FINAL RESEARCH REPORT

DEVELOPMENT OF MICROSCOPICAL METHODS FOR THE SYSTEMATIC ANALYSIS OF CHEMICALLY REACTED, IMPROVISED LOW EXPLOSIVES AND RELATED RESIDUES

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1.0 Purpose

For the microscopical analysis of chemically reacted low explosive (LE) and related residues, the stereomicroscope (SM) and polarized light microscope (PLM) make possible the direct and immediate observation of many physical and optical crystallographic properties often leading to the identification of questioned material and suspect particles. In the hands of a trained microscopist, SM and PLM techniques are rapid, inexpensive, direct, reproducible, and dependable. The forensic scientist, equipped with the same microscopes and accessories that are often used for many other types of physical trace evidence (e.g., hairs, fibers, illicit drugs, glass, paint, pigments, etc.), can expect to find these instruments especially useful for investigative and confirmatory techniques with this type of physical evidence.

Microscopical data and measurements of LE and related residues include morphological and optical properties that are characteristic of the explosive material itself, or it might be the corresponding properties of the unburned, partially burned, or fully burned substances and chemical compounds in question. Sample size ideally suited for SM and PLM can be particles ranging from a few millimeters to less than 1 μm in diameter.

It is usually possible and necessary for the microscopist to make temporary and permanent slide preparations applicable to this type of evidence. These techniques, also refined and detailed in this research, are otherwise well established in the field. The identification of particles and particle residues by microscopy is based on the known morphology and optics of particles, crystals, amorphous solids, and other substances

with little if any destruction of the original material. If necessary, only a few very small, representative particles are tested for solubility in solvents or dissolved for recrystallization, or in preparation for microchemical or microcrystal testing to further the analysis.

Specifically, this research is improving the direct visual comparison, microscopical identification, and chemical analysis of chemically reacted, i.e., unburned, partially burned, and fully burned materials, together with their resultant residues. Furthermore, this research increases the overall understanding of the processes and mechanisms making it possible to obtain analytical results from physical evidence, particularly regarding the analysis of LE by a combined visual, microscopical, and microchemical methodology. Data, including numerous permanent microscope slide preparations together with detailed photomicrographs under a variety of microscope illumination conditions, are compiled and presented with the aim of providing a practical and graphical methodology for the examination of these residues.

In order to successfully identify LE and related residues, the microscopist needs the most accurate, reliable, and generally useful resources for characterization, comparison, and identification of questioned material with known references. The culmination of this research will include the specific methodologies being used, guidance on sampling for microscopical analysis, sample preparation techniques (including permanent slides), tables summarizing all known and verified optical characteristics, practical references, and numerous photomicrographs specifically arranged under a wide range of easily reproduced illumination conditions serving as an atlas of visual, photographic, and photomicrographic images.

2.0 Project Design and Methods

This project includes the study and analysis of dozens of materials, including more than 18 oxidizers (OX), 14 fuels (FU), a variety of metal salts (MS), and miscellaneous inorganic (MI) chemical compounds. Also included are metal powders (MP), black powders (BP), black powder substitutes (BS), smokeless powders (SP), firework/pyrotechnics (FP), and miscellaneous organic (MO) chemical compounds.

This research uses the microscopical examination and documentation of various oxidizers and fuels commonly or occasionally found or reported in commercial and improvised low explosives. Research documentation includes permanent slide preparations and numerous photomicrographs taken with the SM and the PLM, including descriptions for each of the particles that together illustrate all of the necessary polarized light microscopical and visual characteristics such as shape, size, transparency, transmitted-light color, birefringence, extinction characteristics, top-light color, and top-light surface characteristics.

Further research documentation includes presentation of all of these properties together in tables and photomicrographs for three stages of chemically reacted particles, unburned, partially burned, and fully burned conditions, under various microscopical conditions where the same particles are in the same position and field of view, including scale bars for each image. Six different conditions of photomicrography: 1) plane polarized light, 2) plane polarized light with top light, 3) partially uncrossed polars, 4) partially uncrossed polars with top light, 5) crossed polars, and 6) crossed polars with a Red I compensator and top light, are arranged into a single pictorial composition (photomicrographic montage). These stages of unreacted, partially burned,

and fully burned particles are presented together with tables, including optical properties and microscopical conditions that provide a resource that uniquely brings together all of the essential characteristics required by the microscopist.

This research and methodology also describes the incorporation of the necessary and time-tested microcrystal tests, including modifications and improvements for chemical spot tests with selected metals, such as tests for microscopic aluminum, iron, and steel particles. Microcrystal tests for the organic compound urea, a precursor in the manufacture of the improvised explosive urea nitrate, were also improved and developed. The study, data, and photo-documentation of a wide variety of unburned, partially burned, and fully burned commercial and improvised fuels, such as charcoal, dextrin, spices, starches, sugars, sulfur, and wood meal, all presented together will become an integral part of the methodology culminating from this research.

Microcrystal tests using a wide variety of chemical reagents were performed on most of the unburned, partially burned, and fully burned samples to confirm the detection and sensitivity of positive results for specific cations and anions or elements. Samples that tested positive for the presence of a single ion or element on an unburned sample were also tested on partially and fully burned samples with variable success; i.e., certain samples that tested positive on an unburned sample may have yielded inconsistent results on some partially or fully burned residues.

2.1 Instrumentation

The analysis and testing of LE and related residues utilize much of the same instrumentation and accessories that are accessible to many forensic science crime or

other laboratories equipped with microscopes. For the methods of sample preparation and analysis described in this research, the laboratory should be equipped for stereomicroscopy with a SM, preferably binocular and stereoscopic for visual work and a trinocular head (optional) for imaging and photomicrographic documentation. Stereomicroscopic illumination should be reflected white top light, with built-in or external incandescent or LED reflected top light sources. For polarized light microscopy, a PLM, preferably capable of achieving Köhler or Köhler-type Illumination, and the following required accessories:

- 10x, 20x, and 40x objectives
- Binocular head (or trinocular for photomicrography or image capture) for oculars/eyepieces (10x), including one cross-line reticle preferably “keyed” to the eyepiece tube
- 360° circular, rotatable stage, preferably graduated for angular measurements
- Substage condenser with aperture diaphragm
- Polarizer and analyzer that can each be positioned and set with linear vibration directions at 90° to one another (crossed polars), and can be aligned to the cross-line reticle in the ocular/eyepiece
- Accessory slot for wave plates and compensators
- First order Red I compensator retardation wave plate with approximately 550 nm retardation and known slow and fast vibration directions
- Reflected light, top light(s) for oblique illumination

The following are suggested accessories for photomicrographic documentation with the SM and PLM:

- Camera/image capture device and any related software application or storage device
- Microscope-to-camera coupler for mechanical attachment of camera to eyepiece/tube or trinocular head

3.0 Results

The results of this research are multiple products that will aid forensic scientists in their analysis of LE and related evidence. The first is a test method and analytical scheme, which can serve as a flow of analysis or guide in how to properly prepare, analyze, characterize, and compare a wide variety of particle types that may lead the microscopist to a positive identification. Another is an LE characterization table that contains all of the known and verified optical properties and additional information about each of the different types of particles including the most important oxidizers, fuels, metals, metallic salts, etc. This is all accompanied by a photomicrographic presentation of various particles, with multiple photomicrographs arranged in singular pictorial composition and hundreds of images documenting the microscopical appearance of unburned, partially burned, and fully burned particle conditions.

3.1 Test Method and Analytical Scheme

The microscopical identification of LE particles becomes more accurate and rapid with continued practice, and with time, the unique, individual characteristics of a particle, and the appropriate sampling or microscopical preparation techniques leading to

identification, almost become automatic to the microscopist. In less fortunate scenarios, the choice can be usually reduced from a very large number of possibilities down to 2 or 3 possibilities, where reference to articles, tables, and flowcharts will suggest the best path to confirm the final identity.

By studying known reference samples, particle descriptions, or photomicrographs of LE and related particles, the identifying optical properties and characteristics of each particle will become familiar to the beginner. Analytical schemes to aid in identifying a given oxidizer, fuel, or other component have been prepared and are now available. Many can be identified with certainty in various mounting media by color, shape, size, and other quickly observed microscopical optical properties, especially with crossed polars and extinction characteristics in the PLM. Other substances, especially if they are water-soluble, may require recrystallization, e.g., any of the LE oxidizers, and a supplementary microchemical or microcrystal test is always an option.

For identification, it is very important to know what constitutes the minimum number of characteristics for a given substance. It is equally important to avoid forcing a given particle into the wrong category and miss the identification. As part of this research, the methodology for microscopists to begin to identify particles, and to serve as a reminder to experienced microscopists, includes complete descriptions of the characteristics observed in all particles: shape, surface texture, luster, and size or size range (ultra fine <1 μm, fine <1 μm, medium <20 μm, and coarse <100 μm). These properties may be determined on the bulk sample or residue by the SM and before during or after mounting the individual particles in preparation for the PLM using transmitted and reflected top light conditions.

