

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



WPR23LA096

MATERIALS LABORATORY

Factual Report 23-059

August 6, 2023

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A. ACCIDENT INFORMATION

Location: Mesa, Arizona
Date: January 23, 2023
Time: 16:30 Pacific standard time
23:30 coordinated universal time
Vehicle: Cessna 170A, N9534A
Investigator: Kristyn Blocher, AS-WPR

B. COMPONENTS EXAMINED

Remnants of a landing gear leg

C. EXAMINATION PARTICIPANTS

Specialist Erik Mueller, Ph.D., P.E.
Office of Research and Engineering - Materials Laboratory Division
NTSB, Washington, DC

D. DETAILS OF THE EXAMINATION

On January 23, 2023, a Cessna 170A sustained substantial damage during an accident near Mesa, AZ. The pilot, flight instructor, and passenger were not injured. The pilot reported that the tailwheel-equipped airplane drifted to the left during the landing roll. After applying the right rudder to compensate, the airplane veered to the right, and ground looped. A post-accident examination of the airplane revealed that the left main landing gear leg had fractured near the retaining clip attachment point of the brake line. The remnants of this left main landing gear were sent to the NTSB materials laboratory for further examination.

Figure 1 shows the landing gear leg (skid) as received. The leg had broken 17.75 inches from the narrow downward-facing end on the right side of the figure and 23.25 inches from the wider upward-facing end (left in Figure 1).

Figure 2 shows the inboard fracture surface. Most of this fracture surface exhibited a rough, fibrous texture with a dull luster. This fracture surface exhibited chevron marks, consistent with fracture outward, starting along the centerline bore of the retaining clip. The chevron marks emanated from the upper location of the leg, along the inside bore, shown in Figure 3.

The most prominent fracture features originated at small thumbnail cracks, contrasting darker and flatter against the rest of the rougher surface (Figure 3). Figure 4 shows these cracks, annotated to show location and later fracture direction. On the left side of the figure was the largest of the cracks, measuring 2.49 mm (0.098 inches)

wide by 1.2 mm (0.047 inches) deep (see Figure 6). A smaller crack was adjacent to the largest one, located just above it.

On the opposite side were three smaller thumbnail cracks, the largest of which measured 0.49 mm (0.019 inches) wide by 0.33 mm (0.013 inches) deep (see Figure 7). Along the edge of the fracture surface with the radius of the bore, the periphery outside of the cracks exhibited either outward or inward surface features, oriented about 45° to the fracture. These features were consistent with shear lips.

The fracture surface was cleaned in an ultrasonic bath using acetone and then examined using a field emission scanning electron microscope (SEM). Figure 8 shows a closer view of the largest thumbnail crack. The features from this region of the fracture surface exhibited striations consistent with fatigue crack propagation (see Figure 9). The fatigue crack possessed oxide significant enough to obscure the underlying fatigue striations, demonstrated in Figure 10 by the darker gray areas.¹ However, as shown in a secondary electron micrograph in Figure 11, located in the same spot as Figure 10, all the fatigue crack surfaces exhibited some degree of surface oxidation, obscuring many underlying features.

Outside the fatigue crack, the fracture surface exhibited dimpled rupture, consistent with overstress fracture. Figure 12 shows a typical area of the subsequent overstress fracture, located just outside the largest fatigue thumbnail crack.

The fracture surface was cleaned again in an ultrasonic bath with an aqueous solution of Evapo-Rust.² Figure 13 shows the crack initiation site located at the radius of the bore. This location exhibited an inward recess with nonconductive compounds. Figure 14 shows a closer view of this area. The material was examined using energy dispersive x-ray spectroscopy (EDS) to determine its chemical composition.³ The material was consistent with iron oxide, with major amounts of sodium, potassium, calcium, chlorine, and phosphorus. These features were consistent with a corrosion pit at the fatigue crack initiation site.

Significant amounts of cadmium were also found in this area and along the fatigue crack. Cadmium was also found along the bore but was absent on surfaces outside this area. These data were consistent with a cadmium coating process along the valve bore.

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.

² Evapo-Rust - a commercially-available chelating rust stripper currently manufactured CRC Industries, headquartered in Horsham Township, PA.

³ Energy dispersive x-ray spectroscopy (EDS) - a characterization method coupled with SEM where the energy of x-rays characteristic to individual atoms are measured and used to identify elements

Figure 15 shows the smaller fatigue crack adjacent to the largest fatigue crack. This fatigue crack exhibited a corrosion pit at its crack initiation site, shown in Figures 16 and 17.

Figure 18 shows the trio of fatigue cracks on the opposite side of the bore. The largest of these cracks is shown in Figure 19, and with annotations in Figure 20. These figures demonstrate a unique quality of the cracks, which exhibited distinct subregions. Most of the fatigue crack located towards the initiation area showed enough surface oxide and contamination to obscure the underlying fracture features.

The later portions of the crack were absent much of this surface contamination and exhibited clearer striations. Figure 20 demonstrates a demarcation between the two regions, with the lower area appearing darker, consistent with more (thicker) surface oxidation, and the upper area being lighter with more pronounced features. These striations continued at the end of the crack, consistent with the propagation direction until abruptly transitioning to the subsequent overstress fracture, consistent with the final landing event (see Figure 21).

The different oxide areas were examined using EDS, based on their contrast color in backscattered mode in the SEM. Figure 22 shows some of the lighter gray oxides. This material was primarily iron oxide, with minor amounts of zinc and cadmium. Figure 23 shows a closer view of the darker gray oxide. This area exhibited mud-cracking and charging effects, consistent with nonconductive material. Per EDS probes, this area was primarily iron oxide but with high amounts of phosphorus and minor amounts of sodium.

The chemical composition of the leg was inspected on a sectioned area using x-ray fluorescence (XRF). The chemical composition was consistent with alloy steel. The hardness was examined per ASTM E18.⁴ The hardness averaged 47 HRC.⁵ This hardness was consistent with a quench and tempered condition for this alloy.

These features were consistent with fatigue cracking at the radius between the outboard surface and the bore. These fatigue cracks initiated at small corrosion pits along the radius, and propagated until the final landing, when the remainder of the leg fractured from overstress.

⁴ ASTM E18 - *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*. ASTM International, West Conshohocken, PA.

⁵ HRC - Hardness, Rockwell C scale. An indentation method of determining the hardness of harder metal alloys using a conical diamond indenter and 150 kg major load.

Submitted by:

Erik M. Mueller
Materials Research Engineer



Figure 1. View of the landing gear leg pieces, as received.

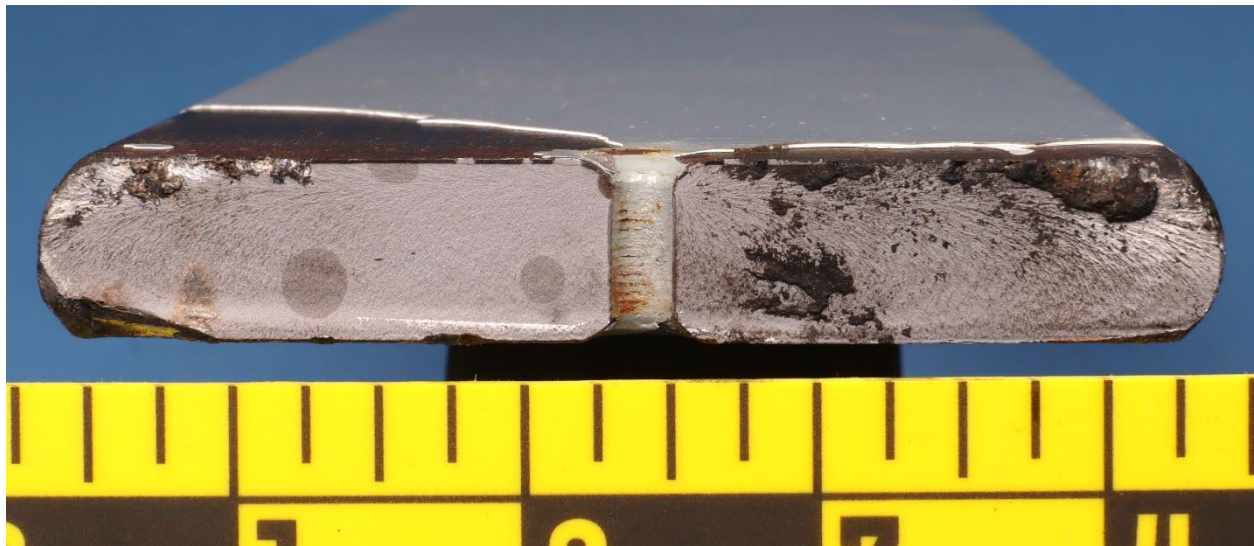


Figure 2. View of the downward leg fracture surface, as received.



