

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



CEN24LA088

MATERIALS LABORATORY

Factual Report 24-021

May 16, 2024

(This page intentionally left blank)

A. ACCIDENT INFORMATION

Location: Spofford, Texas
Date: January 11, 2024
Time: 19:00 central standard time
01:00 coordinated universal time
Vehicle: Eurocopter AS 350-B2, N204TX
Investigator: Mitch Gallo, AS-CEN

B. COMPONENTS EXAMINED

Fuel control unit assembly
Remnants of a fuel control unit actuated arm

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 11, 2024, a Eurocopter AS 350 B2 was substantially damaged when it was involved in an accident near Spofford, TX. The pilot and copilot received minor injuries. During the flight, the pilot felt a violent yaw to the right, saw the engine low-pressure annunciator illuminate, and heard the low rotor horn. After noting the rotor rpm had returned to the normal operating range, the pilot transferred controls to the copilot. The copilot then autorotated and landed the helicopter in a brush-covered field. The aircraft sustained substantial damage to the tail boom and main rotors. The helicopter wreckage was retained, and the fuel control unit subassembly was sent to the NTSB Materials Laboratory for additional examination.

The examination of the pieces from a fuel control unit for the Materials Group of NTSB investigation CEN24LA088 took place at the 5th floor materials laboratory at NTSB headquarters in Washington, DC, on Thursday, February 15, 2024.

The fuel control unit examination focused on the actuated arm, shown in Figure 1. This part had fractured along the two sides of the yoke as it transitioned from the arm to the post. The part exhibited ferromagnetic properties when placed near a permanent magnet. The arm body exhibited two sets of markings, one electroetched and one manually vibroetched. The markings stated:

64D47660 R181M
65.04.381.0 P172MTM

Figures 2 and 3 show the mating fracture surfaces from the post and the actuating arm, respectively. Each fracture surface exhibited a general rough surface texture with a reflective luster, though each also exhibited an area of 20-35% that was flatter and smoother in shape. The bore of the actuating arm, shown in Figure 3, exhibited circumferential marks, consistent with machining marks, along with areas of divots or depressions.

The adjustment bolt in the post shown in Figure 2 exhibited some localized plastic deformation on the edges of the hexagonal head. There were no corresponding witness marks on the face of the post. After removal of the bolt, the mating threads were examined. These areas bore no indications of severe wear, gouging, or corrosion.

For this report, the fracture surfaces were labeled 1 and 2. Figure 4 shows an annotated view of Fracture 1, which exhibited a larger flatter area than Fracture 2. This flatter area exhibited crack arrest marks, consistent with crack propagation under cyclic loading, and ratchet marks, consistent with crack initiation at multiple sites. This initiation area was located to the left of the larger reflective, rough area, shown on the right in Figure 4.

The rightmost edge of Fracture 1 is shown in Figure 5. The edge exhibited an area with a compound that exhibited a darker contrast in backscattered mode.¹ This area is highlighted in Figure 6. This figure shows that the material exhibited charging effects, consistent with its nonmetallic (nonconductive) properties. The chemical composition of the compound was examined using energy-dispersive X-ray spectroscopy (EDS), which was consistent with iron oxide.

EDS examinations of uncontaminated portions of the fracture surface showed the arm material was consistent with stainless steel.

This iron oxide exhibited a wrinkled and undulating surface morphology. The oxide had also cracked in multiple locations. This oxide adhered to the fracture surface, even after cleaning in an ultrasonic bath with acetone.

Figure 7 shows a closer view of the crack initiation area of the flatter region of Fracture 1. This area showed ratchet marks consistent with initiation along the rougher, reflective portion of the fracture surface. One of the crack initiation sites is highlighted in Figure 8. This region shows vertical ratchet marks bounding the site and horizontally oriented parallel striations, consistent with fatigue crack propagation after the crack initiates. As demonstrated in Figure 9, the striations were consistent

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

with crack propagation from the rougher fracture area (right in Figure 4) inward (to the left in Figure 4).

A void was observed below the initiation region in Figure 4, which is annotated by the cyan box and highlighted in Figure 10. The area, shown closer in Figure 11, exhibited smooth surface areas, consistent with internal surfaces typical of solidification voids between the dendrites that form during the casting process. These regions would not have been attached and bore no applied stresses before fracture. In contrast, the rougher areas at the bottom of Figure 11 were consistent with dimpled rupture from overstress fracture. These regions would have been intact before the fracture, breaking under stresses exceeding the local fracture strength.

Figure 12 shows an annotated view of the Fracture 2 surface. This surface exhibited similar fracture feature patterns to Fracture 1, except that the fatigue crack propagation region was smaller. Figure 13 shows the edge of the fracture surface, which was the rightmost edge as oriented in Figure 12. Overall, this surface exhibited large faceted features, also observed in Fracture 1. A closer view of these areas of the fracture surface revealed faceted fracture features with gaps and separation between grains. These features were most prevalent at triple points between grains, illustrated in Figure 14.

These grain facets exhibited parallel features, which were not consistently oriented over the entire fracture. These features also intersected other linear features, consistent with the microstructure morphology of dendrites from cast components. Figure 15 shows a closer view of the interdendritic fracture features. These faceted features were interspersed with areas of dimpled rupture, as illustrated in the middle of Figure 14. These features were consistent with mixed intergranular and overstress fracture over part of the arm yoke cross sections.

Figure 16 shows the fatigue crack region of Fracture 2. Like in Fracture 1, this region exhibited crack arrest marks and ratchet marks consistent with fatigue crack propagation from multiple initiation sites consistent with the faceted features of the initial fracture region. Figure 17 shows the end of this fatigue crack, demonstrating the crack arrest marks. A closer view of this crack portion shows the fine fatigue striations, typical of high-cycle or low-load fatigue (see Figures 17 and 18).

Outside of this crack, the fracture surface exhibited dimpled rupture, consistent with subsequent overstress fracture of the remaining yoke ligaments (Figure 20). In contrast to the fracture surface before the fatigue crack initiation, this area of subsequent overstress fracture was not faceted and consistently exhibited dimpled rupture rather than interdendritic fracture features.

These features were consistent with the initial fracture of the arm clevises through about two-thirds of the cross-section. This crack or fracture edge of this early fracture

then initiated fatigue cracking at multiple sites. Once the fatigue cracks had propagated deep enough, the remainder of the clevis cross sections fractured via overstress.

Submitted by:

Erik M. Mueller
Materials Research Engineer

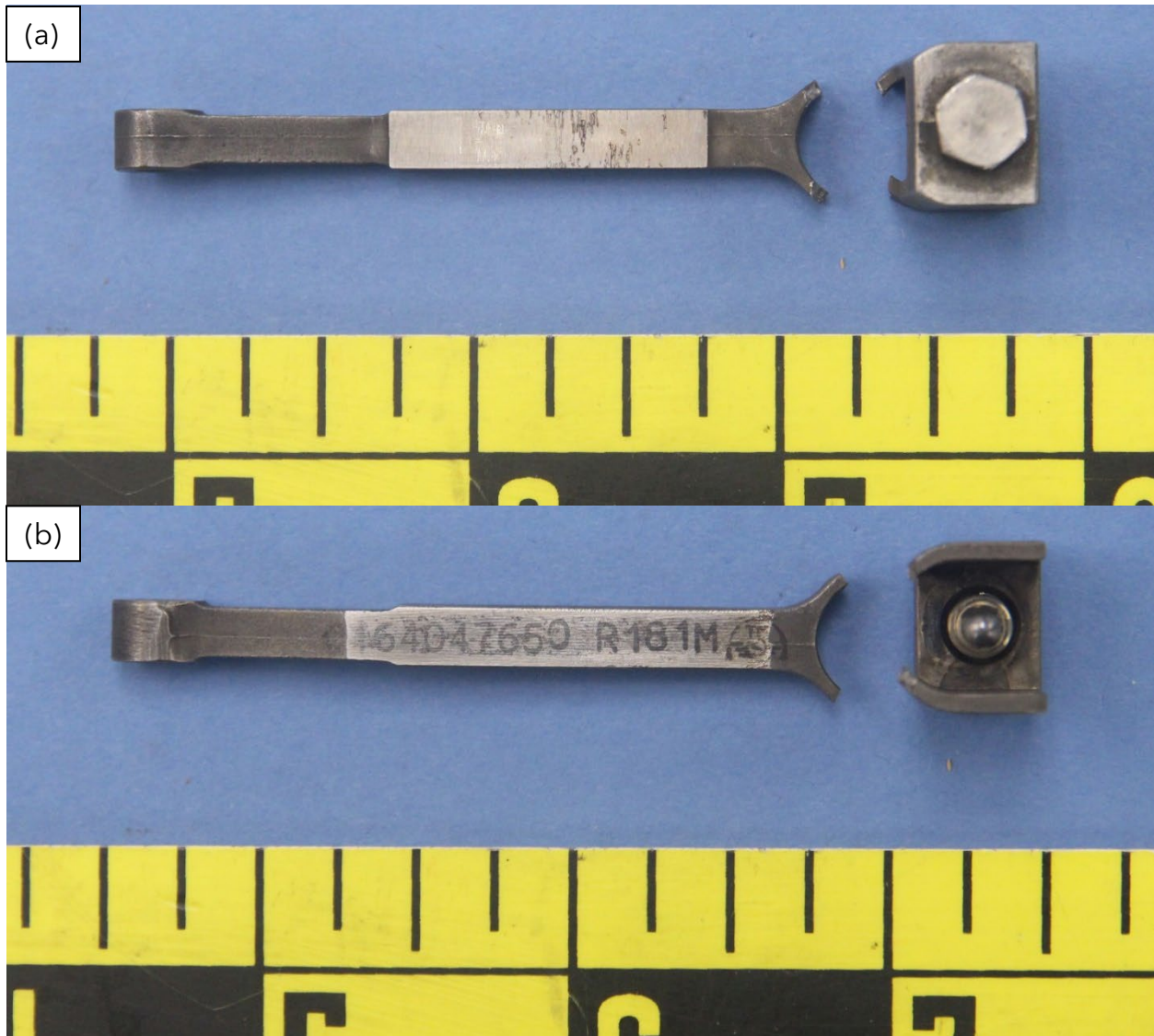


Figure 1. Opposite sides of the arm from (a) the upward facing sides and (b) the downward facing sides.

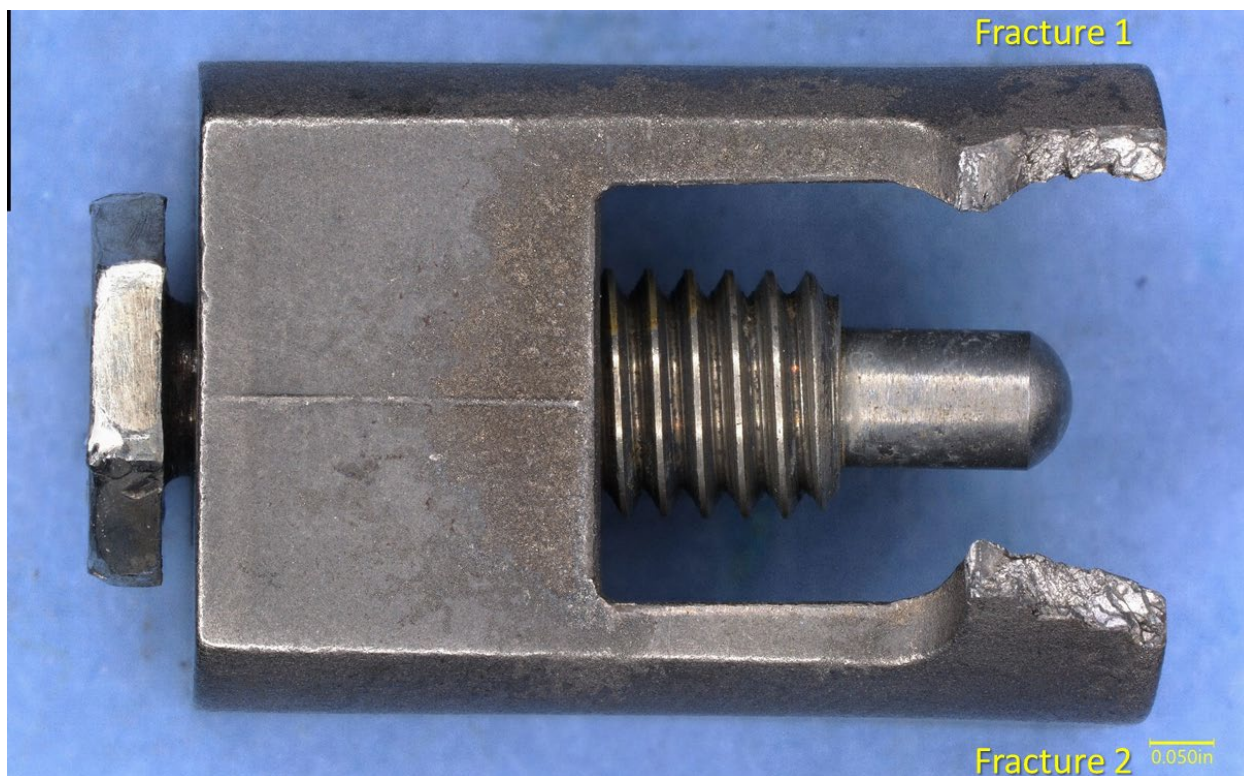


Figure 2. The fractured side of the post, showing the two fractures and the nomenclature used in this report.



Figure 3. Mating fractures of the arms side, showing the bore of the actuating arm.

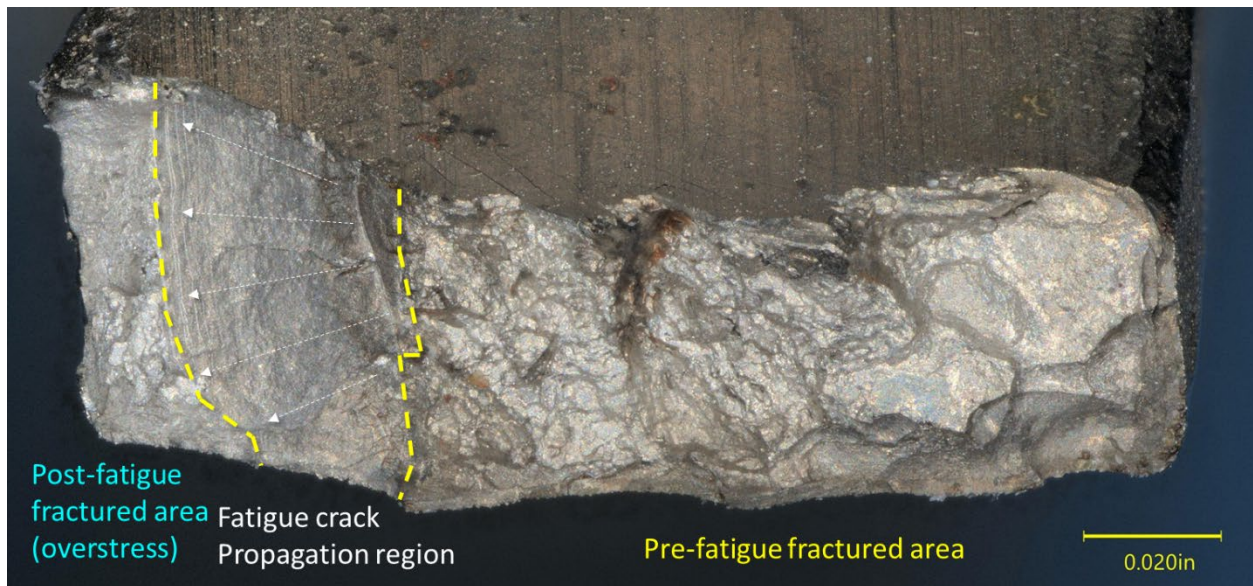


Figure 4. View of Fracture 1, with the three main fracture/cracking regions demarcated.