Crystalline particles, e.g., any of the water-soluble oxidizers, metal salts, sugars, starches, and organic chemical compounds, have morphological properties and a multitude of qualitative and precise quantitative optical properties that uniquely identify them. Degree of isotropy, anisotropy, relative or actual refractive index, and birefringence are just a few examples. Figure 1 is a table of all of the known chemical oxidizers associated with LE, their chemical formulas, and their range of refractive indices. It provides a rapid way for a microscopist to view the properties for possible oxidizers together with their unique range of important optical properties. This table also indicates each oxidizer's relative refractive index to two common microscopical mounting media for PLM: Norland Optical Adhesive 65 (NOA 65) with a refractive index n_D = 1.524 and Meltmount (MM) with a refractive index n_D = 1.662. If the birefringence and relative refractive index can be determined, it is often possible to identify the oxidizer or, by process of elimination, reduce the number of possibilities to a fewer number of chemical compounds.

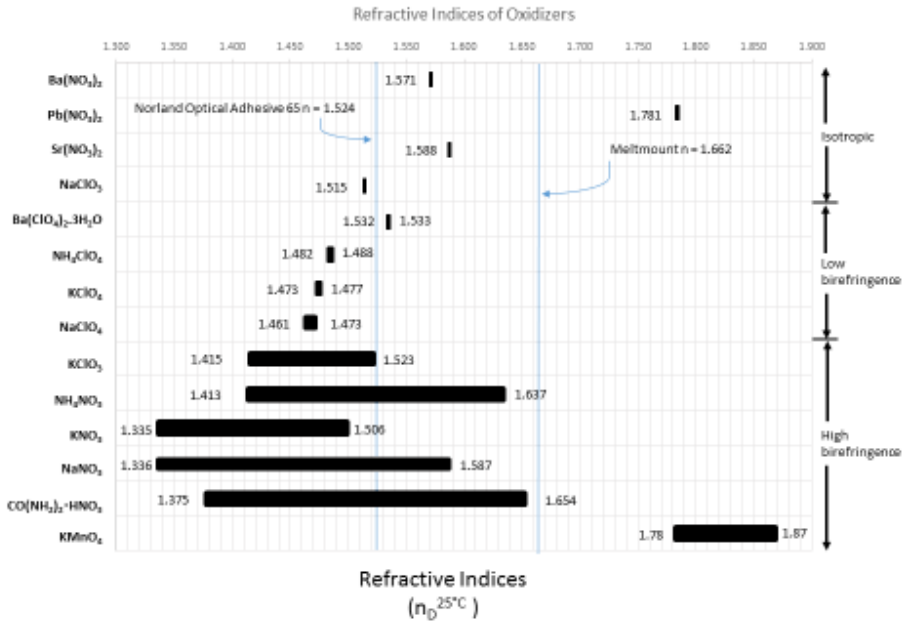

Figure 1. Refractive indices of selected inorganic oxidizers, including degree of isotropy, birefringence, and refractive index relative to mounting medium NOA 65 (n_D = 1.524) and Meltmount (n_D = 1.662).

3.2 Low Explosives Characterization Table

The LE characterization form was produced to aid in characterization and identification of LE particles and related substances (Figure 2). It contains more than 75 different substances, including oxidizers, nitrates, chlorates, perchlorates, metals, fuels, black powder substitutes, smokeless powders, and miscellaneous inorganic and organic chemical compound and materials. The information that accompanies each substance includes optical and physical properties, information regarding chemical solubility, recrystallization, microcrystal and microchemical spot tests, melting points, potential decomposition products, references, and photomicrographs. This table will serve as a quick resource for the microscopist where any and all of the verifiable and most important LE and related residue characterization data are presented together in one location.

Low Explosive Components	code prefix	CODE	Morphology / Shape, Habit, Form	Transparency	Transmitted Light Color	Pleochroism	Crystal System	α and ω	β and ε	γ	Birefringence	Extinction Characteristics / Angles (crossed polars)	Sign of Elongation	Optic Axial Angle 2V and (Optic Sign)	Remarks
Oxidizers, Nitrates – OX	OX														
Ammonium nitrate, NH_4NO_3		OX1A, OX1B, OX1C	recrystallizes as angular, equant, sometimes rounded grains, pseudo tetragonal well formed prisms, blades, thin rods, tablets; conchoidal when ground	transparent	colorless		orthorhombic	1.413	1.611	1.637	0.224			35° (–)	polymorphs, very water soluble
Barium nitrate, $Ba(NO_3)_2$		OX2A, OX2B, OX2C	recrystallizes as flattened octahedra and modified cubes	transparent	colorless		cubic		n = 1.571		0			na	very slightly water soluble, high relief in water
Calcium ammonium nitrate, $Ca(NH_4)_4(NO_3)_2$?; 5Ca(NO3)2.NH4NO3.10H20, double salt		OX3A, OX3B, OX3C	?	?	?		?	1.475	?	1.51	0.035			45° (–?)	$5Ca(NO_3)_2.NH_4NO_3.10H_2O$, double salt
Calcium nitrate tetrahydrate, $Ca(NO_3)\cdot4H_2O$			recrystallizes as elongated prisms	transparent	colorless		monoclinic	1.462-1.468	1.495-1.501	1.501-1.507	0.039			48-52° (–)	water soluble
Cellulose nitrates, nitrocellulose from cotton			mercerized cotton fiber and linter morphology and size	transparent	colorless		noncrystalline	1.53	n = 1.590 for isotropic fibers	1.585	0.055-0.000 decreases with % nitrogen	retardation decrease with % N increase	(+) then (–) at 13% N, then isotropic		nitrogen content = 11-13.5%, highly flammable, soluble in acetone, mercerized cotton fiber and linter,monohidonu and size
Lead nitrate, $Pb(NO_3)_2$		OX4A, OX4B, OX4C	recrystallizes as flattened octahedra and cubes	transparent	colorless		cubic		n = 1.781		0			na	very high relief in water
Potassium nitrate, high temperature polymorph, KNO_3		OX5A (no OX5B or C due to melting)	recrystallizes as rhombohedra, chevrons, isomorphous with $NaNO_3$	transparent	colorless		hexagonal (trigonal)	very high	low		very high >> 0.050	symmetrical		0° (–)	develop from water near the edge of the drop
Potassium nitrate, low temperature polymorph, KNO_3		OX5A (no OX5B or C due to melting)	recrystallizes as prisms, jagged and equant when crushed	transparent	colorless		orthorhombic	1.3346	1.5056	1.5064	0.1718			7° (–)	polymorphs, stable form at room temp
Sodium nitrate, $NaNO_3$		OX6A, OX6B, OX6C	recrystallizes as well-formed rhombohedra, rhombohedral cleavage when ground	transparent	colorless		hexagonal (trigonal)	1.5874	1.3361 (ε' = 1.467)		0.2513	symmetrical (rhomb angles 77° and 103°) ω bisects acute rhomb angle		0° (–)	very water soluble, isomorphous with calcite, no known polymorphs
Strontium nitrate anhydrous, $Sr(NO_3)_2$		OX7A, OX7B, OX7C	recrystallizes as octahedra and cubes octahedra and octahedral distortions ?	transparent	colorless		cubic		n = 1.5878, [1.591 McCrone reference sample, 1.590 Moorehead		0			na	water soluble, probably the only known form is anhydrous
Strontium nitrate monohydrate, $Sr(NO_3)\cdot H_2O$			recrystallizes as octahedra and octahedral distortions	transparent	colorless		cubic		n = 1.589		0			na	may not exist as monohydrate
Strontium nitrate tetrahydrate, $Sr(NO2)\cdot4H_2O$				transparent	colorless		monoclinic								may not exist not purchasable

Figure 2. The Oxidizer (OX) section of the characterization table includes 18 common oxidizers (12 exhibited here) associated with low explosives. Each oxidizer has a unique code that corresponds to accompanying photomicrographs in unburned, partially burned, and fully burned conditions.

