

FORENSIC REPORT  
Orange County, Orlando, Florida  
Final Report

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SUBJECT: Orange County Sheriff's Department case number OCSO#08-069208.  
Results of various tests to determine the possibility of a decompositional event.

DATE: April 28, 2009

On July 24, 2008 Investigator Mike Vincent of the Orange County Sheriff's Department sent us a carpet sample from the trunk of a 1998 Pontiac Sunfire (FL License number G63-XV) to determine if the odor present on the sample and in the trunk of the vehicle was indicative of a decompositional event. Additional air samples, collected by Investigator Vincent on triple sorbent traps (TSTs) (References 1-3,10), were sent to us on September 3, 2008 and included air samples from the vehicle interior and composite air samples from all the items identified in the trunk compartment. Paper towels (for chemical extraction) and a white trash bag (both containing numerous fly pupae) were sent to us by Dr. Neal Haskell. Compounds in all these samples were identified by mass spectral library match, with subsequent retention time verifications of a number of relevant compounds (when possible) with standards purchased from Sigma-Aldrich Chemical Company.

These samples were sent to us in reference to research we have been performing since 2002 in an attempt to identify the chemical composition signature of human decomposition odor. This research has resulted in several peer reviewed publications (References 4-5).

### **Odor Analysis**

The initial carpet sample was enclosed in a sealed metal can. A preliminary analysis was performed by extracting a small (0.8 ml) sample of air from the can and directly injecting the air along with an internal standard into a Hewlett-Packard 5890 Gas Chromatograph/ Mass Spectrometer (GC/MS) equipped with a Hewlett-Packard 5972 Mass Selective Detector. Only a few compounds were observed in this sample (primarily chloroform) so it was deemed necessary to concentrate the sample in order improve the signal-to-noise and to increase the sensitivity for lower abundance compounds (if present).

The technique selected for concentrating the sample was cryogenic trapping (cryo-trapping) which can improve the detection limit for organic constituents in an air sample by a factor of 10 times or greater compared with direct sample injection into a GC/MS. Cryo-trapping is a widely used analytical technique and has been incorporated in many analytical methods and successfully used for the analysis of fragrances and odors (References 17-19).

For these analyses, cryo-trapping was performed by injecting air into a short loop of inert stainless-steel tubing connected between the injector of the gas chromatograph and the head of the GC column. The stainless-steel loop was cooled with liquid nitrogen which condensed the organic compounds present in the air sample, while allowing the nitrogen and oxygen to be vented away from the GC/MS. Normal heating of the GC oven during the analysis cycle vaporized the condensed organic compounds in the stainless-steel loop and allowed them to traverse through the GC column into the mass spectrometer.

The carpet sample was removed from the metal can and placed in a Tedlar bag for two days at 35 degrees Celsius (C) and allowed to off-gas into the Tedlar bag. The analytes from 10 ml of gas from the Tedlar bag were concentrated as described above. Results of this analysis are summarized in Table 1. It is important to note that gasoline was found in the vehicle trunk which was a likely source of significant hydrocarbon interferences (references 7-9) causing overlap with approximately 41% of the chemicals typically observed in decompositional events. Previous reports of a decomposing pizza found in the vehicle trunk were not true and this was incorrectly stated in a preliminary report. An MSDS sheet, listing the ingredients of BlueStar, was obtained and evaluated by a chemist (Dr. Michael Burnett, Oak Ridge National Laboratory). His conclusion was that the components of the product could not have contributed to the chemical signature obtained in these analyses. Additional samples which have been analyzed by GC/MS and/or Laser Induced Breakdown Spectroscopy and are being summarized in this report include:

- 1) control trunk carpet sections obtained from two Pontiac Sunfire vehicles (one from 1998 and one from 1996 – the carpet samples were all a similar color and texture as the Florida vehicle) located in a junkyard in Knoxville, TN and placed in a Tedlar bag at 35 degrees C for two days (collected by Mr. David Glasgow, ORNL). The cars at the junk yard all have a sticker stating the make, model, and year of the vehicle;
- 2) a piece of pizza (mushroom and pepperoni) in the original pizza box which was allowed to decompose for several days at the University of Tennessee's Decay Research Facility and then placed in a Tedlar bag for two days at 35 degrees C (included as a control even though no pizza was actually found in the Florida vehicle). It is interesting to note that no maggots were found on the pizza;
- 3) composite air samples of all the items found in the trunk of the Florida vehicle collected on triple sorbent traps (TSTs);
- 4) air samples from the Florida vehicle interior compartment collected on TSTs;
- 5) Laser Induced Breakdown Spectroscopy (LIBS) results from the Florida trunk carpet sample and control carpet sample;
- 6) air from the laboratory at ORNL where the Florida trunk carpet sample was prepared and stored (control);
- 7) TST Florida trip blank (control);

- 8) TST air sample from garage where Florida vehicle is stored (control);
- 9) Volatile fatty acid analysis from carpet scrapings used to assist in the determination of a post-mortem interval (PMI);
- 10) Analysis of an adult squirrel allowed to decomposed on control carpet material;
- 11) Chemical extracts of carpet scrapings from the tire well, paper towels found in the trunk of the vehicle and from soil underneath the decedent;
- 12) Samples from a forensic case in Montana where a 3 yr old child (decedent) was wrapped in a blanket and allowed to decompose over a three month period in the trunk of a car (a positive control sample).

Of the 51 chemicals identified from the Florida trunk carpet sample, (many gasoline components detected are not listed in the Table), 41 (80%) are consistent with decompositional events. Only 17 of these overlap with known or possible gasoline constituents leaving 24 compounds (59 %) identified as associated with decomposing human remains potentially unaccounted for. It is important to note that this sample was removed from the trunk and eventually isolated in a Tedlar bag so the compounds which were detected in this analysis were off-gassing from the carpet sample and did not include vapors that may been in the air of the trunk or in an area where the vehicle was stored (Figure 5).

Nine compounds identified in the control carpet samples from the junkyard were also detected in the Florida trunk carpet samples. These were all in trace amounts. Only four of these could not be attributed to possible gasoline vapor components – one of these compounds was chloroform, but was only detected in trace amounts in the control carpet sample (Figure 7).

Only six compounds identified in the pizza, which were also detected in the Florida trunk sample, could not be attributed to gasoline vapor components. Of these six compounds, four were detected in the control carpet samples from the junkyard.

Laboratory air where the sample was stored and processed was sampled to determine if the room contained any chemical components which might have contributed to the odor detected in the Florida trunk carpet sample. None were detected.

The TST trip blank contained a number of additional compounds unrelated to what was found in the Florida car trunk. In order to keep Table 1 as simple as possible not all compounds are listed, but some of the additional compounds detected in this sample included: butane, 2-butene, 2-methyl butane, 1-pentene, 1-hexene, pentanal, 1-heptene, heptane, 1-octene, heptanal and substituted benzenes.

The Florida Forensics Unit Garage TST air sample was composed of primarily gasoline vapors (not all components listed in Table 1), freons and degreasers (tetrachloroethene), all commonly found in garages. No chloroform or sulfur containing compounds were detected in spite of the fact that TSTs could potentially concentrate more material than would direct sampling of the headspace of the carpet sample in a Tedlar bag (10 mLs were injected). The TST pump was adjusted to collect 500mL/minute and 77 minutes were collected so the spectrum would have represented approximately 39 L of air. Freons detected included trichlorofluoromethane, dichlorofluoroethane and trichlorotrifluoroethane. Some of the additional compounds detected in

this sample included: 2-methyl butane, 2-methyl butene, 2,3 dimethyl butane, 2-methyl pentane, cyclohexane, methyl cyclopentane, 3-methyl hexane, cyclopentane, heptane, 3-methyl 2-hexane, methylcyclohexane, 1,2 dimethyl benzene (xylenes) and styrene.

The TST air sampling from the Florida vehicle interior showed common hydrocarbons and significant amounts of xylenes present [69 minutes collection time (34.5 L of air)]. Not all compounds are listed in Table 1. Some additional compounds detected in this sample included: substituted benzenes, pentanes, heptanes, heptenes and 2-propanol.

The composite air sampling of the trash bag contents [72 minutes collection time (36 L of air)] showed that compounds were present which represented primarily ubiquitous hydrocarbons, many of which are also found in gasoline (not all listed in Table 1). Dichlorofluoroethane and tetrachloroethene (also seen in the garage air sample) were detected in low concentrations. Some of the additional compounds detected in this sample include: cyclopropane, dimethyl pentane, substituted hexanes, substituted naphthalenes, cyclopentane, 2-heptene, cyclohexane and heptanal.

An adult squirrel (apparently a hit-and-run victim) obtained from Dr. Walter Klippel (Zooarchaeologist) at the Univ. of Tennessee Anthropology Dept. was placed on one piece of control carpet previously analyzed for volatile organic compounds (VOCs) and allowed to decompose outdoors for approximately ten days in an upended trashcan with fly access. After the specified time period, remnants of the squirrel were removed, the decomposition residue was brushed off with paper towels and the carpet was allowed to air dry. The maggot activity and odor was significantly less than expected. The carpet had a stained appearance and visible traces of what appeared to be blood were evident on the carpet. As much fur as possible was removed with tweezers. The carpet was then placed in a Tedlar bag, incubated at 35 degrees C for two days and 10ml of air was withdrawn from the Tedlar bag and analyzed as before. Results of this analysis showed very little similarity to the Florida carpet sample. No sulfur compounds, chloroform or carbon tetrachloride were detected in the sample.

A positive control sample was also obtained and analyzed for human decomposition products. A 4 x 4 inch section of blanket was sent to us by Dr. Walter L. Kemp, Deputy State Medical Examiner, Forensic Science Division, Department of Justice, State of Montana, autopsy case 08-09-12. In this forensic case, the decedent (last name ManyWhiteHorses - a three year old child) was wrapped in a blanket and decomposed in the trunk of a car for approximately three months. The section of blanket provided to us was markedly stained with decompositional fluid and sealed in a metal container prior to shipping. After the sample was received, it was removed and placed in a previously unused Tedlar bag and incubated at 35 degrees C for two days. 10 mLs of bag headspace were then injected onto the same GC-MS system used for all the other analyses in this case and cryofocused to concentrate the sample. Results are shown in Table 1 and confirm that relevant sulfur containing compounds such as dimethyltrisulfide, dimethyldisulfide and carbon disulfide can be produced during car trunk decompositional events. Chloroform was not detected in the blanket sample.

Select standards were purchased from Sigma-Aldrich and were used primarily to confirm retention times in order to verify compound identities. Select standards and their respective retention times are provided in Table 2.

Table 2. Retention times of select compounds of interest

| Standard purchased from Sigma-Aldrich | Retention time (Rt) |
|---------------------------------------|---------------------|
| Dimethyltrisulfide                    | 25.51               |
| Chloroform                            | 16.14               |
| Carbon tetrachloride                  | 18.36               |
| Carbon disulfide                      | 12.51               |
| Dimethyldisulfide                     | 20.84               |

A quantitation of chloroform was attempted, but the chloroform seen in the Florida carpet sample was much greater than the purchased standard. Increasing the standard concentration by a larger injection volume would have required injecting too much methanol and would have overwhelmed the signal. Looking at the integrated areas under the peaks, the control carpet had approximately 10,270 area counts and the Florida trunk sample had approximately 386,200,000 area counts. 10ng of injected standard yielded an area count of approximately 8,240,000 indicating that the Florida trunk sample had an amount of chloroform present which was in the low parts per million range. Typical concentrations seen during human decompositional events of adults yields amounts in the low parts per trillion range.

### Air sampling summary

Out of 24 compounds detected in the Florida trunk sample which did not overlap with known or possible gasoline constituents, 16 (67 %) known to be associated with human decompositional events were detected in the odor signature from the Florida trunk carpet sample whose source could not be potentially linked to any of the controls which were analyzed. These included 2-methyl furan, acetic acid methyl ester, butanoic acid methyl ester, carbon disulfide, carbon tetrachloride, chloroethane, chloroform, chloromethane, decanal, dichloroethene, dichloromethane, dimethyl trisulfide, dimethyl disulfide, hexanol, methanethiol and trichloroethene (Reference 13). Of these 16 compounds, seven were identified as significant human decomposition chemicals. Only five of these seven compounds are being used to draw conclusions about the possibility of a decompositional event occurring. Decanal and trichloroethene were dropped from this list because they were only detected in trace amounts.

These compounds are:

#### Carbon disulfide

- appears very early in human decomposition (<100 ADDs<sup>a</sup>)
- appears in both aerobic and anaerobic decomposition

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### Carbon tetrachloride

- appears very early in human decomposition (<100 ADDs)
- appears in both aerobic and anaerobic decomposition
- potentially a human specific marker (not seen in select animal remains)

### Chloroform

- appears very early in human decomposition (<100 ADDs)
- primarily detected in deprived oxygen (anaerobic) decompositions

### Dimethyl trisulfide

- appears very early in human decomposition (<100 ADDs)
- appears in both aerobic and anaerobic decomposition

### Dimethyl disulfide

- appears very early in human decomposition (<100 ADDs)
- appears in both aerobic and anaerobic decomposition

<sup>a</sup> ADD – accumulated degree day (an accumulation of average daily temperatures))

This assumes that all the control samples contributed equally to the odor signature in the trunk (which is unlikely) and does not take into account that numerous compounds in the controls were detected in trace amounts and that some were potentially highly concentrated by the TST collection procedure. [For example, fluorinated compounds were detected in the Forensics Unit Garage, but were not detected in the Florida vehicle trunk sample potentially indicating very little, if any, contribution of the garage air to the trunk signature].

TSTs collected from the Florida trunk were analyzed even though the trunk liner had been removed and the odor would not have been representative of what was originally present at the time of vehicle discovery. Even with the liner removed, sulfur containing compounds such as carbon disulfide and dimethyl disulfide, as well as carbon tetrachloride and chloroform, were still detectable in trace amounts. The trunk was the only location where all these types of compounds were detected.

Common fluorinated compounds usually associated with human decomposition were not detected in the Florida trunk sample. It is possible, although this has not been studied, that a 2-3 year old child may not have had sufficient time (many years) to ingest enough fluorinated compounds for them to be incorporated into tissue and then to appear in the decompositional breakdown of soft tissue and bone. Additionally, several of the identified compounds are typically associated with anaerobic decomposition. While the actual significance of this not known, it indicates that any type of decompositional event that might have been associated with the odor in the trunk of the car could have occurred under deprived oxygen conditions.

