

SiC Concentrator Targets, Genesis Samples 60001 and 60003 Contamination Documentation

This report represents the completion of initial image documentation of the two flown SiC Genesis concentrator targets 60001 (serial number: U0639-14) and 60003 (serial number: L0760-08) and should help facilitate target selection.

Results Summary

Particles and features found on both quadrants were similar and can be generally grouped as: dried salt/mud areas – often with debris, transparent angular-outline fragments, black irregular fragments, dark spheres (or elliptical shapes), dark spheres (or elliptical shapes) associated with trails (scratches?), straight black fibers, dried droplet circular features, clusters of transparent spheres (“bubbles”), curves fibers, transparent rods, fractures or imperfections in surface.

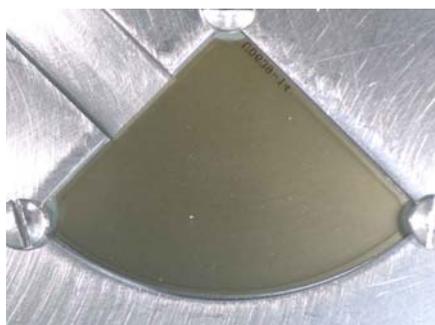


Fig. 1. 60001 SiC, bracketed by cross arms 9 and 12 o'clock.

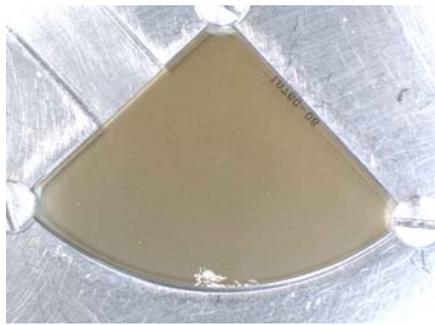


Fig. 2. 60003 SiC, bracketed by cross arms 3 and 6 o'clock.

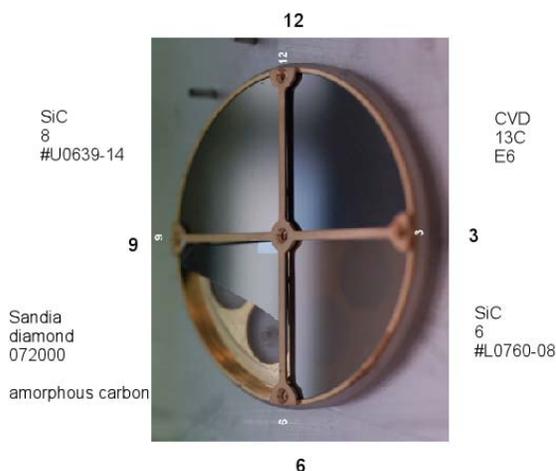


Fig. 3. Mounted targets, post-recovery, showing cross arm clocking designation.

Our overall impression is that observed features are mostly due to crash-related lakebed and SRC debris and to pre-flight quadrant preparation. There is a noticeable lack of crushed collectors, which are commonly observed on wafers.

Crash-related: Presumed lakebed materials include the salt/mud/debris deposits and some of the dried droplet features (dried droplet features are also found on the non-flight quadrant). Presumed SRC materials include the black fibers (compare to SRC backshell carbon fibers), the orange-red fragments of color similar to RTV and silicone made brittle, and one particle that looks like Kapton tape.

Pre-flight effects: Commonly observed are a class of features that we attribute to pre-flight quadrant preparation. These are dark spheres or elliptical shapes associated with trails (scratches). Fig. 4 shows that these features are oriented the same direction, as would be expected from a lapping procedure. In addition, some of these features occur beneath the protected corners of the cross. Similar features are observed on non-flight quadrant 3SiC01847 (see details in Appendix 2).

Unknown origin: The most intriguing features, which are not observed on wafer fragments, are the clusters of transparent spheres. These “bubbles” appear to be thin-wall structures, based on spherical reflections from numerous small fragments of broken bubble shells (Figs.5 & 6). Many of the small size transparent debris fragments may be derived from these bubbles. We speculate on cleaning/polishing slurries, space-environment substrate alteration or crash-derived condensates as possible sources for these features.

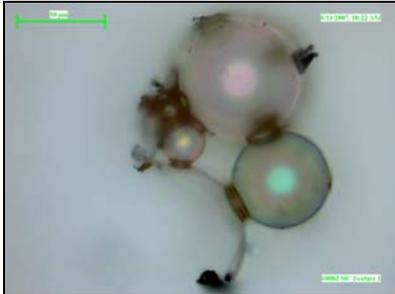


Fig. 5. Cluster of transparent spheres (60003).

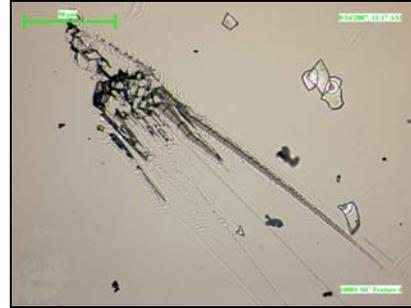


Fig. 6. Particle with trails (left) and “bubble” fragments (right)(60001).

The radial color gradient observed in the mosaic images is real. We are in the process on quantifying the gradient.

Particle size distributions: In the smaller particle size range, cumulative particle counts at 50X on 1mm² area indicate that 60003 is cleaner than 60001 (Fig. 7). Extended detail on particle size distributions is included in the body of this report.

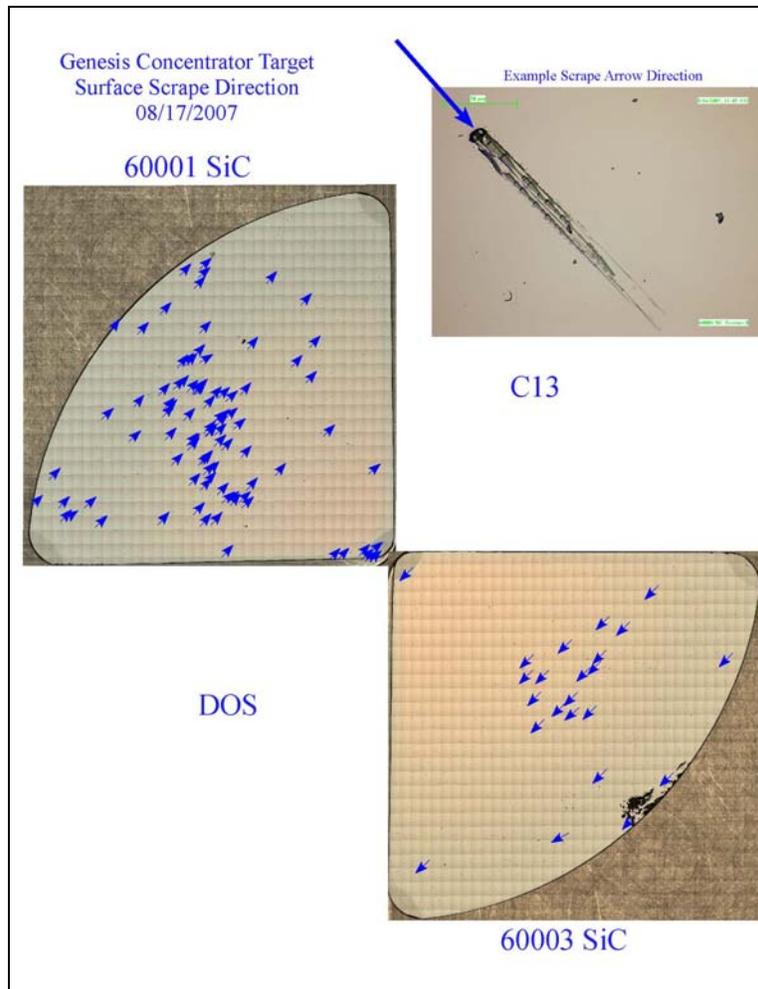


Fig. 4. Direction of trailing “scratch” in class of features with trail.

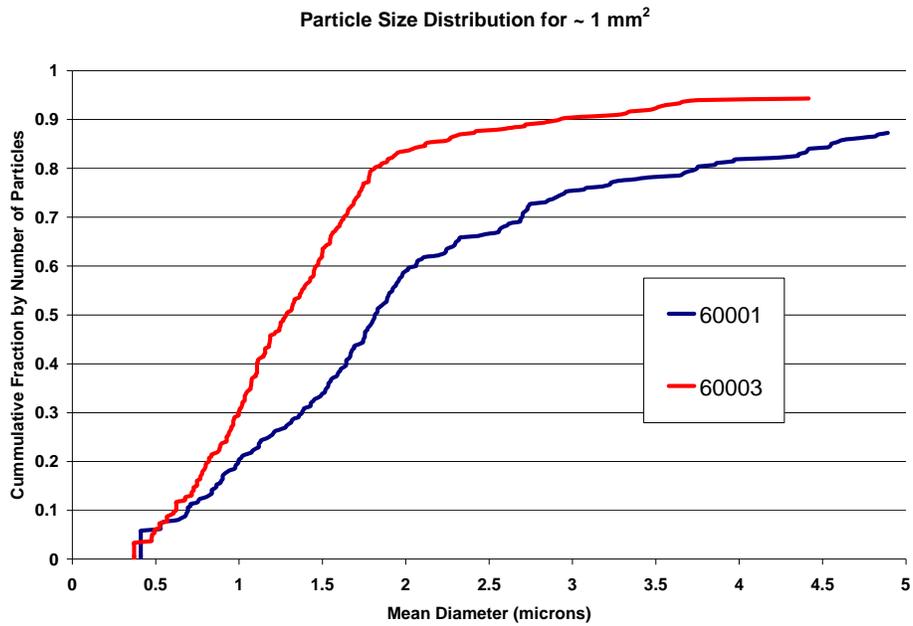


Fig. 7. Cumulative fraction of particles, by number, vs. particle mean diameter in micrometers. The break in slope occurs at about 2 μm .

Outline for Detailed Data

- Handling History
- Overview Images
- 5X Mosaics and Feature Maps
- Feature Images
- 50X Mosaics and Particle Size Statistics
- Appendix 1. Previous imaging of 60001 and 60003
- Appendix 2. Features observed on non-flight SiC quadrant

High resolution images available on DVD/CD.

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Handling History

Previous characterization of the two targets was carried out in June 2006 under CO 14435 with Nikon digital cameras as well as ellipsometry on both targets (Appendix 1). It should be noted that while 60003 ellipsometry data was taken without any problems, 60001 ellipsometry data is not useful due to the target sifting around in the ellipsometer holder. Therefore, further ellipsometry analysis still needs to be done on 60001. Sample Processing Procedure SPP 169, Genesis Mission Concentrator Target Microscopy, details the protocol for imaging concentrator targets in the JSC Genesis curation ISO 4 (class 10) cleanroom laboratory. CO 14752 was initiated for practicing on a SiC engineering model (sample 3SiC001847) and the results can be used for comparing the difference between pre-flight and post-flight contamination. In August 2007, per CO 14822, stereoscope and microscope images were carried out following SPP 169. SiC 60001 and 60003 targets have been imaged with the stereoscope using 0.32x and 1.0x lens as well as microscope images using 5X, 10X, and 50X objectives. The Leica DM6000 M automated microscope fitted with a 50X long objective has a particle resolution of > 0.3 microns in diameter. 60001 and 60003 also had an overview mosaic images made of the entire target on the microscope using the 5X objective. Both targets also had an approximate 1 mm² area mosaic image using a 50X objective lens.

Overview Images with Leica MZ9.5 stereoscope



60001 overview image



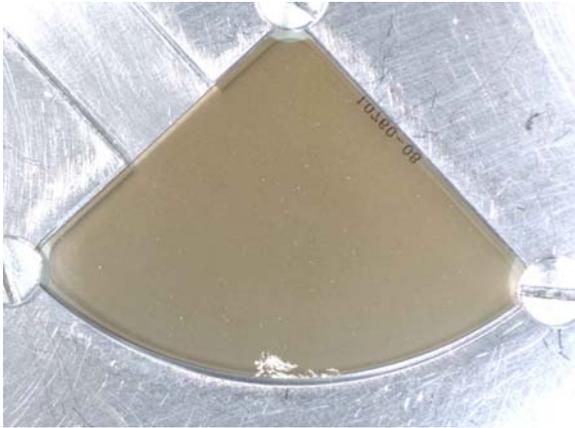
60001 (feature 1)



