

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



DCA23FA417

MATERIALS LABORATORY

Addendum Factual Report 24-015B

September 26, 2024

(This page intentionally left blank)

A. ACCIDENT INFORMATION

Location: Santa Ana, California
Date: August 20, 2023
Time: 23:15 Pacific daylight time
06:15 coordinated universal time
Vehicle: Boeing 737-890, N516AS
Investigator: Michael Hauf, AS-10

B. COMPONENTS EXAMINED

Pieces of a main landing gear trunnion pin

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 August 20, 2023, Alaska Airlines flight 1288, a Boeing 737-890, sustained damage when the left main landing gear collapsed after landing on runway 20R at John Wayne-Orange County Airport (SNA). The 112 passengers and crew evacuated the airplane via stairs onto a taxiway with no reported injuries. A post-accident examination found the left main landing gear assembly was found to have failed, and the left-hand main landing gear aft trunnion pin was found fractured. This part was examined primarily at Boeing EQA in Seattle, WA, with additional work performed at the NTSB Materials Laboratory in Washington, DC. Most of the details of those examinations are described in 24-015 - NTSB Materials Laboratory Factual Report.

The trunnion pin, P/N 161A1192-13 and S/N 65780-0066, exhibited a small thumbnail crack at approximately the 12 o'clock position (see Figure 1). This crack exhibited crack arrest marks, consistent with crack propagation, and ratchet marks, consistent with multiple crack initiation sites. Figure 2 shows a closer view of this crack from the forward pin remnant fracture surface. The depth and length of the crack were 0.144 inches and 0.391 inches, respectively. While most of the thumbnail crack exhibited fatigue striations, a thinner subsurface area exhibited intergranular fracture (see Figure 3). This region's depth was 0.016 inches below the chromium electroplating layer and was 0.29 inches long.

A fatigue crack growth rate analysis was performed by counting striations at intervals along the crack depth to better understand how long the fatigue crack had been present. The fracture surface was cleaned in an ultrasonic bath of acetone for 7

minutes. The fatigue striation counts were taken at 32 random, unique, and non-duplicated places on the fracture surface, with the distances from the initiation site recorded. Figure 4 shows one of the central crack initiation sites of fatigue cracking, occurring at the end of the intergranular region.

This initiation site was labeled as the origin and was located at 41.12585 mm in the X-direction and 0.735 mm in the Y-direction. The working distance (or Z-direction) was initially 10 mm. The distances were measured via a calibrated stage on a field emission scanning electron microscope (FESEM). The location, number of striations counted, and total cycles that occurred up to that location are listed in Table I. The cumulative cycles per crack length and crack growth rate (da/dN) over crack depth are illustrated in charts in Figure 5 and Figure 6. The locations for the 32 spots examined are shown in Figures These locations and the measurements are shown in Figure 7 through Figure 37. No measurements were taken in any overstress, intergranular, or electroplated regions.

Using a FESEM, multiple areas exhibiting striations were counted, and the distance of the counted striations was measured. This analysis assumed that each counted striation (a feature consistent with crack growth) correlated directly to a landing cycle with no other comparable stresses (such as from braking or vibrations). The analysis also assumed that sampled regions were representative regions of fatigue crack growth at each crack depth, the fracture surface was flat, and the fatigue striation spacing increased with crack depth.

Of note from the data was that the total number of cycles from the intergranular initiation site used as the origin to the end of the crack was 797. From the chart in Figure 5, the crack depth steadily increased over time, corresponding with an expected increase in crack growth rate, demonstrated in Figure 6.

The number of landings since the last overhaul at Sunvair was 4710 cycles. The number of striations counted on this fatigue crack, 797, was an order of magnitude lower than the number of landings since the overhaul. These data indicate that a detectable fatigue crack had not been present at, or prior to, the part overhaul.

