization of Automobile Body Fillers and Caulk by Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry for Matching Evidence." Presented at the Midwest Forensics Resource Center Annual Meeting, April 2007, Madison, WI.

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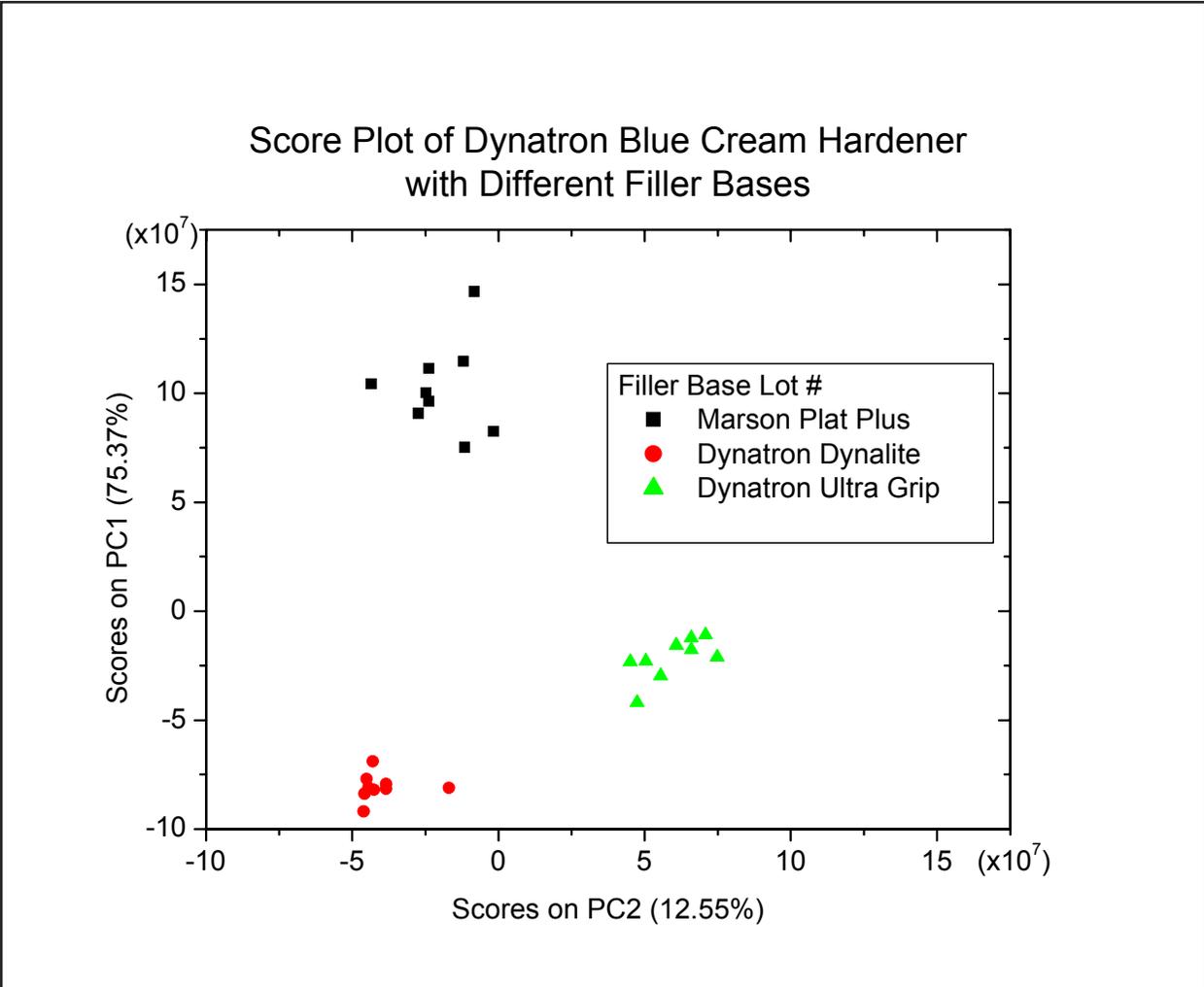


Figure 1. This plot illustrates the PCA of the mass spectra acquired by LA-ICP-MS of three different body fillers (same manufacturer), mixed with the same blue cream hardener, that are not differentiable based on their color. The entire mass spectra (elemental fingerprints of the samples) are used in the analysis. PCA reduces the mass spectra to a few variables, which are used for sample comparisons. When these variables are plotted, the repetitions of the samples cluster together, but the samples occupy different areas on the plot indicating that the caulk samples are of distinguishable elemental composition.

# Evaluation of a Portable Raman Analyzer for Testing Drugs

## FORENSIC TECHNOLOGY NEED

Numerous liquid samples from clandestine labs are submitted for analysis. These analyses are very time consuming and often-times result in case backlogs. Such case backlogs, in return, cause slowdowns and delays in the judicial system. Speedy trial demands are therefore difficult to maintain.

This research project attempts to ease some of the backlog problems by evaluating a portable drug identification system using laser-based Raman technology. This portable Raman system will be evaluated for ease of use and for its ability to analyze controlled substances.

## TECHNOLOGY DESCRIPTION

A screening test (non-confirmatory) is often all that is needed for court administrators to begin the process of prosecuting individuals with controlled substances. Having a portable Raman unit in the field should expedite this process. The Raman is a portable system that can identify controlled substances.

## METHODOLOGY

This project does not intend to repeat the already published studies, but to further investigate the analysis of controlled substances utilizing the portable Raman analyzer. Specific types of samples for this portion of the project include known standards, liquid samples from clandestine laboratories, tablets, powders, as well as other street drugs that law enforcement personnel encounter.

## ACCOMPLISHMENTS AND ONGOING WORK

Ahura (the manufacturer of the Portable

Raman instrument) provided training in operating and using the analyzer. They also provided training in how to run the samples and how to incorporate them into a searchable Bureau of Criminal Apprehension (BCA) library.

So far, 200 samples have been run and incorporated into the library, using the instrument. Approximately 200 new vials will be purchased, as cleaning the vials is time consuming and cross-contamination is an issue. These samples will be incorporated into the library as well.

## TECHNOLOGY BENEFITS

The evaluation of the portable Raman analyzer will be performed in the laboratory and in the field. By implementing a plan to analyze controlled substances in the field, the laboratory case backlog can be alleviated and the prosecution of controlled substance cases can continue in a timely manner. Law enforcement personnel who are trained on the equipment can obtain results within minutes, thereby making it possible to analyze samples while the suspect is still in custody.

Evaluating this system will also increase the possibility of putting additional Raman units in the field. There is potential that the portable Raman unit will be as common as the Breath Testing Units used for determining blood alcohol levels.

## COLLABORATION

The laboratory portion of this project will take place in the Drug Chemistry Section of the Minnesota BCA in St. Paul, Minnesota. Available drug standards will be utilized for analyzing known samples. Some previously in the laboratory analyzed "street" samples will also be used.

The field portion of this project will take place in the Law Enforcement Center (LEC) in Rochester, Minnesota. The LEC houses various law enforcement agencies including field offices for the BCA and the Gang Strike Force. The Southeast Minnesota Drug Task Force, the Rochester Police Department, and the Olmsted County Sheriff's Office are also located in the LEC.

## **IMPLEMENTATION**

The results of this research project will be distributed to a large array of people including forensic scientists and law enforcement personnel. The BCA hosts many training classes including a Clandestine Methamphetamine Lab Certification Course and a Drug Investigation Class.

Throughout the following year, the information will be shared with law enforcement personnel at all drug-related training classes. The information will also be shared with the manufacturer, the MFRC, and at the fall meeting of the Midwestern Association of Forensic Scientists. A written paper will also be submitted to a scientific journal for publication.

## **PUBLICATIONS AND PRESENTATIONS**

This is a new project with no publications or presentations to date.

## **CONTACTS**

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# Fast Gas Chromatography Capabilities in Arson Debris Analysis

## TECHNOLOGY NEED

While autosamplers have increased sample throughput in trace units across the nation's crime laboratories, many labs still find themselves needing more throughput. As defined in *Forensic Sciences: Review of Status and Needs*, there is a need for method development in the recovery of ignitable liquid residues from a variety of matrices. Fast gas chromatography (FGC) is a separation technology capable of increasing the sample throughput of trace element groups.

## TECHNOLOGY DESCRIPTION

The goal of this project is to bridge the gap between the current status of techniques used in the analysis of arson residues and the need of the forensic community for method development for recovery of ignitable liquid residues. The primary objective is to provide and disseminate an enhanced understanding of FGC and its potential benefits (resolution, effectiveness, and throughput) to the detection of accelerant residues in arson debris.

## METHODOLOGY

Two types of GCs are used for this project: an Agilent 6890 Fast GC-FID/ECD and an Agilent 6890-6972 GC-MS. Standards of ignitable liquids, such as gasoline, petroleum distillates, norpars, isopars and miscellaneous oxygenates, are analyzed using best resolution parameters of the two GC. If FGC demonstrates a potential windfall for these standards, experiments will be repeated in realistic, complex matrices similar to those found in arson debris samples.

Resolution is calculated for each of the major peaks determined in two pre-concentration

techniques. Analysis of variance (ANOVA) is employed to determine the point at which the two GC techniques provide similar resolution for each class of compounds. From here, the potential instrumental time savings is calculated for FGC.

## ACCOMPLISHMENTS AND ONGOING WORK

Primary standards corresponding to the major components of common ignitable liquids and evaporated series of ignitable liquids such as gasoline, light petroleum distillates (LPD), medium petroleum distillates (MPD), and heavy petroleum distillates (HPD) were selected from UW-Platteville (UWP) stock and Dr. Wermeling's library of ignitable liquids and standards at the Wisconsin State Crime Laboratory – Madison.

A series of over 150 primary standards and samples were analyzed using the UW-Platteville GC-MS instrumentation for purposes of verifying the identity of the substances by MS and to provide a comparison set of data for conventional GC separation using the aforementioned 30-meter column and helium carrier gas.

Preliminary statistical analysis shows no changes in retention time or resolution between the WSCL-Madison and UWP instruments using conventional columns and GC-MS methods. As expected, improvements in resolution related to simply using hydrogen as a carrier gas have been measured.

FGC analysis of primary standards and samples in dilute CS<sub>2</sub> will be completed in the near future and final statistical data comparisons will be conducted. Solid phase

microextraction work will extend the library and comparison as far as possible in the remaining time period. This will be followed by consultation with Dr. Wermeling regarding the impact of FGC on a practicing laboratory.

## **TECHNOLOGY BENEFITS**

FGC separation is a technology that can have an enormous impact on crime laboratory sample throughput. The current literature, targeting analytical technology, points to reducing instrumental analysis time by as much as 50%. If this study confirms these findings, there is an enormous potential to increase the instrumental capacity of trace element groups and to help clear casework in a timelier manner.

FGC can easily be implemented in the crime labs. Providing 220 or 240V electrical service is available, most of the GCs currently used in the labs can be adapted to FGC for less than \$1,000.

## **COLLABORATION**

This project is a collaborative effort between the UWP and Wisconsin State Crime Laboratory-Madison. Dr. Charles Cornett, principal investigator, supervises undergraduate researchers and experiments performed at UWP using the FGC-FID/ECD. Dr. Joseph Wermeling, co-principal investigator, supervises students using the GC-MS at WSCL-M and lends expertise in the area of arson residue sampling.

## **IMPLEMENTATION**

Research data and findings will be presented to the Midwest Forensic Society and the American Academy of Forensic Science in the form of oral or poster presentation. In addition, the authors will work with the Midwest Forensics Resource Center to optimize

dissemination to professionals in the communities impacted by the work. Meritorious results will be used to assess the feasibility of and seek out funding related to projects addressing the need for portable instruments and technologies in detecting compounds of interest in arson debris.

## **PUBLICATIONS AND PRESENTATIONS**

- Cornett, C., Wermeling, J.R., "Fast Gas Chromatography Capabilities in Arson Debris Analysis." To be presented at the Midwestern Association of Forensic Scientists Annual Meeting, September 2007, Traverse City, MI.
- Cornett, C., Wermeling, J.R., "Fast Gas Chromatography in Arson Debris Analysis." To be presented at the 59th Annual Pittsburgh Conference and Exposition on Analytical Chemistry and Applied Spectroscopy (Pittcon 2008).

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# Forensic Evaluation of Soils for Presence of Decaying Flesh

## FORENSIC TECHNOLOGY NEED

Locating clandestine graves for forensic analysis is currently being performed in many ways. One primary method is with dogs, but the supply and availability of properly trained canines is limited. A handheld portable analyzer capable of finding clandestine graves could supplement or even supplant the use of dogs for this activity. Such instruments ship much easier than dogs, require less maintenance, produce less waste, and have the potential to be operated by someone with minimal training.

## TECHNOLOGY DESCRIPTION

The overall objective of the project is to evaluate the feasibility of using chemical analysis to locate buried human remains and to ultimately develop a field-portable chemical analyzer for this purpose.

Human decomposition produces a range of chemical by-products, which can serve as chemical signatures to the presence of human remains. Traditionally, detection of such a broad range of chemicals was performed in a laboratory using complicated bench-top instruments such as gas chromatography - mass spectrometry (GC-MS), and high performance liquid chromatography (HPLC).