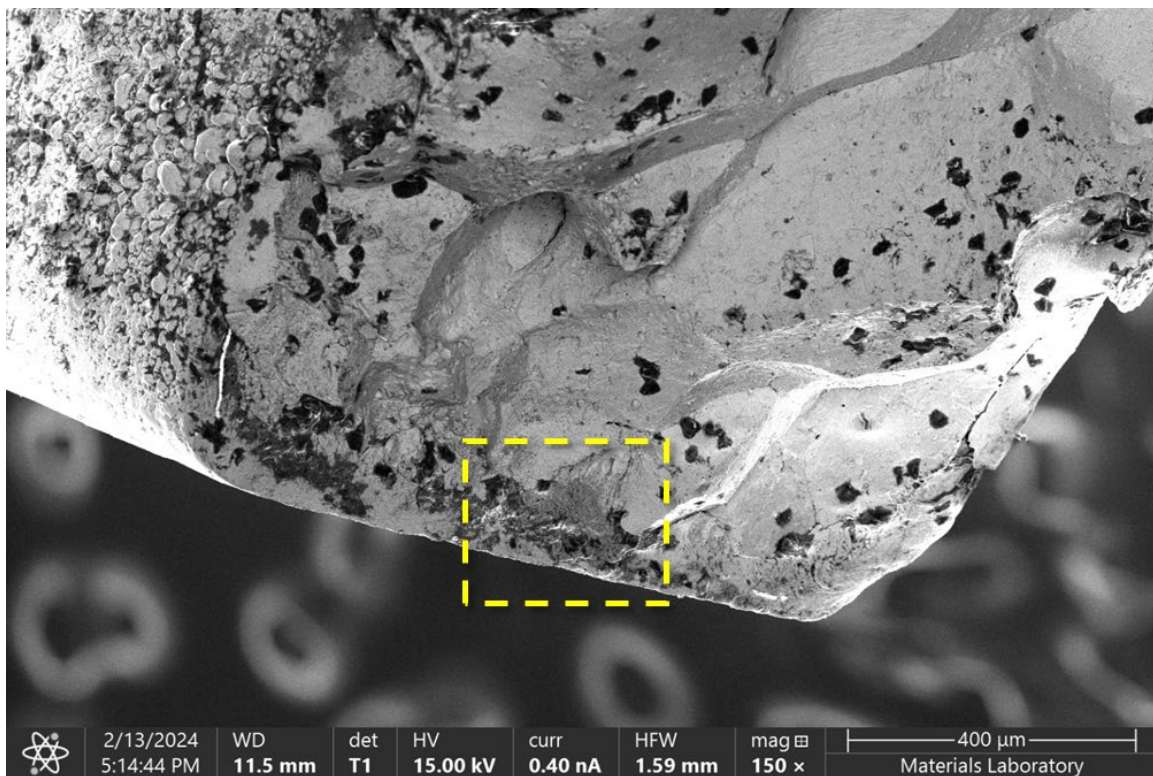


Figure 5. Backscattered electron (BE) micrograph of the right edge of Fracture 1 in Figure 4, with the boxed area shown in Figure 6.

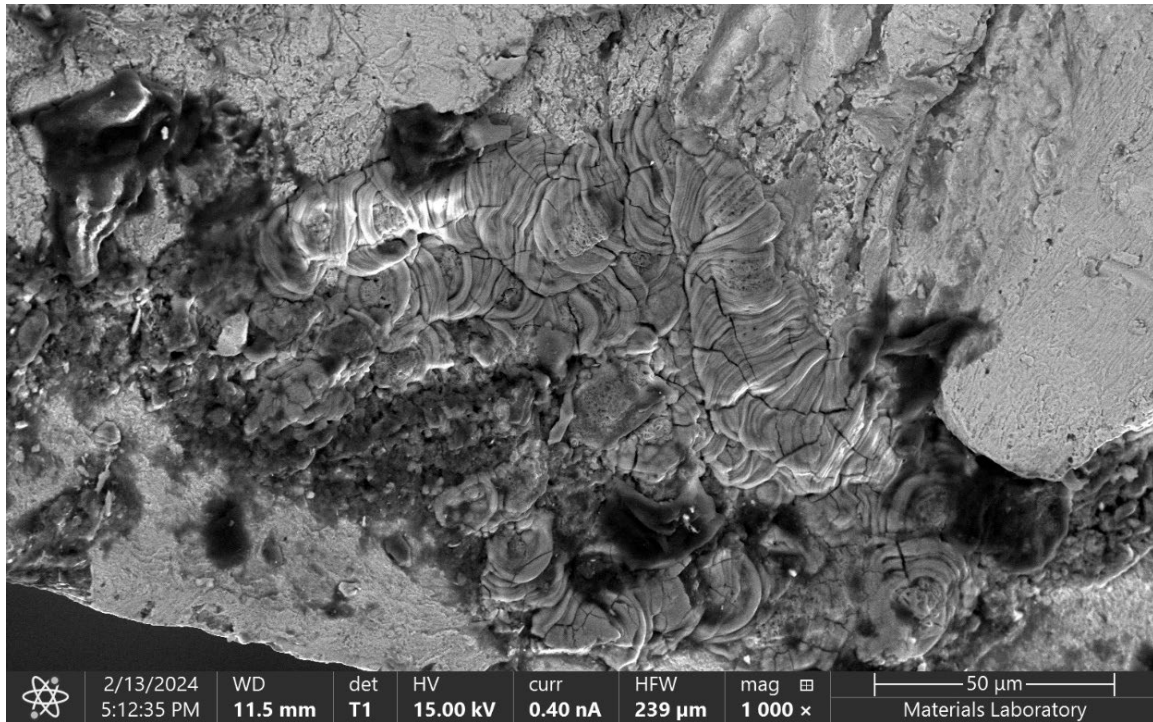


Figure 6. BE micrograph of wrinkled oxide in the boxed area of Figure 5.

