

NATIONAL TRANSPORTATION SAFETY BOARD

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



July 10, 2020

MATERIALS LABORATORY FACTUAL REPORT

Report No. 20-016

1. ACCIDENT INFORMATION

Place : Heber, Utah
Date : September 25, 2018
Vehicle : Smith Aerostar 601P, N90339
NTSB No. : WPR18LA272
Investigator : Zoë Keliher, AS-WPR

2. COMPONENTS EXAMINED

Remnants of a left main landing gear assembly

3. DETAILS OF THE EXAMINATION

On September 25, 2018 about 1100 mountain daylight time, an Aerostar 601P experienced a landing gear collapse during the landing roll at the Heber City Municipal Airport, Heber, UT.¹ The commercial pilot, the sole occupant, was not injured, but the airplane sustained substantial damage to the left-wing strut. The pilot stated he touched down normally, and during the landing roll the airplane veered left and continued off the runway surface. The pilot was unable to regain control, and the right main landing gear collapsed. After egressing the airplane, the pilot observed that the right main landing gear had failed at the strut's weld. Portions of the left main landing gear assembly were sent to the NTSB Materials Laboratory for further examination.

Figure 1 shows the left main landing gear strut assembly remnants, as received. The figure shows the strut cylinder assembly and adjacent attached components from the forward and aft faces of the component. The damaged components and subcomponents of note were a sectioned hydraulic line, a damaged marking plate, and an intermediate link attachment joint that was loose and able to be moved about the cylinder. Figure 2 shows the remainder of the external marking plate on the cylinder, with the cut hydraulic line moved out of the way for illustrative purposes. All of the markings on the plate had been removed and could not be discerned, consistent with abrasive wear during the landing sequence.

¹ The Piper Aerostar (formerly Ted Smith Aerostar) is an American twin-engine propeller-driven light transport aircraft, originally built by Ted Smith Aircraft Company, which after 1978 became part of the Piper Aircraft Corporation, headquartered in Vero Beach, FL.

Figures 3 through 5 show a closer view of the coupling between the cylinder assembly exterior and the attachment joint. This joint had been welded to the cylinder exterior and contained a bushing assembly (with scrapers, washers, rings and a gland) driven against the cylinder. The inboard fitting of the joint was affixed to a linkage assembly by an attachment bolt. This joint was loose where it attached to the cylinder, and it could be rotated against the cylinder exterior. The adjacent hexagonal cap below the loose joint was still tight against the cylinder assembly (Figure 5).

The loose joint revealed a small gap, approximately 0.25 inch in longitudinal length. This gap, seen in Figures 3 and 4, exhibited a reddish-brown color, consistent with the underlying copper-based alloy bushing. The cylinder exterior and the edge of the upward-facing surface of the joint exhibited an undulating, rough fibrous texture, which mirrored each face. These features were consistent with mating fractured surfaces.

The linkage assembly affixed to the attachment joint was removed by disassembling and removing the nut, washer, clip, and bolt that held the assembly together. Figures 6 through 8 show the joint against the cylinder after removal of the linkage. The joint could still be moved to the same degree as when the linkage was still attached, and the cap located downward from the loose joint was still tight against the cylinder, unable to be moved.

The joint was sectioned in two locations, approximately 180° from each other on opposite sides, in order to remove it from the strut cylinder assembly. Figure 9 shows the removed and cleaned attachment joint from the upward and downward facing surfaces. The upward facing surface was the fracture surface. This surface was examined closer using light and electron microscopy. The sectioned joint was cleaned using a degreasing agent followed by immersion in acetone using an ultrasonic bath.

Figure 10 shows a closer view of a typical area of the upward-facing surface of the disassembled joint. The interior consisted of some of the bushing material, surrounded by an external main joint material, consistent with steel (due to its color, luster, and ferromagnetic response in the presence of a permanent magnet). The joint exterior had an external layer of white paint. Figure 11 shows a view of a typical area of the fracture surface from the exterior, showing the protruding lip-shape of the fractured weld remnant, as well as the fractured internal bushing remnant. As can be seen in the figures, the paint layer 0.1 to 0.25 inches closest to the fracture surface was missing. The missing paint pattern consisted of a series of lobes. This pattern in the missing paint was consistent with those typical in parts that separate through an external paint layer.

Figure 12 shows an area of the fracture surface that exhibited less post-fracture damage. The general pattern on the bushing remnant was rough and tortuous. The external paint coating had only partially spalled on the right side, revealing multiple layers of white paint, with an intermediate yellow layer. The joint portion of the fracture near the joint is highlighted in Figure 13. As shown on the left side of Figure 12, the welded steel material exhibited an upward-facing protrusion. The areas adjacent to the fracture surface exhibited repeating circumferential lines, oriented parallel to the fracture surface.

Figure 14 shows an area of the fracture that was partially obliterated by post fracture damage. The middle area of the bushing fracture was undamaged, and exhibited a similar rough, tortuous surface texture as the one illustrated in Figure 12. The areas to either side of this region exhibited smearing, oriented in a rotational direction. This wear pattern was consistent with the tallest portions of the fracture surface grinding on the mating fracture surface. The most severe example of the post-fracture rotational smearing damage is illustrated in Figure 15.

Portions of the joint fracture surface were examined using a scanning electron microscope (SEM). Figure 16 shows a closer view of the circumferential marks seen in Figures 11 and 13. These lines exhibited rounding and folding, consistent with multiple passes from the weld process. The folds exhibited some spreading and separation, consistent with limited local deformation adjacent to the fracture surface.

Most of the fracture surface had been damaged to an extent that any common fracture features were obliterated. This was true in both the bushing and welded regions of the steel joint fracture surface. Figure 17 shows portions of the fracture surface that were undamaged, although most of this region had been destroyed by post-fracture smearing. This damage was most prominent towards the interior of the bushing area. The lower right exhibited circumferential parallel marks consistent with the solidification from multiple passes of the welding process.

This material also exhibited multiple holes or divots, consistent with pores from the welding process. Closer examination did not reveal any cracking, striations, or other progressive fracture features emanating from the pores (see Figure 18). Any repeating linear features were found to be consistent with post-fracture smearing (lower left and right in Figure 18). There were some nonconductive compounds in and around the weld pores. This material was consistent with foreign material that became embedded into the fracture surface while the mating fracture surfaces were in repeated contact.

Figures 19 and 20 show closer views of the tortuous areas of the fracture features shown in Figures 12 and 14. The fracture features were consistent with dimpled rupture, consistent with overstress fracture of these regions. The dimpled rupture features were observed in both the bushing material and the steel joint weld material. No indications of features consistent with progressive crack propagation were found on the fracture surface.

The constituents of the attachment joint were inspected using x-ray fluorescence to determine the chemical composition. The attachment joint composition was consistent with alloy steel, such as Type 4340 or 300M—alloys often used for landing gear components. The surface of the steel joint exhibited high cadmium (Cd) levels, consistent with a surface treatment of cadmium electrodeposition coating. The bushing material was consistent with a copper-based alloy, but it was too thin for this characterization technique to determine a more specific alloy.

A portion of the joint and bushing remnant was cross-sectioned, mounted, and polished. Figure 21 shows a typical cross section through the fracture surface shown in

Figure 10. The cross section included a portion of copper bushing joined on the internal corner of the fracture surface joint to the steel joint. The rest of the cross section shows the steel joint material.

The upper surface in the figure, which was absent the paint in coating in the figure, still included some of the cadmium electrodeposition coating. This coating manifest as thin white lobes on the upper surface in the figure. Figure 22 shows an area to the exterior of Figure 21, demonstrating some of the paint coating layer, present above the cadmium layer. Figure 23 highlights the intact paint coating, overexposed to show the coating layers in cross section. The coating exhibited multiple white-colored layers, as well as the intermediate yellow-orange layer seen in the partially spalled paint. The layers were not entirely parallel to the underlying steel substrate, but rather undulated.

Figure 24 illustrates a closer area of the bushing remnant. This remnant contained a crack or fold which was open to the exterior of the part. This crack contained some dissimilar material, consistent with the cadmium material seen to the right in the figure.

There was another fractured bushing remnant, pictured in Figure 25. This remnant was located downward from the fracture surface, and was present on the interior surface of the attachment joint. There were no indications of internal cracking or large voids on this remnant.