This project focuses on the development of a portable chemical analyzer that uses pyrolysis, low power portable sensors, and pattern recognition to detect and identify chemical signatures associated with decaying flesh.

The analyzer is envisioned to have surface sweep and penetrometer capabilities for the analysis of general surface area and for subsurface analysis of specific locations,

respectively. The penetrometer can serve as verification of locations identified in the sweep mode.

Figure 1 shows an instrument developed to perform near-real-time, in-situ detection of subsurface soil contamination of explosives. Conceptually, the project's probe will be similar, but will allow operation by a single user. The final product will use the best (clearest signal without interference) sensors in a custom electronic nose package.

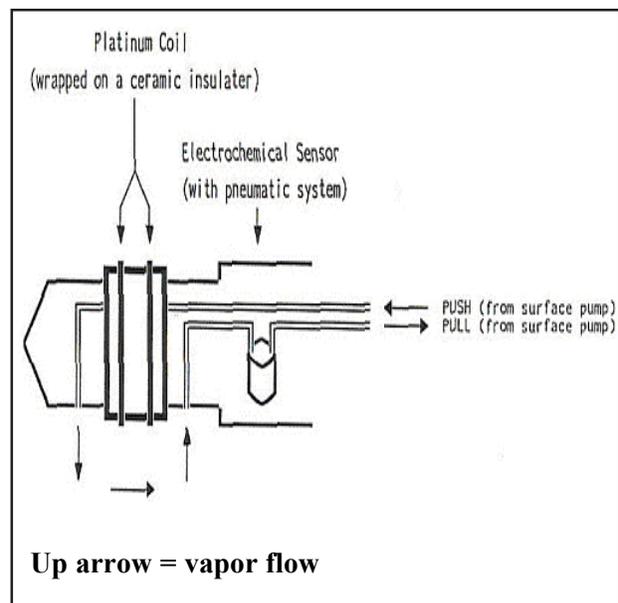


Figure 1. Probe used for subsoil detection of explosives that will serve as the concept-of-probe to detect chemical by-products of human decomposition.

## METHODOLOGY

The investigators will identify sensor types and operational parameters for the detection of appropriate chemicals. This information will guide the development of the actual field-portable instrument which will be easier to use than geophysical probes and less subjective than botanical and/or depression evaluations.

It will ensure that forensic exhumations are performed in the right place.

## **ACCOMPLISHMENTS AND ONGOING WORK**

The project began in May 2006. A wide range of chemicals simulating decaying human remains were exposed to 20 sensors. The sensors represented three types of sensing mechanisms and analyses were performed at high and low concentrations as well as high and low temperatures. Evaluation is ongoing to determine the best subset of sensors for the final instrument as well as the software parameters to apply to them.

In May 2007, a draft design of the instrument was developed. The Illinois State Police Forensic Science Center (one of the partners) will review the instrumented design and make recommendations. The Center will also identify possible sites for deployment studies and facilitate access to these sites. Initial design work has been performed on a prototype instrument.

## **TECHNOLOGY BENEFITS**

Forensic exhumations are costly endeavors, and the cost will be incurred regardless of whether or not the suspect site contains human remains. Potentially significant cost savings can be obtained, with respect to the use of trained forensic exhumers, simply by eliminating “false digs.”

The technology can improve operating efficiency with a battery-powered, cane-size instrument with a handle to facilitate manual deployment beneath the soil surface.

## **COLLABORATION**

This project is a collaborative effort between the Illinois Institute of Technology (IIT) Center for Sensor Science and Engineering, Argonne

National Laboratory (ANL), and the Illinois State Police Forensic Science Center (ISP-FSC).

Dr. William Buttner (IIT), as project PI, manages the administrative and technical project requirements. Dr. Joseph Stetter (IIT), assists Dr. Buttner. Dr. John Schneider (ANL) has extensive field analytical chemistry experience and has appropriate clearance for working with restricted materials. Mr. Nathan Schattke has a joint appointment with ANL and IIT and performs most of the technical experimentation and design. Mr. Scott Rochowicz (of the ISP-FSC at Chicago) provides feedback and guidance on instrument design and will facilitate dissemination of this technology to the forensic community.

## **IMPLEMENTATION**

Results of the laboratory testing will be published in the chemical and forensic science journals. Field testing performance will be published in a forensic journal and technical presentations at a forensic symposium are also envisioned.

## **PUBLICATIONS AND PRESENTATIONS**

- Schattke, N., “Crime Scene Graves: Finding the Best Sensors for Detecting Human Remains.” Oral Presentation at the IIT Biology Chemistry Physics Science (BCPS) Department/Sigma Xi Graduate Student Poster Symposium, Illinois Institute of Technology, March 2007, Chicago, IL.

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# Identifying Co-ops and Farmers as Illicit Sources of Anhydrous Ammonia for Meth Makers

## FORENSIC TECHNOLOGY NEED

The theft of liquid ammonia for illicit use in the manufacture of methamphetamine (meth) is common in Iowa and its neighboring states, as well as in western states such as Washington and Oregon. At this point in time, the majority of thieves steal anhydrous ammonia directly from co-op facilities or nurse tanks in the fields of farmers. However, there are also problems with employees of co-ops and farmers who are selling anhydrous ammonia to meth makers.

A large part of the problem posed by ammonia thieves is that there are thousands of portable anhydrous ammonia storage tanks in farmers' fields plus many dozens of large (100,000 gallon) storage tanks at the co-ops, which are targets. Thieves have little regard for safety issues, removing the anhydrous ammonia with thermos bottles, gas cans, and sometimes simple insulated carriers.

## TECHNOLOGY DESCRIPTION

Meth makers generally do not have access to the sophisticated distillation equipment necessary to pre-purify anhydrous ammonia adulterated with the salts proposed here or the meth synthesis inhibitor we have discovered.

## METHODOLOGY

The objectives of this project are to:

- Develop a salt soluble in anhydrous ammonia that in very small quantities makes a detection compound when lithium, a key component of the illicit meth synthesis, is added (Figure 1).

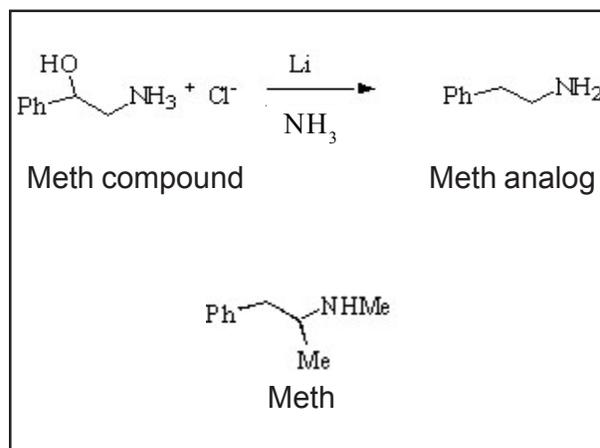


Figure 1. Chemical reaction when lithium is added to anhydrous ammonia.

- Detect the detection compound liberated in the meth synthesis by high performance liquid chromatography (HPLC).
- Generate a variety of salts, each having a different HPLC signature for the detection compound. A given salt will then identify the co-op from which the ammonia was obtained.
- Develop salts that are unharmed to humans and farmers' fields.

## ACCOMPLISHMENTS AND ONGOING WORK

This project was concluded at the point where two salts were identified which meet the criteria for detection in the model compound by HPLC.

## TECHNOLOGY BENEFITS

If anhydrous ammonia were to contain an effective detection compound, which rendered

the meth produced by the lithium/ammonia reaction traceable, then the theft and farm safety issues associated with anhydrous ammonia would be significantly diminished. It is envisioned that the detection compound will be inseparable from the meth without very sophisticated and expensive equipment.

## **COLLABORATION**

The investigators were in close contact with the Iowa Department of Criminal Investigation (DCI) and the Iowa Meth Task Force. The latter served as an information resource group while the DCI also conducted experiments using lithium, ephedrine, and the best salts to generate meth contaminated with detection compounds.

## **IMPLEMENTATION**

Efforts were made to interest the DCI in testing the successful markers. The Iowa DCI laboratory tested the salts to the conditions used in the actual meth synthesis reaction (using ephedrine hydrochloride). Preliminary test results were encouraging. There is no current funding for further work on the project.

## **PUBLICATIONS AND PRESENTATIONS**

- Beeman, P., "Additive makes ammonia much less useful in producing drug." *Des Moines Register*, June 15, 2004.
- Channel 13 News, "DEA says new additive can stop meth production: ISU develops additive for farm fertilizer." June 15, 2004.

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# Long-Term Stability Studies of Liquid Samples from Clandestine Methamphetamine Laboratories

## FORENSIC TECHNOLOGY NEED

Maintaining evidence integrity is a pillar principle of any forensic science laboratory. The American Society of Crime Laboratory Directors Laboratory Accreditation Board (ASCLD-LAB) accreditation process requires laboratories to prove the presence of controls that preserve the integrity of submitted evidentiary items. Generally, issues of integrity involve proper sealing and unbroken chains of custody. However, environmental conditions also play a vital role in the stability and integrity of evidence.

At the current time, very few long-term stability studies have been performed for evidence containing controlled substances outside of biological fluids. Specifically, there is a lack of data and knowledge regarding the stability of methamphetamine and its precursors in solutions from clandestine laboratories. Without this knowledge, there are significant ramifications to the testing and reporting processes. These include evidence awaiting analysis for long periods of time, which may significantly degrade and change the evidence in qualitative or quantitative composition. Forensic scientists' results from degraded samples could be successfully challenged.

## TECHNOLOGY DESCRIPTION

This study investigates the long-term stability of methamphetamine, ephedrine, and pseudoephedrine in solutions typically encountered with clandestine laboratories.

Samples will be analyzed by gas chromatography - mass spectrometry (GC-MS) to determine concentration trends of ephedrine, pseudoephedrine, and methamphetamine.

## METHODOLOGY

Solution stability data will be collected for liquid samples from various stages of methamphetamine production using the Iodine/Red Phosphorus reaction scheme. Solution aliquots will be stored at four distinct storage conditions: Refrigerated (5°C), Ambient, Controlled Room Temperature (25°C/60% RH), and Elevated Room Temperature (40°C). Sample solutions will be pulled at defined time-points up to twelve months.

Results of the analyses will be used to evaluate the precursor and final product stability based on specific sample storage conditions coupled with length of storage. Results of the analyses will also be used to evaluate whether the original levels of precursors and methamphetamine remain stable based on specific sample storage conditions coupled with storage time. Actual temperature/humidity trends of several forensic laboratory evidence lockers will be collected using continuous temperature/humidity circular chart records for up to twelve months.

## ACCOMPLISHMENTS AND ONGOING WORK

Several achievements have occurred during the first six months of study. Primarily, stability analyses have been completed through the "Month Six" time-point.

Along with the solution stability component of the study, the Johnson County Crime Laboratory and five other forensic laboratories in the Midwest agreed to place temperature/humidity chambers in their evidence storage facilities. These units have continuously

monitored and recorded the actual temperature and relative humidity conditions of the evidence storage facilities. This component of the study is designed to determine the actual temperature and humidity trends of forensic laboratories in the Midwest. The data will aid in applying the solution stability results to how forensic laboratories should store sample solutions from methamphetamine laboratories.

## **TECHNOLOGY BENEFITS**

The implications of the collected data on clandestine laboratory liquid sample storage are vast. The results will determine if precursors and final products degrade or convert over time based on the specific solution, the storage condition, and the time of storage. This will answer potential questions concerning the integrity of these solutions while in storage. The results will also determine if collected solutions require specialized storage (i.e., refrigeration) or expedited analysis. Finally, the results will assist the forensic analysts in proper interpretation of data collected from solutions stored for extensive periods of time following collection and submission.

## **COLLABORATION**

The Johnson County Sheriff's Office Criminalistics Laboratory (Mission, Kansas) will conduct a long-term stability study of liquids from clandestine methamphetamine laboratories in collaboration with the Kansas Bureau of Investigation in Topeka, Kansas, the Kansas City Police Department in Kansas City, Missouri, the Missouri State Highway Patrol in Jefferson City, Missouri, the Wisconsin State Crime Laboratory in Milwaukee, Wisconsin, and the Western Forensic Law Enforcement Training Center in Pueblo, Colorado.

## **IMPLEMENTATION**

The results of the research will be disseminated through presentation at forensic meetings of the Midwestern Association of Forensic Scientists and the Clandestine Laboratory Investigating Chemists Association. The research will be submitted for publication in the Journal of Forensic Sciences or other appropriate scientific journals.

## **PUBLICATIONS AND PRESENTATIONS**

- Morris, J., "Long-Term Stability Studies of Liquid Samples from Clandestine Methamphetamine Laboratories." Oral Presentation at the Midwest Forensics Resource Center, Annual Meeting, April 2007, Madison, WI.
- Morris, J., "Long-Term Stability Studies of Liquid Samples from Clandestine Methamphetamine Laboratories." Presentation at the Midwestern Association of Forensic Scientists, Annual Meeting, September 2007, Traverse City, MI.
- Morris, J., "Long-Term Stability Studies of Liquid Samples from Clandestine Methamphetamine Laboratories." Presentation at the Clandestine Laboratory Investigating Chemists Association, Training, September 2007, Columbus, OH.

