

National Transportation Safety Board

Office of Research and Engineering

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MATERIALS LABORATORY

Factual Report 24-055

September 18, 2024

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A. ACCIDENT INFORMATION

Location: Marana, Arizona
Date: April 19, 2024
Time: 13:39 mountain standard time
20:39 coordinated universal time
Vehicle: Piper PA-28-151, N4399X
Investigator: Stacia Joyce, AS-ANC

B. COMPONENTS EXAMINED

Remnants of a piston
Piston pin

C. EXAMINATION PARTICIPANTS

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Office of Research and Engineering – Materials Laboratory Division
NTSB, Washington, DC

D. DETAILS OF THE EXAMINATION

On April 19, 2024, a Piper PA-28-151 airplane was substantially damaged when it was involved in an accident near Marana, AZ. The flight instructor and student pilot were not injured. According to the flight instructor, the engine began to run rough and make grinding noises during cruise, and then stopped producing power. After unsuccessfully attempting to restart the engine, the crew performed a forced landing to a field where the airplane sustained substantial damage to both wings and fuselage. The wreckage was retained for further examination, and several fractured components from the Lycoming O-360-A4M engine were sent to the NTSB Materials Laboratory for examination.¹

Figure 1 shows the fractured remnants of the piston and pin as received. As described in more detail below, all the components received exhibited features consistent with overstress fracture or cracking.

The piston is shown from both the top of the crown and the underside of the skirt in Figure 2. The top of the crown was intact and contained two major areas of tannish-yellow waxy and flaky regions, consistent with the buildup of tetraethyl lead-derived combustion products, typical of avgas fuel.

¹ The Lycoming O-360-A4M is a four-cylinder, direct-drive, horizontally opposed, air-cooled, carbureted piston aircraft engine manufactured by Lycoming Engines, headquartered in Williamsport, PA.

The skirt on the piston underside exhibited the most damage, with the fracture surfaces demonstrated in Figure 2b, and the damage along the skirt shown from the sides in Figures 3 and 4. Approximately half of the skirt material was missing, with the demarcation of fracture located along the bore containing the pin. The lower third of the fracture surfaces of the piston exhibited discernible fracture features, while the rest exhibited reflective lusters with erratic streaks—these areas were consistent with post-fracture smearing damage from impact or rubbing against adjacent parts. In addition, circular impact witness marks were present on the interior surface of the piston remnant (Figure 2b).

The undamaged areas of the piston fracture surface are highlighted in Figures 5 and 6. As shown from the oblique lighting, the fracture surface in the region in Figure 6 exhibited river patterns consistent with fracture from the outer edges inward on the left side, and from the smeared area along the pin bore on the right side.

Figure 7 shows a closer view of the left fracture surface from Figure 6. Figure 8 shows an annotated view illustrating the general fracture direction from the outside piston corner opposite the pin bore. The river patterns in Figure 9 show the direction of the fracture, as illustrated in Figure 10. Figure 10 shows the corner of the fracture surface facing the machine bore that faced the piston pin. This corner exhibited some wear or rubbing marks on the left towards the machine surface, small impact marks, or depressions along the outboard face (Figure 11).

This portion of the fracture surface was excised, cleaned with acetone, and examined using a field emission scanning electron microscope (SEM). Figure 12 shows a typical area of the fracture surface near the edge in Figures 11 and 12. The fracture surface was rough and tortuous, with intermediate areas exhibiting smoother or flatter features. On most of the rougher portions of the fracture surface, illustrated in Figures 13 and 14, the part exhibited fine dimpled rupture, consistent with overstress fracture.

The smoother features on the fracture surface, as typified in Figure 15, were examined using energy dispersive x-ray spectroscopy (EDS) and were rich in silicon. The surrounding area, which exhibited fine dimpled rupture, was mostly aluminum (Figure 16). These chemical characteristics were consistent with an aluminum-silicon casting, and the fracture features were consistent with overstress fracture typical of such casting alloys.

Figure 17 shows isolated areas with parallel linear features on the fracture surface. The features outside these regions were consistent with overstress fracture. A closer view of the areas with streaks showed the linear features to be erratic, inconsistent, and layered (Figures 18 and 19). A closer examination found dimpled rupture in these areas (Figure 20). These regions were consistent with post-fracture smearing damage of the fracture surface rather than other failure modes, such as those

consistent with crack propagation. No features consistent with failure modes other than dimpled rupture were observed on the piston fracture surfaces.

Figure 21 shows multiple views of the piston pin from the side as received. The pin exhibited two prominent darker circumferential wear marks, consistent with rotation against the bearing faces of the connecting rod. Views of the end faces of the piston, shown in Figure 22, revealed three radial cracks on the faces. These cracks had progressed longitudinally along part of the pin.

One crack was intentionally backcut and laboratory-opened to reveal the crack faces, as illustrated in Figure 23. The cracks were generally shaped convex facing inward, exhibiting longer depths along the pin bore than the outer surface. River patterns emanating from the bore were observed as well. These features were consistent with crack origination from the pin bore rather than the outside surface of the pin.

The opened pin cracks were cleaned with acetone and examined using a SEM. Figure 24 shows a typical area of the opened cracks, revealing elongated granular structure and tortuous elevation. The topography of the fracture was consistent with the grain orientation of the pin microstructure, elongated along the length of the pin or the forging direction.

As shown in Figure 25, the fracture surface exhibited dimpled rupture, with mixed sizes of larger, oval dimples and finer, more equiaxed dimples (Figure 26). Along the outer edge of the opened pin cracks, the fracture surface was blockier and more faceted, as shown in Figure 27. Closer views in Figures 28 and 29 show that this fracture surface area consisted of mixed intergranular and dimpled rupture fracture features. These characteristics were consistent with a case-hardened outer surface. These features were consistent with the overstress of the piston pin.

Submitted by:

Erik M. Mueller
Materials Research Engineer

E. FIGURES



Figure 1. The pieces submitted from the accident, the piston remnants and the piston pin.



Figure 2. Views of the piston remnant from (a) the crown and (b) the underside and skirt, as received.



Figure 3. Side views of the piston from the pin boss sides showing (a) the side with the cap still in place and (b) the reverse side.



Figure 4. Side views of the piston remnant from (a) the longer skirt remnant side and (b) the short side, as received.



Figure 5. View of the fracture surface near the pin on the piston.



Figure 6. Oblique lighting view of the piston fracture surface in Figure 5.

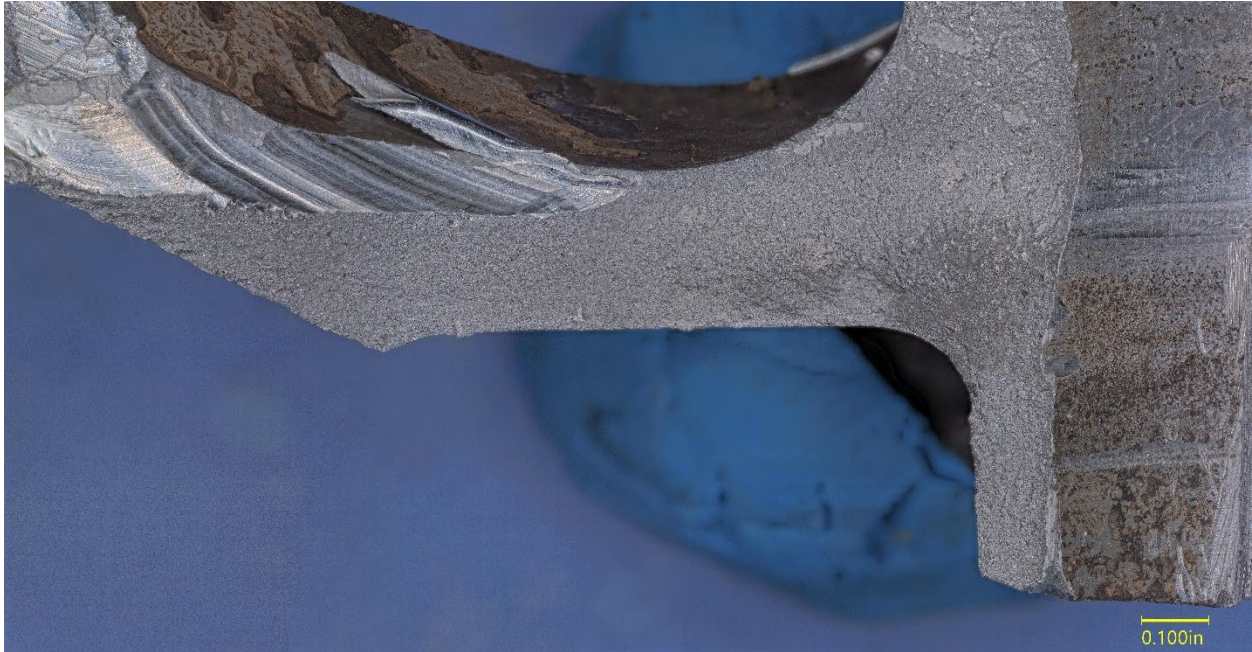


Figure 7. Montage of the piston fracture surface, after sectioning and cleaning.