Erik M Mueller
Materials Research Engineer

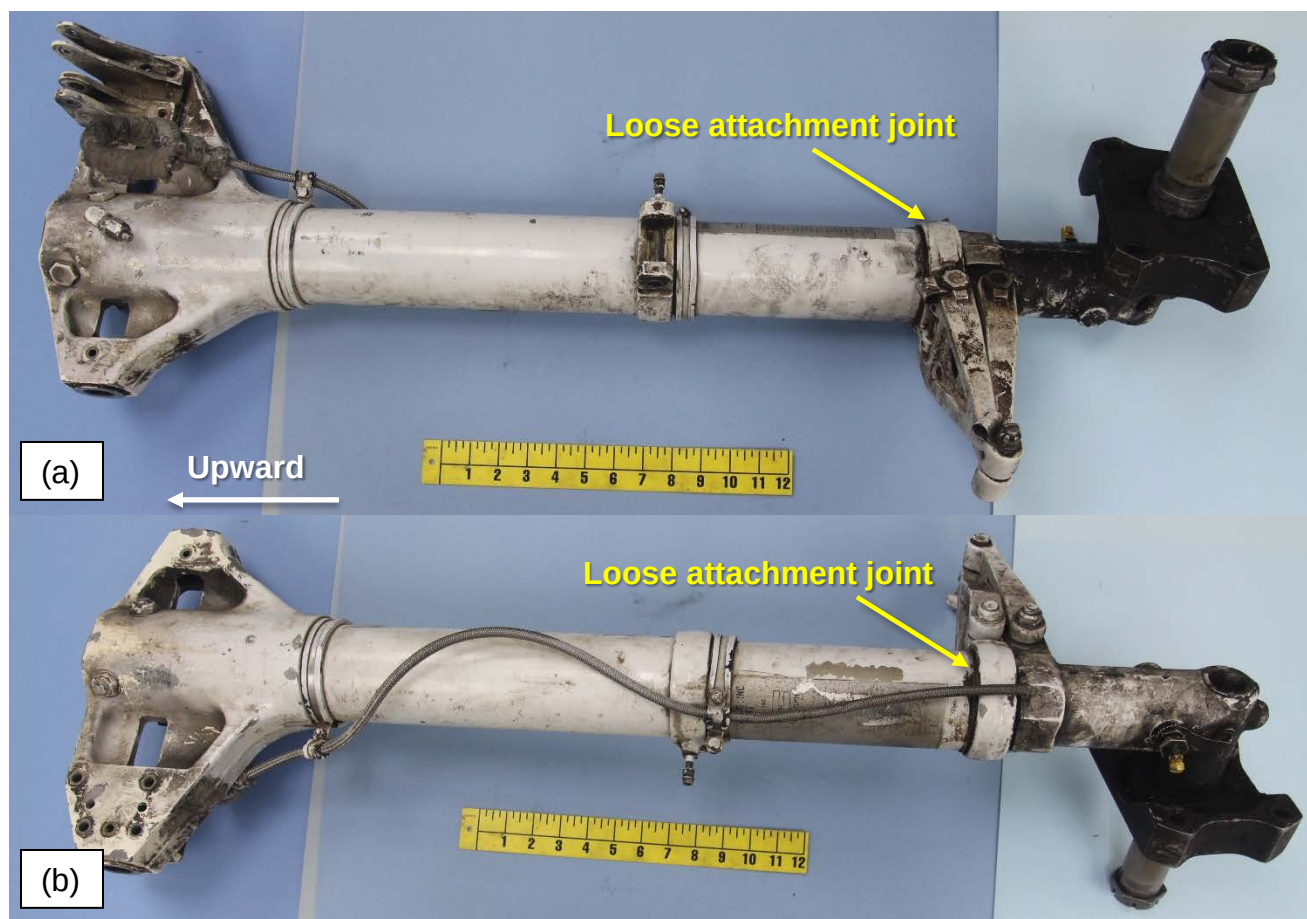


Figure 1 – The landing gear strut assembly, as received, viewed from opposite 180° sides (a) forward looking aft and (b) aft looking forward. The loose attachment joint affixed to linkage assembly is annotated on both figures.



Figure 2 – The label on the landing gear strut cylinder outboard side, showing the damage to the text.



Figure 3 – View of the loose attachment joint, looking downward, showing the gap consistent with a fractured weld.

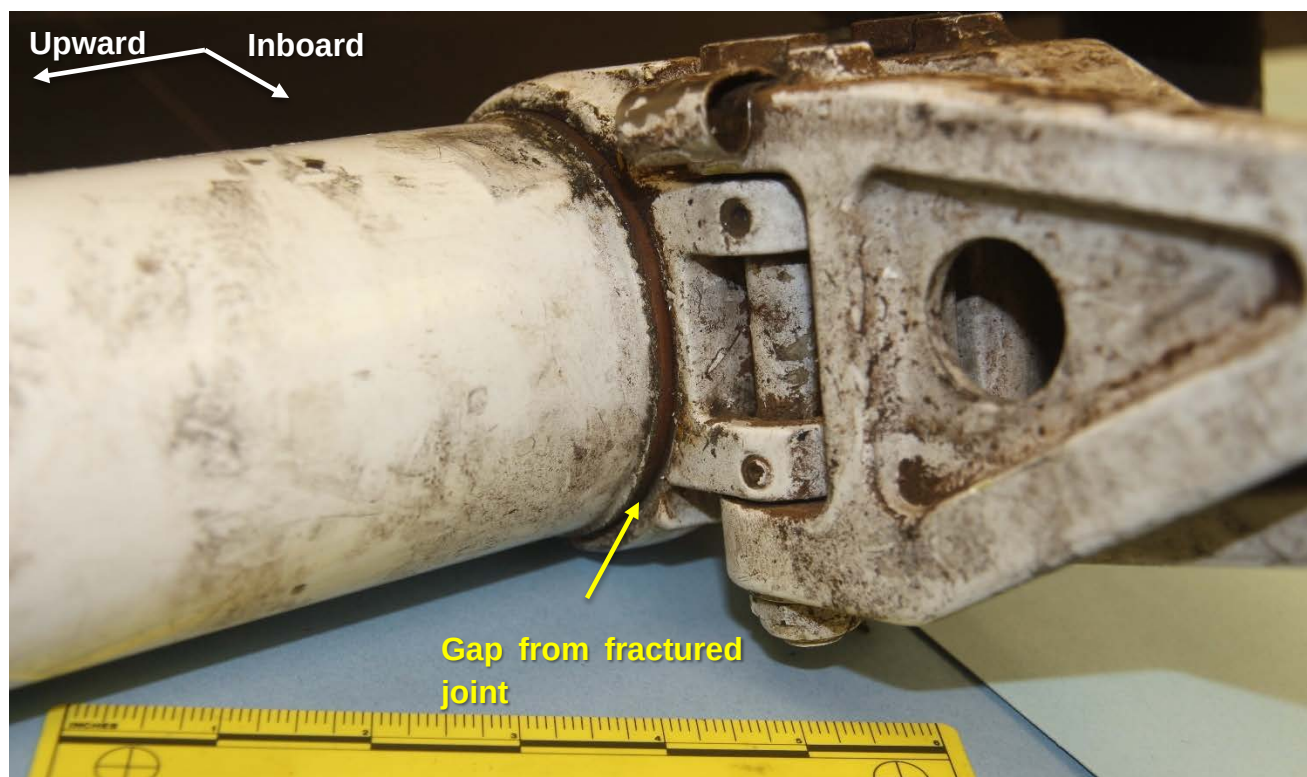


Figure 4 – The gap between the joint and strut cylinder, from an angled inboard view.