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# Micromechanical Cantilever (MC)-based Sensors for Chemical Species Detection

## FORENSIC TECHNOLOGY NEED

Current sensor systems require extensive sample preparation or specialized instrumentation to identify molecules of controlled substances such as cocaine. High specificity and sensitivity Micromechanical Cantilever (MC)-based sensors provide an invaluable tool for forensic science because of their portability, capability for detection, and capability for identification with high sensitivity and specificity. Successful completion of the project will buttress our research efforts towards developing portable sensors for chemical species detection by integration of receptor layer coated micro-cantilevers and high resolution interferometry into a single microfabricated chip.

## TECHNOLOGY DESCRIPTION

Specific aims of this project are to:

- Develop robust miniature sensors for high-resolution measurement of surface stress associated with the formation of affinity complexes on the sensitized surface of micro-cantilevers (Figure 1).
- Characterize the sensitivity and specificity of cocaine detection with MC-based sensors functionalized with suitable receptor layers of aptamer molecules.

a)

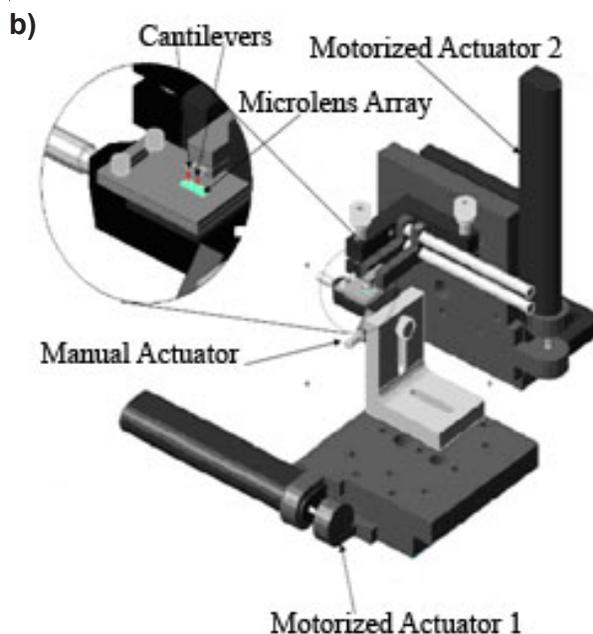
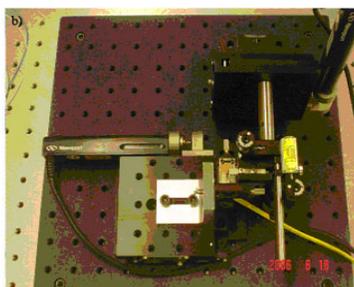


Figure 1. Miniature sensor: a) assembled sensor, and b) design.

- Functionalize micro-cantilevers with an aptamer capable of sensitive and specific detection of cocaine molecules.

## METHODOLOGY

In this project, a proof-of-concept will be developed sensing approach by building an MC-based sensor functionalized with aptamer molecules for sensitive and specific detection of cocaine molecules.

## ACCOMPLISHMENTS AND ONGOING WORK

Over the last year, we have assembled and demonstrated the working of a miniature surface stress sensor. The sensor can be used for measurement of surface stress with an extremely high resolution ( $\sim 0.001$  N/m)

corresponding order of parts per billion sensitivity to analyte species. Sensor functioning has been demonstrated by measurement of surface stresses associated with formation of a self-assembled monolayer of alkanethiol (Figure 2).

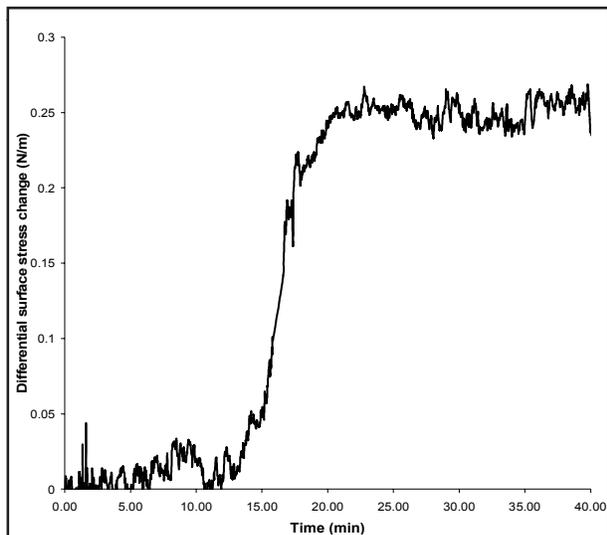


Figure 2. Surface stress change measured during formation of alkanethiol SAM on sensing cantilever.

The affinity of surface-bound aptamer for cocaine molecules with fluorescence measurements was also verified (Figure 3).

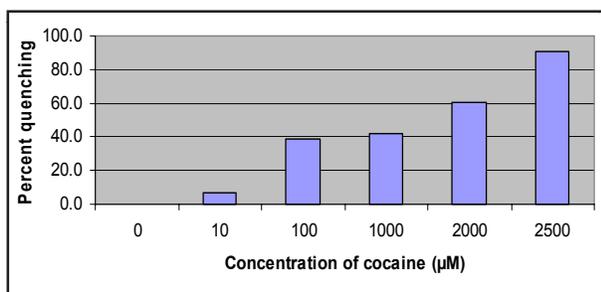


Figure 3. Fluorescence quenching response of aptamer to cocaine solution.

In ongoing work (expected to be completed in the next six months), the sensing cantilever with aptamers that have specific affinity to cocaine molecules will be functionalized and the sensitivity threshold for cocaine detection

through surface-stress measurements will be characterized.

## TECHNOLOGY BENEFITS

Successful completion of the research will serve to advance the mission of the MFRC towards development of new and improved instrumentation capable of sensitive detection and drug identification. In addition, successful demonstration of this sensing approach will set the stage for rapid development of MC-based sensors for a wide variety of molecules of forensic interest, including detection of DNA, explosives, and toxic chemical species.

Development of MC-based sensors will be an important breakthrough for forensic science because of the tremendous sensitivity that can be achieved by aptamer-coated micro-cantilevers and the specificity imparted by aptamers for identification of chemical species at concentrations of parts-per-billion. Such sensitivity will revolutionize forensic analysis of controlled substances, explosives, toxic species, biological molecules, and DNA matching required for crime-scene identification.

## COLLABORATION

The principal investigators worked with the MFRC to develop partnerships with partner crime laboratories and to share the developed sensor technology.

As part of this effort, Dr. James Siefert (Forensic Science Division, Michigan State Police, email: [siefertj@michigan.gov](mailto:siefertj@michigan.gov) and phone: 989-777-9300) will explore the possibility of establishing a collaboration in order to leverage his expertise in the area of controlled substance identification for the sensor development.

The investigators will utilize the results of this project to seek further funding from NIJ, NSF,

DOE, and the Homeland Security Advanced Research Projects Agency for development of portable Micro Electro Mechanical Systems (MEMS) sensors.

## **IMPLEMENTATION**

Results of the research will be disseminated through peer-reviewed journal publications in the Journal of Forensic Sciences and by presentations at annual meetings of American Academy of Forensic Science and Midwestern Association of Forensic Scientists. In order to facilitate wide dissemination of research findings in the forensic community, the investigators will work with the MFRC to share the developed sensor technology with partnering crime laboratories.

## **PUBLICATIONS AND PRESENTATIONS**

- Kang, K., Marquardt, J., Shrotriya, P., "Surface stress sensors for detection of chemical and biological species." Society of Photographic Instrumentation Engineers 14<sup>th</sup> International Symposium on Smart Structures and Materials and Nondestructive Evaluation and Health Monitoring, March 2007, San Diego, CA.

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# Optimization of Headspace-Solid Phase Microextraction (HS-SPME) for Organic Impurity Profiling of Illicit MDMA Tablets

## TECHNOLOGY NEED

Current profiling of illicit methylene dioxy methamphetamine (MDMA) tablets is based on physical and chemical characterization of tablets. As tablets with the same physical characteristics do not necessarily have the same chemical composition, chemical profiling has become the preferred method used by law enforcement agencies.

Conventionally, organic impurities are extracted using liquid-liquid extraction (LLE) procedures and then analyzed by gas chromatography - mass spectrometry (GC-MS) to generate an impurity profile. Although the success of this technique has been documented in the literature, the procedure has a number of disadvantages, including: 1) relatively large sample masses are required, 2) trace impurities may be masked by the controlled substance when present at high concentrations, and 3) use of organic solvents may require expensive disposal.

## TECHNOLOGY DESCRIPTION

The specific aims of this project are to:

- Optimize HS-SPME methods to extract organic impurities from MDMA tablets.
- Optimize GC-MS method for extract analysis.
- Assess variation in impurities among individual tablets.
- Apply pattern recognition methods to non-subjectively group similar tablets, based on the impurities present.

## METHODOLOGY

In this study, HS-SPME procedures for the extraction of organic impurities from illicit MDMA tablets are developed. Two different fiber types are investigated, a statistical experimental design procedure is used to optimize the extraction time and temperature for each. The optimal fiber type is assessed based on the number of impurities extracted, as well as repeatability and reproducibility of the extraction. The optimized HS-SPME is then compared to a conventional LLE procedure, in terms of the number and level of impurities extracted, repeatability, and reproducibility of the two extraction procedures.

## ACCOMPLISHMENTS AND ONGOING WORK

Accomplishments to date include:

- Completed preliminary experiments to assess the effects of sample mass, sample vial volume, and desorption time on the HS-SPME procedure.
- Generated the circumscribed central composite experimental design for the optimization of extraction time and temperature.
- Completed the experimental design for one fiber type (DVB/CAR/PDMS).
- Analyzed liquid-liquid extracts for comparison with HS-SPME.

The resulting data from the first experimental design are currently being analyzed to determine the optimal extraction time and temperature for the DVB/CAR/PDMS fiber.

The experimental design for the second experimental fiber is currently underway.

## **TECHNOLOGY BENEFITS**

HS-SPME offers several advantages over conventional LLE procedures. They include: minimal sample preparation; no use of organic solvents; minimal potential for sample loss or contamination; and greater sensitivity and specificity due to preferential extraction of impurities resulting from the low volatility of the MDMA salt.

Based on organic impurities present, it may be possible to identify the route used to synthesize the illicit drug and the laboratory utilized to produce it. Such intelligence may be used by law enforcement agencies to monitor clandestine laboratories, identify dealer-user networks, and crack-down on drug trafficking, both nationally and internationally.

## **COLLABORATION**

This project is a collaboration between principal investigator Ruth Waddell, Michigan State University, and Captain Mike Thomas at the Michigan State Police Crime Laboratory. The collaboration with the crime laboratory provides the MDMA tablets, which are critical to the research.

## **IMPLEMENTATION**

Results of this work will be disseminated locally at the Midwestern Association of Forensic Scientists Fall Meeting 2008. A manuscript will be submitted to the Journal of Forensic Sciences for publication. The principal investigator will create and maintain a database of impurity profiles, which will be available to local and state crime laboratories.

## **PUBLICATIONS AND PRESENTATIONS**

This is a new project with no publications or presentations to date.

## **CONTACTS**

### Principal Investigator

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# The Temporal Fate of Drugs in Decomposing Tissues

## FORENSIC TECHNOLOGY NEED

Interpreting drug concentrations found in decomposed remains is always difficult. Postmortem tissues that are routinely collected and analyzed (blood, urine, vitreous humor), to provide the largest comparative database for interpretation, are frequently lost in the early stages of putrefaction. Consequently when drugs are found in weathered tissues, there is currently little or no information available to help guide the toxicologist, and subsequently the pathologist, in evaluating whether a drug or drugs played any significant role in causing the death. This study follows the fate of sixteen drugs that commonly cause intoxications in seven different tissues collected from decomposing pigs.

## TECHNOLOGY DESCRIPTION

This study targets what happens to specific drugs after they have been absorbed, distributed, and metabolized and the organism dies. Decomposing bodies are found in all types of environments both in- and outdoors.

This protocol is designed to monitor concentrations of various drugs, in multiple tissues and organs, during whole body decomposition in the outside environment.

Specific questions targeted are:

- How does the concentration of drugs change during tissue decomposition?
- How long do drugs and metabolites persist in tissues at detectable levels?
- Which collection sites are most useful for detecting drug exposure and interpreting results?

Answers obtained will help toxicologists and pathologists uncover how individuals died. This information will serve victims' families, law enforcement officials, and our communities.

The lack of information about the fate of drugs in decomposing tissue is understandable, as studies in humans are not a realistic possibility. Challenges in this study include selection of an appropriate animal model and study location, maintenance of animal corpses, drugs to be evaluated, tissues to be collected, and over what time interval.

## METHODOLOGY

The study uses *Sus scrofa* or *Sus domestica*, the domestic pig. Pigs were selected because their size is comparable to humans allowing high-level dosing and sequential sampling of multiple tissues. Also, their physiology is similar to humans. Specifically, their digestive and cardiovascular physiology should allow for drug absorption and distribution that closely mimics those of humans.

Although the number of drugs to be evaluated is vast, resources and time require that this study be limited in scope. Selection of the drugs to be evaluated will be based on chemical stability during putrefaction, the prevalence of use of the drug in a general population, the drug's propensity for causing or contributing to death in humans, and whether an active metabolite will be formed. These criteria leave important parameters, such as volume of distribution and half-life, randomized.

Specific tissues (10-15 g) to be collected at each time period, or as long as available, will include liver, brain, kidney, muscle, bone marrow, stomach contents, maggots and insects, and soil (beneath the carcass).