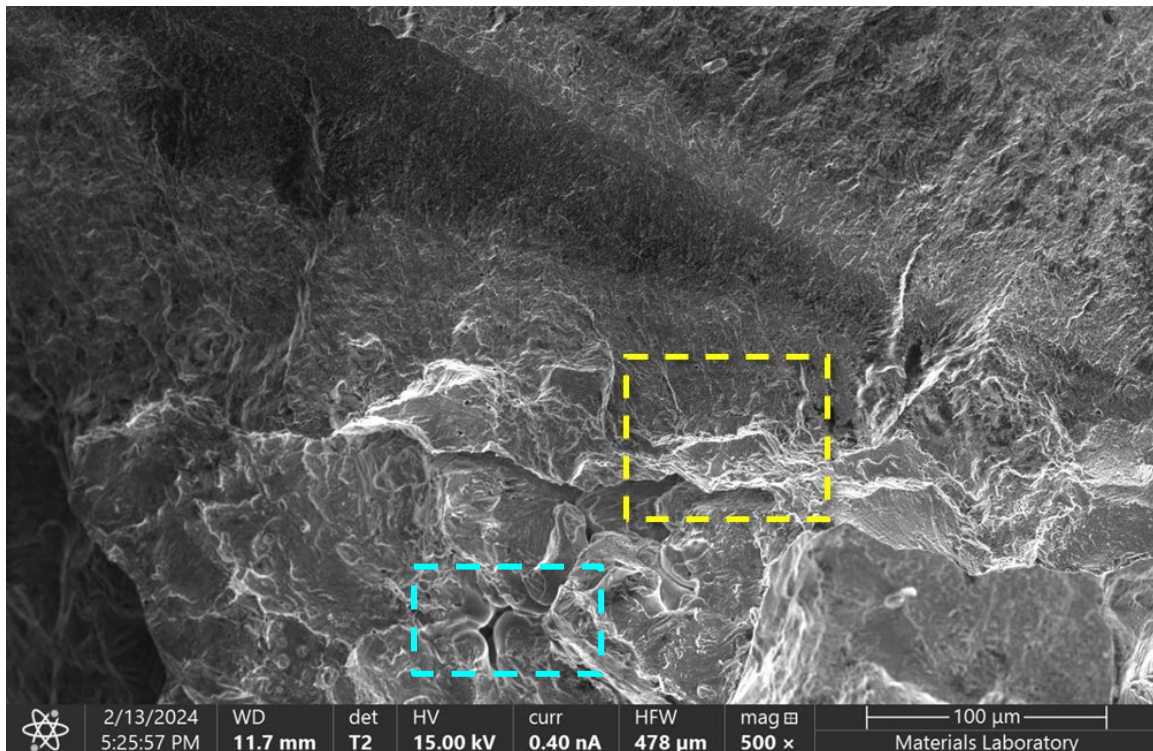


Figure 7. Secondary electron (SE) micrograph of the initiation of the fatigue crack propagation in the middle of Figure 4. The yellow boxed area is shown in Figure 8, and the cyan boxed area is shown in Figure 10.

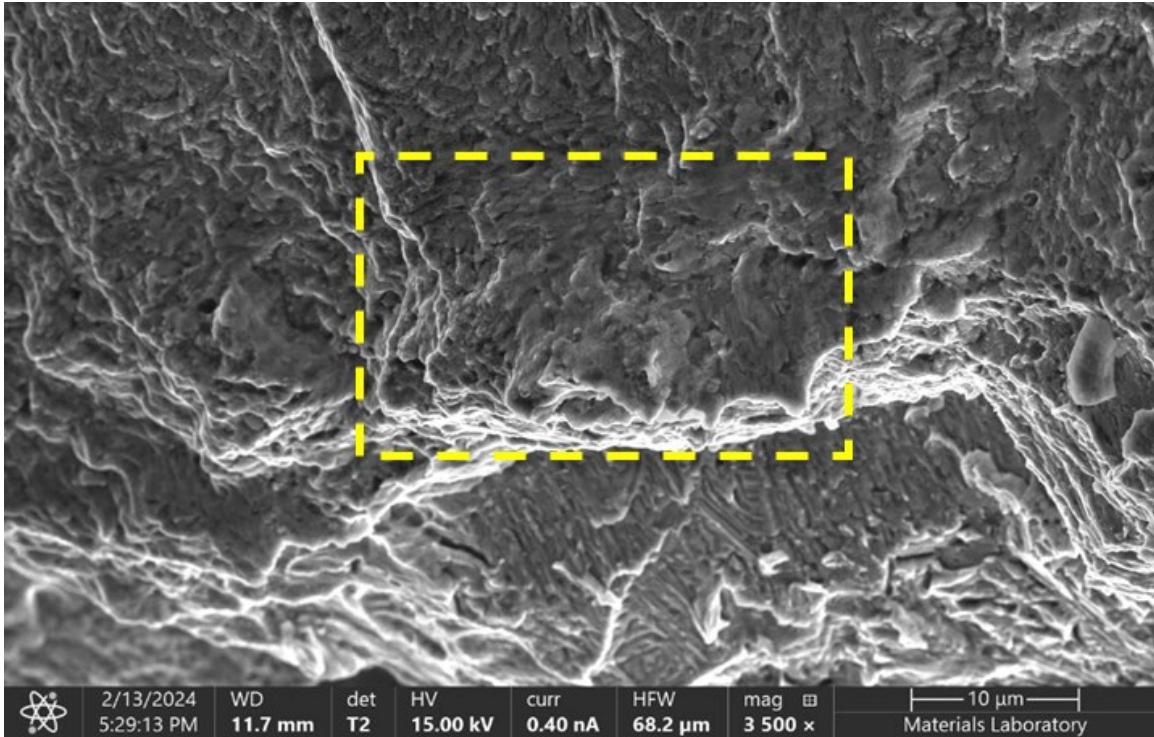


Figure 8. SE micrograph of an initiation site of the fatigue crack in Fracture 1 (boxed area in Figure 7).

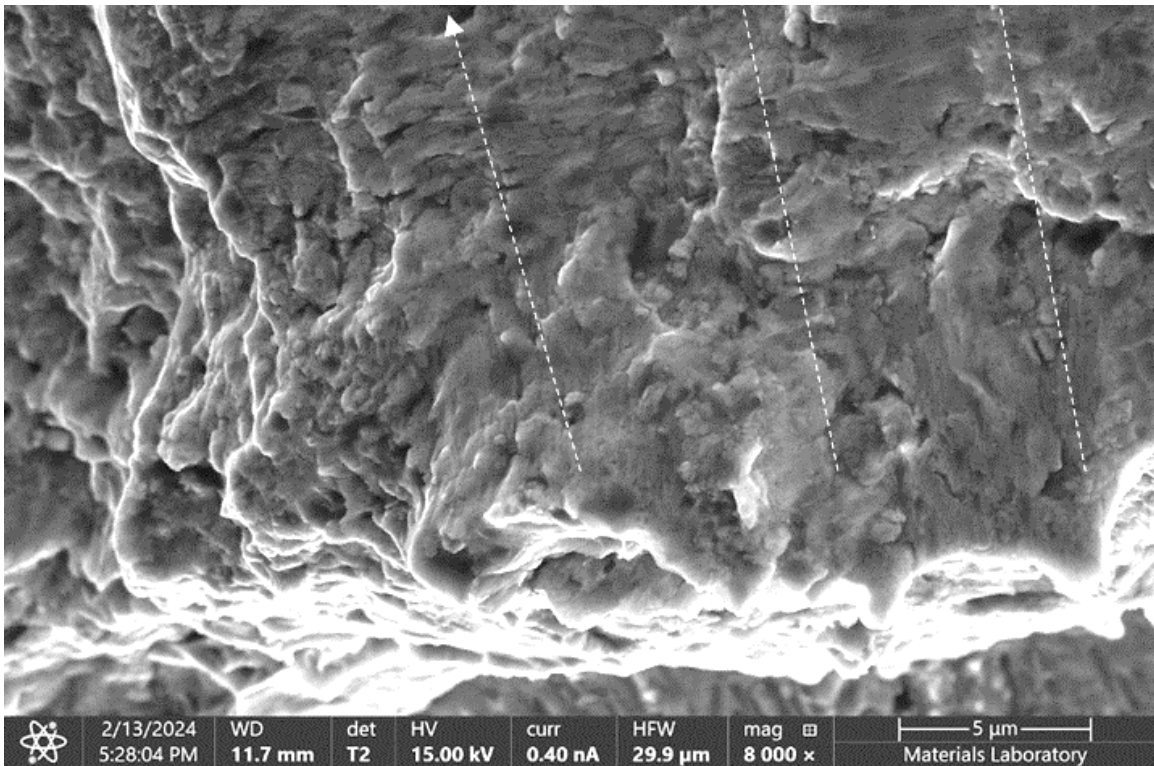


Figure 9. SE micrograph of striations at the initiation site in Figure 8, with crack growth direction indicated by the white arrows.

