

NATIONAL TRANSPORTATION SAFETY BOARD

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



January 21, 2022

MATERIALS LABORATORY FACTUAL REPORT

Report No. 21-099

1. ACCIDENT INFORMATION

Place : Rensselaer, Indiana
Date : March 11, 2020
Vehicle : Piper PA-32R-301T, N599ST
NTSB No. : CEN20LA118
Investigator : Craig Hatch, AS-CEN

2. COMPONENTS EXAMINED

Section of control cable

3. DETAILS OF THE EXAMINATION

On March 11, 2020, about 0635 central daylight time, a Piper PA-32R airplane was substantially damaged when it was involved in an accident near Jasper County Airport in Rensselaer, IN. The pilot was seriously injured. The airplane wreckage was located in a field about one mile east of the airport. The wreckage was retained for further examination, and remnants of an aft fuselage down stabilator control cable were sent to the NTSB Materials Laboratory.

Figure 1 shows the three remnants of the control cable, as received by the Materials Laboratory. The assembly number for the cable was 62701-208, with part number 653-908 (PS60043-9). This cable exhibited a 7x19 lay of galvanized steel wires with a 1/8 inch diameter. The cable consisted of three remnants, including a fractured turnbuckle in the center. The longest remnant (shown on the left in Figure 1) measured 15 inches total, with the turnbuckle being 3.50 inches long, and the cable measuring 11.5 inches from the turnbuckle to fracture surface.

The right section of cable measured 4.25 inches long. The middle section of the cable assembly, including the opposite fractured turnbuckle remnant, measured 8.38 inches long, of which 3.5 inches was the turnbuckle remnant. The distance from the turnbuckle face to the cable fracture surface on this segment was 4.78 inches.

The cable itself exhibited two fracture surfaces, shown overall in Figure 1, but also highlighted in Figure 2 and Figure 3, respectively. The rightmost section of cable exhibited indications of having been sectioned after the accident. While the fracture surfaces in

Figure 2 exhibited some indications of localized deformation and fraying near the fracture, the other fracture in Figure 3 had tapered to a relatively flat end. This fracture was oriented nearly perpendicular to the wire direction. The areas around the fracture surfaces, and in fact much of the cable surfaces, exhibited dark brown and grayish colored surface compounds, along with dark, reflective compounds on and between the wire strands.

Figure 4 shows a closer view of the cable fracture surface in Figure 3. While most of the outer surface of the cable exhibited the darker colored compounds, many of the fractured wire strands exhibited reflective surfaces. These surfaces were flat and oriented perpendicular to the wire strand direction.

This wire fracture surface was lightly cleaned with acetone in an ultrasonic bath, and then examined using a scanning electron microscope (SEM). Figure 5 and Figure 6 show an overall view of the fractured wire strands, with the second figure showing a backscattered micrograph, illustrating the absence of non-conductive compounds on the strand fractures.¹ While some of the fractures were oblong or semicircular, for the most part, the strand fractures exhibited a circular shape, consistent with a perpendicular fracture orientation.

A typical wire strand fracture is shown in Figure 7, exhibiting a faceted surface appearance. This faceted or blocky fracture surface appearance is highlighted in Figure 9, showing flat features consistent with the metal alloy grain boundaries, along with some tearing and localized cleavage facets (Figure 10). These features were consistent with intergranular fracture of the wire strand. Examination of the other exposed fractured strands in Figure 6 found intergranular fracture as well.

Figure 11 shows the fracture surface of the cable fracture, towards the right in Figure 1. As shown in Figure 13, this fracture exhibited more surface compounds that were nonconductive when examined using a SEM (i.e., nonmetallic). The compounds manifest as thick, layered material present on the outer surfaces and fracture surfaces of the fractured wires.

Even after cleaning, the fracture wire strands exhibited a mottled, rounded appearance, consistent with the extensive surface compounds present. However, one wire strand with less surface oxidation is shown in Figure 13, exhibiting an angled appearance. As shown from a closer view in Figure 14, the fracture surface exhibited slanted dimpled rupture, consistent with overstress fracture in a shear direction.

The turnbuckle on the left of Figure 1 also exhibited a fracture surface, as illustrated in Figure 16. The turnbuckle had fractured at the location of a perpendicular hole consistent with a safety wire cavity. The turnbuckle part number was 489-910, where MS21251-2004 was stamped on the turnbuckle surface. While the external surfaces,

¹ Backscattered electrons: SEM micrographs produced using backscattered electrons display contrast that is associated with the atomic numbers of the elements in the micrograph. Materials containing elements with higher atomic numbers visually appear lighter relative to other materials containing elements with lower atomic numbers.

including the safety wire holes, exhibited a dull appearance consistent with surface contamination, the fracture surface itself was blocky and reflective, similar to the fractured wire strands in Figure 4. A closer view of the turnbuckle fracture surface found it also exhibited a faceted surface.

The turnbuckle fracture was examined using a SEM, and a typical area of the fracture surface is shown in Figure 18. As illustrated in Figure 19, the faceted appearance was consistent with surfaces of individual metallic grains, consistent with an intergranular fracture mechanism. However, in contrast with the sharp edges and local grain boundary tears seen in the wire strands, the intergranular fracture of the turnbuckle was more rounded and smoothed. There were also indications of different material present in the boundaries and triple points between grains, as illustrated in Figure 20.

The fracture surface of the turnbuckle was cross sectioned, mounted, and polished. Figure 21 shows one half of the cross sectioned fracture surface, demonstrating the faceted nature of the fracture surface, as well as the internal thread roots. Parallel to the fracture surface were a series of incomplete intergranular cracks. While these cracks were present around grains, they also exhibited a more rounded appearance, as shown in Figure 22. As seen by the light gray material outlining the internal cracking, there was a thin layer of nonmetallic material along the intergranular separation (Figure 23).

Figure 24 shows the opposite fracture surface of the turnbuckle, which had also been cross sectioned. This fracture surface shows an individual grain that, while mostly separated, was still attached by a small, unbroken filament (see Figure 25). These features were consistent with the intergranular fracture observed on previous examination of the fracture surface. The cross section in Figure 25 also shows section through dimpled rupture filaments near the area of the grain still attached to the main material of the turnbuckle.

Figure 26 shows an area of intergranular voids. Unlike the intergranular fracture features along the fracture surface (see Figure 24 and Figure 25), these features were more rounded rather than flat and faceted. These voids were located near the thread roots in Figure 26, but also were observed throughout the cross section of the turnbuckle. These features were consistent with voids present between individual grains of the part microstructure.

Figure 27 and Figure 28 show closer cross sections where the threads of the brass turnbuckle had engaged with those of the internal steel fitting. As seen in the figures, some of the brass material was present along the surfaces of the steel threads. This material transfer is most notable on the flank of the steel thread shown in Figure 28, exhibiting the golden-colored brass material on the gray colored steel. These features were consistent with material transfer of the softer brass material on the harder steel threads.

There were also indications of darker colored, nonmetallic material present along the thread root of the brass turnbuckle shown in Figure 28. Figure 29 shows a backscattered micrograph of the surface contamination at the thread root, consistent with

nonmetallic material. Examination using energy dispersive x-ray spectroscopy (EDS) found the material to be consistent with a zinc oxide, with minor amounts of copper, calcium, and chlorine. The chemical composition of the main body of the turnbuckle was also examined using EDS. The turnbuckle composition was consistent with a yellow brass, containing trace amounts of lead. The composition of the threaded fitting was consistent with an austenitic stainless steel.

Figure 30 shows the dissimilar material at an intact filament along the intergranular fracture from Figure 25. Examination by EDS found the brightest areas to exhibit high lead levels, whereas the darker areas were consistent with oxides as exemplified by the higher oxygen content. These tended to exhibit higher zinc levels than the alloying amount, consistent with zinc oxides. There were also high levels of copper in some of the regions of the oxide examined. These chemical compositions were consistent with the more widespread oxide observed near the fracture surface, as shown in Figure 31. Here the zinc and copper oxides were present along the intergranular regions, along with elevated levels of salt species such as sodium, chlorine, and magnesium.

The hardness of the cross sectioned turnbuckle was evaluated with an automated microindentation hardness tester, per ASTM E384.² The hardness averaged 61 HK₅₀₀, which is softer than the Rockwell B scale.³ The hardness of the internal stainless steel fitting averaged 93 HRB (199 HK₅₀₀). This later hardness was consistent with being in an annealed state.

These observations were consistent with the cable and turnbuckles having fractured from intergranular fracture. A few of the wires in the cable fracture exhibited dimpled rupture, consistent with fracture from overstress.

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² ASTM E384 – *Standard Test Method for Knoop and Vickers Hardness of Materials*. ASTM International, West Conshohocken, PA

³ HRB – Hardness, Rockwell B scale. An indentation method of determining the hardness of softer metals using a 1/16-inch diameter ball indenter and 100 kg major load.