The fate of the different drugs, in different tissues, will be monitored in each of the four test group animals by measuring the concentration of the drugs over time. Appropriate statistical analyses will be performed by Dr. David Jarjoura, Center for Biostatistics, The Ohio State University, Columbus, Ohio.

## ACCOMPLISHMENTS AND ONGOING WORK

Twenty-four pigs were obtained for testing. Nine of 24 pigs were sacrificed in the initial attempt – five for testing and four as controls. Control pigs were included to determine whether total organ weight changed as a result of necropsy.

The initial attempt to dose the pigs through their food was unsatisfactory. The amount of drugs consumed was of very low levels and varied from animal to animal. It was decided that drugs needed to be administered by gavage as slurry.

It was also found that the rate of decomposition was much faster than anticipated: no tissue other than bone was available after two weeks. As a result, the tissue collection was revised to 0, 24, 48, 96 hours, 1 and 2 weeks. Collection of bone tissue will be performed at 2 weeks, 3, 6 and 12 months. Soil and maggot specimens will be collected to establish how soon drugs appear in these specimens.

Tissue collection for Group A pigs, dosed with morphine, amitriptyline, diazepam and citalopram, is complete. Preliminary results for three of the four drugs in liver tissue collected for two weeks is shown in Figure 1.

Group D pigs were recently dosed and Group B and C animals will be dosed and sacrificed shortly. Tissue collection, extraction and analysis will continue for all groups.

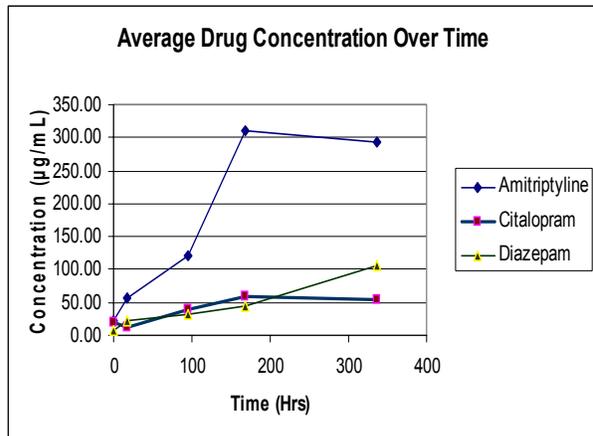


Figure 1. Results for three of the four drugs in liver tissue collected for two weeks.

## TECHNOLOGY BENEFITS

This investigation will provide important insights into the fate of drugs in various tissues over an extended period of decay. The information gained will allow pathologists, toxicologists, and criminologists to interpret case results more accurately thereby providing a more complete conclusion regarding cause of death and fate of victims.

## COLLABORATION

This is a collaborative project between the Franklin County Coroner's Office and The Ohio State University. Pathologists from both institutions will direct the collection of tissues and the toxicologist will direct the analyses of these tissues.

## IMPLEMENTATION

Presentations of findings will be made at the Society of Forensic Toxicology or the American Academy of Forensic Sciences meetings. At least one manuscript will be prepared and submitted for publication in the Journal of Forensic Sciences or the Journal of Analytical Toxicology. The results of this research are expected to be in the scientific

literature no later than two years after commencement of the study.

## **PUBLICATIONS AND PRESENTATIONS**

This is a new project with no publications or presentations to date.

## **CONTACTS**

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# Trace Metal Analysis of Ecstasy by Microwave-Assisted Digestion and Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES)

## FORENSIC TECHNOLOGY NEED

One illicit drug for which trace metal profiling might hold promise is 3,4-methylene-dioxy-methamphetamine (MDMA or ecstasy). This is largely due to the two distinct synthetic methods of producing the drug. Depending on the pathway and reagents used in the synthesis, these pathways should be distinguishable.

## TECHNOLOGY DESCRIPTION

Trace metal impurity profiling of ecstasy samples offers a potential advantage for forensic scientists over ecstasy logo-profiling and organic-impurity profiling. Trace metal profiling takes full advantage of the rather limited number of synthetic methods for preparing ecstasy.

Work will focus on investigating whether:

- Ecstasy tablets obtained in the same seizure and bearing the same logos have statistically identical trace metal impurity profiles.
- Ecstasy tablets obtained from different seizures and/or bearing different logos have statistically differentiable trace metal impurity profiles.
- The characteristic trace metal impurities found in samples of ecstasy are inherent to the synthetic route employed by the clandestine labs.

## METHODOLOGY

Instead of two distinct routes with two sets of distinguishing organic by-products, trace

metal profiling enables the analyst to examine discrete differences within a given synthetic method. For example, the "imine" formed from piperonylacetone during the synthesis of MDMA must be reduced:

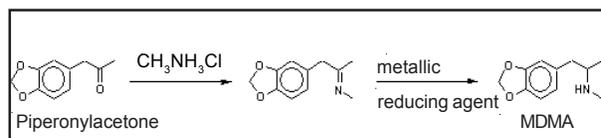


Figure 1. MDMA synthesis by the reductive amination route from piperonylacetone.

Chemically, there are a number of metal-based reducing agents available to accomplish this step. Depending upon which reducing agent is used, a number of unique trace metal impurities could potentially be introduced into the final product. Samples of the synthesized product from each reductive route will be digested in acidic media and analyzed using inductively coupled plasma - optical emission spectrometry (ICP-OES).

## ACCOMPLISHMENTS AND ONGOING WORK

This project is ongoing and is continuing beyond the grant period. Two approaches have been used to determine if samples from the same preparative batch can be positively linked together and distinguished from separate batches based upon their trace metal profiles.

The first approach involved the trace metal analysis by ICP-OES of a synthetic N+1 homolog of MDMA, 4-(3,4-methylenedioxy-methamphetamine)butan-2-ylamine. Acid digested samples of the product from each reductive route were analyzed using ICP-OES.

Principal component analysis (PCA) revealed that samples could be distinguished from each other with a 90% confidence interval.

In the second approach, attention focused on the trace metal analysis of ecstasy samples received from the Drug Enforcement Agency (DEA). Currently, trace metal contents of 10-12 samples from each batch were analyzed by ICP-OES using microwave assisted digestion in acidic media to determine if analyte results allow for discrimination between different categories of samples. In general, results seem to indicate that certain metals are present in distinctive concentrations for ecstasy tablets from the same seizure, i.e. application of PCA to the ICP-OES data does allow discrimination between certain batches. In addition, we hope to attempt the classification of the different batches based on regions of seizure or date of seizure.

## **TECHNOLOGY BENEFITS**

It is hoped that the results of this study will allow researchers to make a more guided (or less haphazard) approach to trace metal signature profiling of ecstasy tablets. As such, this work will provide the forensic analyst with an additional tool in the fight against the trafficking of ecstasy.

## **COLLABORATION**

This project has been carried out as a collaboration between Southeast Missouri State University and the Missouri State Highway Patrol, Crime Laboratory Division, Troop E Satellite Laboratory (formerly the Southeast Missouri Regional Crime Laboratory) in Cape Girardeau, Missouri, and the DEA. The DEA provided samples of the synthesized product.

In order to obtain samples from the DEA, a DEA research license was applied for and obtained during 2005. Samples were received

by and stored at the crime laboratory for security and legal purposes, and all microwave digestions were performed there prior to trace metal analysis at the Department of Chemistry at Southeast Missouri State University.

## **IMPLEMENTATION**

Dissemination of research results and findings will be conducted through publication in peer-reviewed journals and presentations at professional meetings. The results of this ongoing work have been presented twice at MFRC meetings, and will be shared with interested parties at other crime labs, the FBI, DEA, and MFRC member organizations.

## **PUBLICATIONS AND PRESENTATIONS**

- Crawford, P., McGill, J., Johnson, P., "Trace Metal Analysis of Ecstasy by Microwave-Assisted Digestion and Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES)." Presentation at the Midwest Forensics Resource Center Annual Meeting, April 2006, St. Louis, MO.
- Crawford, P., McGill, J., Johnson P., "Trace Metal Analysis of Ecstasy by Microwave-Assisted Digestion and Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES)." Presentation at the Midwest Forensics Resource Center Annual Meeting, June 2005, Ames, IA.

## **CONTACTS**

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# Ultra-Fast Gradient Elution HPLC as a High Throughput, High Information Content Screening Tool for Drugs of Abuse

## TECHNOLOGY NEED

Gradient elution high performance liquid chromatography (HPLC) with diode array detection is a common method used for screening and even identifying drugs of abuse in biological samples. Although the technique has tremendous chemical selectivity and can produce precise retention time data under well-controlled conditions, the technology is quite slow, requiring 20-30 minutes per run. As the sample load in forensic laboratories continues to increase, using HPLC techniques to deliver analytical sample judgment in a timely fashion is becoming more difficult.

## TECHNOLOGY DESCRIPTION

In a previously funded project, the principal investigators developed an ultra-fast gradient elution reversed-phase HPLC with diode array detection as a fast tool for screening samples for regulated intoxicants. Through a combination of precise retention measurements and chemometric analysis of the spectro-chromatograms, both the speed and selectivity of older HPLC methods could be significantly improved. This project enhances these improvements by decreasing the error rates, facilitating chemometric analysis, and optimizing chromatographic resolution.

## METHODOLOGY

To decrease error rates and facilitate chemometric analysis, the primary objective is to use a secondary "orthogonal" column that has very different selectivity than the standard (primary) column. Analytes that cannot be identified in the first separation (due to incomplete chromatographic or spectroscopic resolution) are now subjected to a second,

orthogonal ultra-fast liquid chromatography separation resulting in a dramatic reduction in the number of indistinguishable analytes at very low cost in time.

To optimize chromatographic resolution, a secondary objective is to use a newly developed general purpose optimization scheme. By using real samples whose compositions have been pre-assessed by accepted confirmatory methods, the sensitivity and specificity of the methodology can be evaluated. A tertiary objective is to transfer the methodology, after demonstrating adequate predictive capability, to the Minnesota Bureau of Criminal Apprehension Forensic Science Laboratory for establishing performance statistics.

## ACCOMPLISHMENTS AND ONGOING WORK

This is a new project that currently is testing the Snyder scheme to see if it can successfully predict similarities and differences in phase behavior for pharmaceutically interesting compounds.

In Step 1, the retention times of at least thirty drug substances will be measured. Similarity will be tested first under the effluent conditions used by Snyder to classify phases.

In Step 2, a set of three maximally different phases will be located. They will be tested with the same set of thirty drug substances.

## TECHNOLOGY BENEFITS

This work will vastly improve the screening for drugs in blood, urine, and other tissue samples. It will also make a dramatic impact in forensic toxicology.

## **COLLABORATION**

This project is a collaborative effort between Professor Peter Carr, University of Minnesota, and Mr. Glenn Hardin's toxicology group at the Minnesota Bureau of Criminal Apprehension Forensic Science Laboratory. In previously funded work, the collaboration has consisted of forensic scientists from the BCA Forensic Science Laboratory visiting Peter Carr's laboratory and attending group meetings. In return, Peter Carr's group visited the BCA several times to work on specific project aspects. The collaboration is assumed to be similar in this study.

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## **IMPLEMENTATION**

Information on and data from this work will be published in Analytical Chemistry and the Journal of Chromatography. Additionally, research information and findings will be presented at key meetings, such as the Pittcon, Eastern Analytical Symposium, and American Chemical Society meetings.

Collaborative writing will be published in the Journal of Forensic Sciences and the Journal of Analytical Toxicology, and presented at the American Academy of Forensic Science and the Society of Forensic Toxicologists meetings.

## **PUBLICATIONS AND PRESENTATIONS**

This is a new project with no publications or presentations to date.

## **CONTACTS**

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# Development of Forensic Imaging Technique for Fast Analysis of Magnetic Tapes with High Spatial Resolution

## FORENSIC TECHNOLOGY NEED

Currently, video cameras are widely used as tools for recording criminal acts. Due to recent advances in editing technologies, digital editing or fabrication of videotape evidence has become possible. Today, fine magnetic particles or ferrofluids are used to visualize any artificial alteration on magnetic tapes. However, the use of magnetic particles and ferrofluids is time consuming, inaccurate, and can easily cause contamination or even damage on the surface of tape evidence.

## TECHNOLOGY DESCRIPTION

This project develops a new forensic imaging technique that will allow fast and accurate visualization of magnetic patterns of magnetic tapes using a transparent magneto-optic film indicator.

## METHODOLOGY

The forensic imaging technique is based on a magneto-optic film indicator (Figure 1) which can replace the magnetic particles or ferrofluids for visualization of magnetic fields and give a non-invasive method of detection with a high spatial resolution and fast inspection time.

When placing a transparent magneto-optic film indicator onto a magnetic tape, magnetic fields from the recorded magnetic patterns on the tape will magnetize the magneto-optic film indicator up or down locally in accordance with the recording pattern of tape. This domain magnetization pattern can be readily visualized using the Faraday effect and the magnetic image can be recorded using a charge-coupled device (CCD) digital camera for storage and processing.

