

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594



November 22, 2004

MATERIALS LABORATORY FACTUAL REPORT

Report No. 04-133

A. ACCIDENT

Place : Dugway, Utah
Date : September 8, 2004
Vehicle : Genesis Spacecraft
NTSB No. : ENG04SA028
Investigator : Clint Crookshanks, AS-40

B. COMPONENTS EXAMINED

Sample return capsule wiring harness and bolt catcher.

C. DETAILS OF THE EXAMINATION

An overall view of the submitted wiring harness and bolt catcher is shown in figure 1 as the components were received in the NTSB Materials Laboratory. The harness is shown as packaged, supported by a dark gray foam. Damage areas are indicated by arrows "Area 1", "Area 2" and "Area 3". Damage Areas 2 and 3 were further supported with wood tongue depressors taped to the harness. Another view of damage Areas 1, 2, and 3 after removing the packing material is shown in figure 2.

The submitted harness included a power cable that was connected to a battery at the battery connector indicated in figures 1 and 2. The power cable consisted of eight silver-coated copper strands with polyimide insulation (four colored yellow and four colored green). The cable was enclosed in a Kapton film and an aluminized Kapton film. The power cable was then wrapped in an aluminized Mylar wrap, as were any adjacent cables.

Wiring Harness Visual Examination

Four areas were identified where the aluminized Mylar wrap was damaged, and internal wires were exposed. The areas were numbered in order with increasing distance from the battery connector and are listed in table 1. Views of each of the areas of damage are shown in figures 3 to 8.

Damage Areas

Damage area number	Distance from the base of the battery connector (inch)
1	8.5
2	13
3	15-17
4	34

Area 1

Closer views of the damage at Area 1 are shown in figures 3 and 4. The aluminized Mylar wrap was fractured and gaped open, revealing internal wires and cables. Charring, deformed power cable wrapping material, and missing power cable strand insulators were observed, indicative of heat damage. Bare wires of the power cable were visible as indicated in figure 4.

Area 2

A view of the damage at Area 2 is shown in figure 5. The aluminized Mylar wrap was charred black in this area. The shrink tubing on the exterior of the aluminized Mylar wrap (shown at the right in figure 5) was blackened and melted adjacent to this. A power cable wire melt bead was observed penetrating through the aluminized Mylar wrap as indicated by the arrow in figure 5.

Area 3

The regions of most severe damage in Area 3 were on approximately opposite sides of the harness and are shown in figures 6 and 7. The end of the damage area further from the battery connector is shown in figure 6, and the end closer to the battery connector is shown in figure 7. The aluminized Mylar wrap at the end further from the battery connector was fractured and gaped open as shown in figure 6. All eight of the power cable strands were either fractured or melted at this location. In addition, two adjacent strands with white insulators were fractured. Black deposits, charred insulators, and melted strands were observed in the area, consistent with exposure to heat. The shrink tubing on the exterior of the aluminized Mylar wrap adjacent to the area (shown at the left in figure 6) was blackened, partially melted, and opened back away from the damage at Area 3. At the end of Area 3 closer to the battery connector as shown in figure 7, the aluminized Mylar was gaped open, exposing the power cable. The insulators for the power cable were charred consistent with exposure to heat.

Area 4

A close view of the damage at Area 4 is shown in figure 8. The aluminized Mylar was fractured and gaped slightly open. None of the underlying strand insulators for the power cable were penetrated, and no heat damage was observed. An irregular-shaped piece of white debris measuring 100 micrometers across was observed in this area. The

piece was examined in a scanning electron microscope using energy dispersive x-ray spectroscopy (EDS), and the resulting spectrum showed high peaks of gallium and zinc.

Wiring Harness Disassembly

The aluminized Mylar and aluminized Kapton were removed from the power cable where possible. As these wraps were removed near Area 1, a portion of the power cable with the battery connector separated from the remainder of the harness. The separated piece is shown in figure 9.

As the aluminized Mylar was removed further, charred and separated remnants of the power cable were exposed in the section between Areas 1 and 3. A view of the harness in this area with the largest of the exposed power cable remnants is shown in figure 10.

The aluminized Mylar in the section shown in figure 10 showed evidence of charring and heating and tore more easily than in other sections. Also, the shrink tubing in this area was stiffer than the tubing in other areas.

Post-Disassembly Wiring Harness Examination

Battery Connector to Area 1

A view of the damaged end of the power cable piece attached to the battery connector is shown in figure 11. No heat damage was noted directly adjacent to the battery connector and up to a distance of about 3.3 inches from the connector. Starting at a distance of 3.3 inches from the base of the battery connector, the Kapton film around the power cable strands was shrunk onto the strands. Starting at a distance of 5.4 inches from the base of the battery connector, the aluminized Kapton was fused to the underlying Kapton film. Starting at a distance of 8.3 inches from the base of the battery connector, the power cable strand insulators were mostly missing, and bare wires were exposed. The strands on this piece of the power cable were fractured or melted 9.8 to 10.3 inches from the base of the battery connector. A closer view of the ends of the power cable piece at this location is shown in figure 12. Several of the fractured and melted ends are shown in figure 13 as viewed using scanning electron microscopy (SEM). As shown in figures 12 and 13, the power cable strand ends were rounded, individual wires within a strand were fused, and irregular thinning was observed consistent with melting. Where fractured, significant thinning of the strand was observed adjacent to the fracture, consistent with fracture at high temperature.

Area 1 to Area 3

The power cable between Area 1 and Area 3 was charred, and the strands showed evidence of melting. Many partially melted strand fragments and charred insulation fragments were present in this area. Strands in the harness adjacent to the power cable were also slightly charred and had black deposits on their surfaces. One charred section of

the power cable in this area remained relatively intact as shown in figure 14. This section was held together by the aluminized mylar wrap.

Area 3

A view of the harness at Area 3 after removal of the shrink tubing, aluminized Mylar, and aluminized Kapton is shown in figure 14. The power cable Kapton film showed charring and heat damage within 0.2 to 0.3 inches of the fractured or melted ends of the power cable strands. Also, two of the adjacent strands with white insulation showed heat damage and slight charring within 0.2 inches of their fractured ends. Black fibrous deposits also were observed throughout the area, visible in many of the close views of strands in this section.

A closer view of the damage in Area 3 is shown in figure 16. As indicated in figure 16, the Kapton sleeve for a strand adjacent to the power cable was fractured and pushed back in the direction of the battery connector, consistent with contact with another object. The Kapton sleeve also was charred, consistent with exposure to heat, and the charring was not continuous across the mating sides of the fracture, indicating the charring occurred after the fracture. The fractured ends of two white strands indicated in figure 16 were bent inward, also consistent with contact with another object. These fractured strands mated with the two white strands labeled in figure 15.

The strands that were either fractured or melted in Area 3 were numbered for reference. The two fractured strands with white insulation adjacent to the power cable were numbered arbitrarily as shown in figure 15. The power cable strands were numbered such that green strands were assigned an odd number, and yellow strands were assigned an even number. Close views of each of these strands are shown in figures 17 to 20 and figures 23 to 35.

The fractured ends of white strands 1 and 2 are shown in figures 17 to 20. Approximately 0.06 inch of bare wire was exposed on each strand. The fractured ends of the strands were bent and flattened, and individual wires were sheared consistent with contact with another object. On white strand 1, several wires were inadvertently bent outward during disassembly of the aluminized Mylar and aluminized Kapton. On both strands, the adjacent insulator was charred. Black deposits were observed on the strand. In areas where the deposits were not present, the wires had a light brown color. Using energy dispersive x-ray spectroscopy (EDS), a typical spectrum of the white strand insulator material was obtained and is shown in figure 21. The spectrum showed a high peak of fluorine and much smaller peaks of titanium and carbon. A typical EDS spectrum for the black deposits on the bare end of white strand 2 is shown in figure 22. The deposits had a high peak of carbon with smaller peaks of oxygen, fluorine, and silicon. A silver peak also was observed, consistent with the coating on the underlying wire material.

Views of power cable strand 1 are shown in figures 23 and 24. The fractured end of the strand came to a chisel-like point, and each strand was sheared consistent with contact with another object. The exposed strand had black deposits, and the adjacent insulator

was charred. Black fibrous deposits also were observed in the area. The insulator and several wires of this strand also were fractured at a location 0.24 inch from the fractured end of the strand (not visible in figures 23 and 24). The fractured wires were deformed consistent with contact with another object.

Power cable strand 2 is shown in figure 25. This fracture was located furthest from the battery connector among the eight power cable strand fractures. The individual wires of strand 2 had a chisel-like fracture consistent with an overstress fracture in tension. The end of the strand appeared light brown, darker than the exposed strand adjacent to the insulator. No insulator charring was observed on this strand at this location.

Views of power cable strand 3 are shown in figures 26 and 27. The strand was fractured with some wires sheared and others showing necking consistent with overstress fracture in tension. The ends of the exposed bare strand had black deposits, and in areas where the black deposits were not present, the ends appeared light brown. The strand had a more shiny silver appearance adjacent to the insulator. The insulator adjacent to the bare strand was charred. Black fibrous deposits also were observed in the area.

Views of power cable strand 4 are shown in figures 26 and 28. The strand end was bent and individual wires were sheared, consistent with contact with another object. Some charring was observed on the insulator adjacent to the bare strand, and where the insulator was charred, the exposed strand was tinted slightly brown mixed with some black deposits.

Views of power cable strand 5 are shown in figures 29 and 30. The strand end was bent and individual wires were sheared, consistent with contact with another object. Black deposits were observed on the fractured ends, and where deposits were not present, the strands had a light brown color. The insulator adjacent to the exposed bare strand was charred. Black fibrous deposits also were observed in the area.

Views of power cable strand 6 are shown in figures 31 and 32. The wires of the strand end were flattened, bent, and sheared, consistent with contact with another object. The insulator adjacent to the bare strand was discolored slightly brown.

Views of power cable strand 7 are shown in figures 33 and 34. Several wires at the end of this strand were melted into a ball and the ball was oriented at an angle relative to the strand. Several other wires were melted together with an irregular melt shape. The insulator adjacent to the bare strand was charred.

Views of the power cable strand 8 are shown in figures 33 and 35. Individual wires were fused into a single melt ball and the melt ball was oriented at an angle relative to the strand in approximately the same direction as the melt ball of strand 7. The insulator adjacent to the bare strand was charred.

The EDS spectra for the green and yellow power cable strand insulators are shown in figure 36. Both insulator colors had a high peak of carbon and a smaller peak of oxygen. One color also had a peak of titanium.

An EDS spectrum for undamaged shrink tubing is shown in figure 37. High peaks of carbon and fluorine were observed with smaller peaks of oxygen, aluminum, silicon, and potassium. A black portion of the charred shrink tubing located at Area 3 also was examined using EDS, and the resulting spectrum is shown in figure 38. Peaks of carbon and oxygen were observed in similar ratios to that of the undamaged shrink tubing, but the fluorine peak was substantially smaller.

Bolt Catcher Examination

An area of the bolt catcher had black deposits on its surface. A close view of this area of the bolt catcher is shown in figure 39. The flats at the base of the bolt catcher were damaged consistent with wrench contact, which occurred during disassembly of the bolt catcher after recovery.