3.3 Atlas of Unburned, Partially Burned, and Fully Burned Low Explosive and Related Materials

To further enhance the characterization and identification of LE materials, and integral to this research, are photomicrographic montages of selected particles, oxidizers, fuels, metals, etc., prepared and photographed by the PLM and arranged in single pictorial compositions. These montages collectively will help to serve as an atlas and visual guide when analyzing particles microscopically. The majority of the substances that were prepared, analyzed, and photographed under different microscopical conditions were arranged into single photomicrographic montages that will allow microscopists to easily view and compare relevant morphological and optical properties simultaneously in the following 6 polarized light microscopical conditions: plane polarized light, plane polarized light with top light, partially uncrossed polars (12°), partially uncrossed polars (12°) with top light, crossed polars, and crossed polars with a

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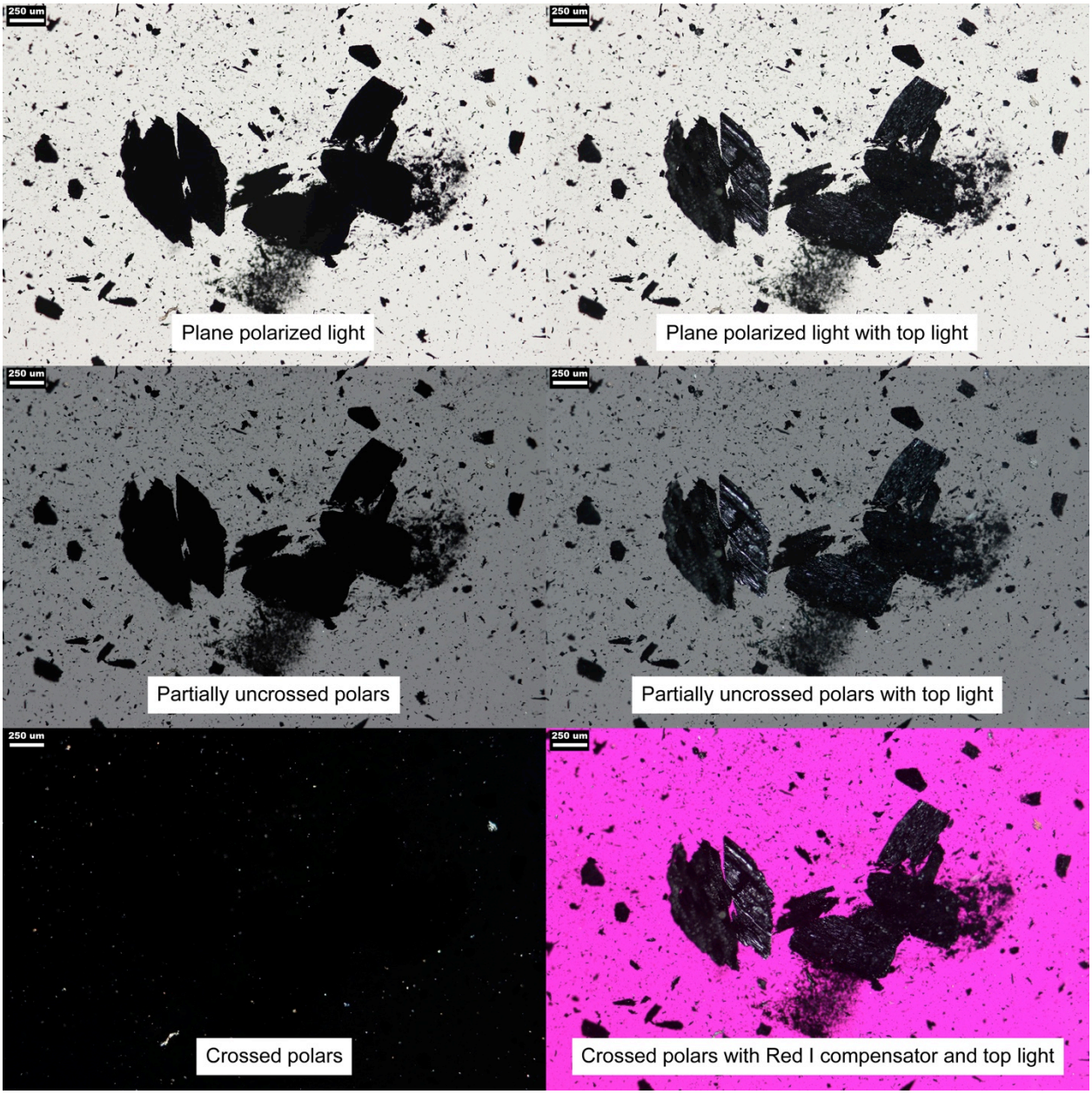
Red I (530 nm) compensator and top light. Figure 3 shows the PLM setup that was used to take photomicrographs in order to prepare the montage images.

Figure 3. Microscope, illumination, and camera arrangement used to take images for the photomicrographic photomontages obtained in this research. This convenient setup utilizes a conventional PLM and the use of various illumination conditions. All photomicrographs were taken with a digital, single-lens reflex camera paired with commercially available image-capture software.

The following are examples of photomicrographic montages for a typical charcoal (fuel), aluminum (metal powder), and ammonium nitrate (oxidizer), each arranged in 6 different PLM illumination conditions and for each unburned, partially burned, and fully burned conditions allowing for direct and side-by-side visual comparison (Figures 4–12).

FU3A CHARCOAL (MIXED HARDWOOD), UNBURNED



FU3A

Figure 4. Charcoal particles are brown to opaque black flakes, somewhat fibrous with curved fractures. Wood charcoal surfaces can appear shiny and black with wood cell structures (tracheids, vessels, pits, etc.) that are more apparent in top light conditions.

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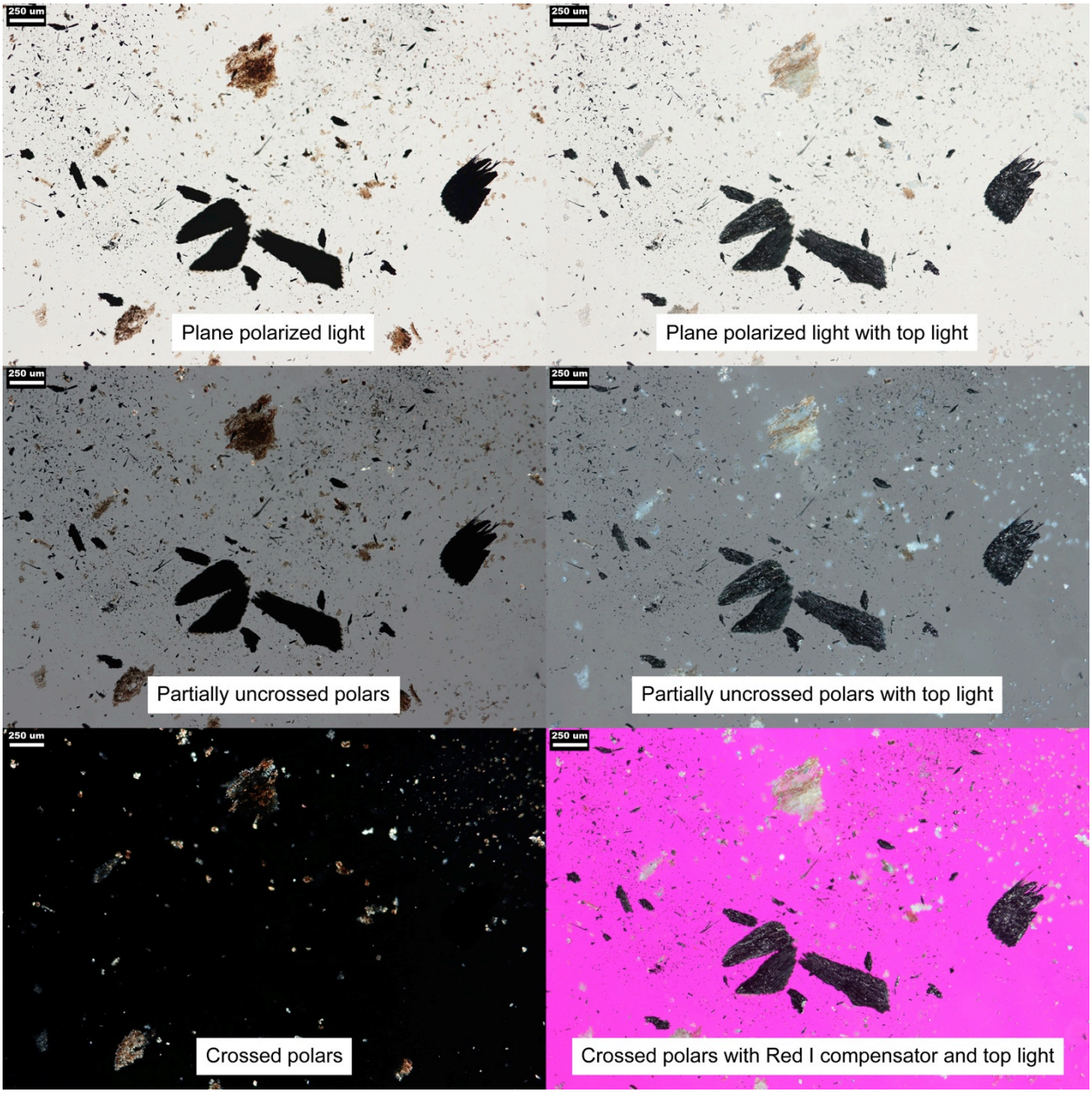
FU3B CHARCOAL (MIXED HARDWOOD), PARTIALLY BURNED



FU3B

Figure 5. These partially burned charcoal particles are slightly fibrous, curved fractures with traces of fine, colorless, transparent, birefringent particles that reflect tan, light brown, or white in top light. Some medium and fine, colorless, transparent, and birefringent particles are also visible.