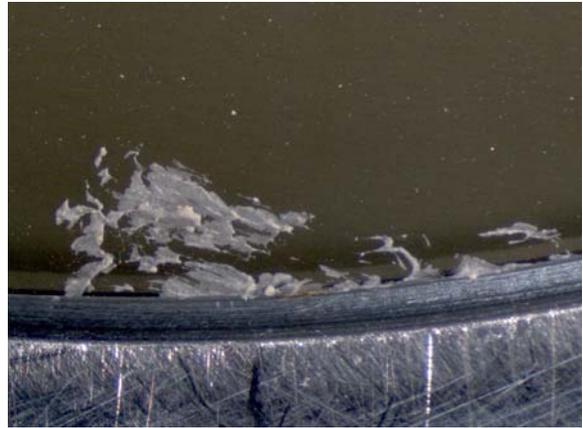
60001 small dried salt/mud area



60001: black fiber



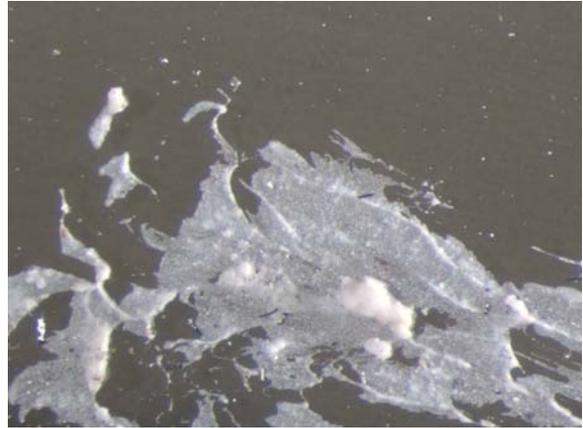
60003: overview image



60003: salt/mud smear



60003: salt/mud smear



60003: salt/mud smear

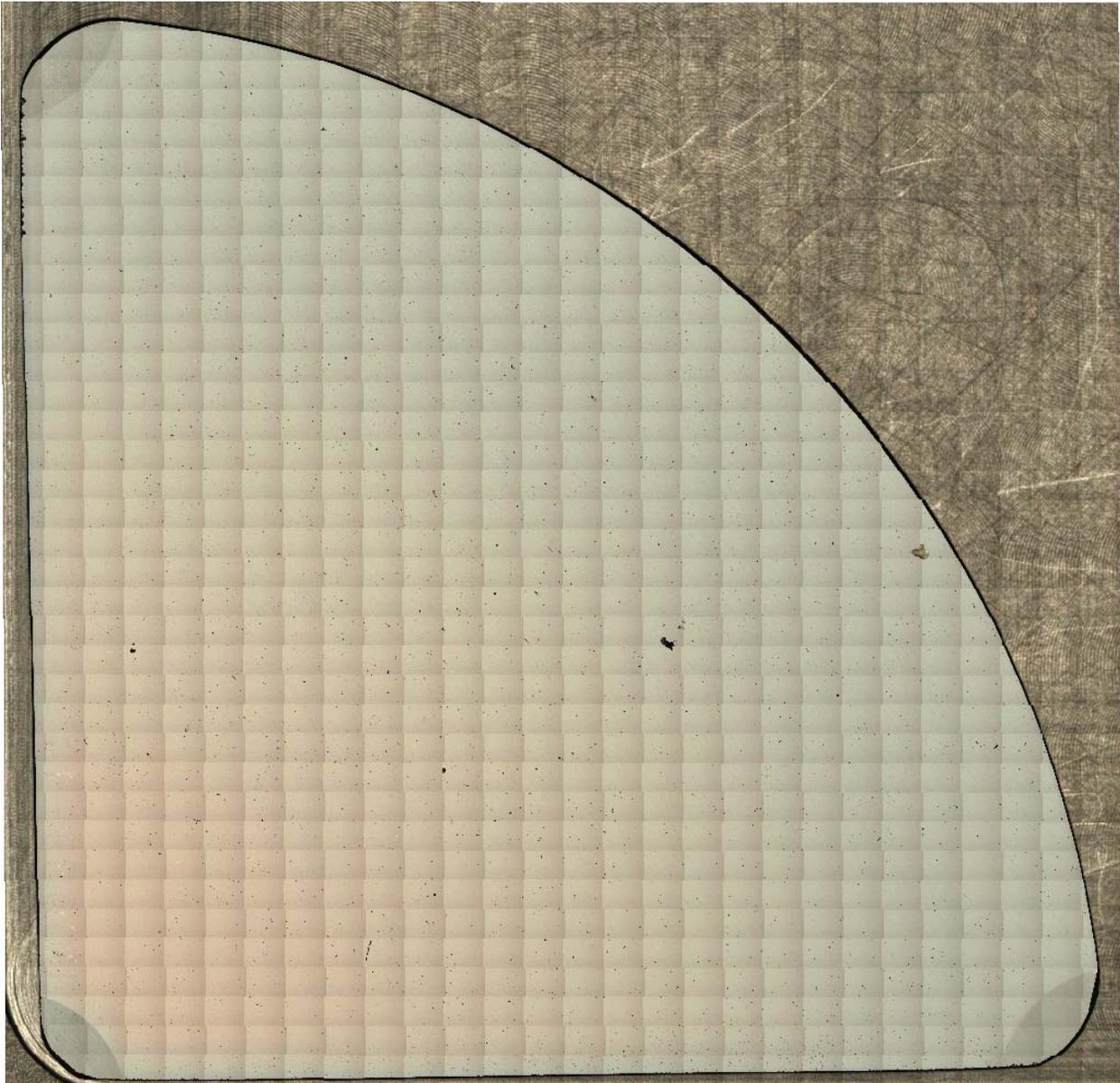


60003: row of scratches



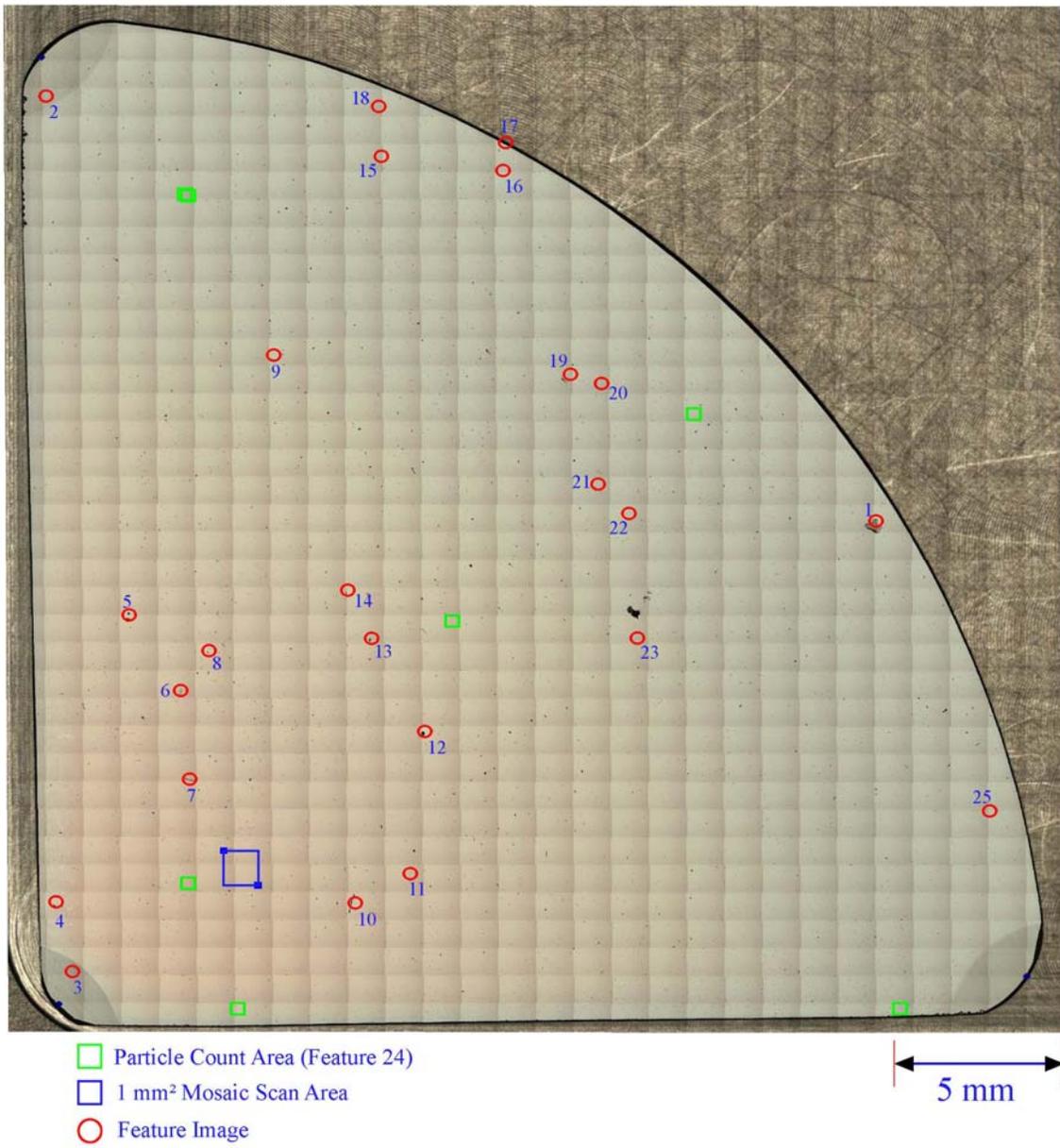
60003: fine particles and two bubble clusters

5X Mosaics and Feature Maps



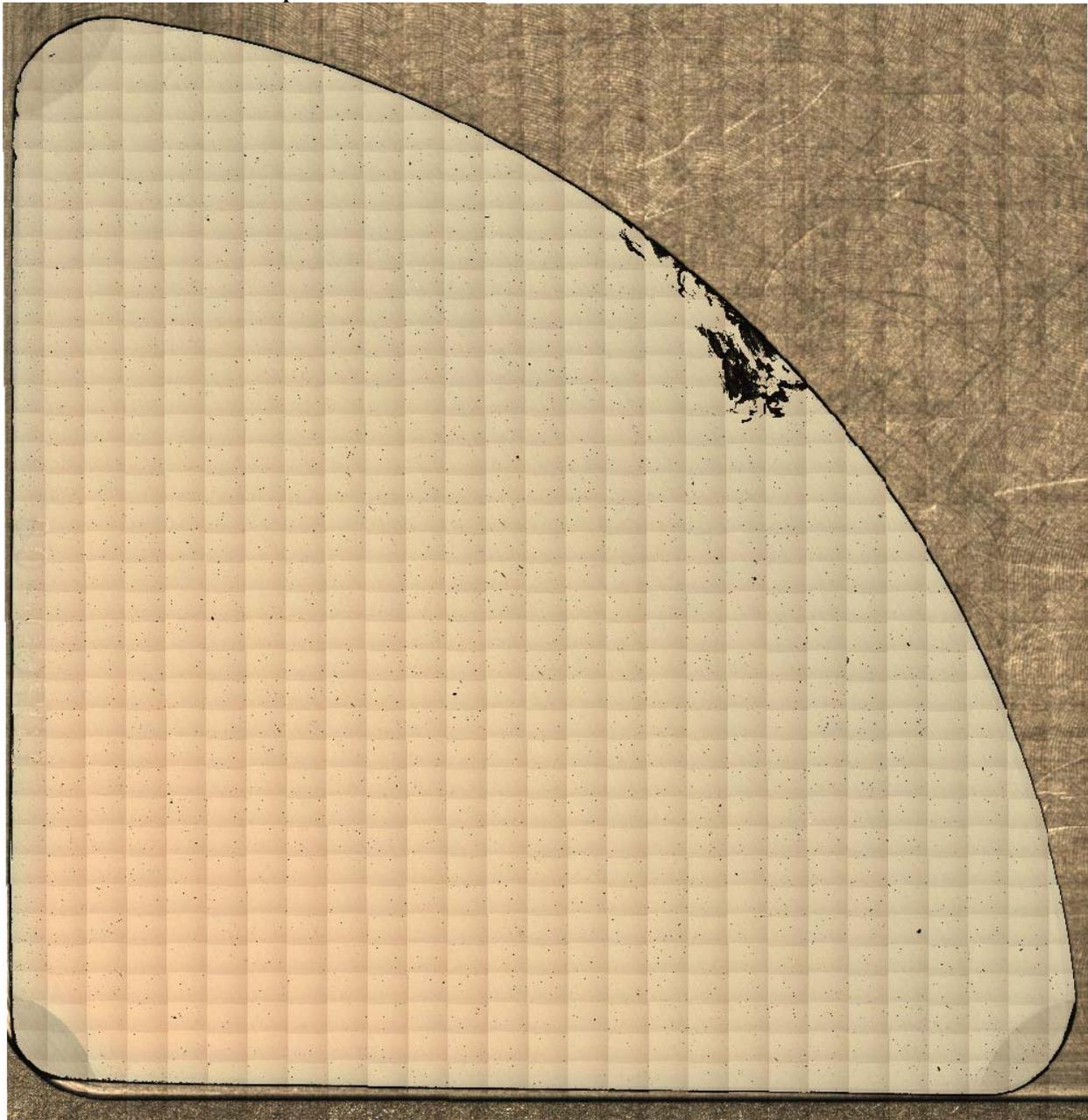
60001 bright-field mosaic microscope image, 5X objective. Each square is an individual image that can be viewed at a high resolution. The ~ 50 MB bitmap image (not attached in this report) can be used to zoom into various locations and highlight an area for viewing. The mosaic contrast was not on auto and remained constant for all frames; thus, this color variation, with radial distance from focal point, is real.

5X Mosaics and Feature Maps



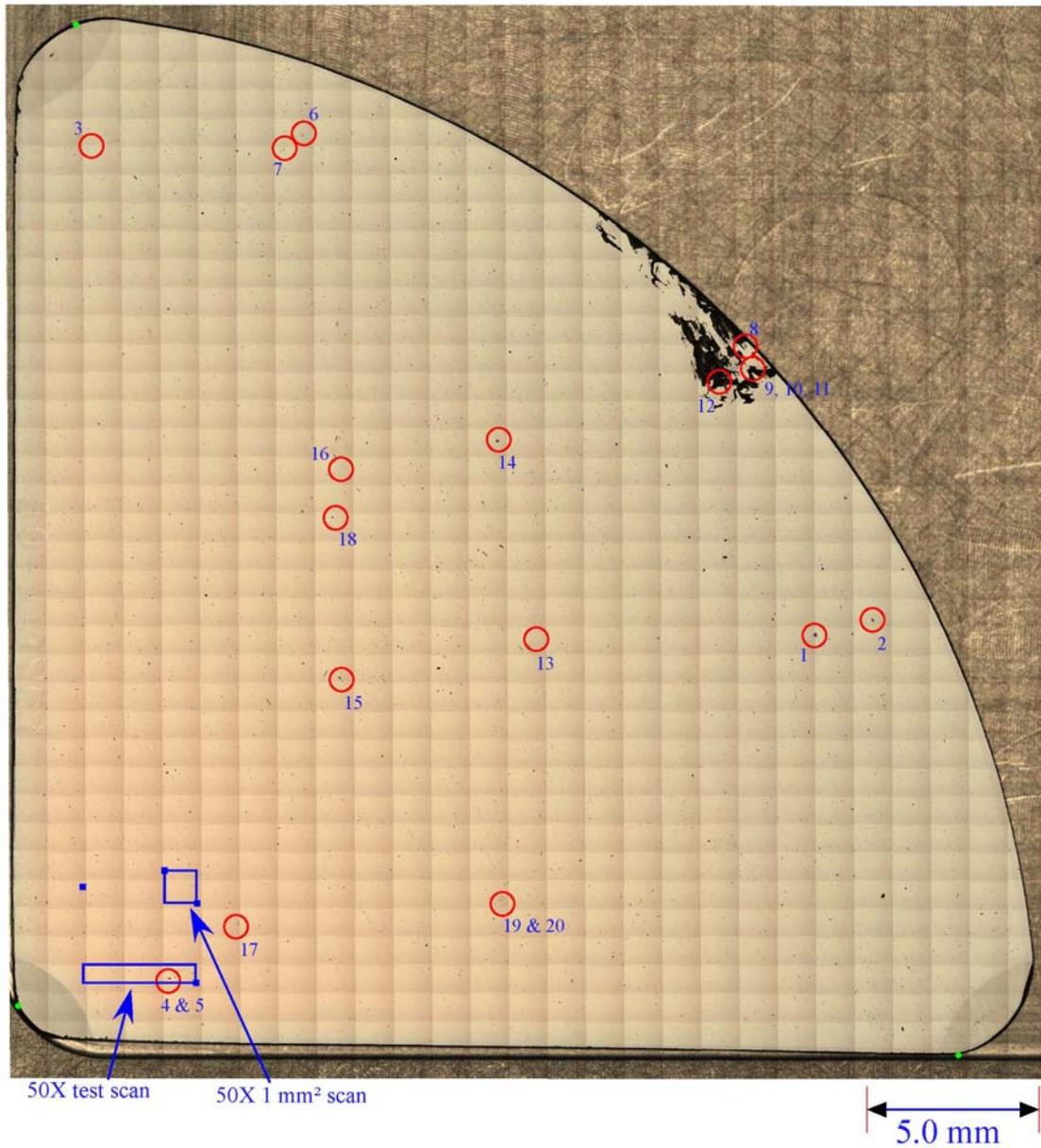
Location map for features and scan areas for sample 60001.