The deposits on the bolt catcher were examined using SEM and EDS. An SEM view using backscattered electrons is shown in figure 40. The deposits appeared mostly darker than the underlying bolt catcher material, but some areas appeared brighter. Most of the brighter areas were round with diameters ranging from less than a micrometer to several micrometers.

An EDS spectrum of the bolt catcher is shown in figure 41. The bolt catcher had a high peak of aluminum and much smaller peaks of chromium and carbon.

An EDS spectrum of the black deposits on the bolt catcher is shown in figure 42. This spectrum had high peaks of silicon, carbon, and aluminum with smaller peaks of fluorine and oxygen and much smaller peaks of sulfur and chromium.

An EDS spectrum of the deposits appearing round and white in figure 40 is shown in figure 43. The spectrum had high peaks of copper with much smaller peaks of silver and carbon.

Irregular-shaped deposits appearing lighter on the surface of the bolt catcher also were examined using EDS. The spectra for these deposits had high peaks of gallium and zinc.

Matthew R. Fox
Senior Materials Engineer

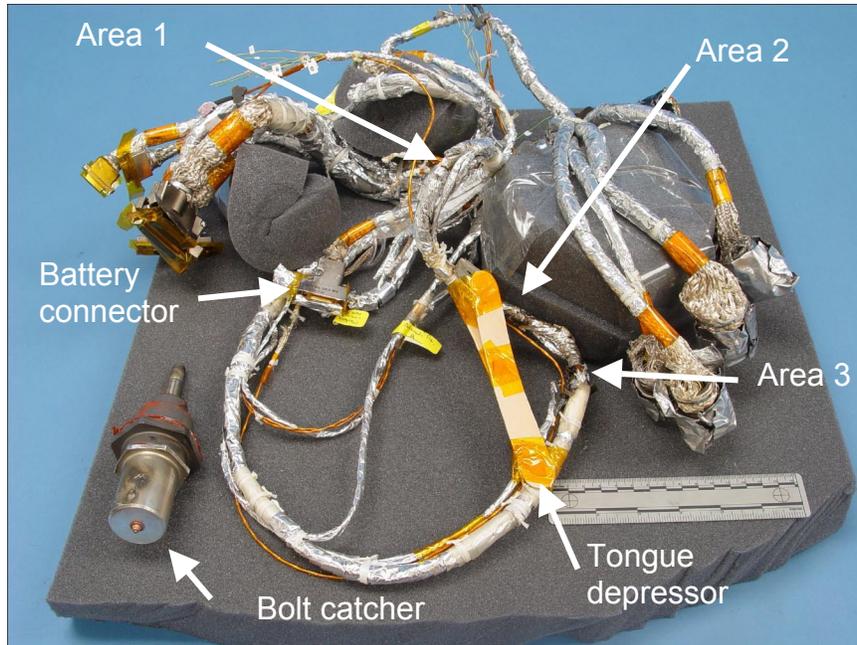


Image No.:0411A00200, Project No.: 2004110004

Figure 1. Overall view of the as-received wiring harness and bolt catcher. Wrap disturbance at areas 1 to 3 are indicated. Also, a splice consisting of wood tongue depressors for stabilization during shipping is indicated.

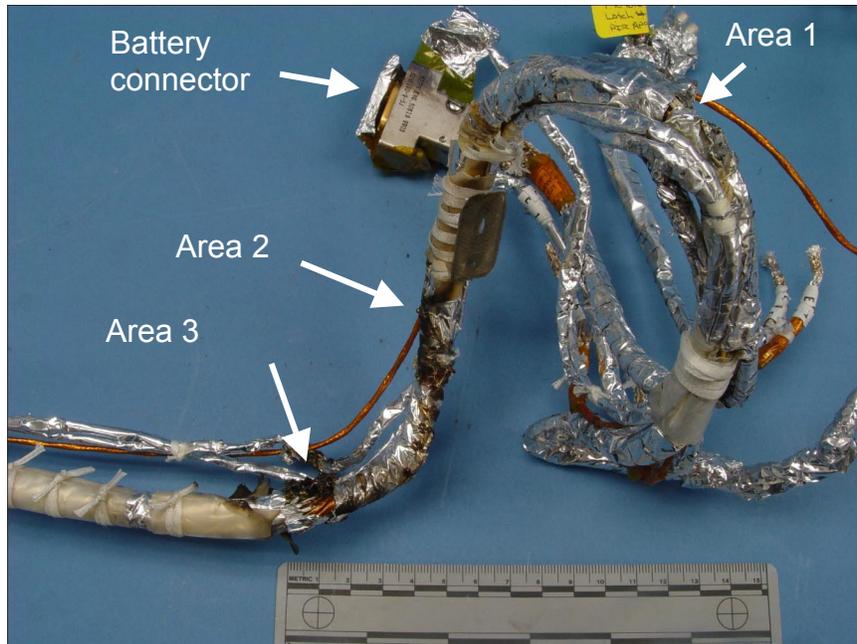


Image No.:0411A00202, Project No.: 2004110004

Figure 2. Another view of the harness at areas 1 to 3 with the packaging material removed.

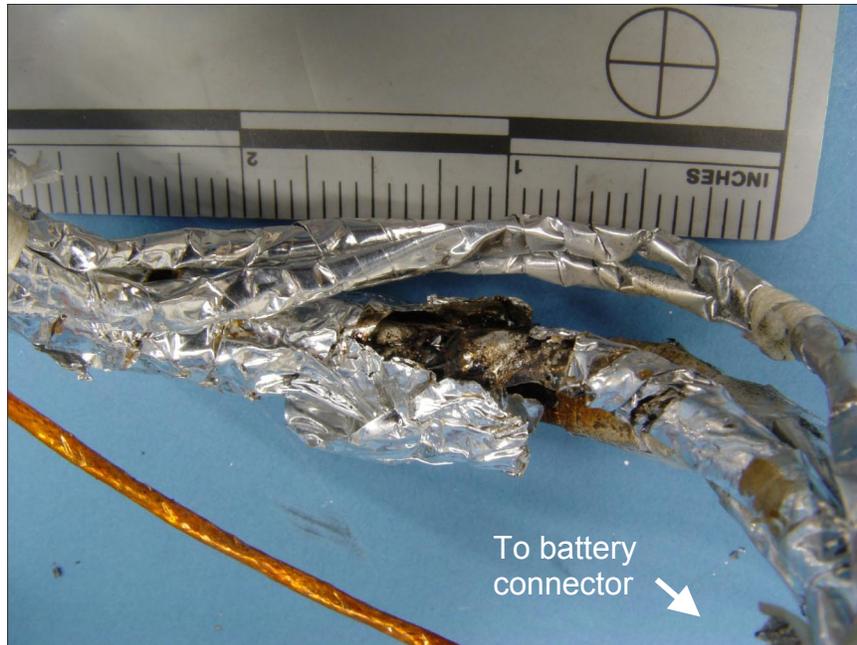


Image No.:0411A00208, Project No.: 2004110004

Figure 3. Another view of the wrap disturbance at Area 1.

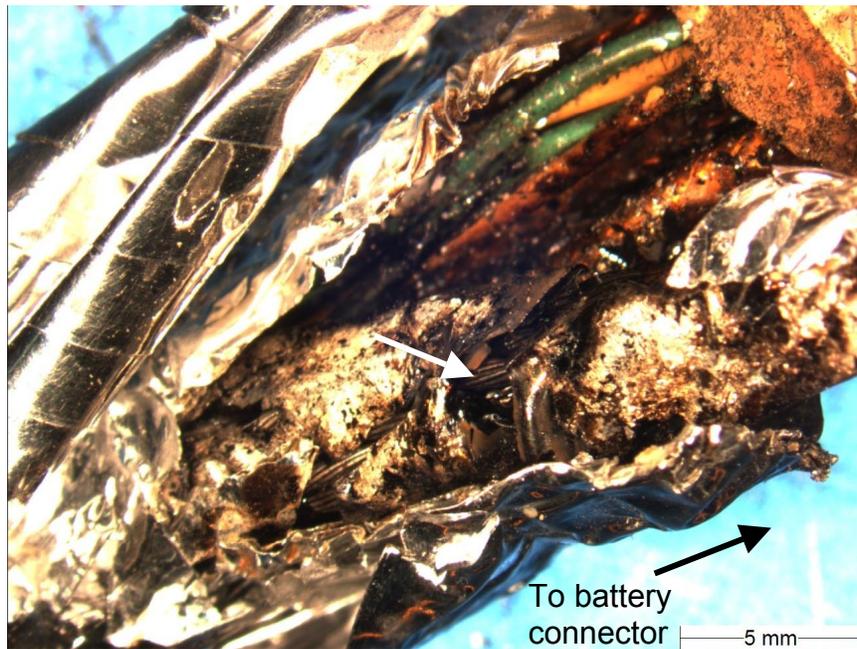


Image No.:0411A00229, Project No.: 2004110004

Figure 4. A closer view of Area 1. An unlabeled arrow indicates exposed power cable strands with missing insulation.

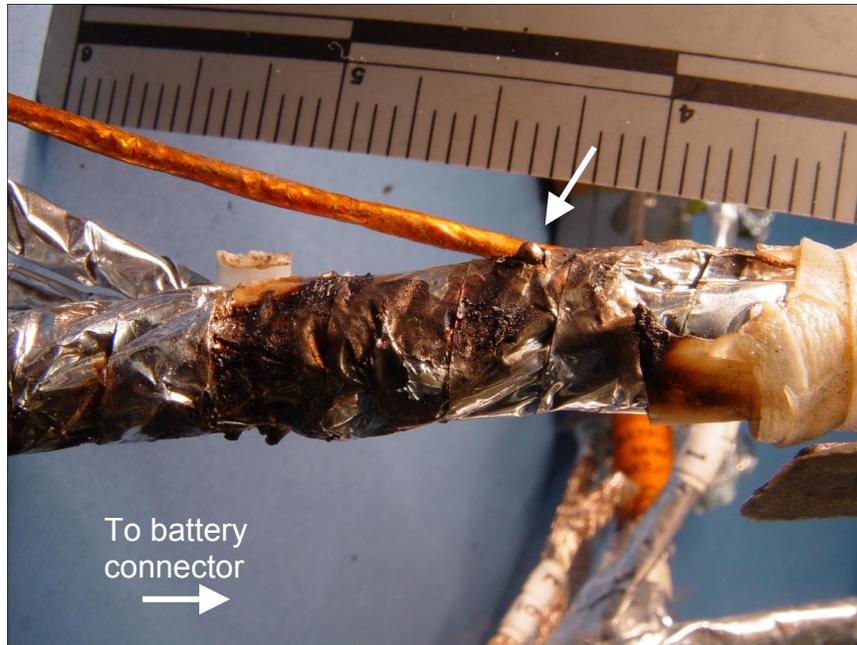


Image No.:0411A00206, Project No.: 2004110004

Figure 5. Close view of the damage at Area 2. An unlabeled arrow indicates where a melt bead penetrated the aluminized Mylar wrap.