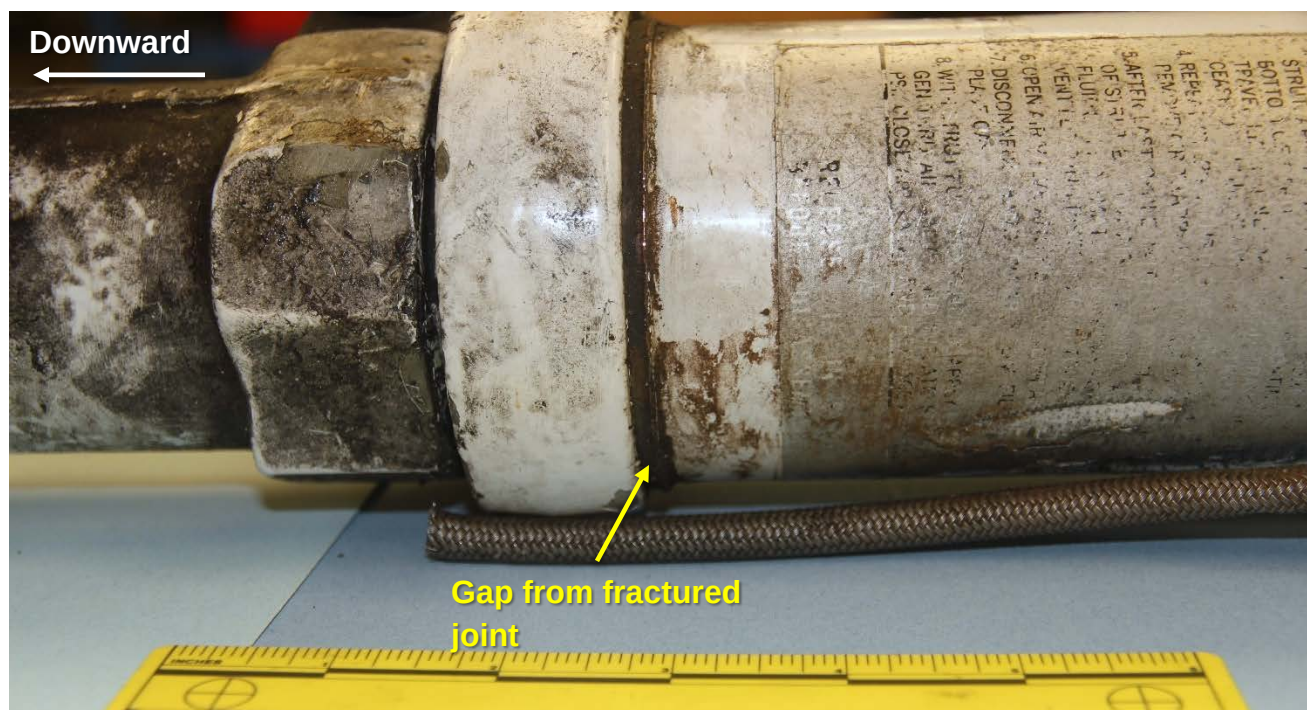


Figure 5 – The gap between the joint and cylinder, viewed from the outboard side.

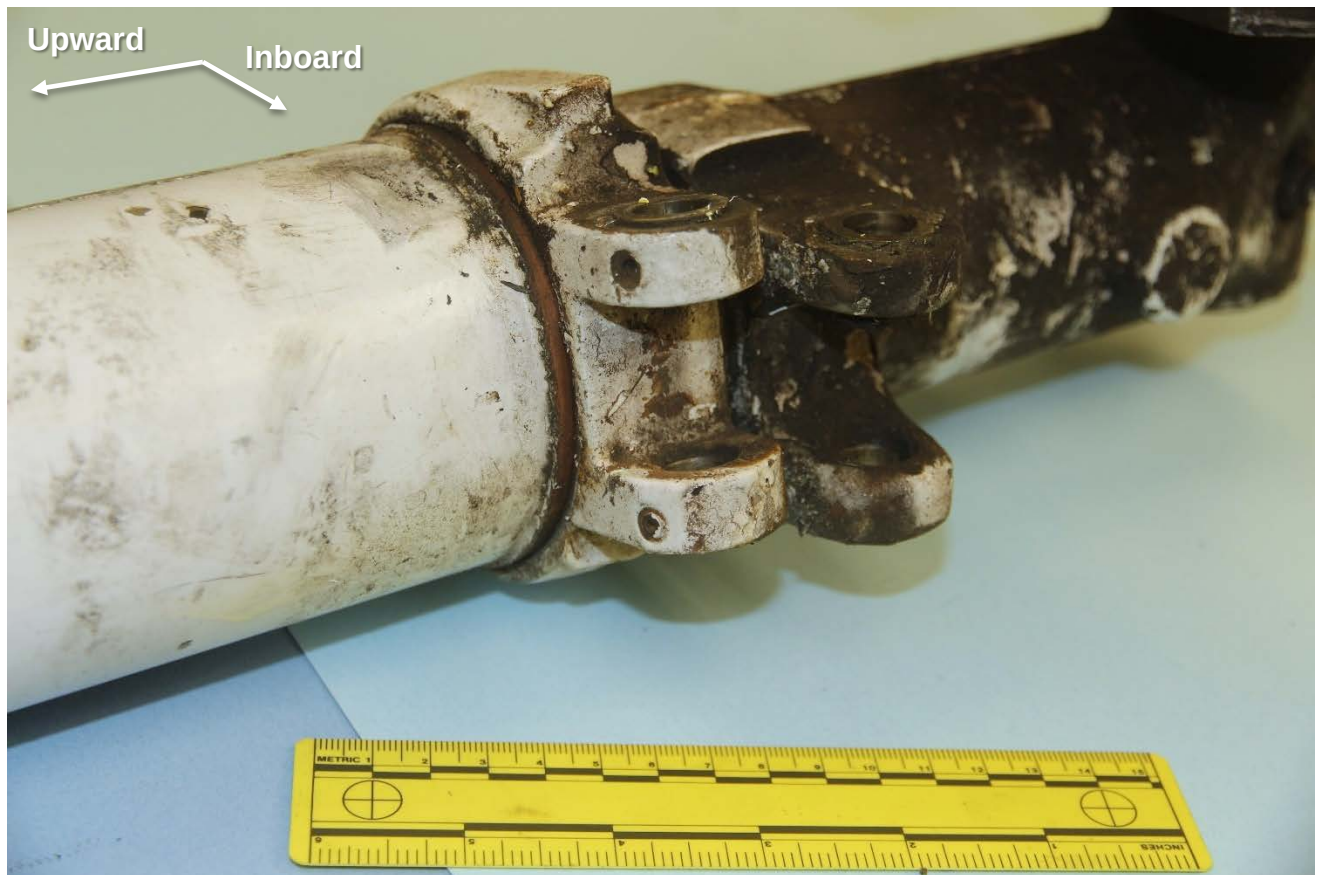


Figure 6 – View of the loose attachment joint on the strut cylinder from an angled inboard view, after removal of the linkage and connecting bolt assemblies.



Figure 7 – View of the loose joint on the strut cylinder from the outboard surface, after removal of the linkage and connecting bolt assemblies.



Figure 8 – The loose joint after removal of the linkage and bolt assemblies, viewed forward looking aft.

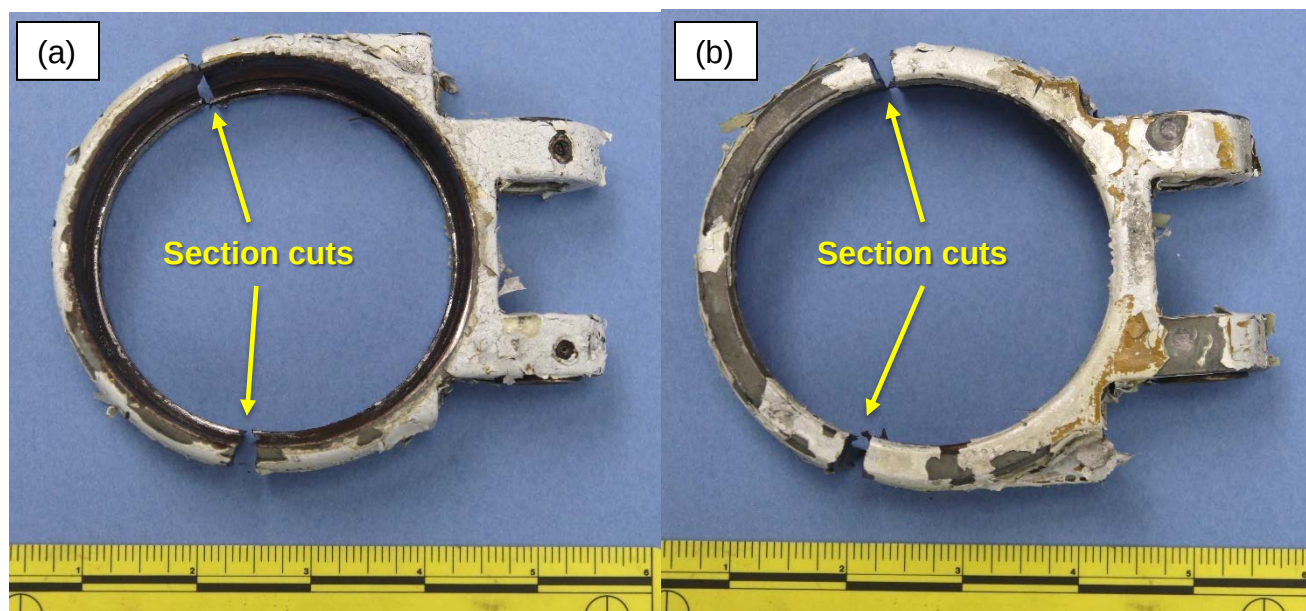


Figure 9 – View of the joint, after sectioning from the strut cylinder assembly, shown from (a) the upward and (b) the downward face.



