

NATIONAL TRANSPORTATION SAFETY BOARD

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



May 26, 2022

MATERIALS LABORATORY FACTUAL REPORT

Report No. 22-034

1. ACCIDENT INFORMATION

Place : Amado, Arizona
Date : August 2, 2021
Vehicle : Piper PA-28-140, N44245
NTSB No. : WPR21LA301
Investigator : Andrew Swick, AS-WPR

2. COMPONENTS EXAMINED

Section of a propeller blade remnant

3. DETAILS OF THE EXAMINATION

On August 2, 2021, about 0925 mountain standard time, a Piper PA-28-140 airplane was substantially damaged when it was involved in an accident near Amado, AZ. The pilot and passenger were not injured. The pilot reported that while in level flight, the airplane developed a sudden and severe vibration. When the engine shut down, the pilot initiated a forced landing. Examination of the accident site revealed substantial damage to the right wing, with the midsection exhibiting impact marks and embedded tree debris in the leading edge. The propeller remained attached to the engine, but one blade was missing about two-thirds of the outboard portion. A section of the fractured blade was sent to the NTSB Materials Laboratory for further examination.

Figure 1 shows the propeller blade remnant, as received. The blade had fractured perpendicular to the longitudinal direction, with the remnant having been sectioned about 2.5 inches from the fracture surface (see Figure 2). Overall, the fracture surface of the blade remnant was generally flat in orientation, but closer to the leading edge was more tortuous with elevated features.

Figure 2 shows a view of the blade from the flatter face surface. This view showed a lack of paint along the trailing edge surface, which revealed the underlying metallic substrate material. This absence of paint was consistent along the face side trailing edge but was also accompanied by indications of a red paint transfer.

Figures 3 and 4 show closer views of the trailing edge of the fractured blade remnant. This area showed indications of impact marks, along with linear smearing marks.

These witness marks were present on the fracture surface near the trailing edge tip, as well as along the edge with the blade face. There was still paint present up to the fractured edges along the back side of the blade, shown in Figure 4.

Figure 5 shows a montage view of the blade fracture surface. The left two-thirds of the fracture surface was relatively flat and exhibited a reflective luster. This area of surface exhibited convex crack arrest marks, consistent with progressive fracture modes. The arrest marks bowed away from the trailing edge tip, indicating the crack originated from that location. Outside of the progressive fracture, towards the right in Figure 5, the fracture surface was rougher and more elevated, exhibiting a dull luster. The length of the progressive crack region was 3.5 inches along the blade face, and 3.1 inches on the blade back from the trailing edge.

Figure 6 shows a closer view of the trailing edge of the fracture surface, with Figure 7 illustrating a higher magnification view. There was a discontinuous streak near the tip, consistent with post-fracture smearing of the surface. The edge of the fracture surface with the face exhibited a protruding lip, which folded upward slightly in the figure. Figure 7 also shows a small amount of missing or inwardly deformed material at the tip location. In addition, vertically-oriented features were observed radiating upward in the figure, from the face edge lip. These features were consistent with ratchet marks and river patterns, consistent with fracture propagation from the face surface near the trailing edge tip.

The blade remnant was sectioned near the fracture and cleaned with acetone in an ultrasonic bath. After cleaning, portions of the blade fracture surface were examined using a field emission scanning electron microscope (SEM). Figure 8 shows a typical view of the progressive region of the fracture surface. As highlighted in Figure 9, the fracture surface exhibited striations, consistent with fatigue crack propagation. The morphology of the striations was consistent with crack growth from the trailing edge inward.

Figure 10 shows the terminus of the fatigue crack. This figure exemplifies fatigue striations until the crack ends, transitioning to a more tortuous surface morphology. Closer examination found the areas outside the fatigue crack to exhibit dimpled rupture, consistent with subsequent overstress fracture (Figure 11).

The blade remnant was examined using energy dispersive x-ray spectroscopy (EDS) and x-ray fluorescence (XRF). The chemical composition was consistent with AA 2014 aluminum alloy. The hardness was examined per ASTM E18.¹ The hardness averaged 68 HRBW. The electrical conductivity was examined using ASTM E1004.² The conductivity averaged 36.9 %IACS. These data were consistent with a T3 or T4 temper for this alloy.

¹ ASTM E18 – *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*. ASTM International, West Conshohocken, PA.

² ASTM E1004 – *Standard Test Method for Determining Electrical Conductivity Using the Electromagnetic (Eddy-Current) Method*. ASTM International, West Conshohocken, PA

Figure 12 and Figure 13 show closer views of the fatigue crack initiation sites near the trailing edge. As shown in the figures, the fatigue striations and ratchet marks emanated from the edge with the blade face, rather than the trailing edge tip (see Figure 14). Additional crack initiation sites were found away from the trailing edge, as illustrated in Figure 15 and Figure 16.

The edge of the fracture surface with the crack initiation sites was examined using EDS to map the area in Figure 14 and Figure 15. These x-ray maps provide compositional information on the concentration of specific elements in the area scanned, and areas of higher concentration are depicted with brighter color intensity, as depicted for aluminum and copper in Figure 17. While most of the area scanned exhibited primarily aluminum, the edge area was absent aluminum, and exhibited indications of copper, as well as iron and manganese. These indicate material transfer from an alloy dissimilar to that of the blade.

However, no additional details could be gleaned at the local start of the initiation sites, as the edge with the blade face had been deformed inward and folded toward the fracture surface.

Erik M Mueller
Materials Research Engineer



Figure 1 – Angled view of the propeller blade remnant, showing the fracture surface, as received.



Figure 2 – View of the blade face surface of the propeller blade remnant, showing lack of paint and impact marks on the trailing edge (right in the figure).