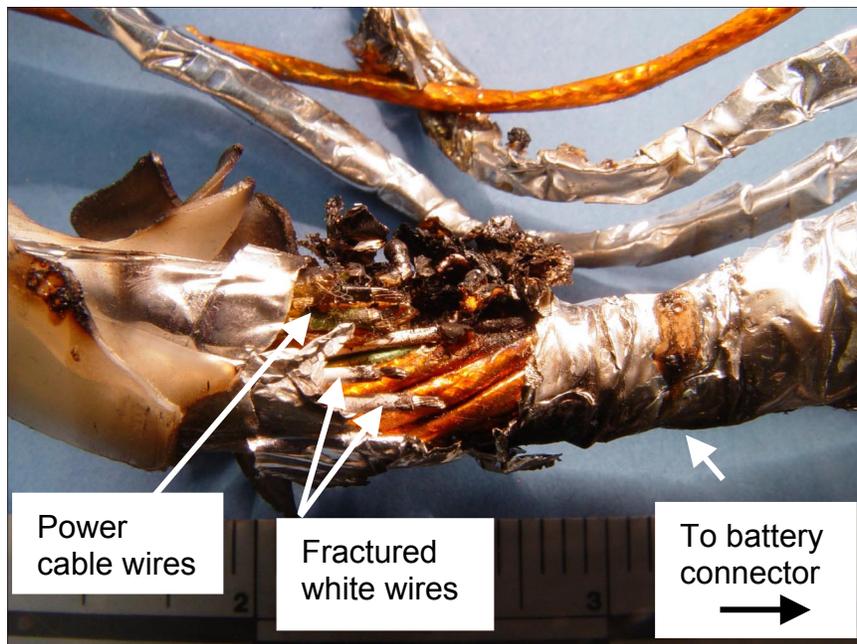


Image No.:0411A00204, Project No.: 2004110004

Figure 6. Close view of the damage at area 3. The unlabeled arrow indicates the direction of viewing for figure 7.

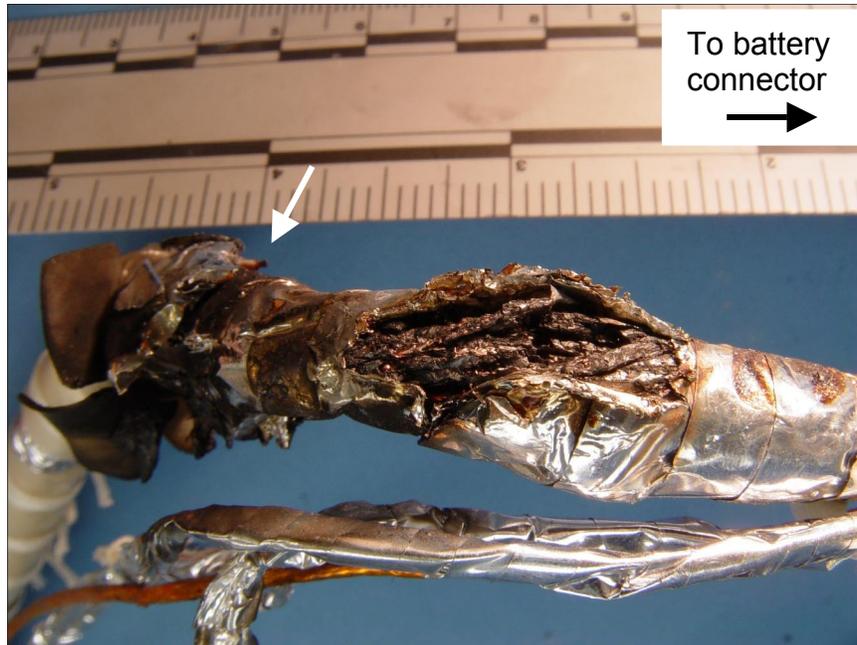


Image No.:0411A00207, Project No.: 2004110004

Figure 7. Damage at area 3 adjacent to the damage shown in figure 6 located closer to the battery connector. The unlabeled arrow indicates the direction of viewing for figure 6.

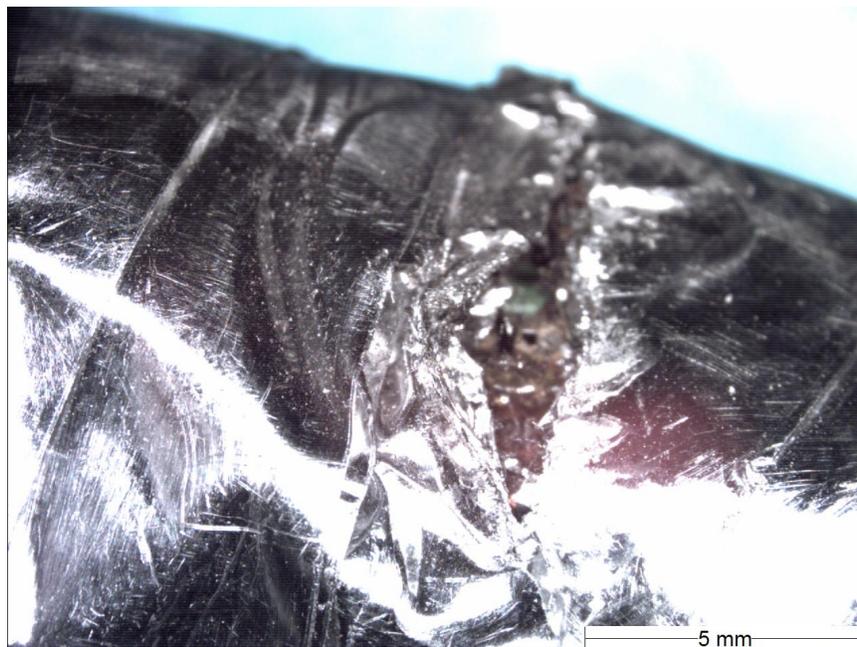


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Figure 8. View of the damage at area 4.

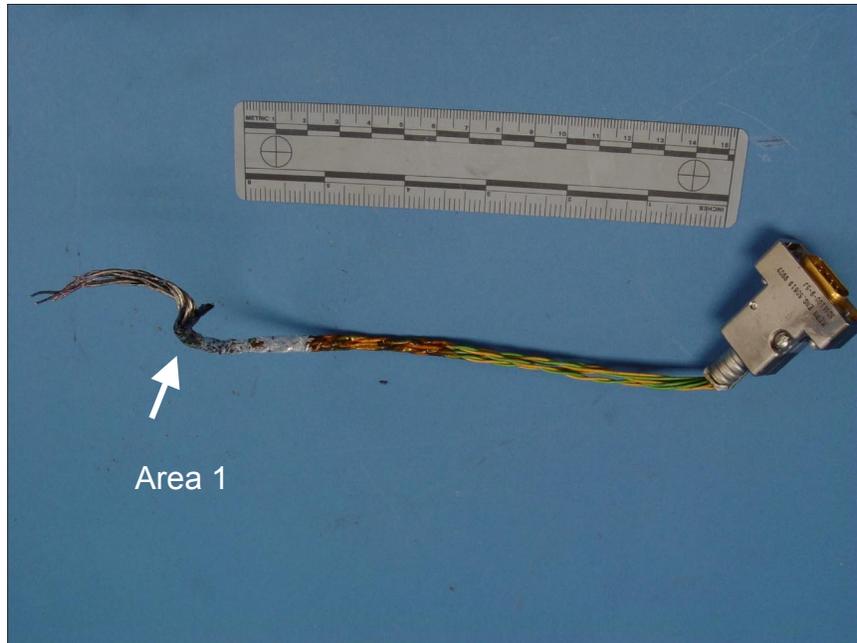


Image No.:0411A00246, Project No.: 2004110004

Figure 9. View of the battery connector and power cable after removal of the outer aluminized Mylar wrap. The cable strands were melted and fractured in the vicinity of Area 1.

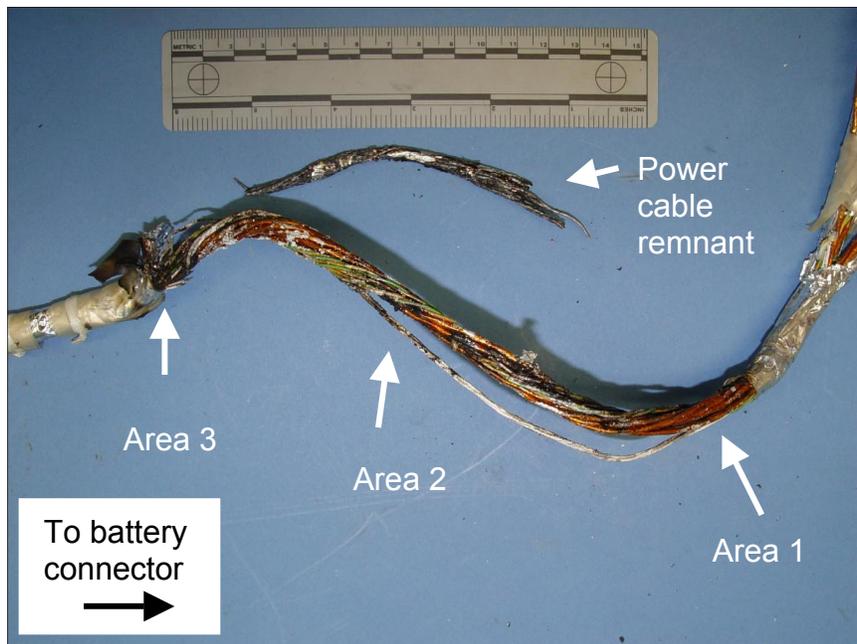


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Figure 10. View of the harness between Areas 1 and 3 after removal of the outer aluminized Mylar wrap.

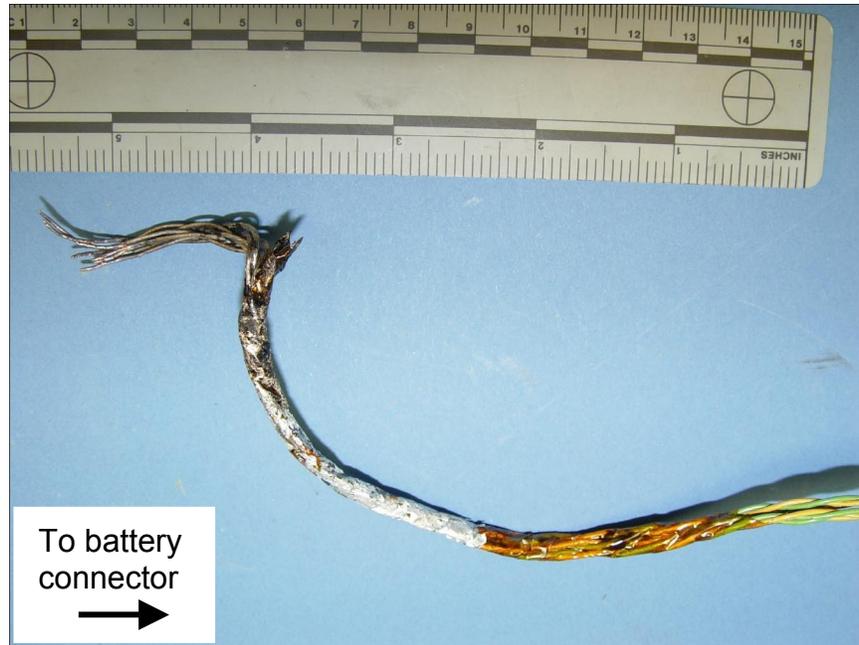


Image No.:0411A00255, Project No.: 2004110004

Figure 11. Closer view of the damaged end of the power cable piece shown in figure 9.