5X Mosaics and Feature Maps



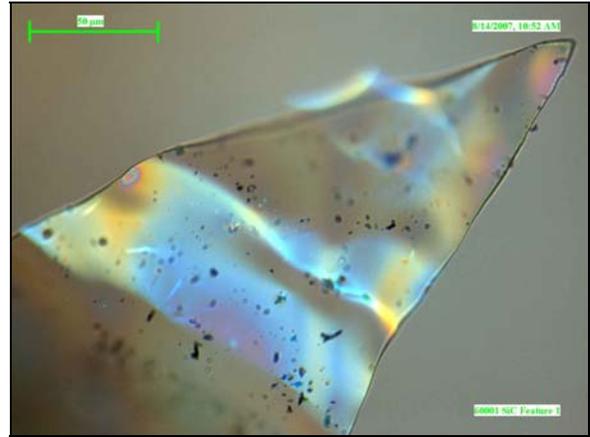
60003 bright-field mosaic microscope image, 5X objective. Each square is an individual image that can be viewed at a high resolution. The ~ 50 MB bitmap image (not attached in this report) can be used to zoom into various locations and highlight an area for viewing. The mosaic contrast was not on auto and remained constant for all frames; thus, this color variation, with radial distance from focal point, is real.

5X Mosaics and Feature Maps

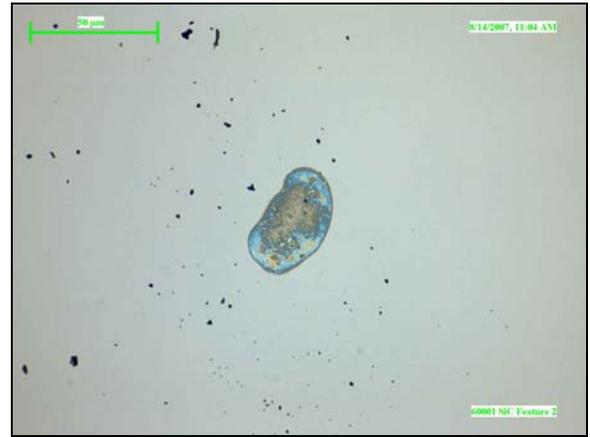
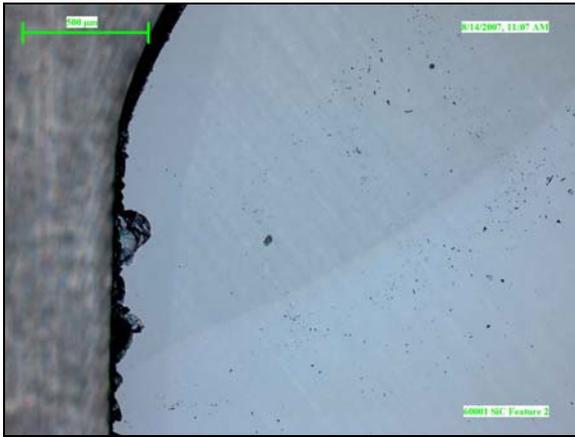


Location map for features and scan areas for sample 60003.

60001 Target Features



Feature 1: Thin transparent film fragment on surface of SiC target (looks like Kapton tape). Scale bars 500 μm and 50 μm.

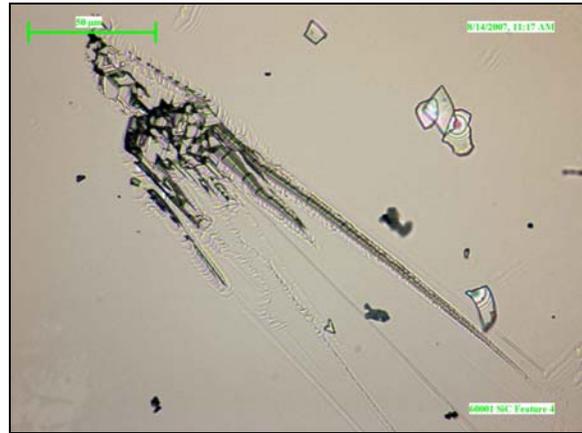


Feature 2: Transparent blue/gray area on SiC target shielded corner (under cross). Scale bars 500 μm and 50 μm.

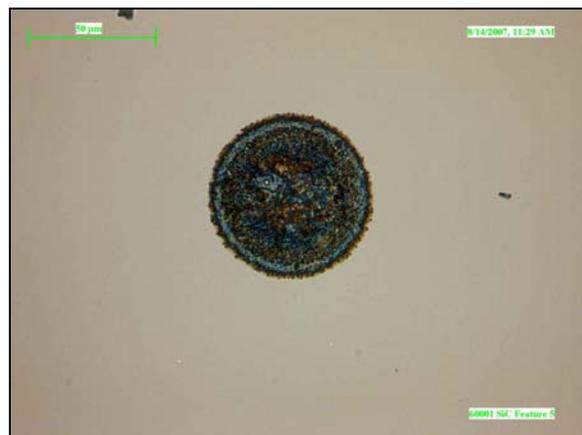


Feature 3: Two examples from a cluster of four scratches on SiC target corner. Scale bars 50 μm.

60001 Target Features



Feature 4: Angular scratch near edge of SiC target, nearby transparent debris with spherical reflection/refraction. Scale bars 500 μm and 50 μm.



Feature 5: These objects appear close together at 10X. Image at left shows detail of debris cluster, amber-colored transparent sphere attached to a light colored fibrous mass. Additional images of this mass reveal additional colorless bubble-like spheres among fibers. Image at right is a common flat circular form. Discrete colored edge and interior visibly different from bubble-like objects. Scale bars 50 μm.

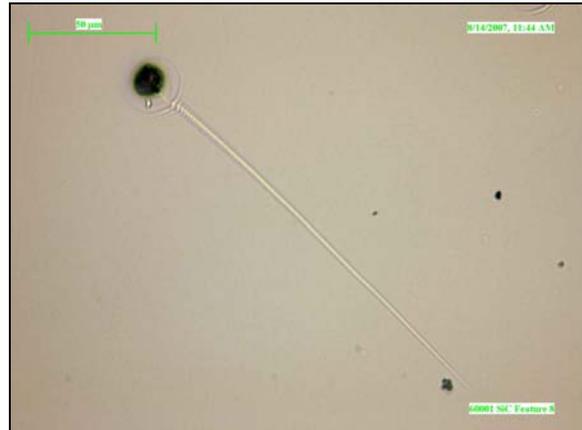


Feature 6: Unique form, transparent with clear edge definition. Interior particles are uniform in color. Scale bars 200 μm and 50 μm.

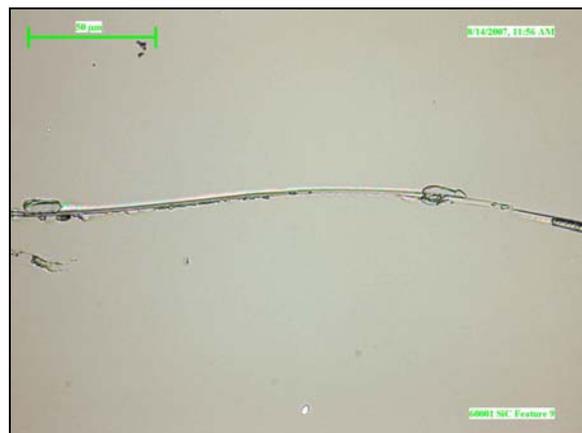
60001 Target Features



Feature 7: These dark fibers appear on both SiC targets; they vary in length. Striations appear reflective in image at left. A brown particle appears to be surrounding the end of a small “frayed branch” of the fiber. Additional images show transparent particulate contamination attached directly to fibers. Scale bars 200 μm and 50 μm.

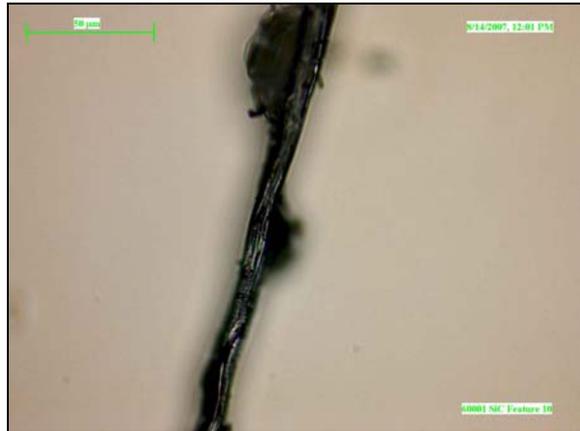
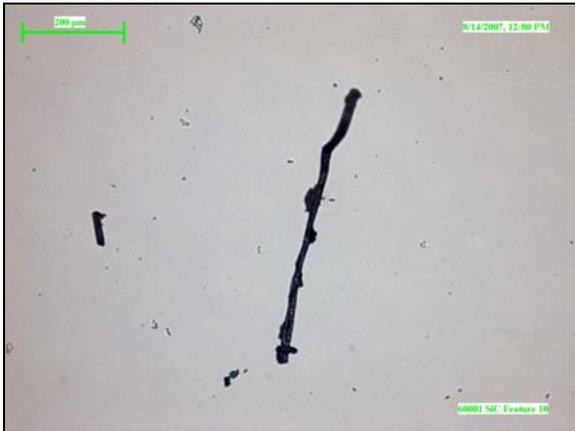


Feature 8: One example from a cluster of four scratches on SiC target. Image at right shows a small spherical feature with trail. Scale bars 200 μm and 50 μm.

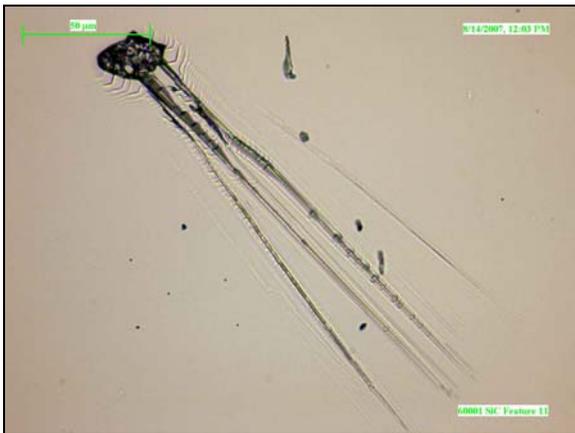


Feature 9: Long thin scratch, made in two parts. Scratch edges appear very rough, with various fracture marks. Particulate debris observed at various points along the length of the scratch at higher magnification. Scale bars 200 μm and 50 μm.

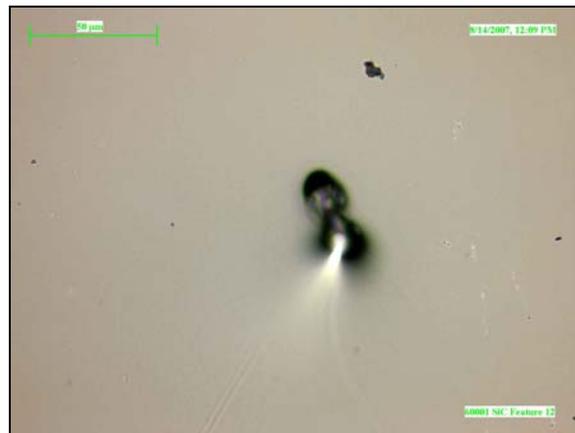
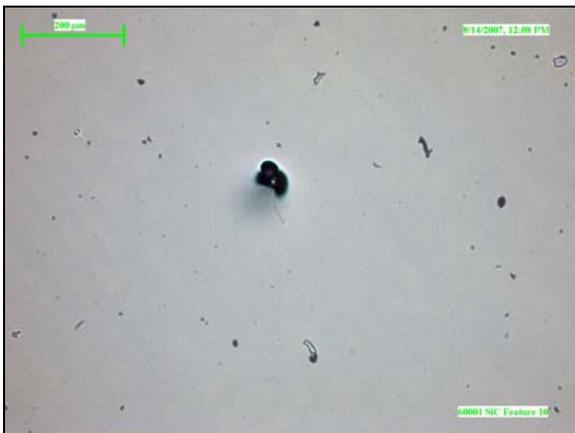
60001 Target Features



Feature 10: Dark fiber, similar striations, metallic luster and particulate attachments as seen in feature 7. Scale bars 200 μm and 50 μm.

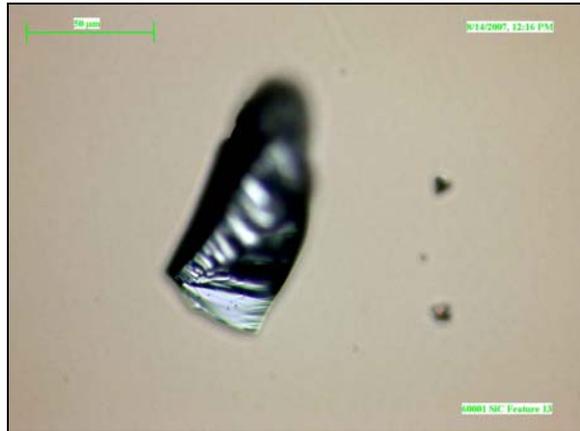
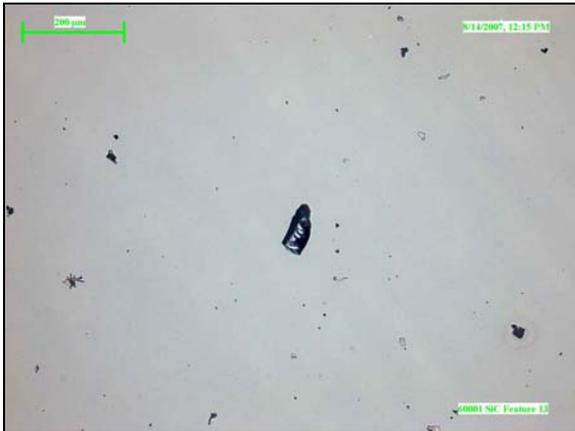


Feature 11: Bright and dark field images at show an irregularly shaped imbedded particle with trails. Stress/fracture markings observed surrounding particle and trail. Scale bars 50 μm.