## Chemical Extracts

While not the main focus of these analyses, chemical extracts were also performed to determine if any additional information could be gleaned from the paper towels and a comparison on the control carpet material to carpet from the Florida car trunk. The identities of the compounds detected in these samples were performed using mass spectral library matches. Numerous attempts using standards to verify retention times were problematic. Many of the compounds

identified typically require derivatization prior to identification using GC-MS. Interestingly, the carpet extract samples (without derivatization) showed very sharp peaks with high spectral match correlations. Standards, also without derivatization, were very broad and had poor correlations. Derivatizations of the standards were not performed since this would not have been a valid comparative analysis. Additionally, persistent siloxane peaks were appearing after injection of the carpet samples which could alter the retention times of the standard compounds. This could indicate that chemicals in the carpet (e.g. Scotchgard, gasoline, chloroform, etc.) might have affected the polarity of the compounds detected in the samples (similar to derivatization). No attempt was made to mimic possible chemical conditions of the carpet material since it was not known what might have caused this effect nor was the GC column changed to one that would be more amenable to identification of these compounds without prior derivatization.

## 1. Paper towels

50mg of stained and unstained paper towels (part of the trash debris found in the trunk of the Florida vehicle) were extracted overnight in 1.0 mL methanol at room temperature along with a methanol blank. The paper towels were harbouring fly pupae which was the reason for the extraction - to determine what could have attracted the flies to the paper towels.

After injecting 1ul of extract, analysis with GC-MS detected 4-6 major peaks from the stained paper towels (Figure 6). These included: palmitic acid, stearic acid, oleic/cis-vaccenic acid (isomers – not differentiated) and myristic acid. Small amounts of THC and cannibinol were also detected. Significant furfuran derivatives were also detected potentially indicating the breakdown of cellulose in the paper towels.

Fatty acids, such as the ones detected, (palmitic, stearic, myristic, oleic) indicate a fat decomposition product like adipocere (grave wax) present on the paper towels. In typical older adipocere, palmitic acid is the most prominent acid, followed by stearic and then myristic/oleic (Reference 14). Because adipose tissue (fat) is predominantly composed of oleic acid, recent decomposing tissue samples would contain much higher concentrations of oleic acid than normal because they have not had time to convert to the saturated acids such as palmitic and stearic. This implies that the conversion of oleic acid could have occurred during the month the car was sitting in the summer heat. The percentages of fatty acids found on the paper towels were approximately: Oleic/vaccenic 38%, palmitic 33%, stearic 23% and myristic 6%. (These relative abundances are based on an assumed response factor of one in the total ion chromatogram for each of these compounds and were not experimentally verified). Palmitoleic acid was also present in the sample. While the amounts of these acids can vary, the fatty acid ratios detected on the paper towels are quite consistent with those identified in human and pig decomposition studies. (I. Bull, et. al, publication in press; S. Forbes (Reference 14 and personal communication).

## 2. Tire well scrapings

Methanol extracts of the tire well scrapings showed many diverse compounds (Acetic acid, Octadecane, 1-Heptanol, 1-Undecanol, 1-Nonanol, etc). Acetic acid (in an acid environment) and/or acetate ion (in an alkaline environment) are by-products of making chloroform with

acetone and chlorine. pH measurements of the Florida trunk carpet sample indicate that the pH of the Florida trunk carpet was approximately 5.5 (acidic), which could have caused the formation of acetic acid.

### **Laser-Induced Breakdown Spectroscopy (LIBS) for elemental analysis**

LIBS analysis was also performed on both the Florida trunk carpet sample and the control samples. As decomposition progresses, various inorganic elements found in human tissue, such as magnesium (Mg), calcium (Ca), iron (Fe) and sodium (Na) are found in increasing concentrations (over time) in drainage from decompositional events. This technique was utilized to determine if known inorganic components of decompositional events were elevated over the controls and also to determine if the relative abundance ratios of these elements could be used to determine a rough post-mortem interval (reference 6).

#### Introduction to LIBS

LIBS provides rapid multielemental microanalysis of bulk samples (solid, liquid, gas, aerosol) in the parts-per-million (ppm) range with little or no sample preparation which has been widely demonstrated (references 11-12). In this technique, a laser vaporizes a small volume of sample material with sufficient energy for optical excitation of the elemental species in the resultant sample plume. The vaporized species then undergo de-excitation and optical emission on a microsecond time scale, and time-dependent ultraviolet-visible spectroscopy fingerprints the elements associated with the spectral peaks. LIBS is typically a surface analytical technique, with each laser pulse vaporizing microgram or submicrogram sample masses. However, the rapidity of sampling (typically 10 Hz laser repetition rate) and the ability to scan a sample surface provides sufficient statistics for bulk sampling.

The greatest advantage of LIBS is its capability for remote chemical analysis of samples with minimal handling and little or no sample preparation, which minimizes generation of waste to the microgram per pulse of ablated material. The instrumentation and operation of a LIBS system is simpler than some of the more sensitive techniques, and analysis times, on the order of minutes, make it more amenable for real-time analyses of chemical processes. Although calibration standards are required for quantitative analysis, the generation of a single calibration curve typically will suffice for the analysis of samples in a similar matrix.

The experimental setup employs a Spectra Physics™ laser, model INDI-50. This is a Q-switched Nd: YAG laser that has output wavelengths at the fundamental wavelength of 1064-nm, frequency doubled to 532-nm, and frequency quadrupled to 266-nm. The maximum beam energies at 266, 532, and 1064-nm are 80, 250 and 500 mJ per pulse, respectively. The laser pulse width is 6-8 ns and the repetition rate is 10 Hz. All the processes such as plasma formation, emission, gated detection, data collection, and analysis are completed within 100 milliseconds until the next pulse arrives in the sample volume.

The pulsed laser beam is focused onto the carpet sample creating a plasma that emits bright light in all directions. The light emitted by the plasma is collected by a second lens array situated at a 45° angle to the direction of the incident laser beam and is delivered to an Acton



Research Inc. spectrometer (SpectraPro-500) via a carbon-core fiber-optic cable bundle. The resolved spectrum is detected by an intensified charge coupled device (ICCD) built by Andor Tech., with the ICCD delayed and gated by a Stanford Research Systems model SRS535 delay generator. The smallest gate width that can be achieved by this detector is 1.2 ns. All the measurements were obtained using a 2 Hz repetition rate, and the data were averaged for 25 laser shots, which is equivalent to a 12.5 seconds spectral collection time. Since the spectrometer has mechanically mounted gratings, the collected range of the spectrum is ~ 40 nm. The spectral resolution for the 40 nm window is 0.05 nm. A detailed description and drawing of the LIBS configuration can be found in a previous publication (Martin et. al. 2003) – reference #15.

The dependence of the spectral information on the input wavelength has been attributed to the enhancement of local fields associated with the wavelength of excitation and the predominant effect of multiphoton ionization at shorter wavelengths. The energy of the 532-nm photons (2.33 eV) is greater than the energy of 1064 nm photons (1.67 eV), which means that coupling of the laser and the sample is more efficient at 532-nm than at 1064-nm. A more detailed discussion of laser-matter interaction for the LIBS technique can be found in Martin and Cheng (2000) - reference #16.

All the experimental parameters such as the laser wavelength, laser energy, lens to focus the incident laser beam, and the collection lens that delivers the light emitted by plasma generated at the surface of the sample were kept constant. The only thing that was changed was the sample that was being tested. This made the experimental and data acquisition design very consistent and truly repeatable. The systematic and methodical way in which the experimentation and data acquisition was performed, gives us the utmost confidence in the data that was collected for comparative analyses of these particular samples.

In the analysis of the carpet samples that were obtained, care was taken to scan the sample consistently. The laser beam (532 nm wavelength) was focused onto the surface of the Florida trunk and control carpet samples collecting the excited light using collection optics that were delivered to a spectrometer which detected specific ranges of wavelengths. These wavelengths corresponded to between 260 nm to 300 nm for Mg, between 390 to 420 nm for Ca, between 570 to 610 nm for Na, and between 240 to 280 nm for Fe. The data were collected in multiples of five and compared to each other. All spectral information was very consistent within the multiples of spectra that were captured and analyzed. It is interesting to note that every element known to be associated with a decompositional event (that could be detected using this technique) was elevated over control values. [Other elements such as potassium, chlorine, etc. have a much different laser-matter coupling mechanism with the sample matrix than most of the metallic and semi-metallic elements and could not be detected using the current laser system].

The LIBS spectra of Ca, Mg, Na, and Fe for the control carpet and sample carpet are shown in Figures 1-4.

Calcium Signal for Control versus Sample

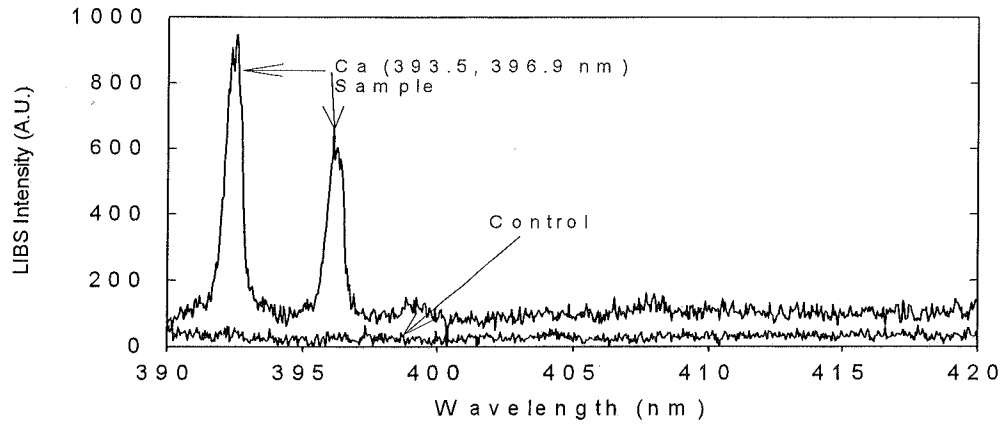


Figure 1. Spectra of control carpet and sample carpet for the presence of Calcium (Ca).

Magnesium Signal for Control versus Sample

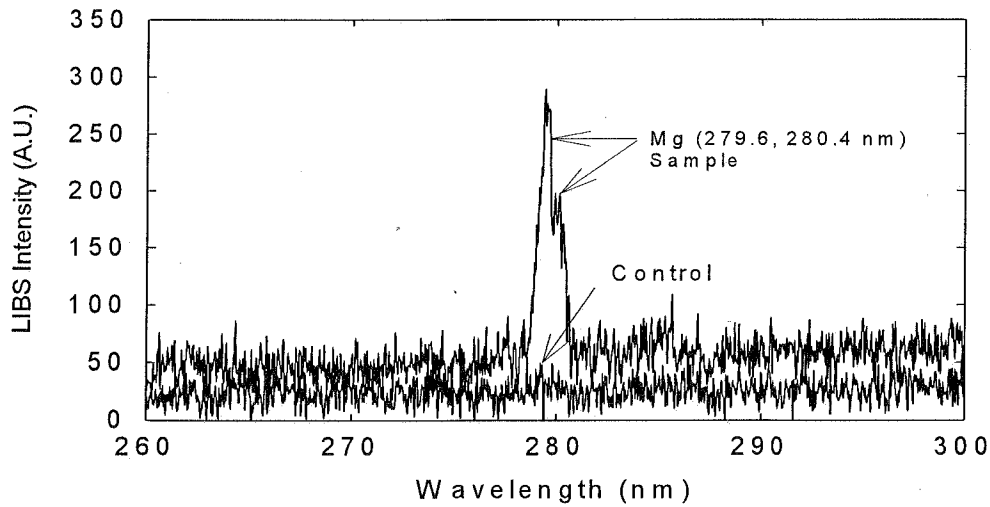


Figure 2. Spectra of control carpet and sample carpet for the presence of Magnesium (Mg).

### Sodium Signal for Control versus Sample

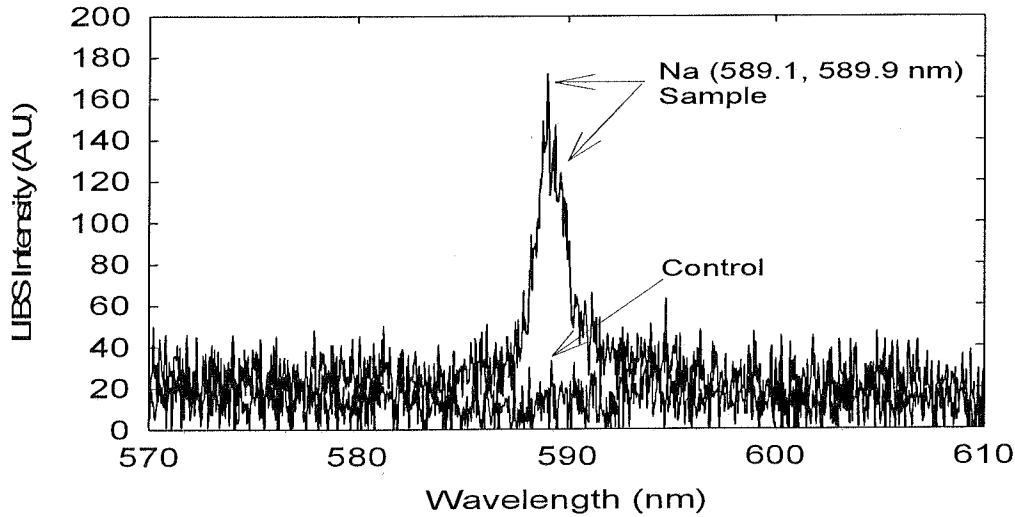


Figure 3. Spectra of control carpet and sample carpet for the presence of Sodium (Na).

### Iron Signal for Control versus Sample

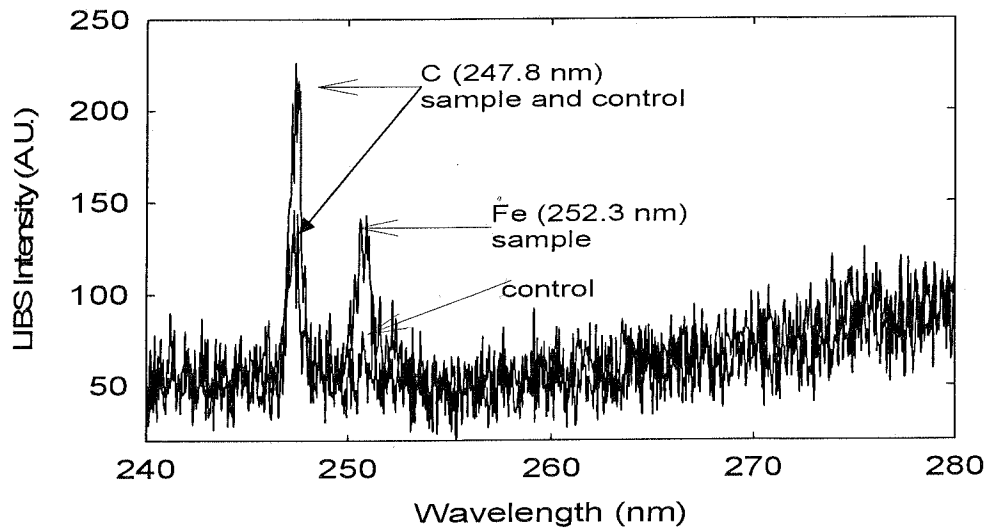


Figure 4. Spectra of control carpet and sample carpet for the presence of Iron (Fe). Carbon - (C).