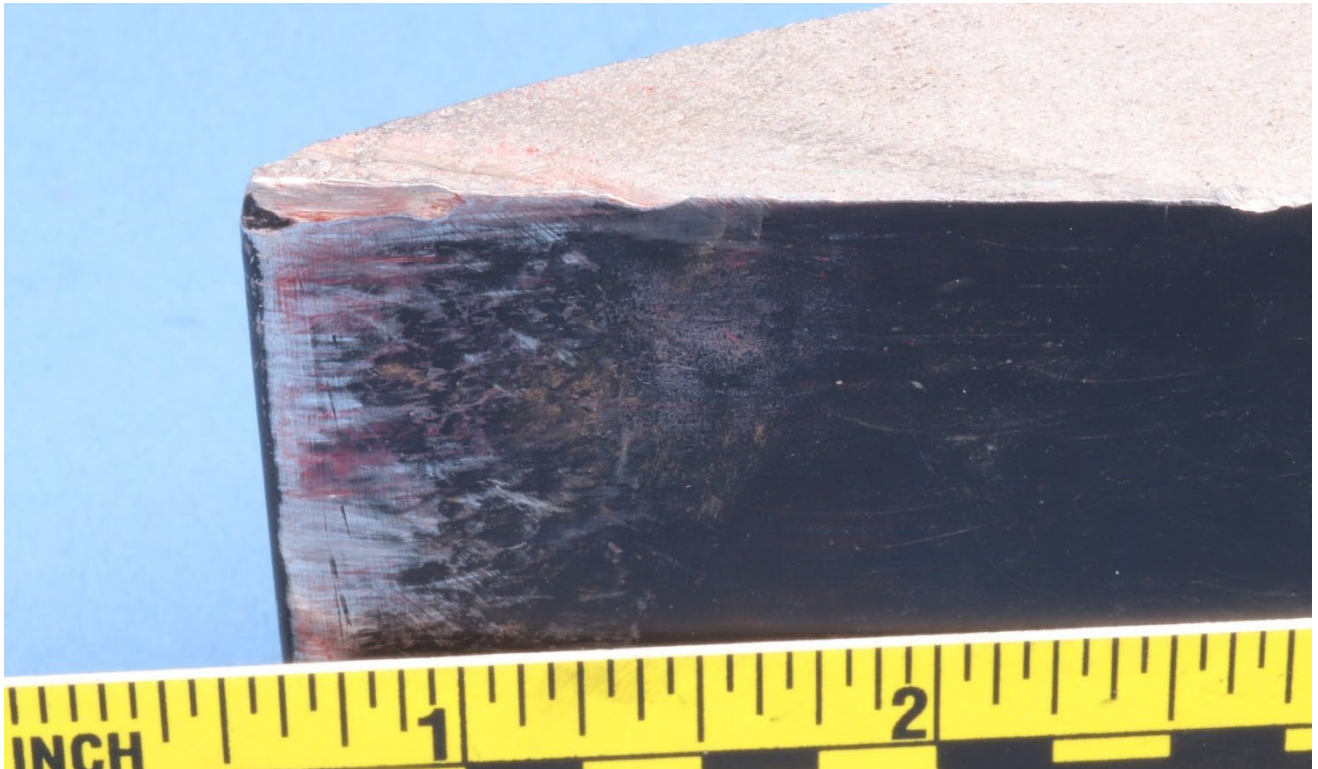


Figure 3 – Closer view of the remnant trailing edge, showing smearing and impact marks.

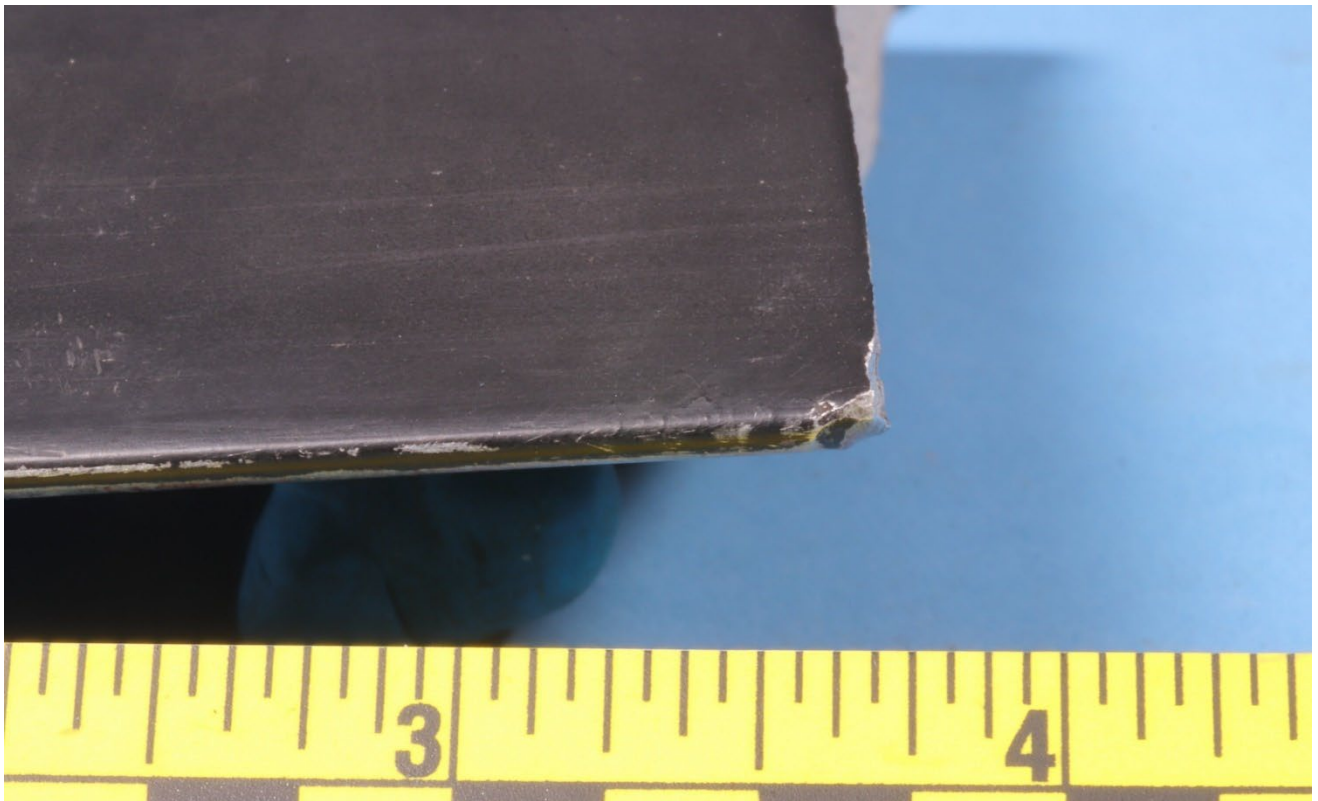


Figure 4 – View of the trailing edge of the fractured propeller blade, viewed from the blade back opposite the face surface that in Figure 3.