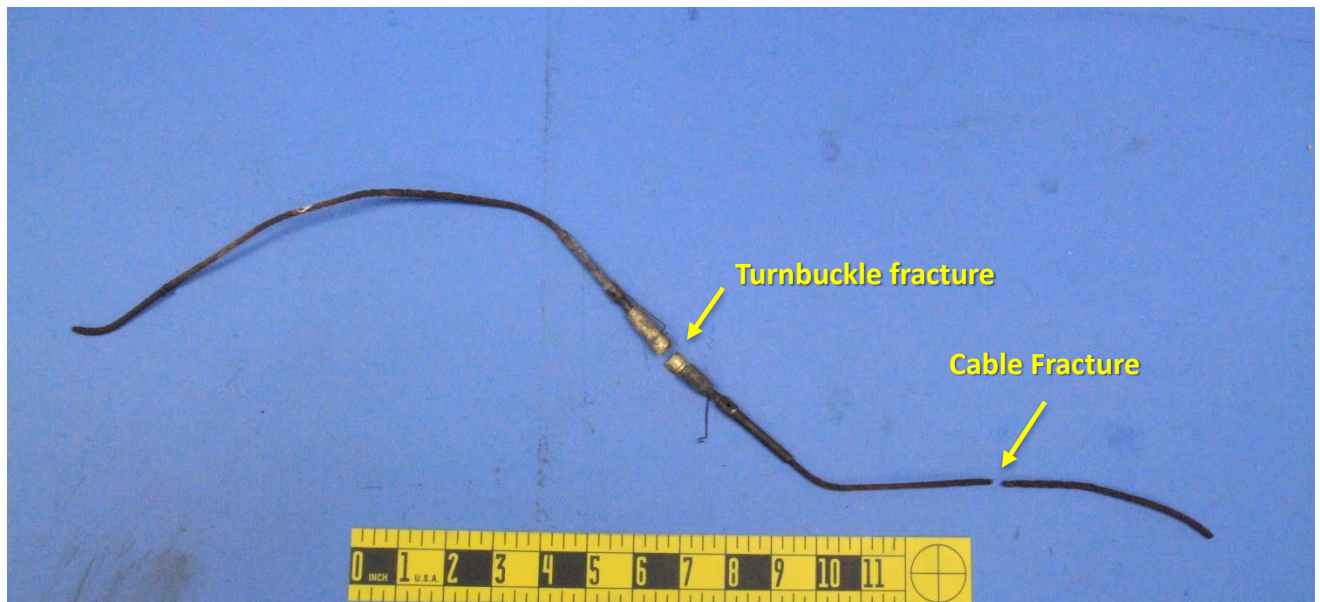


Figure 1 – View of the fractured control cable remnants, repositioned to show the location of the remnants at fracture, after cleaning and disassembly.



Figure 2 – Closer view of the cable fracture towards right in Figure 1.



Figure 3 – Closer view of the fracture towards the longer fragment side (left in Figure 1).



Figure 4 – Fracture surface of the cable from Figure 3 (long remnant).



Figure 5 – Secondary electron (SE) micrograph of a typical area of the fractured wires in Figure 4.



Figure 6 – Backscattered electron (BE) micrograph of a typical area of the fractured wires in Figure 4.



Figure 7 – SE micrograph of one of the fractured strands in Figure 5, showing intergranular fracture.

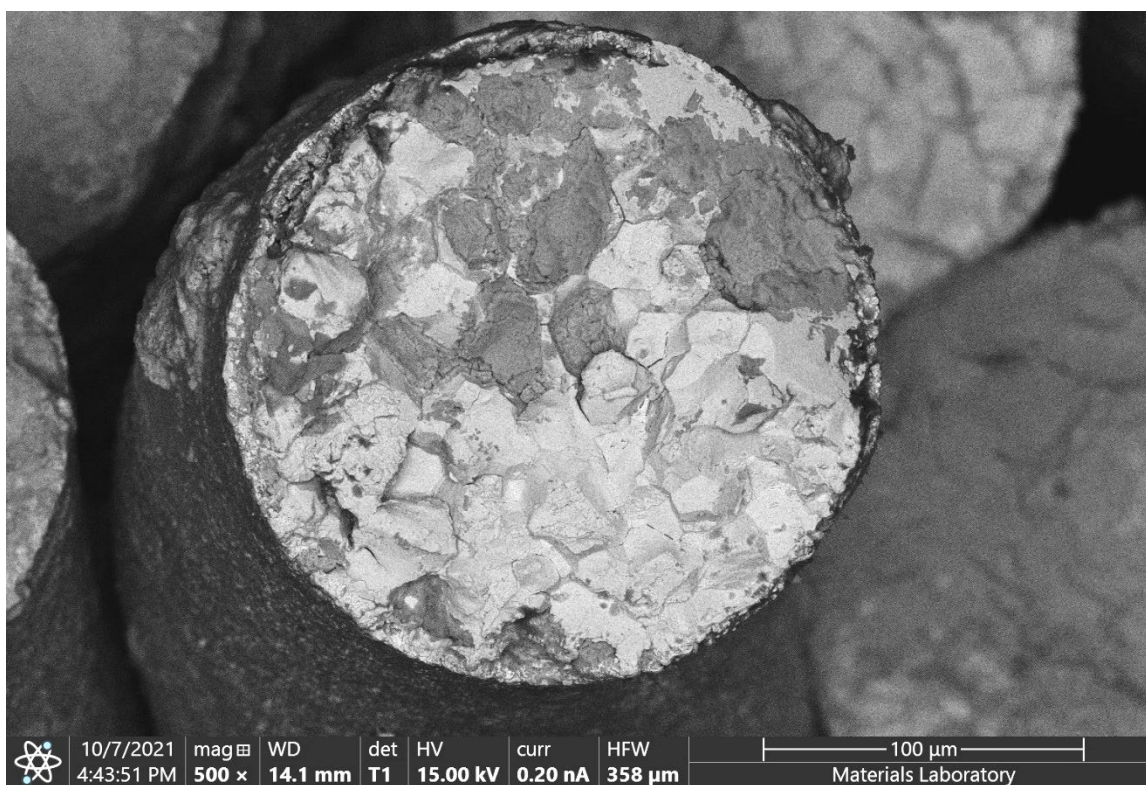


Figure 8 – SE micrograph of the fracture surface in Figure 7.

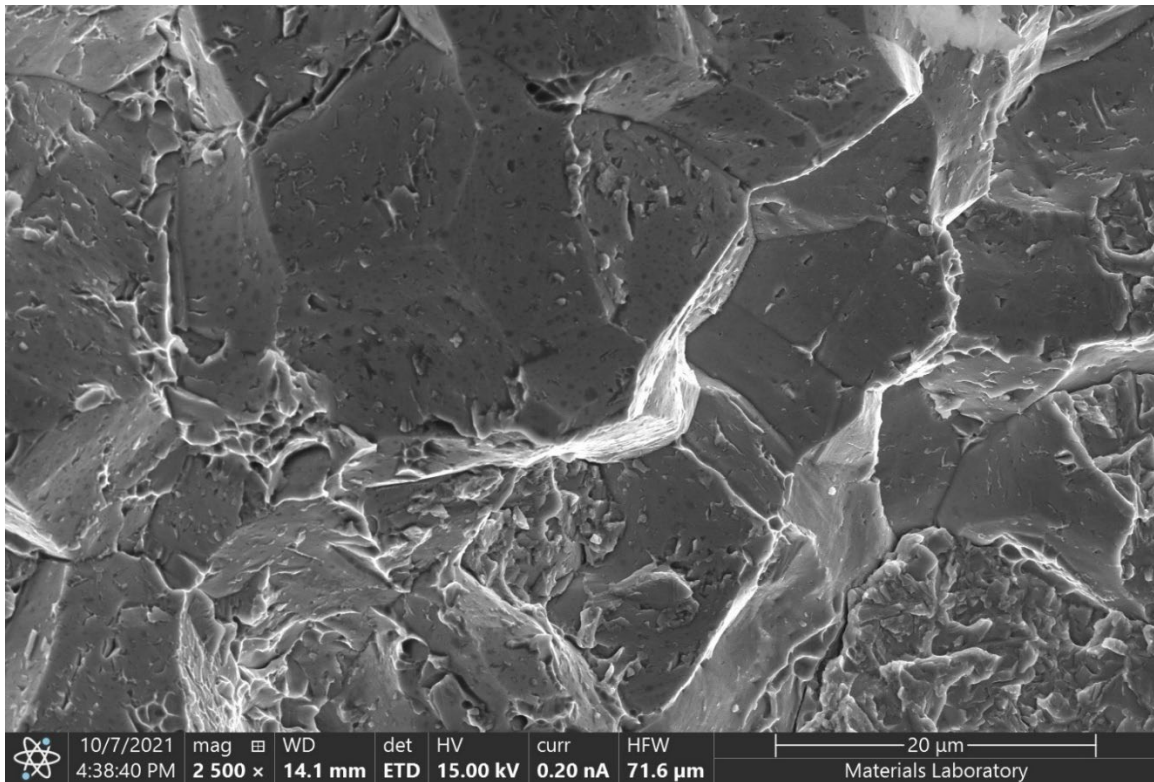


Figure 9 – SE micrograph of the intergranular facets in Figure 7.