Submitted by:

Erik M. Mueller
Materials Research Engineer

Table 1 - Compiled data of the fatigue analysis on the fatigue crack, showing the individual striations counted and distance measured for each micrograph site (1 through 31).

Point	X (mm)	Y (mm)	Distance from Origin (mm)	Increment (μ m)	Sample Length (μ m)	Striations #	da/dN (μ m /cycle)	Increment Cycles #	Total Cycles #
ORI GIN	41.2585	0.735	0	0	Origin		0		0
2	41.1492	0.7753	0.1165	116.5	30.50	11	2.773	42	42
1	41.1492	0.6937	0.1168	0.3	24.46	7	3.494	0	42
3	40.978	0.6755	0.2867	169.9	19.40	6	3.233	53	95
4	40.894	0.7267	0.3646	77.9	23.25	8	2.906	27	121
5	40.8033	0.6057	0.4732	108.6	29.12	11	2.647	41	162
6	40.7841	0.506	0.5268	53.6	43.17	18	2.398	22	185
7	40.7027	0.4133	0.6422	115.4	16.00	9	1.778	65	250
10	40.5869	0.7115	0.6720	29.8	20.33	11	1.848	16	266
9	40.6122	0.4783	0.6954	23.4	31.24	11	2.840	8	274
8	40.6437	0.3915	0.7043	8.8	40.17	14	2.869	3	277
11	40.4982	0.5795	0.7760	71.8	24.79	8	3.099	23	300
12	40.4097	0.6443	0.8536	77.6	25.27	9	2.808	28	328
13	40.3727	0.7229	0.8859	32.3	34.23	11	3.112	10	338
14	40.312	0.5863	0.9581	72.2	56.42	11	5.129	14	352
15	40.1919	0.5108	1.0899	131.8	61.14	12	5.095	26	378
16	40.097	0.3753	1.2159	126.0	29.04	9	3.227	39	417
17	40.036	0.3075	1.2951	79.2	33.77	11	3.070	26	443
18	39.955	0.4517	1.3339	38.8	27.88	9	3.098	13	456
19	39.8556	0.3028	1.4680	134.0	21.65	7	3.093	43	499
20	39.8079	0.3165	1.5098	41.8	21.45	6	3.575	12	511
21	39.6917	0.2971	1.6268	117.1	53.85	9	5.983	20	530
22	39.5979	0.2046	1.7432	116.4	43.92	10	4.392	27	557
23	39.4693	0.0475	1.9167	173.5	65.12	13	5.009	35	591
24	39.4094	0.2	1.9249	8.2	87.48	14	6.249	1	593
25	39.3153	1.0131	1.9630	38.1	81.84	11	7.440	5	598
26	39.1537	1.5437	2.2548	291.8	56.85	9	6.317	46	644
27	39.1013	1.617	2.3305	75.7	46.66	10	4.666	16	660
28	38.9805	1.5707	2.4265	95.9	69.82	10	6.982	14	674
29	38.8182	2.2985	2.8982	471.8	83.83	11	7.621	62	736
30	38.6959	2.6355	3.1904	292.2	73.76	9	8.196	36	772
32	38.0845	1.1262	3.1980	7.6	50.97	7	7.281	1	773
31	38.6785	2.953	3.4023	204.3	58.61	7	8.373	24	797