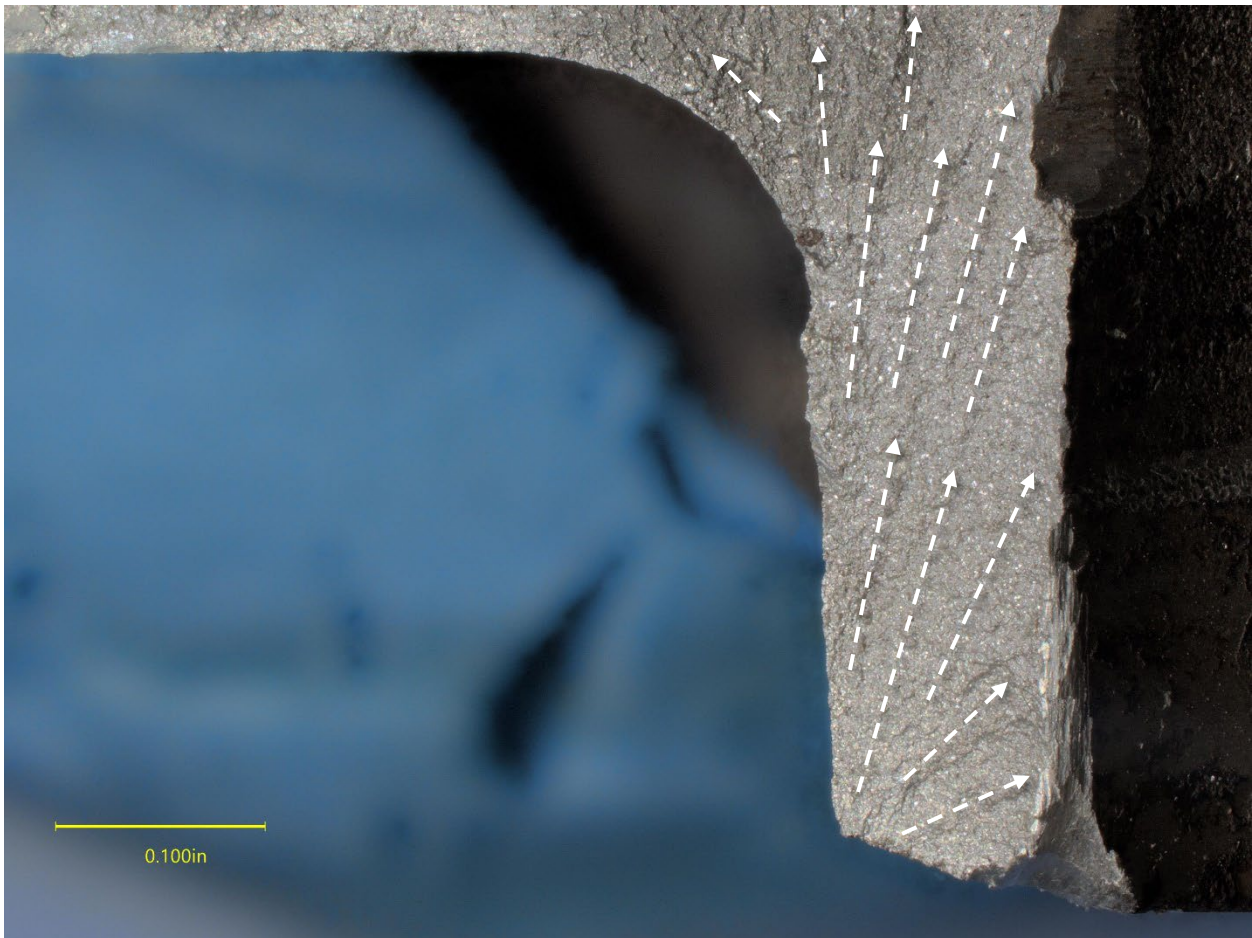


Figure 8. The initial area of the piston fracture surface, after sectioning and cleaning.

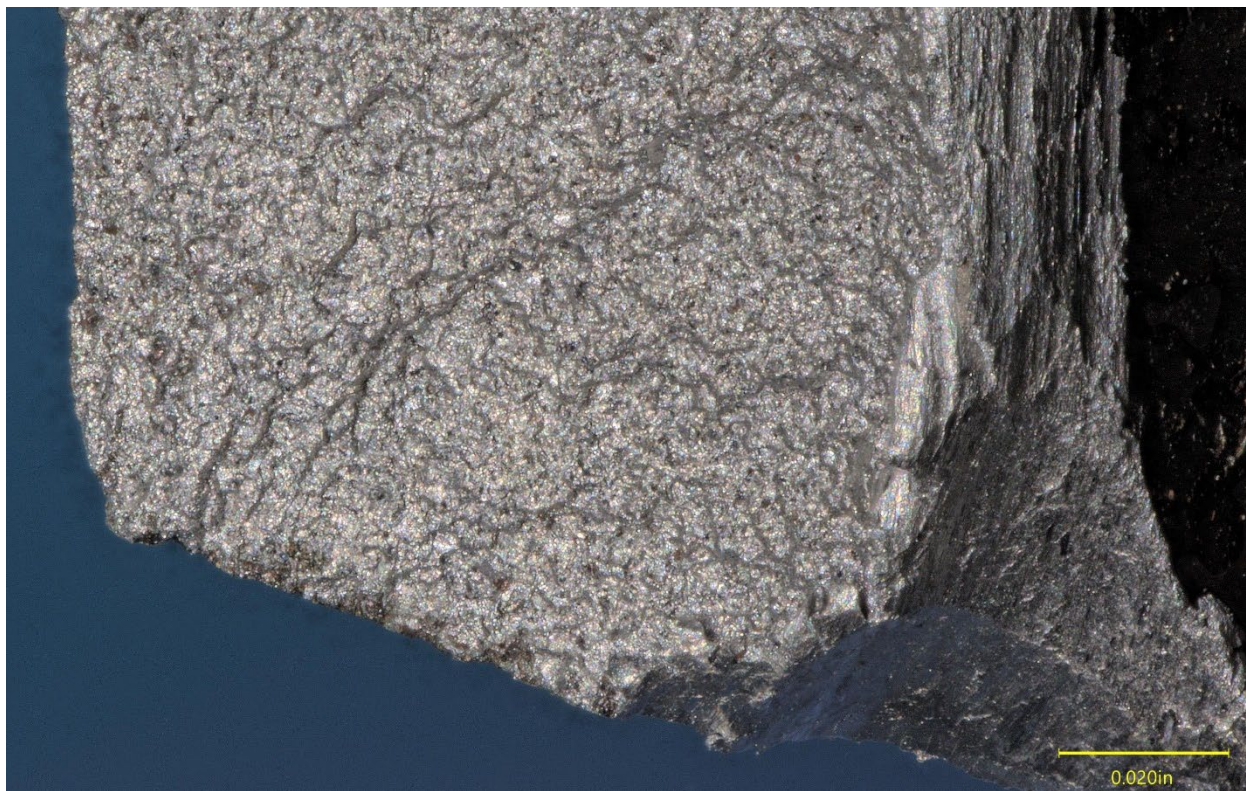


Figure 9. The initial fracture region on the outboard pin corner of the piston surface.



Figure 10. Angled view of the piston initiation area, annotated to show the fracture direction.



Figure 11. Angled view of the piston initiation area.