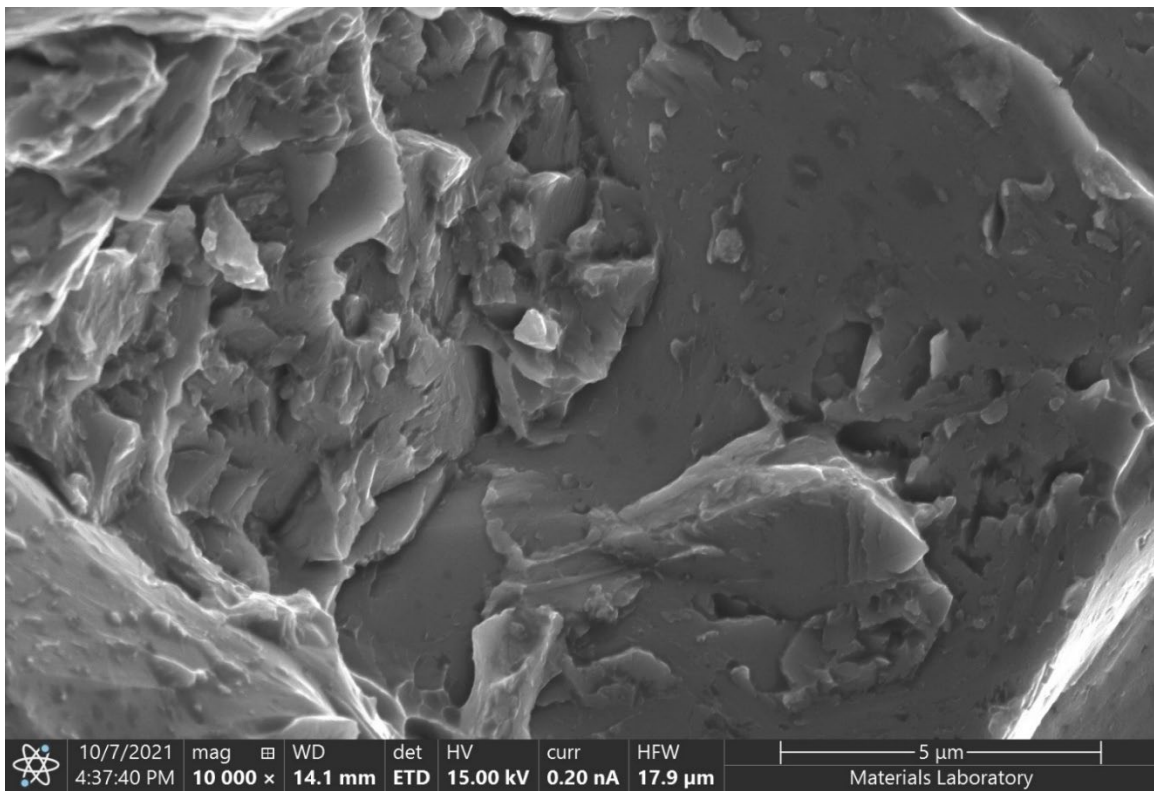


Figure 10 – SE micrograph of a smooth and rough facet (with tear ridges) from Figure 9.



Figure 11 – Fracture surface of the middle remnant facing the short segment.

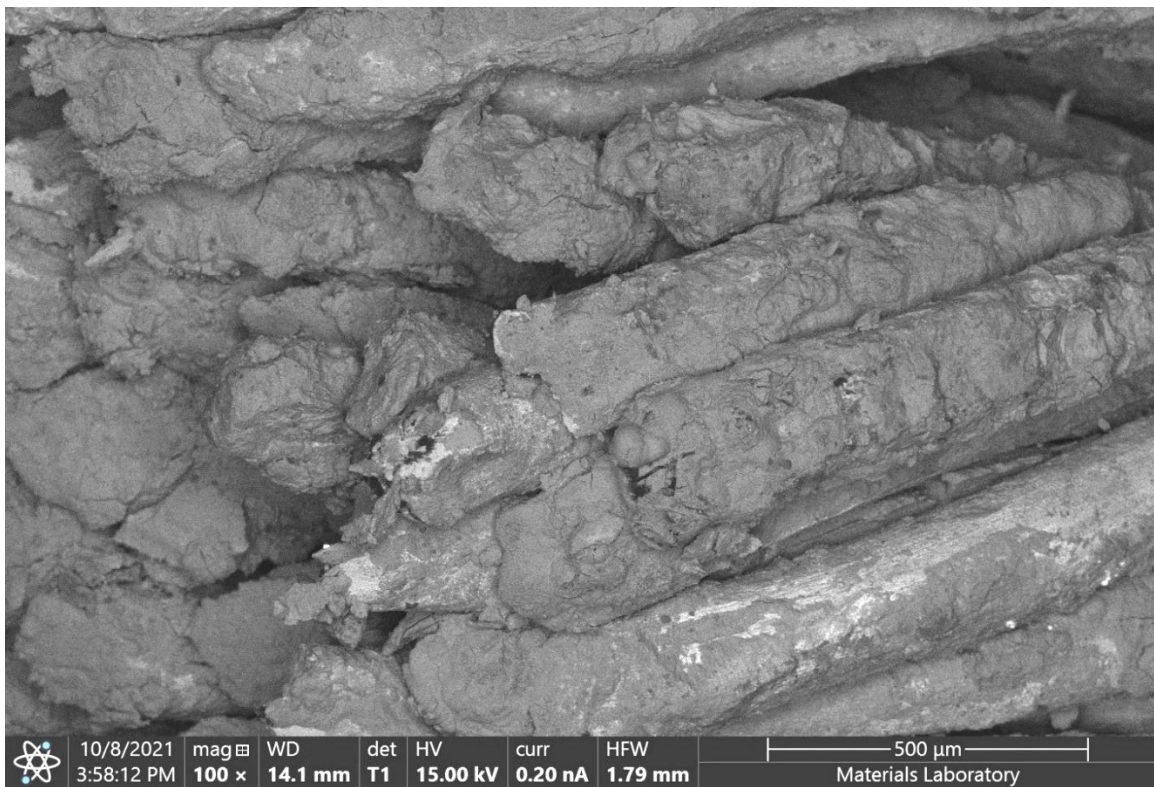


Figure 12 – BE micrograph of the fractured strands in Figure 11.

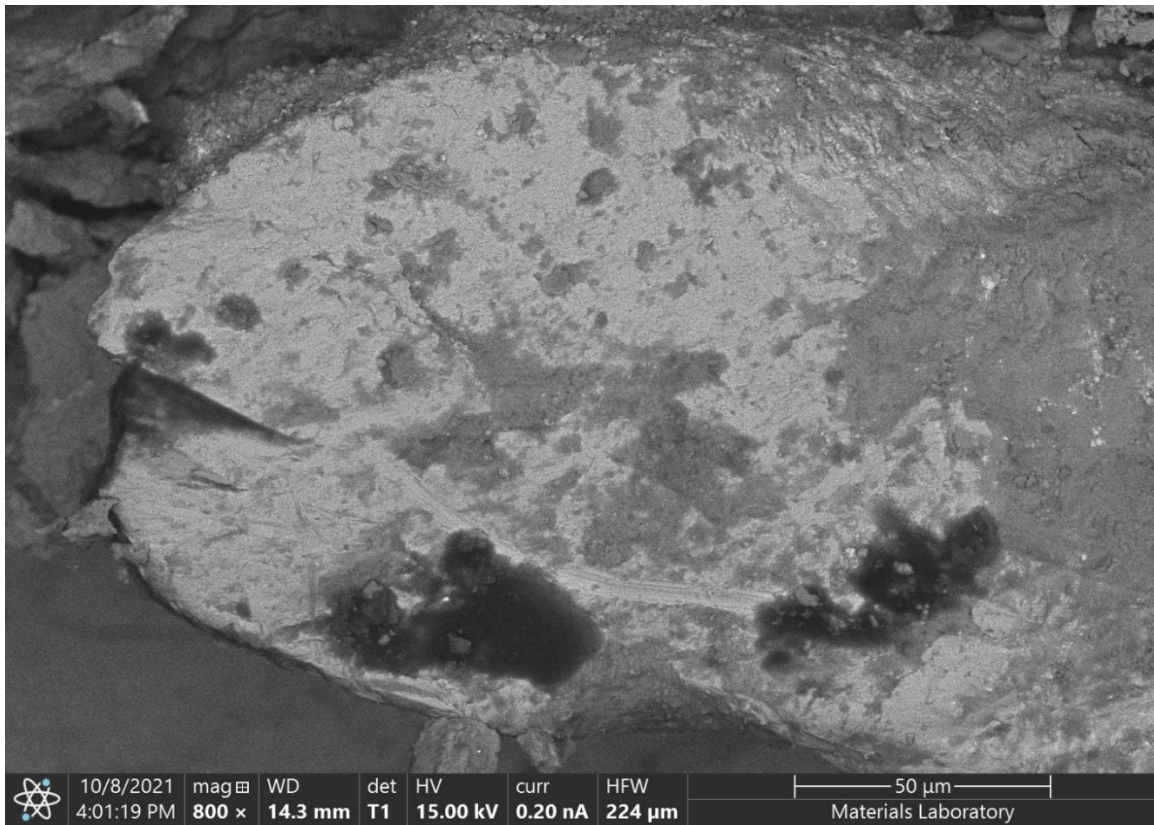


Figure 13 – BE micrograph of one of the less oxidized strands in Figure 12.