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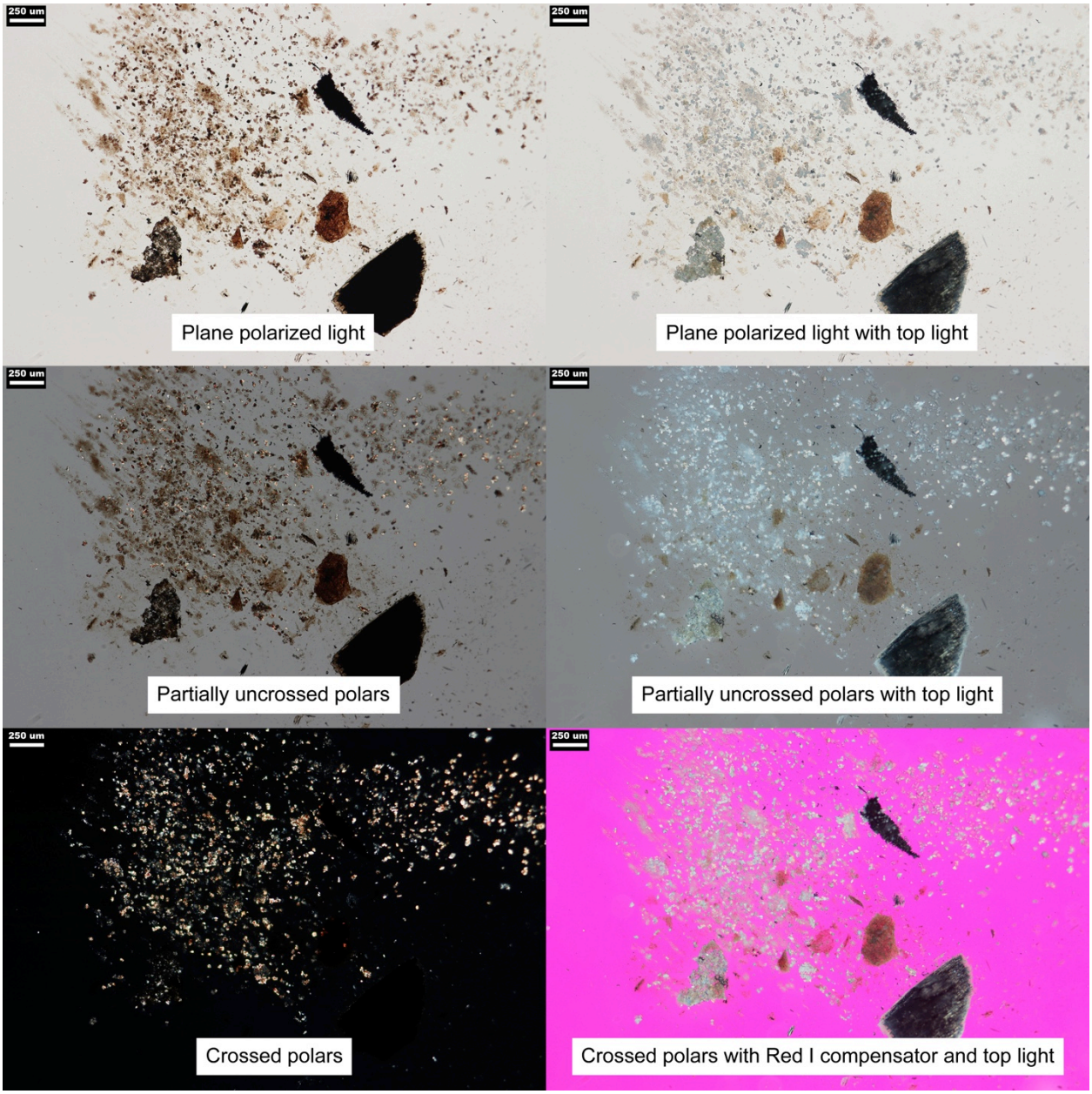
FU3C CHARCOAL (MIXED HARDWOOD), FULLY BURNED



FU3C

Figure 6. Some completely opaque, coarse, black flakes, slightly fibrous with semitransparent and brown particle edges, together with numerous medium and fine colorless, white, gray, tan, and brown, particles in top light. Also, some well-formed bipyramid habits with high birefringence and polycrystalline extinction in crossed polars, possibly calcium oxalates, remain.

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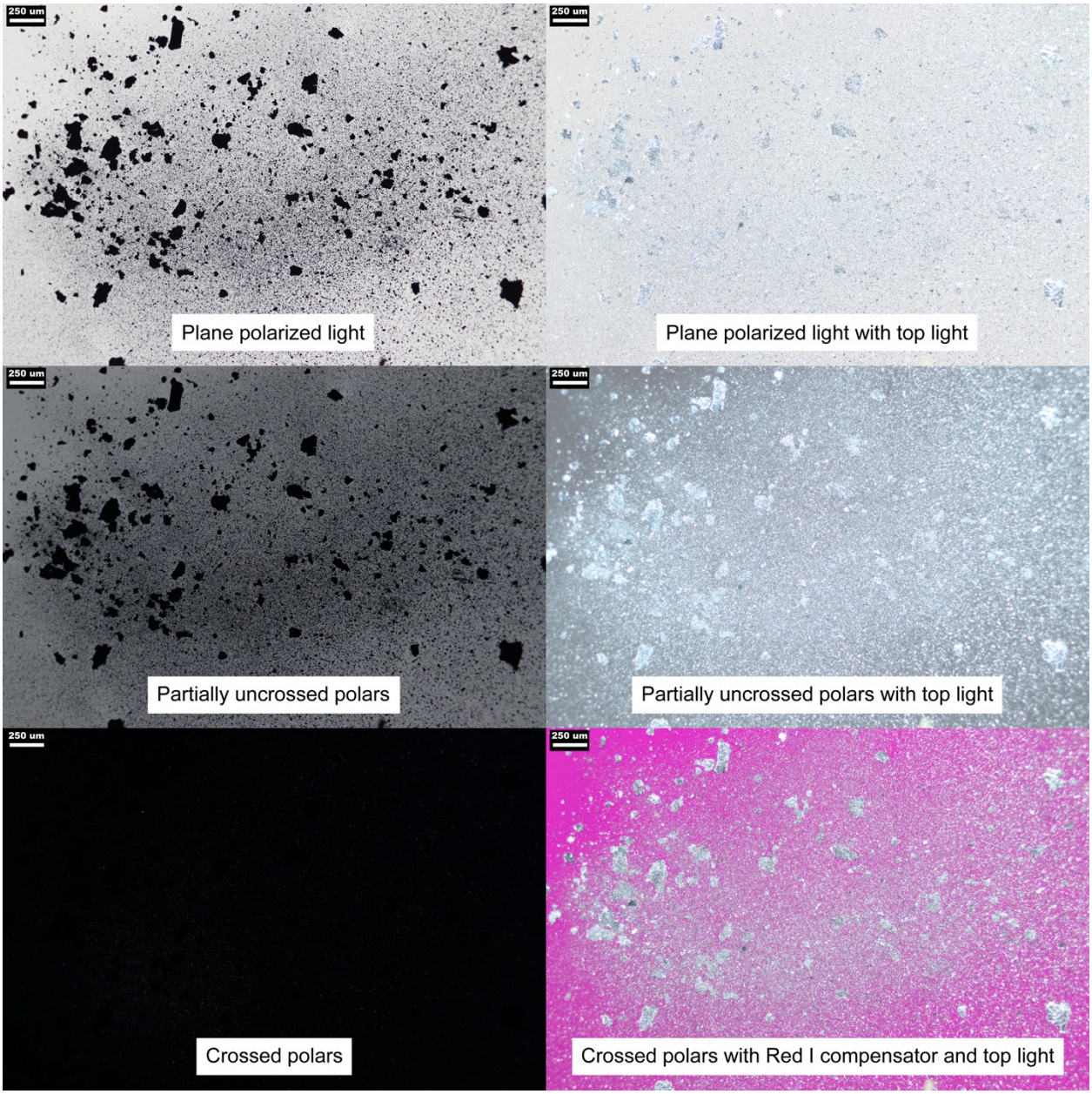
MP1A ALUMINUM POWDER (325 MESH), UNBURNED



MP1A

Figure 7. Thin, irregular metallic flakes and clumps; most flakes are fine, <10 µm with agglomerates that can be up to 200 µm in diameter that are opaque, shiny and silver with top light. Metals are opaque and are therefore invisible in crossed polars.