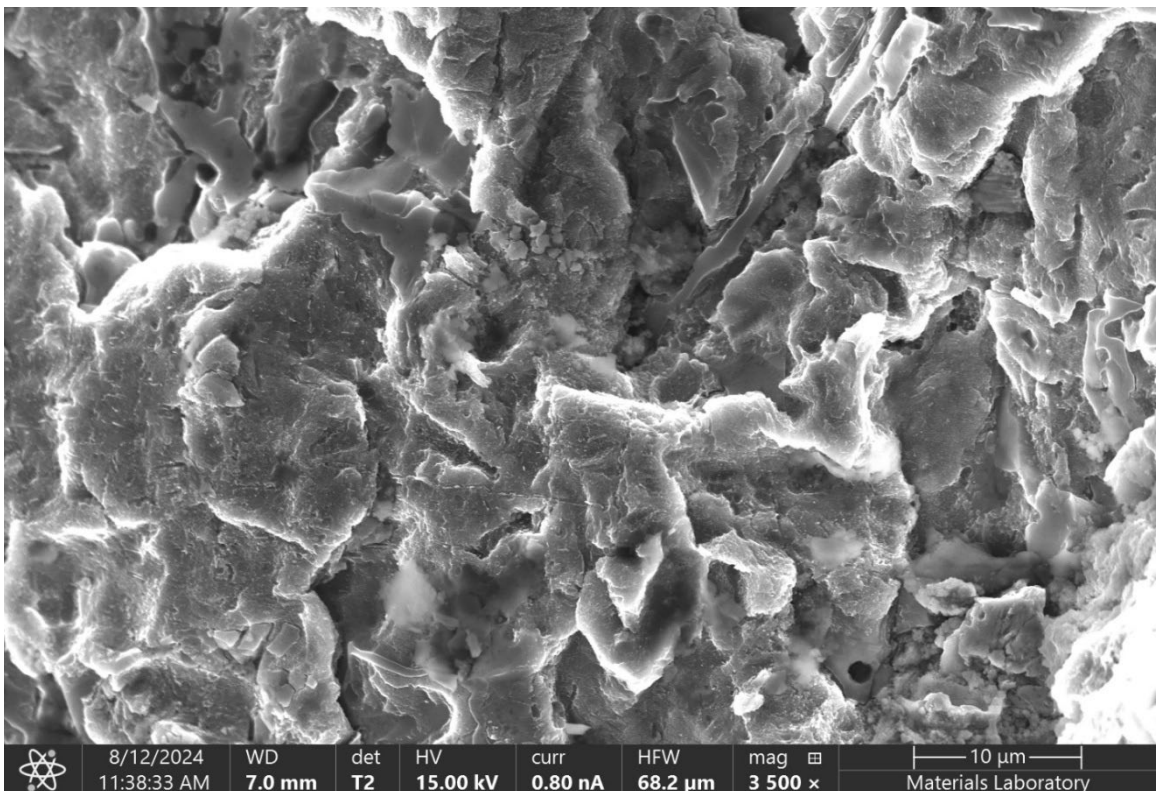


Figure 12. Secondary electron (SE) micrograph of an area near the outboard edge of the piston fracture surface.

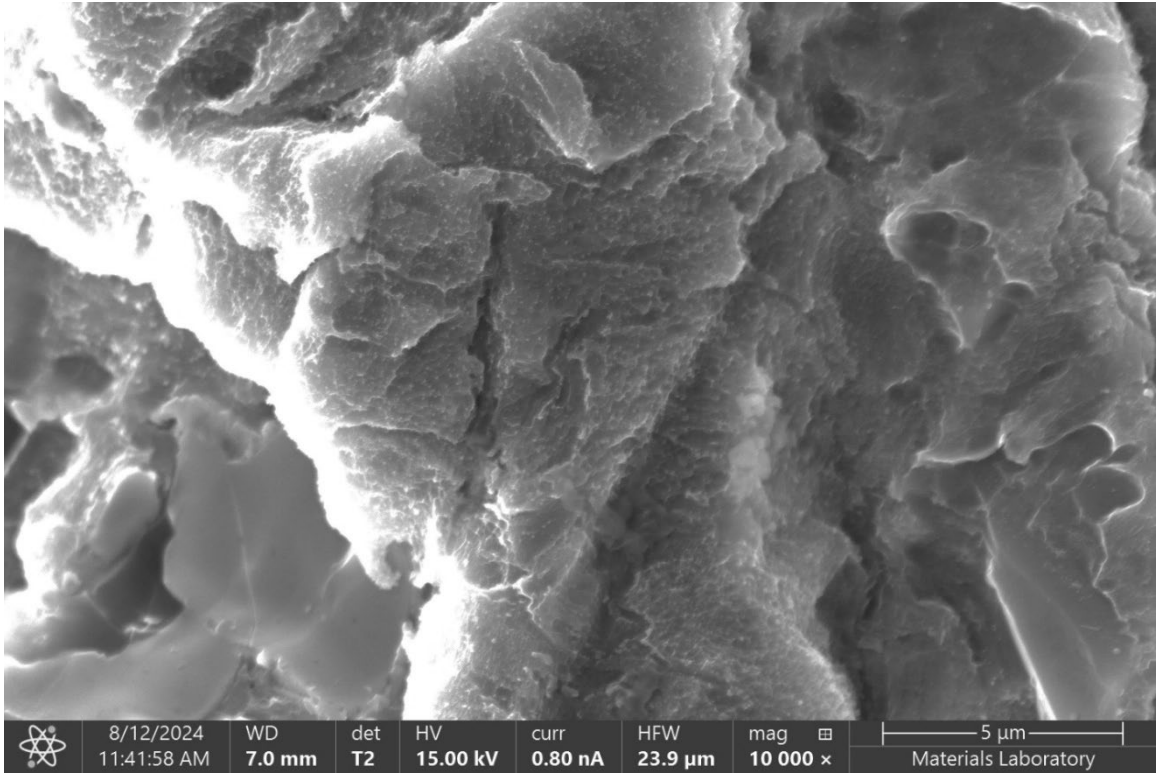


Figure 13. SE micrograph of the upper central area in Figure 12.

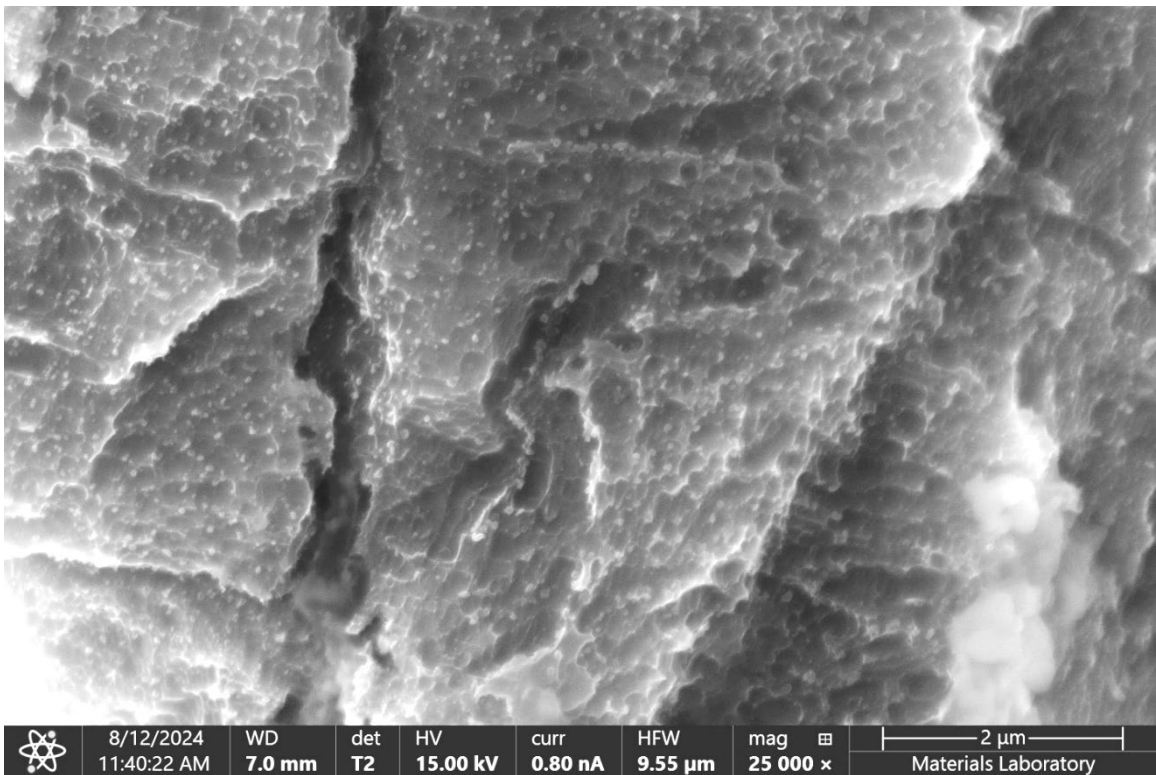


Figure 14. SE micrograph of dimpled rupture from the area in Figure 13.