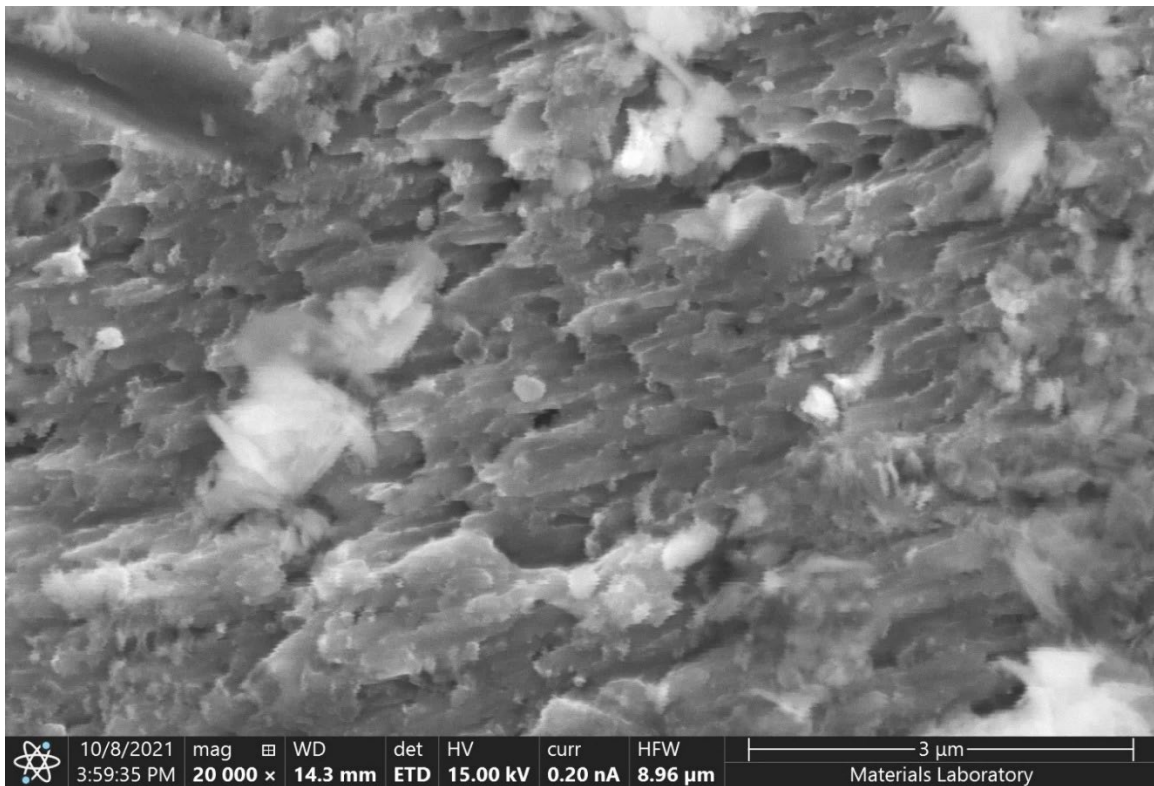


Figure 14 – SE micrograph of dimpled rupture on the fractured strand in Figure 13.



Figure 15 – View of the fractured turnbuckle (after sectioning and cleaning).



Figure 16 – View of the fracture surface of the cable turnbuckle.



Figure 17 – View of a quadrant of the turnbuckle fracture, showing a faceted surface morphology.

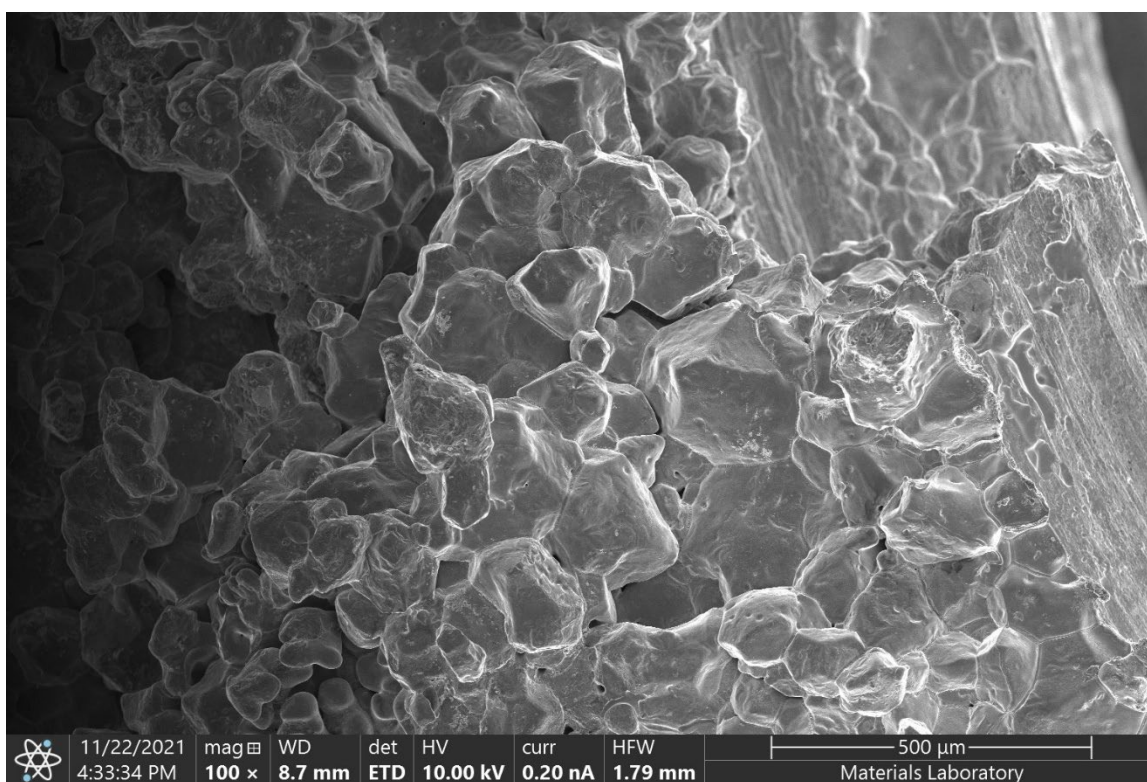


Figure 18 – SE micrograph of intergranular fracture on the surface in Figure 17.