Figure 3. Montage of the cleaned fracture surface near the centerline clip bore.

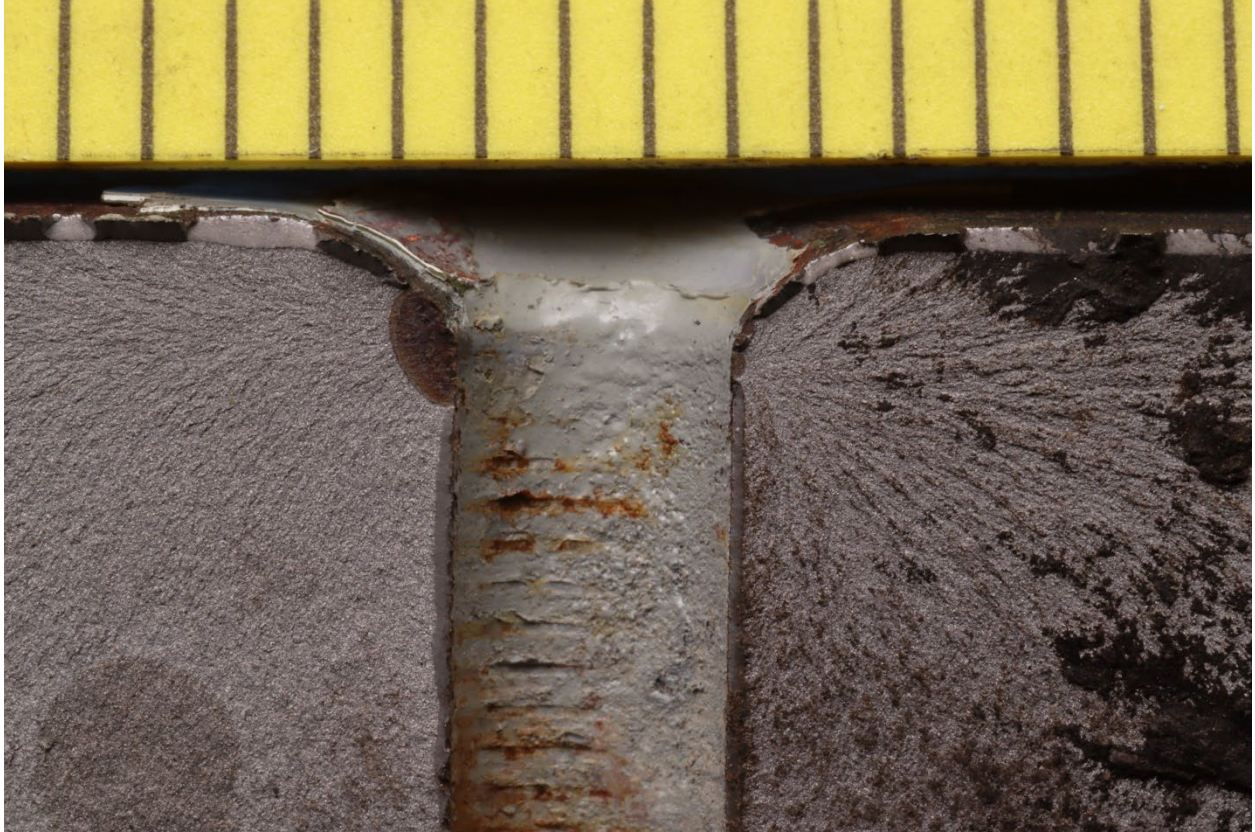


Figure 4. View of the outboard edge of the fractured leg in **Figure 2**, along the center clip bore, showing chevron marks emanating from darker colored thumbnail cracks.

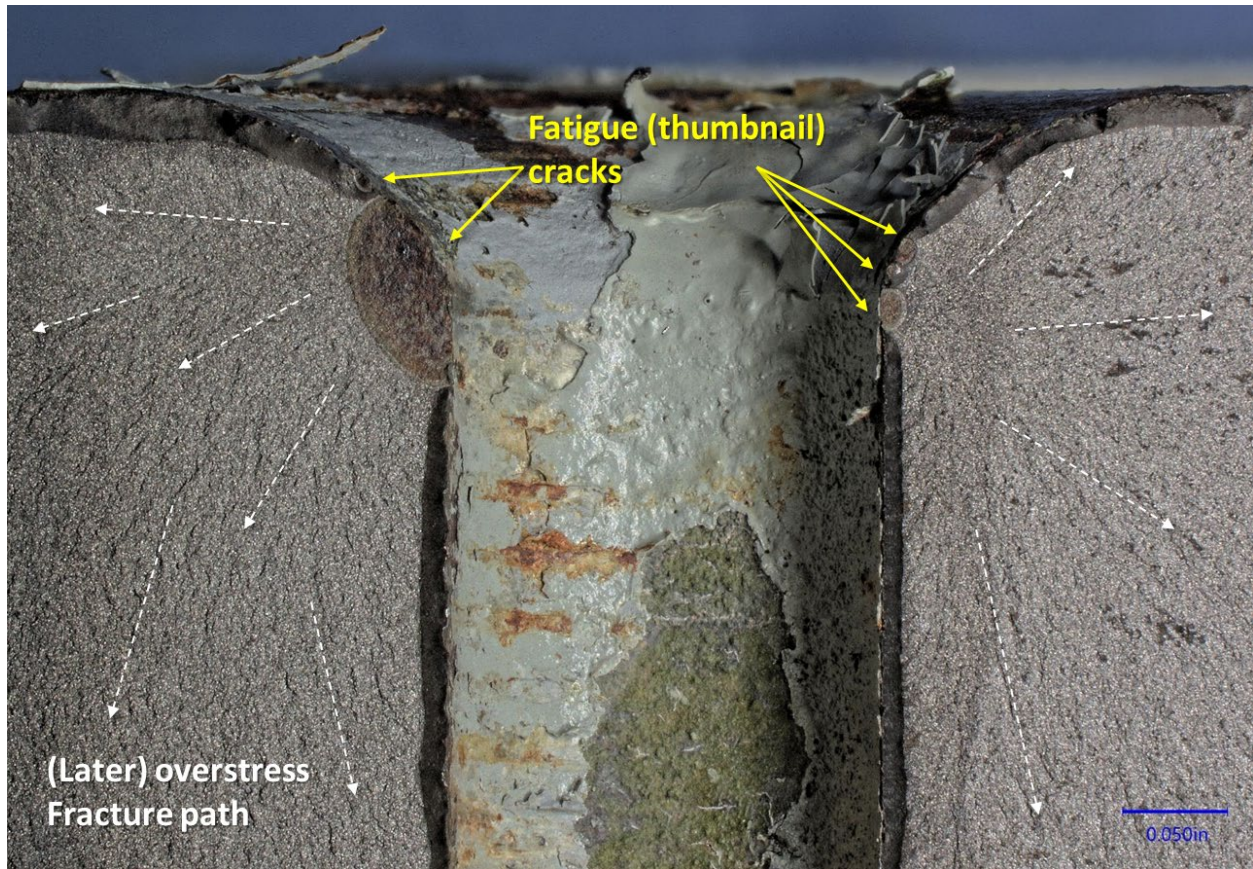


Figure 5. Closer view of the thumbnail cracks, after cleaning with acetone.



Figure 6. The largest thumbnail crack in the upper left of **Figure 5**, showing crack arrest marks.



Figure 7. View of the smaller thumbnail cracks in the upper right of **Figure 5**, showing crack arrest marks.