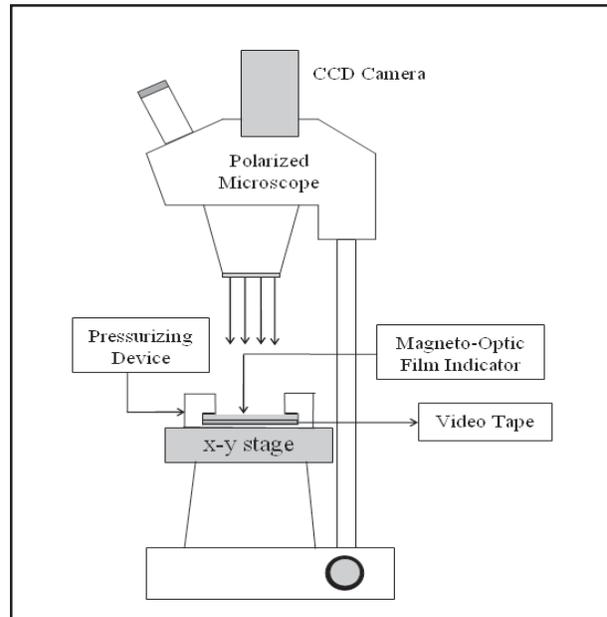


Figure 1. A schematic diagram of forensic magneto-optic imaging system.

Figure 2, portrays the magnetic pattern of a credit card taken from the forensic imaging technique developed in this project. This method uses a magneto-optic film indicator that can immediately reveal magnetic patterns of a credit card nondestructively, while the method using magnetic particle suspension via a chemical solution requires solution preparation, application to the tape, and waiting for drying of the solution before the magnetic patterns on the credit card can be visualized.

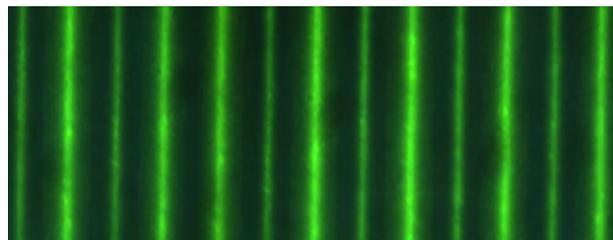


Figure 2. Magnetic patterns of a credit card taken from the forensic magneto-optic imaging system.

## ACCOMPLISHMENTS AND ONGOING WORK

The two accomplishments to date are: 1) design and fabrication of pressurizing device, and 2) identification of magneto-optic indicator films with high spatial resolution.

### *Design and Fabrication of Pressurizing Device*

The strength of magnetic fields from video tapes is much weaker than credit cards, thus visualization of magnetic patterns on video tapes is difficult compared to credit cards. In order to overcome this problem, a pressurizing device was developed (Figure 3) that allows close contact between the magneto-optic film and video tape.

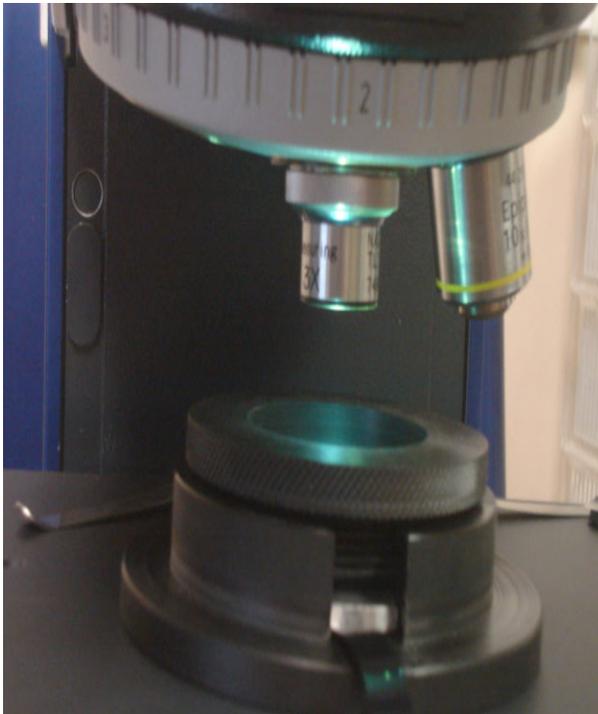


Figure 3. Pressurizing device is on the Zeiss Axio imager compound microscope table.

### *Identification of Magneto-optic Indicator Films with High Spatial Resolution*

New magneto-optic indicator garnet films with higher magnetic moment and a mixed planar-

serpentine domain state with small stripe widths were used for visualization of magnetic patterns of video tapes. The magneto-optic film indicators were coated with gold to prevent Newton's rings using a gold deposition system. The spatial resolution of the magneto-optic images was good enough to visualize micrometer-sized magnetic patterns of video tapes (Figures 4 and 5).

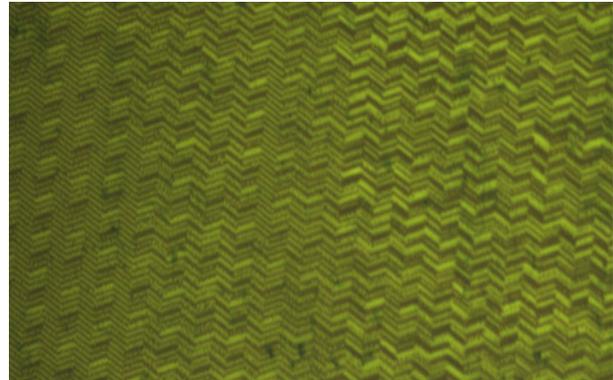


Figure 4. Magnetic patterns on Mini-DV recording of SMPTE color bars.



Figure 5. Magnetic patterns on Digital 8 recording of SMPTE color bars.

For more practical application of this magneto-optic technique for forensic application, a larger magneto-optic film indicator and low magnification to cover whole surface areas of video tapes would be necessary.

Visualization of magnetic patterns of magnetic test tapes from Wisconsin State Crime Laboratory has been performed. Any alteration from the originally recorded patterns can be visualized easily from this technique.

## TECHNOLOGY BENEFITS

The technique described can be used for investigating any recording patterns on magnetic tapes quickly and nondestructively. Because of this, the technique will have a significant impact on forensic analysis of magnetic recording media by offering a nondestructive method for imaging magnetic patterns with improved spatial resolution and speed.

Furthermore, when video evidence is damaged by cutting it into strips, this technique will be useful in visualizing the recording to properly align the strips so they can be spliced back together and to the damaged videotape be played. At the present time, this requires the use of a magnetic tape developer such as Kyread dip, which is basically a fine magnetic powder suspended in a chemical solution. However, it damages the tapes and is a time-consuming process.

## COLLABORATION

This project was carried out in collaboration with R. C. Sanders, Forensic Imaging Unit Leader, Wisconsin State Crime Laboratory.

## IMPLEMENTATION

The results of this work will be disseminated in international forensic science journals, such as the Journal of Forensic Sciences and Forensic Science International. Additionally, research findings will be published in the Journal of NDE, Review of Progress in Quantitative Non-Destructive Evaluation, and IEEE Transactions on magnetics.

## PUBLICATIONS AND PRESENTATIONS

- Lee, S.J., "Development of Forensic Imaging Technique for Fast Analysis of Magnetic Tapes with High Spatial Resolution." Presentation at the Midwest Forensics Resource Center Annual Meeting, April 2007, Madison, WI.

## CONTACTS

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# Application of a Crystal Orientation Method to Forensic Physical Matching of Metal Surfaces along a Fracture Line

## FORENSIC TECHNOLOGY NEED

Examples of metal fragments found at a crime scene include knife tips, pieces from weapons, pry tools, or automobile parts such as antennas or trim pieces. A physical match between two surfaces is routinely viewed as definitive proof that the fracture surfaces were generated from the same part. However, in the Summer 2005 issue of the Association of Firearm and Toolmark Examiners (AFTE) Journal, Katterwe indicated that there were current “trial challenges” to the practice of fracture matching examinations by tool mark examiners.

To date, there has been little systematic effort to establish a basis for the uniqueness of a physical match of surfaces. Rocky Stone, in the Fall 2004 issue of the AFTE Journal, presented a mathematical probability model to duplicate the complex nature of a fracture surface. He indicated that the calculations did not account for the class characteristics that are present in actual fractures such as the nature and the characteristics of the alloy that further individualize a particular fracture.

Consequently, there is a need for a method to measure the nature and characteristics of materials with a known error rate that can be applied to performing physical matches.

## TECHNOLOGY DESCRIPTION

This study examines the feasibility of using surface crystal orientation to associate, or differentiate, metal fracture fragments.

The overall objective of this project is to evaluate whether surface crystal orientation can be used to associate metal fracture fragments.

Electron Back Scatter Defraction (EBSD) is a point-to-point (grain-to-grain) measurement on the surface of the metal that can be used to determine the orientation of individual crystals. EBSD’s basic operation collects electron back-scattered patterns using a specialized collector on the scanning electron microscope. Orientation patterns are generated by sample interaction with the electron beam.

## METHODOLOGY

This study tests if the orientations of the fractured crystals across the fracture plane for two surfaces, determined using a forensic examiner by conventional methods, are in fact unique and can be relied on to determine that the two pieces sharing the fracture plane at one time belonged to the same piece.

This study also investigates the feasibility of using EBSD in combination with conventional forensic methods to physically associate broken surfaces of metal pieces to determine whether the broken pieces at one time belonged to the same piece (Figure 1).

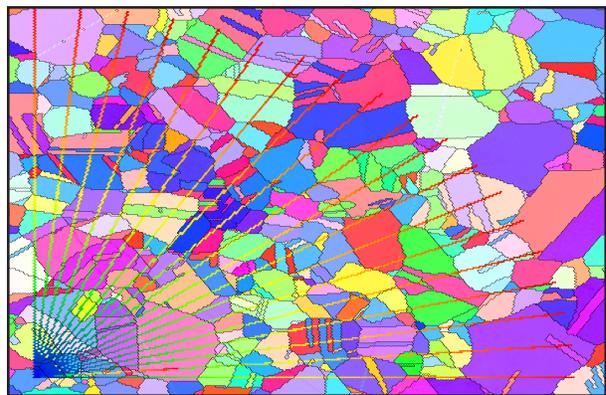


Figure 1. Grid placement for point-to-origin misorientation vector with 5° angular separation between vectors.

## ACCOMPLISHMENTS AND ONGOING WORK

Early efforts focused on establishing an empirical basis for the assumption that a minimum sequence of grains is needed to identify a metal fracture line. Figure 2 shows that, by placing point-to-origin vectors at a common origin grain, the misorientation between a small number of grains can be characterized.

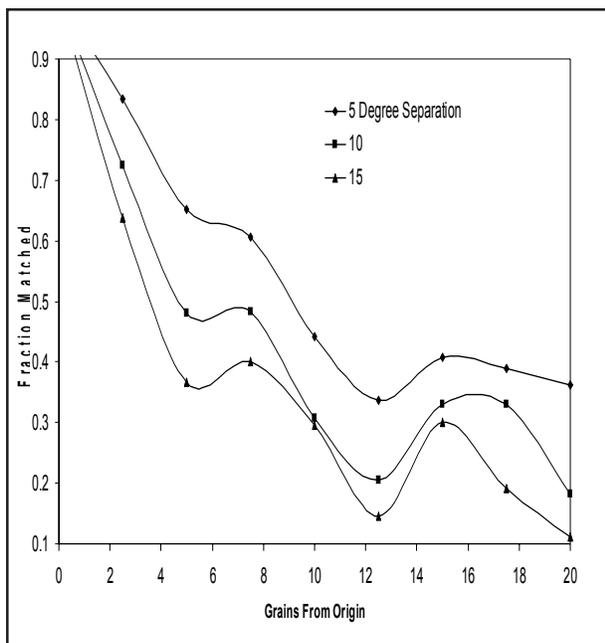


Figure 2. Plot of point-to-point matching data from all scans. The matching fraction decreases with distance from the origin vector and with increased angular separation.

This suggests that a relatively low number of grains needs to be analyzed to uniquely characterize a fracture line by relative crystallographic orientations and opens the possibility to a more extensive statistical review of concepts and data.

## TECHNOLOGY BENEFITS

One objective of this study is to determine the feasibility of obtaining suitable patterns from “real” fracture surfaces. The outcome of this

project will be a workable measure of the orientation of crystals along the fracture line of many materials such as metal fractures of knives, pry tools, and car antennas.

This study also serves as the basis for establishing the unique combination of crystal orientation patterns along both sides of the fracture line. These experimental studies test the core assumptions that if the pattern matches, the surfaces were originally together because of the assumption that a fracture surface is stochastically complex and, therefore, unique. The data collection will strengthen the scientific foundation of the fracture match practice with data to begin the task of estimating error rates.

## COLLABORATION

This work is conducted at the Ames Laboratory in collaboration with Jim Kreiser, a retired toolmark examiner from the Illinois State Police. Kreiser will perform the preliminary match of the test materials prior to the EBSD measurements. The principal investigators, Barbara Lograsso (Michigan Technological University) and Thomas Lograsso (Ames Laboratory), will generate the EBSD experimental data.

## IMPLEMENTATION

The PIs will disseminate their findings in presentations at the MFRC Annual Meeting, the Midwestern Association of Forensic Scientists, American Academy of Forensic Sciences, and AFTE annual meetings and regional meetings. The results will also be presented as a paper to be submitted to forensic journals such as the Journal of Forensic Sciences. They will further be disseminated in report form on the MFRC web site.

