## B135 Statistical Characterization of Aluminum (Al) Powders in Explosives Using Automated Particle Micromorphometry

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After attending this presentation, attendees will better understand the forensic potential of automated particle micromorphometry and statistical analysis to aid in making comparisons between questioned and known Al powders.

This presentation will impact the forensic science community by demonstrating the application of Al particle micromorphometry as a quantitative method for the characterization and comparison of explosive evidence, which may also provide valuable lead identification for forensic investigations.

Starting materials for an Improvised Explosive Device (IED) are readily obtainable from local commercial sources. Al powder, a common metallic fuel, has a wide variety of legitimate uses and is widely available without significant regulatory constraints.[1] Al powders can be obtained from industrial manufacturers or can be produced inexpensively using basic instructional manuals and videos. Due to the online sharing of instructional manuals and published books on how to construct IEDs, bomb makers are now informed on the easily accessible household materials that can be used to make explosive chemical mixtures.[2]

Previous results using S Scanning Electron Microscopy with Energy-Dispersive X-ray Spectroscopy (SEM/EDS) showed morphology and surface characteristics can differentiate some methods of Al powder manufacturing (i.e., industrial vs. homemade). Particle micromorphometry may be used as a complementary method to gain additional information to differentiate Al powder sources. This presentation addresses fundamental factors of Al particle metrology, including sample slide preparation, imaging parameters, and potential methods to minimize sampling biases; the statistical methods used to analyze these large multidimensional datasets will be discussed.

Al powder samples were obtained from legitimate industrial manufacturers, various "in-house" production methods, and seized IEDs. The amateur methods were replicated to produce Al powder from easily available sources, including 25 brands of Al foil, 7 brands of metallic spray paints (40 cans), 24 Al ingots melted from Al cans and filed or lathed, 23 pyrotechnics, and 40 catalyst packets from two brands of binary exploding targets. To prepare microscope slides for imaging, a subsample containing ~1,000µg from bulk Al powder was placed into a microtube containing Permount® mounting medium. The solution was mixed until evenly dispersed, then an aliquot of the subsample was placed dropwise onto a microscope slide and a coverslip added. Preliminary statistical analysis on these microscope slide preparations that contained only four subsamples and one aliquot from each subsample determined there were large within-sample variations; therefore, more subsamples are needed for a representative sample of the bulk Al powder. A subset of 17 Al powder samples were prepared using ten subsamples and three aliquots for each subsample. Leave-One-Out Cross-Validation (LOOCV) was performed on this subset of samples and it was statistically determined that seven subsamples of the bulk Al powder and three aliquots for each subsample were sufficient to obtain a representative sample of the bulk Al powder.

Transmitted light microscope images ($n \approx 4{,}200$ fields of view/sample) of the Al samples were acquired using an automated stage and automated Z-focus. Dimensional analysis was calibrated using a National Institute of Standards and Technology (NIST) -traceable stage micrometer; polystyrene spheres of 100µm, 50µm, and 10µm were used as secondary standards to assess linear calibration. Images were batch processed using commercial image analysis software and customized code. Each image was converted to a binary image to enhance edge detection and the particles were counted and measured. Seventeen parameters were measured for each particle within the image field of view, including area, aspect ratio, perimeter, roundness, mean diameter, mean feret, radii (maximum and minimum distance from particle centroid to edge), radius ratio, box height, box width, and fractal dimension. The large multidimensional datasets ($n \approx 90{,}000$-$500{,}000$ particles/sample) were analyzed using an open source statistical package.

The datasets are too large and complex to analyze at this point without some dimensionality reduction. Preliminary work focused on the use of a weighted summary of 17 morphometric measurements on the subsamples. This was achieved by first taking weighted averages of the particles per Fields Of View (FOV) yielding a 17-dimensional vector for each FOV (i.e., average particle for each FOV). Then, the average of the average vectors for each FOV per aliquot was calculated, giving a 17-dimensional vector per aliquot. Likewise, the average vector across the aliquots corresponding to a given subsample was calculated, resulting in one 17-dimensional vector for the entire subsample for each sample. The classification accuracy between sources of Al powders using this weighted approach and results from the various multivariate statistical methods tested will be presented.

**Reference(s):**

1. Kosanke, K.L, and Kosanke, B.J. 2007. A Study Evaluating Potential for Various Aluminum Metal Powders to Make Exploding Fireworks. *Pyrotechnics Guild International Bulletin.* No. 154.
2. Larabee, A. 2015. The Wrong Hands: Popular Weapons Manuals and Their Historic Challenges to a Democratic Society. Oxford University Press New York, New York.

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