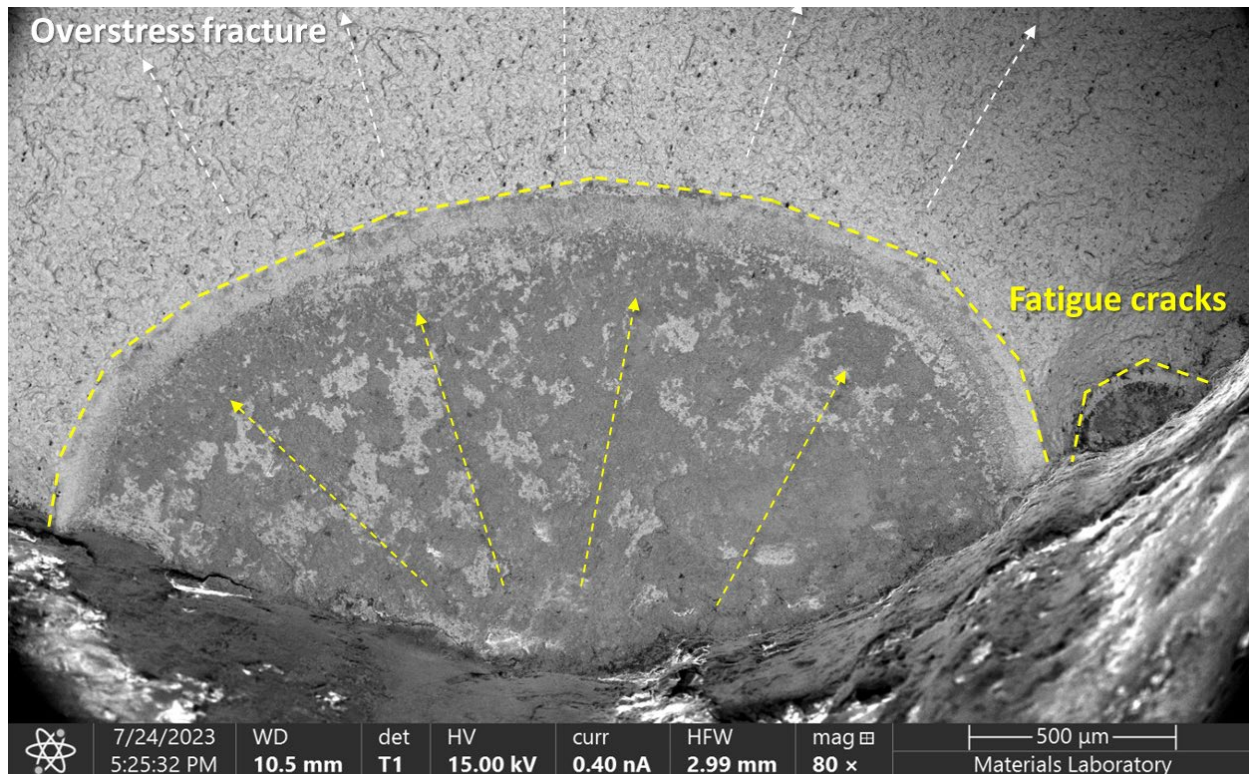


Figure 8. Backscattered electron (BE) micrograph of the largest thumbnail crack, showing lower-mass material on the surface and a second, smaller crack on the right.

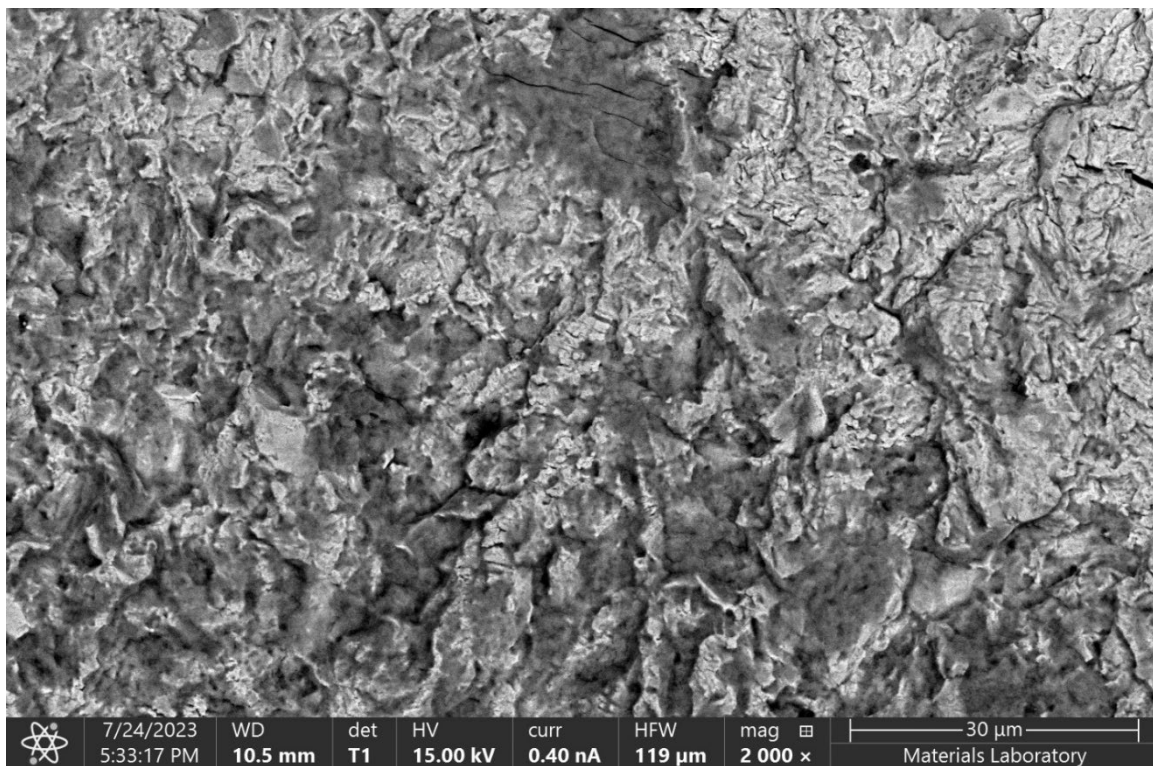


Figure 9. BE micrograph showing a closer view of the end of the crack, revealing fatigue striations.

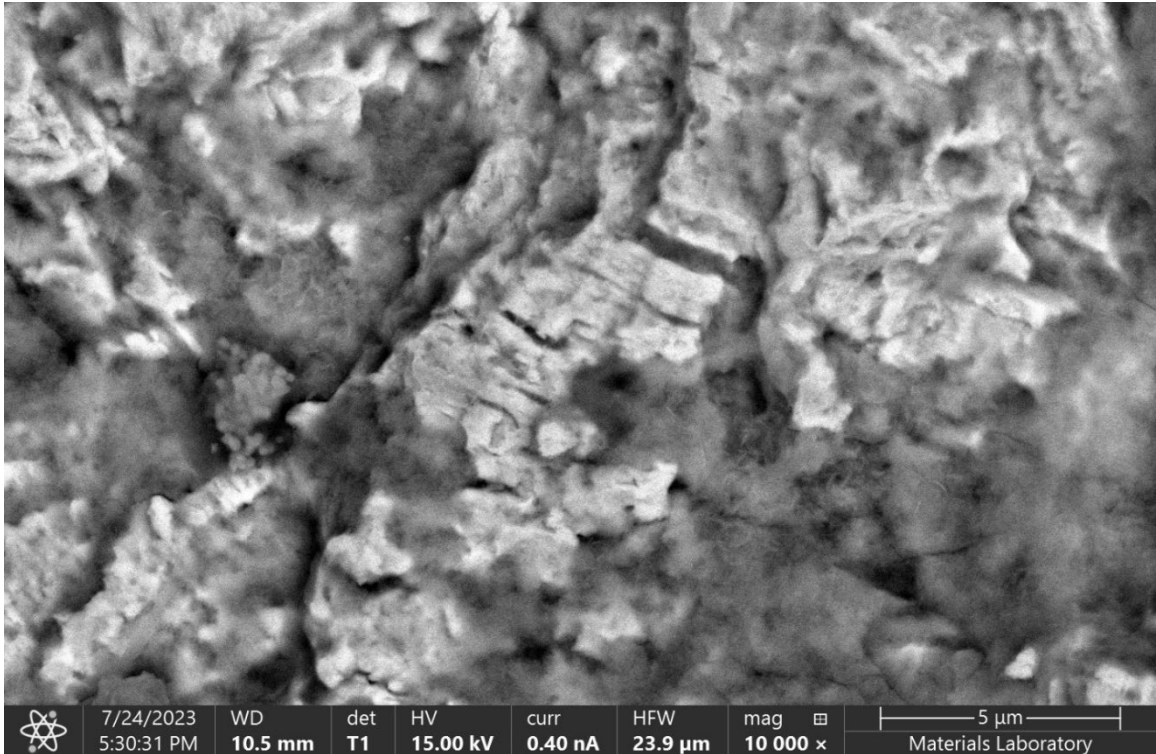


Figure 10. BE micrograph of fatigue striations from the area in **Figure 9**.