Image No.:0411A00242, Project No.: 2004110004

Figure 12. Closer view of the melted and fractured strands of the power cable piece shown in figure 11.

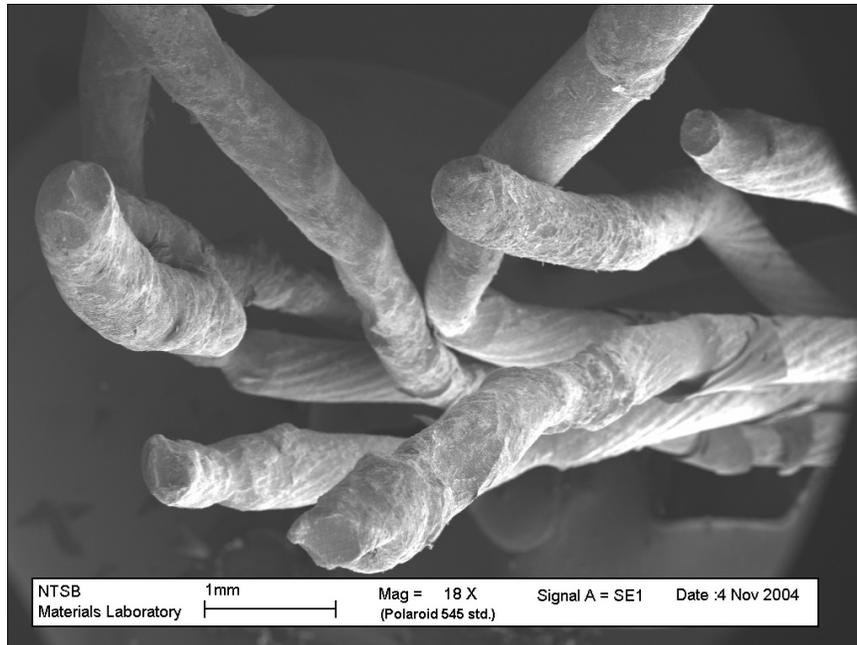


Image No.:0411A00663, Project No.: 2004110004

Figure 13. Strands from the power cable near Area 1 as viewed using SEM.

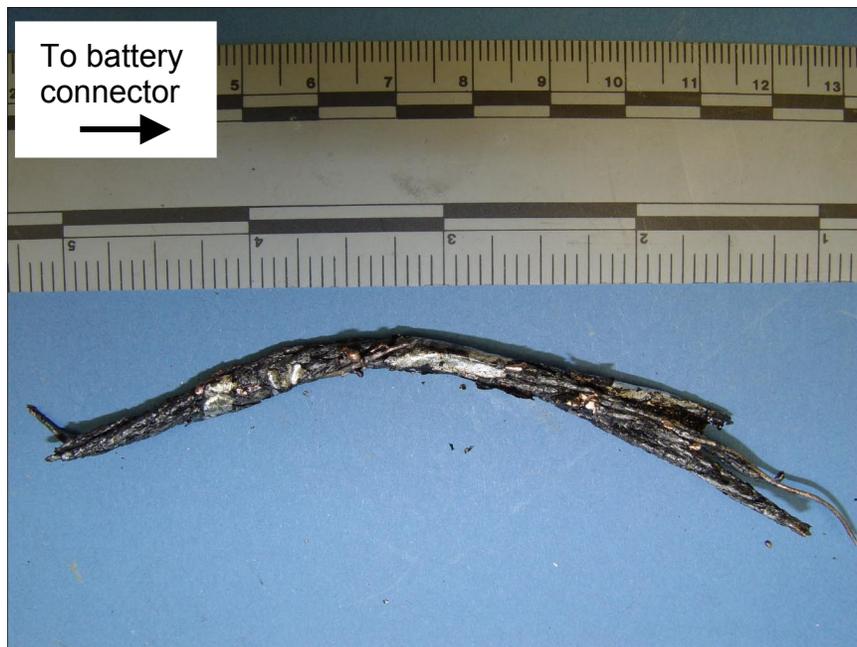


Image No.:0411A00291, Project No.: 2004110004

Figure 14. Closer view of the power cable remnant from between areas 1 and 3 (also shown in figure 10).

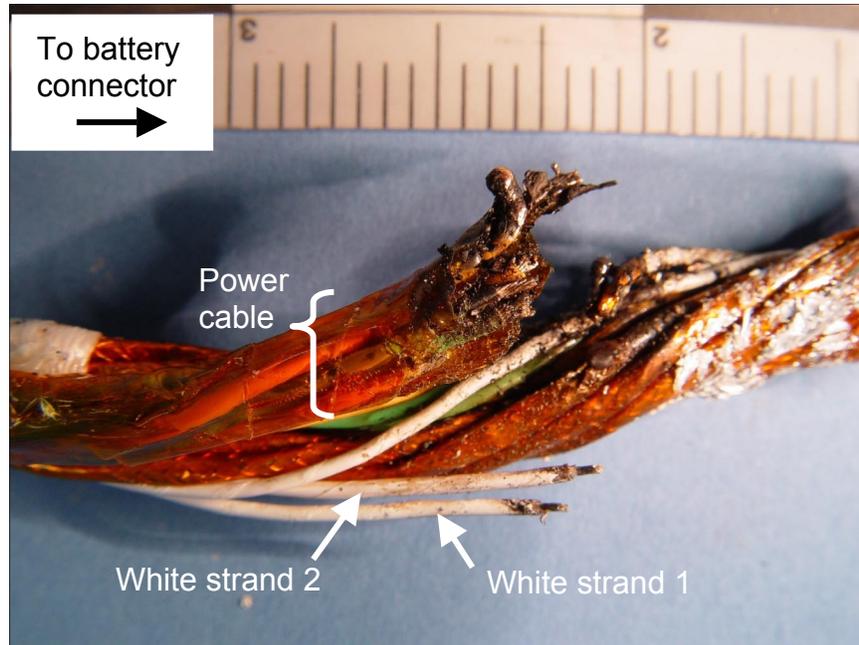


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Figure 15. Close view of the damage at area 3 after removal of the outer aluminized Mylar wrap.

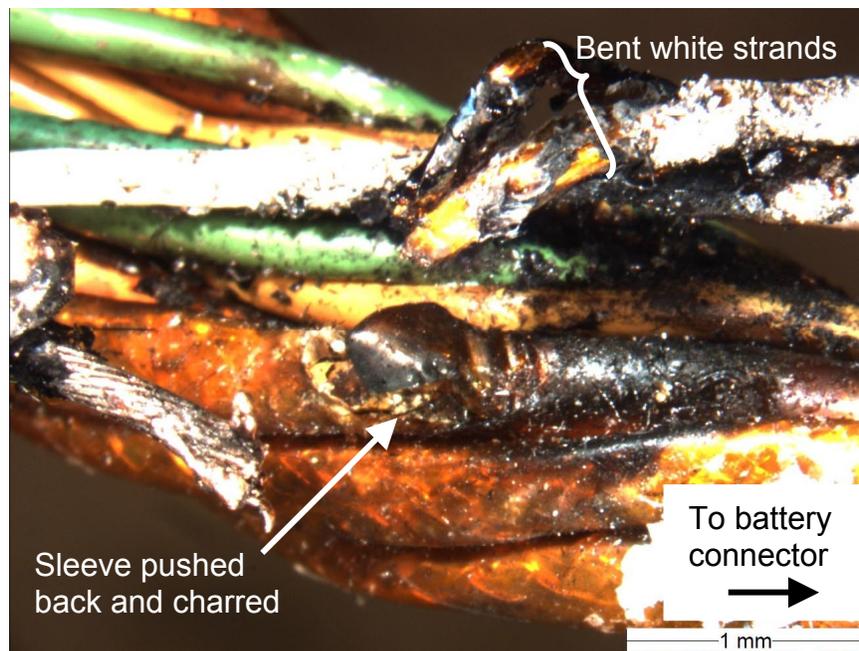


Image No.:0411A00578, Project No.: 2004110004

Figure 16. Close view of the damage in area 3 showing the bent mating ends of white strands 1 and 2. Damage to the Kapton sleeve of an adjacent strand also is indicated in the figure.



Image No.:0411A00568, Project No.: 2004110004

Figure 17. Close view of white strand 1 in Area 3. Several strands were bent during the wrap removal process.

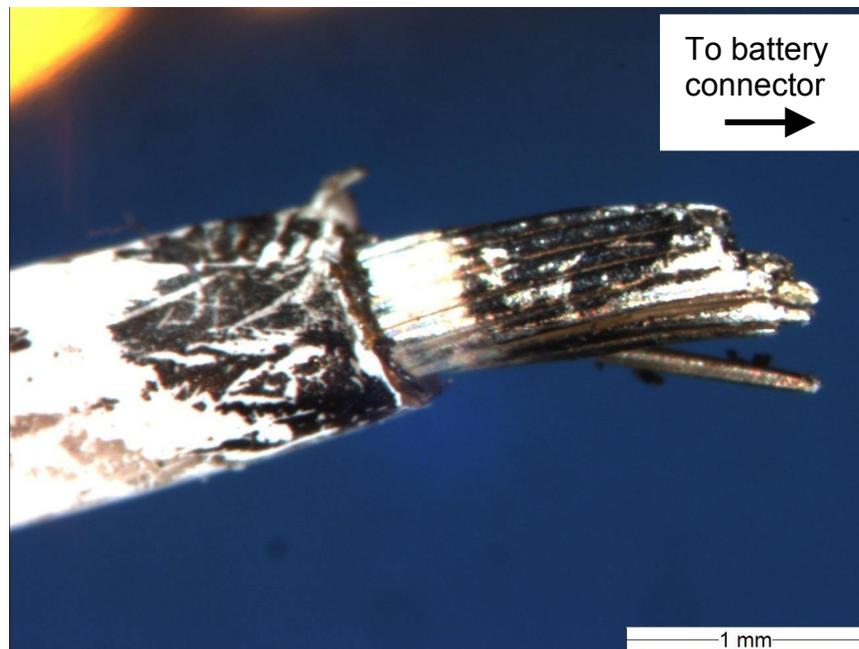


Image No.:0411A00569, Project No.: 2004110004

Figure 18. Close view of white strand 2 in Area 3.