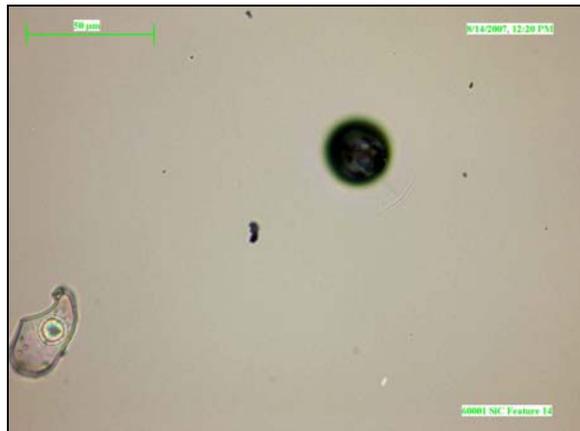
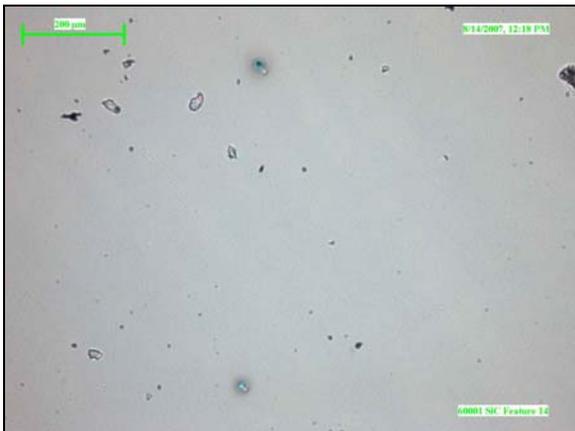


Feature 12: Feature, 300 μm top to bottom dimension. Light is reflected directionally. Scale bars 200 μm and 50 μm.

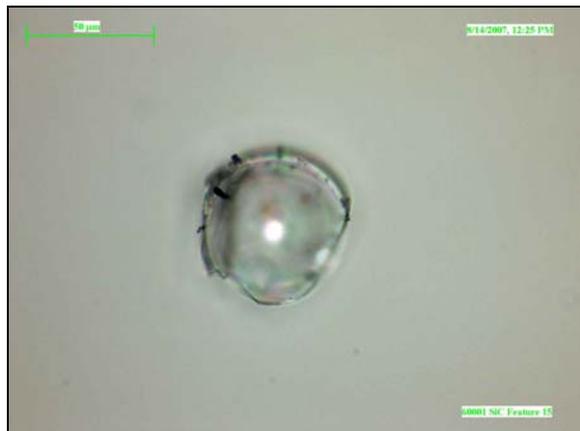
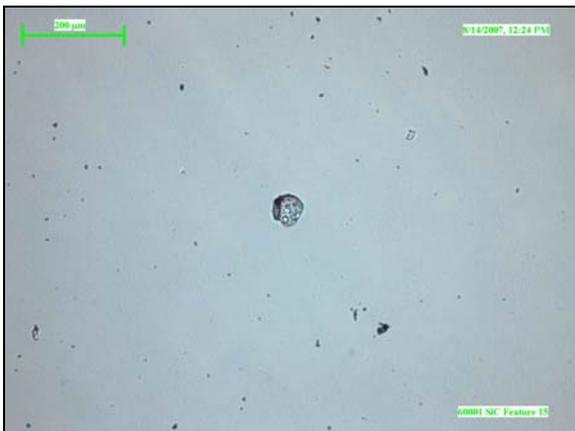
60001 Target Features



Feature 13: Dark flake on surface of SiC target; looks like a Si collector fragment. Fracture/chipping effects clearly seen on particle edge. Scale bars 200 μm and 50 μm.



Feature 14: At left, area with three spherical features, seen among transparent particulate contamination. Close-up of 50 μm dark spherical feature with measured top to bottom dimension of 150 μm. Scale bars 200 μm and 50 μm.



Feature 15: Transparent “flake” seen at 10X. At higher magnification appears to be a reflective, bubble-like, fragmented form with jagged edges. Scale bars 200 μm and 50 μm.

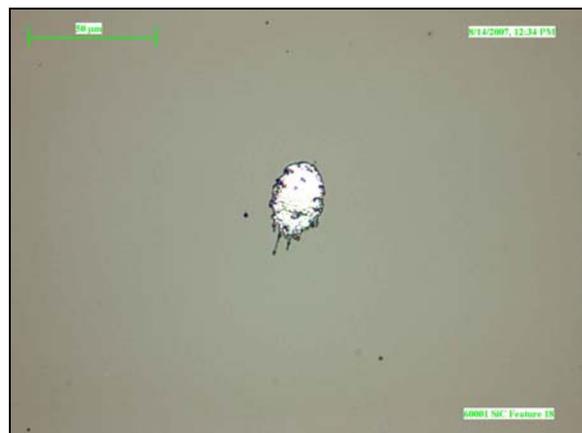
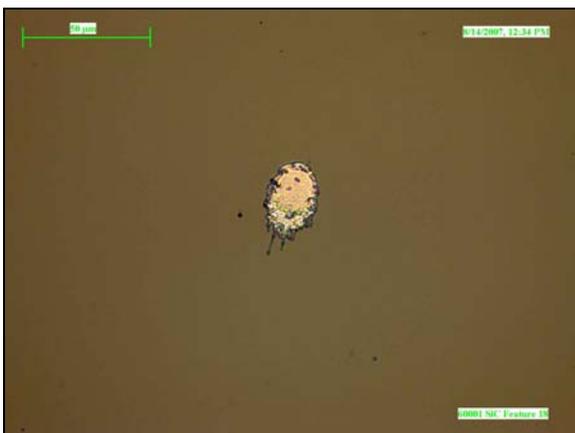
60001 Target Features



Feature 16: Images show debris fragment on top of a flat circular form. Debris fragment has reflective striations common to dark fibers found throughout target surfaces. Scale bars 50 μm .



Figure 17: Evaporation rings visible surrounding particle at 10X. Rings consist of fine brown colored droplets, decreasing in size away from particle. Scale bars 200 μm and 50 μm .



Feature 18: Light and dark field images of a reflective, irregular shaped mass. Smaller dark particles rest on top of the layered mass. Scale bars 50 μm .

60001 Target Features

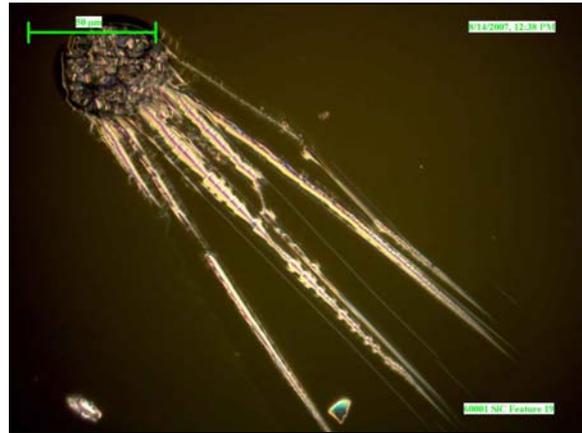
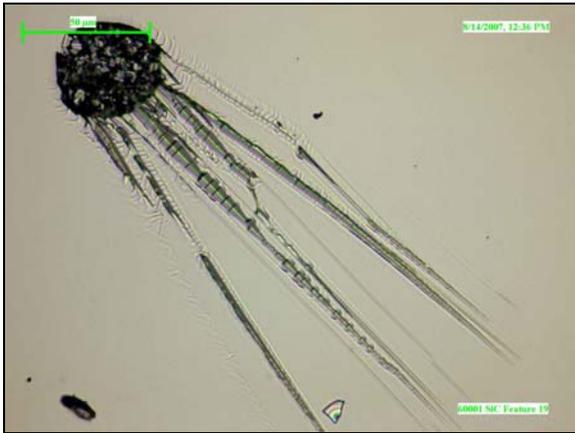
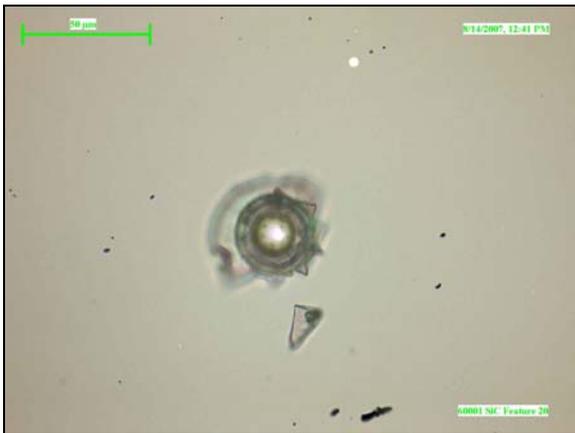
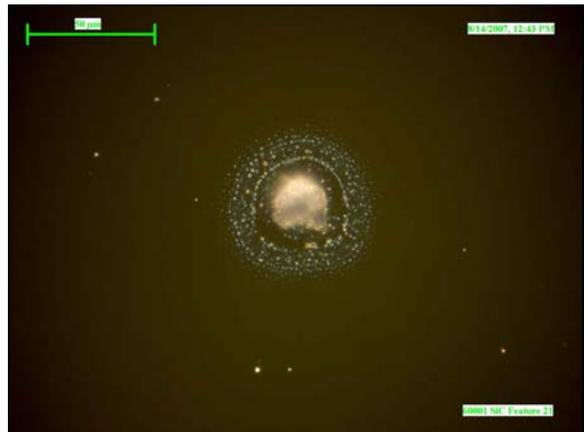
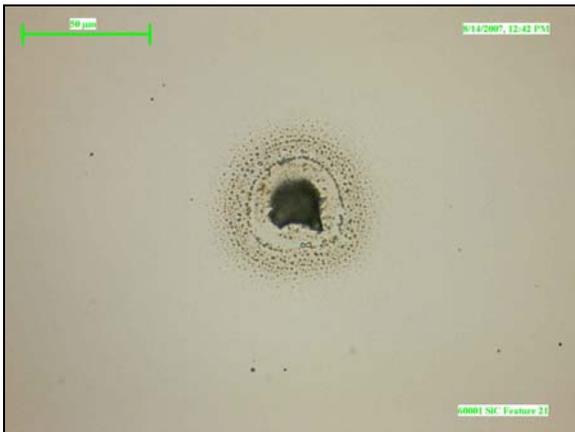


Figure 19: Bright and dark field images of a feature with segmented trails. Scale bars 50 μm .



Feature 20: A reflective, colorless, bubble-like form appears to have transparent flakes both attached to and surrounding it. Scale bar 50 μm .

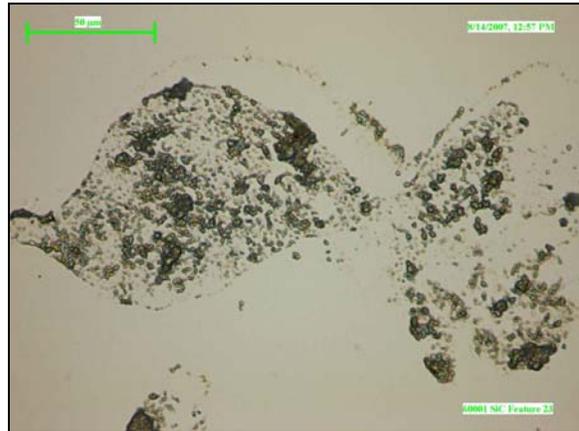


Feature 21: Light and dark field images of large particle (approx 20 μm in height) surrounded by evaporation rings. The images show similar coloring and droplet dispersion seen in feature 17. Scale bars 50 μm .

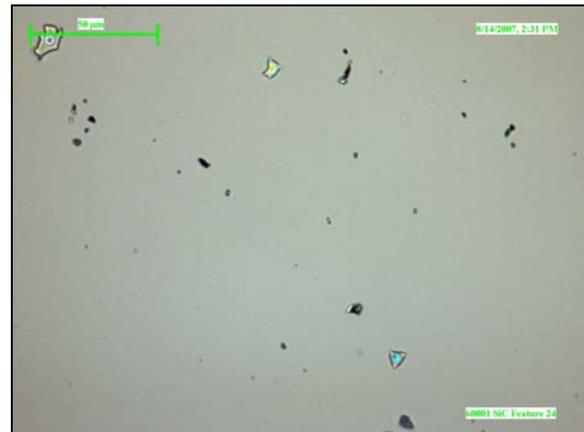
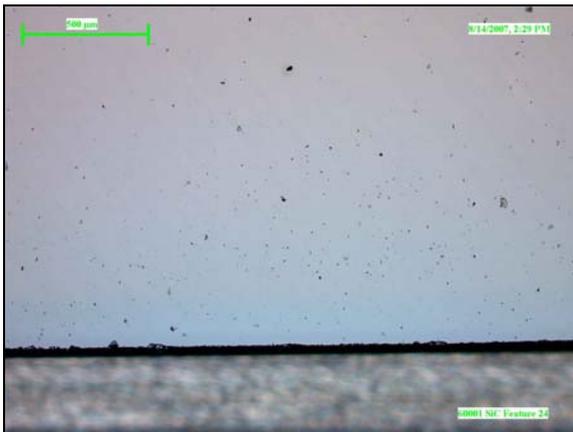
60001 Target Features



Feature 22: Irregularly shaped round particle (approx. 60 μm from top to bottom) and trail. Stress/fracture markings observed surrounding particle and trail. Scale bar 50 μm .

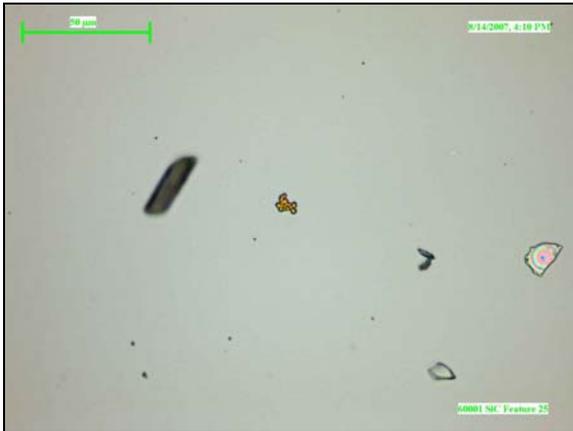


Feature 23: At left, dark field image of an area with salt/mud/debris clump. A light-colored mass covers one end of lower deposit, the mass appears dark in color in bright field view. At right, bright field image of possible remnants of salt/mud/debris clump. Scale bars 200 μm and 50 μm .