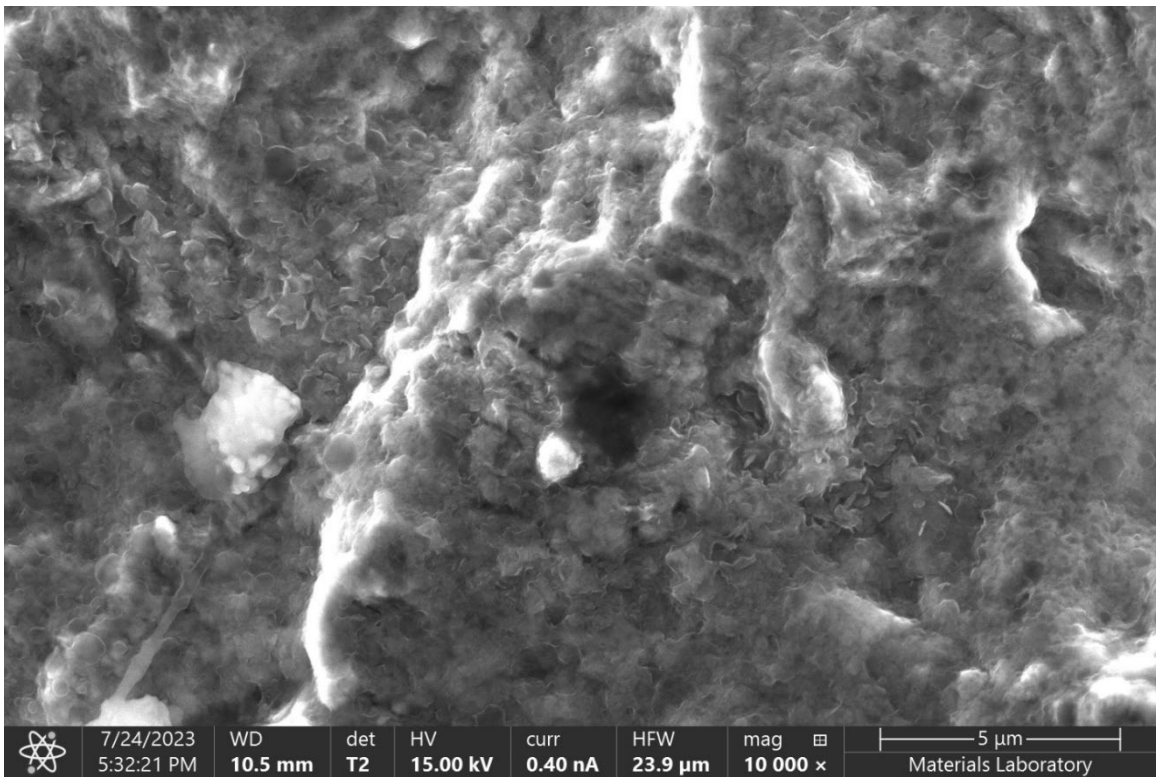


Figure 11. Secondary electron (SE) micrograph of the fatigue striations in **Figure 10**, showing the surface oxide layer.

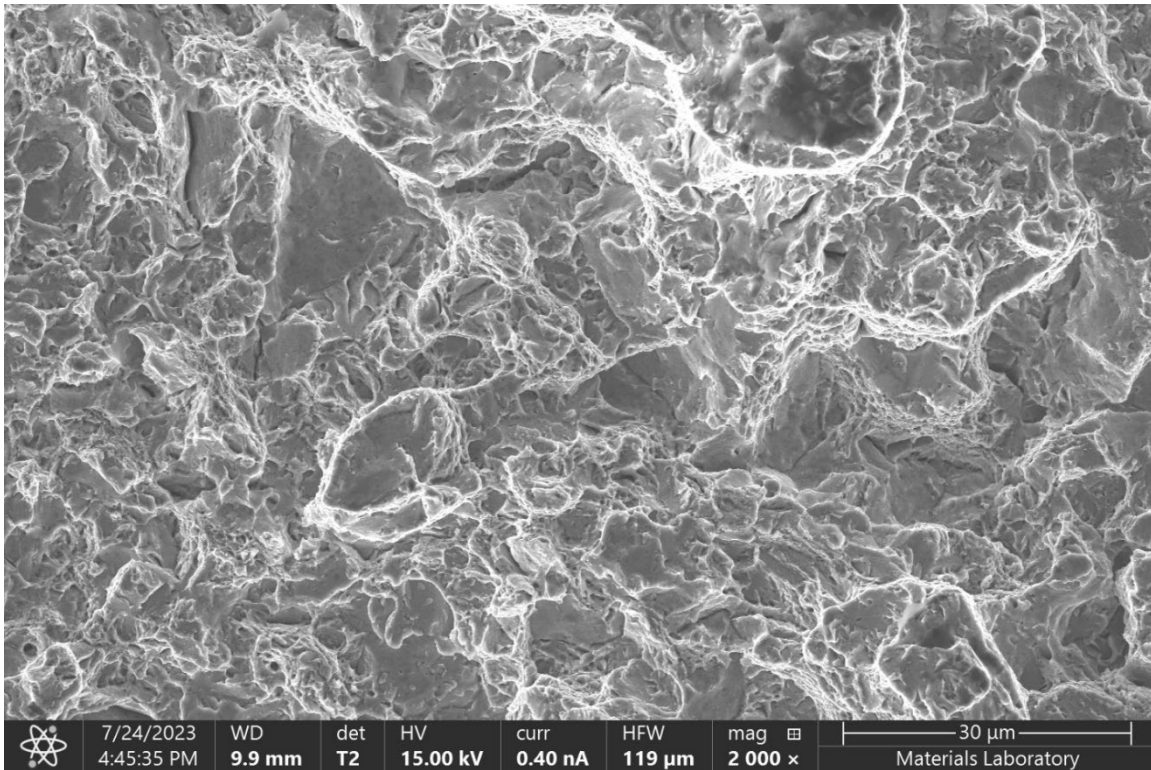


Figure 12. SE micrograph of dimpled rupture outside the thumbnail cracks on the fracture surface.

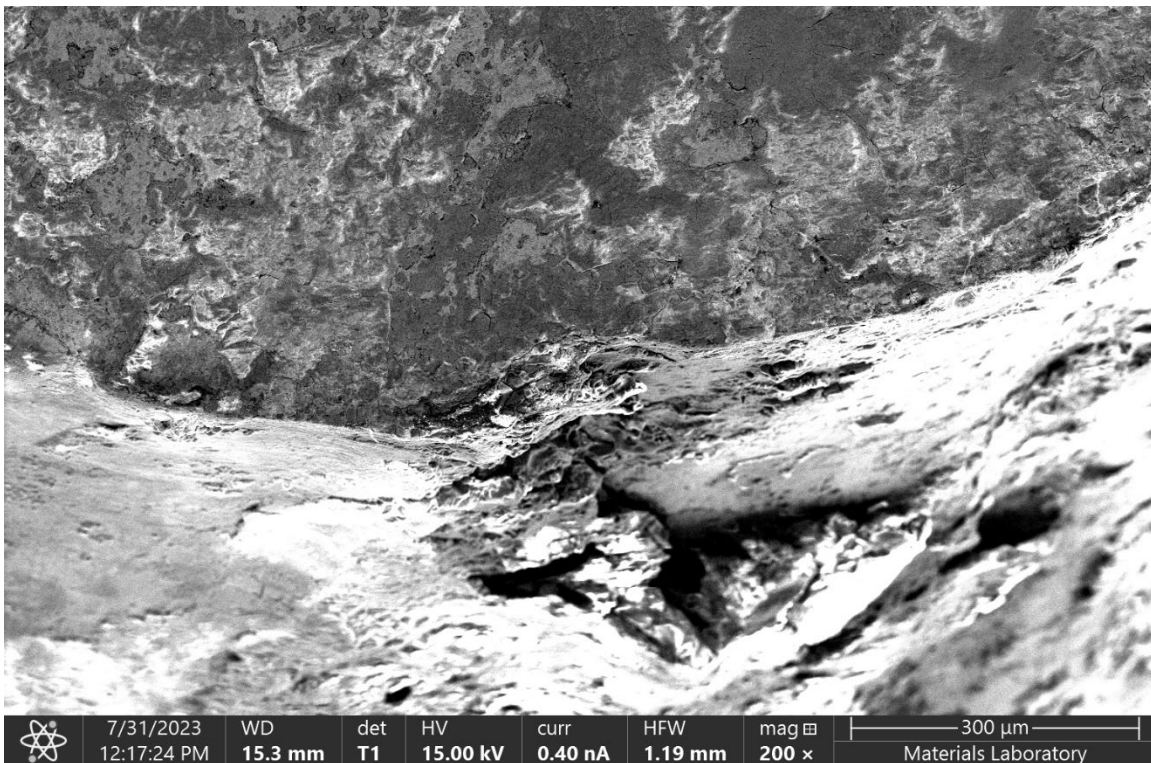


Figure 13. BE micrograph of the edge of the fracture, showing the fatigue crack initiation site obscured by surface oxide and contamination.