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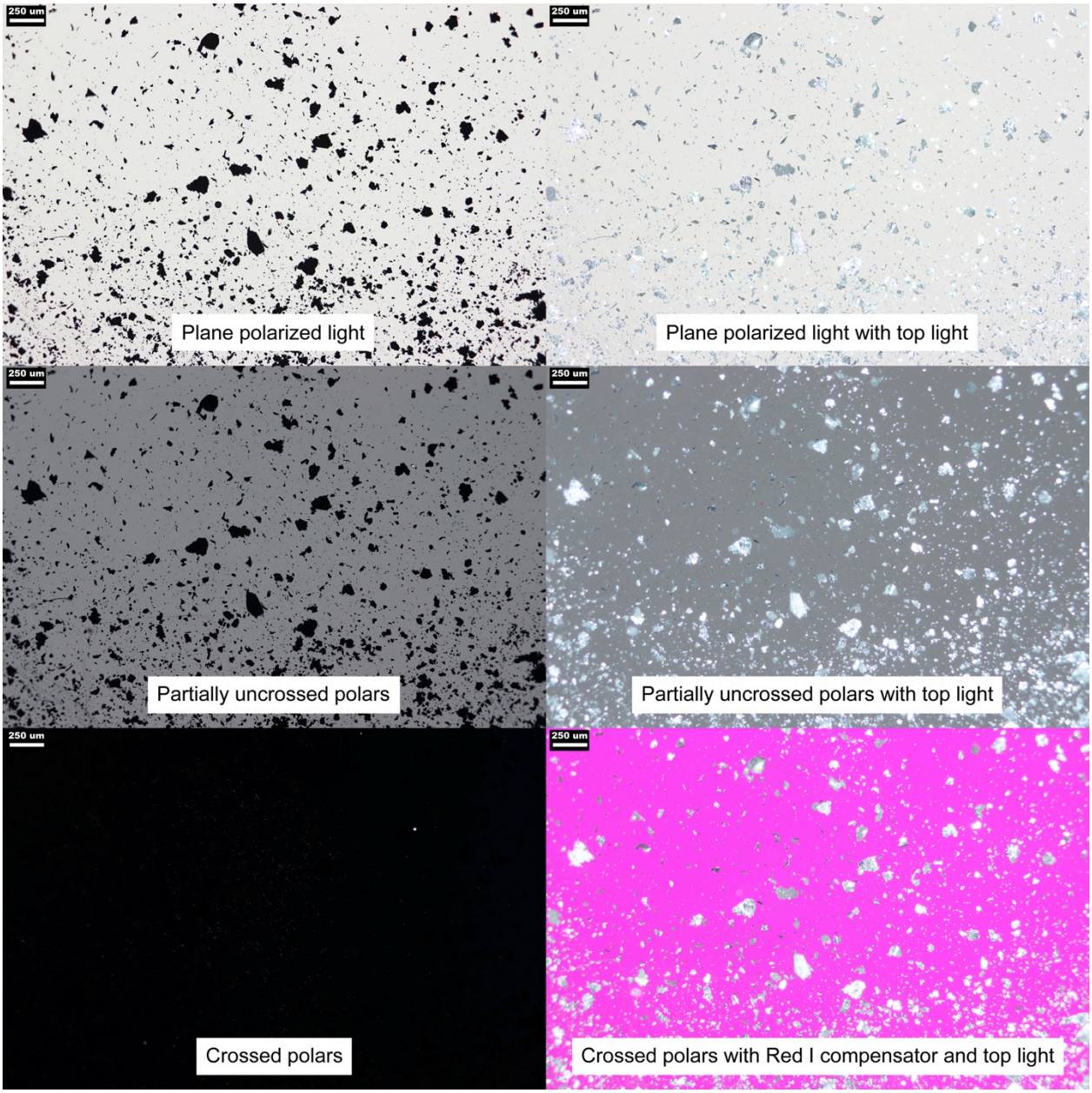
MP1B ALUMINUM POWDER (325 MESH), PARTIALLY BURNED



MP1B

Figure 8. Aluminum has a melting point of 660° C. No changes in appearance are observed after partial burning.

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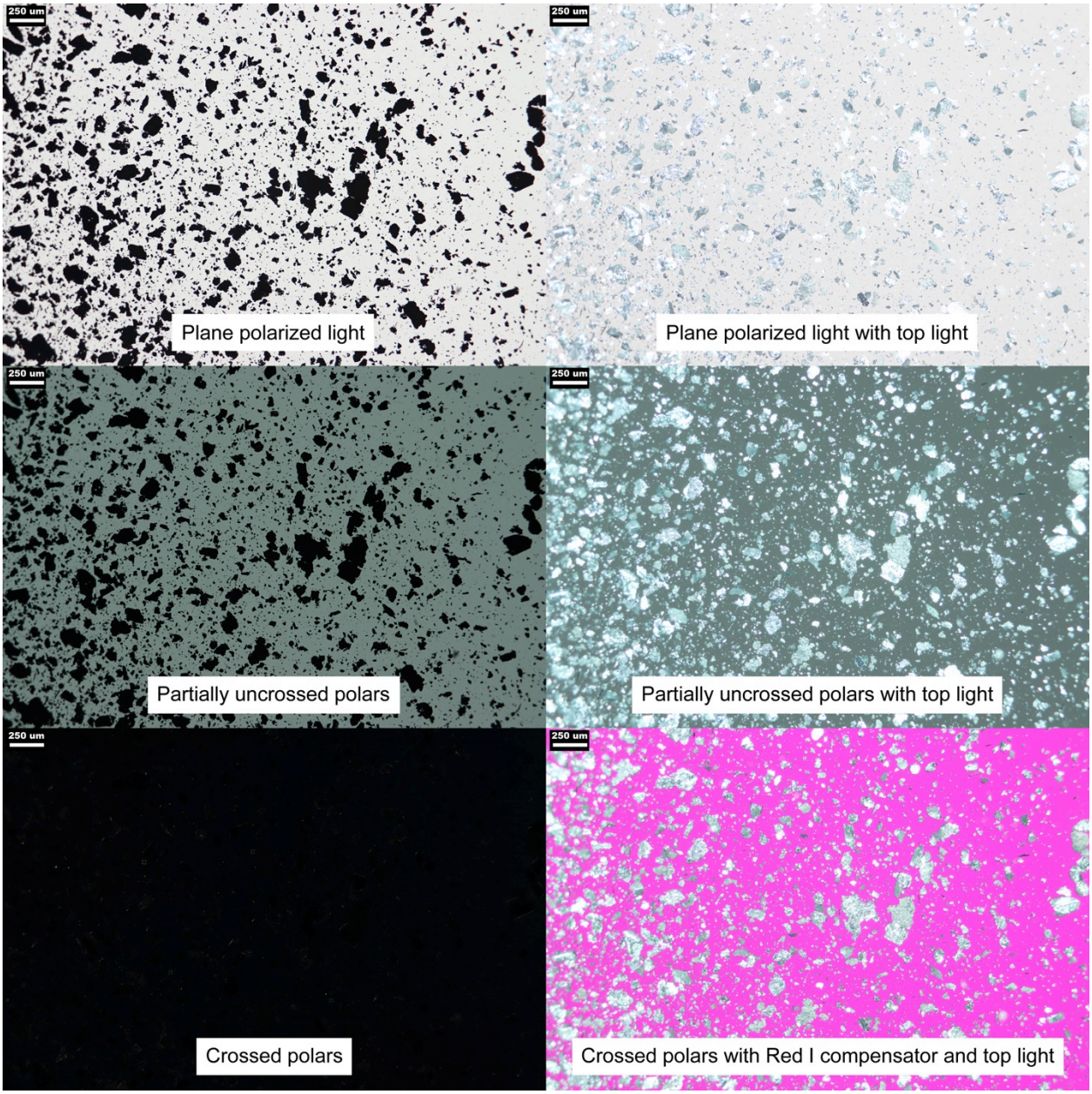
MP1C ALUMINUM POWDER (325 MESH), FULLY BURNED



MP1C

Figure 9. With a high melting point of 660° C, no changes in microscopical appearance occur after attempts to fully burn the sample. Evidence of melting would be a smoothing and rounding of particle edges not observed here. These particles appear unchanged from their unburned condition.