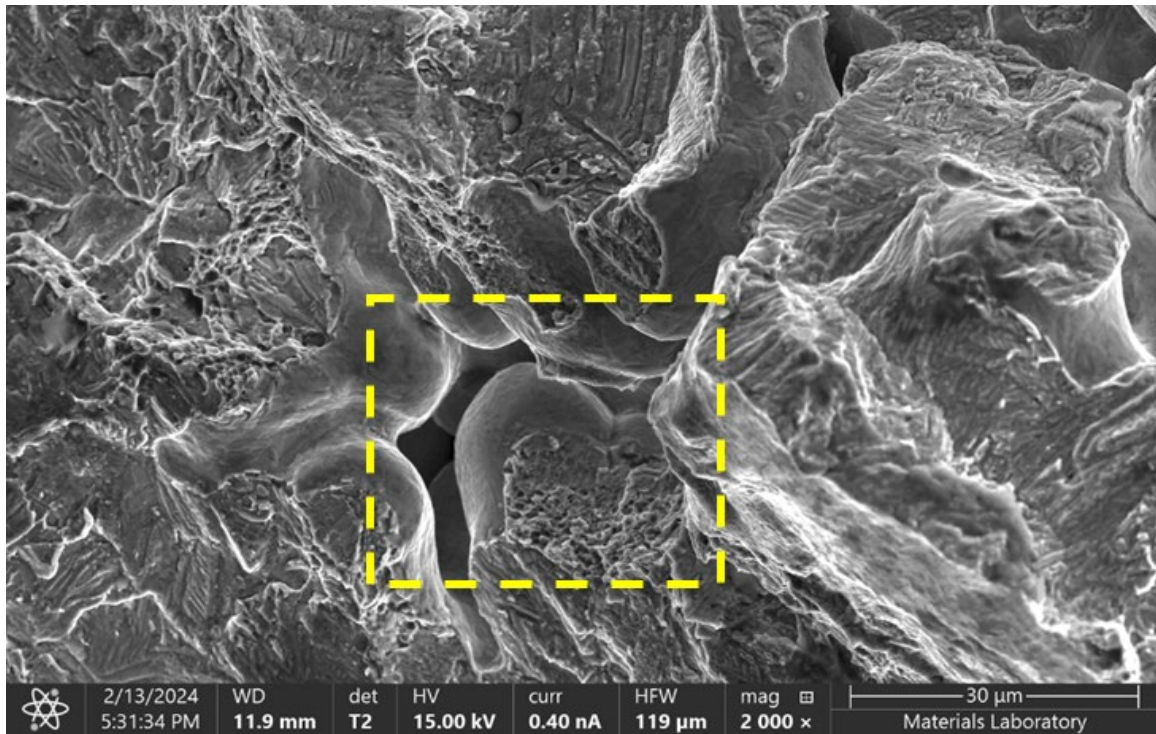


Figure 10. SE micrograph of a void in Figure 4 (cyan box) below the fatigue initiation.

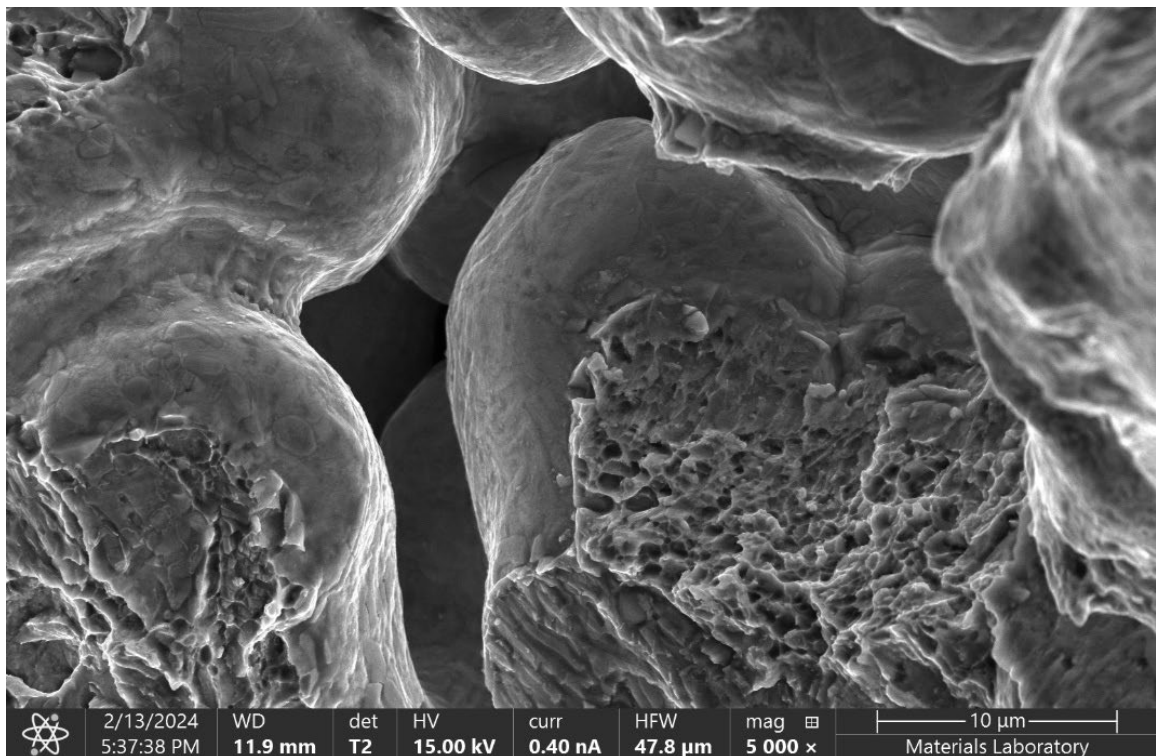


Figure 11. SE micrograph of the void boxed area in Figure 10, showing smooth areas with limited areas of dimpled rupture.

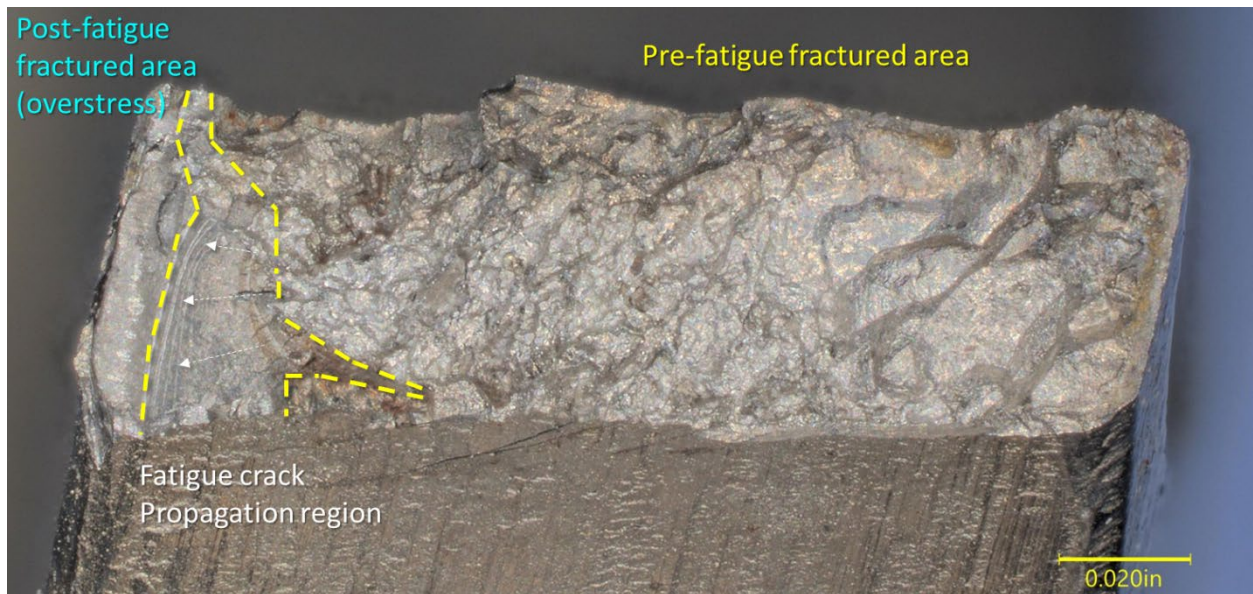


Figure 12. View of Fracture 2, with the three main fracture/cracking regions demarcated.