### Post Mortem Interval Determination

The primary value in these LIBS data is establishing that known elements associated with human decomposition (sodium, calcium, magnesium, iron, etc) are elevated in the Florida trunk carpet sample compared to the negative control. It is also hoped that these LIBS data can be used in a

crude fashion to give a rough approximation of the post-mortem interval by using ratios of inorganic elements. For this study, the ratios between calcium and magnesium were determined using integrated areas from under the peaks in the LIBS analysis. These peaks correspond only to the primary wavelengths where these elements can be detected. Interestingly, the area ratio (3070:867) or 3.5:1 (calcium: magnesium) occurs early in the decomposition process when based on Accumulated Degree Days (ADD) - typically (<250 ADD). An ADD is simply the accumulation of average daily temperatures (in Celsius) over time, but the exact temperatures inside the vehicle trunk are not known. If one assumes it would be quite warm – Florida in the summer (~95 degrees F or 35 degrees C), this equates to <7 days of decomposition. Levels of sodium begin to rise very rapidly soon after the onset of decomposition so the levels of sodium should have been much higher than what was detected using LIBS if decomposition had truly been out to 7 days. Even though the error estimation for sodium is quite high as one approaches the beginning of decomposition, this points to a much earlier post-mortem interval. The low concentration of sodium also indicates almost no contribution to the sample from the BlueStar product. Low amounts of carbon (C) also indicate a potentially recent PMI.

Volatile fatty acid (VFA) analysis is the best means of determining a post-mortem interval in this instance (reference 6). Analysis of the Florida trunk carpet indicated that the only VFA detectable in the Florida trunk sample was butyric acid. This fits very nicely with an early decomposition model since valeric and propionic acids do not appear until 94 and 150 ADD, respectively. Butyric acid becomes detectable after only 25 ADD (Reference 6). Using the 35 degree Celsius model described above, this indicates a post-mortem interval of less than 2.6 days (range of 0.7-2.6 days).

Inorganic analyses of soil samples taken from underneath the remains of the decedent in this case were analyzed to assist in determining and refining the post-mortem interval. Results of these analyses were inconclusive and a post-mortem interval could not be established in this manner. This was most likely due to large amounts of water (flooding) diluting the soil to the point where the inorganic indicators became unreliable.

Finally, we wish to discuss the possibility that these chemical signatures are of human origin. The decomposition odor products of animal remains (dog, deer and pig - primarily bone) have been studied since these are the most commonly encountered in outdoor environments. These animals can be distinguished from human remains by the percentages of certain classes of chemicals (ketones, amides, aldehydes and alcohols). While the direct correlation of animal bone to early human decomposition may not be exact, the results are interesting and potentially point to a human origin as the source of the scent. Table 3 shows which compounds were detected in the Florida trunk sample and compares them to what is known about animal decomposition.

Table 3

| Compound Class | Compound                       | Detected in FL trunk Tedlar bag sample? | Detected in selected animal remains? | Detected in human remains | Approximate ADD when first detected in human remains |
|----------------|--------------------------------|---|--------------------------------------|---------------------------|--|
| Ketone         | 2-propanone                    | yes                                     | Yes (pig only)                       | yes                       | 230  |
| Ketone         | 2-decanone                     | no                                      | yes                                  | yes                       | 1976 (late)  |
| Ketone         | 2-nonanone                     | no                                      | yes                                  | yes                       | 4011 (late)  |
| Amide          | <b>Acetamide, N,N-dimethyl</b> | no                                      | yes                                  | no                        |  |
| Aldehyde       | hexanal                        | no                                      | yes                                  | yes                       | 1698 (late and low concentration)                    |
| Aldehyde       | heptanal                       | no                                      | yes                                  | yes                       | 1698 (late and low concentration)                    |
| Aldehyde       | nonanal                        | no                                      | yes                                  | yes                       | 400 (very low concentration)                         |
| Aldehyde       | octanal                        | no                                      | yes                                  | yes                       | 4011 (late)  |
| Aldehyde       | pentanal                       | no                                      | yes                                  | yes                       | 4011 (late)  |
| Aldehyde       | decanal                        | yes                                     | yes                                  | yes                       | 475  |
| Aldehyde       | butanal                        | Yes (trace)                             | Yes (pig only)                       | yes                       | Aerobic decomposition product only                   |
| Alcohol        | Phenol                         | no                                      | Yes (dog only)                       | yes                       | 200 (primarily aerobic decomposition product)        |
| Alcohol        | 1-pentanol                     | no                                      | yes                                  | yes                       | 1307   |
| Alcohol        | <b>1-heptanol</b>              | no                                      | yes                                  | no                        |  |
| Alcohol        | 1-hexanol                      | yes                                     | Yes (pig only)                       | yes                       | 536  |
| Alcohol        | ethanol                        | yes                                     | Yes (pig only)                       | yes                       | 1307 (gasoline component)                            |

While not conclusive, these data indicate that:

- 1) Nearly all the compounds present in early human decomposition were detected in the trunk samples if their concentrations were high enough to detect. Carbon tetrachloride was also detected and is a human specific marker within these animal sets.
- 2) Compounds that have been detected in these select animal remains and not in humans were not detected in the Florida trunk carpet sample (1-heptanol, Acetamide, N,N-dimethyl). This is also suggestive of a human decompositional event.
- 3) Compounds associated with anaerobic decomposition are seen supporting a possible deprived oxygen type of decompositional event.
- 4) Compounds with a late ADD were not detected supporting an early stage decompositional event.

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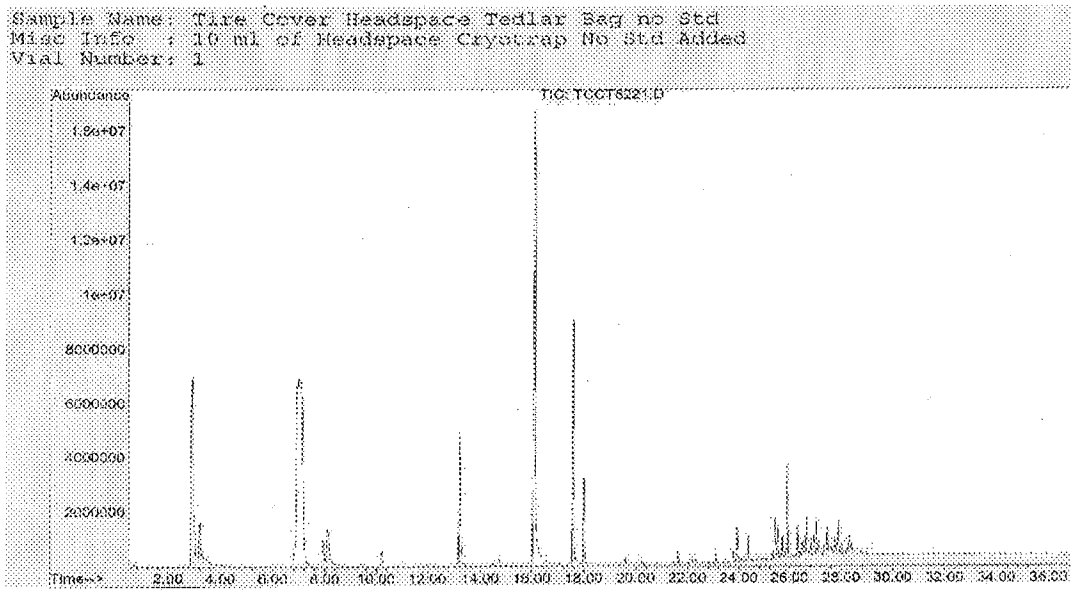


Figure 5. GC/MS of Florida trunk carpet sample headspace. The largest peak is chloroform at 16 min (Rt).

Sample Name: Methanol Extract of Contaminated Towel  
Misc Info : 1 ul Injection Expanded Scan Range  
Vial Number: 1

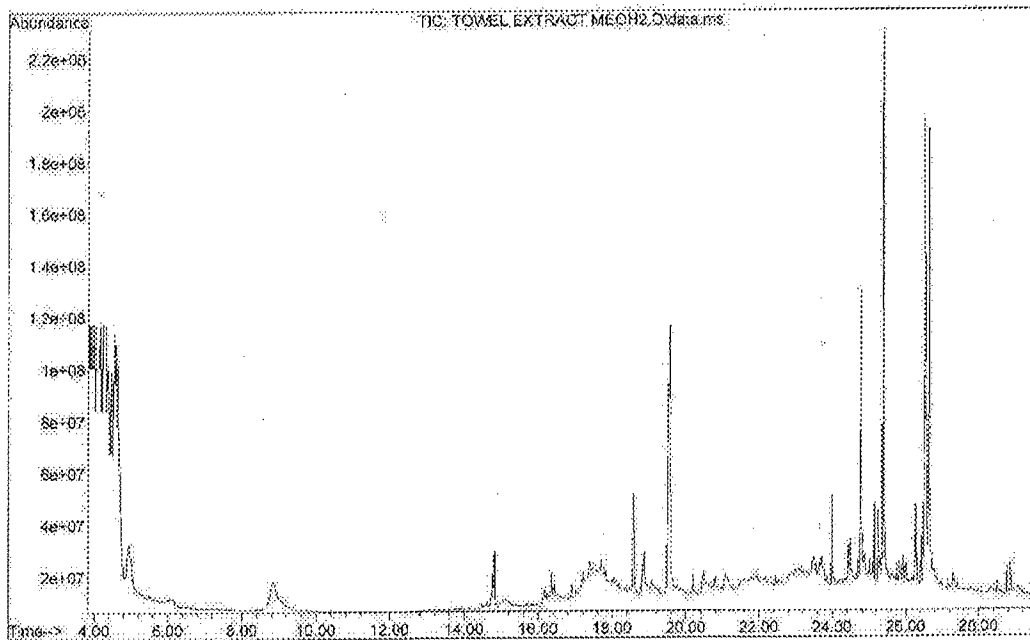


Figure 6. Methanol extract of paper towels. Largest peaks (25-27 minutes) are fatty acids potentially associated with adipocere formation.

Law Enforcement Sensitive

Sample Name: Control Carpet Sample from Junkyard  
Misc Info : 10 ml. of Air Tedlar Bag  
Vial Number: 1

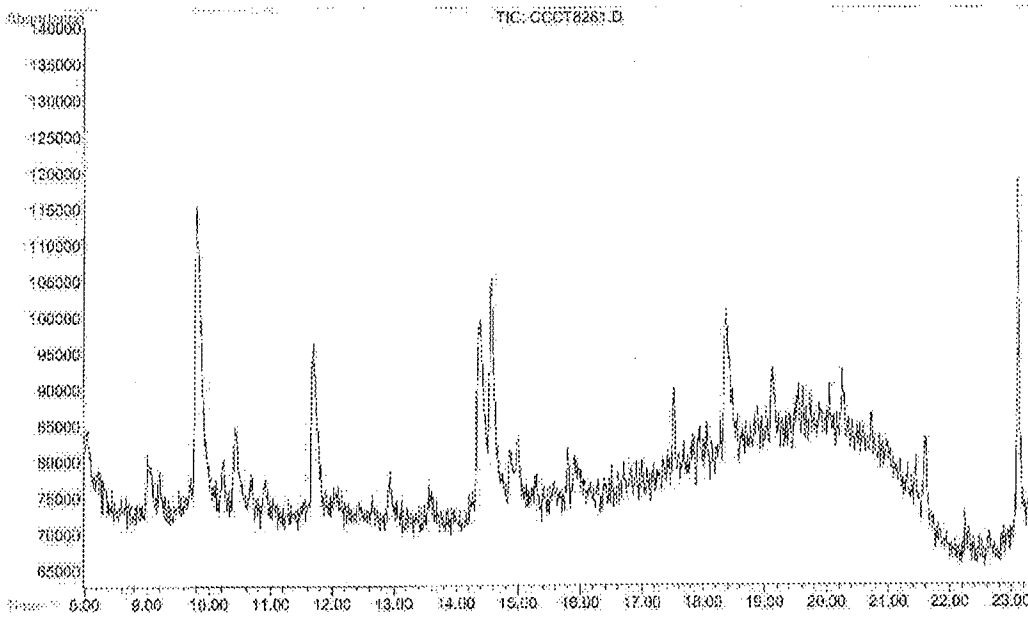


Figure 7. Close-up of trace amounts of chloroform seen in control carpet sample at 16 minutes. Note the scale difference compared to Fig. 5.

## Conclusions

### **The correlations between the following techniques:**

- 1) LIBS – showing elevated elements typically associated with human decomposition;
- 2) VFA analysis – showing early PMI;
- 3) Chemical Extractions – showing adipocere ratios consistent with human decomposition and the presence of acetic acid;
- 4) The comparison to what is known about the decomposition of human and animal remains;
- 5) Indications of early decomposition products and the presence of the five key major compounds associated with human decomposition (primarily the sulfur containing compounds);
- 6) Montana positive control sample;

**indicate that a portion of the total odor signature identified in the Florida vehicle trunk is consistent with an early decompositional event that could be of human origin.**

Additional components that made up a portion of the total odor signature included gasoline constituents and an unusually large concentration of chloroform - far greater than what is typically seen in human decomposition. [Of particular interest is the presence of chloroform (not a common ingredient in commercial products) and sulfur containing compounds in the Florida trunk carpet sample which are particularly characteristic of decompositional events].

These results still do not rule out the remote possibility that an unusual variety of products or materials (not present in the trunk at the time of vehicle discovery) may have had some contribution to the overall chemical signature.