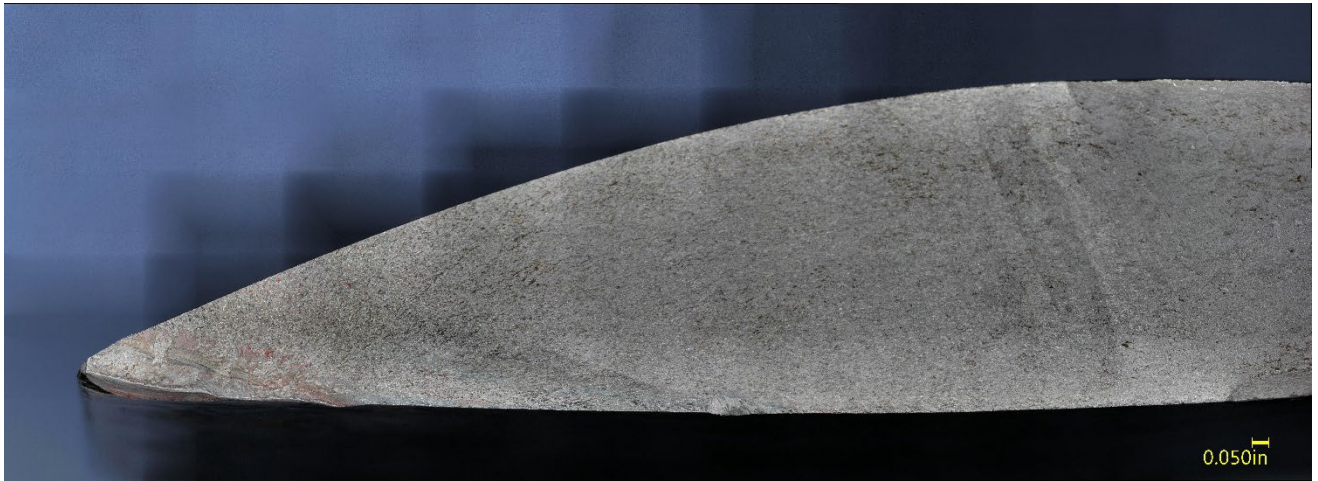


Figure 5 – Montage view of the propeller blade remnant fracture surface.

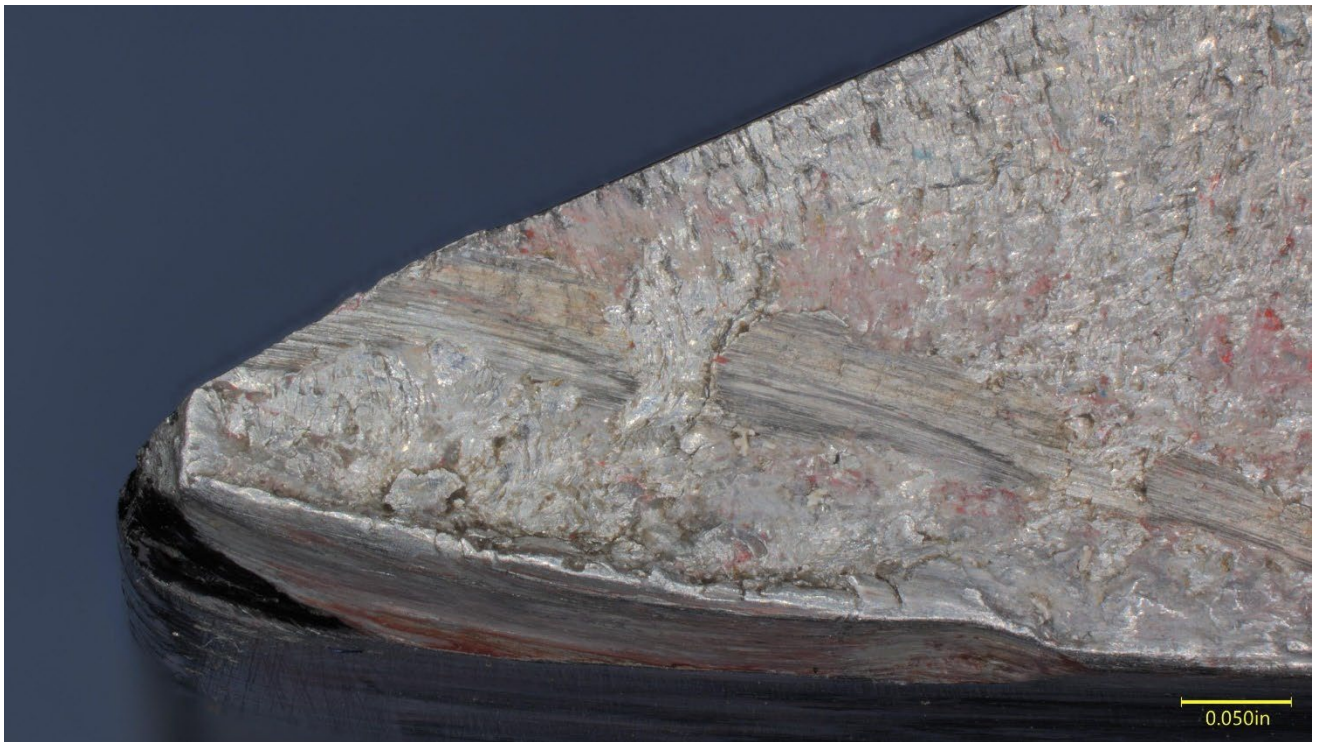


Figure 6 – Closer view of the trailing end of the propeller.