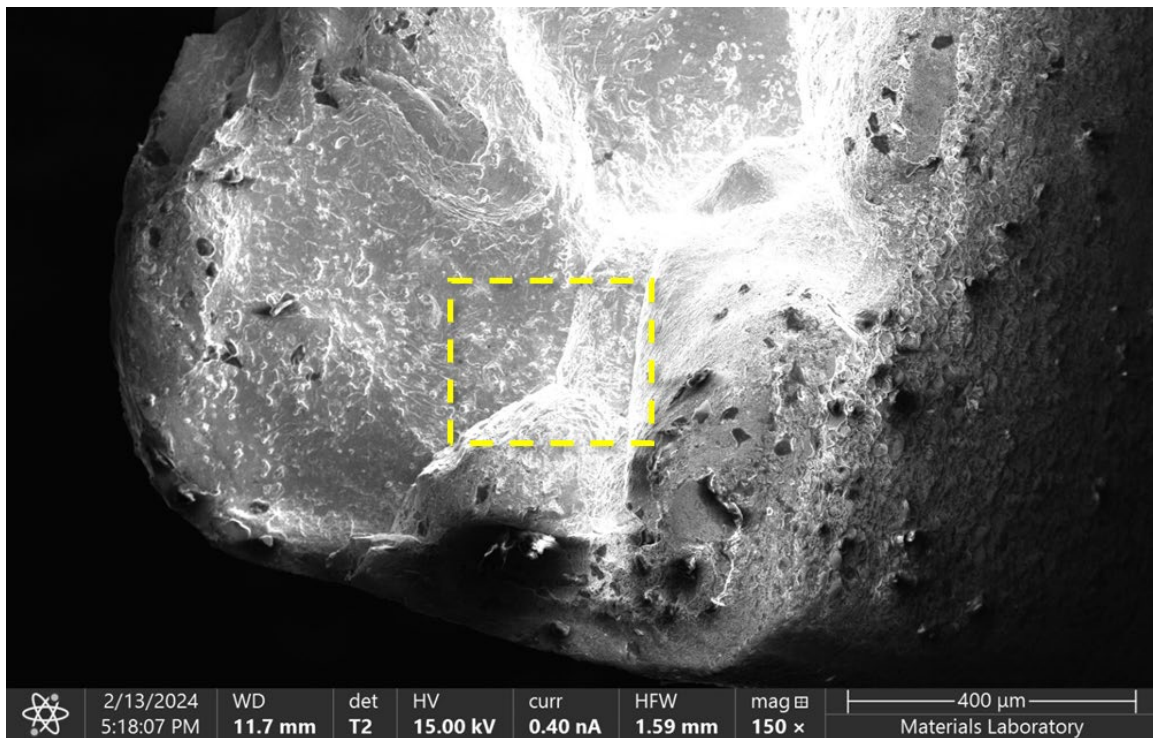


Figure 13. SE micrograph of rightmost edge of Fracture 2 as shown in Figure 12.

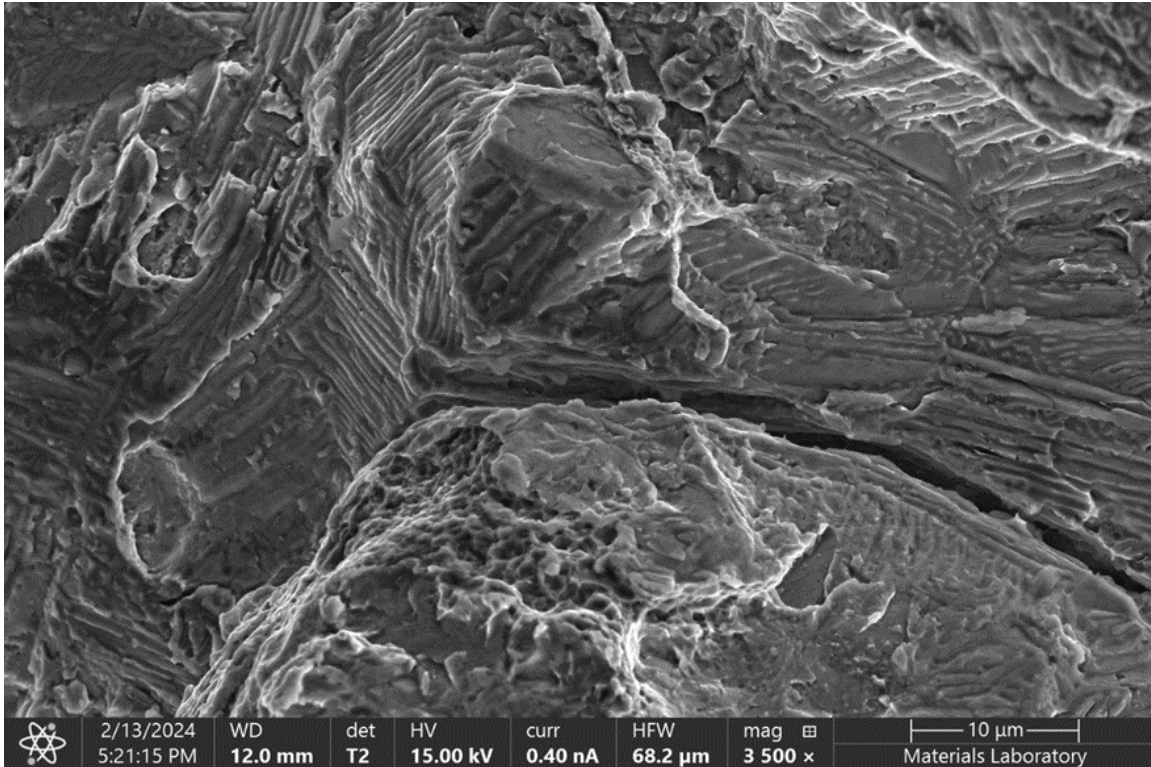


Figure 14. SE micrograph of the boxed area in Figure 13 showing a triple point intergranular fracture, exhibiting parallel features and limited dimpled rupture.

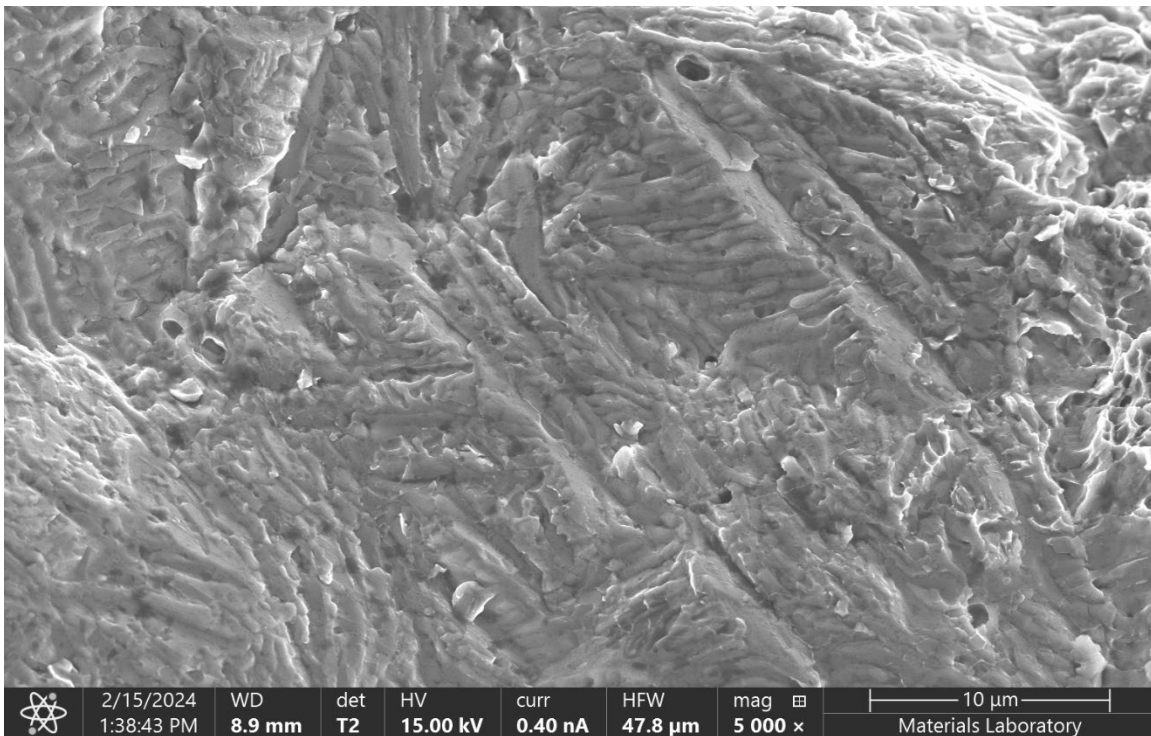


Figure 15. SE micrograph of a closer view of the area in Figure 13, showing cross-shaped parallel features consistent with dendrite arms.