Figure 10 – View of the upward face of the joint fracture surface, showing the smeared bushing material, the fractured white paint and the underlying joint steel material.

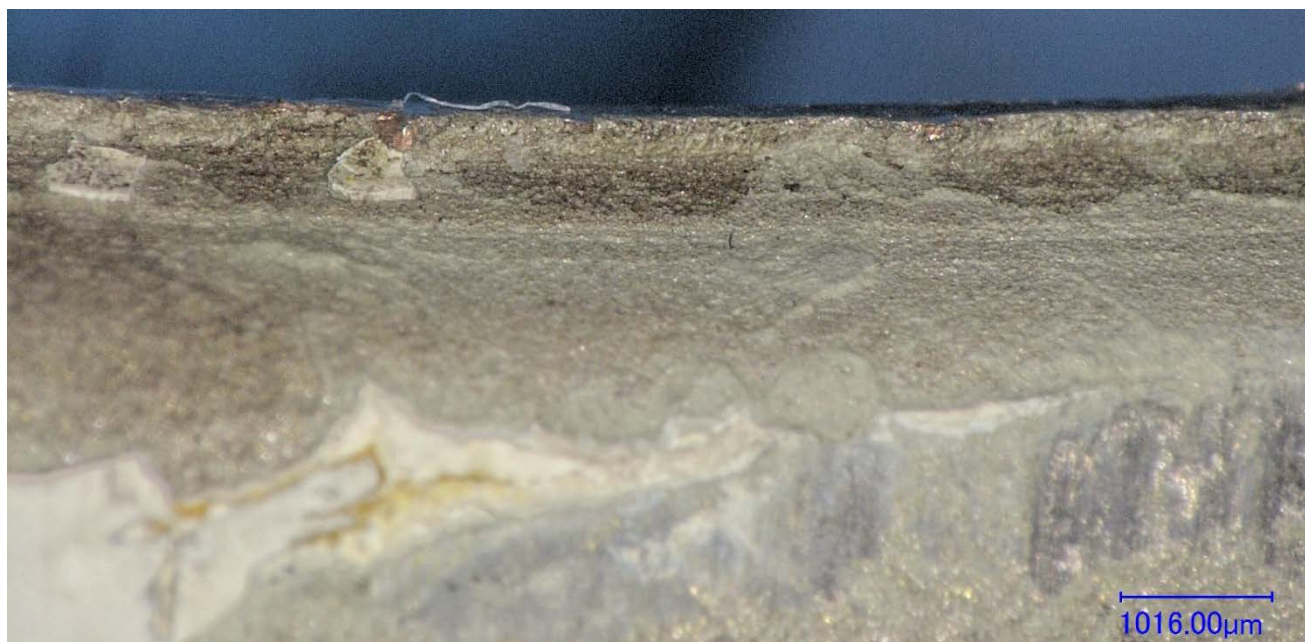


Figure 11 – View of the joint weld from the outer face, showing parallel circumferential lines near the fracture.



Figure 12 – View of fracture features on the bushing portion of the joint fracture surface.



Figure 13 – The outside view of the fracture surface in Figure 12, showing circumferential weld lines parallel to the surface.

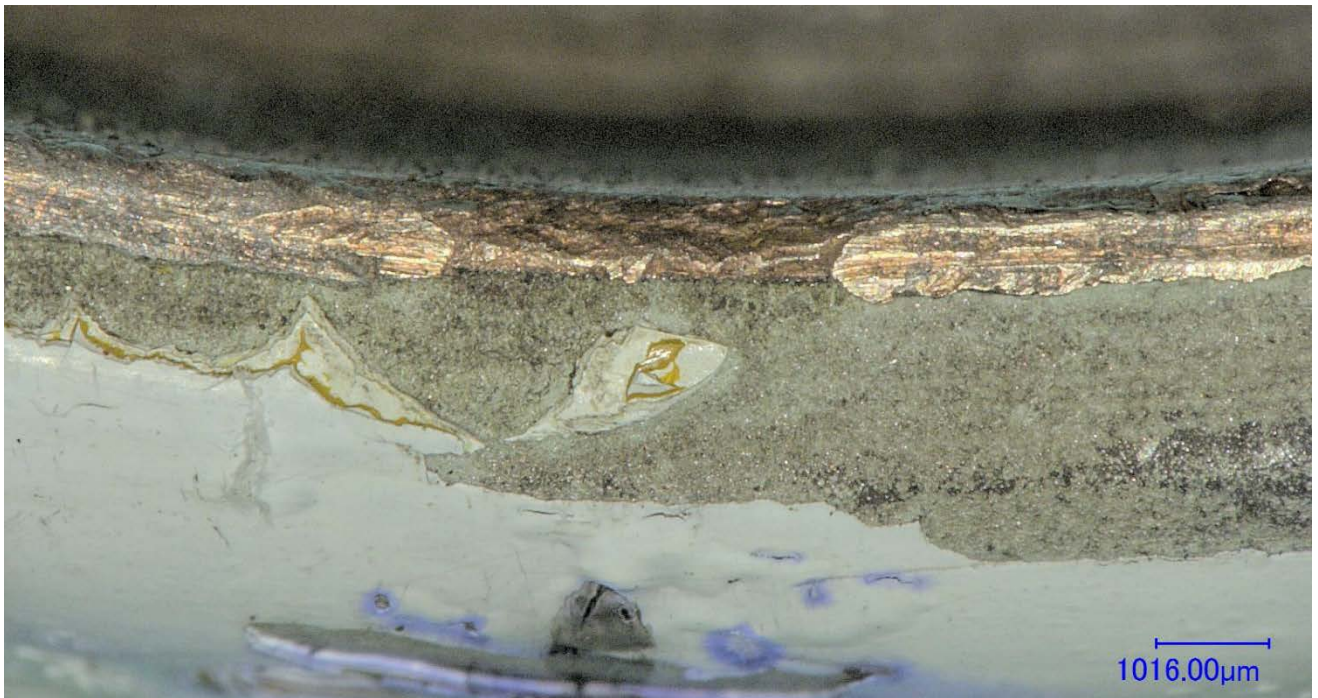


Figure 14 – View of an undamaged fracture area of the removed attachment joint.