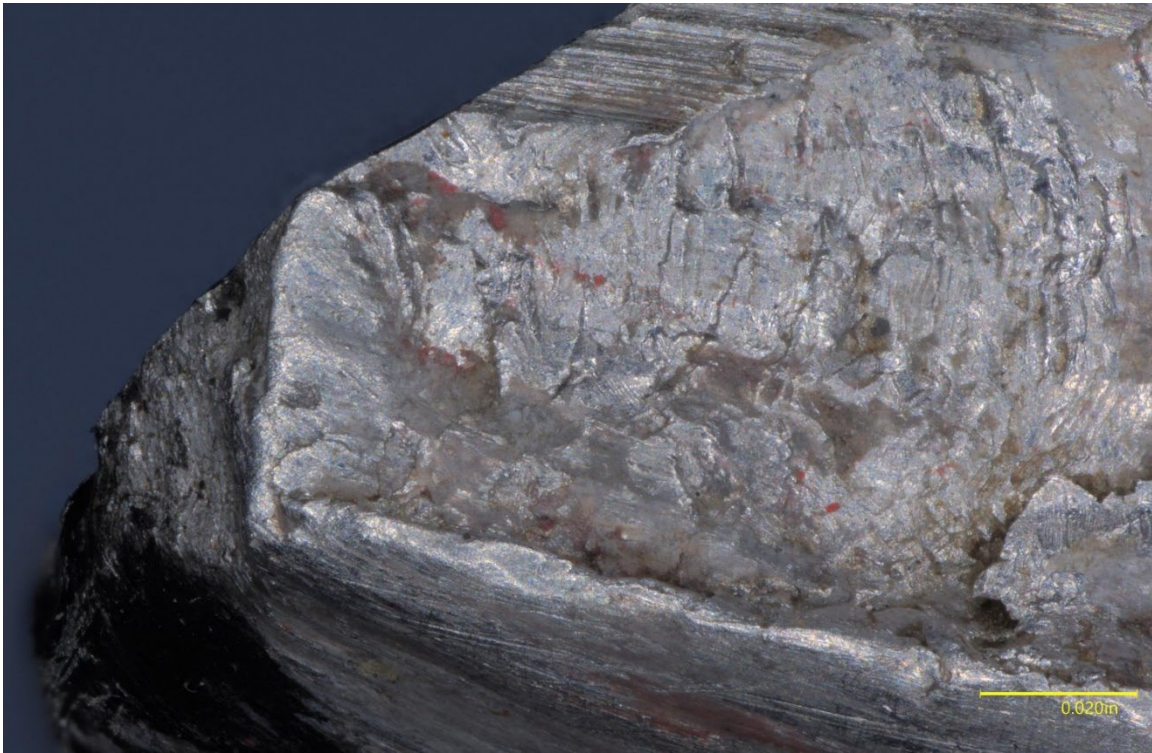


Figure 7 – Closer view of the trailing edge of the propeller in Figure 6.

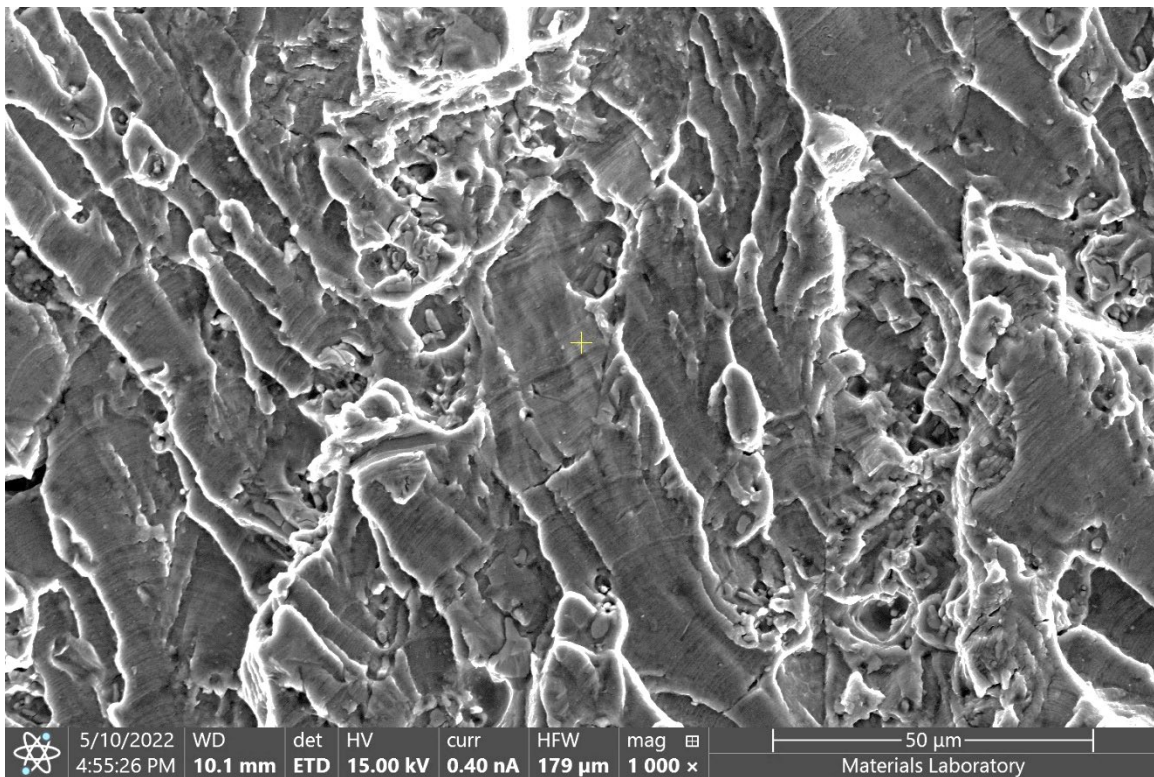


Figure 8 – Secondary electron (SE) micrograph of a typical area of fatigue striations on the propeller fracture surface.