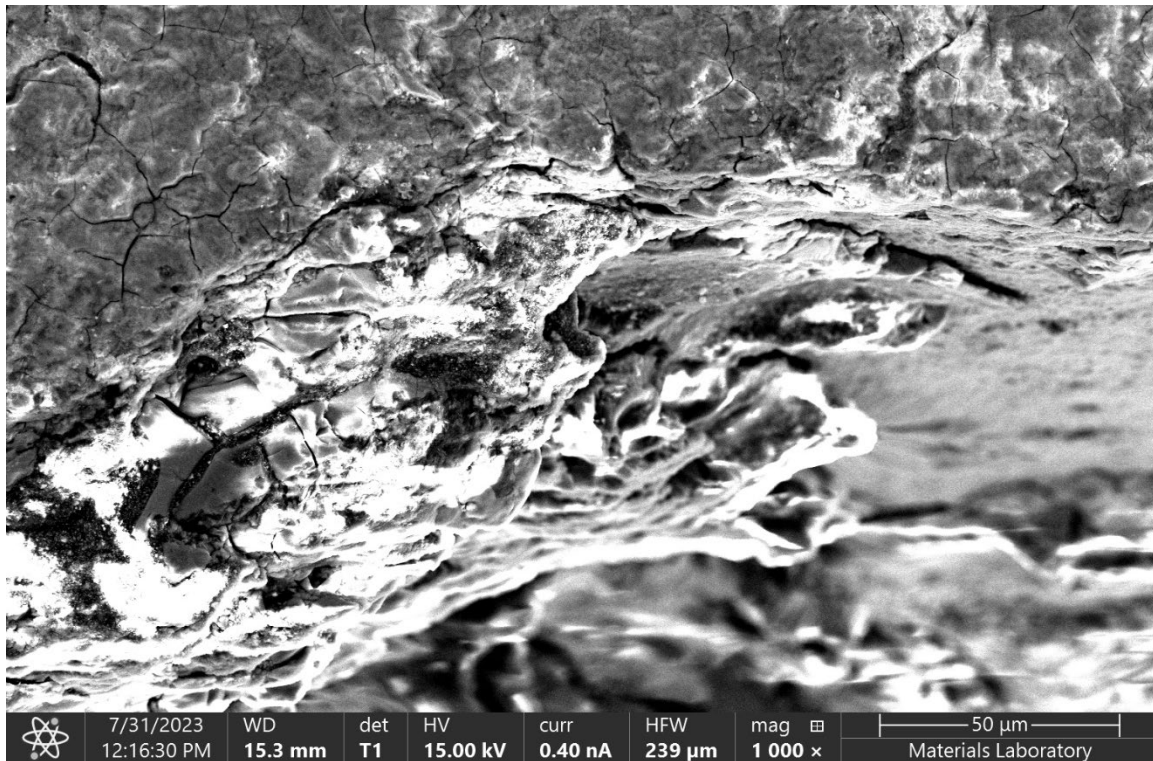


Figure 14. BE micrograph of the corrosion pit at the crack initiation site in **Figure 13**.

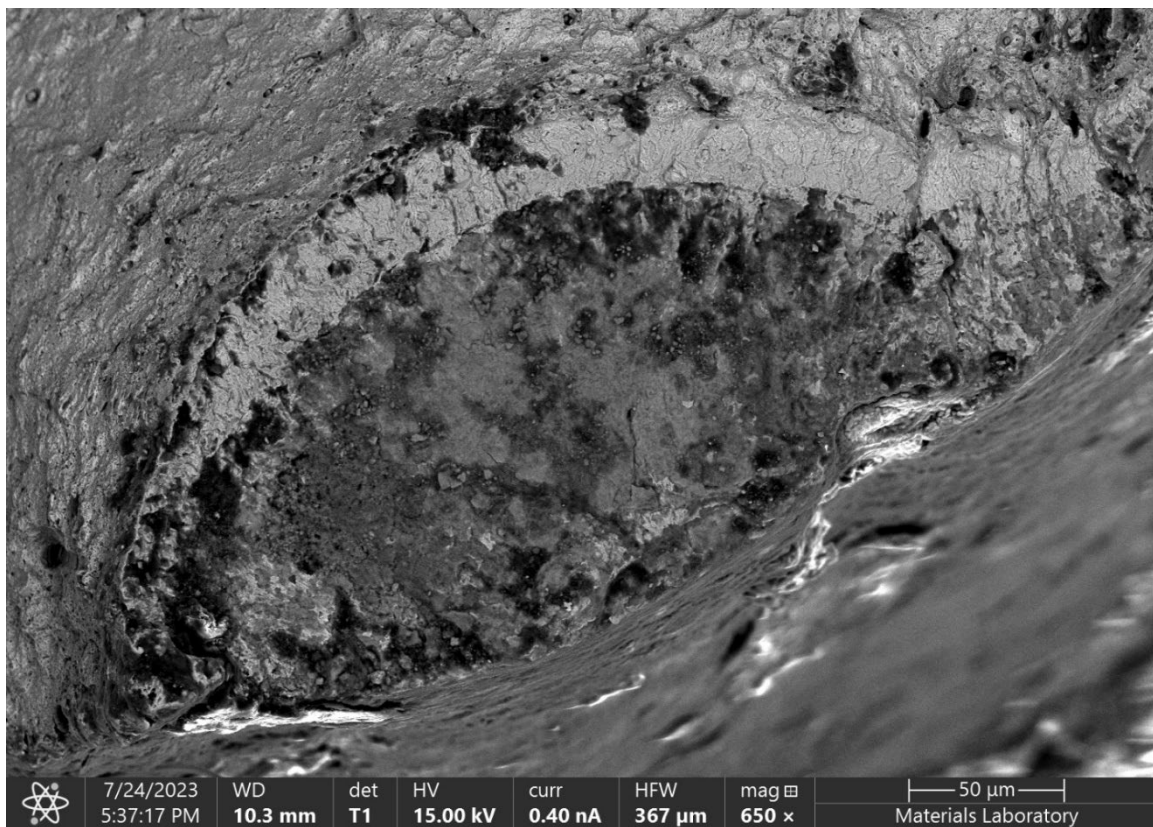


Figure 15. BE micrograph of the smaller fatigue crack towards the right in **Figure 8**.