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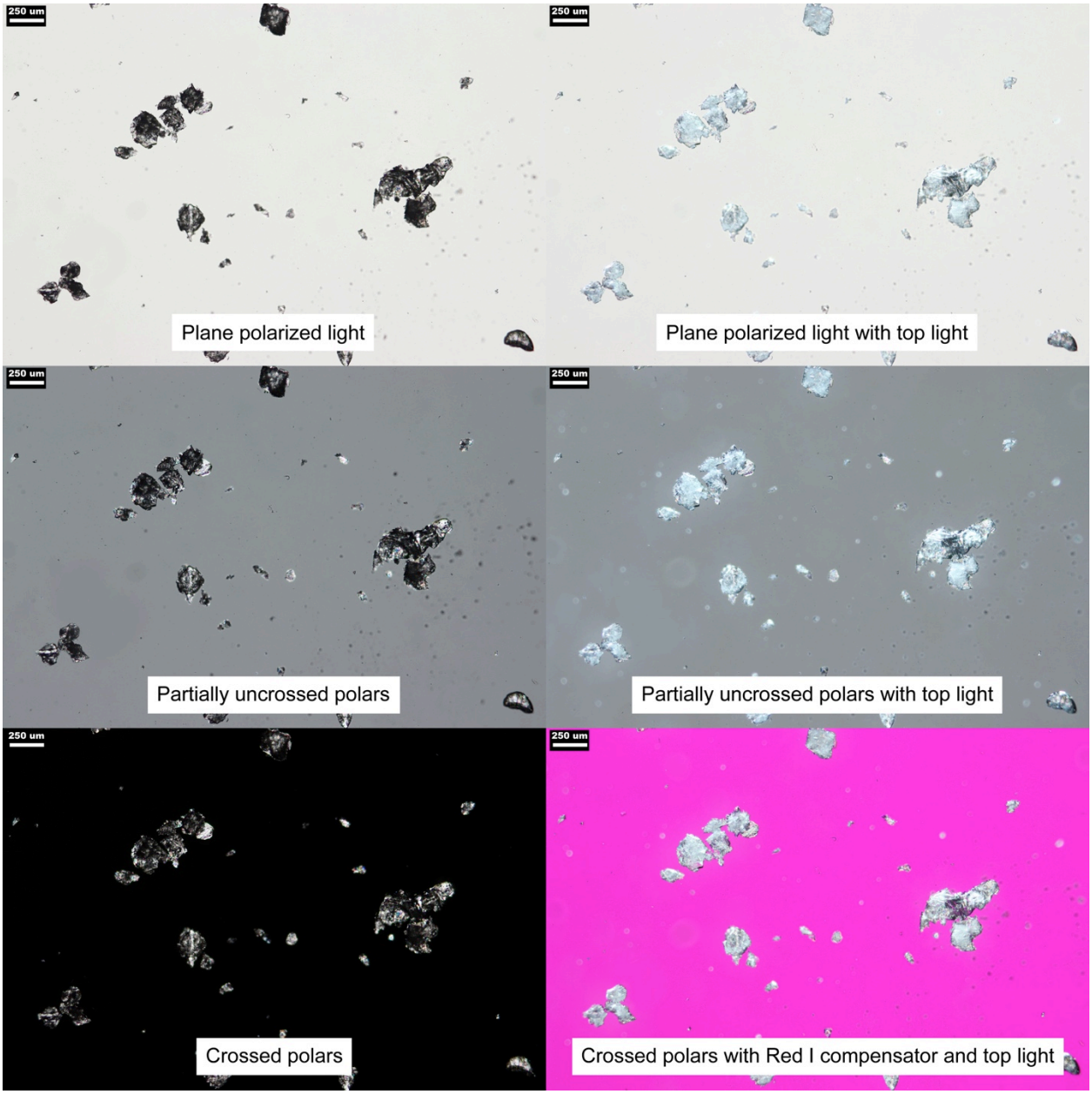
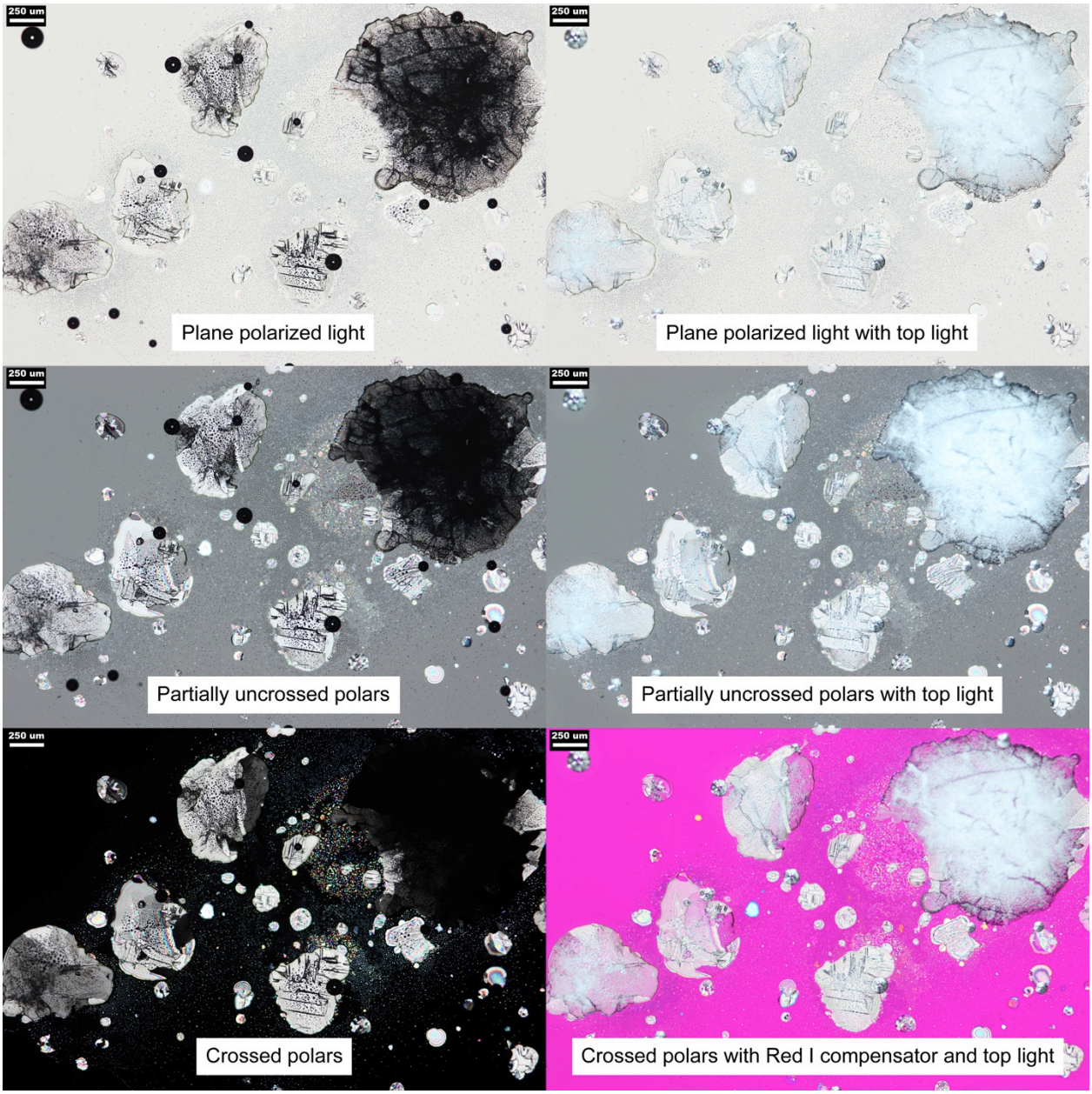
OX1A AMMONIUM NITRATE, UNBURNED, NH_4NO_3



OX1A

Figure 10. Ammonium nitrate particles are ground, irregular, conchoidal, transparent, and colorless crystals with low refractive indices and very high birefringence. They reflect white with top light.

OX1B AMMONIUM NITRATE, PARTIALLY BURNED, NH_4NO_3



OX1B

Figure 11. Ammonium nitrate is a hygroscopic and relatively low melting crystal (at 169° C). When partially burned, absorbed water and spontaneous cooling and subsequent spontaneous recrystallization results in coarse, rounded particles, with internal cracks and inclusions that appear dark in transmitted light and white in top light. Coarse-, medium-, and fine-rounded birefringent particles may be the result of partial burning and fusing together of smaller particles.