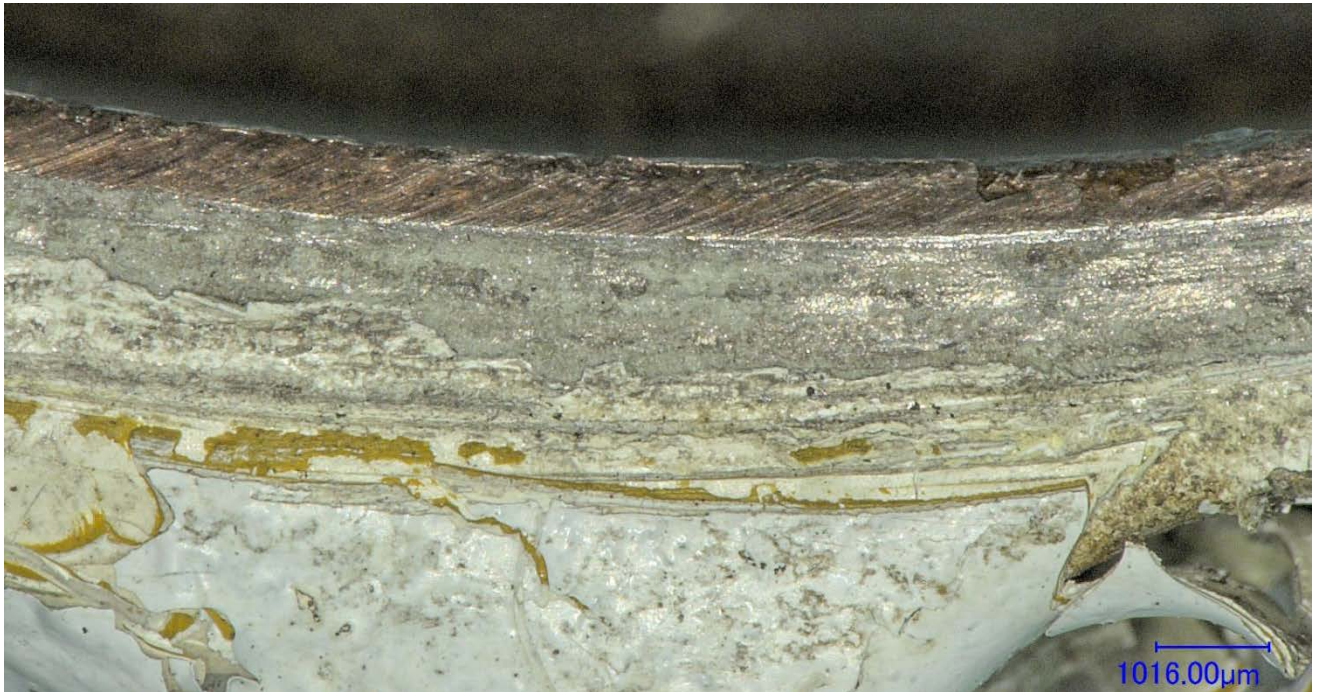


Figure 15 – View of the joint fracture surface from the inboard side, showing complete obliteration of the fracture surface.

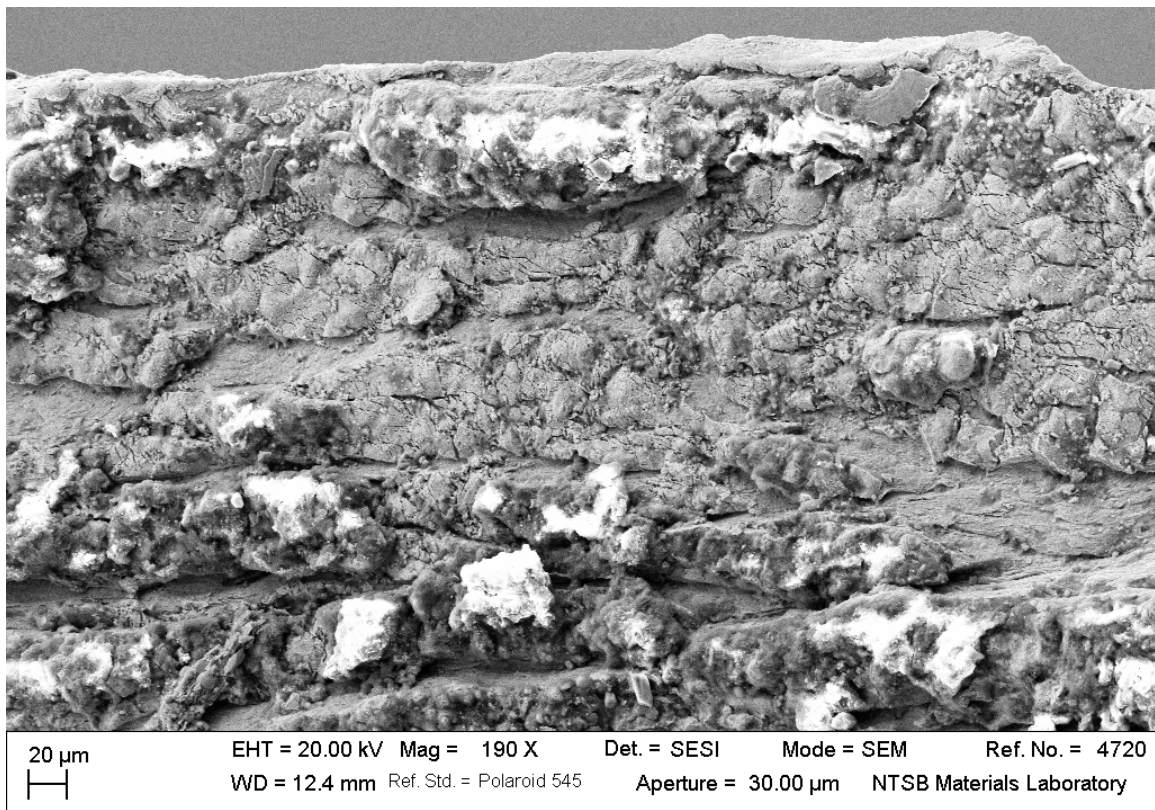


Figure 16 – Secondary electron (SE) micrograph of the outside weld area in Figure 13, showing wrinkling on the surface (fracture surface faces upward).

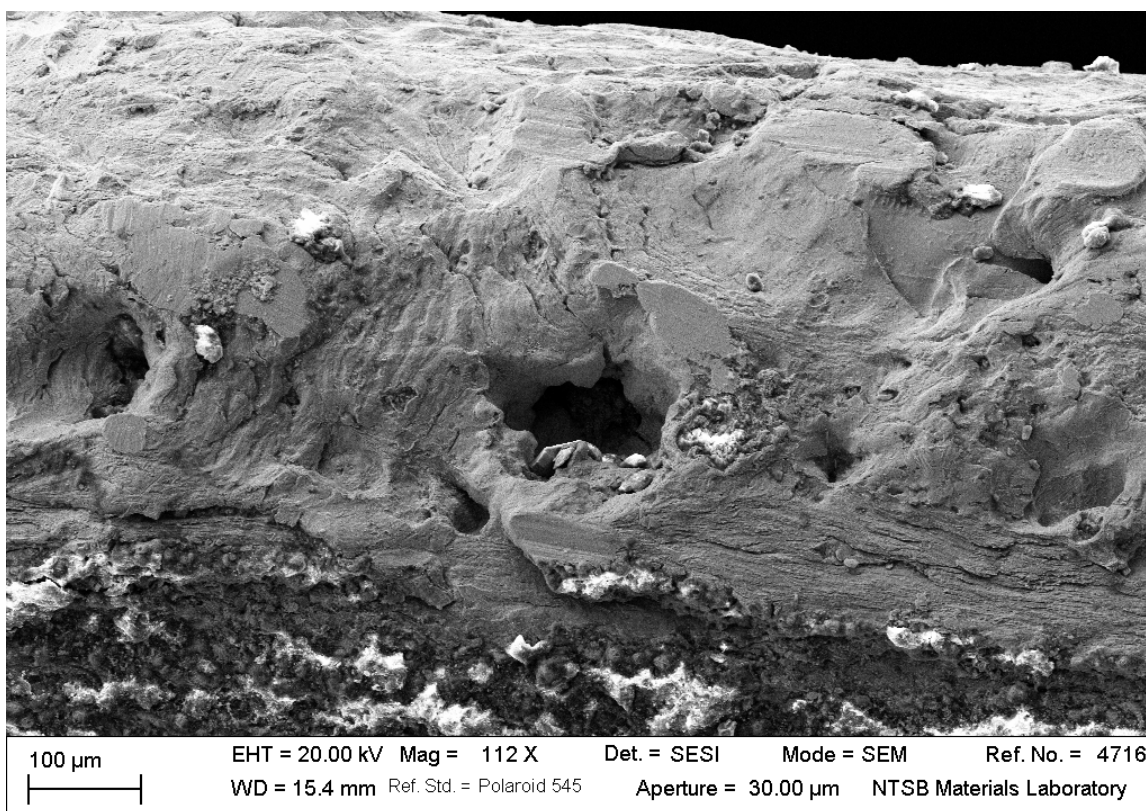


Figure 17 – SE micrograph of the damaged fracture surface, showing voids.



Figure 18 – SE micrograph of a closer view of Figure 17, absent pore cracking.