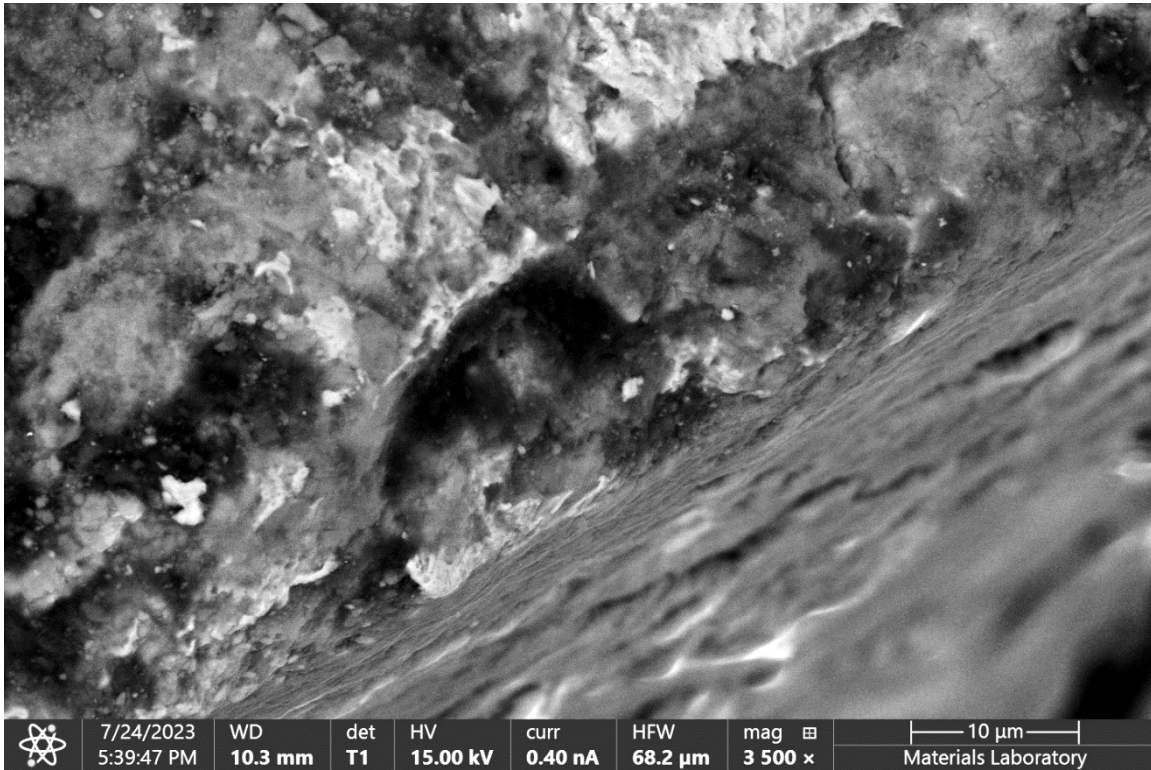


Figure 16. BE micrograph of the initiation site of the fatigue crack in **Figure 14**, showing a pit like divot.

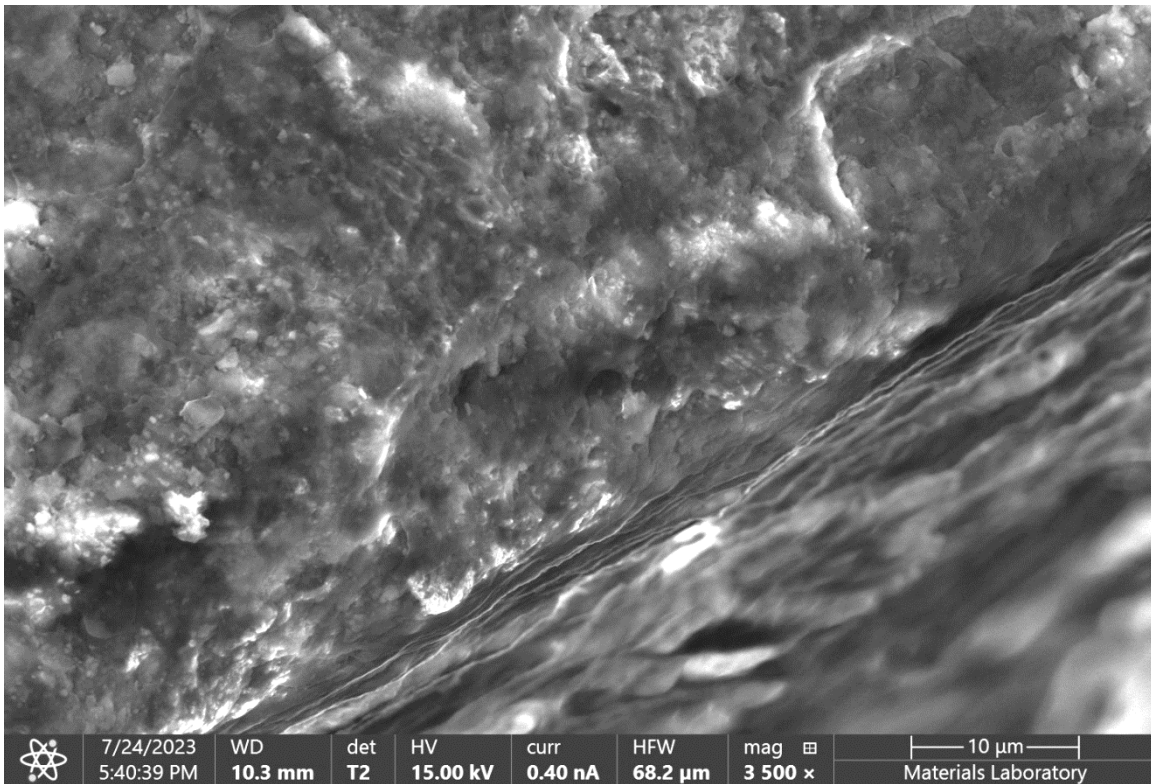


Figure 17. SE micrograph of the crack initiation site in **Figure 15**.

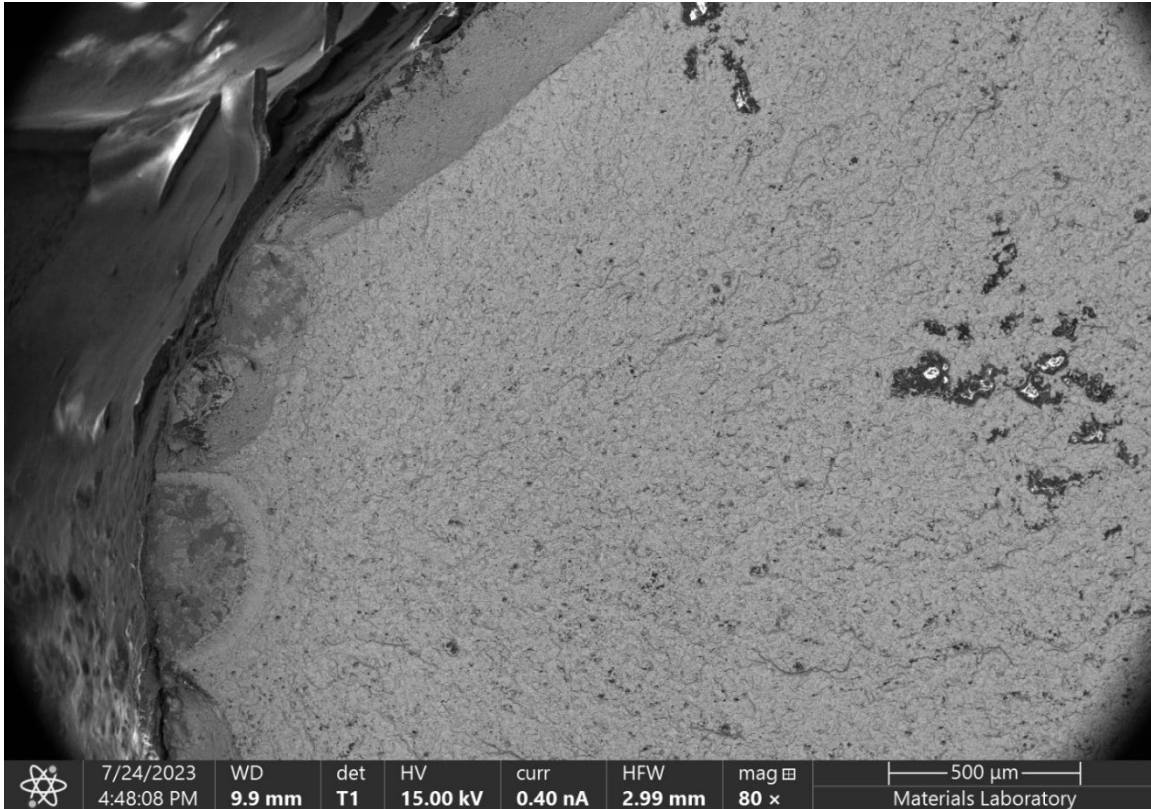


Figure 18. BE micrograph of the smaller fatigue cracks in the right in **Figure 5**.