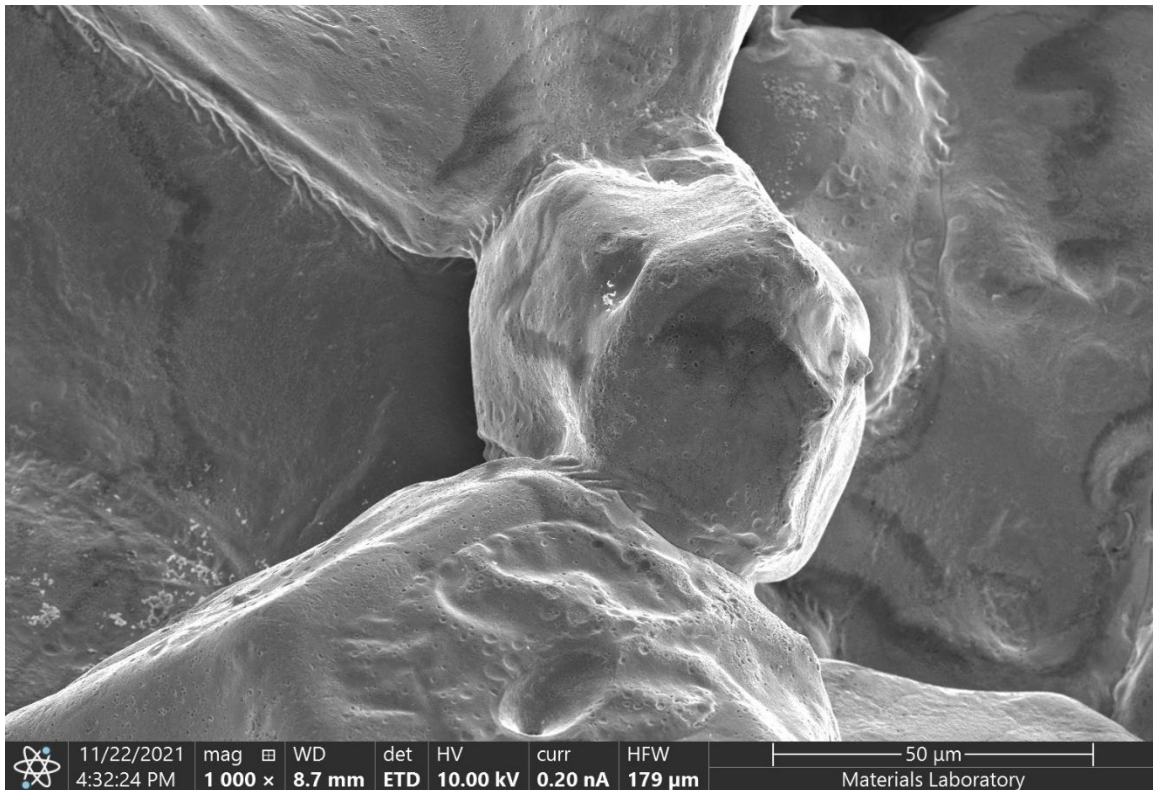


Figure 19 – SE micrograph of the rounded edges of some intergranular facets.



Figure 20 – BE micrograph of a triple point between facets, consistent with dissimilar materials.



Figure 21 – Bright-field (BF) optical micrograph of a cross section of one side of the turnbuckle fracture surface, showing subsurface intergranular cracking (~25X, as-polished).

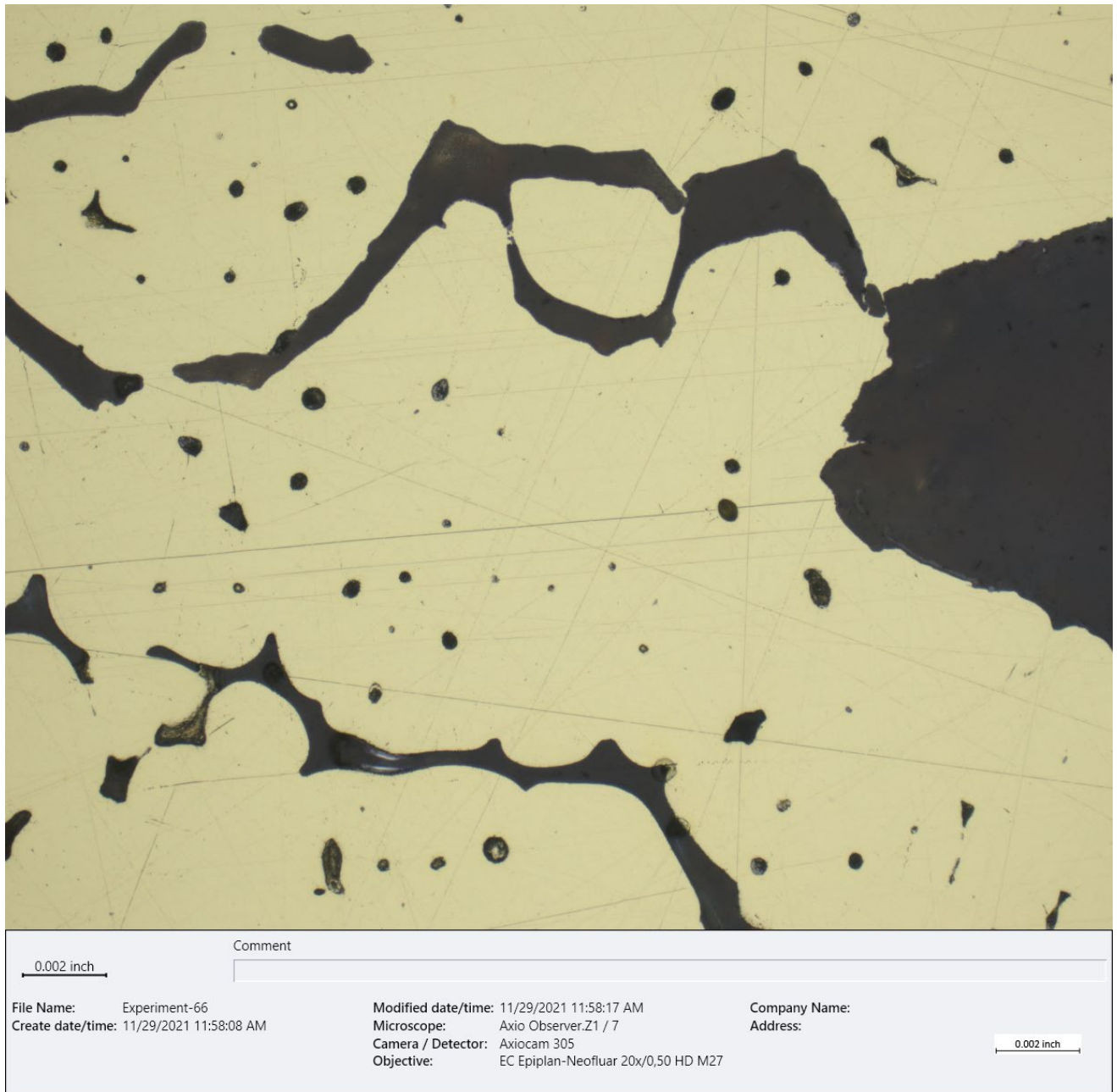


Figure 22 – BF micrograph of intergranular cracking at a thread root in Figure 21 (~200X, as-polished).

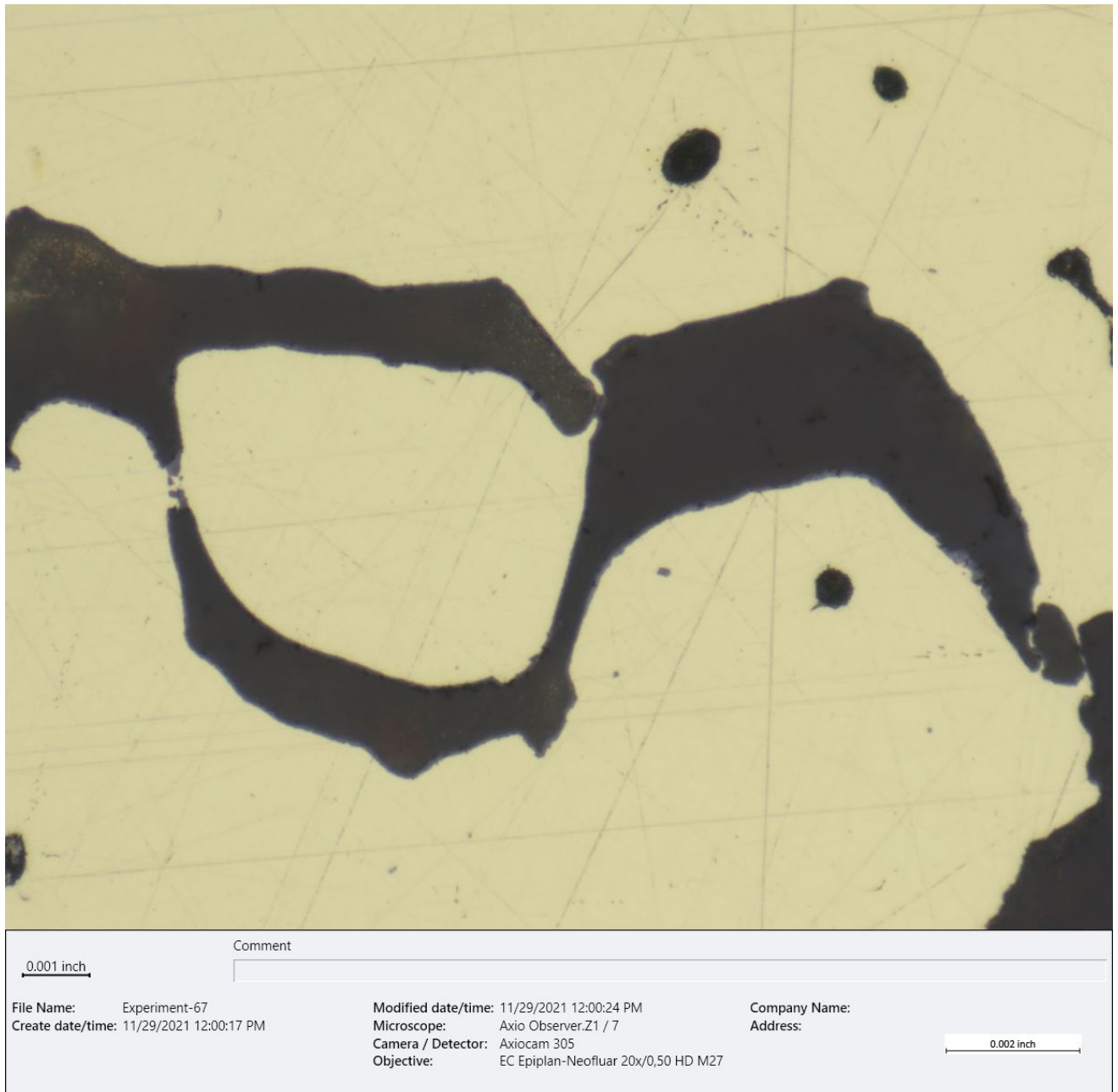


Figure 23 – BF micrograph of the intergranular crack in Figure 22, showing small ruptured dimple along the crack (~500X, as-polished).