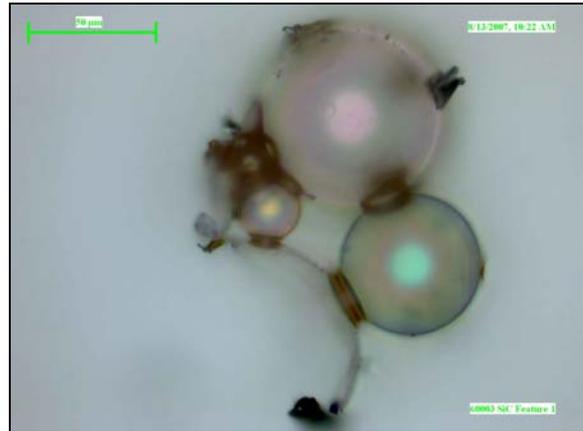
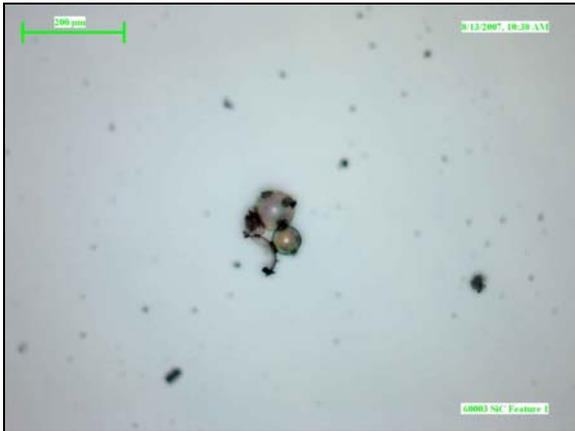
Feature 24: Particulate contamination on SiC quadrant edge. The particle density appeared to increase toward the center of the target along this edge. The particles are very small; most appear to be transparent shards and flakes on target surface (bubble remnants?). Scale bars 500 μm and 50 μm .

60001 Target Features

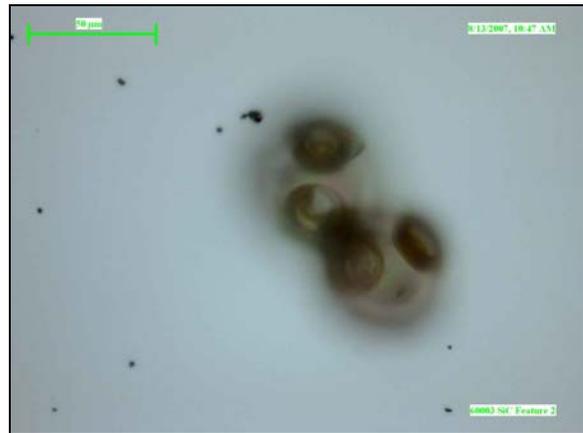
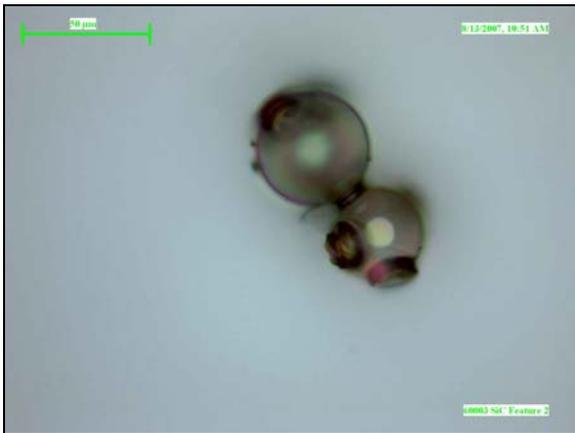


Feature 25: Unique, 10µm diameter cluster of about 20 one-to-two µm-size, gold-color spheres. Toward right is transparent fragment with spherical reflection/refraction (bubble shard?). Scale bar 50 µm.

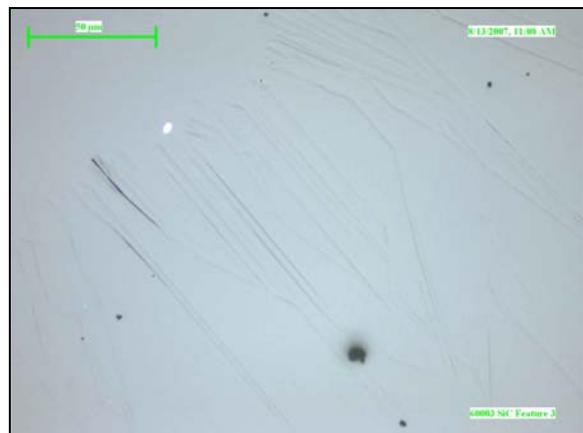
60003 Target Features



Feature 1: Cluster of three iridescent bubble-like spheres from 25 to 50 μm. The spheres appear to be connected by a brown concentric material. Debris and a partial bubble fragment surround the cluster. Additional images show height of feature to be 148 μm. Scale bars 200 μm and 50 μm.

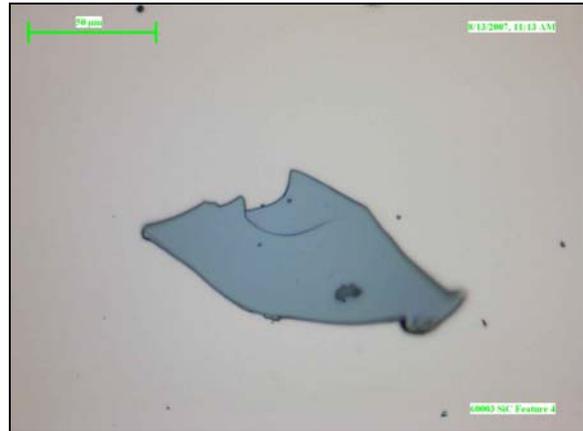
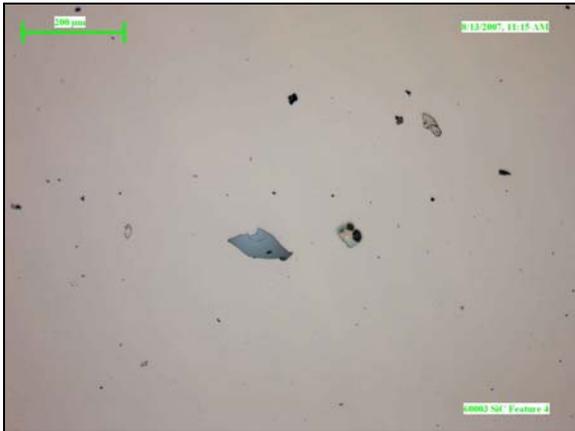


Feature 2: Cluster of two bubble-like spheres. A different focus (at right) shows other adhesion material locations. Scale bars 50 μm.

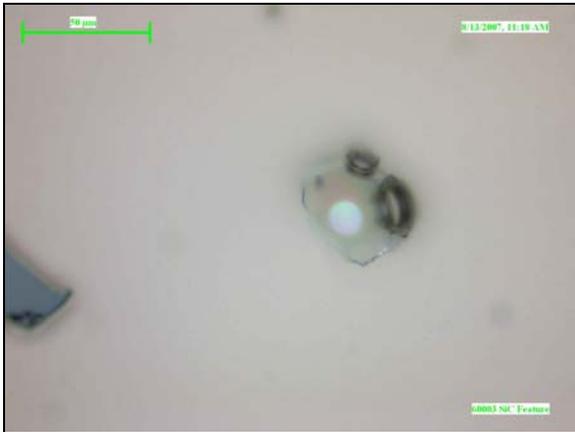


Feature 3: Area of faint, featherlike scratches surrounded by sparse particulate contamination. Scale bars 500 μm and 50 μm.

60003 Target Features



Feature 4: Thin, shiny, bluish color fragment on target surface. Scale bars 200 μm and 50 μm.

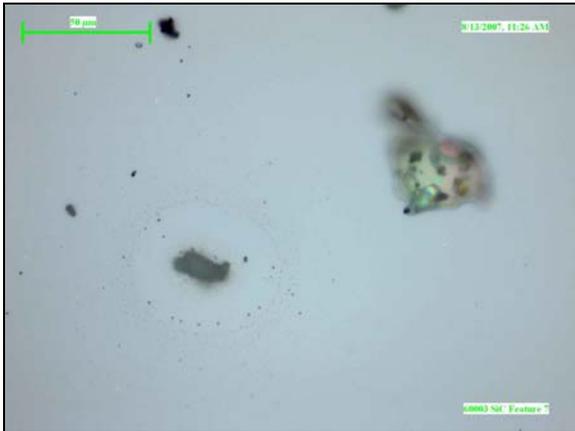


Feature 5: Also visible in feature 4, partial bubble-like fragment with brown concentric adhesion material. Scale bar 50 μm.

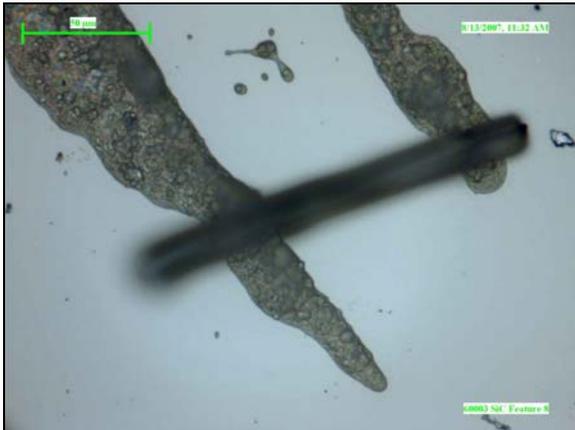


Feature 6: Area of dark fibers among particulate contamination. Shiny striations and blunt ends on fiber are visible at higher magnification. Fiber diameter about 20 μm. Scale bars 500 μm and 50 μm.

60003 Target Features



Feature 7: Area shows a particle surrounded by faint evaporation rings (image at left) and a large transparent convex fragment. The convex fragment is similar to the partial bubble-like form seen in feature 1. Scale bars 50 μm

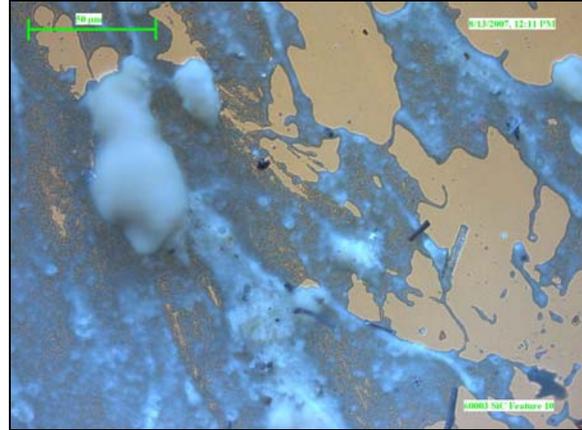
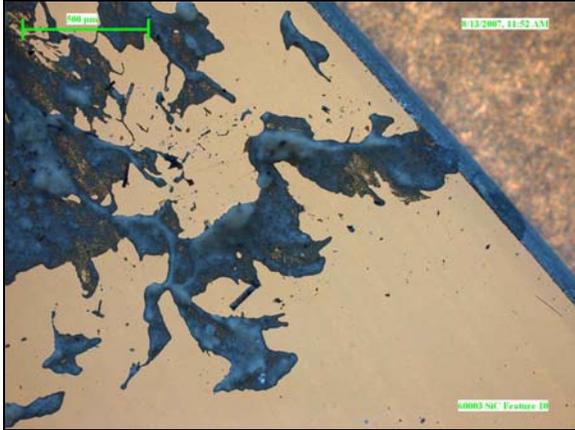


Feature 8: Dark fiber on top of salt/mud/debris deposit. Scale bar 50 μm

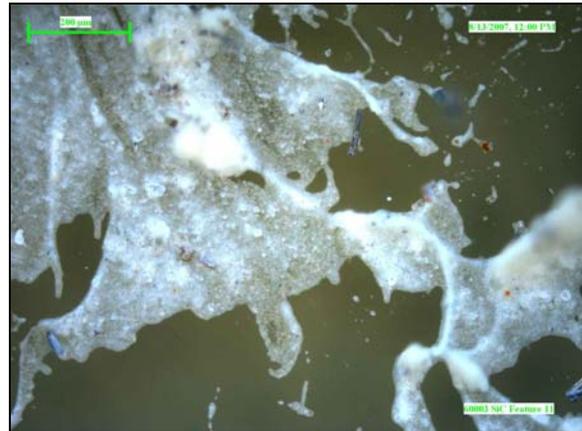
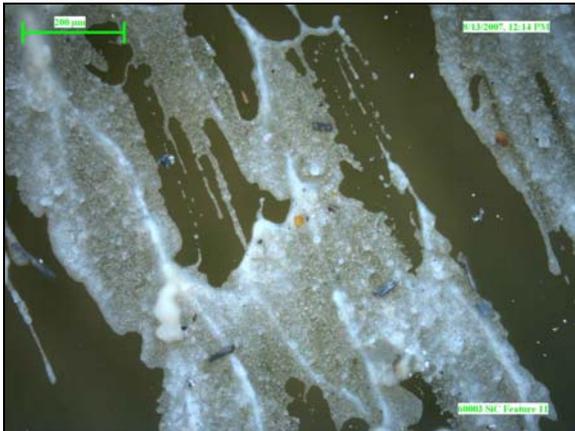


Feature 9: Bright and dark field images of two reddish fragments embedded at the top of salt/mud/debris deposit shown in feature 9 above. Scale bars 50 μm

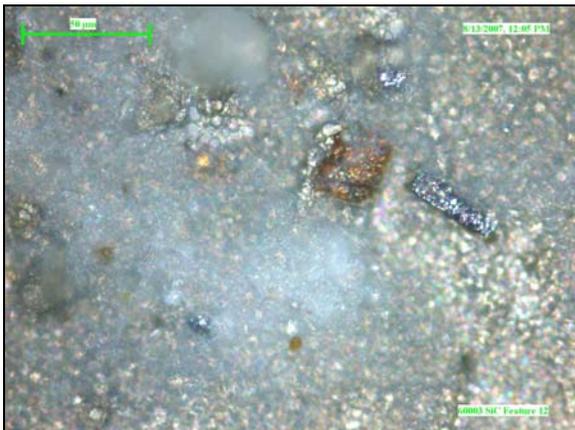
60003 Target Features



Feature 10: Area of salt/mud/debris on outer radius curve of SiC target. Lighting adjustment applied to enhance distinction between contaminants. Scale bars 500 µm and 50 µm

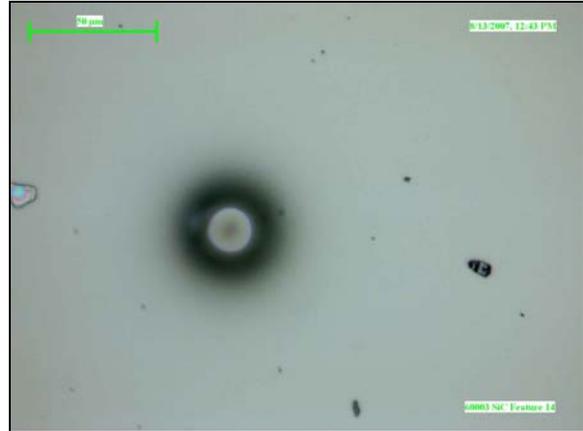


Feature 11: Dark field images of salt/mud/debris deposit shown in feature 11 above. Hydrophobic tension with the target surface is observed at deposit edges. Reddish particles and dark fibers are seen within mass. Scale bars 200 µm.