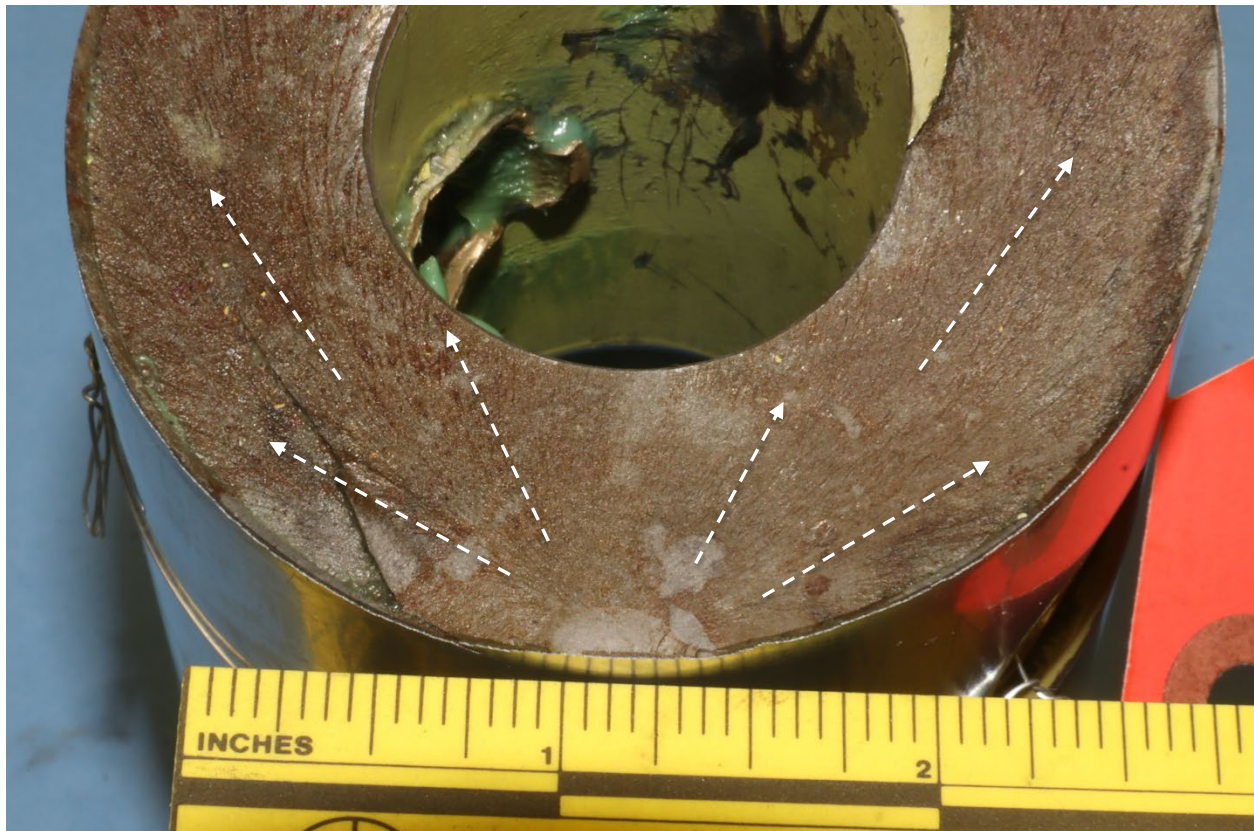


Figure 1. Fracture surface of the forward fracture surface of the aft trunnion pin, showing a thumbnail crack with dashed arrows denote the fracture direction from the thumbnail.



Figure 2. Microscopic view of the thumbnail crack in Figure 1., annotated to show various dimensions.