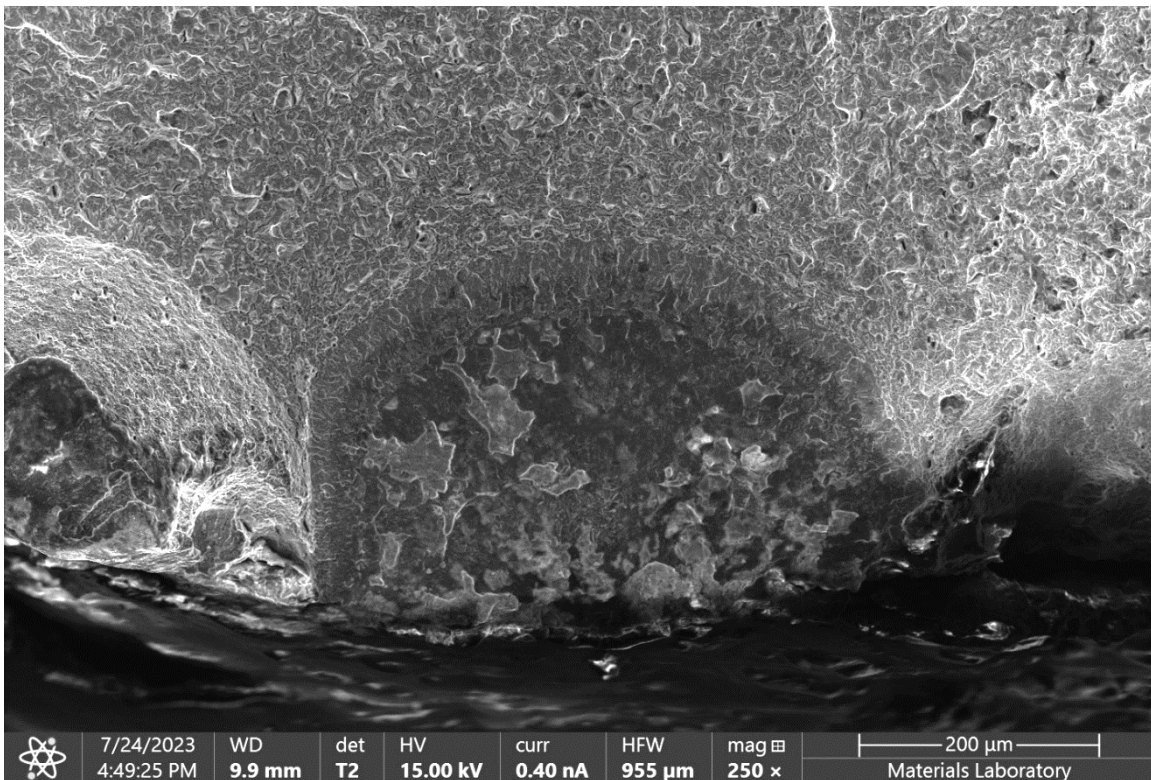


Figure 19. SE micrograph of the largest of the three cracks in **Figure 17**, rotated 90°.

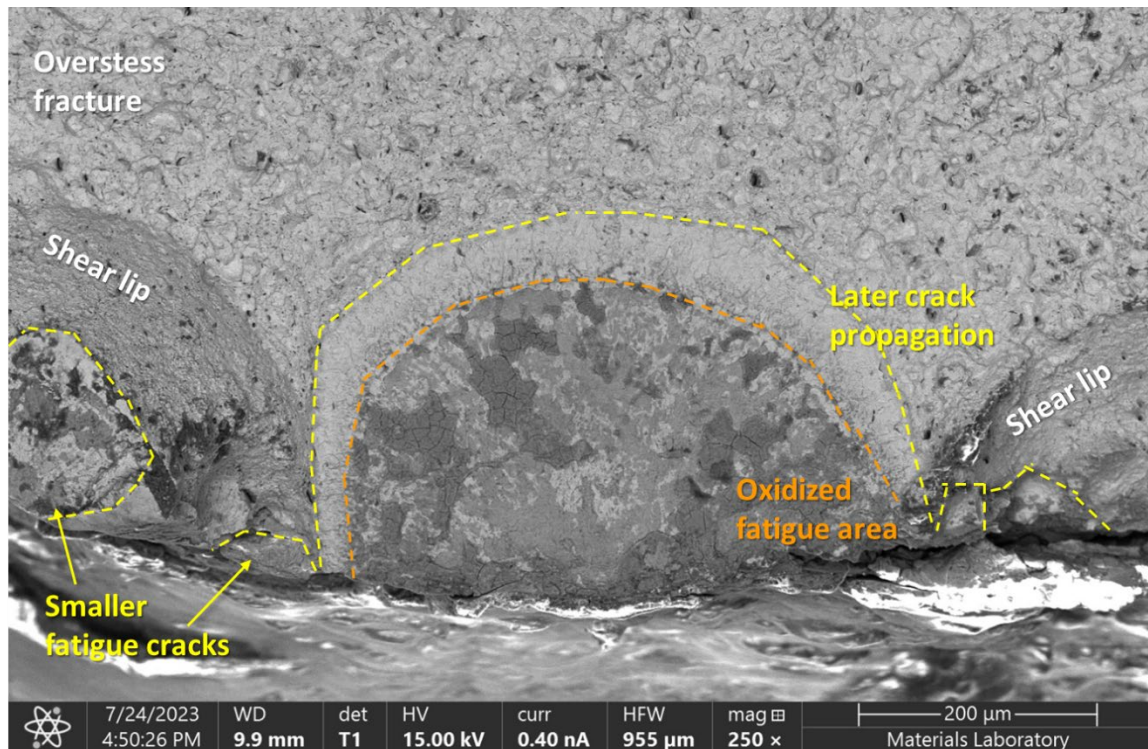


Figure 20. BE micrograph of the fatigue crack in **Figure 18**, showing areas of surface oxide and later crack growth.

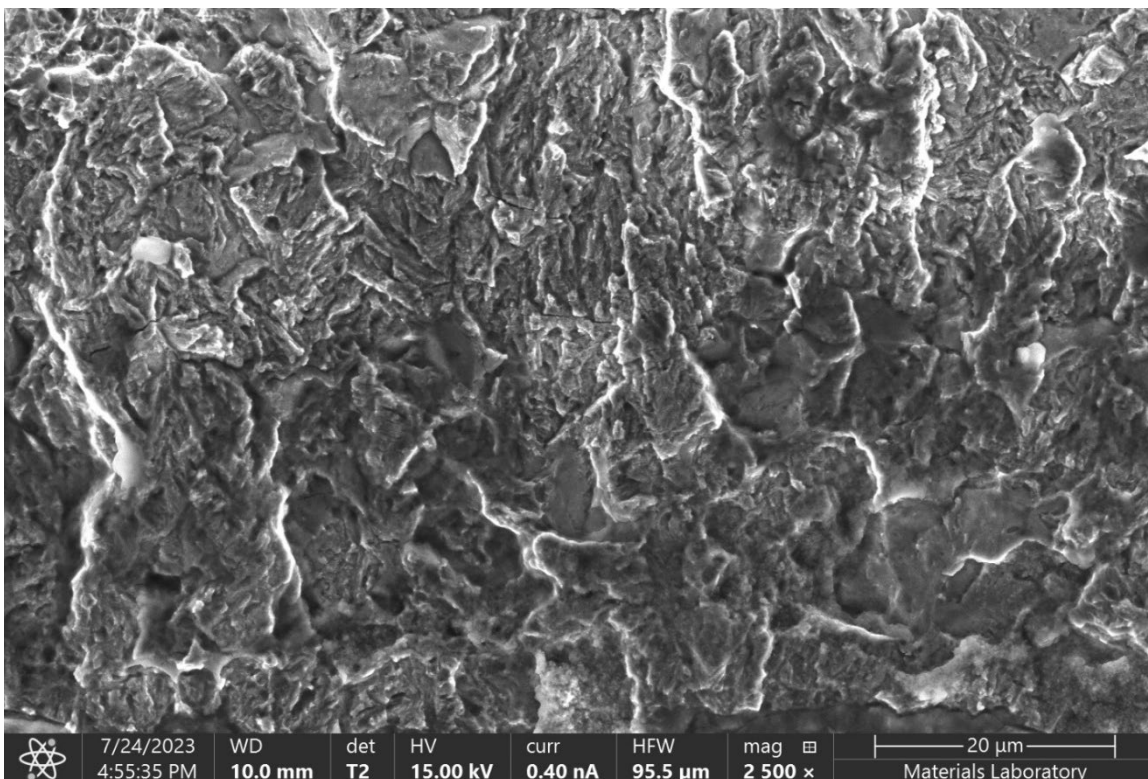


Figure 21. SE micrograph of the area of demarcation between the earlier (lower) and later (upper) crack growth in the fatigue crack in **Figure 19**.