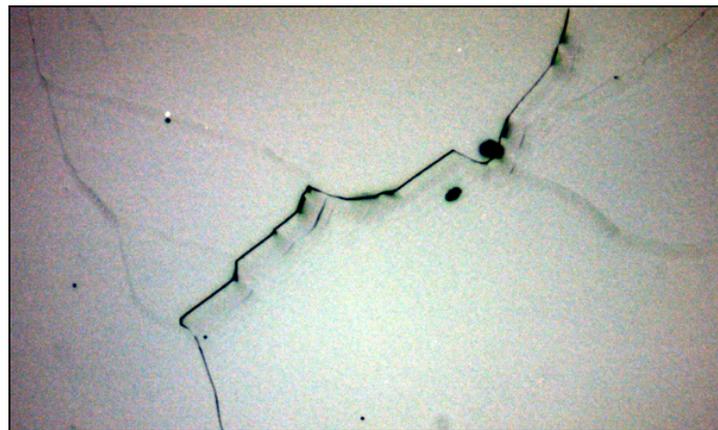


Feature 12: Salt/mud/debris area of feature 10 & 11 above shown at higher magnification. Detail of embedded debris and contour of matrix particles is improved in this view. Scale bars 50 µm

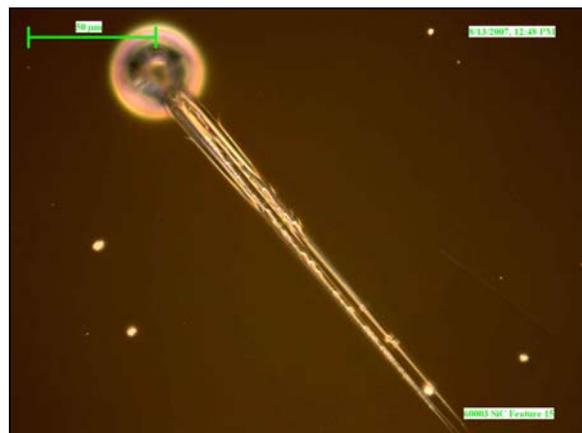
60003 Target Features



Feature 13: Area of an irregular fracture or surface imperfection or deformation. Scale bar 500 μm. Many of the transparent fragments (above left, at high zoom) exhibit the spherical reflection/refraction from curved surfaces (broken bubbles?). **Feature 14** (above, left): Spherical feature (also in feature 13 field of view) of approximate 200 μm top to bottom dimension. Scale bar 50 μm.

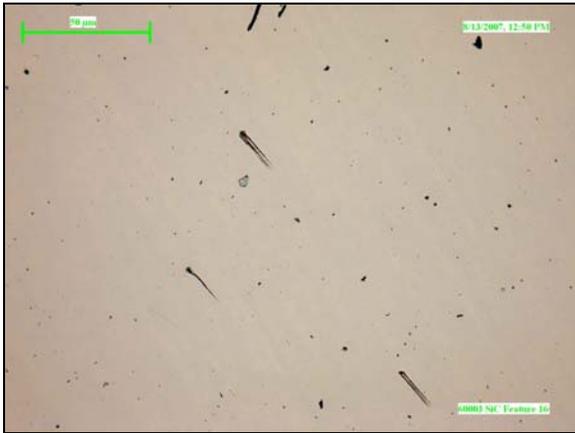


Feature 13: Contrast enhanced and close-up.



Feature 15: Spherical feature with trailing streak/scratch. Scale bars 50 μm

60003 Target Features



Feature 16: Area of three circular features with trailing scratches. Scale bar 50 μm

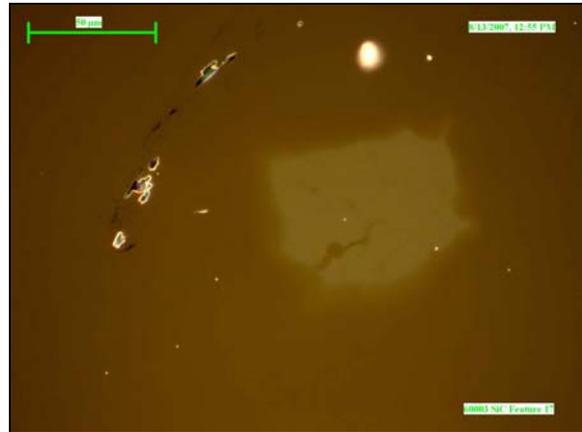
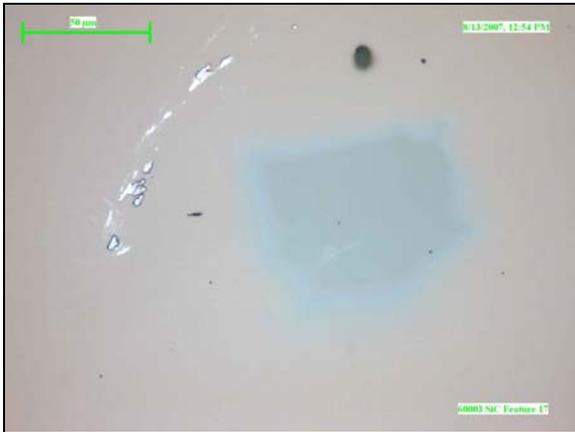


Figure 17: Bright and dark field images of a bluish colored area with blurred outline. Scale bars 50 μm



Figure 18: Area of three adjacent spherical features with trailing scratches. The interiors of the spherical features exhibit faceted surfaces. Scale bars 50 μm

60003 Target Features

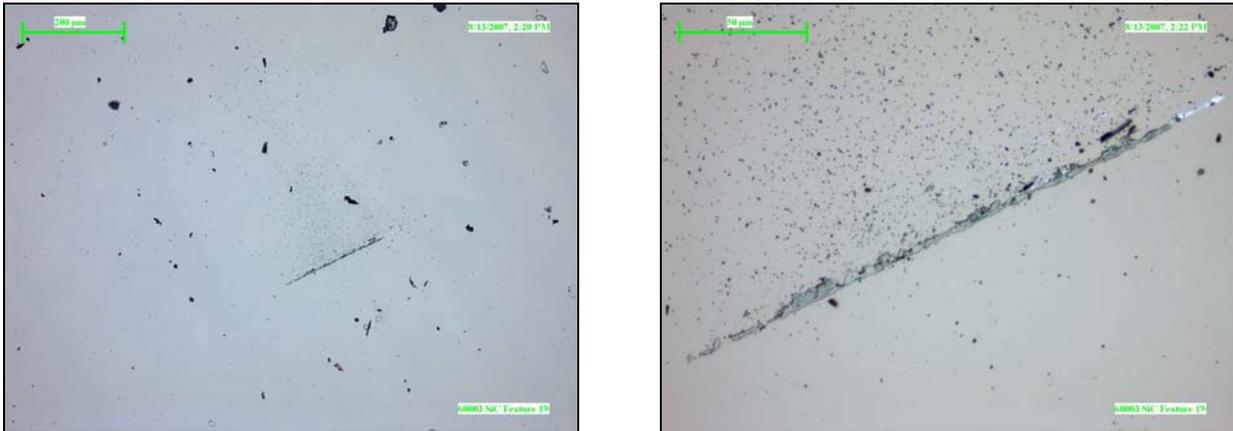


Figure 19: Straight scratch with jagged edges. Fine particulates are smeared in one direction from this scratch. Many of the transparent fragments in left view (at high zoom) exhibit the spherical reflection/refraction from curved surfaces (broken bubbles?). Scale bars 200 μm and 50 μm

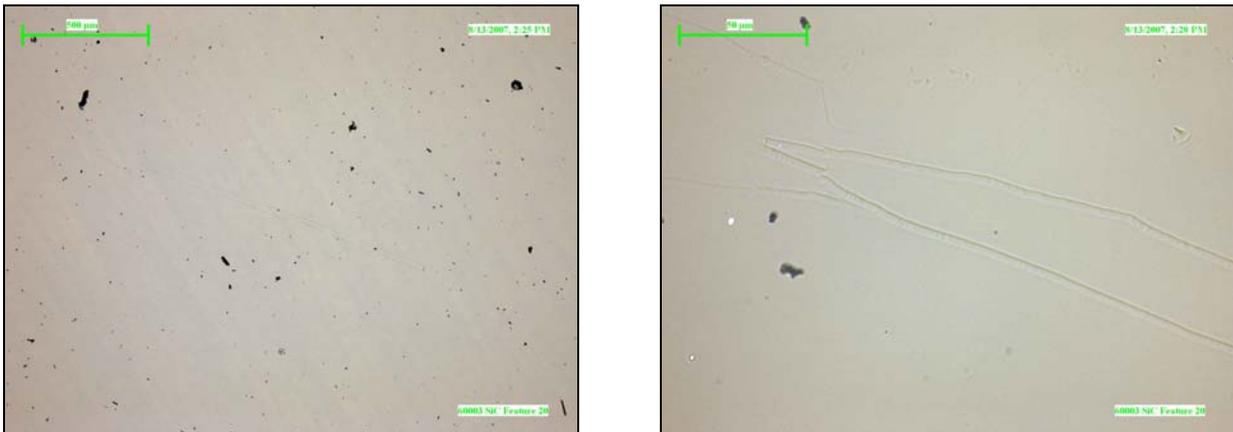
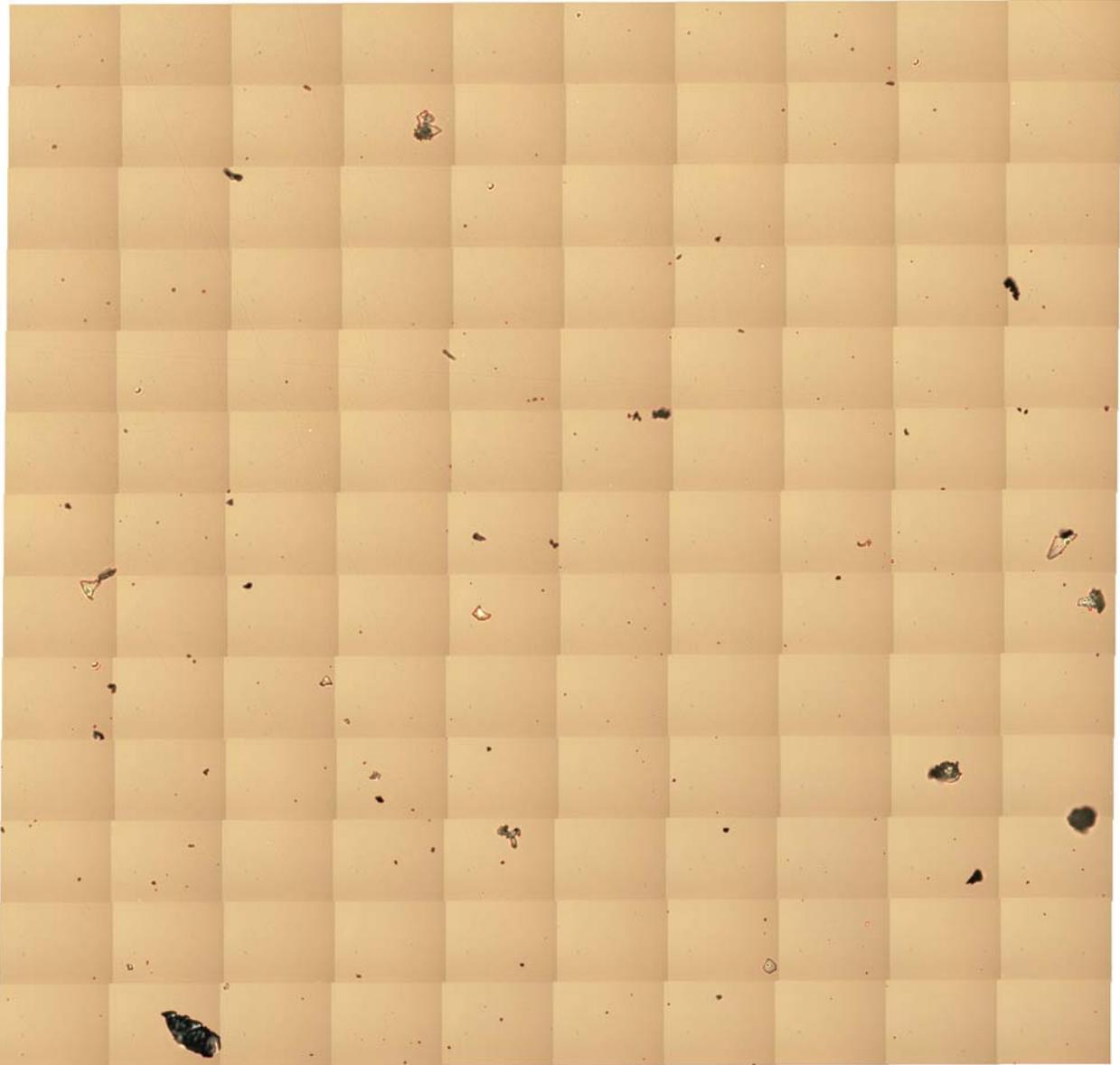


Figure 20: Area of a fracture or surface imperfection similar to feature 13. Scale bars 500 μm and 50 μm