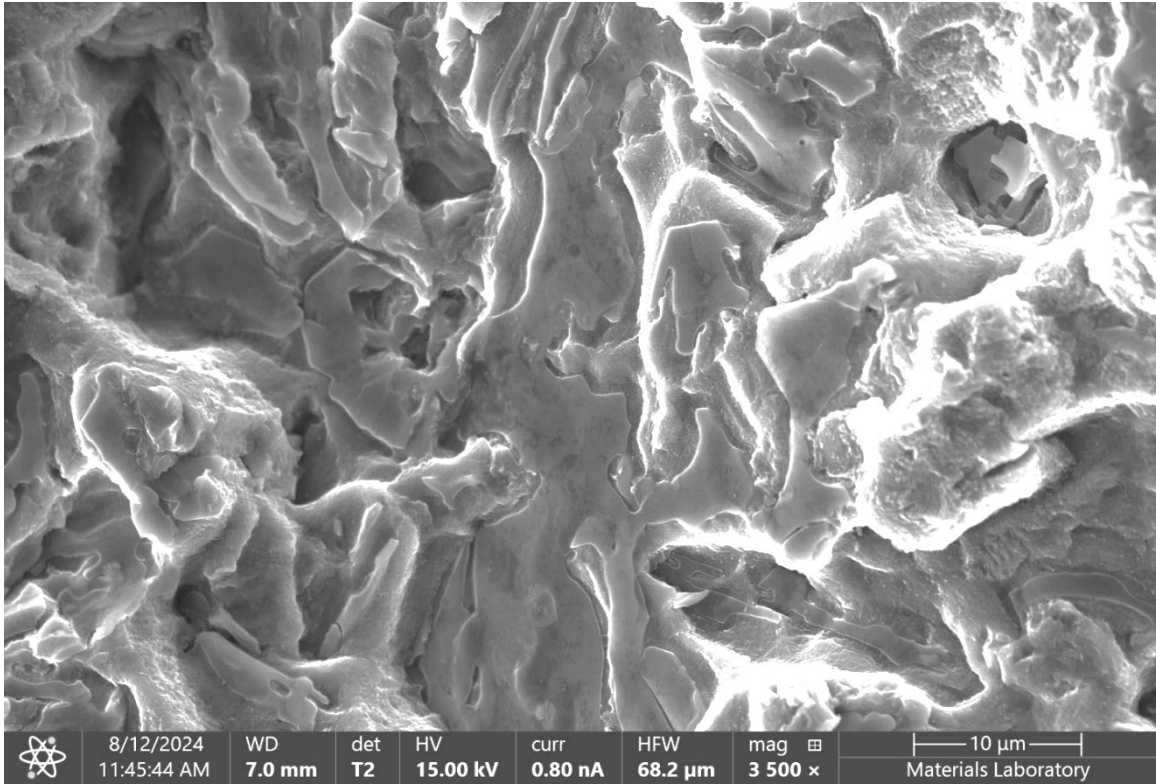


Figure 15. SE micrograph of a flat fracture feature consistent with fracture of a Si-rich phase.

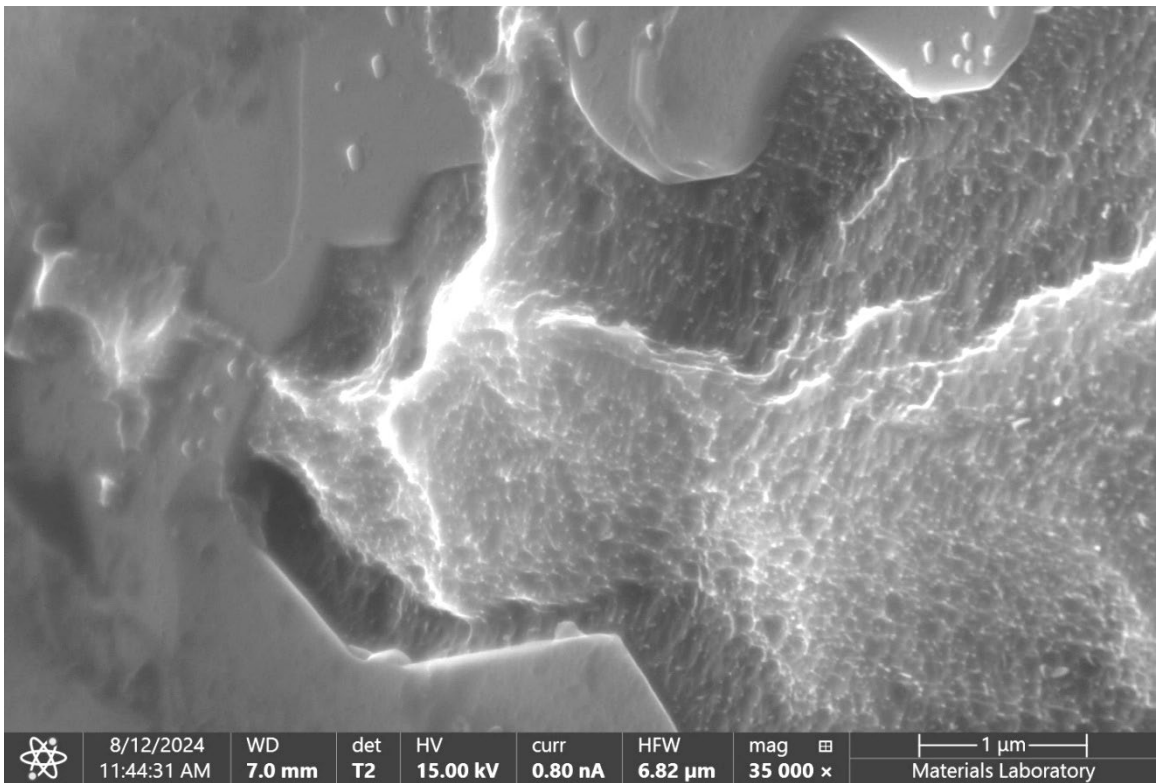


Figure 16. SE micrograph of fine dimpled rupture near the Si-rich phase in Figure 15.

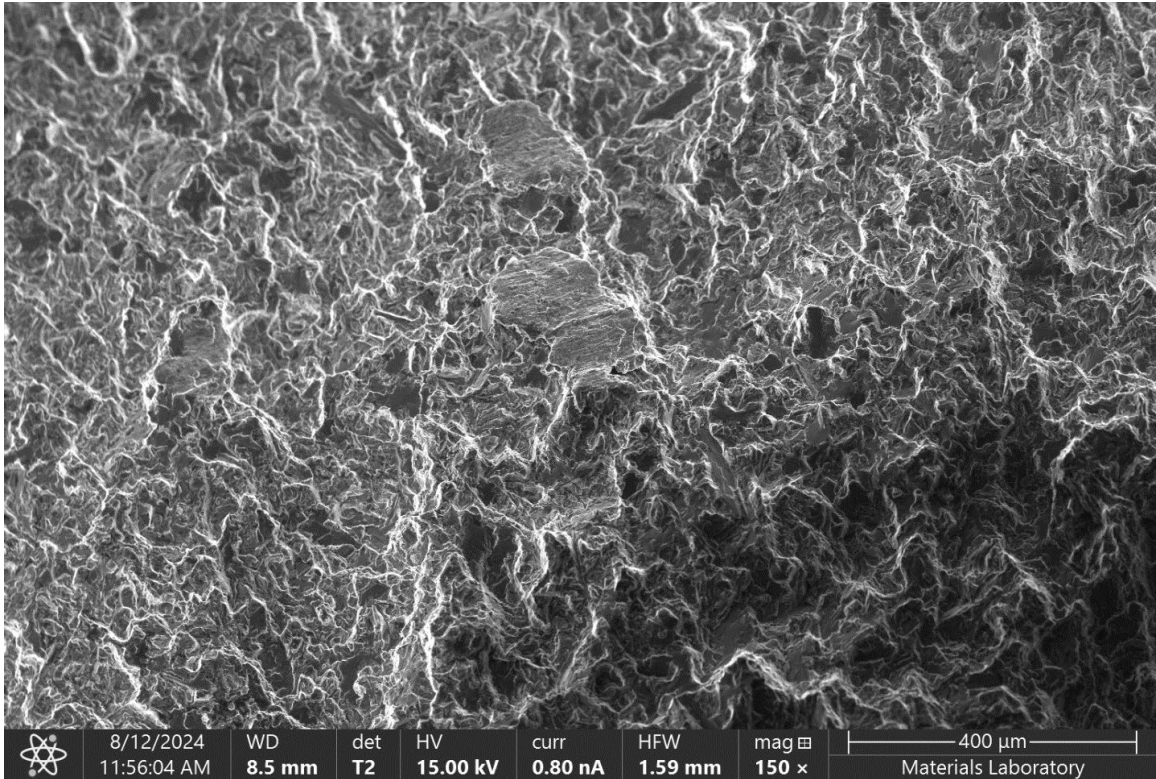


Figure 17. SE micrograph of isolated areas of smearing damage on the piston fracture surface.