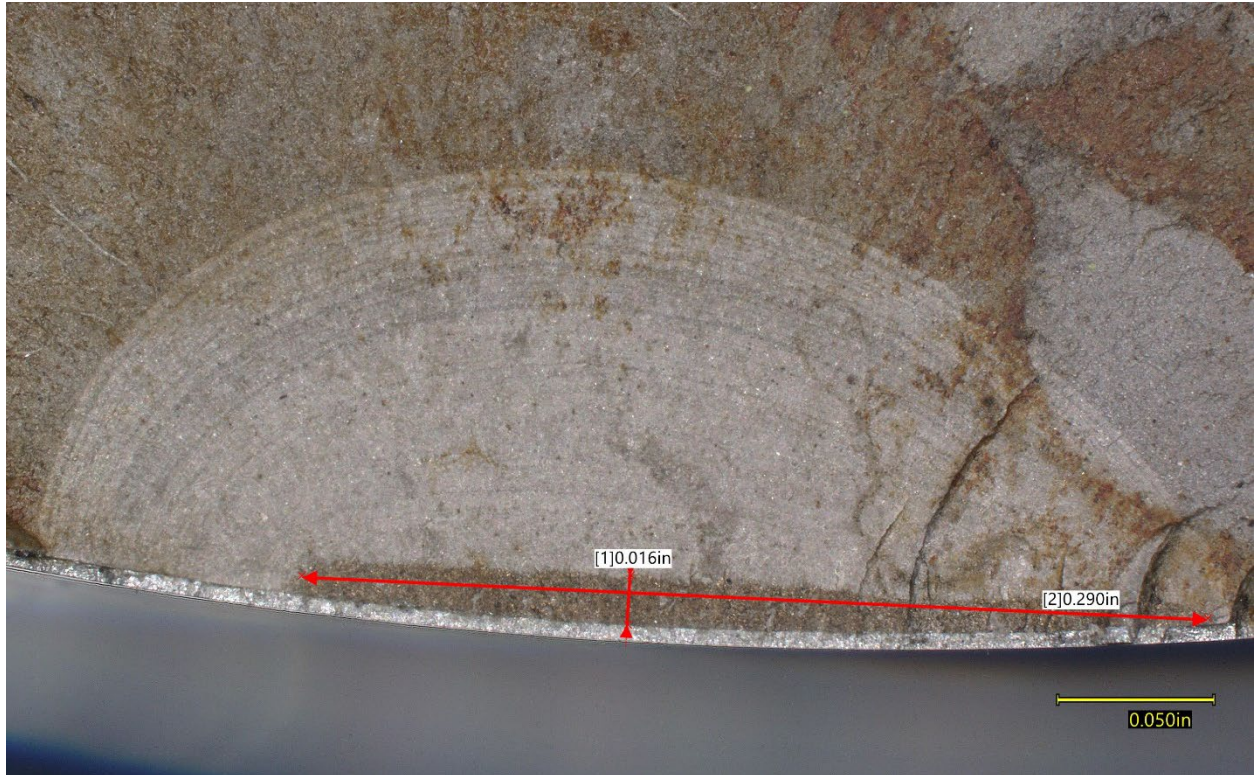


Figure 3. Secondary electron (SE) micrograph of the overall view of the thumbnail crack, annotated to show various measurements.