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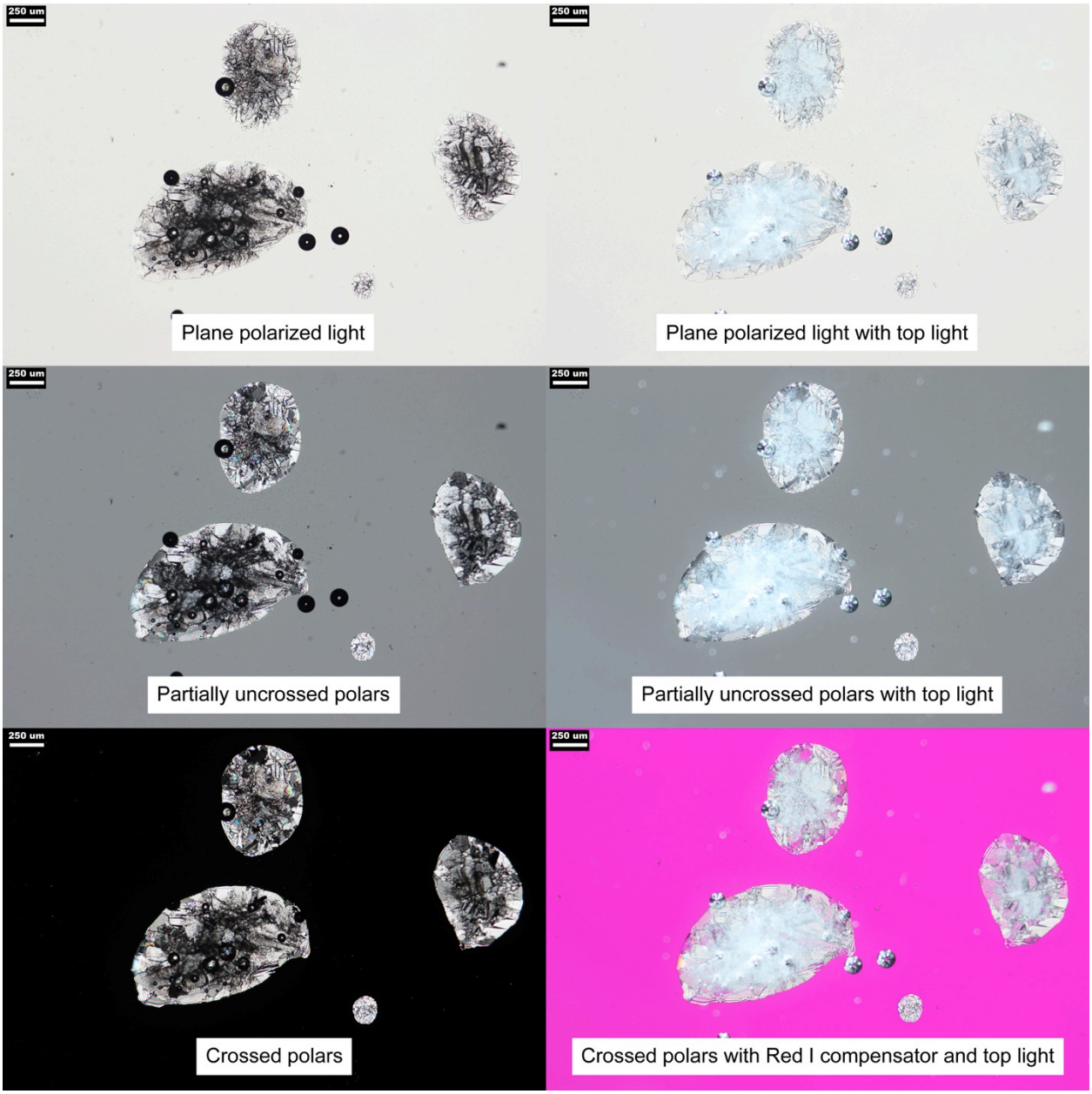
OX1C AMMONIUM NITRATE, FULLY BURNED, NH_4NO_3



OX1C

Figure 12. With a low melting point (169° C) and little or no decomposition after dehydration, ammonium nitrate may boil or begin to vaporize when fully burned. Coarse, rounded, internally cracked, and occluded highly birefringent polycrystalline particles that reflect white in top light result. Medium and fine particles are less numerous probably due to vaporization.

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In addition to the assembled photomicrographic montages, a supplementary array of additional materials and substances were specifically photographed and arranged due to their unique nature. A variety of organic fuels, smokeless powders, and different types of fireworks were selected. Fireworks were photographed intact, dissected, and then each individual component was also photographed and imaged macroscopically with the SM at low magnification and at high magnification under various conditions with the PLM. Examples include a ground spice (ginger) used as fuel (Figure 13), a ground/flying spinner type of firework (Figure 14), and a single-base smokeless powder (Figure 15)

Fuel

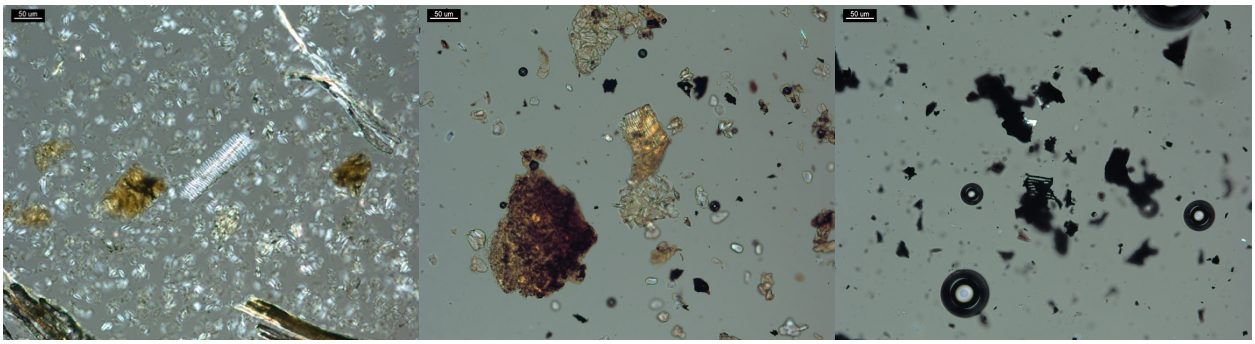

Figure 13. Ground ginger (fuel) in slightly uncrossed polars. Unburned ground ginger particles include numerous, small, oval, and round starch grains occurring together with large, elongated birefringent vessels from the rhizome (left). Partially burned ground ginger exhibits fewer starch grains due to gelatinization and charring of the carbohydrate. Vessels become yellow to brown but are recognizable with some residual birefringence (center). Fully burned ground ginger shows no evidence of starch, with the majority of residue being totally black and opaque and morphological remains of the vessels still present. Unburned, partially burned, and fully burned samples of this spice all show evidence of the organic plant material.

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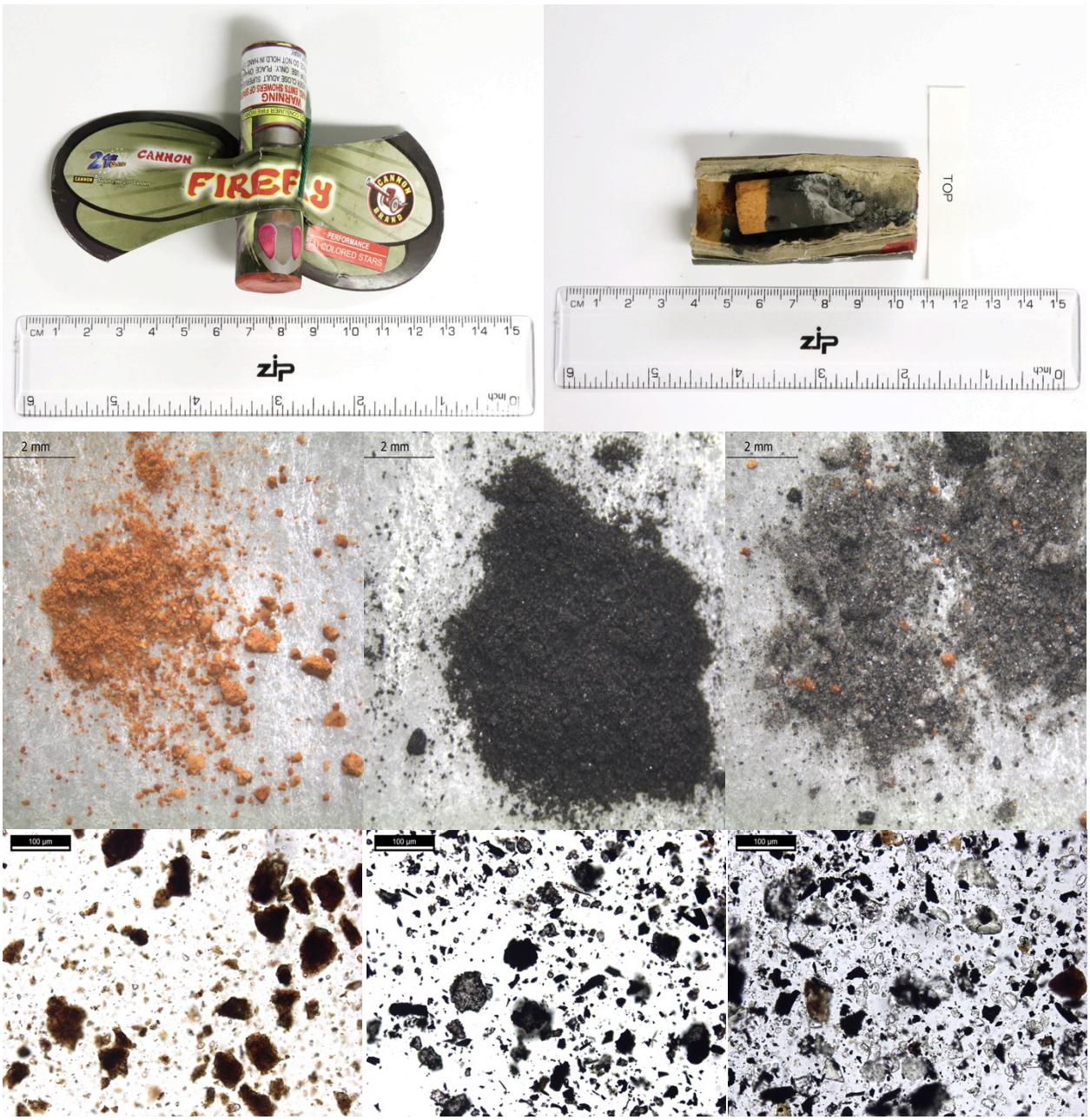

Figure 14. Ground/flying spinner firework. Top row: firework as received (left) and partially dissected (right). Middle row (stereomicroscopy), from left: bottom, center, and top components of dissected firework. Bottom row (polarized light microscopy), from left: bottom, center, and top of dissected firework. All images are in the unburned state.