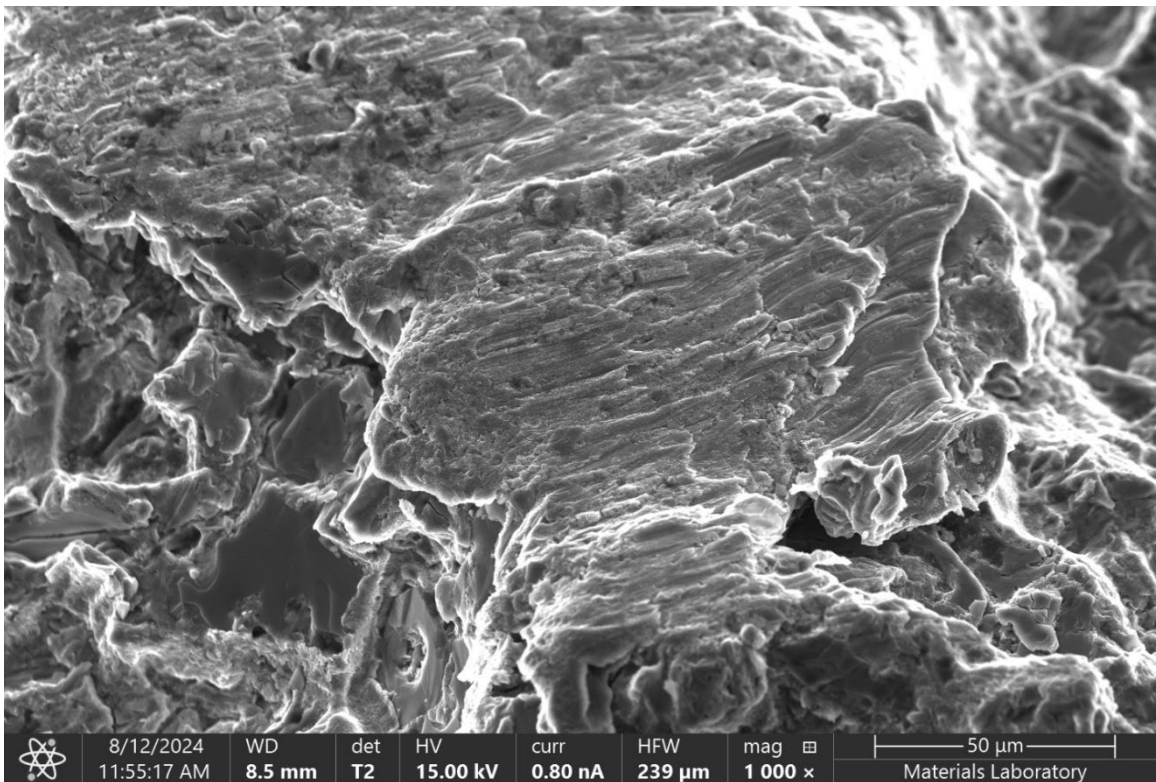


Figure 18. SE micrograph of the smeared region in Figure 17.

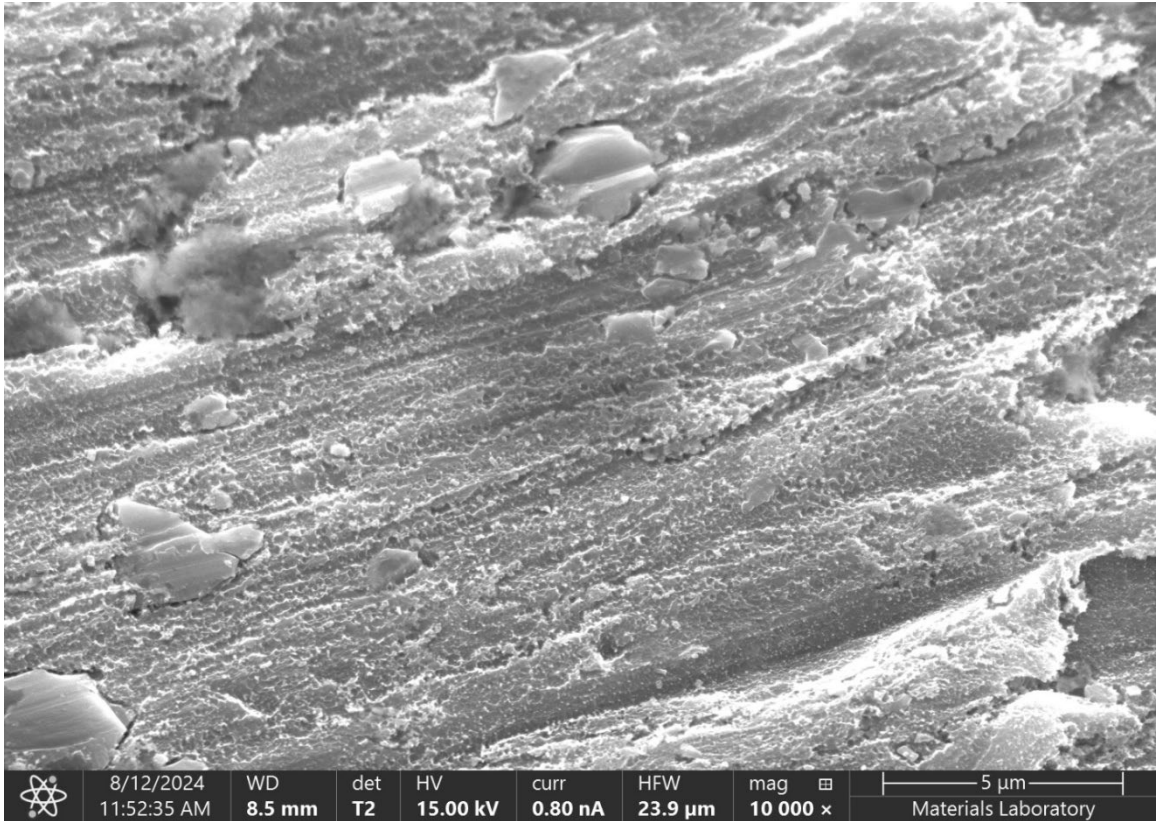


Figure 19. SE micrograph of the smeared streaks in Figure 18.

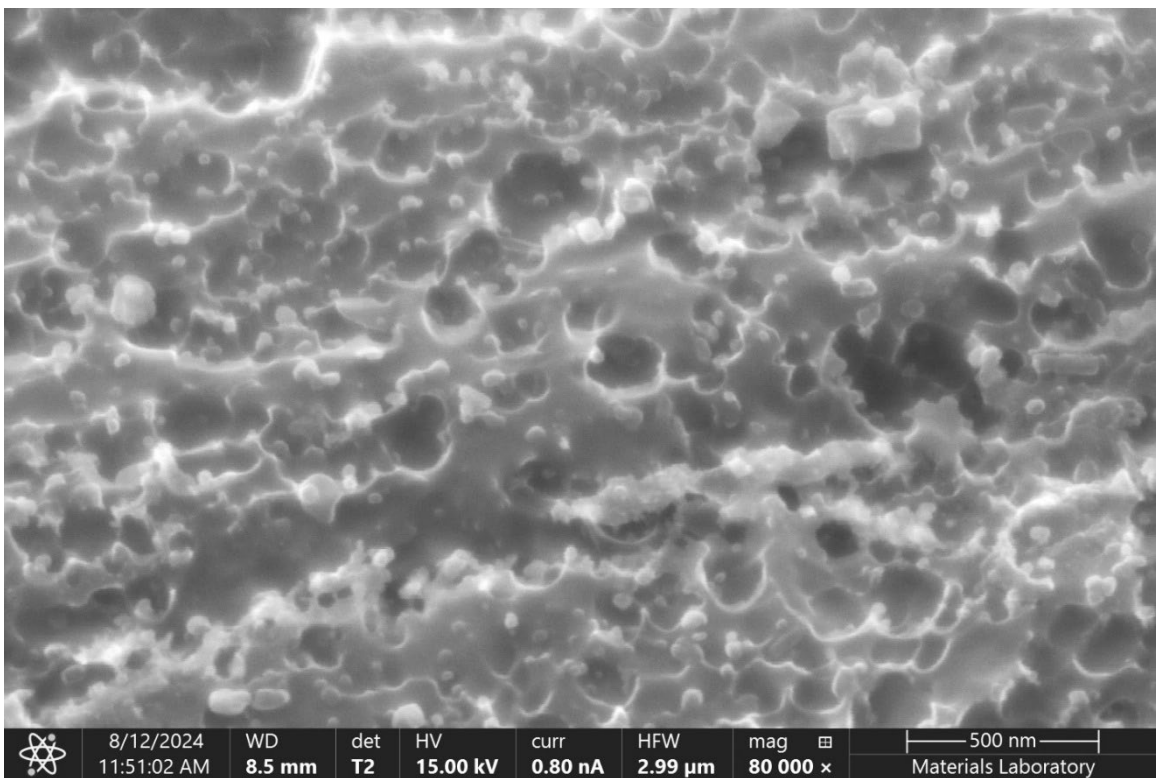


Figure 20. SE micrograph of dimpled rupture in the streaks in Figure 19.