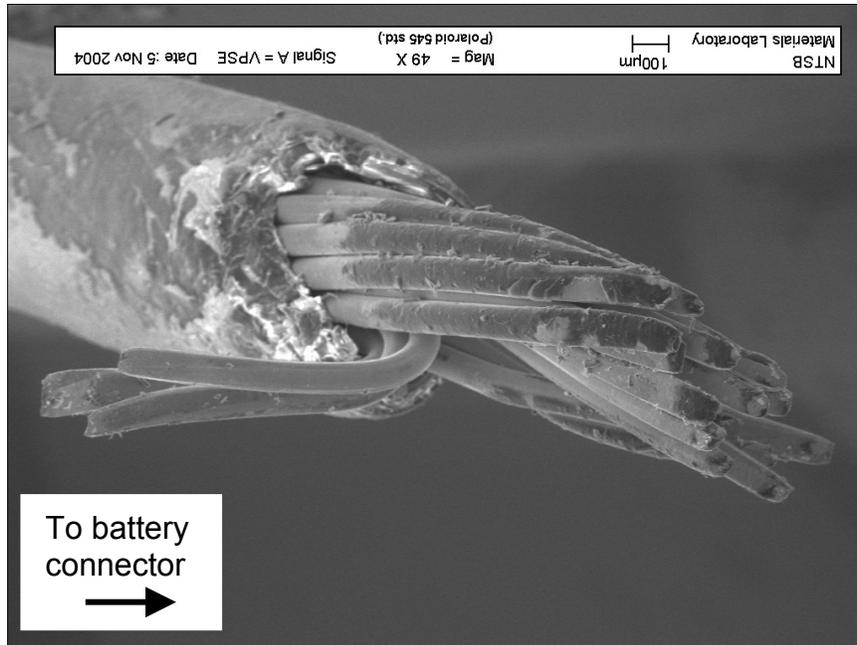


Image No.:0411A00671, Project No.: 2004110004

Figure 19. SEM view of white strand 1 at Area 3.

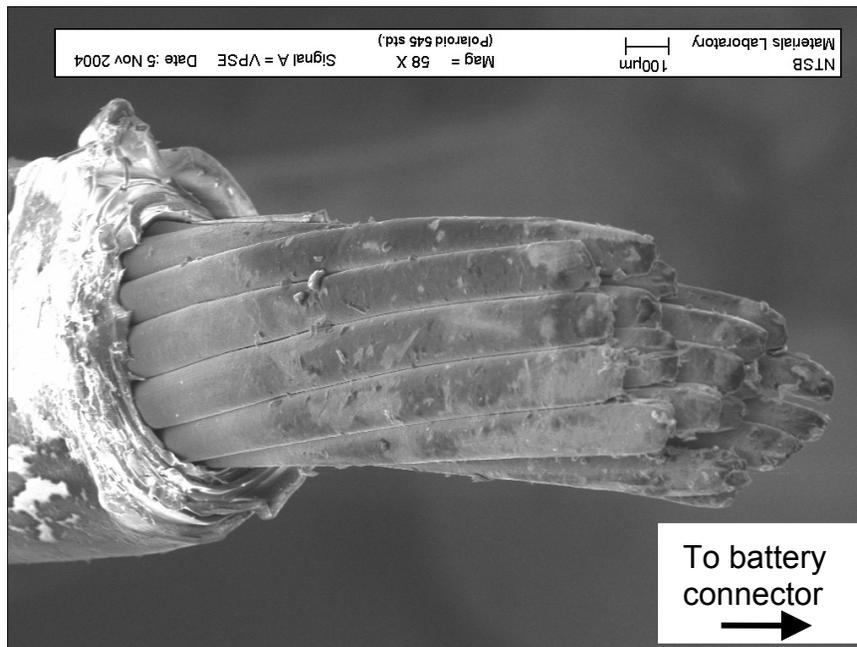


Image No.:0411A00672, Project No.: 2004110004

Figure 20. SEM view of white strand 2 at Area 3.

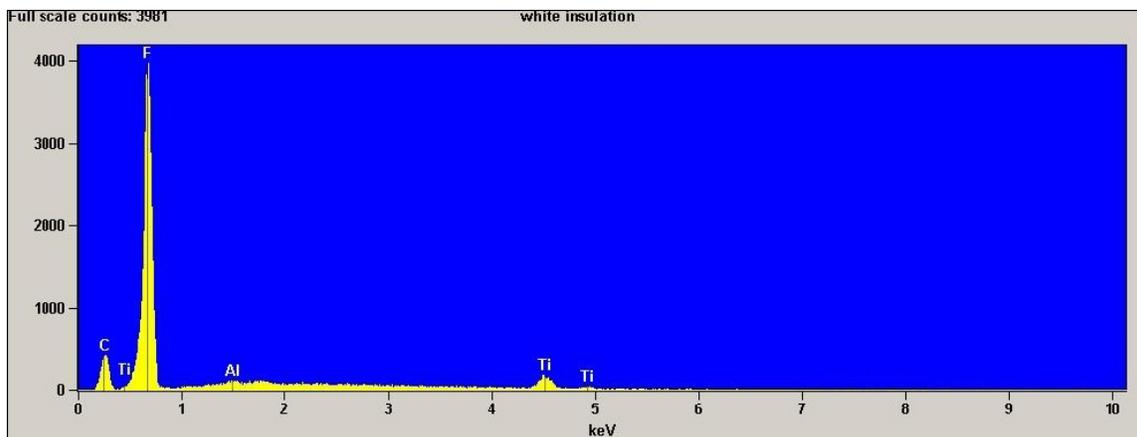


Image No.:0411A00690, Project No.: 2004110004

Figure 21. EDS spectrum for the white strand insulator adjacent to the power cable.

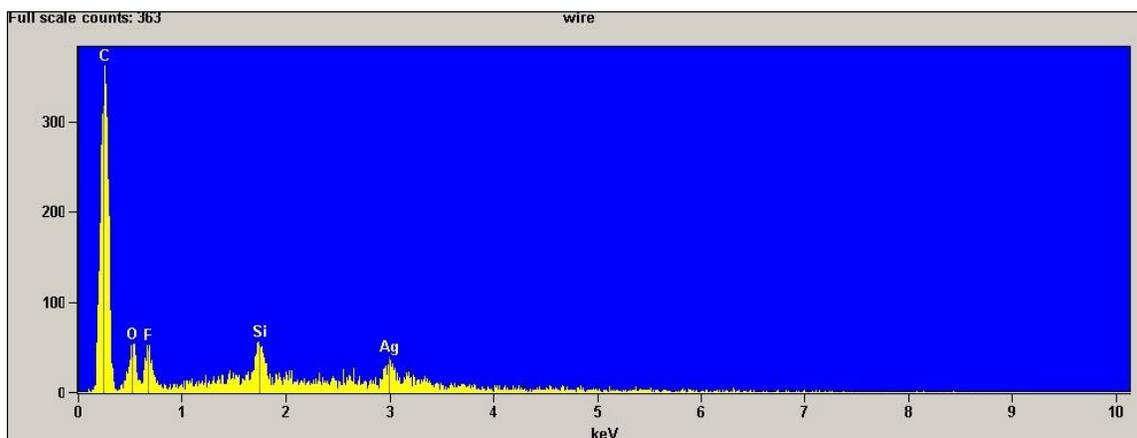


Image No.:0411A00691, Project No.: 2004110004

Figure 22. EDS spectrum for black deposits on the exposed white strand at Area 3.

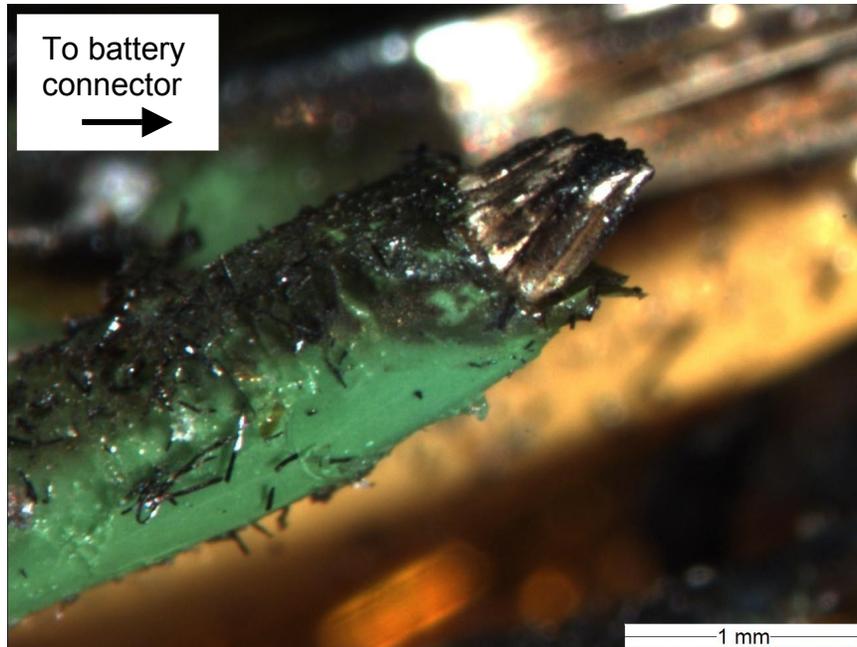


Image No.:0411A00572, Project No.: 2004110004

Figure 23. Close view of power cable strand 1 in Area 3.

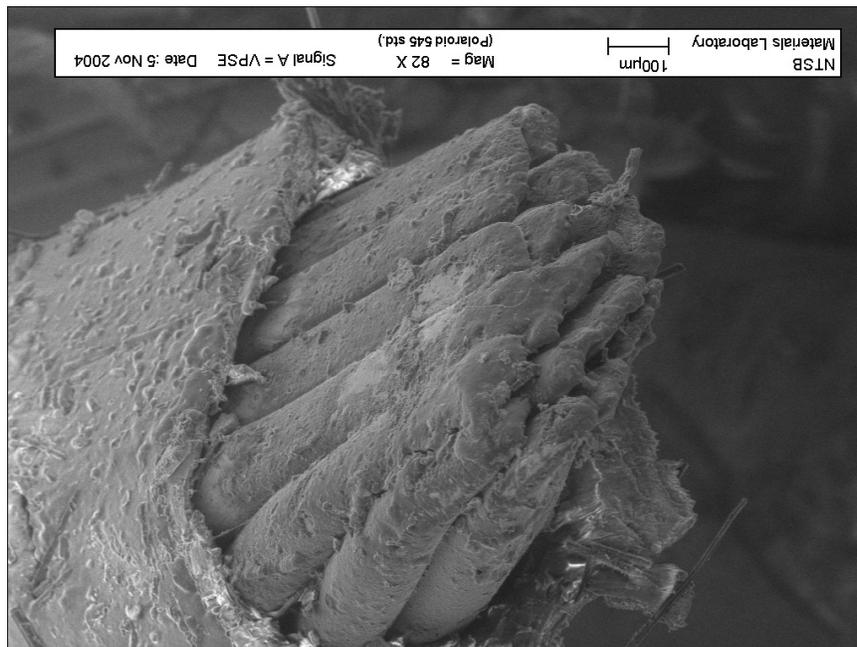


Image No.:0411A00675, Project No.: 2004110004

Figure 24. SEM view of power cable strand 1 at Area 3.