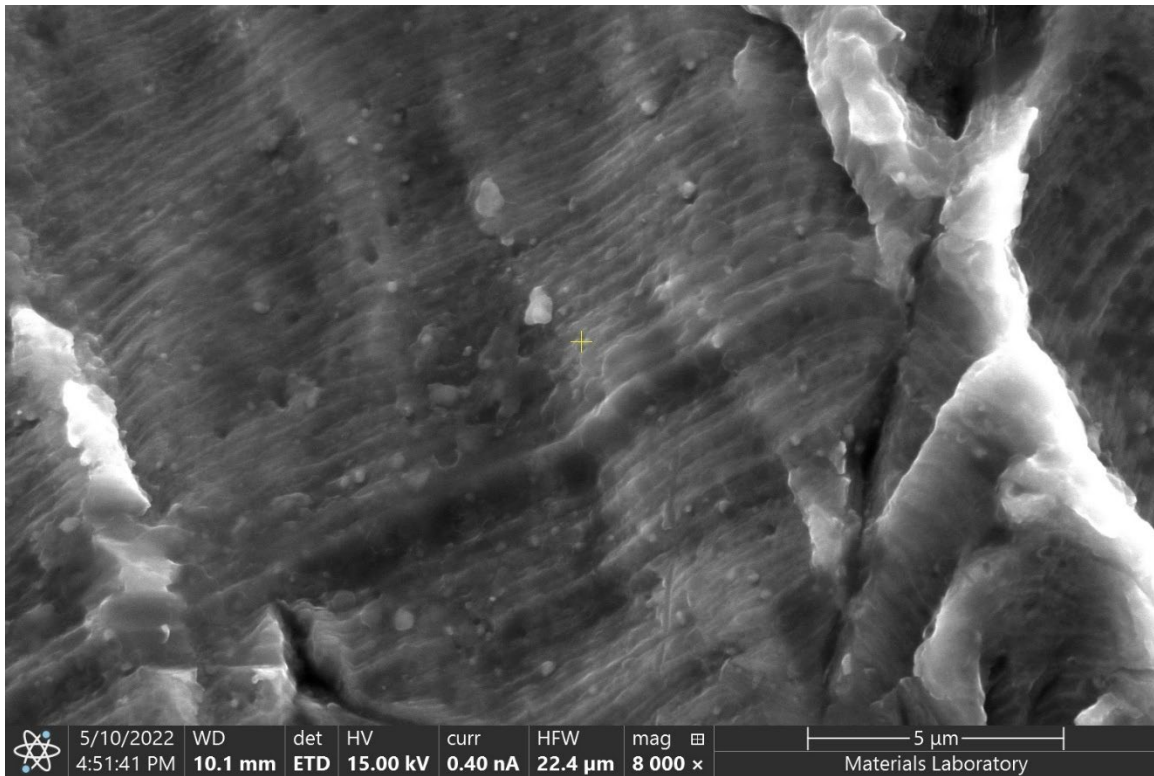


Figure 9 – SE micrograph of the fatigue striations in Figure 8.

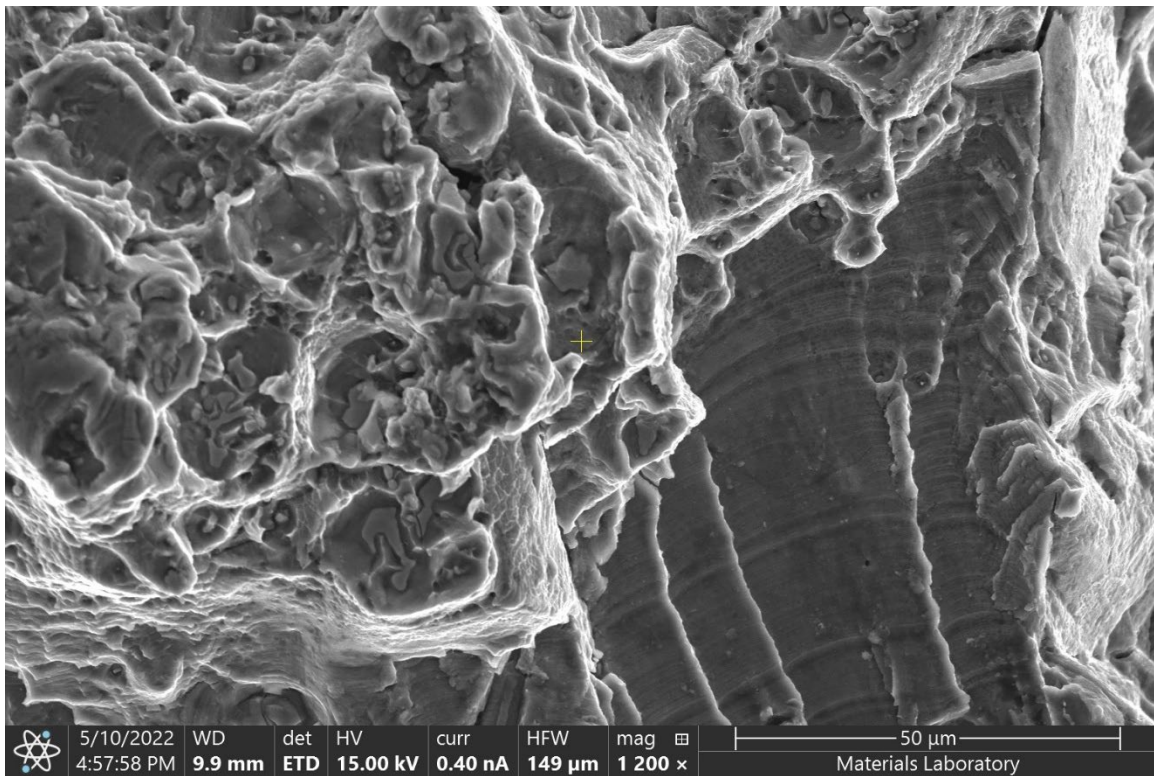


Figure 10 – SE micrograph of the terminus of the fatigue crack.

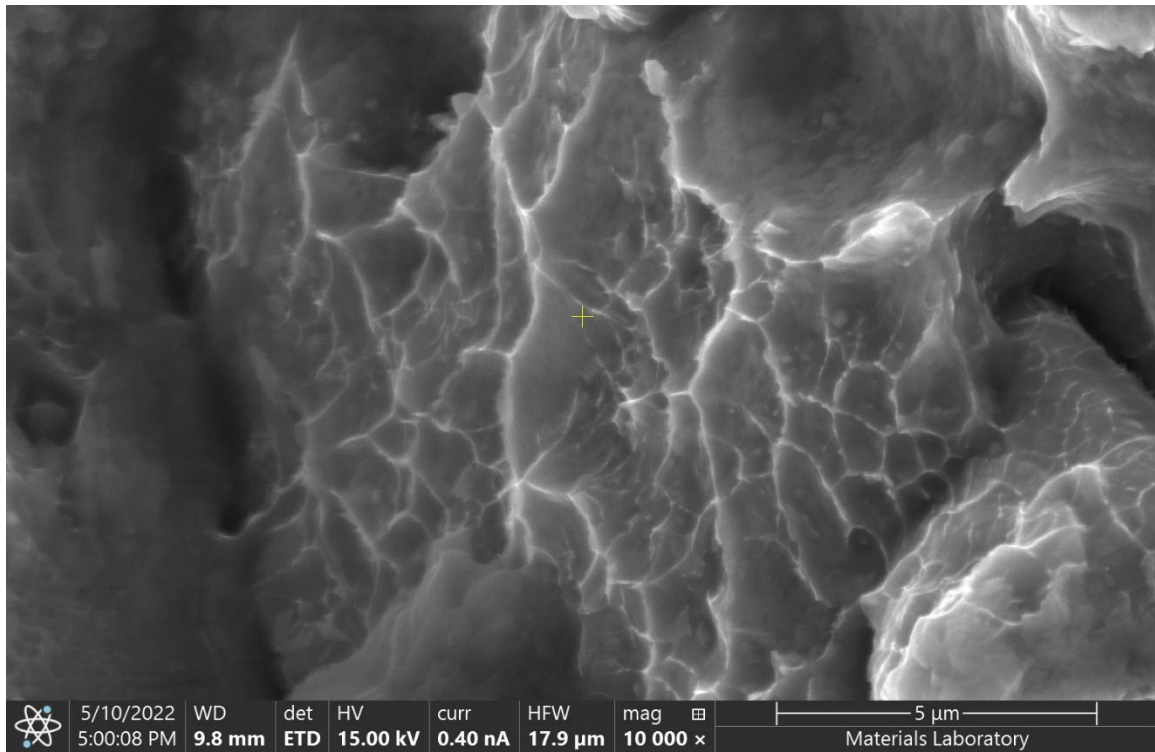


Figure 11 – SE micrograph of dimpled rupture past the fatigue crack terminus.