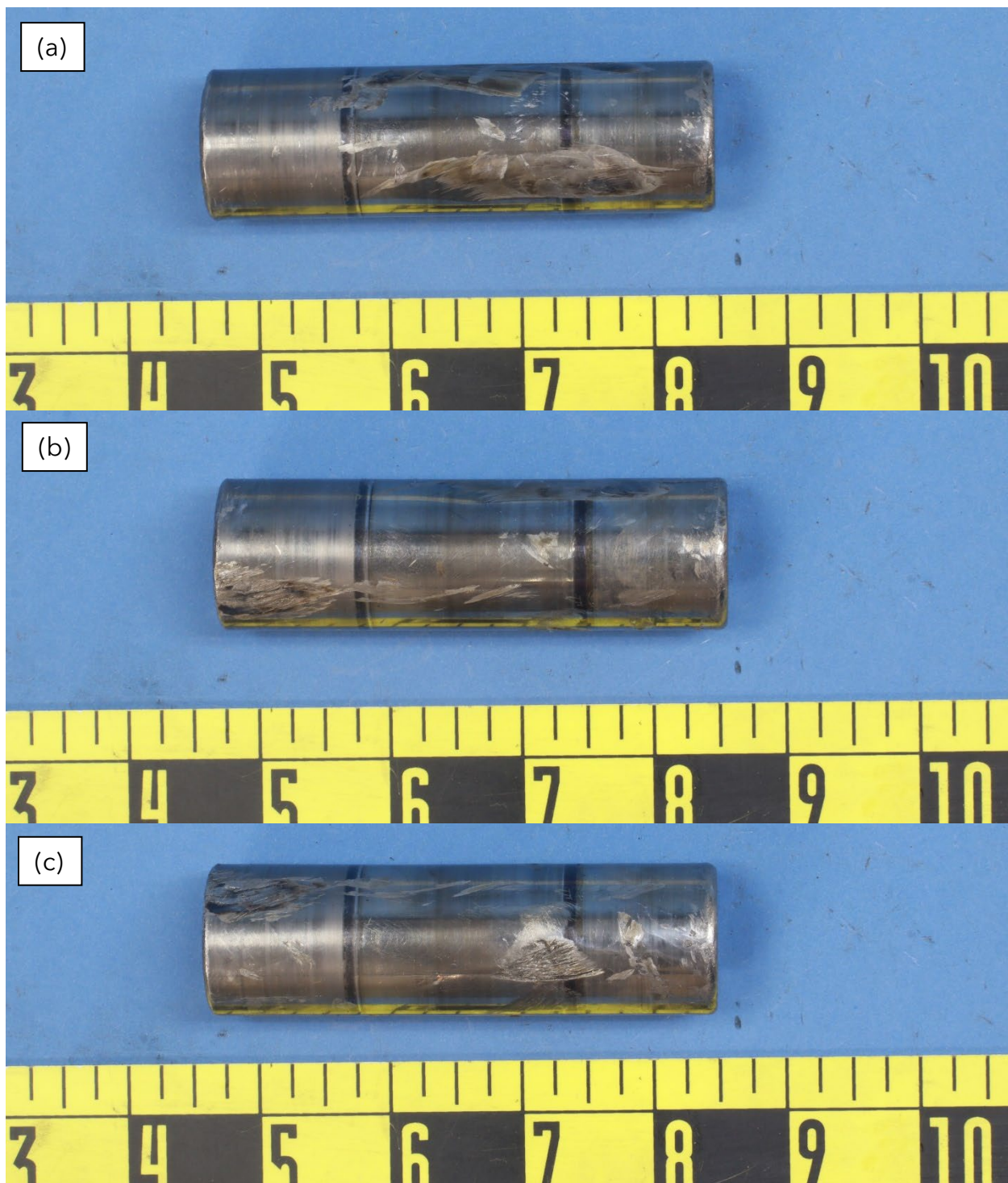


Figure 21. Circumferential views of the piston pin from (a) the 0°, (b) 120°, and (c) the 240° rotations.

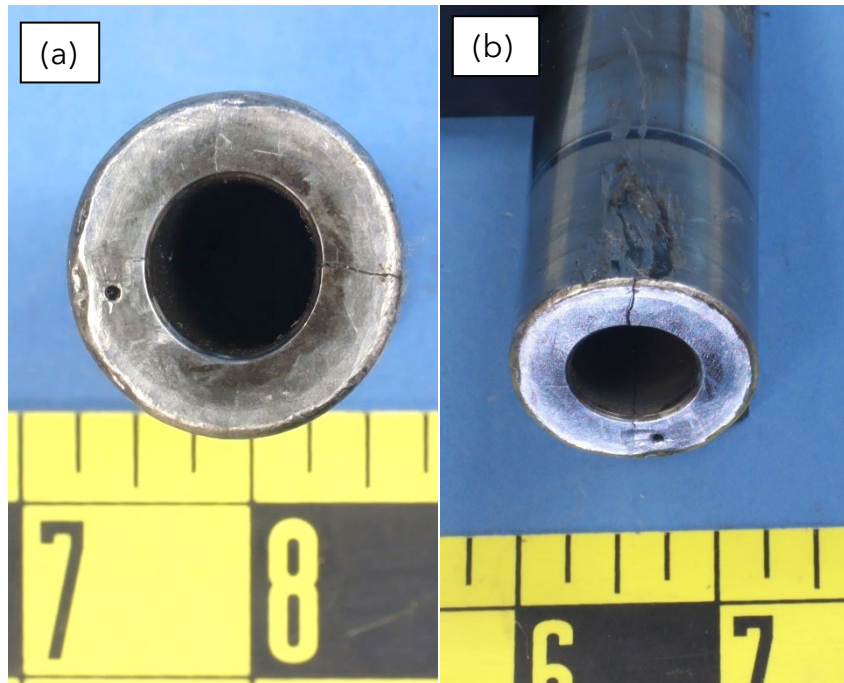


Figure 22. The piston pin face showing cracks from (a) an end view and (b) an angled view.

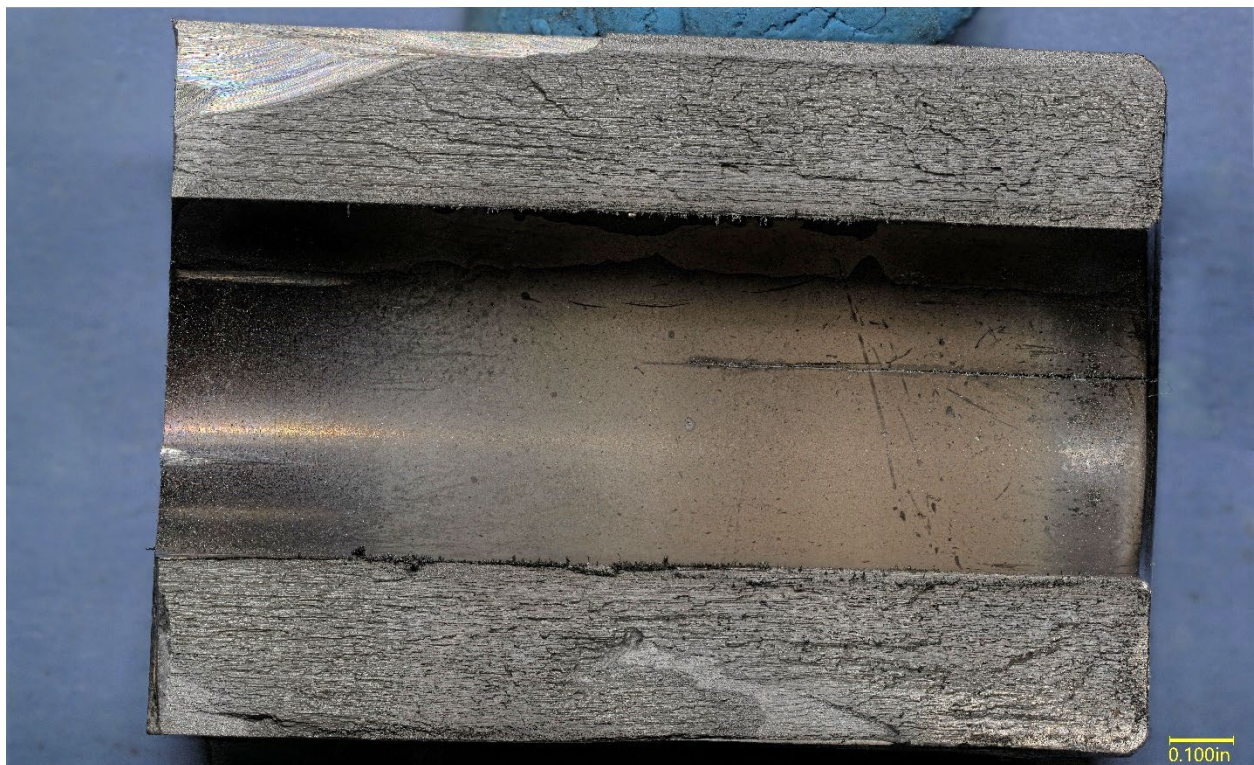


Figure 23. One of the opened crack faces from the piston pin.