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Analytical chemist

Madhavi Martin, Ph.D.  
Physicist



References:

1. Cecil E. Higgins, Roger A. Jenkins, and Michael R. Guerin, "Organic Vapor Phase Composition of Sidestream and Environmental Tobacco Smoke from Cigarettes," Proceedings of the 1987 EPA/APCA Symposium on Measurement of Toxic and Related Air Pollutants, pp. 140-145, 1987.
2. Cheng-Yu Ma, J. Todd Skeen, Amy B. Dindal, Charles K. Bayne, and Roger A. Jenkins; "Performance Evaluation of a Thermal Desorption /Gas Chromatography/Mass Spectrometric Method for the Characterization of Waste Tank Headspace Samples," *Environmental Science and Technology*, 31, 853- 859 (1997).
3. Sung-Ok Baik and Roger A. Jenkins, (2004) "Characterization of Trace Organic Compounds Associated with Aged and Diluted Sidestream Tobacco Smoke in a Controlled Atmosphere-Volatile Organic Compounds and Polycyclic Aromatic Hydrocarbons," *Atmospheric Environment*, 38, 65-83.
4. Vass, A.A., Smith, R.R., Thompson C.V., Burnett, M.N., Dulgerian N., Eckenrode B.A. Odor Analysis of Decomposing Buried Human Remains. *J. Forensic Sciences*, 53 (2): 384-392, March 2008.
5. Vass, A.A., Smith, R.R., Thompson C.V., Burnett, M.N., Wolf D.A., Synstelien J.A., Eckenrode B.A., Dulgerian N. Decompositional Odor Analysis Database. *J. Forensic Sciences*, 49 (4): 760-769, July 2004.
6. Vass, A.A., Bass, W.M., Wolt, J.D., Foss, J.E., Ammons, J.T., "Time Since Death Determinations of Human Cadavers Using Soil Solution", *Journal of Forensic Sciences*, 37(5):1236-1253, Sept. 1992.
7. Cole, G.M. 1994. Assessment and Remediation of Petroleum Contaminated sites. Lewis Publishers, Boca Raton, Fl, 360p.
8. Cummings, W.M. 1977. "Fuel and Lubricant Additives – I: Fuel additives." *Lubrication*, Vol 63, No. 1: 1-12.
9. Irwin, R.J., M. Van Mouwerik, L. Stevens, M.D. Seese, and W. Basham. 1997. Environmental Contaminants Encyclopedia. National Park Service, Water Resource Division, Fort Collins, CO.
10. Ma, C.Y. Skeen, J.T. Dindal, A.B. Higgins, C.E. Jenkins, R.A. Triple sorbent thermal desorption/gas chromatography/mass spectrometry determination of vapor phase organic contaminants. Conference number CONF-9405167-1: Measurement of toxic and related air pollutants, Durham, NC, 3-6 May 1994.
11. Madhavi Z. Martin, Nicole Labbe, Timothy G. Rials, and Stan D. Wullschleger, "Analysis of preservative-treated wood by multivariate analysis of LIBS spectra", *Spectra Chimica Acta B.*, Vol. 60/7-8 pp 1179-1185, 2005.
12. Madhavi Z. Martin, Stan. Wullschleger, Charles T. Garten Jr., Anthony V. Palumbo, and John G. Smith. "Elemental Analysis of Environmental and Biological Samples using Laser-Induced Breakdown Spectroscopy and Pulsed Raman Spectroscopy". *J. Disper. Sci. and Technol.* Vol. 25, No. 5, pp. 689–696, 2004.
13. Statheropoulos, M., Spiliopoulou, C., Agapiou, A. A study of volatile organic compounds evolved from the decaying human body. *Forensic Science International*, 153, pp. 147-155, 2005.
14. S.L. Forbes, B.H. Stuart, B.B. Dent. The identification of adipocere in grave soils. *Forensic Science International* 127, pp. 225–230, 2002.

15. Madhavi Martin, Stan Wullschleger, Charles Garten Jr., and Anthony Palumbo, "Laser-induced Breakdown Spectroscopy for the Environmental Determination of Total Carbon and Nitrogen in Soils," *Applied Optics*, 42(12), 2072-2077 (2003).
16. Martin, M. Z. and M. D. Cheng, "The Detection of Chromium Aerosol using Time-Resolved Laser-Induced Plasma Spectroscopy," *Appl. Spectrosc.*, 54(9).
17. Rosenfeld, P.E., Henry, C. Dills, R.L., Harrison, R.B. "Comparison of odor emissions from three different biosolids applied to forest soil". *Water, Air and Soil Pollution* 127:173-191, 2001.
18. Ranau, R. Steinhart, H. "Identification and evaluation of volatile odor-active pollutants from different odor emission sources in the food industry". *Eur Food Res Technol* 220:226-231, 2005.
19. ASTM Standards: Method TO-3, April 1984. "Method for the determination of volatile organic compounds in ambient air using cryogenic preconcentration techniques and gas chromatography with flame ionization and electron capture detection". Rev 1.0.

Tables listing the constituents of gasoline

**Table 3. Constituents of Motor Gasoline**

|                 |   |   |
|-----------------|---|---|
| <b>Organics</b> | <p>methyl tertiary-butyl ether (MTBE)</p> <p>ethanol</p> <p>ethyl tertiary-butyl ether (ETBE)</p> <p>tert-butyl alcohol (TBA)</p> <p>tert-amyl ethyl ether (TAE)</p> <p>disopropyl ether (DPE)</p> <p>tert-amyl methyl ether (TAME)</p> <p>tert-amyl alcohol (TAA)</p> <p>methanol</p> <p>Anti-knock compounds</p> <p>tert-amyl lead (TEL)</p> <p>tert-butyl lead (TBL)</p> <p>tert-butylcyclopentadienyl manganese tricarbonyl (TBM)</p> <p>Anti-oxidant compounds</p> <p>lindered phenols</p> <p>phenyleth diamines</p> <p>antioxidants</p> <p>Anti-icing compounds</p> <p>isopropyl alcohol</p> <p>aromatic amines</p> <p>glycols</p> <p>organophosphoric ammonium salts</p> | <p>Corrosion inhibitors</p> <p>carboxylic acids</p> <p>sulfonates</p> <p>aminealkyl phosphates</p> <p>Metal deactivators</p> <p>disalcylate amines</p> <p>phosphoric amines</p> <p>thiourea</p> <p>Ignition controller additives</p> <p>tri-o-cresol phosphates</p> <p>Detergents</p> <p>aminopolyoxyamide</p> <p>alkylphenols</p> <p>imidazolones</p> <p>Lead scavengers</p> <p>1,2-dithioethane (EDC)</p> <p>1,2-dithiocethane (EUB)</p> <p>Dyes</p> <p>azobenzene-4-oxo-2-naphthol</p> <p>benzene-oxo-2-naphthol</p> <p>penta-diethyl aminoazobenzene</p> <p>1,4-dithiooxytarnitouracilamine</p> |
|-----------------|---|---|

Source: Adapted from Chemicals (1977) and Davis, et. al. (1987).

**Table 4. Representative Organic Compounds Found in Gasoline**

|                               |   |   |
|-------------------------------|---|---|
| <b>Straight Chain Alkanes</b> | <p>propane</p> <p>n-hexane</p> <p>n-dodecane</p>                                  | <p>Cycloalkanes</p> <p>cyclopentane</p> <p>3-methylcyclopentane</p>   |
| <b>Branched Alkanes</b>       | <p>isobutane</p> <p>2,2-dimethylbutane</p> <p>isopentane</p> <p>3-ethylhexane</p> | <p>Alkyl Benzenes</p> <p>benzene</p> <p>toluene</p> <p>ethylbenzene</p> <p>o-xylene</p> <p>m-xylene</p> <p>p-xylene</p> <p>1,2-dimethyl-3-ethylbenzene</p> <p>1,2,5-trimethylbenzene</p> <p>1,2,4,5-tetramethylbenzene</p> <p>n-propylbenzene</p> |
| <b>Cycloalkanes</b>           | <p>cyclohexane</p> <p>n-propylcyclopentane</p> <p>ethylcyclohexane</p>            | <p>Other Aromatics</p> <p>indan</p> <p>1-methylindan</p> <p>prenol</p>  |
| <b>Straight Chain Alkanes</b> | <p>cis-2-hexene</p> <p>1-pentene</p> <p>trans-2-heptene</p>                       | <p>Polycyclic Aromatic Hydrocarbons (PAHs)</p> <p>naphthalene</p>   |
| <b>Branched Alkanes</b>       | <p>2-methyl-1-butene</p> <p>4,4-dimethyl-cis-2-pentene</p>                        | <p>Source: Adapted from Cole (1984).</p>  |

Table 1

| Compounds identified in odor from Florida trunk carpet sample (Tedlar bag) | Is compound listed in Decompositional Odor Database? | Compounds identified in control carpet samples from Knoxville Junkyard? | TST -Compounds identified in trash bag contents from Florida trunk? | TST - Compounds identified in Florida vehicle interior | Compounds detected in ORNL laboratory air | Compounds detected in decomposing pizza | Is compound found in gasoline vapors? | TST - Compounds detected in FL garage air | TST - Compounds detected in trip blank | Positive control sample from Montana | Comments   |
|--|--|---|---|--|---|---|---------------------------------------|---|--|--------------------------------------|--|
| 1-methyl-ethyl benzene   | Yes  | no  | no  | no   | no  | no                                      | Yes                                   | no  | no                                     | no                                   |  |
| 1,2-Pentadiene   | Yes  | no  | no  | no   | no  | no                                      | maybe                                 | no  | no                                     | no                                   |  |
| 2-butanone   | Yes  | no  | no  | no   | no  | Yes <sup>1</sup>                        | no                                    | no  | no                                     | Yes                                  |  |
| 2-chloropropane  | no   | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   |  |
| 2-methyl furan   | Yes  | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   |  |
| 2-methyl hexane  | Yes  | no  | Yes   | no   | no  | no                                      | Yes                                   | no  | no                                     | no                                   |  |
| 2-methyl propanenitrile  | no   | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   |  |
| 2,3-butanediene  | no   | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   |  |
| 2-methyl butanal   | no   | no  | no  | no   | no  | Yes <sup>1</sup>                        | no                                    | no  | Yes                                    | Yes                                  |  |
| 3-methyl butanol   | no   | no  | Yes   | Yes  | no  | Yes <sup>1</sup>                        | maybe                                 | no  | no                                     | no                                   |  |
| 3-methyl hexane  | Yes  | no  | Yes   | Yes  | no  | no                                      | maybe                                 | Yes                                       | no                                     | no                                   |  |
| 3-methyl pentane   | Yes  | no  | Yes   | Yes  | no  | no                                      | Yes                                   | Yes                                       | no                                     | no                                   |  |
| 3-methyl butanal   | Yes  | Yes <sup>1</sup>  | no  | no   | no  | Yes <sup>1</sup>                        | no                                    | no  | no                                     | Yes                                  |  |
| 4-methyl-2-pentanone   | no   | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   |  |
| Acetaldehyde   | Yes  | Yes <sup>1</sup>  | no  | no   | no  | Yes                                     | Yes                                   | no  | no                                     | Yes                                  |  |
| Acetic acid, methyl ester  | Yes  | Yes <sup>1</sup>  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   |  |
| Acetone (2-propanone)  | Yes  | Yes <sup>1</sup>  | no  | no   | no  | Yes <sup>1</sup>                        | no                                    | no  | no                                     | no                                   |  |
| Benzene  | Yes  | no  | Yes   | Yes  | no  | Yes                                     | Yes                                   | Yes                                       | Yes                                    | Yes                                  | One of top chemicals in database   |
| Butanal  | Yes  | Yes <sup>1</sup>  | no  | no   | no  | no                                      | no                                    | no  | Yes                                    | Yes                                  |  |
| Butanoic acid, methyl ester  | Yes  | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   |  |
| Carbon disulfide   | Yes  | trace*  | no  | no   | no  | no                                      | no                                    | no  | no                                     | Yes                                  | One of top chemicals in database   |
| Carbon tetrachloride   | Yes  | no  | trace*  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   | One of top chemicals in database   |
| Chloroethane   | Yes  | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   | Unusually high amount detected; One of top chemicals in database (anaerobic formation) |
| Chloroform   | Yes  | Yes <sup>1</sup> (trace amounts)  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   | One of top chemicals in database   |
| Chloromethane  | Yes  | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | Yes                                  | One of top chemicals in database   |
| Decanal  | Yes (trace)  | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   | One of top chemicals in database   |
| Dichloroethane   | Yes  | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | Yes                                  | One of top chemicals in database   |
| Dichloromethane  | Yes  | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | Yes                                  | One of top chemicals in database   |
| Dimethyl trisulfide  | Yes  | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | Yes                                  | One of top chemicals in database   |
| Dimethyl undecane  | no   | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   | One of top chemicals in database   |
| Dimethyldisulfide  | Yes  | no  | no  | trace <sup>1</sup>                                     | no  | trace <sup>1</sup>                      | no                                    | no  | no                                     | Yes                                  | One of top chemicals in database   |
| Ethanol  | Yes  | Yes <sup>1</sup>  | no  | no   | no  | Yes (large amount)                      | Yes                                   | no  | no                                     | Yes                                  |  |
| Etheneamine  | no   | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   |  |
| Ethyl benzene  | Yes  | no  | no  | no   | no  | no                                      | Yes                                   | no  | no                                     | no                                   | One of top chemicals in database   |
| Hexane   | Yes (trace)  | Yes   | no  | Yes  | no  | Yes <sup>1</sup>                        | Yes                                   | no  | no                                     | no                                   | One of top chemicals in database   |
| Hexanol  | Yes  | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   |  |
| Isobutanol   | Yes  | no  | no  | no   | no  | Yes <sup>1</sup>                        | no                                    | no  | no                                     | no                                   |  |
| Isocitane  | Yes  | no  | no  | no   | no  | no                                      | Yes                                   | no  | no                                     | no                                   |  |
| Limonene/Pinene  | Yes  | no  | Yes (limonene)  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   | Terpenes (one source is from vegetation)   |
| Methanethiol   | Yes  | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | Yes                                  |  |
| Methanol   | Yes - see comment                                    | Yes <sup>1</sup>  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   | Methanol identified subsequent to database development                                 |
| Naphthalene  | Yes  | no  | Yes   | no   | no  | Yes                                     | Yes                                   | no  | no                                     | no                                   | One of top chemicals in database (anaerobic formation)                                 |
| Oxane  | Yes  | no  | no  | Yes  | no  | no                                      | Yes                                   | Yes                                       | Yes                                    | no                                   |  |
| Pentane  | Yes  | no  | no  | Yes  | no  | Yes <sup>1</sup>                        | no                                    | Yes                                       | Yes                                    | no                                   | One of top chemicals in database (anaerobic formation)                                 |
| Tetrachloroethene  | Yes  | no  | Yes   | no   | no  | no                                      | no                                    | Yes                                       | no                                     | no                                   |  |

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Table 1 - cont (page 2/2)

| Compounds identified in odor from Florida trunk carpet sample (Tedlar bag) | Is compound listed in Decompositional Odor Database? | Compounds identified in control carpet samples from Knoxville Junkyard? | TST -Compounds identified in trash bag contents from Florida trunk? | TST - Compounds identified in Florida vehicle interior | Compounds detected in ORNL laboratory air | Compounds detected in decomposing pizza | Is compound found in gasoline vapors? | TST - Compounds detected in FL garage air | TST - Compounds detected in trip blank | Positive control sample from Montana | Comments                             |
|--|--|---|---|--|---|---|---------------------------------------|---|--|--------------------------------------|--------------------------------------|
| Tetrahydro furan   | no   | no  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   |                                      |
| Toluene  | Yes  | Yes <sup>1</sup>  | Yes   | Yes  | no  | Yes                                     | Yes                                   | no  | no                                     | Yes                                  | One of top chemicals in database     |
| Trichloroethene  | Yes (trace)  | no  | no  | no   | no  | no                                      | no                                    | Yes (less than in FL carpet sample)       | no                                     | no                                   | One of top chemicals in database     |
| Trimethyl pentene  | Yes  | no  | no  | no   | no  | no                                      | maybe                                 | no  | no                                     | no                                   |                                      |
| Xylene(s)  | Yes  | no  | Yes   | Yes  | no  | Yes <sup>1</sup>                        | Yes                                   | no  | no                                     | no                                   |                                      |
|  | yes  | no  | Yes   | no   | 1,3 butadiene, 2-methyl <sup>1</sup>      | no                                      | no                                    | Yes                                       | no                                     | no                                   | Not detected in Florida trunk sample |
|  | no   | no  | no  | Yes  | 1,3 Pentadiene <sup>1</sup>               | no                                      | maybe                                 | Yes                                       | no                                     | no                                   | Not detected in Florida trunk sample |
|  | no   | I-butanol   | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   | Not detected in Florida trunk sample |
|  | no   | 2-methyl propanol   | no  | no   | no  | 2-methyl propanol                       | no                                    | no  | no                                     | no                                   | Not detected in Florida trunk sample |
|  | yes  | 2-methyl-1-propene  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   | Not detected in Florida trunk sample |
|  | yes  | 2-propanol  | no  | no   | no  | no                                      | no                                    | no  | no                                     | no                                   | Not detected in Florida trunk sample |
|  | yes  | no  | no  | no   | no  | Hexanal                                 | no                                    | no  | Yes                                    | no                                   | Not detected in Florida trunk sample |

<sup>1</sup>Significantly less detected than in 1998 Pontiac Sunbird in Florida; trace\* - tentative identification, unable to confirm identification due to very low concentration and overlap with higher abundance constituents

What are Tedlar® bags?