## **PUBLICATIONS AND PRESENTATIONS**

- Lograsso, B.K., Lograsso, T.A., Glamm, R., “Crystallographic Descriptors of a Metal Surface Along a Fracture Line.” Poster presentation at the International Association of Identification International Educational Conference, July 2007, San Diego, CA.
- Lograsso, B.K. “Application of Crystal Orientation Method to Fracture Evaluation.” Oral presentation at the Midwest Forensics Resource Center Annual Meeting, April 2007, Madison, WI.
- Lograsso, B.K., Lograsso, T.A., Glamm, R., “Crystallographic Descriptors of a Metal Surface Along a Fracture Line.” Poster presentation at the Midwest Forensics Resource Center Annual Meeting, April 2007, Madison, WI.

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# High-Speed Digital Video Analysis of Bloodstain Pattern Formation from Common Bloodletting Mechanisms

## FORENSIC TECHNOLOGY NEED

The analysis of bloodstain patterns is used by criminal investigators to draw inferences about the events that gave rise to the formation of the pattern. It is asserted here that an understanding of the dynamics of a blood transfer event is critical to the sound interpretation of the resultant bloodstain pattern. This project systematically studies the formation of some of the common bloodstain patterns by using a high-speed digital video (HSDV) camera to record the blood transfer as it occurs. It is hoped that the outcome will be a significant contribution to the strengthening of the science underpinning bloodstain pattern analysis (BPA).

## TECHNOLOGY DESCRIPTION

Bloodstains form on two-dimensional surfaces and from the mechanism that gave rise to their formation, a bloodletting incident is often a complex set of events that takes place in a three-dimensional space. Blood volumes that are transferred generally undergo some change prior to their subsequent deposition on a surface. For example, a pool of blood is broken up into droplets of varying size that are projected outwards when the volume is subjected to an impact force.

HSDV is used to analyze and document the dynamics of common blood transfer events. Video clips of common blood transfer events will be compiled to assist instructors in a bloodstain pattern course. The project will provide experience in the use of HSDV for analyzing blood transfer events and will increase the understanding of the dynamics of blood transfer that gives rise to bloodstain patterns.

## METHODOLOGY

The underlying hypothesis to be tested in this project is that understanding the dynamics of these changes is critical to the sound interpretation of the resultant bloodstain pattern.

This project aims to take the first steps in the task of studying and documenting the three-dimensional dynamics of the major blood transfer events. It is anticipated that this will lead in turn to a new understanding of even the most common bloodstain patterns encountered by crime scene investigators the world over. It is also anticipated that some hitherto unknown aspects of blood transfer will surface and invite ongoing investigation.

The project consists of five phases:

- Set up the video equipment and complete user training.
- Perform single drop experiments on hard and fabric surfaces, cast-off experiments, blunt force trauma impact spatter experiments, and experiments with impact spatter from a shooting completed.
- Analyze the data from phase two, document findings, and design necessary supplementary experiments.
- Complete supplementary experiments, analyze data, and document findings.
- Complete teaching aids and presentations or complete training for local and regional forensic staff.

## **ACCOMPLISHMENTS AND ONGOING WORK**

This is a new project that started in March, 2007 but the experimental work is not expected to start until about October, 2007.

## **TECHNOLOGY BENEFITS**

In the past, bloodstain pattern analysts have been trained in BPA primarily by studying the aftermath of blood-letting events. The recording of major blood-letting events by high speed digital video and making these videos available to the forensic community will enhance the ability of the bloodstain pattern analyst to understand and interpret bloodstain patterns. It is hoped that the observation and study of how the blood is deposited in specific events will assist in the differentiation of closely related events that previously could not be differentiated.

The project will also contribute to the underlying science behind BPA methods and the validation of current bloodstain pattern recognition methods. The foundations of BPA opinion evidence in court will be strengthened by this study. The study of bloodstain patterns is a study of the aftermath of a blood transfer event.

Almost every discipline in the area of forensic science through advanced technology has improved its capability to provide more and better information to the law enforcement community to assist them in solving crimes. The use of high speed digital video to study the dynamics of how bloodstain patterns are formed will do the same for the field of bloodstain pattern analysis. In addition, this technology will enhance the expert witness' opinion and help to satisfy the continued demand by courts to use the most advanced technologies available.

## **COLLABORATION**

This project is a collaborative effort between Terry Laber, Forensic Science Laboratory, Minnesota Bureau of Criminal Apprehension; Bart Epstein, Forensic Consultant; and Dr. Michael Taylor, Institute of Environmental Science and Research.

## **IMPLEMENTATION**

The video clips will be made available to forensic science educators and BPA instructors. A full, in-house report of the outcomes of the project will be made available to the Minnesota BCA Forensic Laboratory and the ESR in New Zealand. The results and conclusions of the research will be presented at regional, national, and international forensic science meetings and seminars. One or more papers will be prepared for submittal to suitable, peer-reviewed forensic journals.

## **PUBLICATIONS AND PRESENTATIONS**

This is a new project with no publications or presentations to date.

## **CONTACTS**

### Principal Investigators

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# Proposed CD-ROM Based Digital Information Database on Pipe and Tubing Utilized in Improvised Explosive Devices

## FORENSIC TECHNOLOGY NEED

The rise in terrorist bombings has made the identification of bomb materials a priority for the forensic scientist. The volume of evidence to be analyzed and the importance of such testing for preventative and investigative purposes have increased the need for tools. Such tools can aid in the identification of specific tubing material used for bombs.

Currently, available information on tubing materials and their manufacturers is either outdated or incomplete. Additionally, the data that has been gathered is either in printed format or in handwritten notes. No digital captures of this information are currently available. By putting this type of information in a searchable database, it will cut down on time spent looking for the information by investigators and forensic laboratories at all levels of law enforcement.

## TECHNOLOGY DESCRIPTION

The objectives of this project are to document all known types of pipes and tubing, worldwide pipe and tubing manufacturers, manufacturing identification marks on pipes and tubing, companies that import pipes and tubing into the United States, and companies that regularly stock or market each type of pipe and tubing.

All of this information will be placed into a searchable database. The database will be forwarded to the Midwest Forensics Resource Center (MFRC) for final compilation into a searchable CD format. As the CDs are completed, the MFRC will be responsible for their distribution.

## METHODOLOGY

The first part of the project targets documenting as many manufactures of pipes and tubing as can be found. This can be done primarily by internet searches. The next step is to contact them to request information regarding any identification markings. Samples of as many types as possible of pipe and tubing will be purchased. This includes purchasing samples in various regions of the U.S. The samples will be measured, digitally photographed and all data entered into the database. All companies that import pipes and tubing into the U.S. will be identified and documented. Additionally, all companies that commercially sell pipes and tubing will be documented, as well as any identifying sales tags.

## ACCOMPLISHMENTS AND ONGOING WORK

At this point, the project is nearly 99% complete. The database is comprised of 113 entries from 25 countries and currently consists of the following information fields:

- Company Name
- Contact Information
- City/State
- Zip Code
- Country
- Telephone
- Fax
- Logo Description
- Miscellaneous Information
- Website Information

Additionally, there are two fields for any photos that can be found or produced for the individual pipes as well as drawings of any logos or characteristic markings. At this time, the database deals only with steel pipe. However,

updates are planned to include plastic and other types. The database was placed in a self-running platform called Filemaker, which does not require the user to own that software.

## TECHNOLOGY BENEFITS

The database will be of great use to law enforcement agencies nationwide. From 1992 to 2002 there were a total of 5,307 pipe bombs nationwide involving Improvised Explosive Devices (IEDs). Of these, 1,374 (26%) occurred in the Midwest (Table 1).

Arkansas	40
Indiana	106
Iowa	98
Kansas	73
Kentucky	56
Michigan	201
Minnesota	57
Missouri	241
Nebraska	27
Ohio	219
Oklahoma	78
Tennessee	111
Wisconsin	67

Table 1. Incidents involving IEDs by Midwest state.

The availability of a searchable database should greatly reduce the amount of time and effort that is required by forensic scientists to process bomb samples.

## COLLABORATION

This project is a collaboration between the Western Law Enforcement Training Center (WFLETC), Missouri State Highway Patrol, and the Lake County Crime Laboratory in Painesville, Ohio.

The initial phases of this program were conducted by internet searches and direct contact with manufacturers, distributors and retailers of pipe and tubing that can be used to

construct pipe bombs. These contacts were made by personnel from the WFLETC, Lake County Regional Crime Laboratory, and the Missouri State Highway Patrol Crime Laboratory involved in the project. The data obtained from these contacts was forwarded to the WFLETC. All samples of pipe and tubing purchased for the project were shipped to the WFLETC for documentation. The equipment needed to digitally document the pipe/tubing was housed at the WFLETC.

## IMPLEMENTATION

The final CD-ROM product is intended for distribution nationwide to all levels of law enforcement. This will include both the investigative and forensic laboratory levels. The MFRC will be the disseminating agency for this product. The CD will also be distributed at various forensic conferences and at the International Association of Bomb Technicians and Investigators. Credit for the final CD-ROM will be shared by the MFRC, the WFLETC, the Lake County Regional Crime Laboratory, and the Missouri State Highway Patrol Crime Laboratory.

## PUBLICATIONS AND PRESENTATIONS

- Crippin, J., "Pipe and Tubing Database." Presented at WFLETC explosives classes, Pueblo, CO.
- Crippin, J., "Pipe and Tubing Database." Presented at State Department post-blast investigation classes.
- Crippin, J., "Pipe and Tubing Database." Presented at American Academy of Forensic Science 59th Annual Meeting, February 2007, San Antonio, TX.

- Crippin, J., "Pipe and Tubing Database." beta version distributed for testing at the AAFS, San Antonio, TX, and to several state and federal agencies, including the FBI and TSA.

## **CONTACTS**

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# Quantification of the Individual Characteristics of Human Dentition

## FORENSIC TECHNOLOGY NEED

*Daubert vs. Merrell Dow Pharmaceuticals* has raised the bar for admissibility of comparative science testimony. Although it is generally accepted in the dental community that the human dentition is unique, there has been little research generating statistical evidence to support this supposition, or even the ability to quantify the occurrence of specific traits.

Currently, forensic Odontologists, in the analysis of bite mark evidence, are unable to quantitatively state the frequency with which a given set of dental characteristics occurs in the population. Without this ability, their conclusions lack a scientific basis and are limited to subjective opinions.

## TECHNOLOGY DESCRIPTION

This project has three specific aims. They are to:

- Develop a computer assisted methodology for analyzing, measuring, and recording the measurement of dental characteristics.
- Investigate, using six measurements, the pattern of each of 400 samples, and calculating the probability that any two would be judged to be the same.
- Establish the feasibility of the development of a database that can be used to quantify the occurrence of a given set of dental characteristics in the population.

## METHODOLOGY

This pilot study is developing a database on the frequency distribution of six dental characteristics in the population and developed

a computer assisted methodology for capturing and recording the data (Figure 1). It will also generate statistical evidence for an inter-operator and intra-operator error rate for those analysts conducting the research, answering another of the Daubert factors.

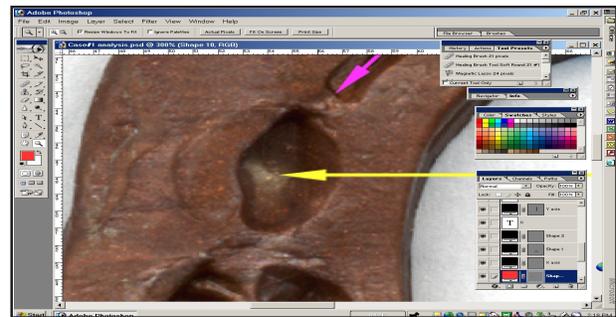


Figure 1. The tools in Adobe Photoshop CS2 are utilized to measure and record size and angle of rotation from the X axis.

## ACCOMPLISHMENTS AND ONGOING WORK

This study has, to date, utilized tooth exemplars of 400 male volunteers between the ages of 18 and 44. The sample size (n=400), to complete the study, was derived from power calculations by a biostatistician using nQuery Advisor®.

Measurement and compilation of the data on the 85 remaining exemplars is being accomplished. Final calculations will be accomplished using SAS® Statistical Analysis Software. The convenience sample was derived from dental clinic patients, representing a diverse population composed of Caucasians, Blacks, Asians, and Hispanics that mirrors the general population.

To limit the size of the study, only males were sampled. A total of 500 exemplars have been

collected throughout the two years of this research to allow for as many as 100 drop-outs (exemplars that don't meet the standards required).

## TECHNOLOGY BENEFITS

Utilizing professional imaging and statistical software, this protocol has vastly improved the accuracy of observing, recording and calculating the measurements, and calculating the frequency of the attributes being studied in this random, ethnically diverse, sample population (Figure 2). As an indirect benefit of the project, the serendipitous discovery of two automated software programs under development at Marquette University enabled their adaptation to verification of the accuracy of the data capture, creating an efficient and reliable technique of quality control.