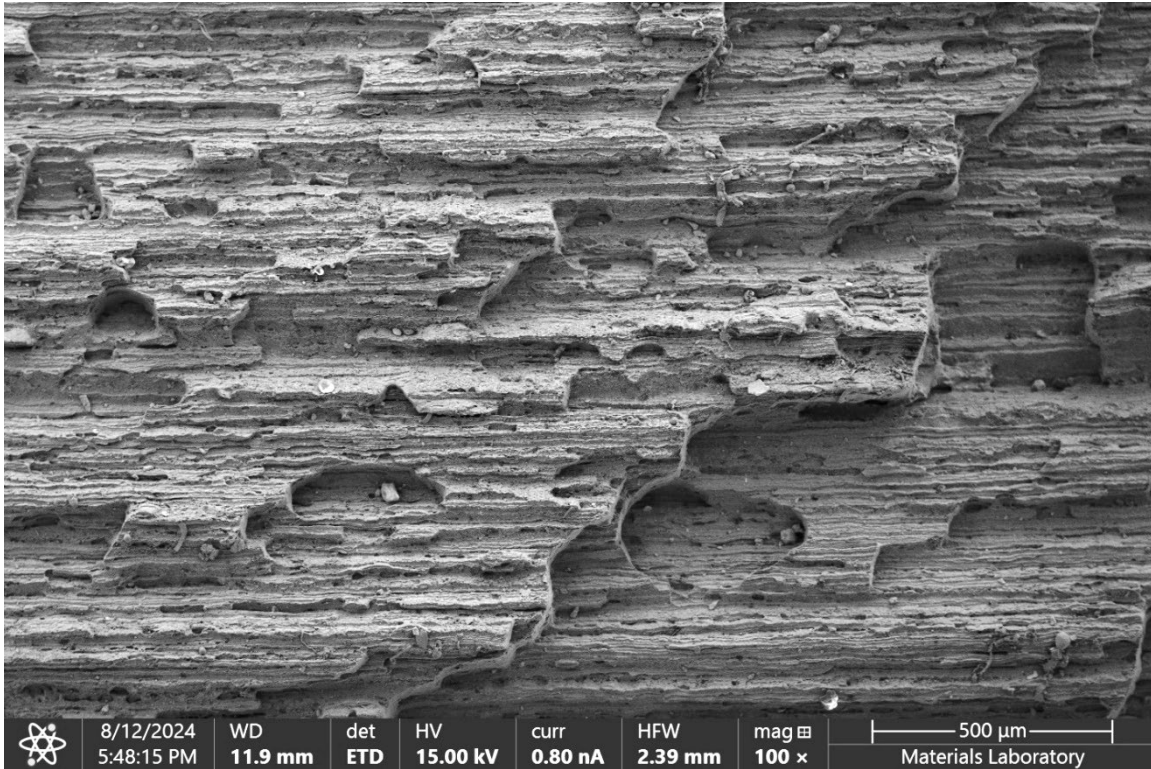


Figure 24. SE micrograph of a typical area of the opened crack in the piston pin.

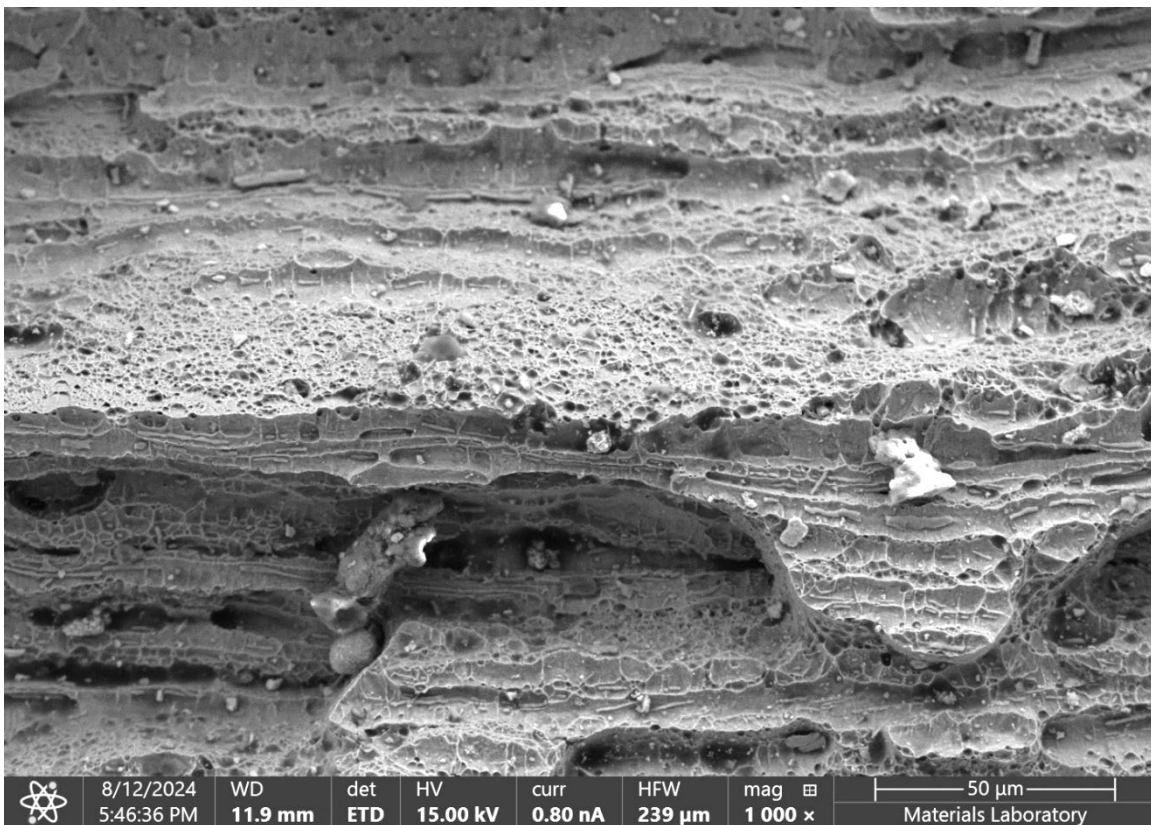


Figure 25. SE micrograph of large and fine dimpled rupture on the open piston pin crack.

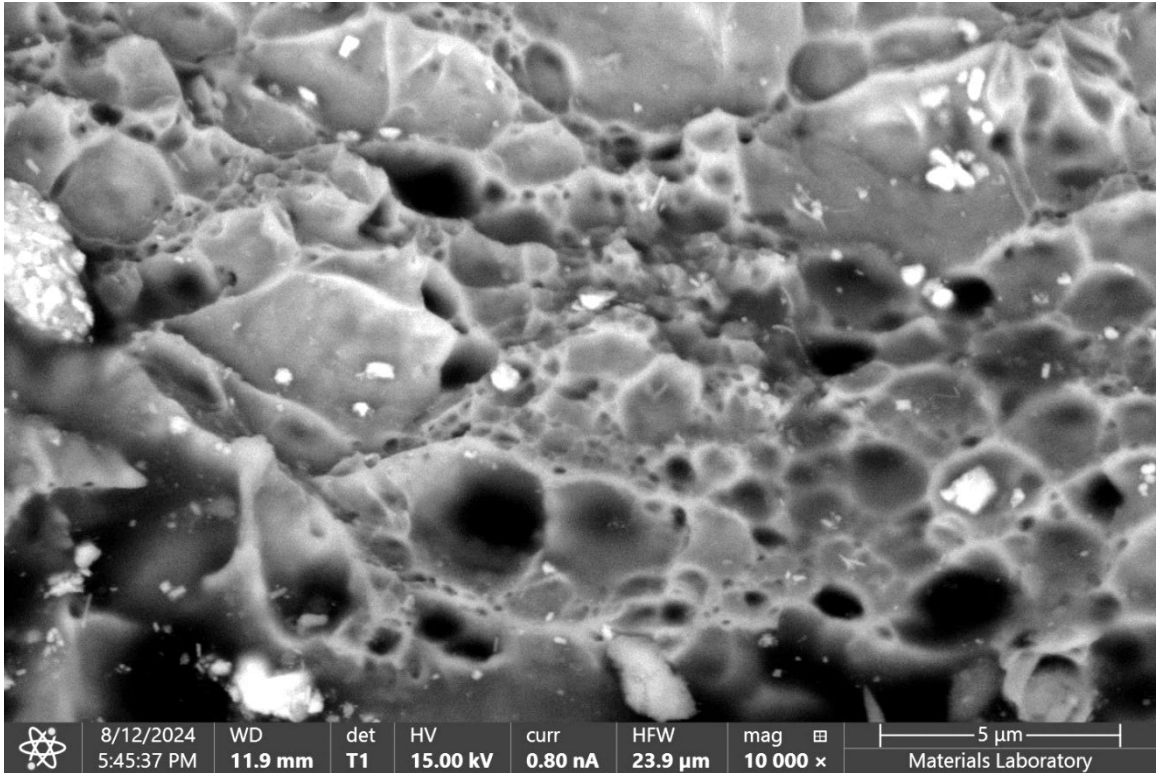


Figure 26. SE micrograph of the dimpled rupture from the opened piston crack.