Figure 24 – BF optical micrograph of the opposite turnbuckle fracture surface (~25X, as-polished).

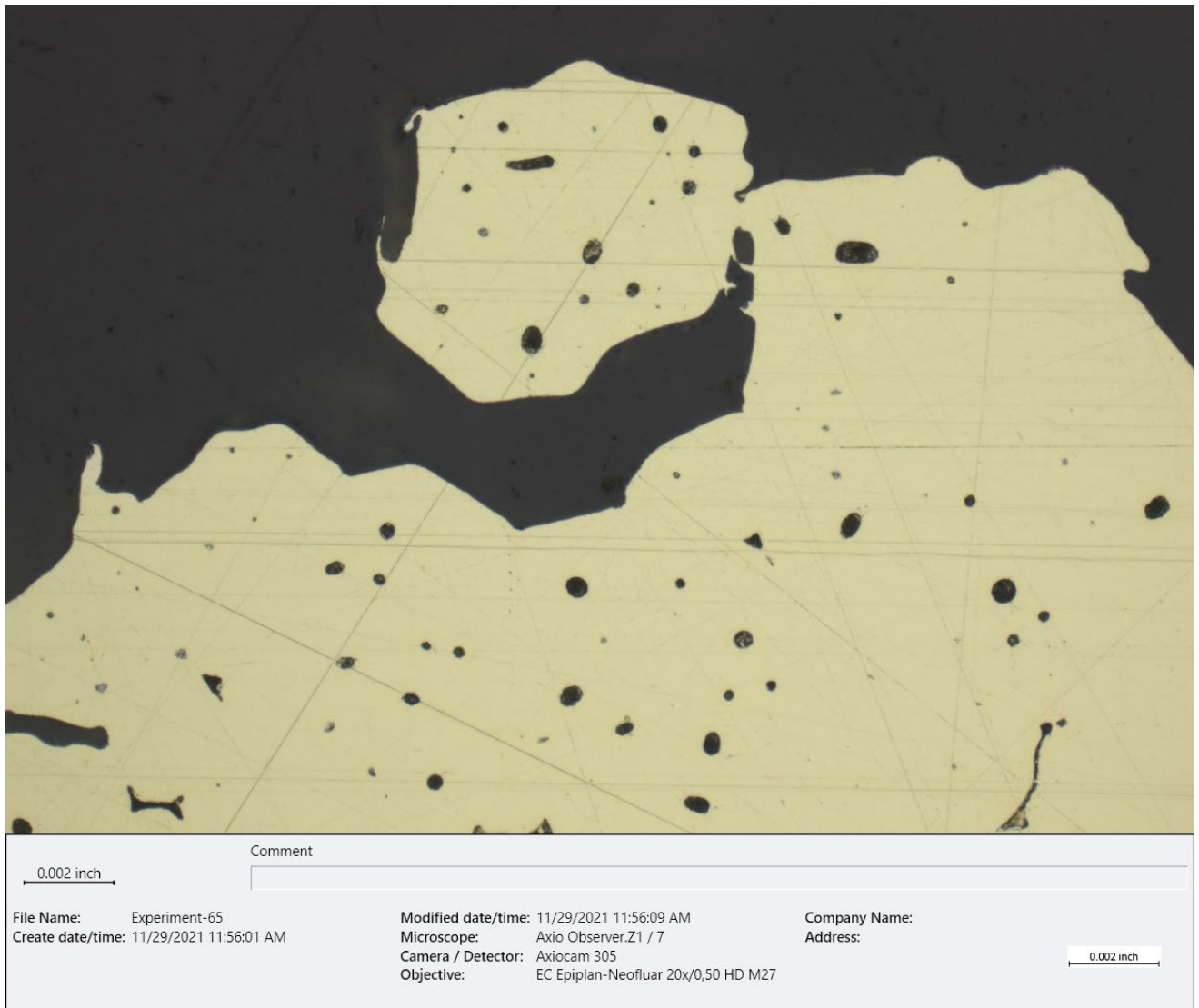


Figure 25 – BF optical micrograph of a mostly fractured grain at the turnbuckle fracture surface (~200X, as-polished).

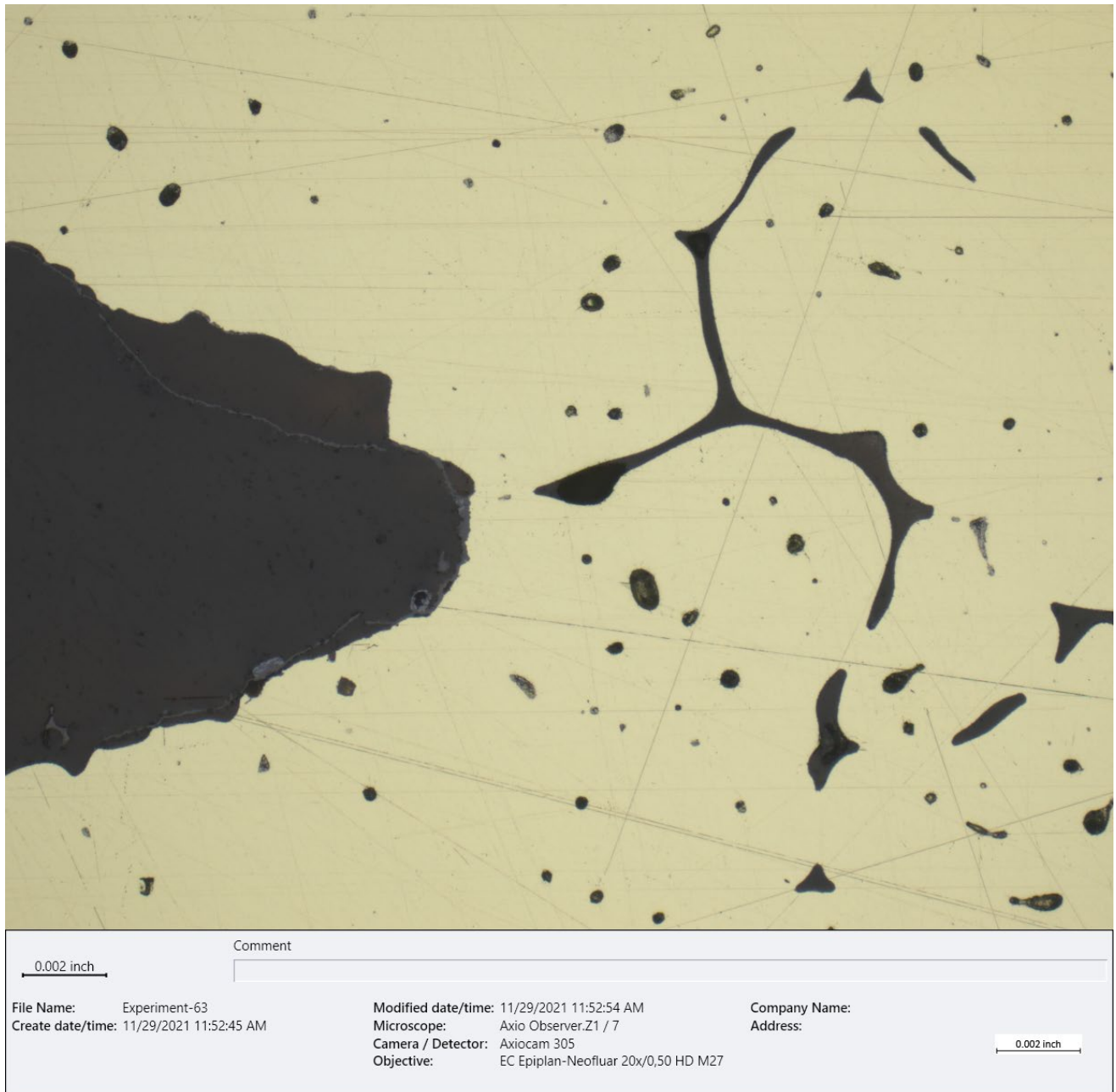


Figure 26 – BF micrograph of intergranular voids near a thread root of the cross section in Figure 24 (~500X, as-polished).