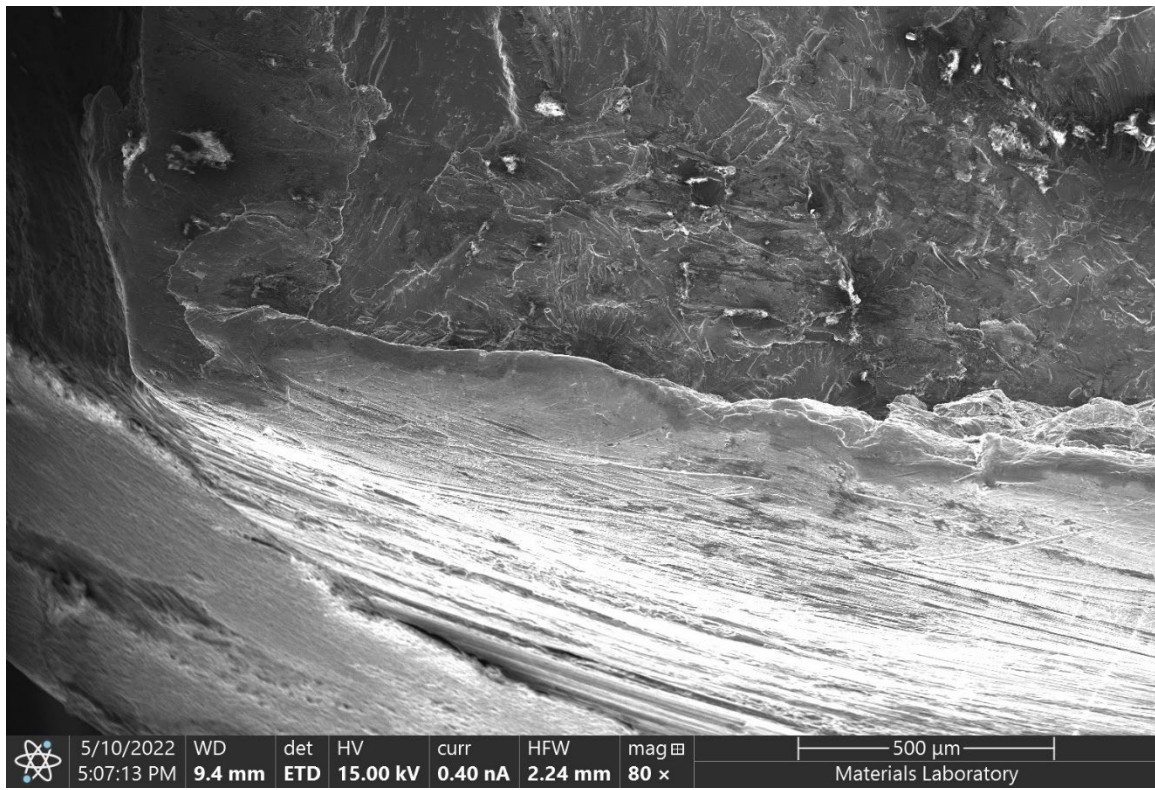


Figure 12 – SE micrograph of the trailing edge, showing crack initiation sites, and material folded over the fracture.

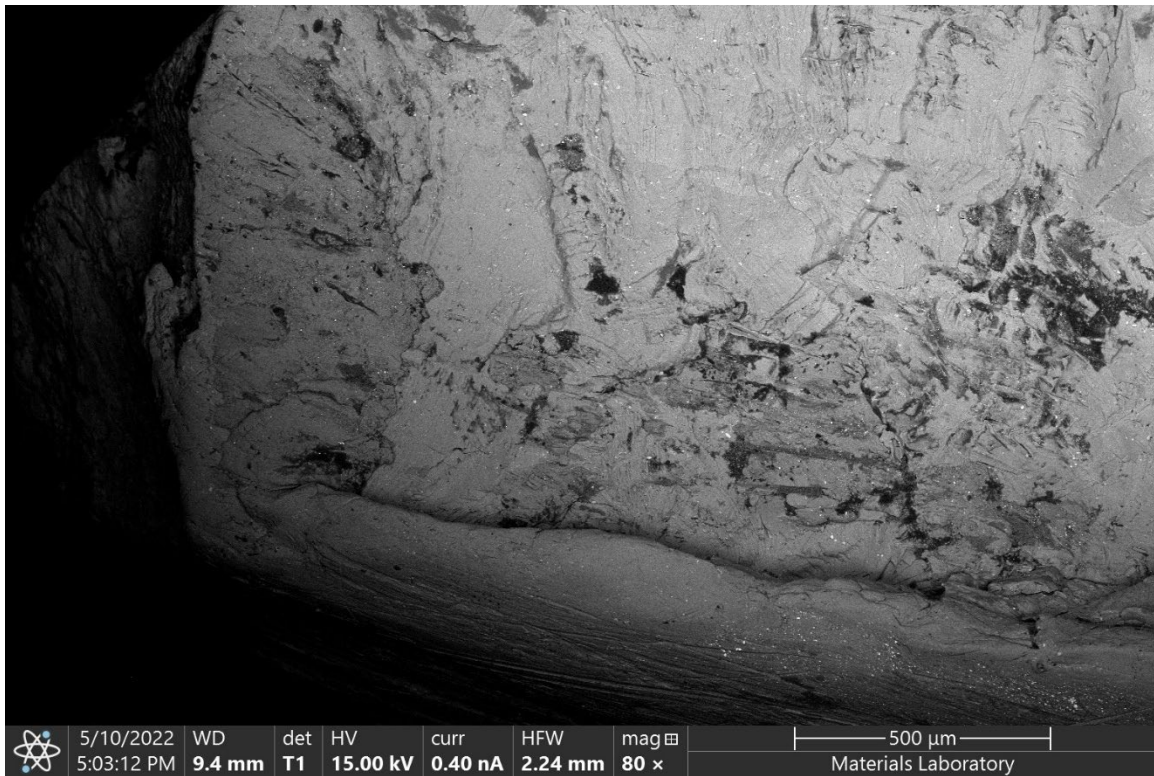


Figure 13 – Backscattered electron (BE) view of Figure 12.