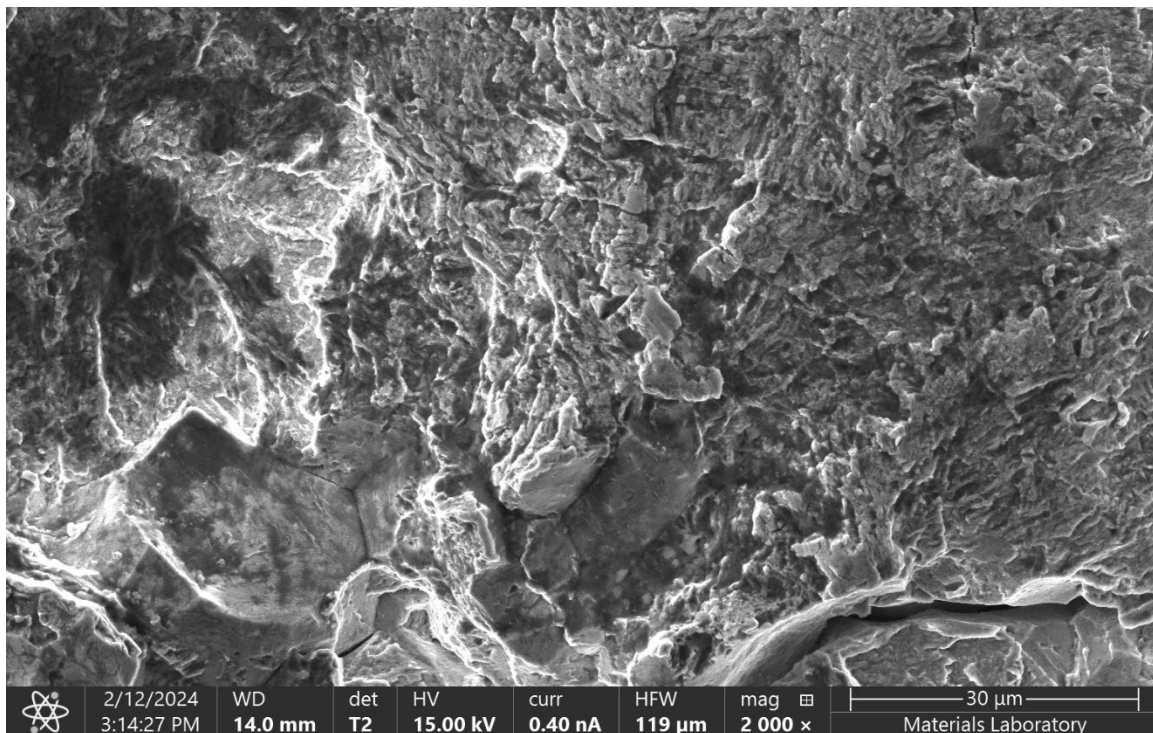


Figure 4. Secondary electron (SE) micrograph of an initiation site of fatigue cracking at the end of the intergranular region, used as the origin for counting.