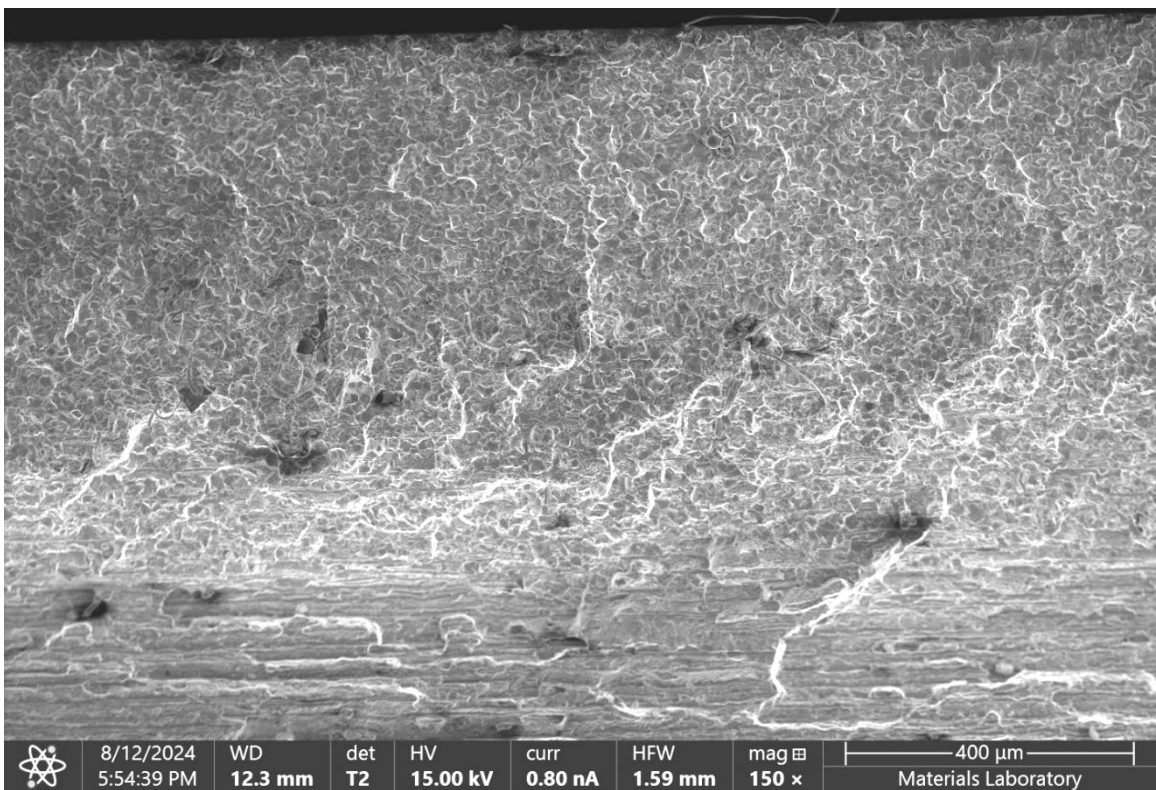


Figure 27. SE micrograph of the opened crack edge with the pin exterior, showing different fracture regions.

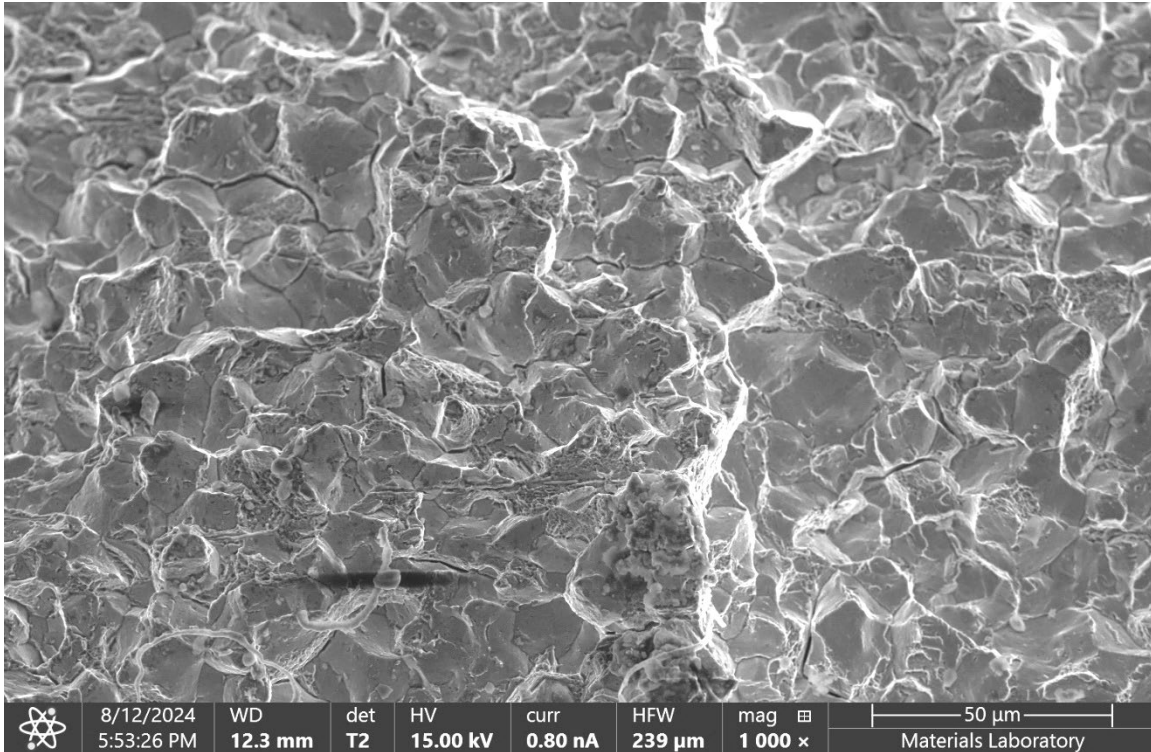


Figure 28. SE micrograph of a closer of the outward fracture features of the opened pin crack.

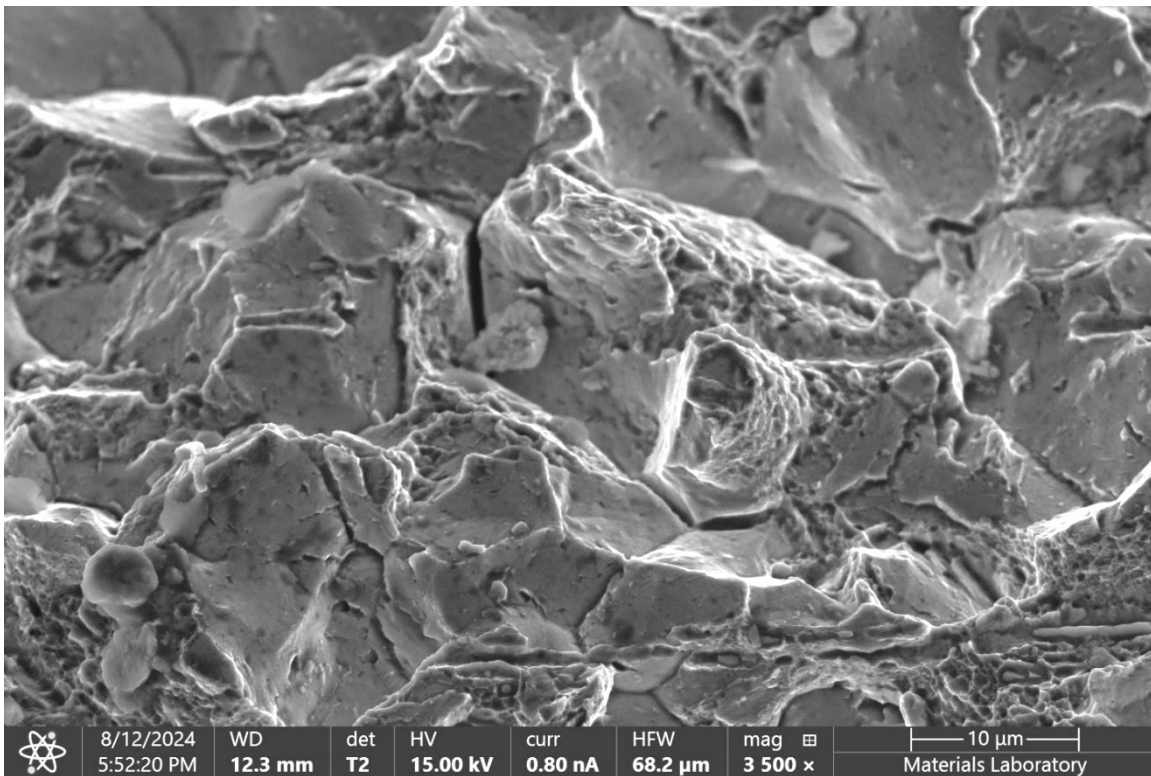


Figure 29. SE micrograph of the region in Figure 28, showing intergranular fracture and dimpled rupture along grain facets.