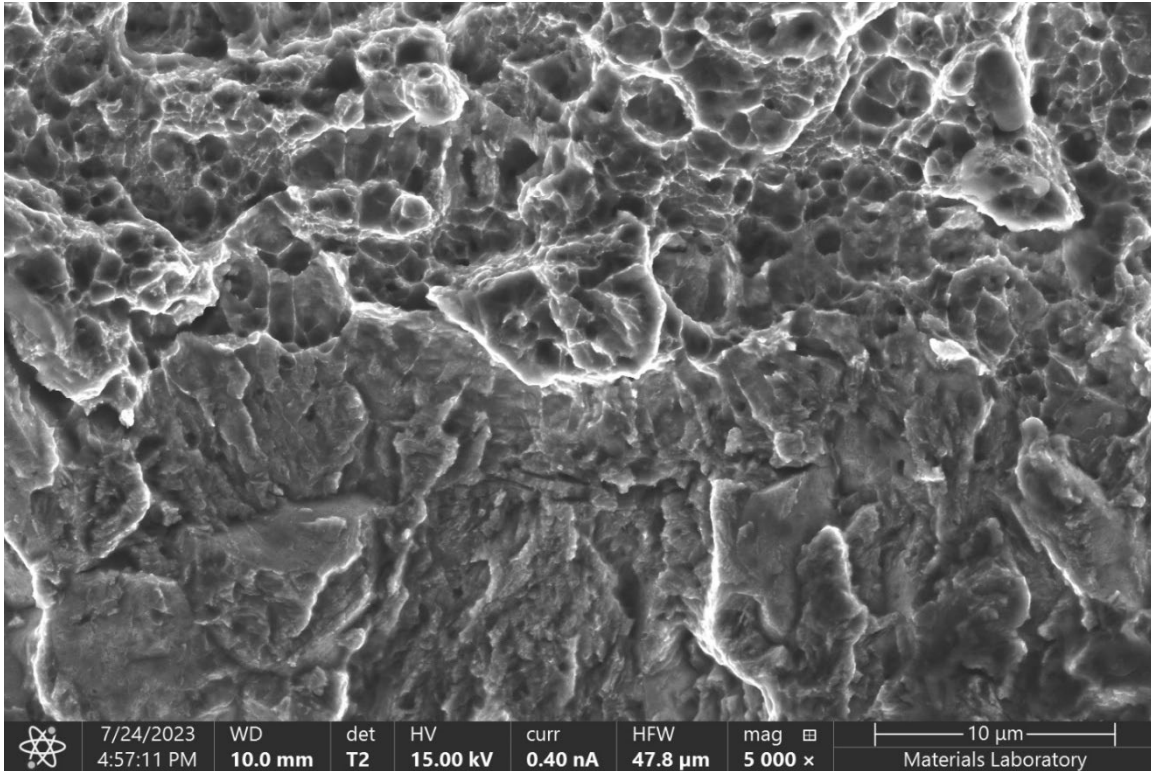


Figure 22. SE micrograph of the line of demarcation between the fatigue crack (lower) and the overstress fracture / dimpled rupture (upper) regions in **Figure 19**.

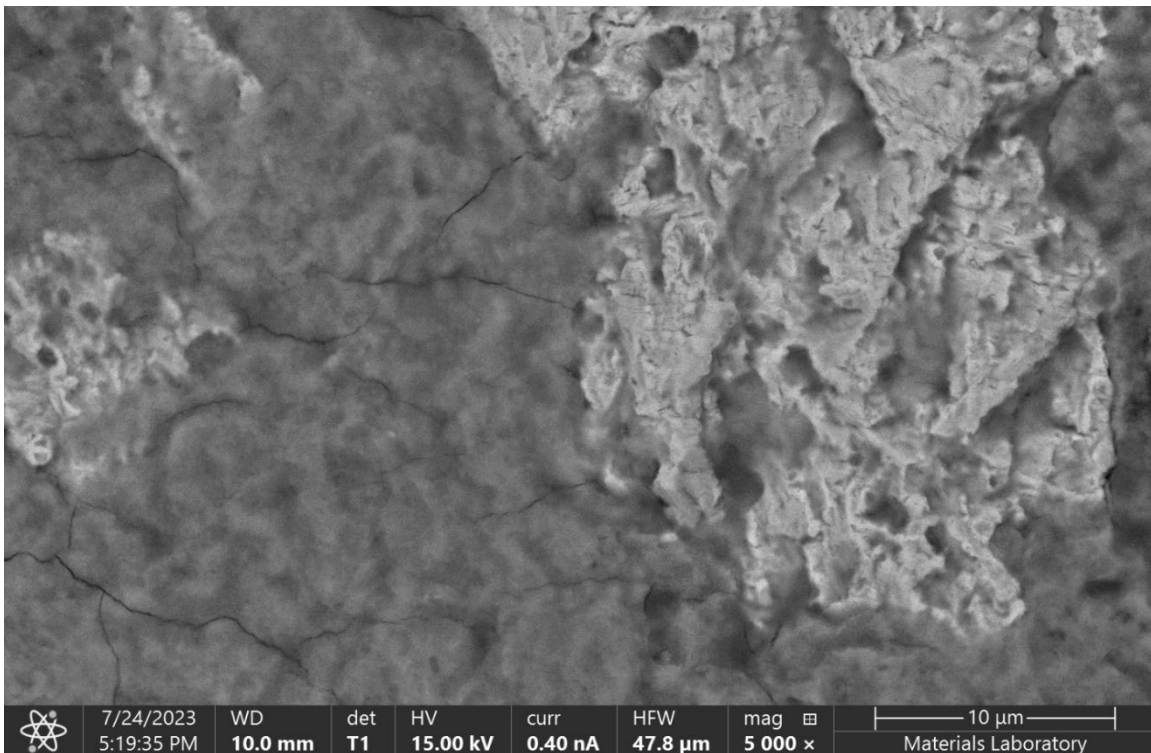


Figure 23. BE micrograph near the crack initiation site, showing darker-contrasting oxide over underlying fatigue striations (lighter contrast).

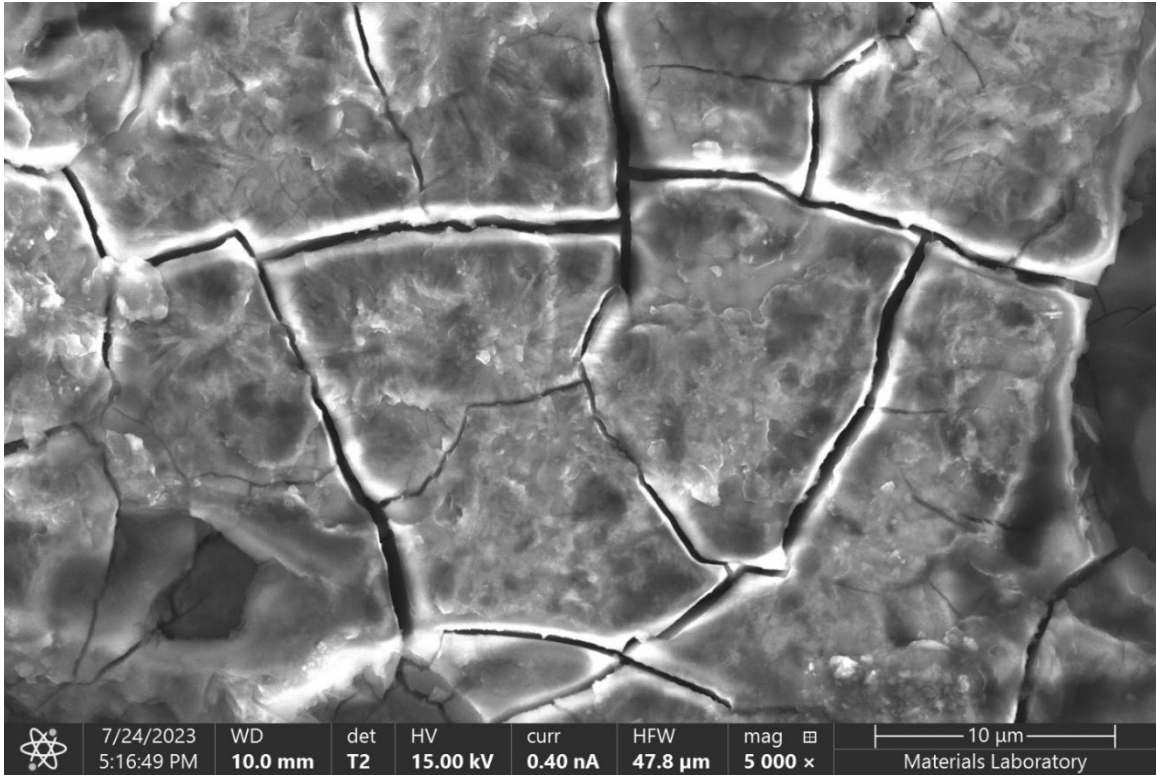


Figure 24. SE micrograph of thicker oxide near the crack initiation site.