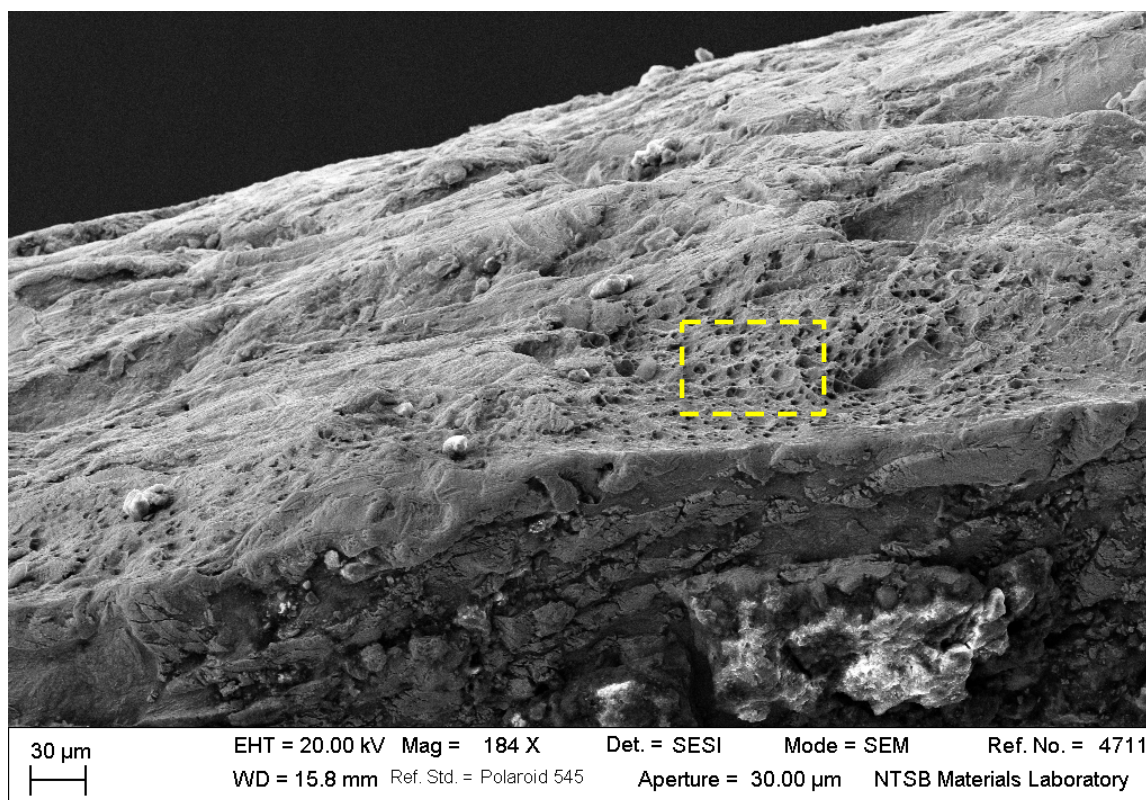


Figure 19 – SE micrograph of the undamaged area in Figure 14.

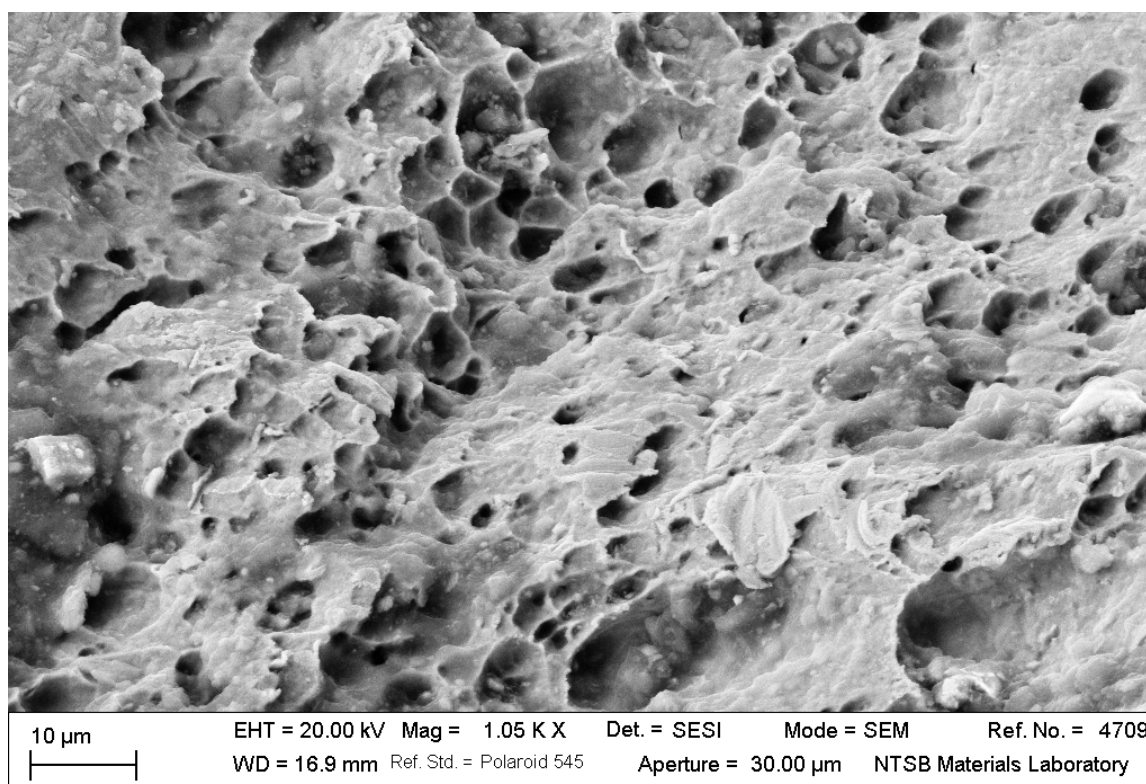


Figure 20 – SE micrograph of a closer view of the boxed area in Figure 19, showing dimpled rupture.

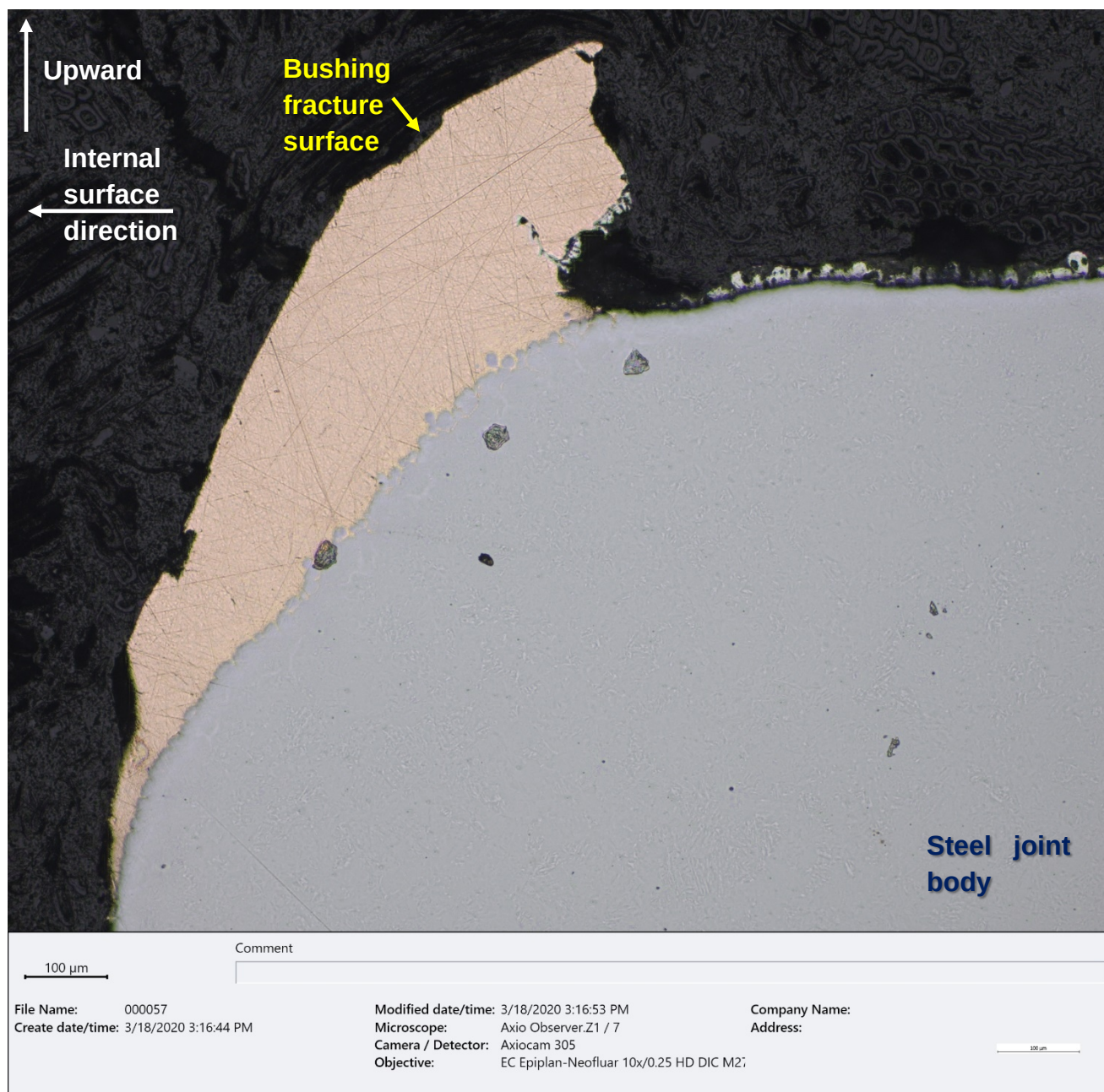


Figure 21 – Bright-field (BF) optical micrograph cross section of the fracture surface, showing the fractured bushing remnant on the steel substrate (~100X, as-polished).