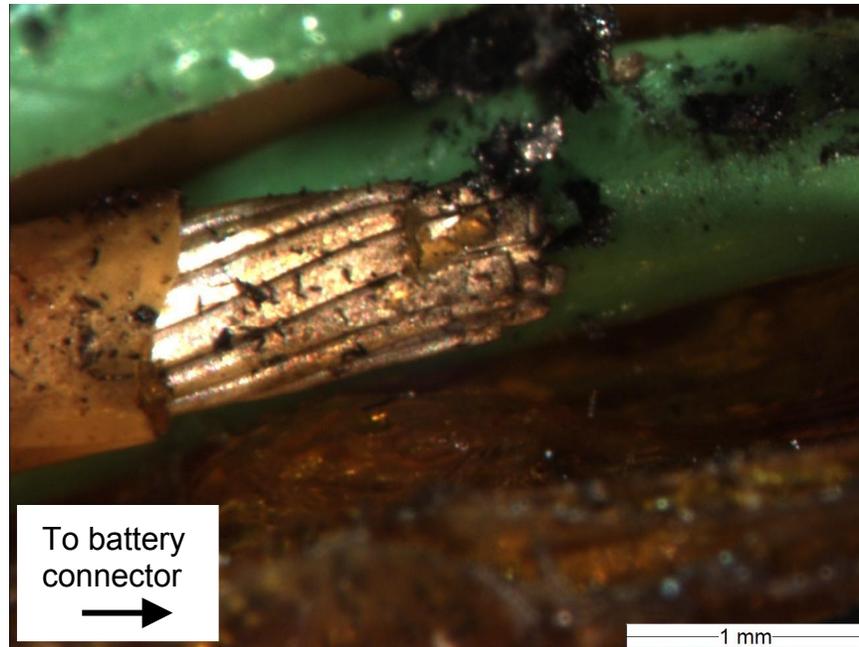


Image No.:0411A00576, Project No.: 2004110004

Figure 25. Close view of power cable strand 2 in area 3.

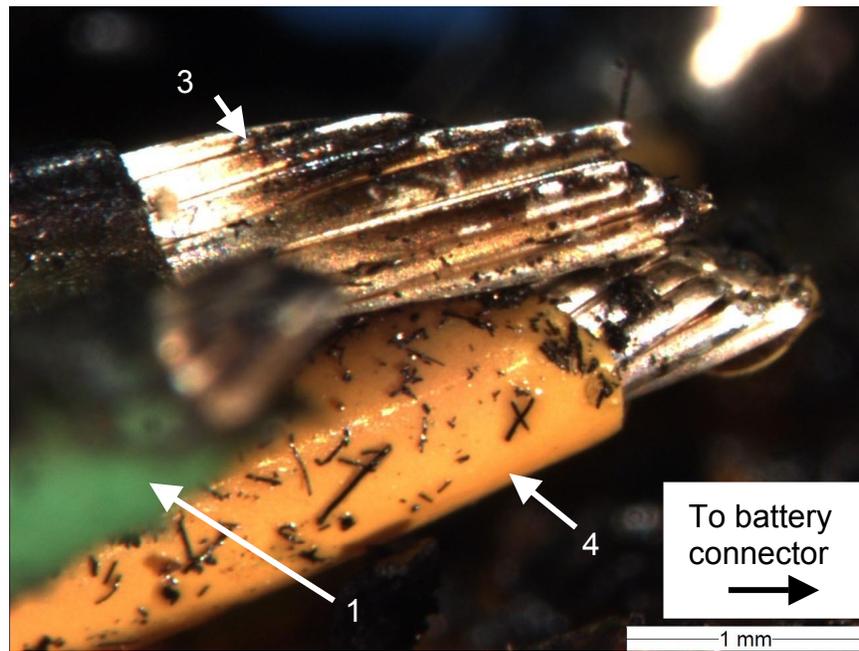


Image No.:0411A00573, Project No.: 2004110004

Figure 26. Close view of power cable strands 3 and 4 in Area 3.

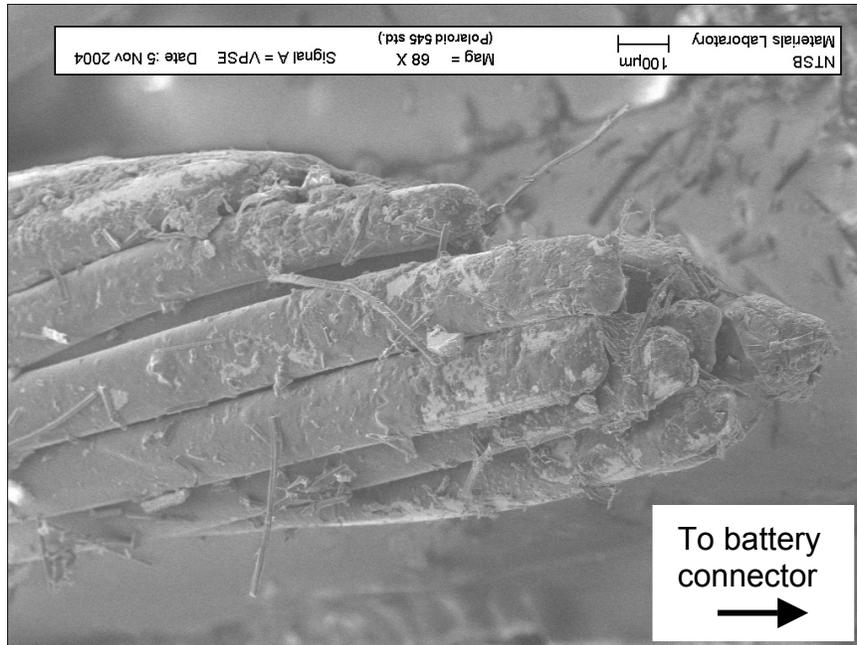


Image No.:0411A00680, Project No.: 2004110004

Figure 27. SEM view of power cable strand 3 at Area 3.

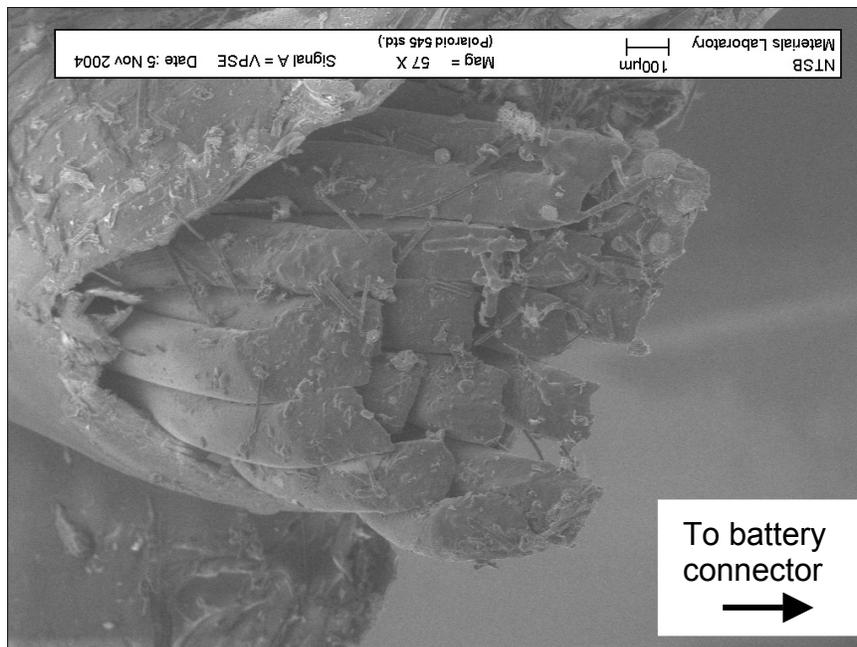


Image No.:0411A00677, Project No.: 2004110004

Figure 28. SEM view of power cable strand 4 at Area 3.

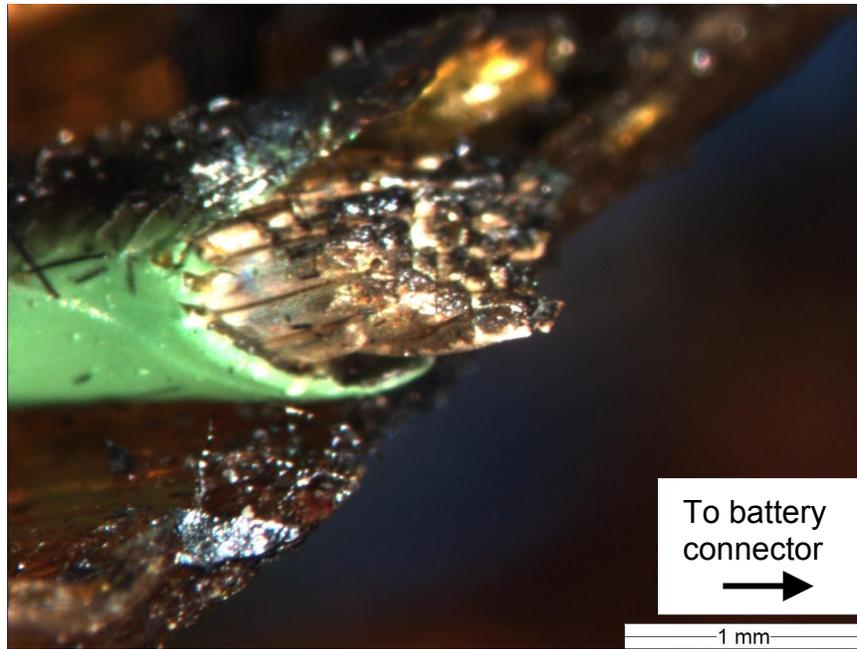


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Figure 29. View of power cable strand 5 in Area 3.

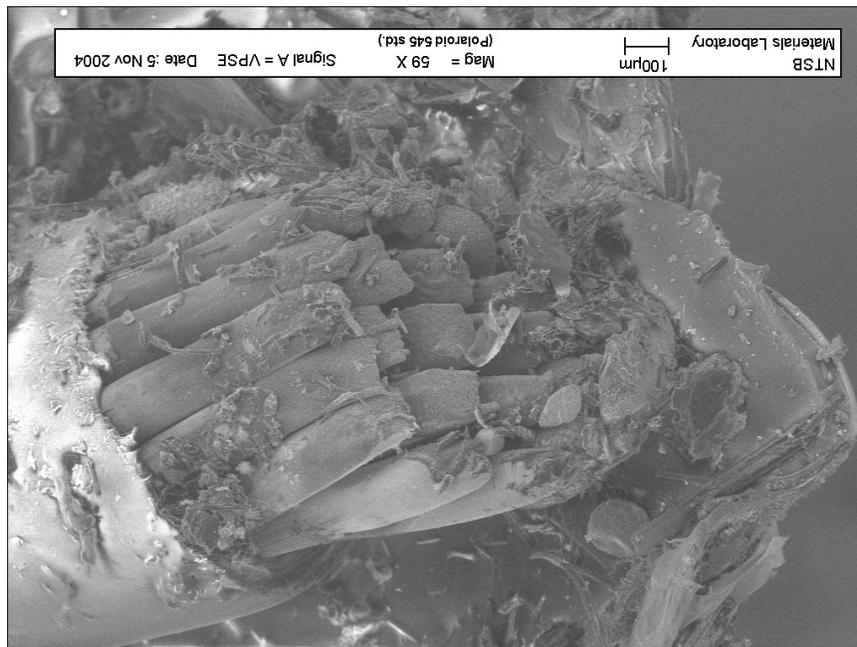


Image No.:0411A00678, Project No.: 2004110004

Figure 30. SEM view of power cable strand 5 at Area 3.