Tedlar® bags are made from a polyvinyl fluoride (PVF) film that is tough, durable, and chemically inert to a wide range of compounds. Bags used in environmental applications typically have a 2 mil film thickness and are applicable for a wide temperature range (98-225 °F). The bags have heat sealed, leak-proof seams and can be used to collect both liquid and air samples. This versatility allows the bags to be used for a variety of applications. Applications include: stack sampling, vent/flue sampling, soil gas sampling, TCLP extractions, calibration gas blending and preparation of standards, indoor air sampling, and ground water testing.

What compounds can be collected in a Tedlar® bag?

Tedlar® bags are not recommended for use with reactive compounds and compounds that might adhere to the bag's surface. Due to the chemical structure of Tedlar®, highly polar compounds (such as alcohols or amines) will adhere to the inner surface of the bag. Additionally, low molecular weight compounds may permeate the bag. Keep in mind that the more reactive the compound, the less time it may be kept in the bag before the sample results begin to be compromised. Holding times of 24 hours are recommended for mercaptans, hydrogen sulfide, and other sulfur gases. A 72-hour holding time is recommended for atmospheric gases such as oxygen, nitrogen, carbon monoxide, etc.

Can Tedlar® bags be used to collect light sensitive compounds?

Light sensitive compounds and halogenated volatile organic compounds (VOCs) can be collected in black or layered Tedlar® bags. The black and layered bags protect the contents from light that causes sample degradation. Note that black Tedlar® contains carbon black which may absorb some compounds. Layered bags are typically constructed with layer of black Tedlar® on the outside and a layer of clear Tedlar® on the inside of the bag removing the worry of any compounds being absorbed by the carbon black.

Can Tedlar® bags be reused?

It is possible to reuse Tedlar® bags for some applications. You should not reuse the bag after sampling compounds found at ppbv (parts per billion) concentrations, reactive compounds, or compounds that are known to adhere to the surface of the bag. Prior to reuse, the bags must be evacuated and thoroughly cleaned and flushed after each use with purified air or nitrogen. It's recommended to perform an analysis of the final flush to ensure that the background levels present in the bag are acceptable for its intended use.

Can Tedlar® bags be sent via an air courier?

Tedlar® bags shipped by air are placed in the cargo holds that are not pressurized. The contents of the bags will expand when exposed to the lower pressure conditions reached

at cruising altitudes. For this reason, fill the bag to less than 50% of its maximum volume to give the contents room to expand. Otherwise, the bag may burst during transit.

How do I collect a sample using a Tedlar® bag?

There are commercially available systems available for rent or purchase to use for sample collection. All systems essentially work in the same manner. A Tedlar® bag is placed in a leak-free box, cylinder, or even plastic bucket connected to a sample pump. The bag is connected to Teflon tubing that extends outside the container holding the bag into the area to be sampled. The pump draws a vacuum within the container and resulting pressure differential causes the sample to be drawn through the Teflon tubing into the bag. Note that the sample in the Tedlar® bag never passes through the sample pump. Shown below are diagrams of a typical cylinder sampling container and a diagram of a vacuum box.

### Sampling Tips

- Store sample bags in a clean environment away from potential sources of contamination.
- During transportation to the sample site or laboratory, keep the bags away from potential sources of contamination such as automobile exhaust.
- Use only Teflon tubing and Teflon-lined septums for bag sampling.
- Ensure the Teflon tubing used to collect the sample is clean.
- Flush the bag thoroughly w/ purified air or nitrogen before sampling.
- Always leak check the bags prior to use by filling the bag and leaving it under pressure overnight. If the bag deflates, it should not be used for sample collection.
- Consider collecting a Trip Blank that contains zero air to detect any contamination within the bag.
- Avoid marking directly on the bag with a marker or affixing a sample label as the adhesives found in the label and volatile compounds found in the marker may permeate the bag and contaminate the sample.

### Chemically Inert

Tedlar film is inert to a wide range of chemicals. Since Tedlar will not react with or alter the composition of collected chemicals, sample integrity is assured.

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**OBJECTIVE** Pursue R&D in the design, fabrication, and testing of environmental sensors specifically for chemical and biological applications.

**EXPERTISE** Design, fabrication, and testing of ion mobility spectrometer on a chip  
Laser-induced Breakdown and remote Raman spectroscopy, Time-of-flight mass spectrometry, Fabrication of microstrip line, coplanar waveguide, and coplanar strip line photoconductive, switches using silicon-on-sapphire, low-temperature GaAs, and -silicon materials, Mask alignment, thickness measurement, lapping and polishing, wire bonding, electroplating, Optoelectronic characterization of three terminal devices (PHEMTs, HBTs, MESFETs), Cryogenic behavior of semiconductor devices, Photoluminescence of heterostructure layers.

**EDUCATION** **Ph.D. in Physics**, University of California, Los Angeles, 1992  
Thesis Topic: Picosecond Optical Response of Three-Terminal Devices  
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**M.S. in Solid-State Physics**, Shivaji University, Kolhapur, India, 1982  
Thesis Topic: Transport and Magnetic Properties of Amorphous Semiconductors  
**B.S. in Physics**, University of Nagpur, India, 1980

**HONORS** **Journal: Applied Optics**  
Feature Issue on Laser Induced Breakdown Spectroscopy  
**Editors: Jagdish P. Singh, Madhavi Z. Martin, and Andrzej W. Miziolek (1 Nov 2008)**  
**Awarded Sir Frederick McMaster Fellowship by the Commonwealth Scientific and Industrial Research Organization (CSIRO)** in Australia in 2007-2008 to explore the development of rapid assessment tools for characterizing the chemical and mechanical properties of wood, wood products, and woody and herbaceous biomass for biofuels applications.  
**Appointed to the International Scientific Committee** for the Laser-induced Breakdown Spectroscopy Society, 2004-present  
**SERDP Project of the Year Award**, Co-PI of the project for continuous monitoring of smoke stack emissions by LIPS, 1997 – 2000  
**Graduate Opportunity Fellowship**, University of California, Los Angeles, 1989 – 1990  
**Rotary Fellowship**, Rotary International Foundation, 1985 - 1986  
**University Grants Commission Fellowship**, India, 1983 – 1985  
**Gold Medal in Physics**, Shivaji University, India, 1982

**PATENT DISCLOSURES**

US Patent No 7,251,022 issued for “Dual Fiber Microprobe for Mapping Elemental Distributions in Biological Cells.”  
Invention Disclosure 0713 was filed for “Novel method for preparing and encapsulating radioactive material source forms.”  
Patent disclosure 1108 was filed for “Ultra-performance Detector for Chemical, Biological Warfare Agents and for Homeland Defense.”



**EXPERIENCE**

Oak Ridge National Laboratory, Oak Ridge, Tenn.

1999 - present, Staff Research Scientist

1994 - 1999, Research Associate

**LIBS of natural and engineered wood:** Research in the design and evaluation of a laser-induced breakdown spectroscopy (LIBS) system capable of rapid and simultaneous elemental analysis in wood.

**LIBS of soil:** Detection of total carbon and nitrogen in soils. Heavy metal and radionuclide detection in soils.

**Raman spectroscopy of soil:** Characterization of soil organic matter for carbon sequestration.

**Microwave heating of soil:** Release of dense non-aqueous phase liquid contaminants from soil for in situ detection.

**Laser-induced plasma spectroscopy:** R&D of portable toxic metal monitor for smoke stack emissions and optimized for Cr, Ni, V, Hg, and Pb aerosols. Extension to solids, cellular, and soil sampling.

**Laboratory-on-a-chip:** Development and testing of miniature ion mobility spectrometer.

**Chemical physics of ions and clusters:** Laser-induced clustering of NO using time-of-flight mass spectrometry. Electron attachment to laser-excited molecules (SiH<sub>4</sub>, H<sub>2</sub>O, CH<sub>4</sub>).

University of Tennessee, Knoxville, Measurement and Control Engrg. Center, 1992-1994,  
Research Associate

**Optical acid sensor:** Proposed and developed a non-intrusive optical method for on-line and remote pH measurements of strongly acidic solutions (pH < 1). Patent disclosure filed for thin film optical pH sensor.

**Fiber optic Raman spectroscopy:** Remote monitoring for process control on industrial-scale organic distillation column.

University of California, Los Angeles, Depts. of Physics, Electrical Engineering, and Chemistry,  
1986-1992

**Optical and electrical properties of three-terminal devices:** Used an optical picosecond network analyzer system to measure the optoelectronic response of HEMTs and HBTs (S-parameters, optical response, cryogenic temperature behavior, photoluminescence), polymer waveguides, and state-of-the-art high-frequency microwave devices fabricated by local industry (TRW, Rockwell, Hughes). Experienced in test fixture fabrication and use of spectrum and parameter analyzers and related instrumentation.

**Transport properties of CuCl thin film heterostructures:** Modified resistivity measurement equipment for application to high resistivity materials and thin film heterostructures. Designed and built a room-temperature four-probe resistivity measuring apparatus. Analyzed samples using FTIR spectroscopy.

Shivaji University, Physics Department, 1983-1985

**Transport and magnetic properties of amorphous semiconductors:** Designed and built high-temperature conductivity equipment. Grew amorphous semiconductors and chalcogenide glasses; analyzed their resistivity, magnetic properties, thermoelectric power, and effects of  $\gamma$ -irradiation on transport properties.

**PUBLICATIONS (total 34)**

Nicole Labbé, Isabel Maya Swamidoss, Nicolas André, Madhavi Z. Martin, Timothy M. Young, and Timothy G. Rials, "Extraction of information from laser-induced breakdown spectroscopy spectral data by multivariate analysis", *Appl. Opts.* vol 47 No.31 (Nov 1 2008) G158-G165.

Madhavi Z. Martin, Nicole Labbé, Nicolas André, Ronny Harris, Michael Ebinger, Stan D. Wullschleger, and Arpad A. Vass, "High resolution applications of laser-induced breakdown spectroscopy for environmental and forensic applications", *Spectrochimica Acta Part B* vol 62 No.12 (2007) 1426-32.

Nicole Labbe, Timothy G. Rials, Stephen S. Kelley, and Madhavi Martin, "Characterization of materials by high throughput technologies Near Infrared and Laser Induced Breakdown Spectroscopy", ACS Symposium Series 945, Pg 495-512, (2007).

M. Z. Martin, S. D. Wullschleger, C. T. Garten Jr., Anthony V. Palumbo, "Measurement of carbon for carbon sequestration and site monitoring", *Laser-induced breakdown spectroscopy Chapter 15*, pp. 341-351, Ed., J.P. Singh and Surya Narayan Thakur, Elsevier Science B.V., 2007.

Madhavi Z. Martin, Stan D. Wullschleger, Arpad A. Vass, Rodger C. Martin, and Henri Grissino-Mayer, High-Resolution Laser-Induced Breakdown Spectroscopy used in Homeland Security and Forensic Applications, *Bull. Las. Spectrosc. Soc. India.*, Special Issue No. 14. pp 23-35, 2006.

Steven D. Brown, Madhavi Martin, Sameer Deshpande, Sudipta Seal, Katherine Huang, Eric Alm, Yunfeng Yang, Liyou Wu, Tingfen Yan, Xueduan Liu, Adam Arkin, Karuna Chourey, Jizhong Zhou, and Dorothea K. Thompson, "Cellular Response of *Shewanella oneidensis* to Strontium-Stress", *Appl. Environ. Microbiol.*, Vol 72, No. 1, pp 890-900, 2006.

R. Singh, M. Martin, and N. B. Dahotre, "Influence of laser surface modification on corrosion behavior of stainless steel 316L and Ti-6Al-4V in simulated biofluid", *Surface Engineering*, Vol. 21, No 4, pp. 297-306, 2005.

Madhavi Z. Martin, Nicole Labbe, Timothy G. Rials, and Stan D. Wullschleger, "Analysis of preservative-treated wood by multivariate analysis of LIBS spectra", *Spectra Chimica Acta B.*, Vol 60/7-8 pp 1179-1185, 2005.

Vass, A.A., Madhavi, M., Synstelién, J. and Collins, K. "Elemental Characterization of Skeletal Remains Using Laser-Induced Breakdown Spectroscopy (LIBS)". *Proceedings of the American Academy of Forensic Sciences, Annual Meeting*, New Orleans, LA February 21-26, 2005. p. 307-8.

Madhavi Z. Martin, Stan. Wullschleger, Charles T. Garten Jr., Anthony V. Palumbo, and John G. Smith. "Elemental Analysis of Environmental and Biological Samples using Laser-Induced Breakdown Spectroscopy and Pulsed Raman Spectroscopy". *J. Disper. Sci. and Technol.* Vol. 25, No. 5, pp. 689–696, 2004.

Palumbo, A. V., S. Fisher, M. Martin, Z. Yang, J. Tarver, S. D. Wullschleger. "Application of emerging tools and techniques for measuring carbon and microbial communities in reclaimed mine soils". *Environmental Management*. Volume 33, supplement 1, 2004.

Martin, M., B. Evans, H. O'Neill, and J. Woodward, "Laser-induced breakdown spectroscopy used to detect palladium and silver metal dispersed in bacterial cellulose membranes". *Appl. Optics*, 2003. **42**(30): p. 6174-6178.