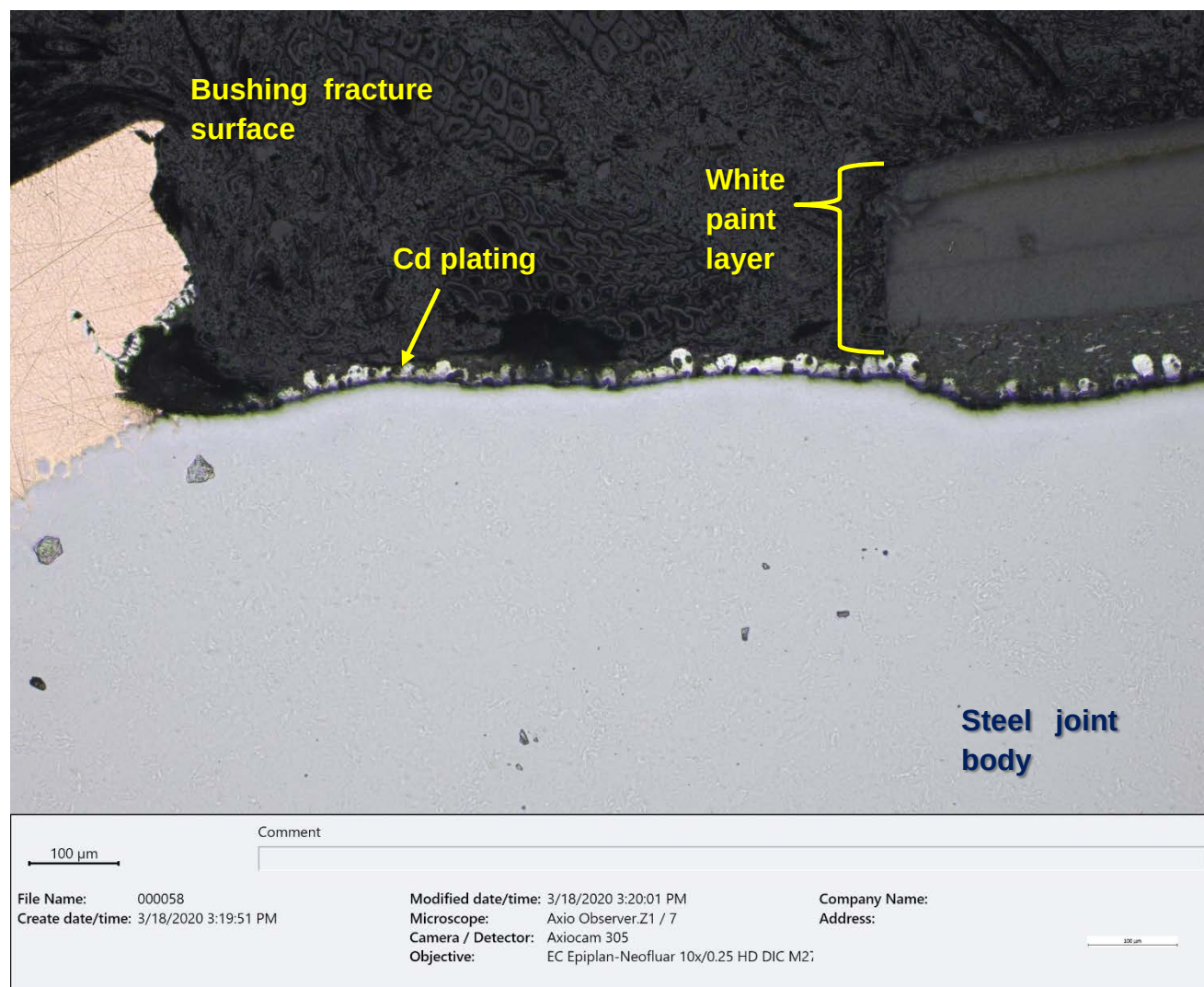


Figure 22 – BF optical micrograph of a view of the area just right of Figure 21, showing the different layers annotated (~100X, as-polished).

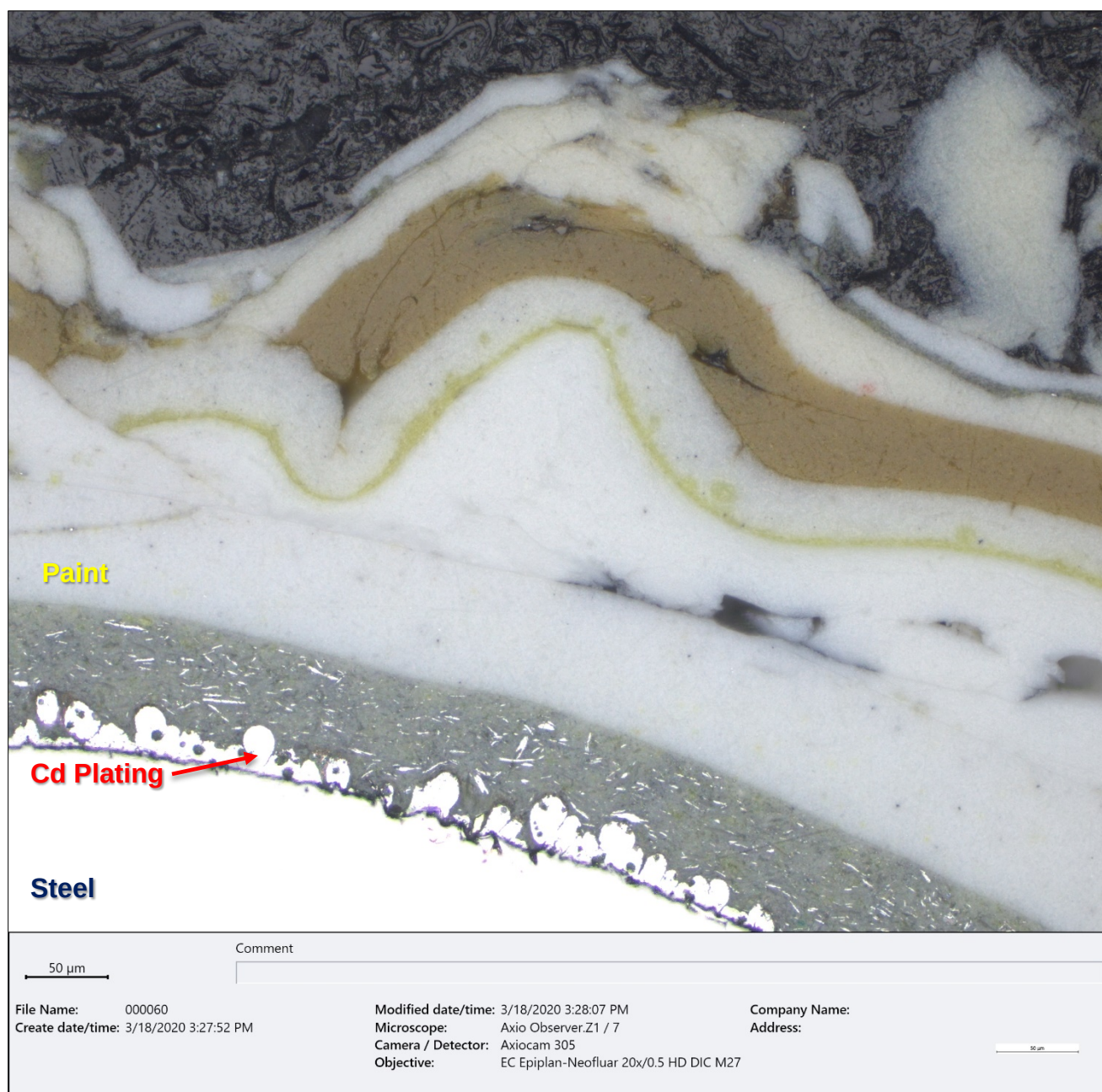


Figure 23 – BF optical micrograph of the undulating layers of coatings on an undamaged area of the joint, showing the underlying paint and Cd-plating layers on the overexposed steel substrate (~200X, as-polished).