Image No.:0411A00742, Project No.: 2004110004

Figure 31. Close view of power cable strand 6 in Area 3.

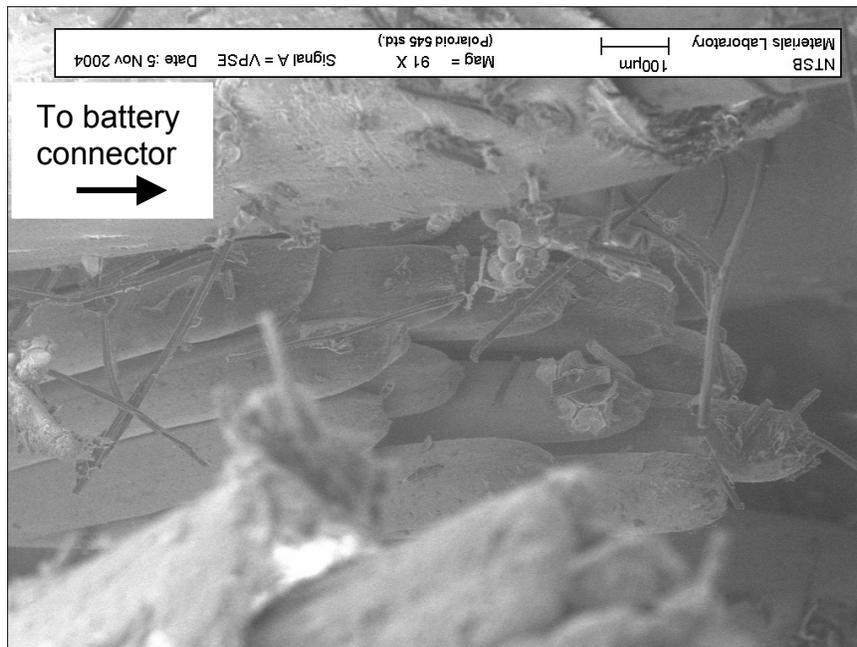


Image No.:0411A00679, Project No.: 2004110004

Figure 32. SEM view of power cable strand 6 at Area 3.

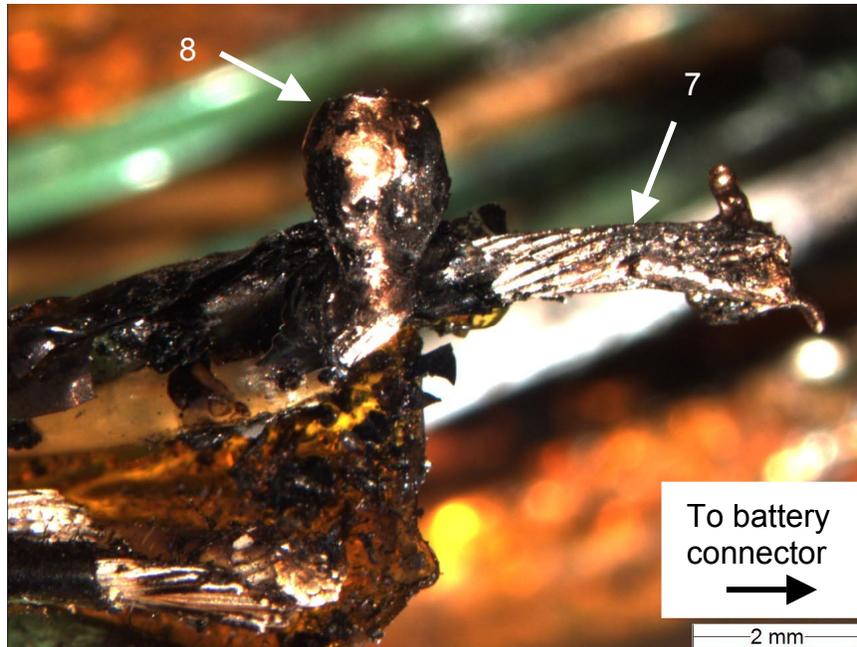


Image No.:0411A00739, Project No.: 2004110004

Figure 33. Close view of power cable strands 7 and 8 in Area 3.

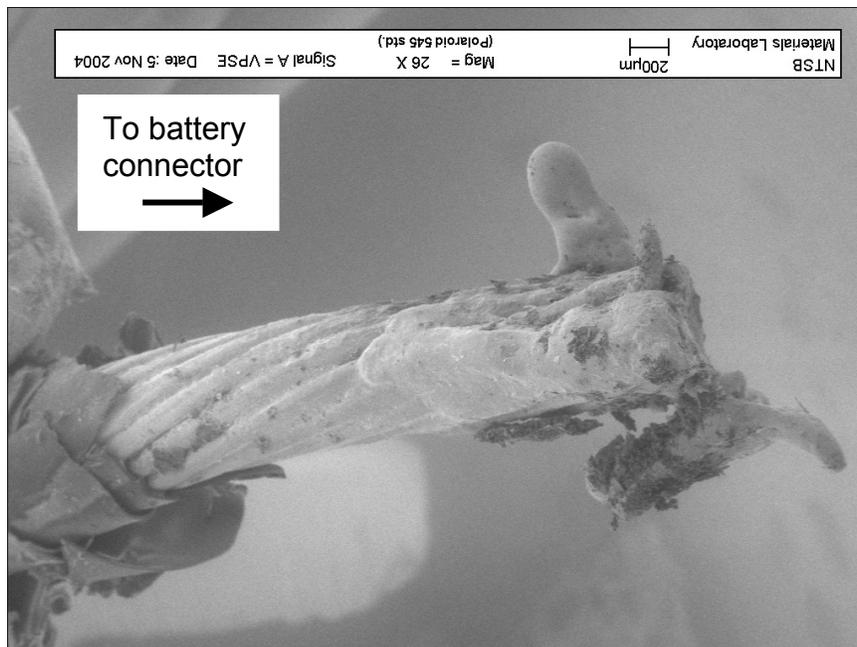


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Figure 34. SEM view of power cable strand 7 at Area 3.

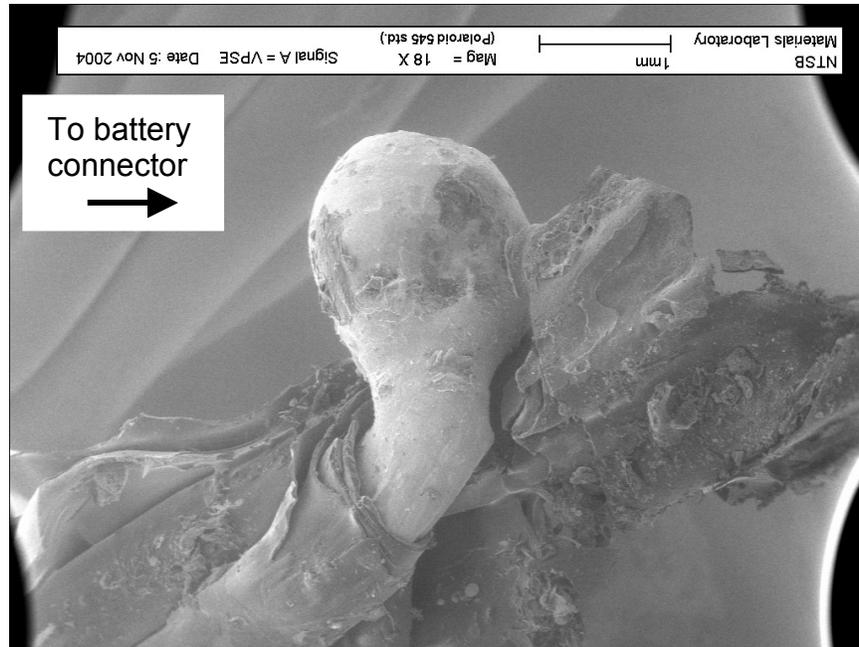


Image No.:0411A00681, Project No.: 2004110004

Figure 35. SEM view of power cable strand 8 at Area 3.

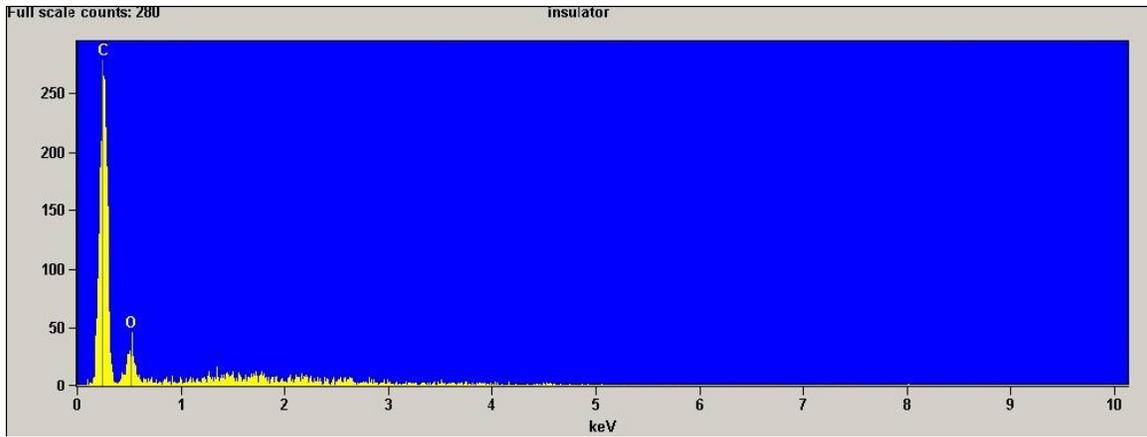


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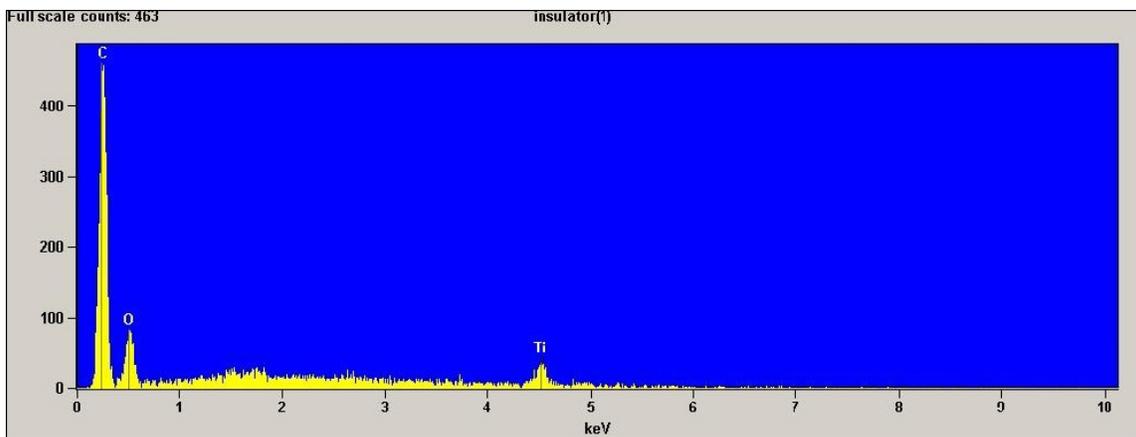


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Figure 36. EDS spectra for the yellow and green power cable strand insulators.