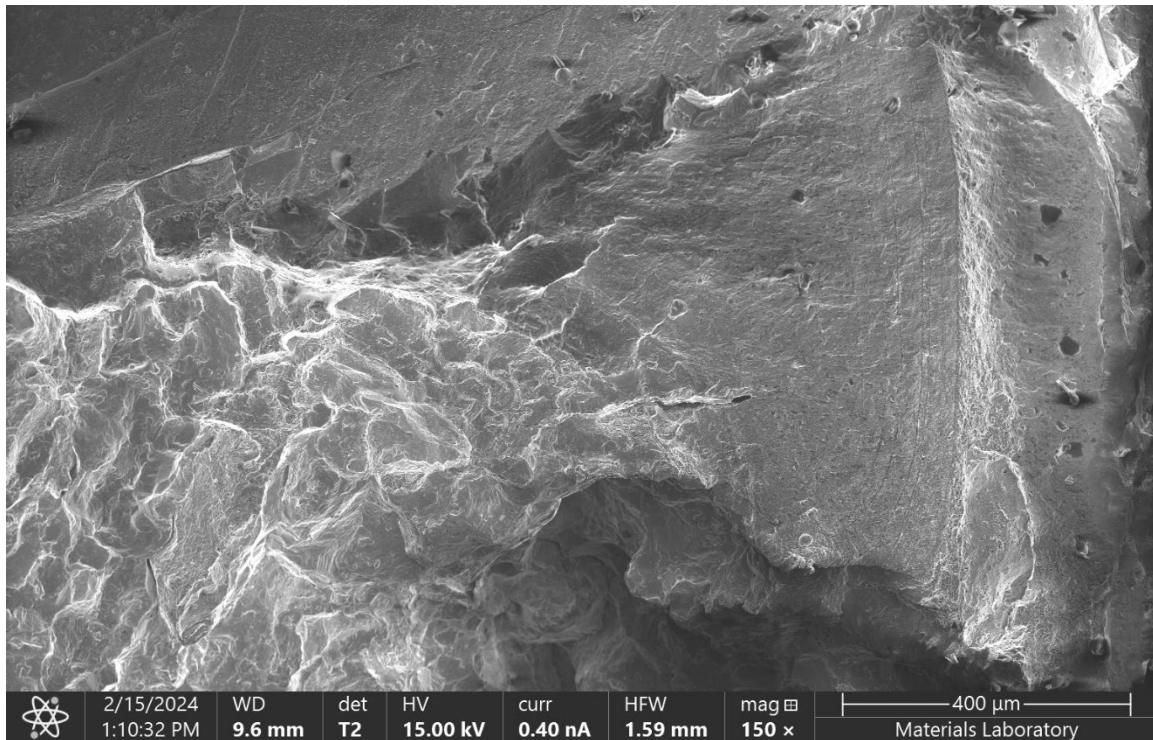


Figure 16. SE micrograph of the fatigue crack of Fracture 2.

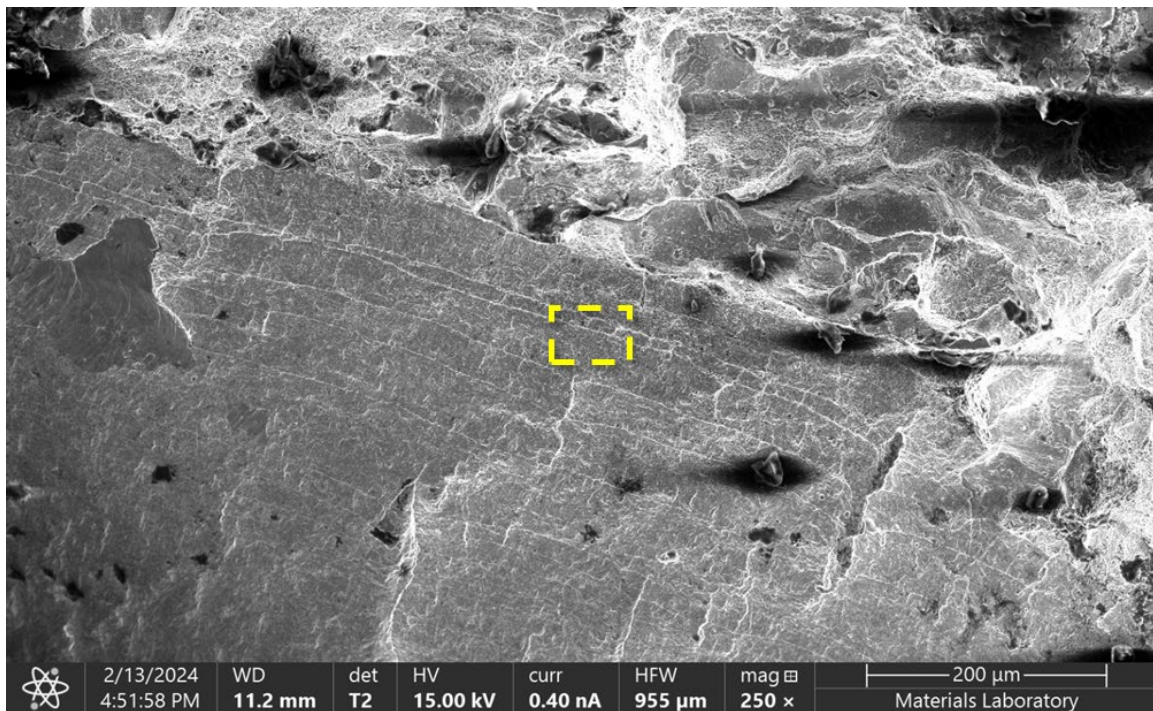


Figure 17. SE micrograph of the end of the fatigue crack in Fracture 2, showing parallel crack arrest marks, rotated 90° from Figure 16. The boxed area is shown in Figure 18.