60001 50X Mosaic and Particle Size Statistics



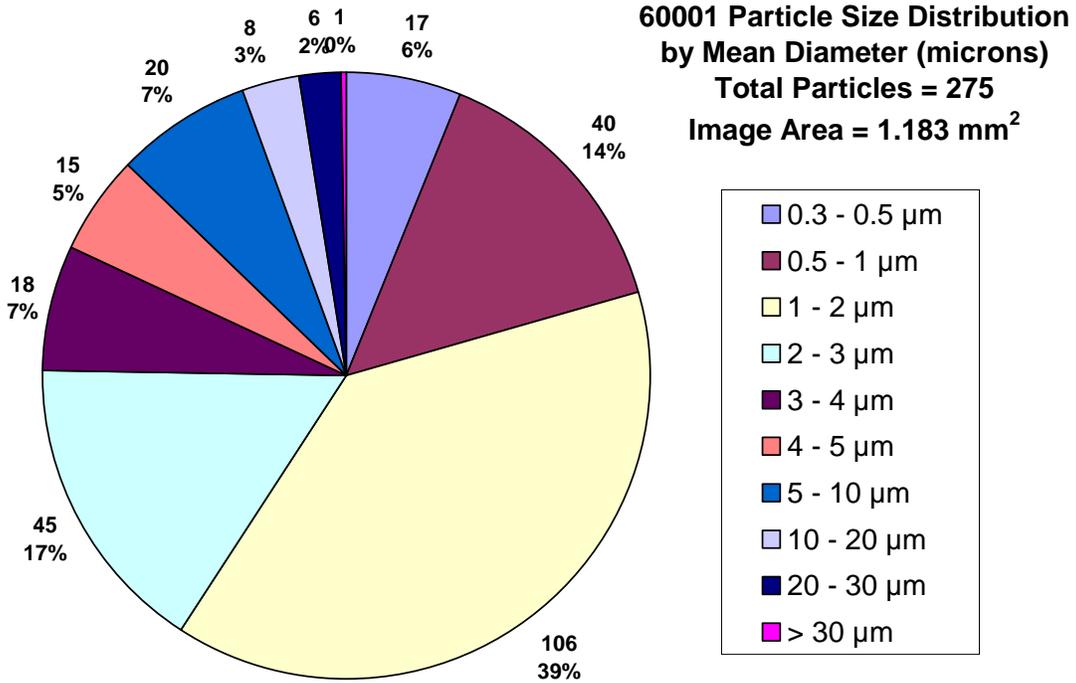
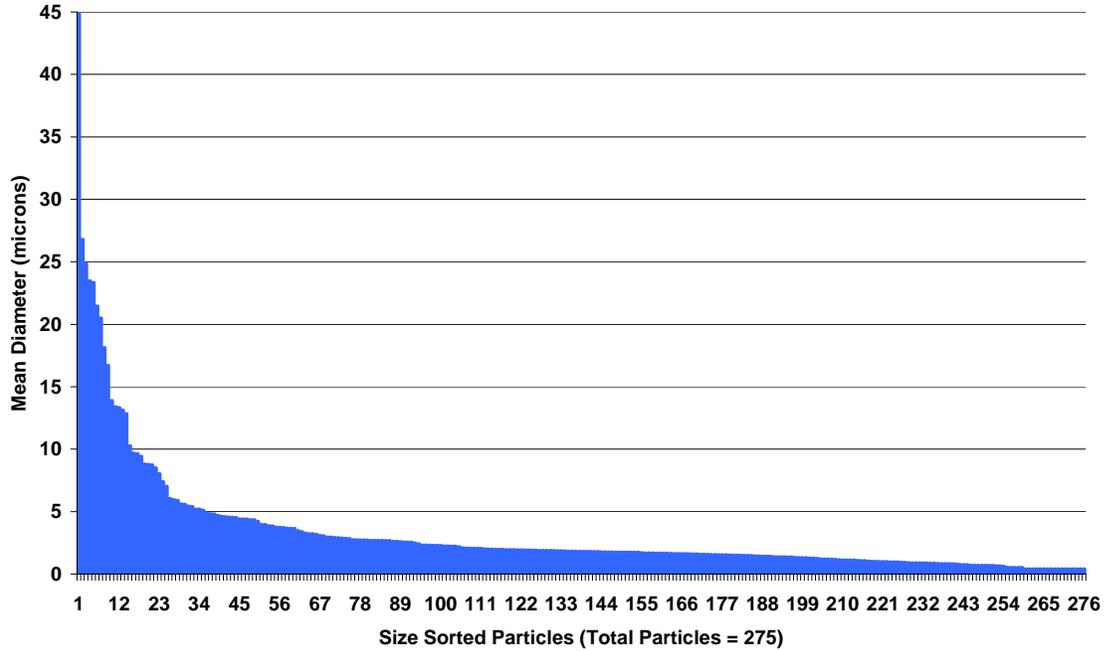
60001 50X objective mosaic scan particle map. Image area is 1.183 mm² with 275 particles identified > 0.3 microns. The red outline around an object is to mark where ImageProPlus has identified a particle. These particle outlines are shown below.



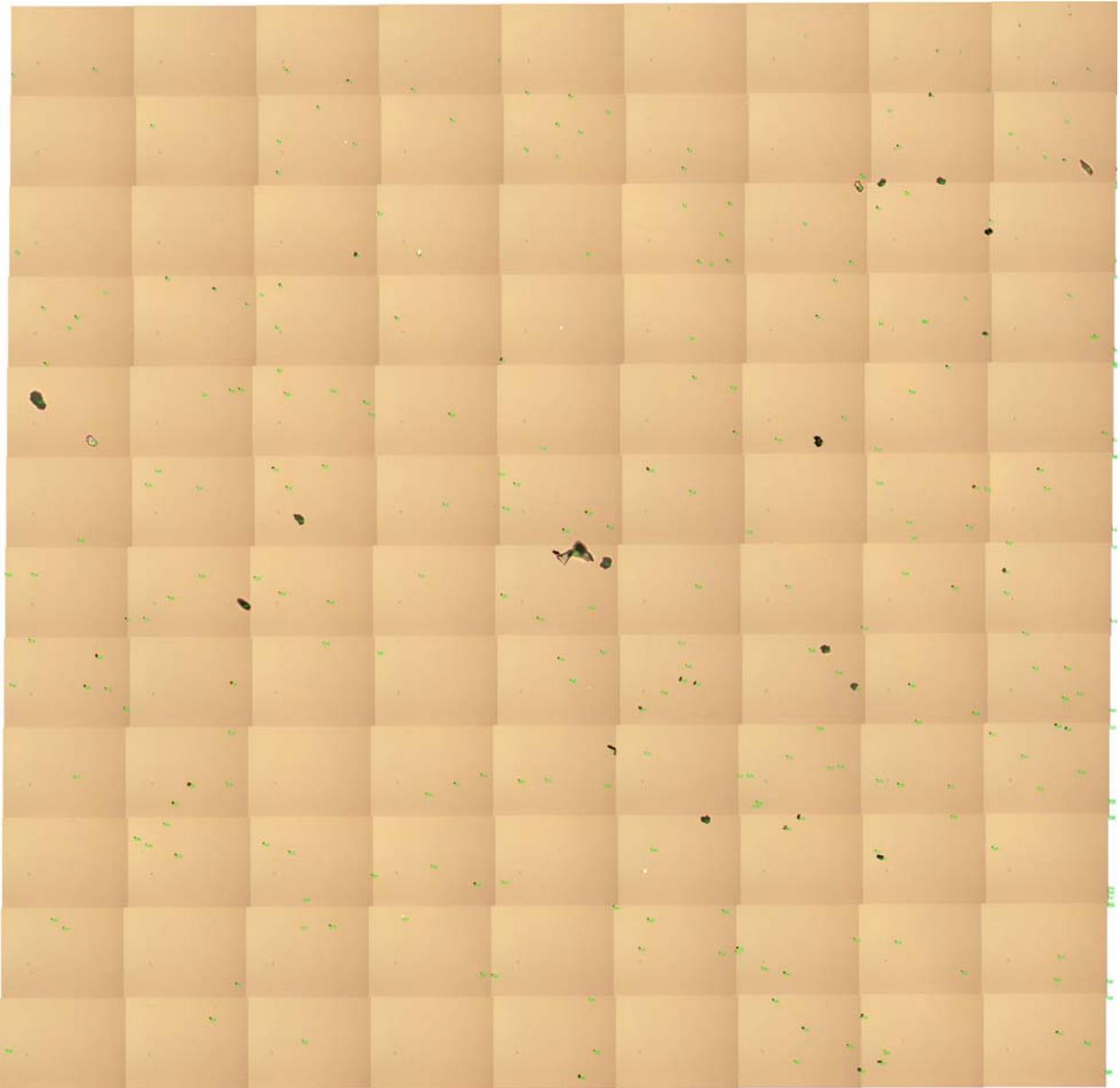
60001 50X mosaic scan particle sort by size distribution.

60001 50X Mosaic and Particle Size Statistics

60001 Individual Particle Diameter for ~ 1 mm²



60003 50X Mosaic and Particle Size Statistics



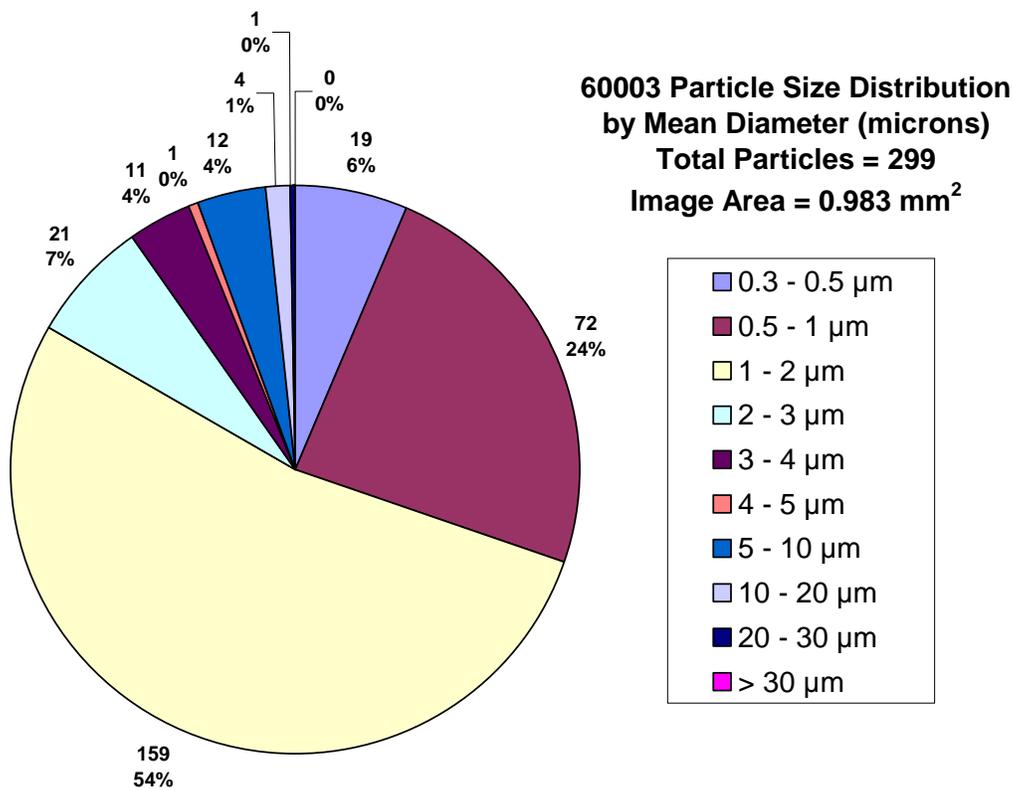
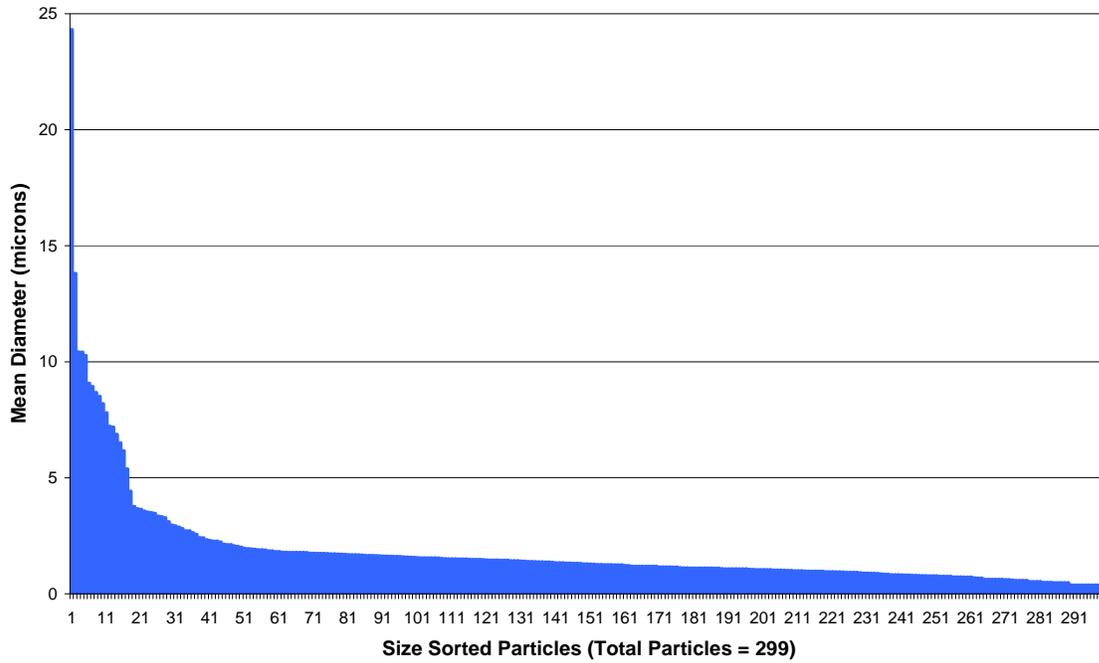
60003 50X objective mosaic scan particle map. Image area is 0.983 mm² with 299 particles identified > 0.3 microns. The red outline around an object and green number is to mark were ImageProPlus has identified a particle. These particle outlines are shown below.