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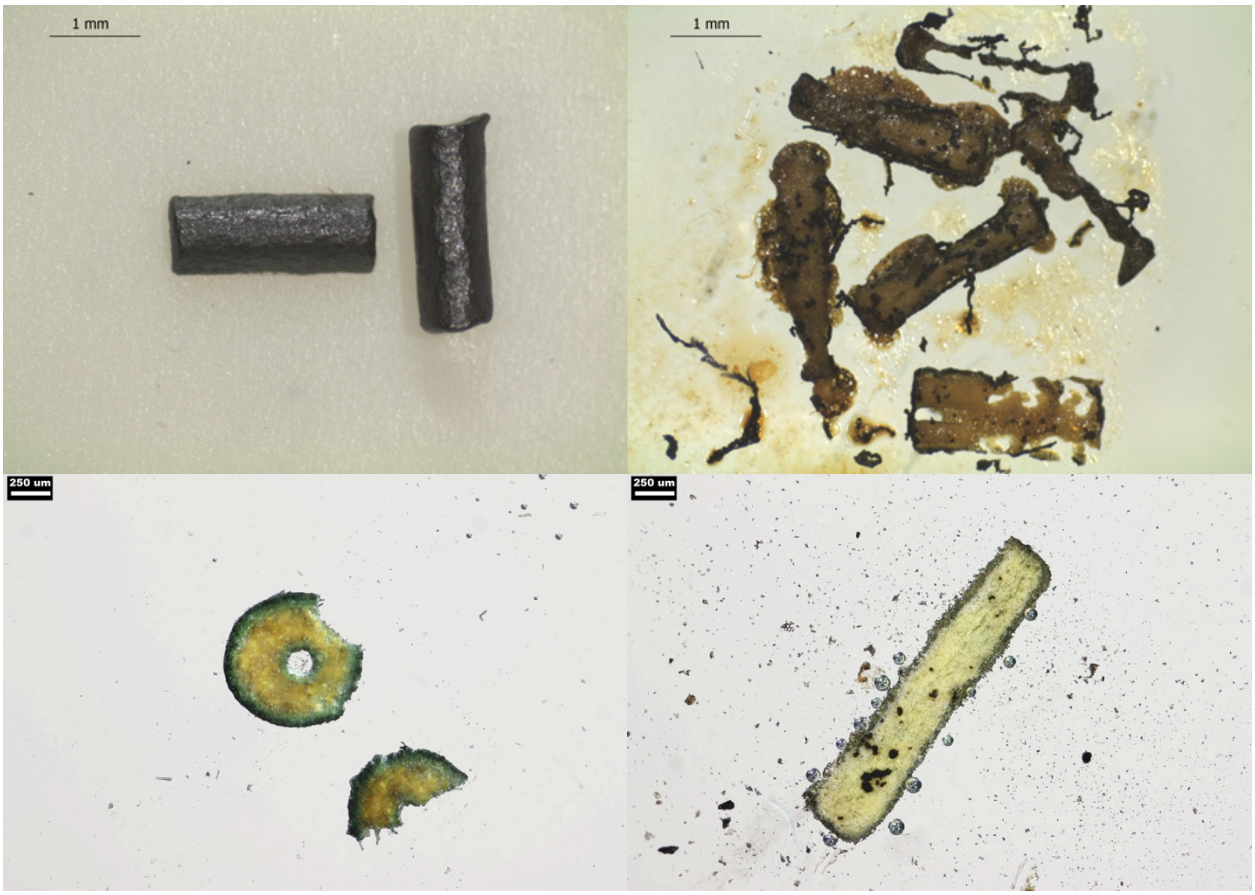

Figure 15. Smokeless powder, single base. Unburned cylinder shapes viewed with low-power SM (top left). Smokeless powder cylinders after burning showing transparent yellow and opaque, black, lacy residues (top right). Unburned transverse cross section through the cylinder in transmitted plane polarized light by PLM showing a perforation, as a hole, running parallel to the length of the cylinder (lower left). Partially burned smokeless-powder cylinder showing transparent yellow interior and additional black to brown, fine, opaque particles and residue (lower right).

3.4 Past Presentations and Planned Scholarly Products

Past presentations include the following oral presentation that was delivered at the Inter/Micro 2022 international microscopy conference, hosted by the McCrone Research Institute in Chicago on September 21, 2022.

Development of Microscopical Methods for the Systematic Analysis of Chemically Reacted, Improvised Low Explosives and Related Residues: Project Update
Meggan King Dempsey — McCrone Research Institute

In January of 2020, McCrone Research Institute began a research project to use a microscopical approach to investigate the particles and residues resulting from a controlled burning and ashing of low explosives and related materials. The goal is to improve the comparison and analysis of unreacted, chemically reacted, and post-blast related residues and increase the overall understanding of the process and mechanism that may result in the inability to obtain analytical results from evidence. Extensive photomicrographs are being collected which will also serve as the starting point of an "Atlas of Charred Particles" at a future date. This presentation will discuss current progress and examine what is needed for project completion. This project was supported by Award No. NIJ-2019-DU-BX-0047, awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice.

The following oral presentations were delivered at the Inter/Micro 2023 international microscopy conference, hosted by the McCrone Research Institute in Chicago on June 13–14, 2023:

Development of Microscopical Methods for the Systematic Analysis of Chemically Reacted, Improvised Low Explosives, and Related Residues: Project Update II
Meggan King Dempsey — McCrone Research Institute

In January of 2020, McCrone Research Institute began a research project to use a microscopical approach to investigate the particles and residues resulting from a controlled burning and ashing of low explosives and related materials. One goal is to improve the comparison and analysis of unreacted, chemically reacted, and post-blast related residues and increase the overall understanding of the process and mechanism that may result in the inability to obtain analytical results from evidence. Careful laboratory techniques have improved the success of historically challenging

microchemical tests. Useful spot tests have also been identified, and detailed photomicrographs are still being collected. A simple confirmatory test for urea will be discussed. This presentation will also detail current progress and the remaining steps for project completion. This project was supported by Award No. NIJ-2019-DU-BX-0047, awarded by the National Institute of Justice, Office of Justice Program

The Perfect Shots: Crafting a Photomicrographic Setup and Image List for an Atlas of Charred Particles

Sebastian Sparenga — McCrone Research Institute

When presenting scientific research, one sometimes has the difficult task of showing the results of their work in the most comprehensive manner. As a microscopist, one of the best ways to do this is with one or more photomicrographs. This presentation will discuss a setup necessary to obtain the most beneficial images using a wide variety of light microscope illumination conditions, including plane polarized light, top/reflected light, crossed polars, slightly uncrossed polars, crossed polars and a Red I compensator, and various combined conditions, including how to display them for publication. This work is in preparation of a current research project involving unreacted, partially burned, and fully burned particles associated with low explosives and their microscopic residues. This project was supported by Award No. NIJ-2019-DU-BX-0047, awarded by the National Institute of Justice, Office of Justice Programs, U.S. Department of Justice.

A final product of this research includes the culmination and publication of a comprehensive test methodology for the analysis of low explosives and related residues and at least one scientific paper related to the methodology suitable for publication in an appropriate, peer-reviewed journal such as *Journal of Forensic Sciences*, *Forensic Science International*, *The Microscope*, etc. The completed and ready for publication works and publishable data of this research may then be available together with other research and resources on our website (www.mccroneinstitute.org) or in the "Research" section on our home page as viewable/downloadable documents, tables, photomicrographs, monographs, or published articles, in their various formats; PDFs, DOC, XLS, JPG, etc., citable and maintained with revisions over time.

4.0 Implications for Criminal Justice Policy and Practice in the U.S.

This research forms an ideal basis for a published methodology and practical training or workshops that could be conducted in-house, at various schools, and national and regional forensic science meetings. Much of current explosives training and analyses do not consider using a microscopical approach to identify unburned, partially burned, and fully burned improvised low explosives and related residues; thus both proficient and less experienced forensic scientists would benefit from any newly published methodology or practical workshops. McCrone Research Institute regularly conducts courses around the country, and maintains a traveling set of microscopes and accessories specifically for such purposes. McCrone may now be able to extend these services to include a wider variety of explosive residues and resources related to low explosives.

McCrone faculty, together with visiting instructors, guest speakers, and collaborators, regularly present research on the microscopy of explosives and related material. They also attend national and regional forensic science conferences, including the AAFS annual meeting, the NIJ-sponsored Trace Symposia, Regional Forensic Science annual meetings, and Inter/Micro. Such meetings are ideal for introducing new and experienced forensic scientists and practitioners to this research for discussion and improvement