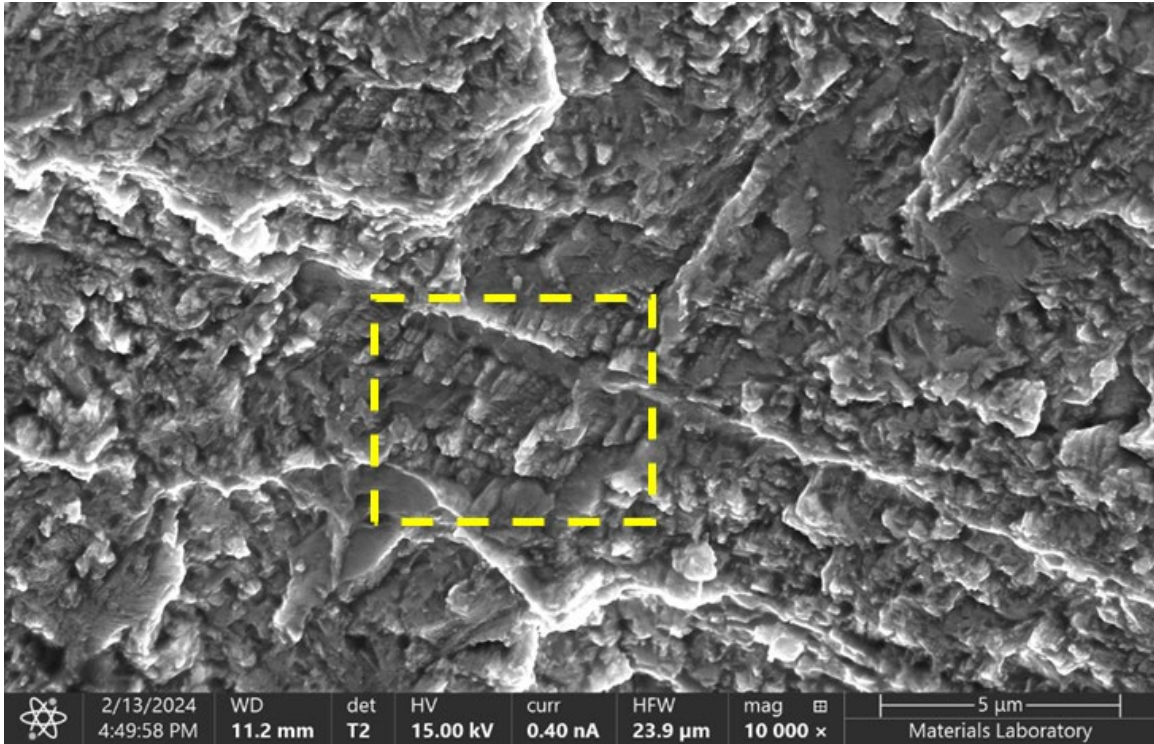


Figure 18. SE micrograph of the boxed area in Figure 17 showing arrest marks and striations.

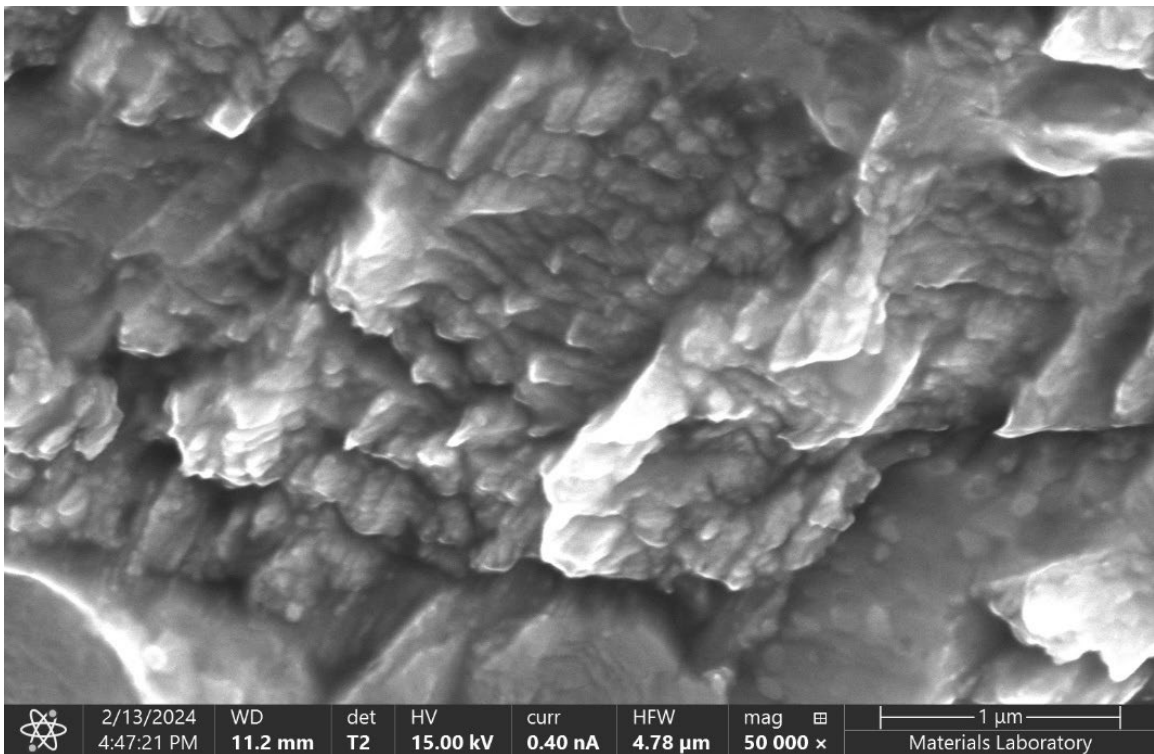


Figure 19. SE micrograph of a closer view of the boxed area in Figure 18, showing fatigue striations.

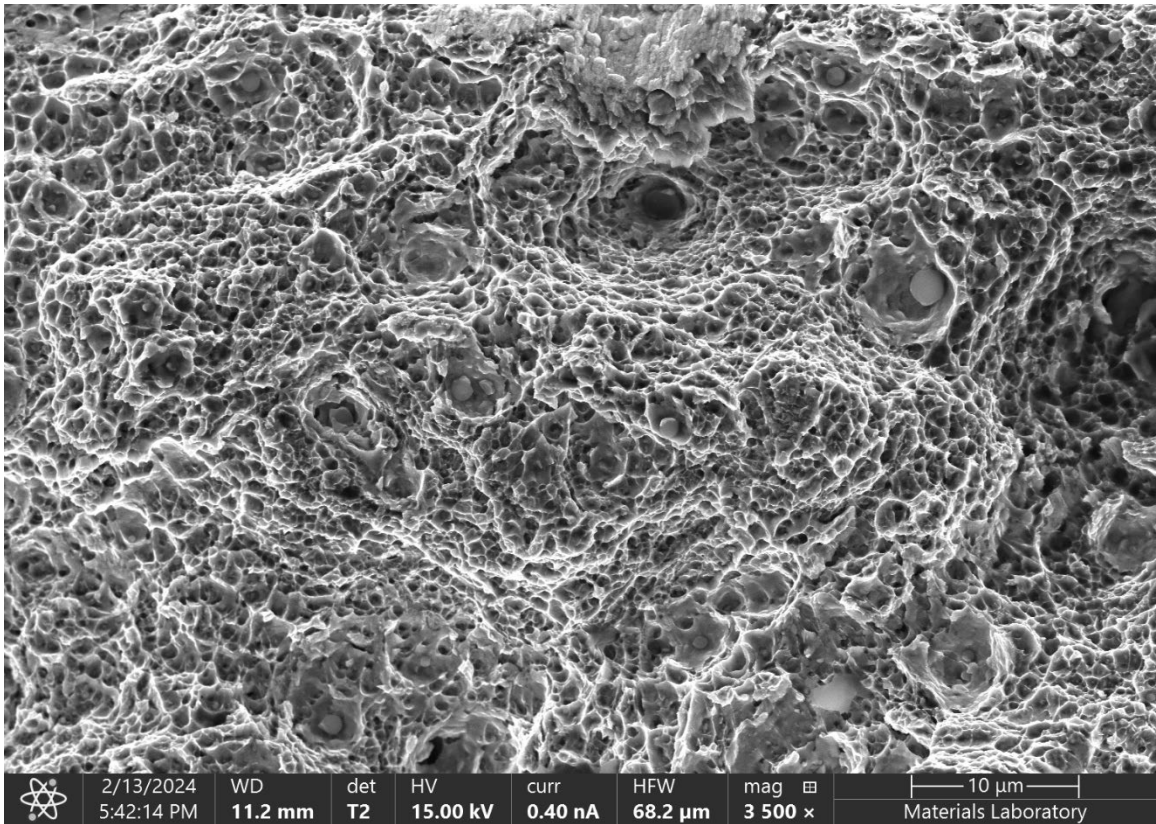


Figure 20. SE micrograph of dimpled rupture on the area of Fracture 2 outside of the fatigue crack propagation region.