R. C. Martin, D. C. Glasgow, and M. Z. Martin. "Applications of Californium-252 Neutron Irradiations and Other Nondestructive Methods at Oak Ridge National Laboratory," *Radioanalytical Methods in Interdisciplinary Research. Fundamentals in Cutting-Edge Applications*, C. A. Laue and K. L. Nash, eds., American Chemical Society Symposium Series No. 868, chapter 7, 2004.

Madhavi Martin, Stan Wullschleger, Charles Garten Jr., and Anthony Palumbo, "Laser-induced Breakdown Spectroscopy for the Environmental Determination of Total Carbon and Nitrogen in Soils," *Applied Optics*, 42(12), 2072-2077 (2003).

#### Madhavi Martin –Page 4

M. Z. Martin and O. R. West, "In Situ Chemical Oxidation through Lance Permeation at the Portsmouth Gaseous Diffusion Plant (PORTS)," Oak Ridge National Laboratory Report ORNL/TM-2002/272, Feb. 2003.

Madhavi Martin, Stan Wullschleger, and Charles Garten Jr., "Laser-induced breakdown spectroscopy for environmental monitoring of soil carbon and nitrogen," Proceedings of SPIE, Eds. Tuan Vo-Dinh and Stephanus Buttgenbach, vol 4576, pp. 188-195 (2002).

Martin, M. Z. and M. D. Cheng, "The Detection of Chromium Aerosol using Time-Resolved Laser-Induced Plasma Spectroscopy," *Appl. Spectrosc.*, 54(9) (2000).

Martin, M. Z., M. D. Cheng, and R. C. Martin, "Aerosol Measurement by Laser-Induced Plasma Technique: A Review," *Aerosol Sci. and Technol.*, 31(6) (1999) 409-421.

M. Z. Martin, S. R. Desai, C. S. Feigerle, and J. C. Miller, "Chemistry in Clusters: Synthesis of  $\text{NO}^+(\text{N}_2\text{O}_3)_n$  and  $\text{NO}_2^+(\text{N}_2\text{O}_3)_n$  Species," *J. Phys. Chem.*, 100 (1996) 8170-74.

L. A. Pinnaduwege, M. Z. Martin, and L. G. Christophorou, "Enhanced Negative Ion Formation in ArF-Laser-Irradiated Methane: Possible Implications for Plasma Processing Discharges," *IEEE Trans. Plasma Sci.*, 35 (1995) 433-38.

M. Z. Martin and A. A. Garrison, "Optical pH-Sensor - A Tool for On-line Chemical Process Control," *AT-PROCESS: J. Process Anal. Chem.*, (1994) 127-131.

A. A. Garrison and M. Z. Martin, "Acid Sensing by Remote Raman Spectroscopy," *AT-PROCESS: J. Process Anal. Chem.*, (1994) 95-98.

L. A. Pinnaduwege, M. Z. Martin, and L. G. Christophorou, "Enhanced Negative Ion Formation in UV-Laser-Irradiated Silane; Implications for Plasma Deposition of Amorphous Silicon," *Appl. Phys. Letters*, 65 (1994) 2571-73.

M. Z. Martin, F. K. Oshita, M. Matloubian, H. R. Fetterman, W. J. Ho, N. L. Wang, F. Chang, and D. Cheung, "The Electrical and Optical Response of a Very High Frequency AlGaAs/GaAs Heterojunction Bipolar Transistor," *J. Appl. Phys.*, 76 (1994) 3847-49.

M. Z. Martin, A. A. Garrison, M. J. Roberts, P. D. Hall, and C. F. Moore, "Composition monitoring by on-line remote Raman spectroscopy," *Process Control and Quality*, 5 (1993) 187-92; invited talk at Seventh International Forum Process Analytical Chemistry, Galvaston, Texas, Jan. 26-27, 1993.

R. C. Martin and M. Z. Martin, "Analytical Techniques for SiC Characterization: Literature Review and Project Status," Oak Ridge National Laboratory Report ORNL/TM-12352, Nov. 1993.

M. Z. Martin, F. K. Oshita, M. Matloubian, H. R. Fetterman, L. Shaw, and K. L. Tan, "High-Speed Optical Response of Pseudomorphic InGaAs High Electron Mobility Transistors," *IEEE Photonics Technology Letters*, 4 (1992) 1012-14.

F. Oshita, M. Martin, M. Matloubian, H. Fetterman, H. Wang, K. Tan, and D. Streit, "Cryogenic Performance of a Monolithic W-Band Amplifier Using Picosecond Optoelectronic Technique," *IEEE Microwave and Guided Wave Letters*, 2 (1992) 340-42.

Madhavi Z. Martin, D. K. Shuh, R. S. Williams, and R. M. Ostrum, "Transport Properties and Infrared Spectra of CuCl Thin Films," *J. Appl. Phys.*, **67** (1990) 3097-3101.

#### Madhavi Martin –Page 5

Muragi B. D., Zope M. J., Zope J. K., "Mechanism for Nonlinear IV Behavior and the Temperature-Dependence of Threshold Switching in the Se-Te-Sn System M", *Appl. Phys. A-Materials Science & Processing* **46(4)** (Aug 1988) 299-303.

Madhavi Zope, B. D. Muragi, and J. K. Zope, "Electrical Conductivity Measurements in a Ge-Se-Tl System," *J. Non-Crystalline Solids*, **103** (1988) 195-200.

Madhavi J. Zope and J. K. Zope, "Effect of  $\gamma$ -Irradiation on Non-Linear I-V Behaviour and Thermoelectric Measurements in Amorphous Semiconducting As-Se-Te System," *J. Non-Crystalline Solids*, **74** (1985) 47-55.

Madhavi J. Zope and J. K. Zope, "Nonlinear I-V Behaviour and Thermoelectric Measurements in Amorphous Semiconducting As-Te-I System," *Indian J. Pure & Appl. Physics*, **23** (1985) 68-70.

Madhavi J. Zope and J. K. Zope, "Nonlinear I-V Behaviour and Conductivity Measurements in Amorphous Semiconducting Ge-As-Te System," *J. Mat. Sci. Lett.*, **3** (1984) 850-52.

#### PRESENTATIONS (total 32)

Madhavi Z. Martin, Timothy J. Tschaplinski, Nicole Labbe, and Simon Potter, "Assessing Biofuels Individually and by Phenotyping of Woody Biomass: Chemical Quantification by Laser-Induced Breakdown Spectroscopy and Near Infrared Spectroscopy", LIBS 2008, (Invited Talk) Berlin, Germany, Sept. 22-26. 2008.

Madhavi Z. Martin, Justin Baba, Paul Hanson, Jerry Tuskan, Rebekah Wagner, Nicole Labbé and Nicolas André, "Synergistic approach of using WoodCAT and Laser-Induced Breakdown Spectroscopy for High-Throughput, Data Collection, and Analysis of Biomass", NASLIBS, (Invited Talk) New Orleans, October 8-10 2007.

Madhavi Martin, Nicole Labbé, Nicolas André, and Timothy G. Rials, "A High Resolution Laser-Based Technique for Quantifying the Elemental Composition of Wood: Applications in Biomass Characterization", SWST-2007, (Invited Talk) Knoxville, TN, June 10-14 2007.

M. Z. Martin, S. D. Wullschleger, A.A. Vass, R. D. Harris, M. H. Ebinger, T. G. Rials, and N. Labbe, High Resolution Applications of Laser-Induced Breakdown Spectroscopy for Environmental and Forensic Samples Related to Homeland Security Applications, LIBS 2006, (Invited Talk) Montreal, Canada, Sept. 5-8. 2006.

Madhavi Z. Martin, Stan D. Wullschleger, Nicole Labbe, and Timothy Rials, "High resolution applications of Laser-induced breakdown spectroscopy for Forensic and environmental applications", PITTCON 2006, (Invited Talk) Orlando FL, March 13-17, 2006.

Madhavi Martin, Stan D. Wullschleger, Nicole Labbe, Nicolas Andre, and Timothy G. Rials, "A High Resolution Laser-Based Technique for Quantifying the Elemental Composition of Wood: Applications in Forest Fire Ecological Response", Central Hardwood Conference 2006, Knoxville TN, February 27-March 1, 2006.

Madhavi Z. Martin, Stan D. Wullschleger, and Arpad Vass, "High Resolution applications of Laser-induced breakdown spectroscopy for Homeland Security and Forensic Applications", First Indo-US Workshop on Spectroscopy, (Invited Talk), Jan 9-12, 2006, Varanasi, India.

Madhavi Z. Martin, Stan D. Wullschleger, Arthur J. Stewart, John G. Smith, Timothy G. Rials, and Nicole Labbe, "High-throughput and High Resolution applications of Laser-induced breakdown spectroscopy for environmental samples", PACIFICHEM 2005, (Invited Talk), December 15-20, 2005, Honolulu, Hawaii, USA.

#### **Madhavi Martin –Page 6**

Madhavi Z. Martin, Stan D. Wullschleger, Timothy G. Rials, and Nicole Labbe, "Developing Laser-Induced Breakdown Spectroscopy as a High Throughput Technique for Quantifying the Elemental Composition of Wood", The Third International Conference on Laser Induced Plasma Spectroscopy and Applications 28 September - 1 October 2004 Torremolinos (Málaga).

Madhavi Z. Martin, Stan D. Wullschleger, Arthur J. Stewart, John G. Smith, Timothy G. Rials, and Nicole Labbe. August 2004. "High Throughput Elemental Detection in Environmental Samples using Laser-Induced Breakdown Spectroscopy," Gordon Research Conference on laser interaction with matter (*by invitation only*), August 1-6, Andover, NH.

Madhavi Martin, Stan Wullschleger, Charles Garten Jr., Anthony Palumbo, Olivia West, John Smith, Barbara Evans, Hugh O'Neill, and Jonathan Woodward, "Detection of Elements from Environmental and Biological Samples using Laser-Induced Breakdown Spectroscopy," Presented at the 77th Colloid and Surface Science Symposium at Georgia Tech, June 15-18, 2003.

Madhavi Z. Martin, Stan Wullschleger, Anthony Palumbo, Olivia West, John Smith, Barbara Evans, Hugh O'Neill, and Jonathon Woodward "Applications of Laser-Induced Breakdown Spectroscopy to Environmental and Biological Sample Analysis," invited talk at Pittcon '2003, the Pittsburgh Conference & Exposition on Analytical Chemistry & Applied Spectroscopy, Orlando, Fl., March 9 - March 14, 2003.

Palumbo, A. V., M. Martin, Z. Yang, J. Tarver, S. Fisher, W. Lee Daniels and S. Wullschleger. November 2002. Development of measurement techniques for carbon and microbial communities in mine soil. USDA Symposium on Natural Resource Management to Offset GHG Emissions. Raleigh, NC.

Madhavi Martin, Barbara Evans, Hugh O'Neill, and Jonathan Woodward, "Laser-Induced Breakdown Spectroscopy used to Detect Palladium metal Dispersed in Cellulose Membranes," Presented at Laser-Induced Plasma Spectroscopy and Applications (LIBS2002) conference, 9/24/02-9/28/02, Caribe Royale, Lake Buena Vista, Florida.

Madhavi Martin, Stan Wullschleger, Charles Garten Jr., Anthony Palumbo, Barbara Evans, Hugh O'Neill, and Jonathan Woodward, "Environmental and biological applications of Laser-induced breakdown spectroscopy," presented at the Workshop on Advances in Laser Technology and Applications held August 21 & 22, 2002 at Redstone Arsenal AL.

T. E. Byrne, M. Z. Martin, G. W. Kabalka, and M. K. Khan," An Analysis of Boron Compounds Using Laser Microprobe," 10th International Congress on Neutron Capture Therapy, September 8-13, 2002, Essen, Germany.

Madhavi Martin and Stan Wullschleger, "An Overview of the Current Technologies used in the Environmental Monitoring of Soil Carbon," Proc. International Symposium on Environmental and Industrial Sensing, 28 Oct -2 Nov , 2001, Boston, MA SPIE Vol. 4574.

Cheng, M. D., M. Z. Martin, and T. Wainman (1999) A Field Portable Monitor for Real-Time Measurement of Elements on Aerosols, *the Annual Symposium of SERDP Program*, Crystal City, Washington, DC, 11/29-12/3.

M. Z. Martin and M. D. Cheng, "Laser-Induced plasma spectroscopy (LIPS): A tool for in situ spectroscopic characterization of aerosol mercury and chromium," CLEO/QELS Meeting, Baltimore, Md, May 23-28, 1999.

M. Z. Martin and M. D. Cheng, "Detection of Chromium and Mercury in Aerosols using Laser-Induced Plasma Spectroscopy: Wavelength and Buffer Gas Dependence," APS Centennial Meeting, Atlanta, Ga, March 20-26, 1999.

### Madhavi Martin –Page 7

Cheng, M. D. and M. Z. Martin (1998) *Real-Time Measurement of Fine Particles and Trace Elements by Means of Laser-Induced Plasma Spectroscopic Technique*, the Conference on Air Quality, Mercury, Trace Elements, and Particulate Matter, 12/1-4, held in McLean, VA, *Invited*.

Jun Xu, Chung-Yi Kung, Madhavi Martin, William B. Whitten, and J. Michael Ramsey, "Studies of Miniature Ion Mobility Spectrometer," International Conference on Ion Mobility Spectrometry, Hilton Head, SC, September 14-18, 1998.

M. Z. Martin, L. Liu, C. S. Feigerle, and J. C. Miller, "Multiphoton Ionization Studies of Laser Induced Chemistry in Clusters," Resonance Ionization Spectroscopy Meeting, State College, Pa., June 30 - July 5, 1996.

M. Z. Martin, S. R. Desai, C. S. Feigerle, and J. C. Miller, "Laser-Induced Chemistry within Clusters," presented at Laser Applications to Chemical and Environmental Analysis," Orlando, Fl., March 20-22, 1996.

M. Z. Martin, S. R. Desai, C. S. Feigerle, and J. C. Miller, "Laser Ionization Mass Spectrometry of  $(N_xO_y)_n$  Clusters," presented at the International Symposium on the Science and Technology of Atomically Engineered Materials, Richmond, Va., October 30 - November 4, 1995 (winner of *Best Poster Award*).

L. A. Pinnaduwege, M. Z. Martin, and L. G. Christophorou, "Efficient Negative Ion Formation in UV-Laser-Irradiated Silane; Implications for Plasma Deposition Applications," presented at the 47th Annual Gaseous Electronics Conference, Washington, D.C., October 18-21, 1994.

A. A. Garrison, M. Z. Martin, and M. J. Roberts, "Raman Spectroscopy - Academic Laboratory to the Process," presented at Pittcon '94, the Pittsburgh Conference & Exposition on Analytical Chemistry & Applied Spectroscopy, Chicago, Ill., February 28 - March 4, 1994.

A. A. Garrison and M. Z. Martin, "Fourier transform Raman spectroscopy - application to process control," Proc. 9th International Conference on Fourier Transform Spectroscopy, August 23-27, 1993, Calgary, Alberta, Canada, SPIE Vol. 2089, 210-11.