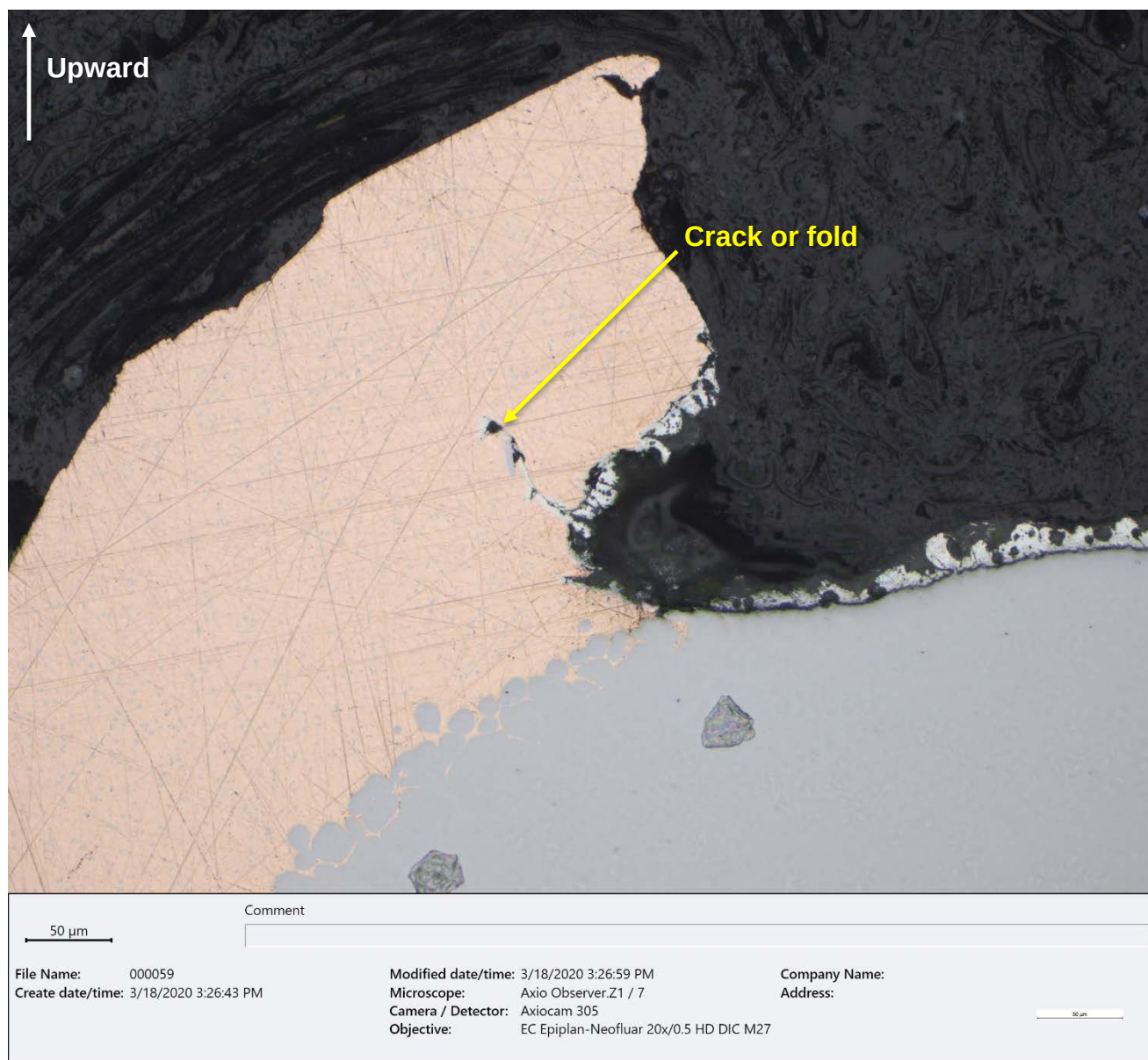


Figure 24 – Closer view of an underlying crack or fold in the fractured bushing material at the fracture surface (~200X, as-polished).

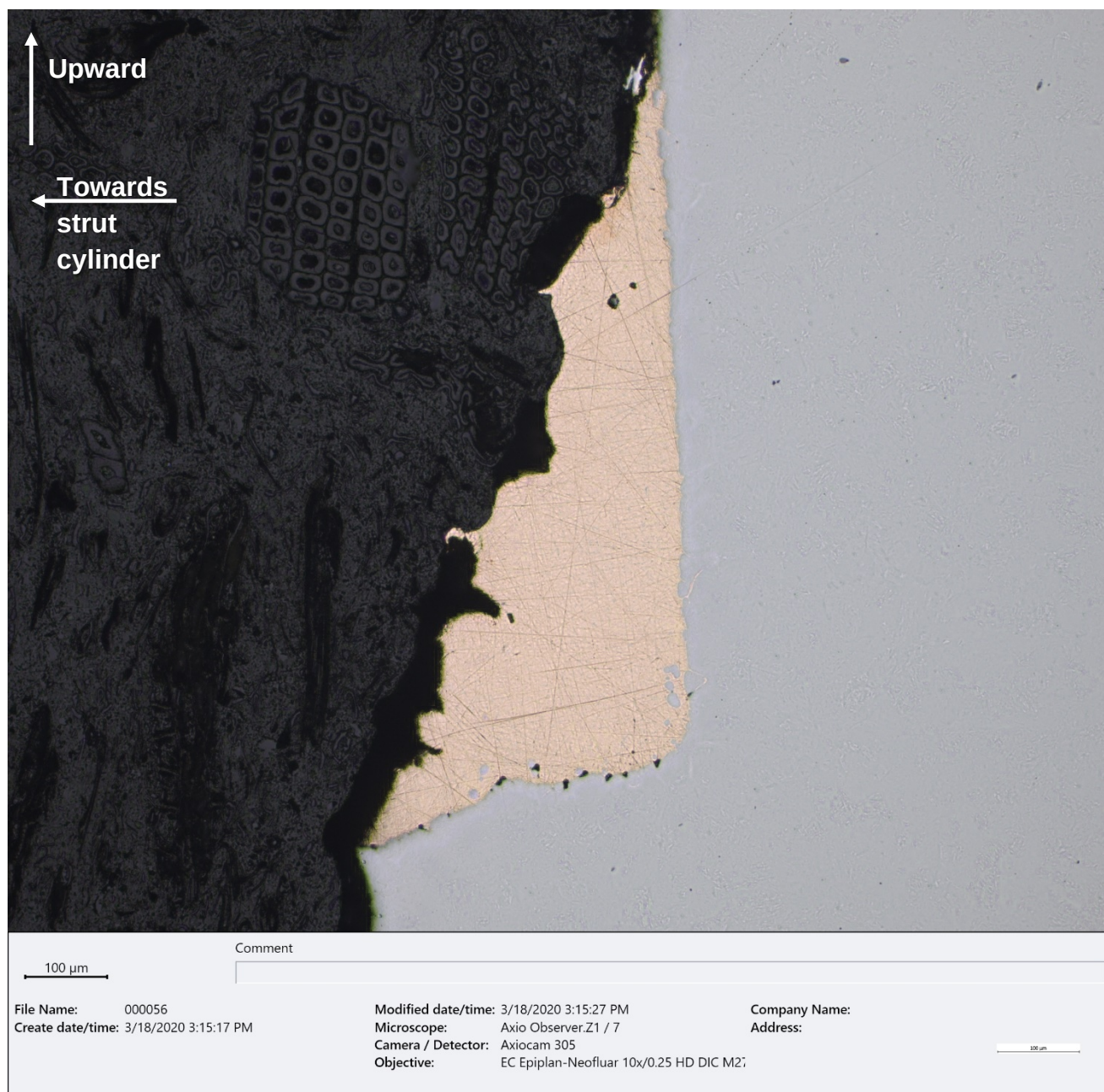


Figure 25 – BF optical micrograph view of another fractured bushing fragment downward from the fracture surface, on the joint interior surface (~100X, as-polished).