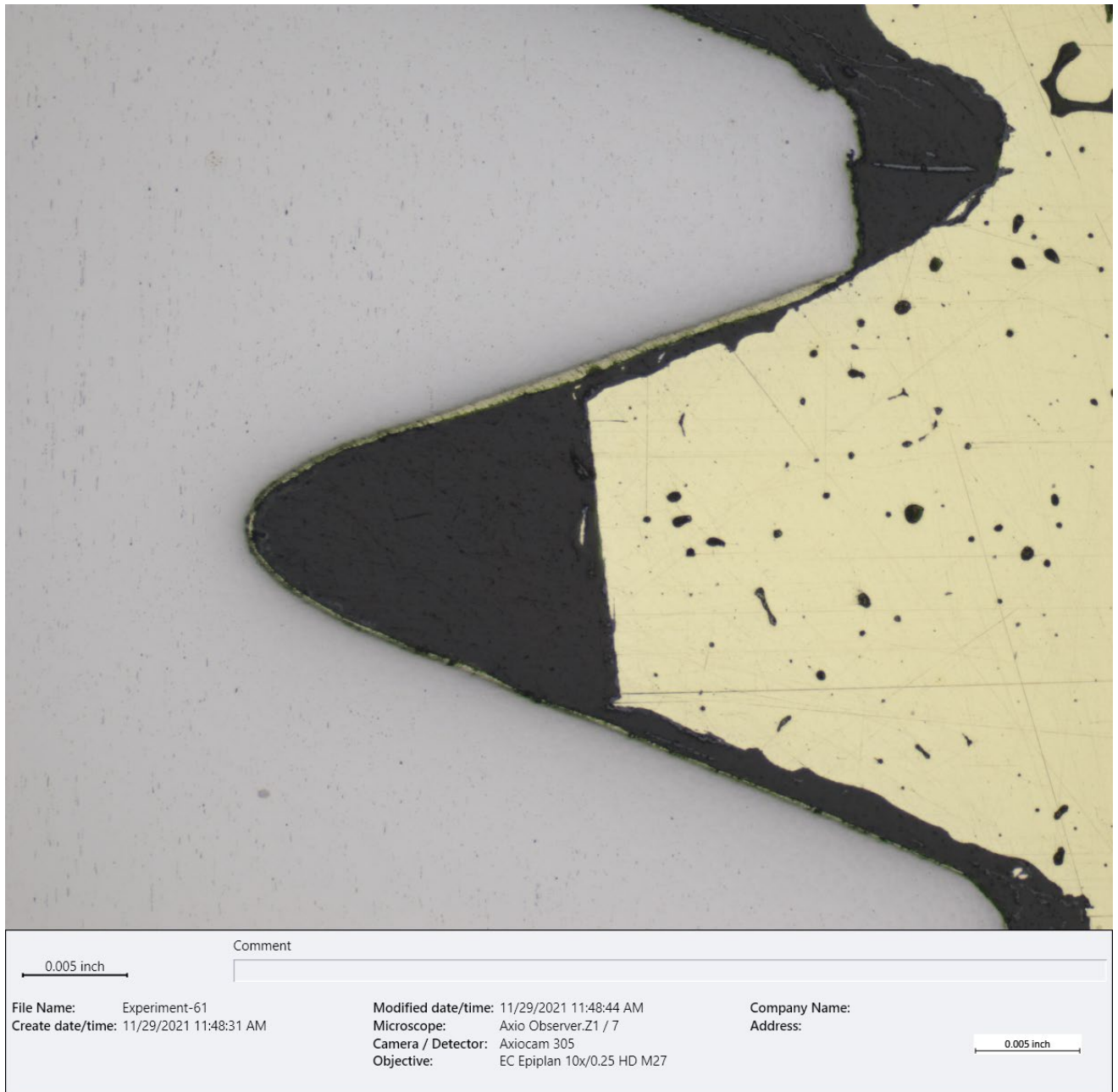


Figure 27 – BF optical micrograph of engaged threads between the turnbuckle and terminal end, showing galling of the turnbuckle brass material on the steel end threads.

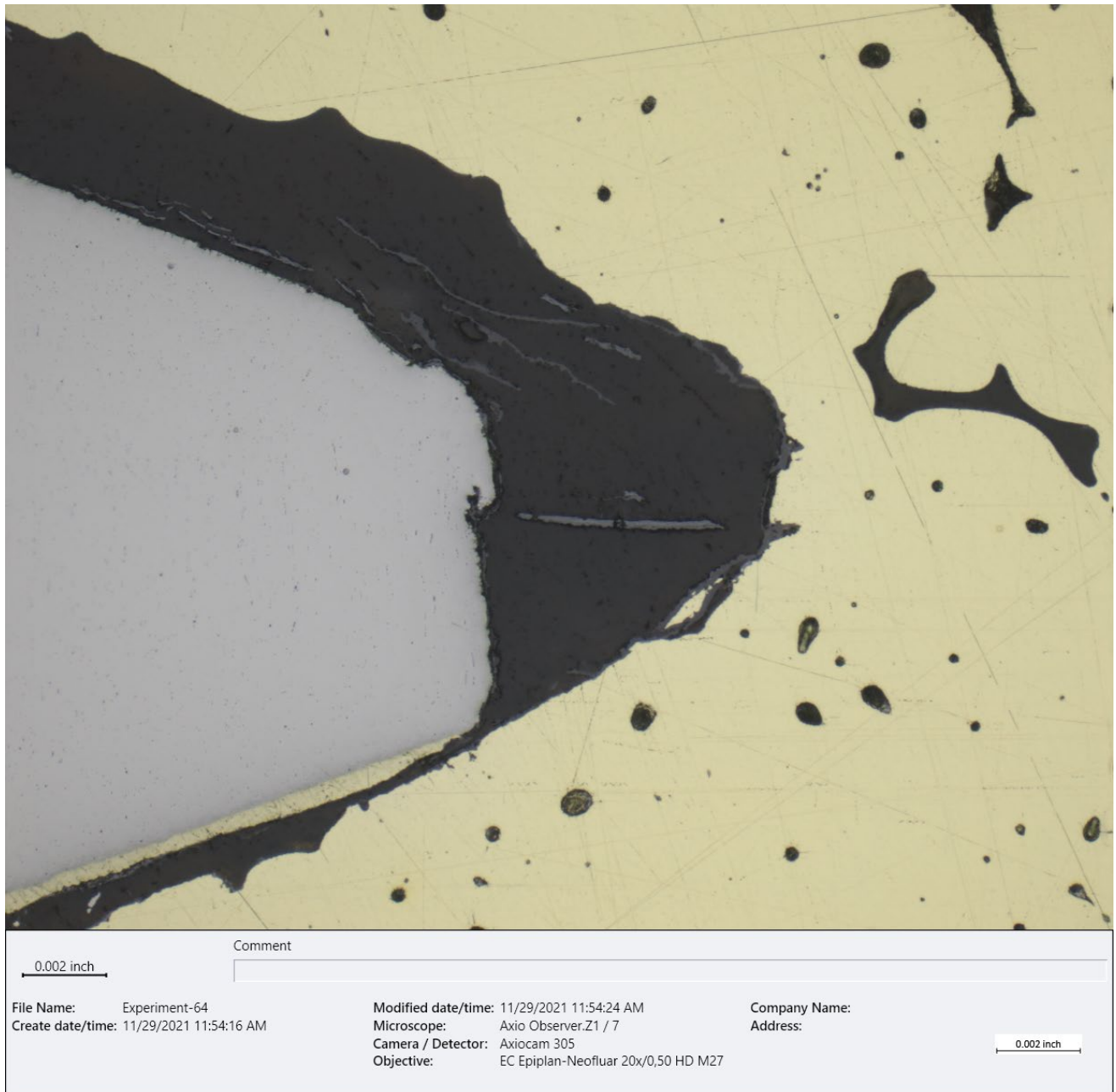


Figure 28 – BF optical micrograph of galled material on the steel end threads (~500X, as polished).