M. Martin, F. Oshita, M. Matloubian, and H. Fetterman, "Picosecond Optoelectronic Characterization of AlGaAs/GaAs HBT at Cryogenic Temperatures," Proceedings of the 1991 International Semiconductor Device Research Symposium, Charlottesville, Va., December 4-6, 1991, pp. 391-94.

F. Oshita, M. Martin, M. Matloubian, and H. Fetterman, "Picosecond Testing of Three-Terminal Devices," National Center for Integrated Photonic Technology, Second Workshop, Lake Arrowhead, Cal., November 11-12, 1991.

F. Oshita, M. Martin, M. Matloubian, and H. Fetterman, "Picosecond Optoelectronic Testing," Jet Propulsion Laboratory Conference on Optical Applications to Microwave and Millimeter-Wave Systems, Pasadena, Cal., October 8, 1991.

H. R. Fetterman, M. Matloubian, D. V. Plant, M. Martin, and F. Oshita, "Picosecond Testing and Evaluation of Three Terminal Devices," IEEE LEOS 1991 Summer Topical Meeting on Optical Millimeter-Wave Interactions, Newport Beach, Cal., July 24-26, 1991, pp. 11-12 (invited talk).

*CURRICULUM VITAE*

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**PROFESSIONAL STATUS**

Research Scientist  
Adjunct Research Professor (Univ. of TN)  
Medical Technologist (Clinical Pathology, Laboratory Scientist)  
Instructor – National Forensic Academy  
Honorary Research Associate – School of Biological Sciences, Victoria University of  
Wellington, NZ  
Group Leader - Biochemical Engineering Research Group (2004)

**EDUCATIONAL BACKGROUND**

Ph.D. Degree, Dissertation: Time Since Death Determinations of Human Cadavers.  
University of Tennessee, Knoxville, TN., 1991.

M.S. Degree, Administration of Justice (Forensic Science). Virginia Commonwealth  
University, Richmond, Virginia. 1989.

Medical Technology Degree. (ASCP,CLS). The Fairfax Hospital, Falls Church, VA. 1984

B.S. Degree, Biology. Virginia Tech, Blacksburg, Virginia. 1981.

Scripps Institute of Oceanography, Antarctic Exploration certification. 1980.

**EXPERIENCE**

Instructor – National Forensic Academy, Law Enforcement Innovation Center, Knoxville,  
TN. 2001 – present. (Blood-borne Pathogens, Weapons of Mass Destruction, Forensic  
Anthropology)

Research Scientist, Oak Ridge National Laboratory, Life Sciences Division, 1992 -  
present. Group Leader - Biochemical Engineering Research Group, 2004  
Custodian. BioSafety Laboratory 3+. Oak Ridge National Laboratory. 1999-2007.

Research Associate, Department of Chemistry, University of Tennessee, Knoxville, TN/Oak Ridge National Laboratory, Health and Safety Research Division. 1990 - 1992.

Forensic Anthropology Center, Department of Anthropology, University of Tennessee, Knoxville, TN. 1988 - present.

Research Associate, Dept. of Microbiology, Univ. of Tennessee, Knoxville, TN. 1985-90.

Medical Technologist - Medical College of Virginia Hospitals. Richmond, VA. 1984-85.

## **CURRENT RESEARCH ACTIVITIES**

### Forensics:

- Time since death determinations of human cadavers: Volatile Fatty Acid, Anion/Cation production. Tissue specific biomarkers, University of Tennessee, Department of Anthropology, Knoxville, TN, 1988- present.
- New Technologies for Locating Buried Corpses: bacteria and human specific biochemical markers: FBI Criminal Response Team 1999-present.

Biological and Chemical Warfare Countermeasures: Detection and Identification. ORNL, February 1997 - present.

Investigations of the inhibitory effects of an Amoebae/Bacterial Preparation on Cultured Carcinoma Cells and the expression of anti-viral properties. ORNL, 1994-present.

Investigations into the pathogenicity of environmental microorganisms in the workplace. Includes indoor air quality, monitoring of cooling towers, water fountains, eyewash stations, etc. ORNL. 1991 - present.

Investigations into the bioremediation of explosives and related compounds. Includes napalm, TNT, propellants, nitroglycerin, hydrazine compounds and metabolic products of their degradation. ORNL, 1991- 1996.

Investigations into the usefulness of newly discovered bacterial biodispersants. Characterization and their ability to emulsify soil fines, hydrocarbons, organic solvents, mercury and desorb toxins from soil. ORNL, 1991-present.

Study of biodegradation, toxicity, carcinogenicity and mutagenicity of various toxins. Assays include Ames, SCE and CHO. Oak Ridge National Laboratory. 1991- present. Study of bacteria-amoeba interactions in consortia as well as in environmental settings. Oak Ridge National Laboratory, 1990-present.



## SELECTED PUBLICATIONS

Vass, A.A. Review of: Soil Analysis in Forensic Taphonomy: Chemical and Biological Effects of Buried Human Remains. *J. Forensic Sciences*, 53 (6): 1484-1485, November 2008.

Vass, A.A., Smith, R.R., Thompson C.V., Burnett, M.N., Dulgerian N., Eckenrode B.A. Odor Analysis of Decomposing Buried Human Remains. *J. Forensic Sciences*, 53 (2): 384-392, March 2008.

Martin, M.Z., Labbé, N., André, N., Harris, R., Ebinger, M., Wullschleger, S.D., Vass, A.A. High Resolution Laser Induced Breakdown Spectroscopy used in Homeland Security and Forensic Applications. *Spectrochimica Acta Part B*. 62 (2007), 1426-1432.

Martin, M.Z., Wullschleger, S.D., Vass, A.A. Martin, R.C., Grissino-Mayer, H. High Resolution Laser Induced Breakdown Spectroscopy used in Homeland Security and Forensic Applications. Bulletin of Laser and Spectroscopy Society of India. Future Trends in Spectroscopy: Applications to National Security. No. 14, pp 9-11. Jan 2006.

Yan, F., Wabuyele, B., Griffin, G., Vass, A., Vo-Dinh. Surface Enhanced Raman Scattering Detection of Chemical and Biological Agent Simulants. *IEEE Sensors Journal*, Vol. 5, No. 4. August 2005, pp. 665-670.

Vass, A.A., Madhavi, M., Synstelién, J. and Collins, K. "Elemental Characterization of Skeletal Remains Using Laser-Induced Breakdown Spectroscopy (LIBS)". Proceedings of the American Academy of Forensic Sciences, Annual Meeting, New Orleans, LA February 21-26, 2005, p307-8.

Vass, A.A., Smith, R.R., Thompson C.V., Burnett, M.N., Wolf D.A., Synstelién J.A., Eckenrode B.A., Dulgerian N. Decompositional Odor Analysis Database. *J. Forensic Sciences*, 49 (4): 760-769, July 2004.

Parkinson R, Horswell J, Cordiner S, Vass A, Chambers G, Sutherland B. Forensic DNA Profiling of Bacterial Communities in Soil, The Australia and New Zealand Forensic Science Society Biennial Conference, Challenges and Changes 17<sup>th</sup> International Symposium of Forensic Sciences, Te Papa, Wellington, New Zealand. 2004.

Griffin GD, Mobley J, Vass AA, Vo-Dinh T. A miniature biochip system for detection of aerosolized *Bacillus globigii* spores Stratis-Cullum DN, *Analytical Chemistry*, 75 (2): 275-280 Jan 15, 2003.

Horita, J. and Vass, A.A. Stable-Isotope Fingerprints of Biological Agents as Forensic Tools, *Journal of Forensic Sciences*, 2003;48 (1):122-126.

W. H. Griest, M.B Wise, K.J. Hart, S. A. Lammert, C. V. Thompson, D. A. Wolf, M. N. Burnett, A. A. Vass, I. F. Robbins, D.A. Clayton, "The Block II Chemical Biological Mass

Spectrometer: Issues and Solutions in Integrated Chemical-Biological Agent Detection,” Integrating Chemical and Biological Detection Technology: Today’s Solutions and Tomorrow’s Issues, Alexandria, VA , May 1, 2002.

Vass, A.A., Barshick, S.A., Sega, G., Caton, J., Skeen, J.T., Love, J.C. and Synsteliën, J.A. Decomposition Chemistry of Human Remains: A New Methodology for Determining the Postmortem Interval, *J. Forensic Sci*, 2002;47(3):542-553.

Vass, A.A., Beyond the Grave – Understanding Human Decomposition. *Microbiology Today*, 28:190-192, Nov, 2001.

Griest, W.H., Wise, M.B., Hart, K.J., Lammert, S.A., Thompson, C.V. and Vass, A.A. Biological Agent Detection and Identification by the Block II Chemical Biological Mass Spectrometer. *Field Analytical Chemistry and Technology*, 5(4):177-184, 2001.

Kennel, S.J., Foote, L.J., Morris, M., Vass, A.A., and Griest, W.A. Mutation Analyses of a Series of TNT-related Compounds Using the CHO-hprt Assay. *J. of Applied Tox.*, 20, 00-00 (2000)

Sega, Gary A., Vass, Arpad A., Caton, John, Barshick, Stacy A., Love, Jennifer C., and Marks, Murray (2000). Measurement Technologies for Determining Time Since Death, 52<sup>nd</sup> Annual Meeting of the American Academy of Forensic Sciences, Reno, NV, Feb. 21-26, 2000.

Barshick, S.A., Wolf, D.A. and Vass, A.A. Differentiation of Microorganisms Based on Pyrolysis-Ion Trap Mass Spectrometry using Chemical Ionization. *Anal. Chem.* 71: 633-641, 1999.

Griest, W.H., Vass, A.A., Stewart, A.J. and Ho, C.-h. Chemical and Toxicological Characterization of Slurry Reactor Biotreatment of Explosives-Contaminated Soils. ORNL/TM-13384. March 1997.

Vass, A.A., Mackowski, R., Anderson, T.A. and Ahmad N. Biocidal Efficacy of Ozone in Cooling Towers. Paper Q99. 96th meeting of the American Society for Microbiology, May 19-23, New Orleans, LA, 1996.

Hurst, G.B., Doktycz, M.J., Vass, A.A. and Buchanan, M.V. Detection of Bacterial DNA Polymerase Chain Reaction Products by Matrix-Assisted Laser Desorption/Ionization Mass Spectroscopy. *Rapid Communications in Mass Spectrometry*, Vol. 10, 377-382, 1996.

Barshick, S.A., Vass, A.A. and Griest, W.H. Electronic aroma technology for forensic and law enforcement applications. *SPIE*, 2941:63-74, 1995.

Barshick, S.A., Vass, A.A., Ma, C.Y., Skeen, J.T. and Griest, W.H. Investigating the Decomposition Chemistry of Human Remains Using Advanced Analytical Technologies.

36th Conference of Analytical Chemistry in Energy Technology. Conf-9510143. pp. 5-6. Gatlinburg, Tennessee, October 10-12, 1995.

Griest, W.H., Tyndall, R.L., Stewart, A.J., Caton, J.E., Vass, A.A., Ho, C.-h., Caldwell, W.M. Chemical Characterization and Toxicological Testing of Windrow Composts from Explosives-Contaminated Sediments. *Environ. Tox. Chem.* Vol 14, No. 1, pp. 51-59, 1995.

Vass, A.A., et. al. The resistance of amoebae, amoebae associated bacteria and derivars to various forms of radiation. *Endocytobiology VI*, Sept, 1995.

Vass, A.A., et. al. Unique characteristics of amoebae associated bacteria and their usefulness in bioremediation. *Endocytobiology VI*, Sept, 1995.

Bowman, E.K., Vass, A.A., Mackowski, R., Owen, B.A., Tyndall, R.L. Quantitation of Free-Living Amoebae and Bacterial Populations in Eyewash Stations. AIHA, March 27, 1995.

Vass, A.A., Tyndall R.L., Mackowski, R. Desorption and Removal of Elemental Mercury from Soil. Paper Q272. 95th meeting of the American Society for Microbiology, May 21-25, Washington D.C., 1995.

Vass, A.A., Tyndall R.L. Application of Amoebae Associated Bacteria in the Degradation of Explosives. Paper Q108. 95th meeting of the American Society for Microbiology, May 21-25, Washington D.C., 1995.

Tyndall, R.L., A.A. Vass. The impact of Protozoa on Human Health in the Indoor Environment. *Biological aerosols: A state of the art review*. Ed. H.A. Burge and M.L. Muilenberg. Chapter 6. CRC Press, Inc. pp 121-132, 1995.

Griest, W.H., Tyndall, R.L., Stewart, A.J., Caton, J.E., Vass, A.A., Ho, C.-h., Caldwell, W.M. Characterization of Explosives Processing Waste Decomposition Due to Composting. ORNL/TM-12812. September 1994.

Vass, A.A., Tyndall, R.L. Radiation Induced Derivars and Their Genetic Similarity to Irradiated Amoebae. 94th General Meeting of the American Society of Microbiology Proceedings, p. 130, May 23-27, 1994. Las Vegas, NV.

Dietz, A.J., Vass, A.A., Mackowski, R.P. Tyndall, R.L. Comparison of Intra- and Extra-Amoebic Bacterial Isolates. 94th General Meeting of the American Society of Microbiology Proceedings, p. 130, May 23-27, 1994. Las Vegas, NV.

Vass, A.A., Tyndall, R.L. Radiation resistance of Free-Living Amoebae and Their Associated Bacteria. Paper Q-23. 93rd General Meeting of the American Society of Microbiology Proceedings, p. 164, May 16-20, 1993. Atlanta, GA.

Vass, A.A., K.S. Ironside, R.L. Tyndall. Bioremediation of Petroleum Contaminated Soils on Kwajalein Island: Microbial Characterization and Biotreatability Studies. Chapter 3: Pathogenicity Profile. ORNL/TM-11925. 1992.

Vass, A.A., R.L. Tyndall. The use of COSTAR Microtiter Plates to study amoebic- bacterial interactions. Paper Q-378, p. 398. Presented at the 92nd General Meeting of the American Society of Microbiology. May 25-31, 1992. New Orleans, LA.

Tyndall, R.L., A.A. Vass. Increased bacterial diversity after passage of bacteria through free-living amoebae. Proceedings of the 5th International Symposium of Endocytobiology, pp. 515-522, Kyoto, Japan. June 15-19, 1992.

Vass, A.A., R.L. Tyndall. Interactions of free-living Amoebae with bacteria resulting in bacterial diversity. Proceedings of the 6th International Conference on the biology and Pathogenicity of free-living amoebae, p. 87, August 2-7, 1992, Richmond, VA.

Vass, A.A., Bass, W.M., Wolt, J.D., Foss, J.E., Ammons, J.T., "Time Since Death Determinations of Human Cadavers Using Soil Solution", *Journal of Forensic Sciences*, 37(5):1236-1253, Sept. 1992.