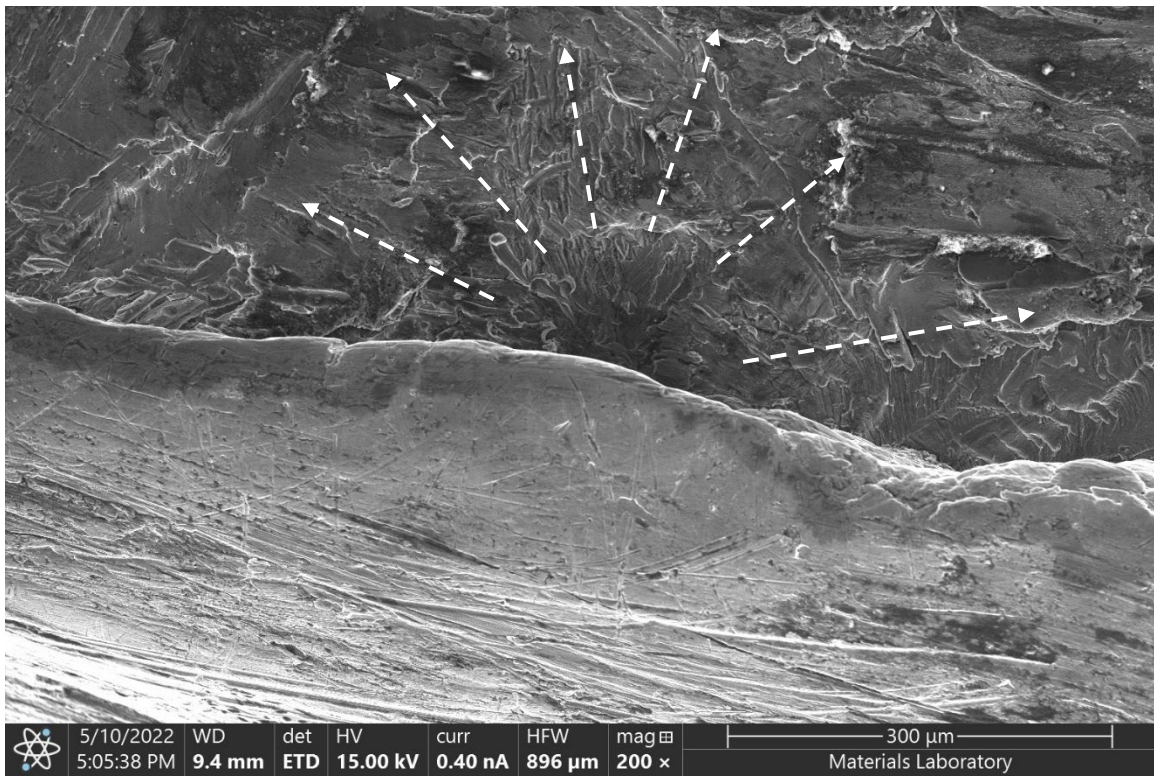


Figure 14 – SE micrograph of a closer view of a crack initiation site. The dashed white arrows demonstrate the crack growth directions.

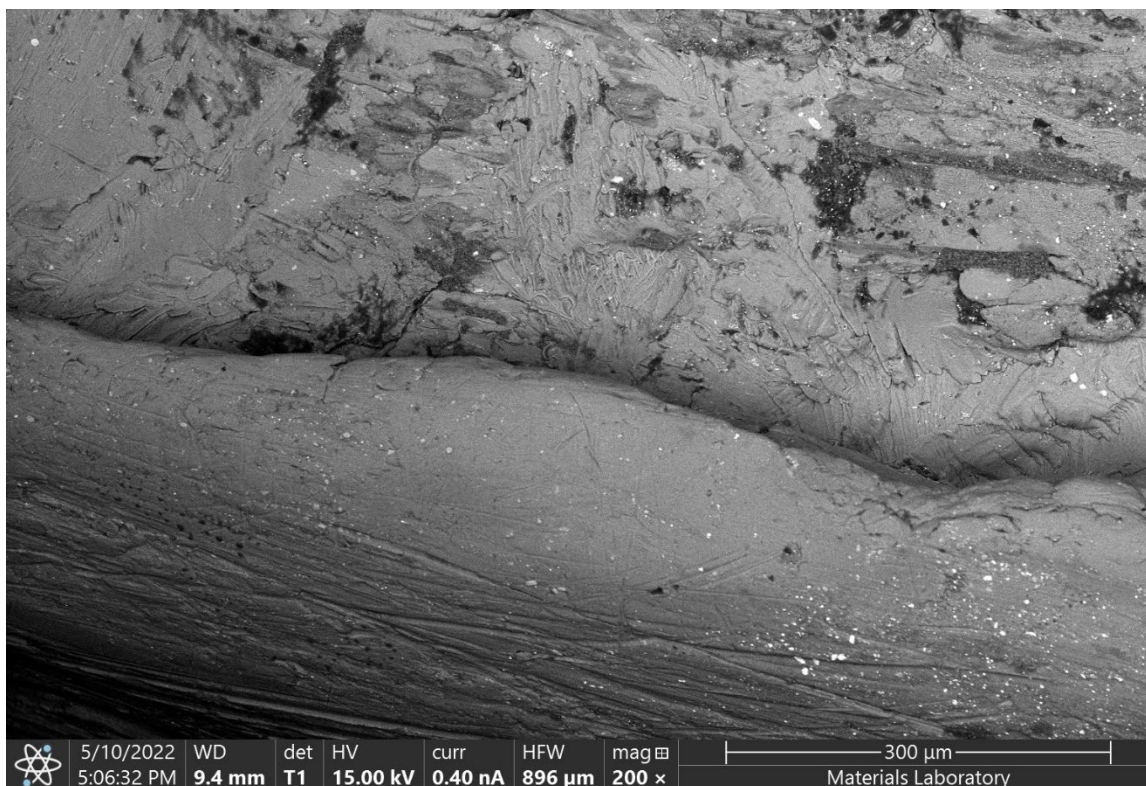


Figure 15 – BE micrograph of the initiation site in Figure 14.