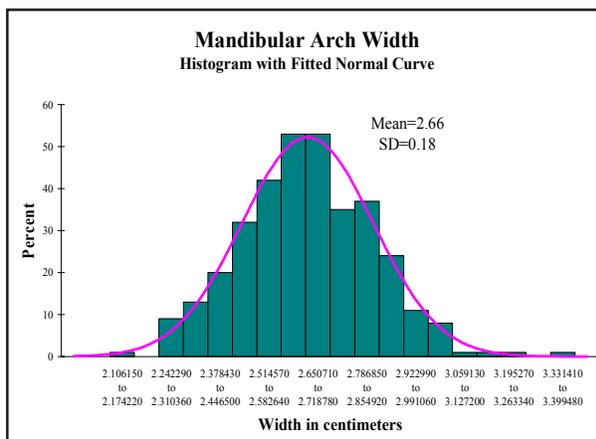


Figure 2. This histogram of the widths of the lower jaw indicates significant outliers in size which provide a statistical basis for their infrequent occurrence in the population.

## COLLABORATION

This project is being completed by a multi-disciplinary team made up of two imaging specialists from the Wisconsin Department of Justice Crime Laboratory – Milwaukee, the principal investigator and Professor of Forensic Dentistry, L. Thomas Johnson, two

faculty co-investigators, a Professor of Evidence from Marquette University Law School, a software programmer, and a biostatistician.

The law school professor has provided expertise on the admissibility and case law pertaining to digital evidence, while the imaging specialists have assured the methodology followed Scientific Working Group on Imaging Technology (SWGIT) guidelines. The biostatistician determined the “n”, calculated the statistical data, and has provided the expertise in preparing the charts and graphs for dissemination.

## IMPLEMENTATION

Research findings and results, so far, have been disseminated via various presentations and publications.

Additionally, the research and its findings have been highlighted on television and in the newspaper. Research findings have been presented at the American Academy of Forensic Sciences, and the International Association for Identification. Upon completion of this study, a paper will be prepared on the methodology for submittal to the Journal of Forensic Sciences.

## PUBLICATIONS AND PRESENTATIONS

- Johnson, L.T., “Quantification of the Individual Characteristics of the Human Dentition: A Preliminary Report.” Oral presentation at the American Academy of Forensic Science, 58<sup>th</sup> Annual Meeting, February 2006, Seattle, WA.
- Fox Channel 6 News at 9 PM, “Dental Database.” May 23, 2007, Milwaukee, WI.
- Johnson, L.T., “Dental Science Assists Criminal Justice.” Oral presentation at the American Academy of Forensic Science,

59<sup>th</sup> Annual Meeting, February 2007, San Antonio, TX.

- Johnson, L. T., Radmer, R., “Dental Science Assists Criminal Justice.” Oral Presentation at the International Association for Identification, International Educational Conference, July 2007, San Diego, CA.
- Johnson, L. T., “Quantification of the Individual Characteristics of the Human Dentition.” Poster presentation at the International Association for Identification, International Educational Conference, July 2007, San Diego, CA.
- Benedict, B., “Bite Mark Study Could Bolster Use as Evidence,” *Milwaukee Sentinel*, August 5, 2007.
- Johnson, L. T., “Dental Science Assists Criminal Justice.” Presentation at the John R. Teggatz Forensic Science Seminar, November 7-8, 2007, Milwaukee, WI.
- Johnson, L. T., “Dental Science Assists Criminal Justice.” Abstract submitted to the Annual Educational Conference of the American Academy of Forensic Sciences, February 2008, Washington, D.C.
- Johnson, L. T., “Quantification of the Individual Characteristics of the Human Dentition.” Paper to be submitted to *Journal of Forensic Sciences*, 2008.

## CONTACTS

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# Spectral Analysis of the 3D Fracture Surfaces for Enhanced Matching

## FORENSIC TECHNOLOGY NEED

Examples of metal fragments found at a crime scene include knife tips, pieces from weapons, pry tools, or automobile parts such as antennas or trim pieces. Physical pattern evidence using both class and individual characteristics of these fragments is used to link suspects to crime scenes and crime victims. Individual characteristics make objects or substances unique even among members of the same class.

There is a need for a method to measure the nature and characteristics of materials with a known error rate that can be applied to performing physical matches. This study will examine the feasibility of measurements of fracture topography 3D spectral analysis of the surface feature distributions to determine if the broken pieces belonged to a single piece.

## TECHNOLOGY DESCRIPTION

The overall objective of this study is to evaluate whether surface feature distribution signatures can be used to associate metal fracture fragments. As such, it will test if the fracture feature distribution signatures for two surfaces as determined by a forensic examiner using conventional methods, are in fact unique. Also, that they can be relied on to determine if the two pieces sharing the fracture surface belonged to a single piece. The analysis will generate a proof-of-concept on well-characterized laboratory specimens.

## METHODOLOGY

Test Samples: A typical knife material (SS-440C) will be used in a flexural three point bend test. Metal samples will be examined

during the proof-of-concept stage. Once proof-of-concept is established, hard plastic and glass coupons will be tested.

Tests / Measurements: The pairs of fractal surfaces will be analyzed by a non-contact 3D optical interferometer. Interferometer measurements are based on the principle that when light is reflected from two opposing surfaces, the reflected beams may interfere with one another to generate interference fringes which can be used to determine the distance between two surfaces. The collection of displacement measurements will then be used to acquire surface height topographic maps from the pairs of fractal surfaces. These height topographic maps will be quantized using spectral analysis (Figure 1) for a broken chisel fracture surface.

Analyses and Physical Matching: Each feature on the fracture surface has a population. The first step of the analysis will

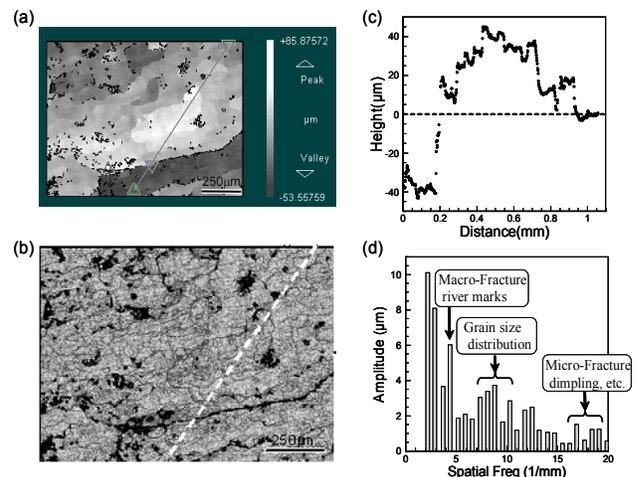


Figure 1. Typical set of measurement and analysis for fractal surface showing the unique signature of the fractal surface: (a) 3D height map, (b) 2D rendering, (c) 1D line profile, and (d) 1D spectral description.

be to identify the number of main features on each image and their populations. For a pair of fractured surfaces the population of these features will be compared via autocorrelation to provide the quality of the match.

Two main issues or challenges will be addressed. First, the proper magnification and the size of the data set that yield the proper surface topography population to identify each unique feature. Second, the directionality of the long wave length features of cracking such as river marks.

## ACCOMPLISHMENTS AND ONGOING WORK

Early efforts have been dedicated to sample examination and baseline sample data generation. Typical knife material (SS-440C) with a precursor notch were prepared. The first quarter focused on exploring the nature and trends of data generated by the fracture surfaces analyzed by the non-contact 3D optical interferometer. During this quarter several experimental issues were examined such as the level of magnification that should be used for the measurements. These preliminary height maps were quantized using spectral analysis (Figure 2) for one of the fractured 440 SS samples along the 1D lines on the sample surface. A 1D analysis was conducted on the same image, wherein several traces were collected, and analyzed to examine the possible commonality of frequency lines (Figure 3). The spectral analysis of data set results in distributions for a range of spatial frequencies, giving the likelihood of feature types (river marks, grain size, dimples) on the fracture surface. In addition, for preparation of 2D analysis, a Matlab-program was devised to read the generated surface height topographic maps.

Investigators met at the Johnson County Sheriff's Office Crime Laboratory in Mission, Kansas on June 7, 2007 to discuss research

findings, and exchange a new set of specially devised field samples. Ongoing work will involve developing testing protocols with Jeremiah Morris at the Johnson County Sheriff's Office Crime Laboratory.

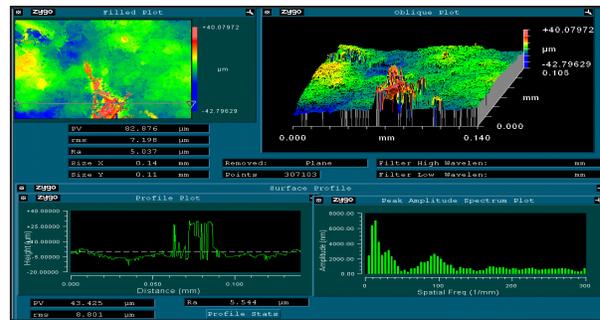


Figure 2. A typical 3D factual analysis of the 3 point bend fractured 440 SS samples, showing the height topography map, a 1D line profile across the map as well as a spectral analysis of the associated frequencies within the line (50X mag.).

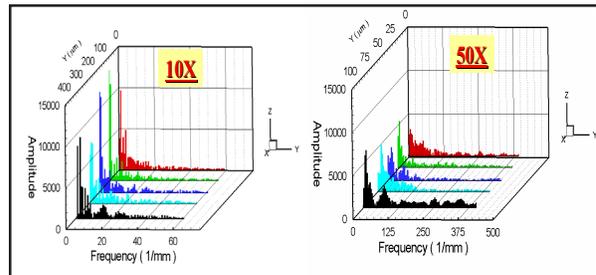


Figure 3. Comparison of the 1-D analysis across several lines, at two different magnifications. Several common frequencies can be spotted. These include:  $f=15\text{mm}^{-1}$  ( $\lambda=66\mu\text{m}$ —grain size),  $f=25\text{mm}^{-1}$  ( $\lambda=40\mu\text{m}$ , texture), and  $f=75\text{-}100\text{mm}^{-1}$  ( $\lambda=10\text{-}13\mu\text{m}$ , fracture mechanisms).

## TECHNOLOGY BENEFITS

One of the objectives of this study is to determine the feasibility of obtaining suitable patterns from “real” fracture surfaces. The outcome of this project will be a workable measure of the signature of features on the fracture surface of many materials such as knives, pry tools, and car antennas.

This technique will allow the forensic scientist to measure and correlate two fractured surface fragments found at a crime scene including materials such as metal (knife tips, pieces from weapons, pry tools, or automobile parts such as antennas or trim pieces), plastics (automobile body parts and paint chips), and glass (window or windshields).

These experimental studies will test the core assumptions that if the pattern matches, the surfaces were originally together because of the assumption that a fracture surface is stochastically complex and, therefore, unique. This data collection will strengthen the scientific foundation of the fracture match practice with data to begin the task of estimating error rates.

## **COLLABORATION**

This work is being conducted at Iowa State University and Ames Laboratory in collaboration with Jeremiah Morris, forensic scientist from the Johnson County Sheriff's Criminalistics Laboratory.

Jeremiah Morris will generate simulated forensic metal fracture samples of the test materials prior to the 3D spectral analysis and will collaborate on the testing protocol. The principal investigators, Ashraf Bastawros of Iowa State University and Barbara Lograsso of Michigan Technological University, will generate the preliminary samples and experimental data and analysis.

## **IMPLEMENTATION**

The PIs will disseminate their findings in presentations at the MFRC Annual Meeting, at the annual meeting of the American Academy of Forensic Sciences, and International Association for Identification annual meetings and regional meetings. The results will be developed into a written paper to be submitted to forensic journals such as the Journal of Forensic Sciences. The results

will be disseminated in report form on the MFRC web site.

## **PUBLICATIONS AND PRESENTATIONS**

- Bastawros, A., Lograsso, B.K., Morris, J., "Spectral Analysis of the 3D Fracture Surfaces for Enhanced Matching." Poster presentation at the International Association for Identification, International Educational Conference, July 2007, San Diego, CA.

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# Statistical Validation Study of Toolmark Uniqueness

## TECHNOLOGY NEED

Recovery and comparison of toolmarks, footprint impressions, and fractured surfaces connected to a crime scene are of great importance in forensic science. It is generally accepted that particular manufacturing methods produce marks on tools that are different from tool to tool. Yet, recent court cases have challenged this proposition.

To date, there have been several studies showing the impact of various tool manufacturing methods on the individuality of toolmarks and striations produced on tools. These studies have also shown that similar and/or sequentially-produced tools make toolmarks that are distinctly distinguishable. The major shortcomings of these studies are that they concentrated on only a single manufacturing method (e.g., broaching) and typically used a small number of samples.

## TECHNOLOGY DESCRIPTION

The overall objective of this project is to provide the basis for, and conduct a numerical validation study of, the proposition that particular manufacturing processes produce marks on tools that are tool specific.

In order to achieve the stated objective, this study attempts to provide the statistical tools necessary to validate tool uniqueness. It extends previous studies by conducting a more comprehensive statistical analysis of toolmark variation produced by several manufacturing methods.

The previous studies, conducted by the project PIs under an FBI grant, provided the proof-of-concept demonstrating that a “degree of association” or “degree of similarity,” relative of a particular manufacturing process, can be

obtained from digital images of toolmarks. They also developed statistical algorithms designed to mimic the comparison process of a forensic scientist (see Publications).

## METHODOLOGY

The initial work from the FBI grant laid the groundwork for this more detailed and comprehensive study on validation. Since the initial feasibility study was based on preliminary algorithms, tested on a limited number of digital images, and optimized for ground surfaces, several refinements and issues of the original work need to be addressed in order to achieve the objectives of this project.