Nivens, D., Jack, R., Vass, A.A., Guckert, J., Chambers, J. 1991. Multi-electrode probe for statistical evaluation. *J. of Microbial Methods*. August 1992. 16(1):47-58.

Tyndall, R.L., Vass, A.A., Fliermans, C.B. Mixed bacterial populations derived from Legionella-infected free living amoeba. Proceedings of ASM 4th International Symposium on Legionella, p 284, Orlando, FL., Jan. 26-29, 1992.

## **SELECTED PRESENTATIONS**

Vass, A.A. "The Dust of Death". 6<sup>th</sup> Annual Vanderbilt-Meharry Alliance Genetics Symposium/A look at genetics in the field of criminal investigations. Vanderbilt University - Invited speaker. September 21, 2005.

Vass, A.A., Martin, M. Elemental Characterization Using Laser-Induced Breakdown Spectroscopy (LIBS) for Forensic Applications. Invited speaker Dept. of Homeland Security Technology series, Gatlinburg, TN. September 15, 2004.

Vass, A.A. Weapons of Mass Destruction. National Forensic Academy Alumni Seminar, Knoxville Convention Center, Knoxville, TN August 23-25, 2004.

Horswell, J.; Parkinson, R.; Cordiner, S.; Sutherland, B.; Speir, T.; Chambers, G. and Vass, A. 2003. Forensic DNA profiling of bacterial communities in soils. International Society of Environmental Forensics, Environmental Forensics: Using Science to Reconstruct Contamination Events. Taipei, Taiwan.

Vass, A.A. Invited plenary speaker. Four presentations on Human decomposition, Time since death and Forensic Anthropology presented at the 17<sup>th</sup> International Symposium of the Forensic Sciences, Wellington, NZ. March 28-April 2, 2004

Vass, A.A. "Odor Analysis of Decomposition", presented at the 56<sup>th</sup> Annual Meeting of the American Academy of Forensic Sciences, Dallas, TX. Feb 16-21, 2004.

Collins, K.C., Vass, A.A. "What's that Smell", presented at the 56<sup>th</sup> Annual Meeting of the American Academy of Forensic Sciences, Dallas, TX. Feb 16-21, 2004.

Vass, A.A. Council for the Advancement of Science (CASW). Interpreting all that Remains: New Insights. Radison Summitt Hotel, Knoxville, TN. October 29, 2003.

Vass, A.A., "Human Decomposition and Biohazards", presented at the American Biorecovery Association (ABRA) conference, Las Vegas, NV, Sept 30 – Oct 4, 2002.

Griest, W. H., M.B. Wise, K. J. Hart, S. A. Lammert, C. V. Thompson, D. A. Wolf, M. N. Burnett, A. A. Vass, I. F. Robbins, and D. A. Clayton, "The Block II Chemical Biological Mass Spectrometer (CBMS): Issues and Solutions in Integrated Chemical-Biological Agent Detection," presentation at Integrating Chemical and Biological Detection Technology: Today's Solutions and Tomorrow's Issues," Alexandria, Virginia, May 1, 2002.

Vass, A.A., "Chemical Issues in Human Decomposition – Implications for TSD Determinations," Presented at the U.S. Army Criminal Investigation Laboratory, Fort Gillem, GA. August 23, 2002.

Vass, A.A., "The University of Tennessee's Forensic Research Facility and ORNL," presented to the East Tennessee Regional Leadership Association Class of 2002, Oak Ridge National Laboratory, Oak Ridge, Tennessee, July 24, 2002 (Invited).

Vass, A.A. "Weapons of Mass Destruction", Seminar on Crime Scene Investigations. National Center for Unresolved Homicides, Orlando, FL., June 17-21, 2002.

W. H. Griest, S. A. Lammert, M. B. Wise, K. J. Hart, A. A. Vass, D. A. Wolf, M. N. Burnett, R. Merriweather, and R. R. Smith, "A Mass Spectrometer-Based System for Integrated Chemical and Biological Agent Detection The Block II CBMS," 50<sup>th</sup> ASMS Conference, Orlando, FL, June 2-6, 2002.

Griest, W. H., M. B. Wise, K. J. Hart, S. A. Lammert, C. V. Thompson, D. A. Wolf, M. N. Burnett, A. A. Vass, I. B. Robbins, and D. A. Clayton, "The Block II Chemical Biological Mass Spectrometer (CBMS): Issues and Solutions in Integrated Chemical-Biological Agent Detection," presentation at the Biodetection Conference, Washington, DC, May 2-3, 2002.

Lammert, S.A., W. H. Griest, M.B. Wise, K.J. Hart, A.A. Vass, D.A. Wolf, M.N. Burnett, R. Merriweather, and R.R. Smith, "A Mass Spectrometer-Based System for Integrated Chemical and Biological Agent Detection - The Block II CBMS," presentation at the 50<sup>th</sup> American Society for Mass Spectrometry (ASMS) Conference, Orlando, FL, June 2, 2002.

Vass, A.A., et. al. Human Decomposition Chemistry. Presented at the 54th Annual Meeting of the American Academy of Forensic Sciences, Atlanta, GA, February 11-15, 2002.

Hart, K.H., S.H. Harmon, D.A. Wolf, A.A. Vass and M.B. Wise, "Detection of Chemical/Biological Agents and Simulants Using Quadrupole Ion Trap Mass Spectrometry". Presented at the 47th ASMS Conference on Mass Spectrometry and Allied Topics, Dallas, TX, June 14-18, 1999.

Vass, A.A. "Forensic Anthropology and Time Since Death". Presented for the Center of Unresolved Homicides in conjunction with the University of Central Florida, Orlando, FL, June 14-18, 1999.

"The resistance of amoebae, amoebae associated bacteria and derivars to various forms of radiation", Vass, A.A., Tyndall, R.L., Presented at the International Conference on the Biology and Pathogenicity of Free-Living Amoebae, Murfreesboro, TN, May 27-June 2, 1998

"The discovery of novel anti-microbial bacterial pigments" Vass, A.A., Tyndall, R.L., Presented at the International Conference on the Biology and Pathogenicity of Free-Living Amoebae, Murfreesboro, TN, May 27-June 2, 1998

"The who, when, but not why, of forensic pathology" Vass, A.A. Presented at the Virginia Military Institute. Lexington, VA. Feb. 6, 1997

"Bones, Decay and Time Since Death", Instructor Presentation for the Center for Unresolved Homicides, Inc. East Coast police coalition agencies. Louisville, KY. Sept. 23-27, 1996.

"The Changing Role of Forensic Anthropologists", Presented at the Boulder Police Training Center by The Center for Unresolved Homicides, Inc. Boulder, CO. April 22-25, 1996.

"Investigating the Decomposition Chemistry of Human Remains Using Advanced Analytical Technologies", 36th Conference of Analytical Chemistry in Energy Technology. Barshick, S.A., Vass, A.A., Ma, C.Y., Skeen, J.T. and Griest, W.H. Conf- 9510143. pp. 5-6, Gatlinburg, Tennessee, October 10-12, 1995.

"Trace Evidence at Crime Scenes/Homicides", Vass A.A., Presented at the 2nd Annual Jacksonville Sheriff's Office Robbery/Homicide Conference, Jacksonville, Fla. July 31-August 4, 1995.

"The resistance of amoebae, amoebae associated bacteria and derivars to various forms of radiation", Vass A.A., Tyndall, R.L., Presented at Endocytobiology VI, Tubingen, Germany, Sept. 6-10, 1995.

"Soil Analysis under Decomposing Remains", Vass A. A., Presented at Challenges in Forensic Pathology and Investigations: District 12 Medical Examiners. 22nd Annual Medical Examiners Program, Nov. 2-5, 1994, Sarasota, Fla.

"The Importance of Protozoa in the Survival and Amplification of Legionella", Tyndall, R.L., Vass A.A. Presented at the ASHRAE National Meeting, June 28, 1994, Orlando, FL.

"Bioremediation Capabilities of Amoebae Associated Bacteria", Vass, A.A., Tyndall, R.L. Presented at the Biotechnology and Biomol. Science Colloquium, March 15-16, 1994.

"Chemical/Toxicological Evaluation of Windrow Composting of Explosives-Contaminated Sediments", Griest, W.H., Tyndall, R.L., Stewart, A.J., Vass, A.A., Ho, C.-h., Caton, J.E., Caldwell, W.M. 35th Rocky Mountain Conference on Analytical Chemistry, Denver, CO., July 25-29, 1993.

"Bioremediation Capabilities and Diversity of Bacteria Sequestered by Amoebae", Expo '93, Oak Ridge National Laboratory, April 1993.

"Time Since Death: the most difficult forensic question to answer." 3rd Annual Mountain, Swamp and Beach meeting for Forensic Anthropologists. University of Tennessee, Knoxville. 1991.

"Time since death determinations of Human Cadavers Utilizing Inorganic Parameters in Soil Solution." 43rd Annual Meeting of the American Academy of Forensic Sciences, Anaheim, CA., February 1991.

"Time since death determinations of Human Cadavers Utilizing Volatile Fatty Acids in Soil Solution." 42nd Annual Meeting of the American Academy of Forensic Sciences, Cincinnati, OH., February 1990.

"Time of Death", Seminar on Forensic Medicine: Homicide Investigation, East Tennessee State University, Quillen-Dishner College of Medicine, Johnson City, TN., August 1989.

## **HONORS/AWARDS**

Antarctic Service Medal of the United States of America  
Certificate of Achievement, New Zealand Survival School  
National Dean's List  
Dean's List Scholar, Virginia Commonwealth University  
Nominee for Omicron Delta Kappa's Paul N. Derring Award for  
Outstanding Sophomore. Va Tech, Blacksburg, VA.  
Excellence in Crime Scene Investigation, FBI Southeastern Regional Competition  
Certificates of Recognition, ORNL Patent Applications (7)  
R&D 100 (2000)  
UT-Battelle Award Recipient (2000)  
UT-Battelle Award Recipient (2001)

United States Army Criminal Investigation Command – Commanding General’s Award  
for Excellence

Nominated top 10 Scientist in TN, 2004 by Business Tennessee Magazine.

UT-Battelle Service Award (2007)

## PATENTS

DOE S-115, 228 – External Split Field Generator (2009)

Docket #: 1300001988 Winnowed Impulse-flow Sample Entrainment and Acoustic  
Spectroscopic Sensor (2007)

Docket 1966 – UT/Battelle: Cooling Garment (2007)

Docket 1911 – UT/Battelle: Universal Body Bag Tray (2007)

Docket 1203 – UT/Battelle: Biocidal material for treatment against pathogens 08/04/04.

US Patent No. 11,748,649 issued 3-6-2008

ESID 1034-X Rescue or Creation of Bacterial Populations by Passage through Protozoa.

ESID 1231-X Process for Degrading Napalm

US Patent No. 5,449,618 issued 9-12-95

Method of degrading TNT

US Patent No. 5,484,730 issued 1-16-96

US Patent No. 5,578,488 issued 11-26-96

ESID 1413-X Mercury Contaminated Soil Cleaning with Copper Pellets and  
Microbial Agents

US Patent No. 5,597,729 issued 1-28-97

ESID 1814-X Novel System for Removal of Infectious Agents Using Pulsed Fields (6-2-97)

ESID 1860-X Inhibitory Effects of an Amoebae/Bacterial Preparation Having  
Anti-Tumor Properties (filed 9-15-97)

ESID 1861-X Inhibitory Effects of an Amoebae/Bacterial Preparation Having  
Anti-Reverse Transcriptase Activity (filed 9-15-97)

ERID 0491 Antimicrobial Effect of an Amoebae/Bacterial Preparation  
(To be filed with the USPTO)

UTRC Time Since Death Determinations of Human Cadavers

US Patent No. 5,162,232 issued Nov. 10, 1992



## Marcus B. Wise

Abbreviated CV

(April 2009)

### Education:

BS (1978), Chemistry, Furman University, Greenville, SC  
MS (1979), Chemistry, Furman University, Greenville, SC  
Ph.D. (1984), Analytical Chemistry, Purdue University, West Lafayette, IN

### Employment:

2006-Present Leader of the Environmental Mass Spectrometry Group, Chemical Sciences Division, ORNL  
2001-2006 Senior Research Scientist, Chemical Sciences Division, ORNL  
1994-2001 Leader of the Instrumentation Group, Chemical and Analytical Sciences Division, ORNL  
1984-1994 Research Staff, Analytical Chemistry Division, ORNL  
1979-1984 Graduate Instructor and Research Assistant, Purdue University, West Lafayette, IN

### Awards, Honors, Patents

IR-100 Award (CBMS Team) (2000)  
LMER Technical Achievement Award (CBMS Team) 2000  
MMES Technical Achievement Award (Direct Sampling Ion Trap Mass Spectrometry) (1993)  
R&D 100 Award (1979)  
7 United States Patents  
1 Foreign Patent  
3 Technology Transfer Licenses

### Expertise and Experience

Dr. Wise is a Senior Research Scientist and Group Leader of the Environmental Mass Spectrometry Group of the Chemical Sciences Division, Oak Ridge National Laboratory. He earned his BS and MS degrees in chemistry from Furman University in 1978 and 1979 respectively and his Ph.D. in analytical chemistry from Purdue University in 1984. He has been a member of the research staff at ORNL since 1984 where he has been a principal investigator on numerous projects related to the rapid analysis of organic chemicals in environmental samples. Dr. Wise has over 25 years of experience in the development of novel mass spectrometric-based techniques and instrumentation for the rapid analysis of volatile organic compounds (VOCs), organic pollutants and chemical weapons in air, water, and soil samples. He is a co-inventor on 7 US patents, including 5 patents related to novel sample introduction systems for ion trap mass spectrometers. He is also one of the authors and developers of EPA Method 8265 for rapid screening of volatile organic compounds in air, water, and soil. In recent years, Dr. Wise has been involved in the development of fieldable mass spectrometers and hand-held sensor systems for the on-site detection of volatile organic compounds and odor signatures.

**Publications:** > 25 peer-reviewed research publications, 3 book chapters, and >100 invited and contributed oral presentations.

Stephen A. Lammert, Wolfgang R. Plass, Cyril V. Thompson, Marcus B. Wise, Design, "Optimization, and Initial Performance of a Toroidal rf Ion Trap Mass Spectrometer", *International Journal of Mass Spectrometry*, **212** (2001), 25-40.  
W.H. Griest, M.B. Wise, K.J. Hart, S.A. Lammert, C.V. Thompson, A.A. Vass, "Biological Agent Detection and Identification by the Block II Chemical Biological Mass Spectrometer", *Field Anal. Chem. & Technol.* **5**, (2001), 177.  
Kevin J. Hart, Marcus B. Wise, Wayne H. Griest, Stephen A. Lammert, "Design, Development, and Performance of a Fieldable Chemical and Biological Agent Detector", *Field Analytical Chemistry and Technology*, **4**, (2000), 93.