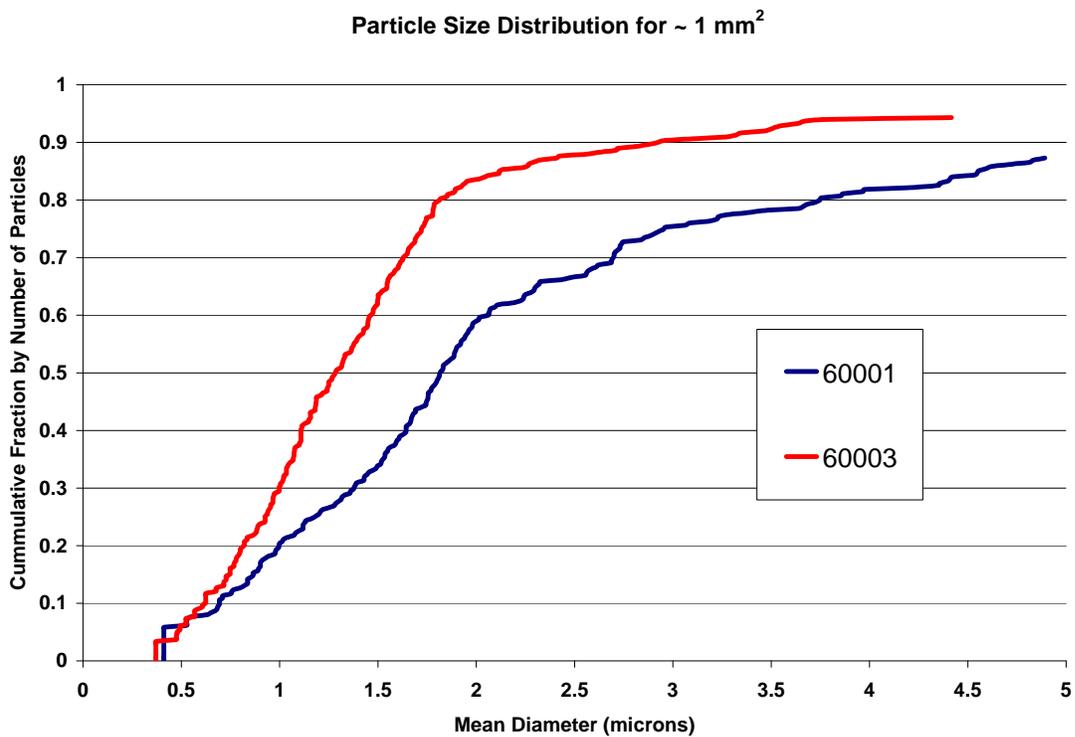
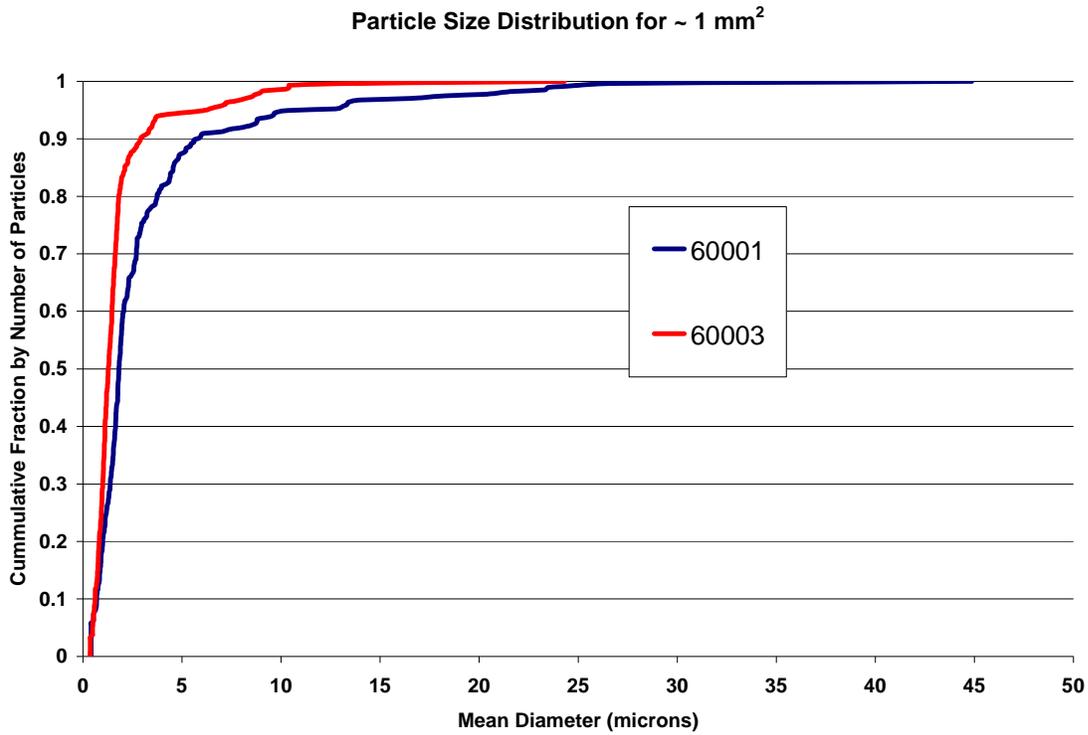
60003 50X mosaic scan particle sort by size distribution.

60003 50X Mosaic and Particle Size Statistics

60003 Individual Particle Diameter for ~ 1 mm²

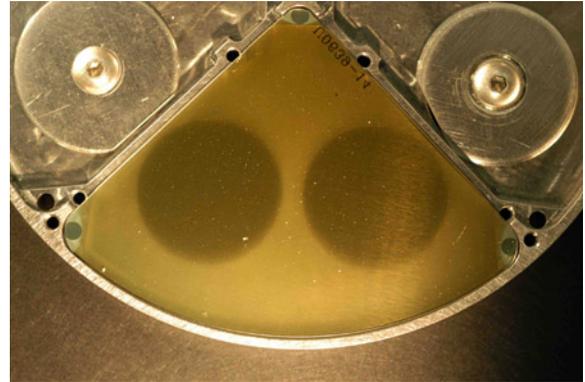
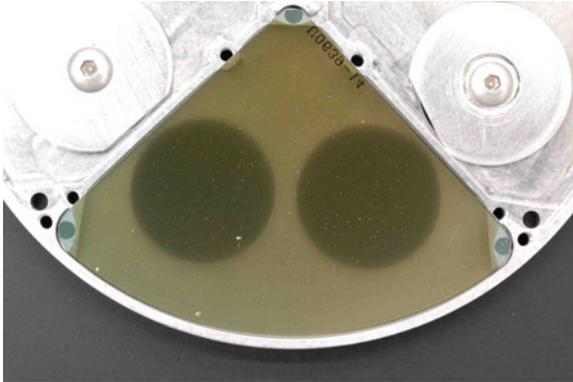


Comparison Particle Size Distributions

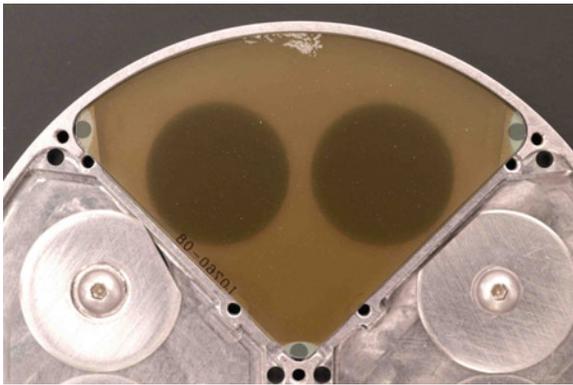


Appendix 1 Previous Images June 2006

Overview Images with Nikon D100



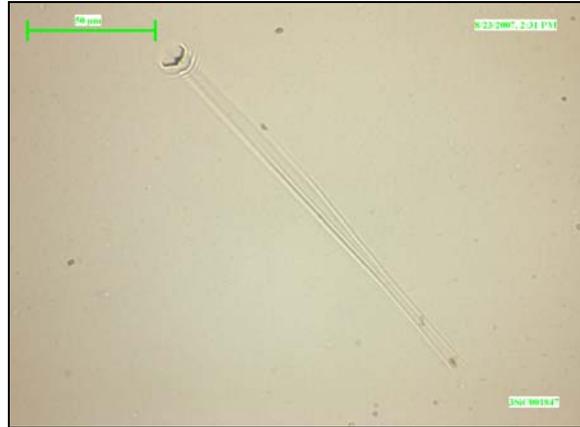
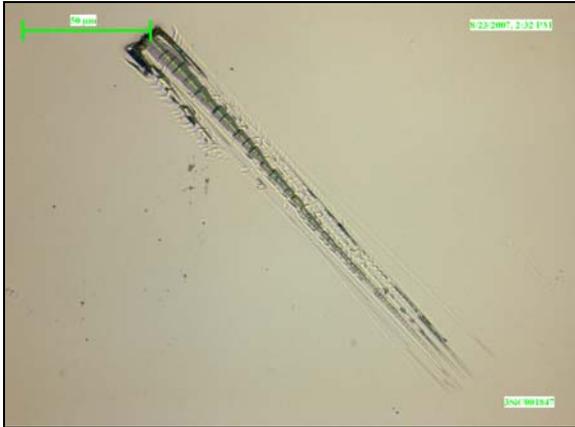
60001 Nikon D100 images in the non-flight stainless steel target holder.



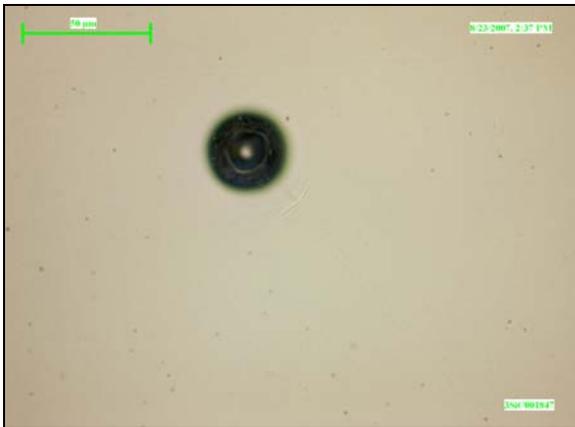
60003 Nikon D100 images in the non-flight stainless steel target holder.

Appendix 2. Features Observed on Non-flight SiC Quadrant

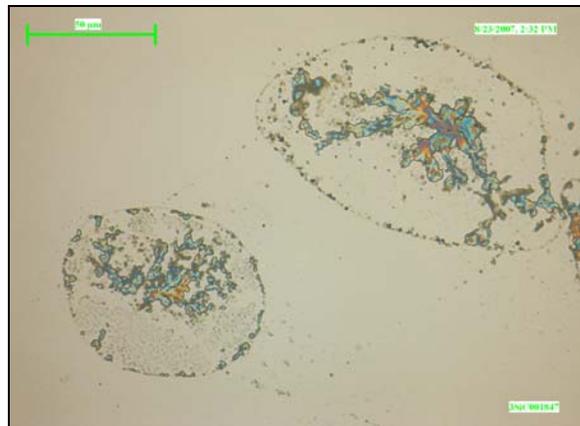
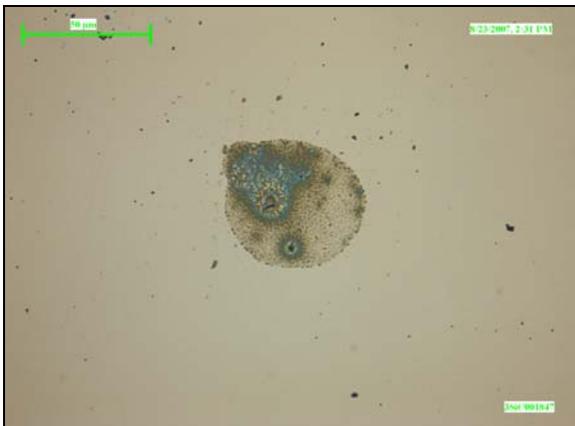
3SiC01847 Genesis Non-flight SiC Engineering Model



Two non-flight features similar to features 3, 4, 8 and 19 in SiC target 60001; and features 3,5, and 18 in SiC target 60003. Segmented scratches, faint trails, and stress markings are nearly identical in the three samples. Scale bars are 50 μm .

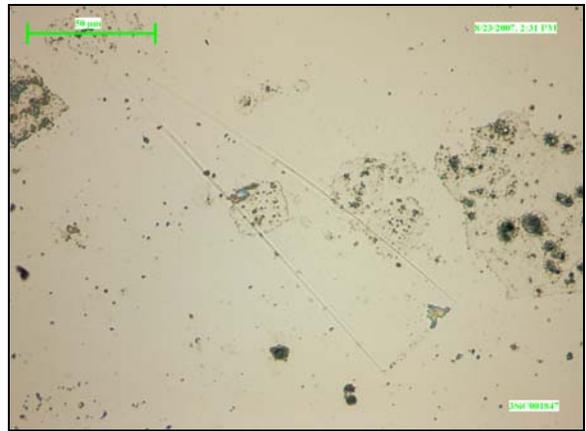
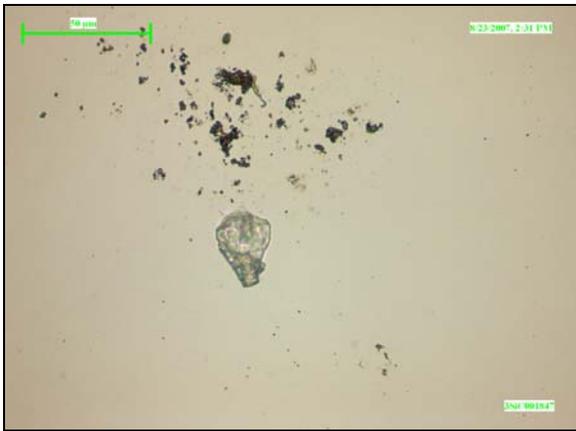
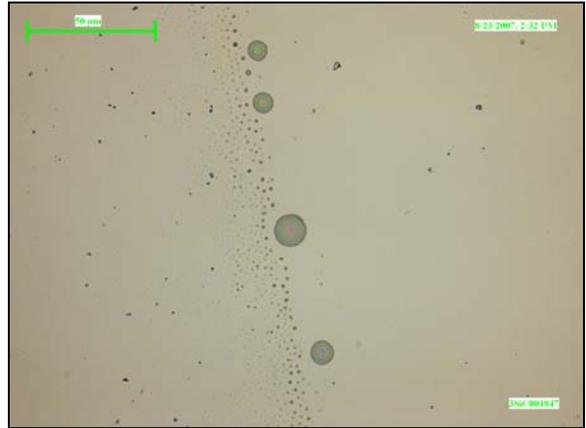
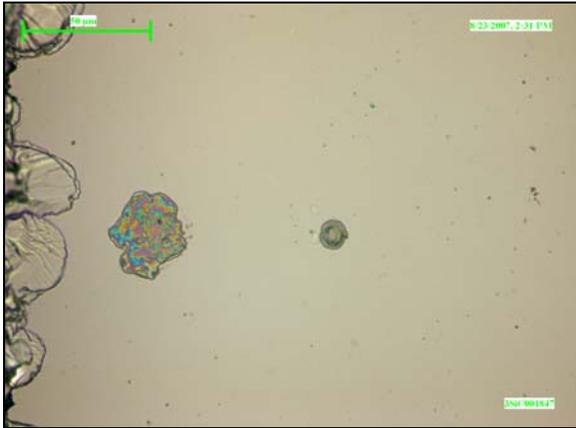


Non-flight spherical features similar to feature 14 in both Genesis-flown targets 60001 and 60003. Scale bar is 50 μm .



Following 6 views are non-flight iridescent or dark residue features. Scale bars are 50 μm .

3SiC01847 Genesis Non-flight SiC Engineering Model



Non-flight fiber/rod feature. Scale bar 50 μ m.