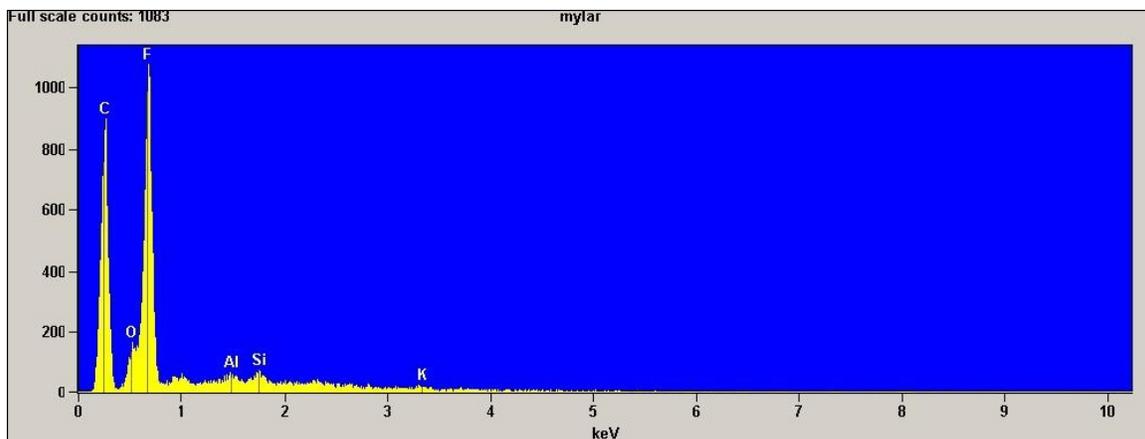


Image No.:0411A00699, Project No.: 2004110004

Figure 37. EDS spectrum for undamaged shrink tubing.

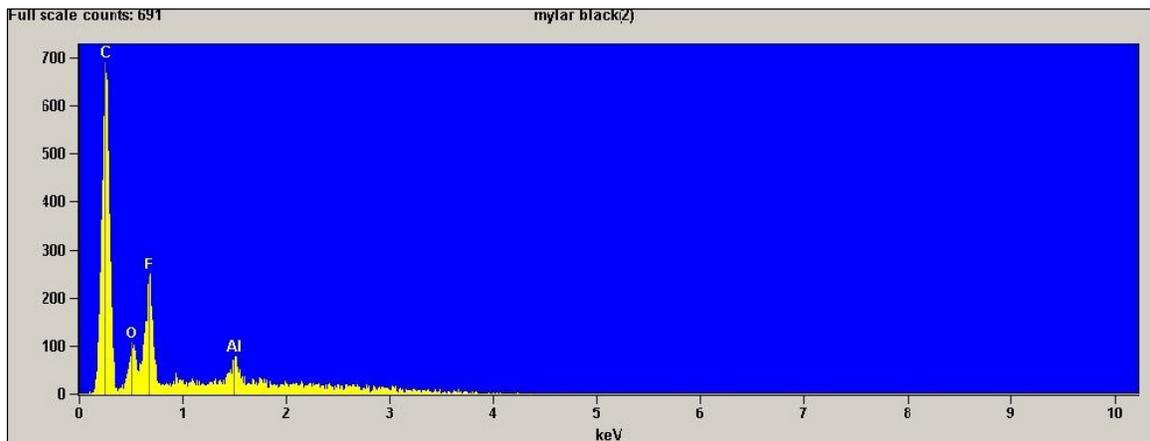


Image No.:0411A00698, Project No.: 2004110004

Figure 38. EDS spectrum for a blackened area of shrink tubing.



Image No.:0411A00319, Project No.: 2004110004

Figure 39. Close view of deposits on the bolt catcher.

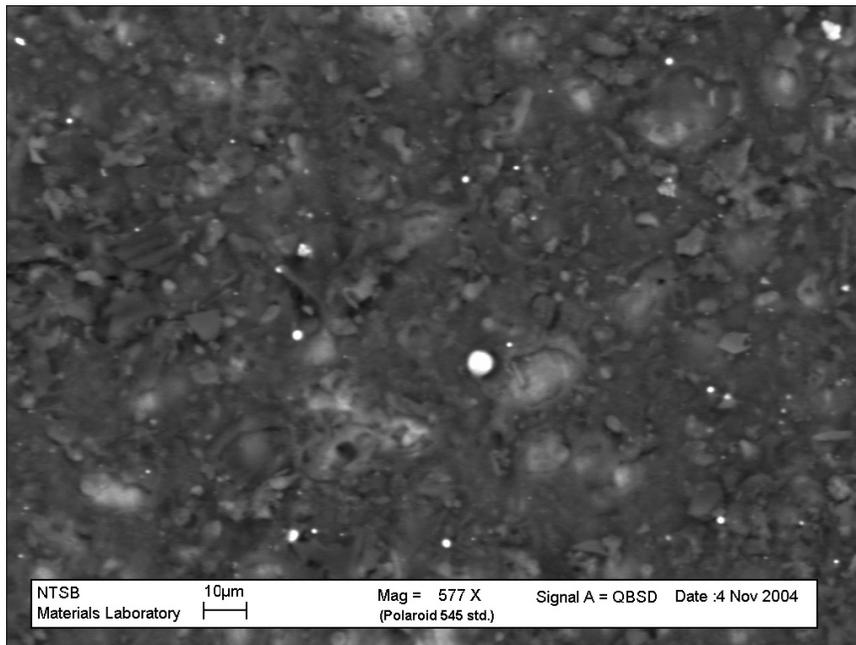


Image No.:0411A00648, Project No.: 2004110004

Figure 40. SEM view of deposits on the bolt catcher as viewed using backscattered electrons.

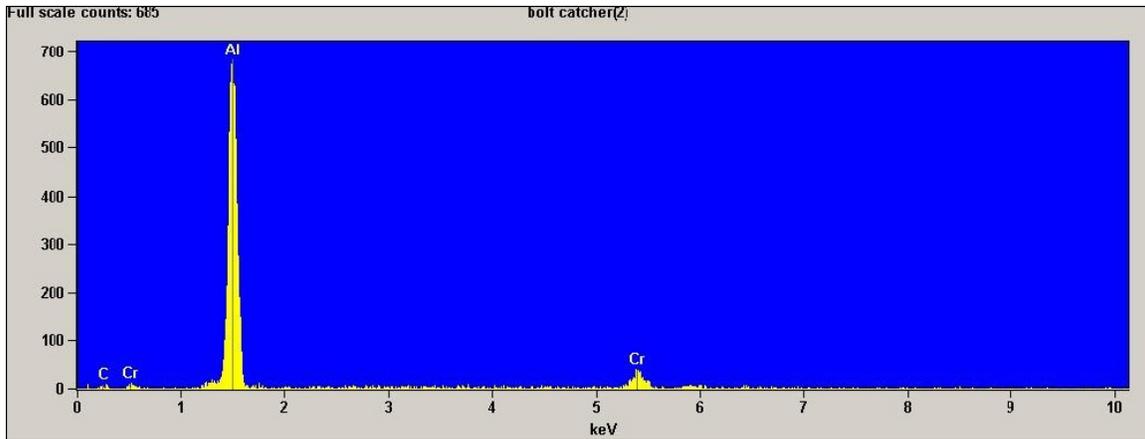


Image No.:0411A00685, Project No.: 2004110004

Figure 41. EDS spectrum of the bolt catcher.

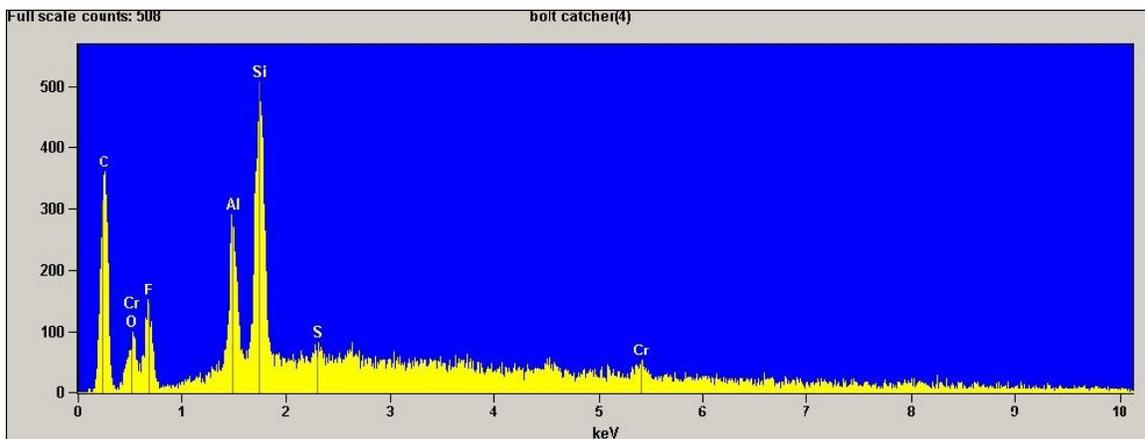


Image No.:0411A00686, Project No.: 2004110004

Figure 42. EDS spectrum of black deposits on the bolt catcher.

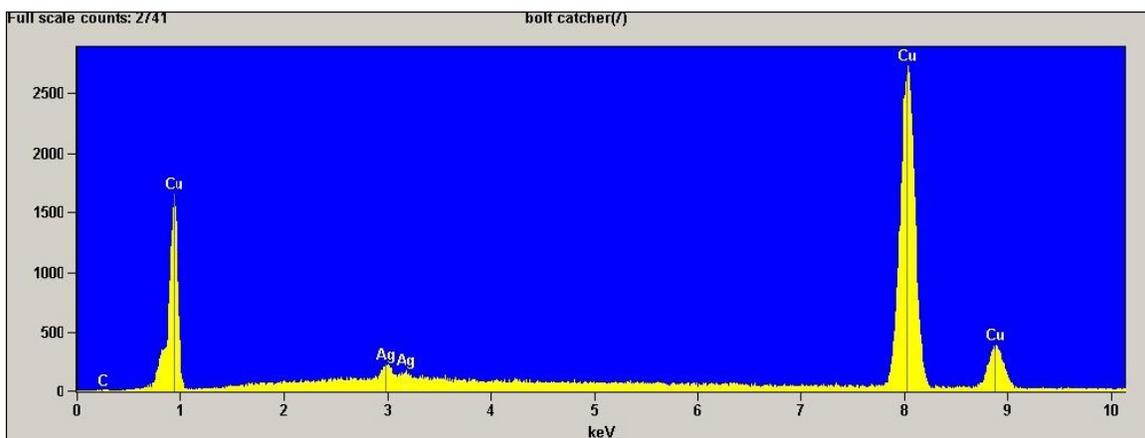


Image No.:0411A00687, Project No.: 2004110004

Figure 43. EDS spectrum of deposits appearing round and white using SEM with backscattered electrons.