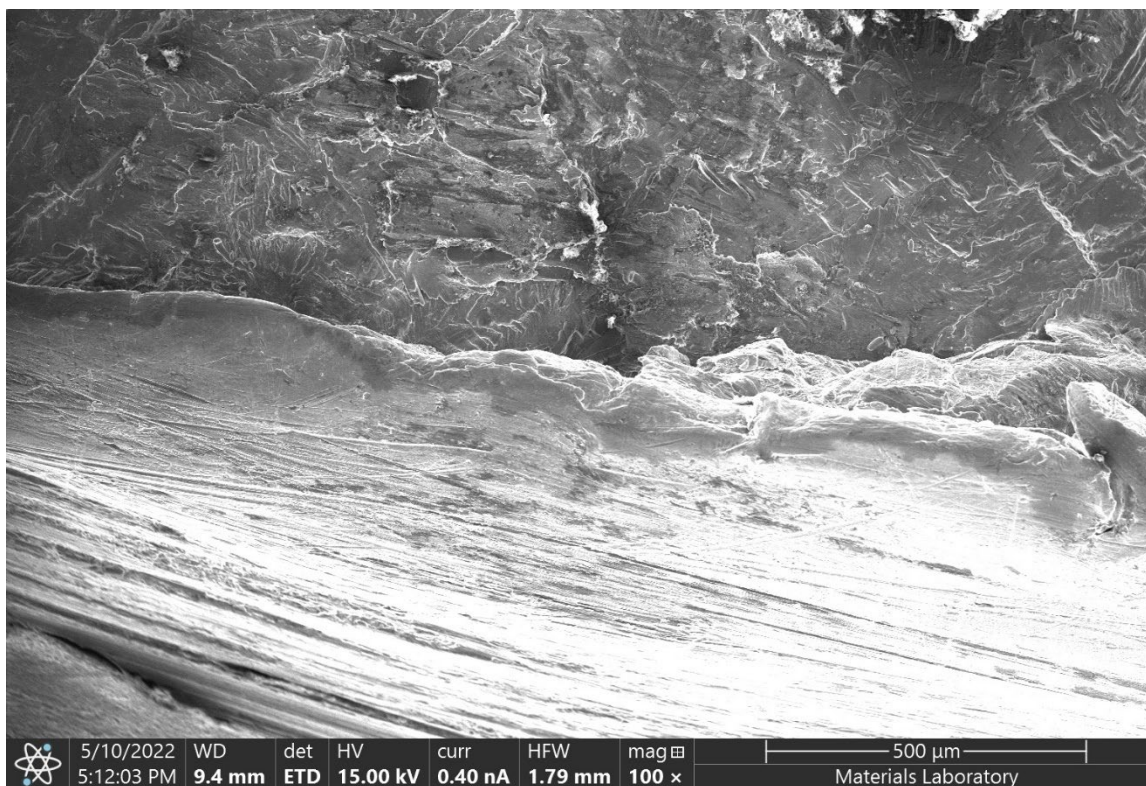


Figure 16 – SE micrograph of additional crack initiation sites along the (remnant bottom).

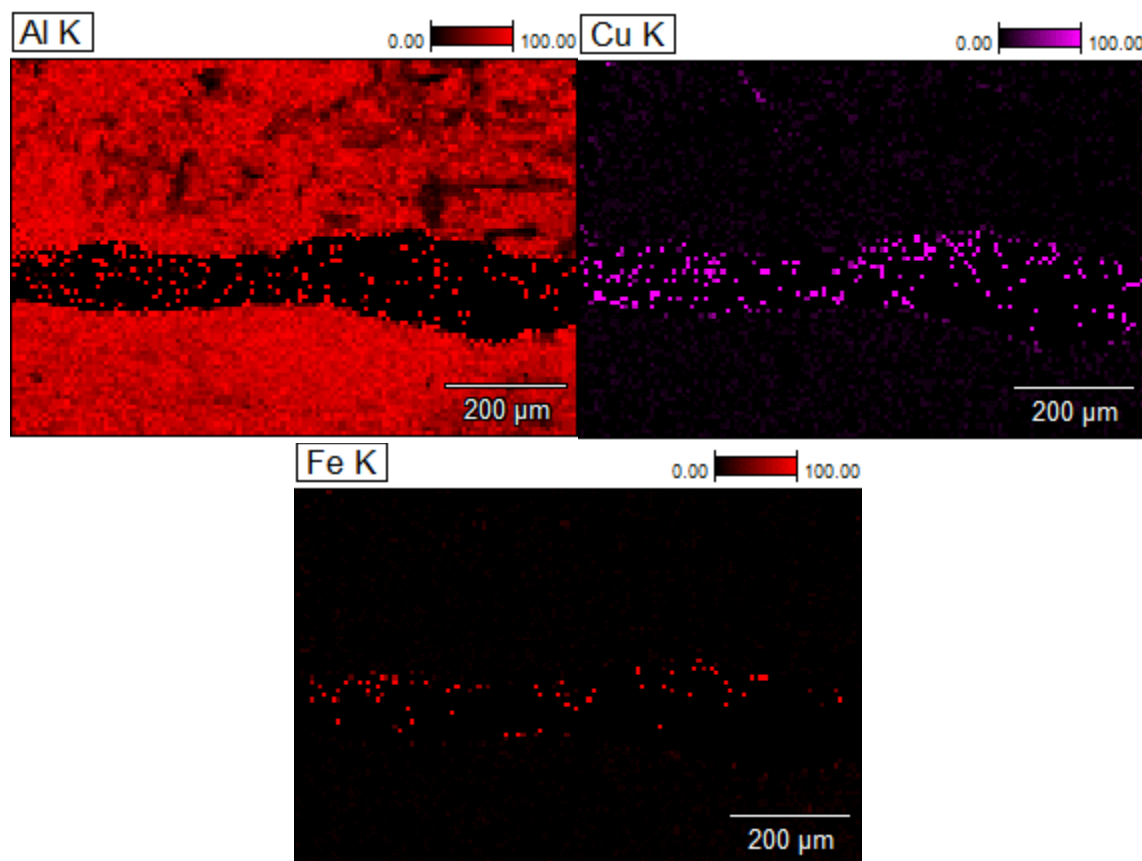


Figure 17 – X-ray maps of the area in Figure 14 and Figure 15, showing an area absent aluminum but rich in copper and iron along the edge of the fracture surface initiation sites.