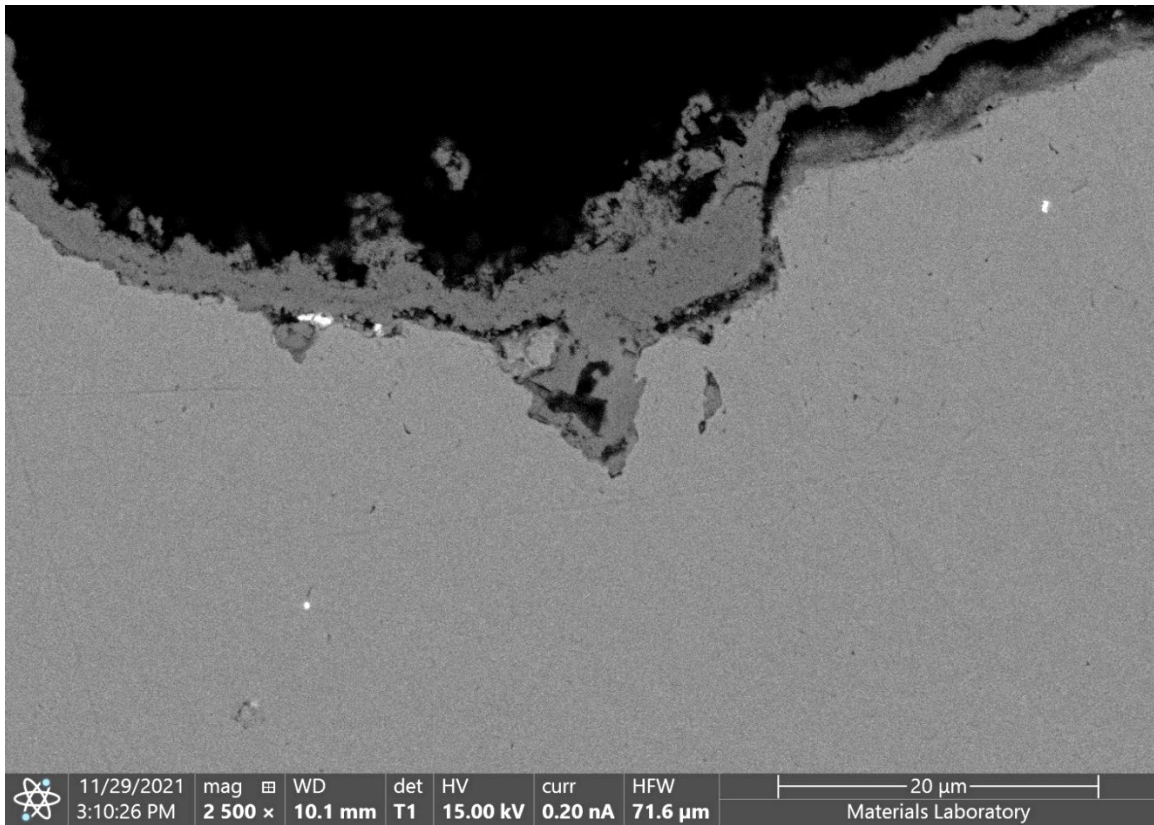


Figure 29 – BE micrograph of the cross section of a turnbuckle thread root surface.

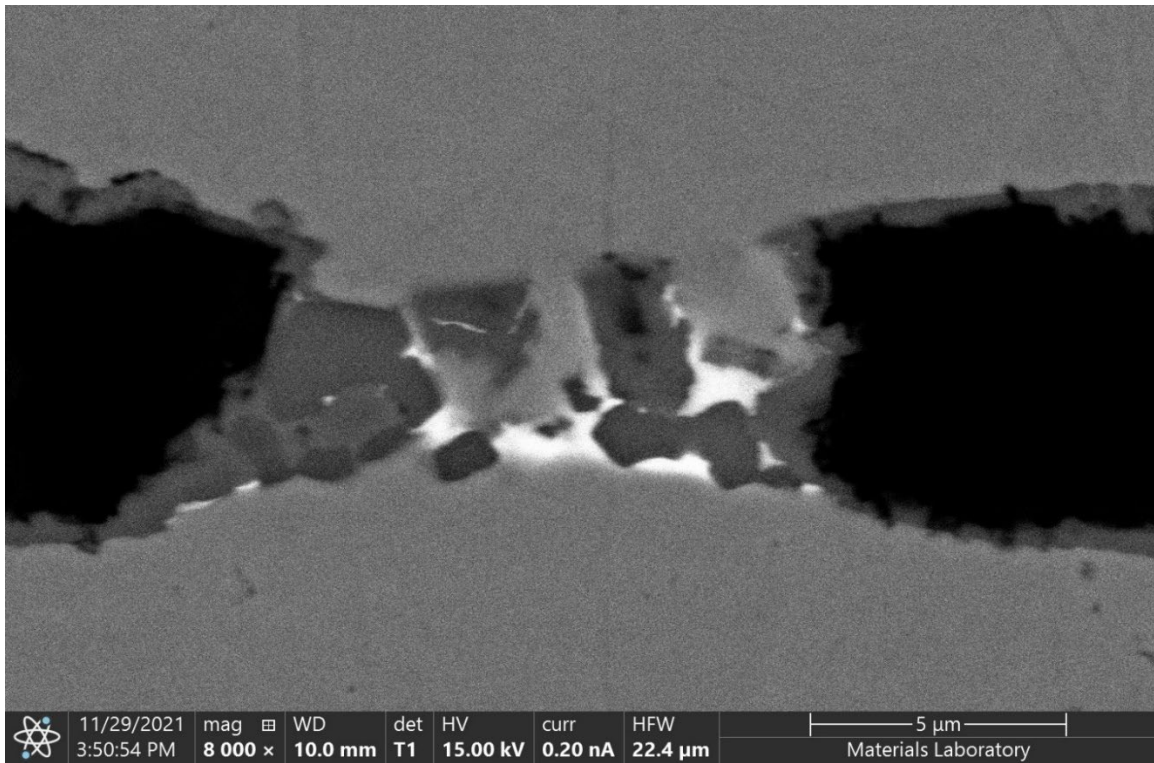


Figure 30 – BE micrograph of compounds between grains of the turnbuckle.

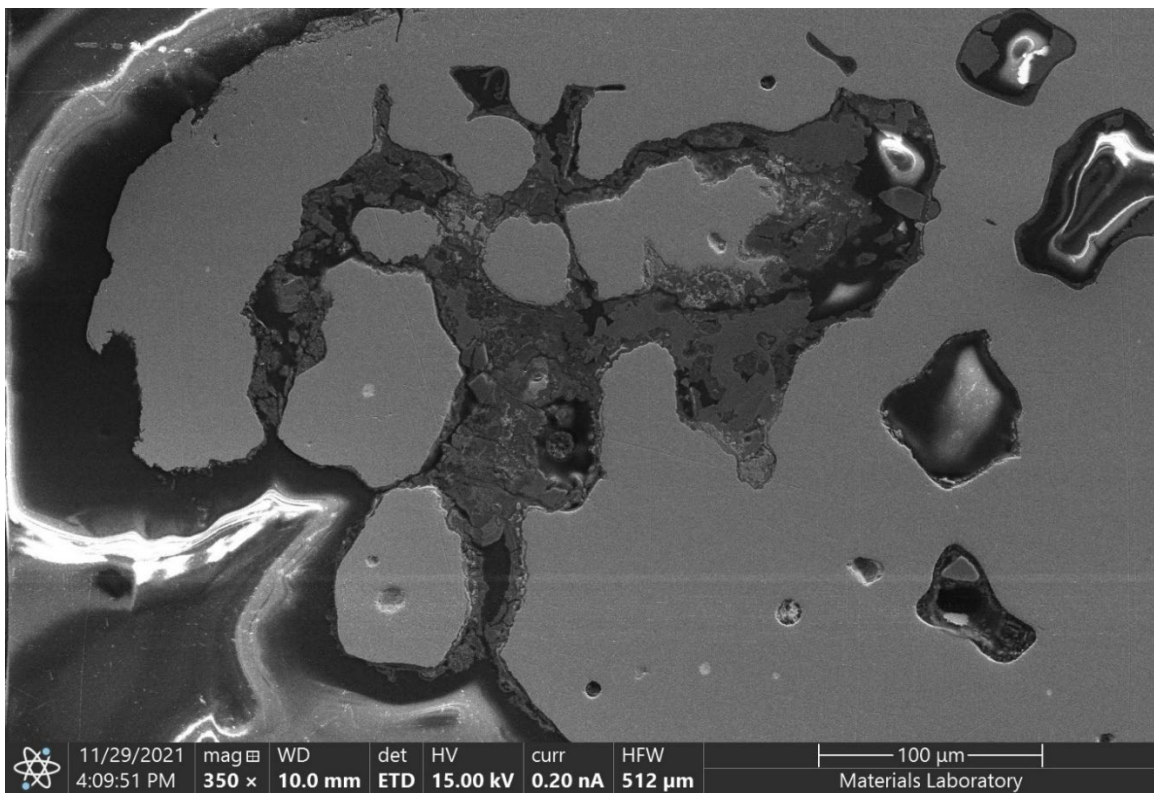


Figure 31 – BE micrograph of the fracture surface cross section, showing large globules of intergranular compounds.