These refinements are:

- Accelerating image comparisons either by exporting the algorithms to a compiled language or integrating the algorithms with commercial pattern-matching software.
- Optimizing algorithms for surfaces from other manufacturing processes (e.g., broach, milled, and filed), since the initial algorithms were optimized using images of ground surfaces.
- Applying faster and more advanced algorithms to an extensive image database for more refined estimates of error rates for various surfaces.

The validation approach involves the development of statistical methods for data reduction and the analysis of a collection of digital images of toolmarks produced by various tool manufacturing methods on produced work-products. The study is being performed on an existing database of over 8,000 digital images representing grinding,

milling, broaching, whetstoning, and filing manufacturing processes on commercial tools as well as consecutively-made samples.

## ACCOMPLISHMENTS AND ONGOING WORK

The FBI funded work demonstrated that a validation study can be performed using digital images and statistical algorithms. It produced a well-defined metric (i.e., index value) to determine the level of differences between known matches and known non-matches for a particular tool manufacturing method.

In this project, a refinement and re-implementation of the original algorithms into a compiled language was completed. A more extensive validation experiment, testing the refinements and investigating the assignment of a “critical” index value for a particular surface type, was also performed (Figure 1).

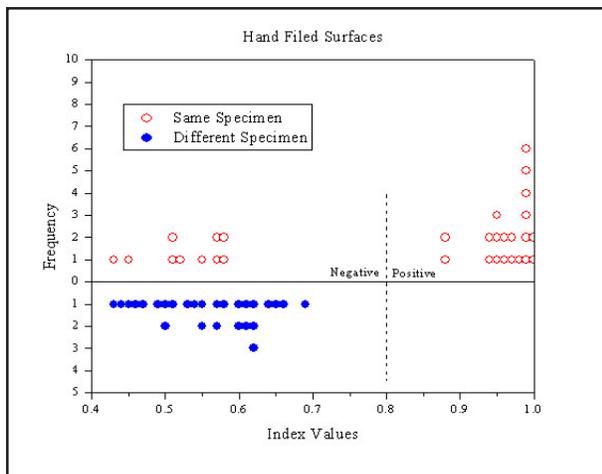


Figure 1. Frequency chart showing results from applying the experimental algorithm to a 30-image data set of hand-filed specimens acquired at 15x magnification. The dotted line may be indicative of a characteristic “break-point” for this surface type.

Error rates were comparable to or better than achieved with the original algorithms suggesting that the refined algorithms are not only faster but also are more effective.

The derived “index value” from these tests serve simply as a general-purpose working value, leaving the question of a formally defensible argument for further research.

## TECHNOLOGY BENEFITS

Implementation of this work will provide formal and objective support to the premise of toolmark uniqueness. This premise is empirically based on a handful of studies, training, and years of proficiency testing and experience of toolmark examiners in making comparisons of known matches and non-matches to develop a knowledge of uniqueness.

An objective validation of tool uniqueness, consistent with sound scientific methods, is particularly important in light of recent court challenges. As such, it supports an examiner’s assigned identification based on alignment of striae of a questioned mark made with a suspect tool.

## COLLABORATION

The initial work was carried out in collaboration with Mr. James Kreiser, an experienced forensic toolmark examiner from the Illinois State Police.

## IMPLEMENTATION

The results of this work will be presented at forensic science meetings and published in relevant forensic science journals.

A number of sub-algorithms (e.g. optimal match location and validation by comparing the match quality with random locations) are being implemented by Dr. Scott Chumbly and Dr. Larry Genalo in another NIJ funded project investigating toolmark matching incorporating profilometry.

## **PUBLICATIONS AND PRESENTATIONS**

- Baldwin, D. P., Morris, M., Bajic, S. J., Zhou, A., "Statistical Tools for Forensic Analysis of Toolmarks." Poster presentation at the American Academy of Forensic Sciences, 56th Annual Meeting, 2004, Dallas, TX.
- Baldwin, D. P., Morris, M., Bajic, S. J., Zhou, A., Kreiser, M. J., "Statistical Tools for Forensic Analysis of Toolmarks- Final Report." FBI/Ames Laboratory Report IS-5160 (2004).

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# Testing for Potential Contextual Bias during the Verification Stage of the ACE-V Methodology when Conducting Latent Print Examinations

## FORENSIC TECHNOLOGY NEED

Recent Daubert challenges to fingerprint evidence and the Analysis, Comparison, Evaluation, and Verification (ACE-V) methodology have questioned the reliability of ACE-V methodology as it is currently applied by experts. Until recently, no research had been conducted to test the effects of potentially biasing context information upon fingerprint experts. A recent study performed by a group in England suggests that experts are biased by context information. However, concerns have been raised about the study design, limited number of participants, and the lack of a control group. This study explores how expert opinion varies under different experimental conditions.

## TECHNOLOGY DESCRIPTION

Objectives of the project are to investigate potential contextual bias during the verification stage of ACE-V. When verifying the conclusions of a latent print examiner, the verifier typically knows the conclusions of the initial examiner. A primary question that needs to be answered is: does this prior knowledge alone influence the verifier's conclusion? A secondary question is: does the identity and reputation of the initial examiner, coupled with prior knowledge of their conclusion, influence the verifier's conclusion.

## METHODOLOGY

These questions are answered through a controlled experiment with experts and non-experts. Experiments involving experts were conducted at the International Association for Identification (IAI) Annual Educational Conference in Boston, MA. Experiments with

non-experts were conducted at a local community college. The principal investigator (PI) instructs an introductory forensic science course, and during three semesters, a class of about 30 students participated in the non-expert experiments.

Each set of expert and non-expert participants was divided randomly into three groups. Each group was provided with a set of six latent fingerprints for which they were instructed to report two variables for measurement. The first variable was the conclusion. The second variable was the amount of information used to reach the conclusion. Statistical analyses were performed on the data collected.

The materials for each group consisted of a series of latent print comparisons of varying difficulty. The latent prints and known exemplars for comparison were derived from a sample of prints whose sources were known to the researchers.

## ACCOMPLISHMENTS AND ONGOING WORK

The expert portion of the experiment was conducted at the IAI conference in Boston, MA, July 2-7, 2006. Forty-three volunteers participated. They were divided randomly into three separate groups. Group A received a series of six latent print comparisons for which they were instructed to provide an expert opinion. This was the control group: no contextual information was provided. Group B was given the same six comparisons as the first group, but this time provided with a conclusion that was said to have been reported by an unnamed expert. Group C was given the same six comparisons as the previous two groups, but was presented with

conclusions by Pat Wertheim an internationally recognized expert in the field.

The same protocol was followed in experiments involving non-experts. The experiment with Group B participants (low bias) was conducted in May 2006, while Group C (high bias) and Group A (control) experiments were conducted in September, 2006, and January, 2007, respectively. During these experiments data were collected and entered into a database. Statistical analyses on the data were performed at the University of Lausanne, Switzerland, and reported before the Ph.D. Thesis Advisory Committee in April, 2007, and at the July 2007 IAI Educational Conference in San Diego.

## **TECHNOLOGY BENEFITS**

The results of this experiment provides valuable insight on the effects of potentially biasing context information when present during the verification of latent print examinations. Strong critical voices have called for a complete overhauling of the identification methodology but presently there is very limited evidence from research to support such actions. If the results of the experiment show an alarming rate of error from biasing contextual information during the verification process, then recommendations will be made to the latent print community to take appropriate actions.

## **COLLABORATION**

This project is a collaboration between the Minnesota Bureau of Criminal Apprehension (BCA), the University of Lausanne Switzerland (UNIL), and the Arizona Department of Public Safety Crime Laboratory.

Glenn Langenburg (PI) is currently a Certified Latent Print Examiner employed by the BCA. He is also a candidate in the Ph.D. program

for forensic science at UNIL. This project represents a portion of his thesis work towards completion of the Ph.D. Chair of his committee, and chief advisor to the project, is Professor Christophe Champod. Professor Champod has an extensive background in statistics, fingerprint science, and research. Pat Wertheim, criminalist at the Arizona Department of Public Safety Crime Laboratory works with the PI to administer tests to volunteer experts and non-experts.

## **IMPLEMENTATION**

The results of this study were presented at the International Association for Identification (IAI) Annual Educational Conference in San Diego July 2007. The information was also presented at the UNIL as part of a thesis defense before an academic committee. Finally, a paper will be submitted for publication in the Journal of Forensic Identification or the Journal of Forensic Sciences.

## **PUBLICATIONS AND PRESENTATIONS**

- Langenburg, G., Champod, C., Wertheim, P. "Testing for Potential Contextual Bias during the Verification Stage of the ACE-V Methodology when Conducting Latent Print Examinations." Presentation at the International Association for Identification, International Educational Conference, July 2007, San Diego, CA.
- Langenburg, G., "Experiments with the ACE-V Process of Fingerprint Comparisons- including a Contextual Bias Study during the Verification Stage." 30<sup>th</sup> Anniversary of the Canadian Identification Society. July 2007, Montreal, Canada.
- Langenburg, G. "Testing for the potential effects of Contextual Bias during the Verification Stage of the Latent Fingerprint Comparisons." International Fingerprint Research Group Symposium, 2007, Canberra, Australia.

- Langenburg, G., "Fingerprint Issues for Latent Examiners." 42<sup>nd</sup> Wisconsin Association for Identification, Educational Conference. March 26-28, 2008, Wauwatosa, WI.

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# Testing DNA Samples for Population of Origin

## FORENSIC TECHNOLOGY NEED

In Missouri, a large portion of annual DNA criminal cases are “unsub cases” with completely unknown information about the perpetrator. For these, Combined DNA Index System (CODIS) DNA profiles can be provided for possible later use by prosecutors, but immediate assistance to field investigators cannot be provided. For such cases, and using available equipment, a forensic technique called “population test” will be developed. The technique will give information about the population of origin (commonly called “ethnic group” or “race”) of a DNA sample.

## TECHNOLOGY DESCRIPTION

The biological basis for the test resides in frequency patterns of a few single nucleotide polymorphisms (SNPs). For most SNPs, allele frequencies among diverse populations are similar. However, for a small fraction of SNPs, they are quite divergent. A collection of the most extreme of these allele frequencies have been identified, called ancestral informative markers (AIMs), and characterized in nine populations.

## METHODOLOGY

The specific aims of this project are to:

- Identify a subset of AIMs that will be sufficiently powerful for the population test.
- Assemble components of the population test, including chemistry and analysis tools, and validate them by characterizing additional sets of DNAs.
- Assist collaborators in implementing the population test, including providing

components, protocols, and technical advice.

- Publicize the population test to the wider forensic science community.

## ACCOMPLISHMENTS AND ONGOING WORK

A subset of AIMs for the population test have been identified and *in silico* simulations using the genotypes from a study by Perlegen were performed. The 400 AIMs identified were very informative and are assayable by known TaqMan assays. With just ten markers, two of the continents of origin for all 78 Perlegen samples could be accurately ruled out (Figure 1). In the near future, the *in silico* tests will continue to further refine the list of AIMs. A small number of TaqMan assays will also be tested.

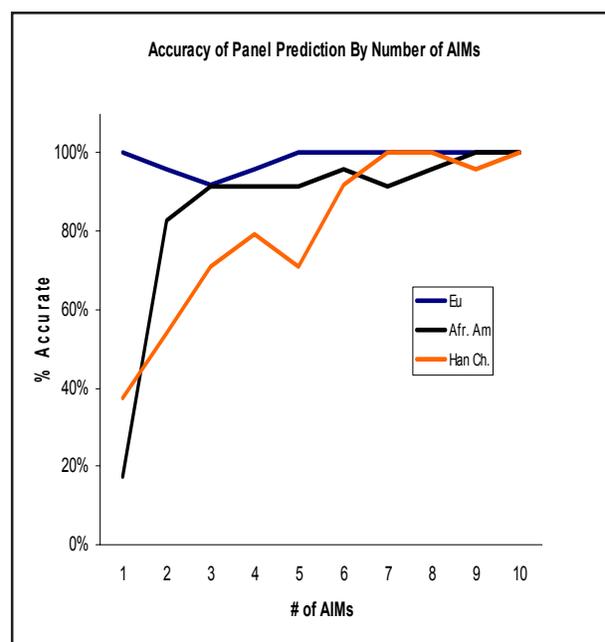


Figure 1. Number of AIMs required.

## **TECHNOLOGY BENEFITS**

The test will use available equipment to genotype ancestry informative SNPs. The results will be compared with known population frequencies of self-described ethnic groups in order to narrow the possible ancestry of the sample.

## **COLLABORATION**

This project is the result of a collaborative effort between the School of Medicine at Washington University, the Missouri State Highway Patrol Crime Laboratory, St. Louis County Crime Laboratory, and the St. Charles County Crime Laboratory.

## **IMPLEMENTATION**

The test will be implemented in laboratories of the three collaborators. For dissemination of research results, we will present at a meeting of the MFRC, and publish the results (with our collaborators as coauthors) in a journal such as the Journal of Forensic Sciences.

All of the protocols, training materials, and data generated as part of this project will be made available through our web site at <http://snp.wustl.edu>. Finally, efforts will be made to optimize these web pages for search engine keywords such as "SNP-based forensics."

## **PUBLICATIONS AND PRESENTATIONS**

Research data and the list of AIMS have been placed on the website: <http://snp.wustl.edu/snp-research/forensics/ancestry-informative-markers.htm>.

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