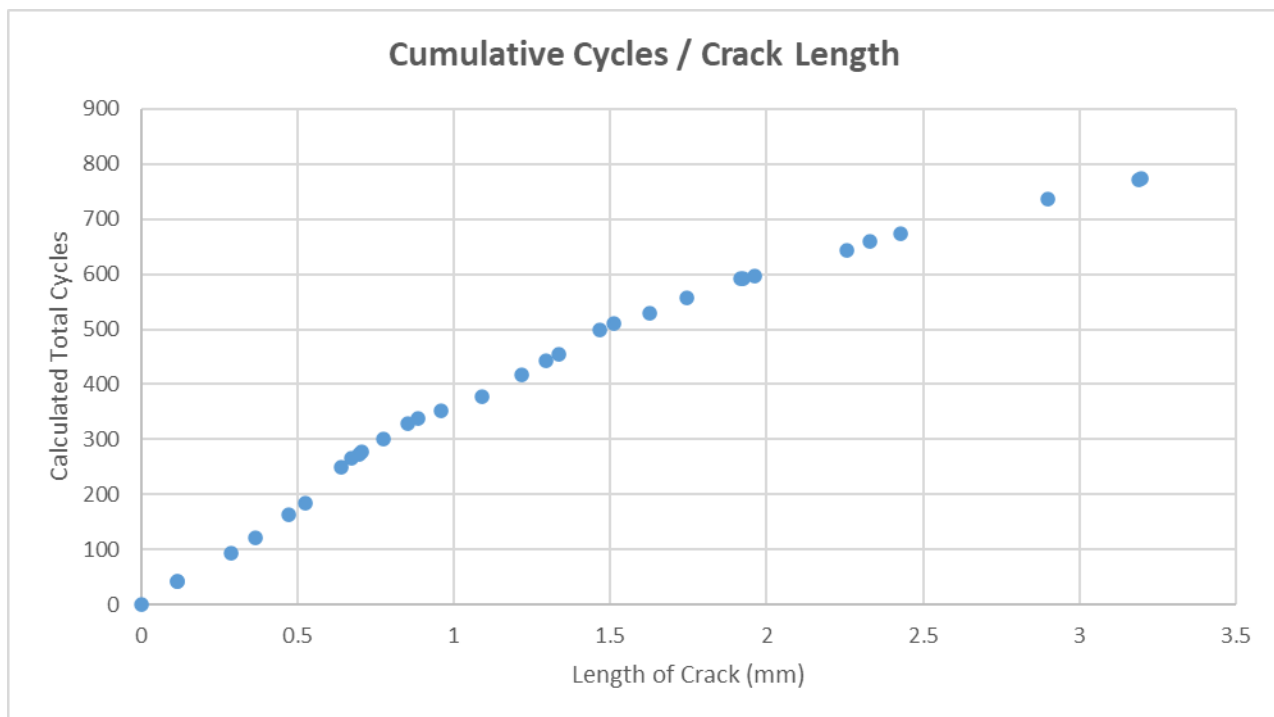


Figure 5. Chart of the total cycles per location at the distance from the intergranular area, representing crack depth.

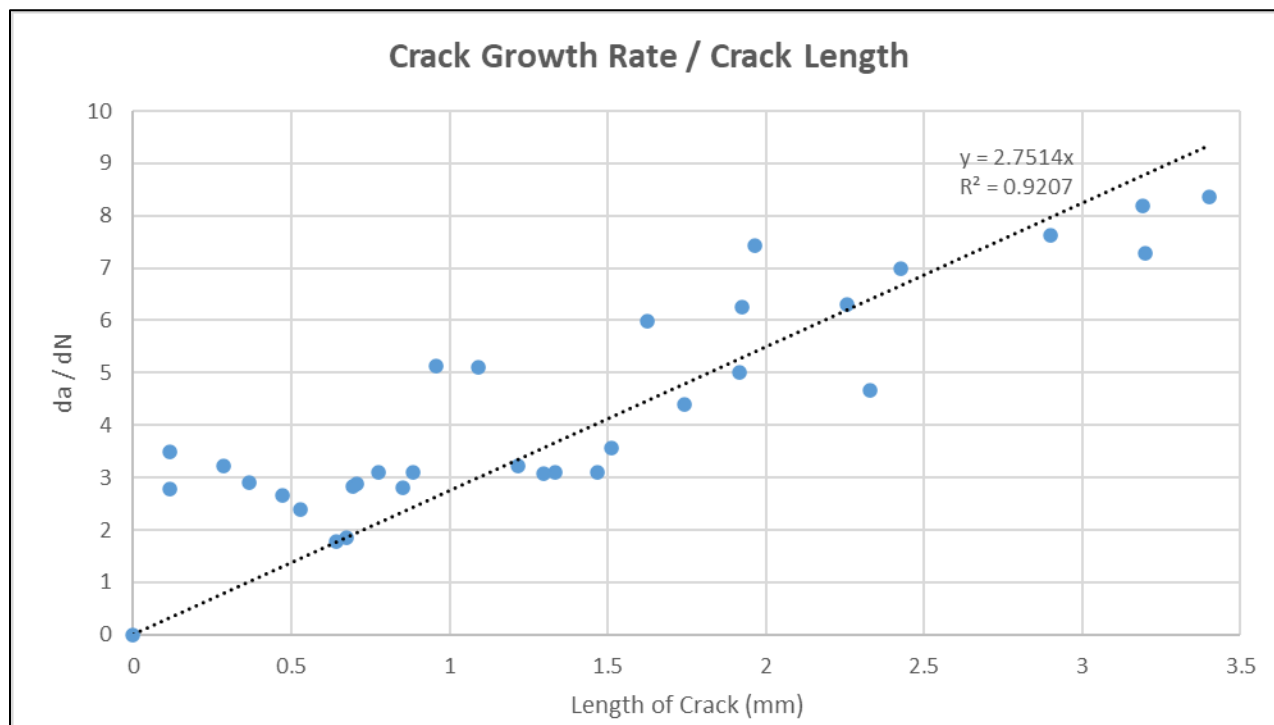


Figure 6. Chart of the da/dN versus the crack depth, with a linear regression superimposed (with y-intercept fixed to 0).

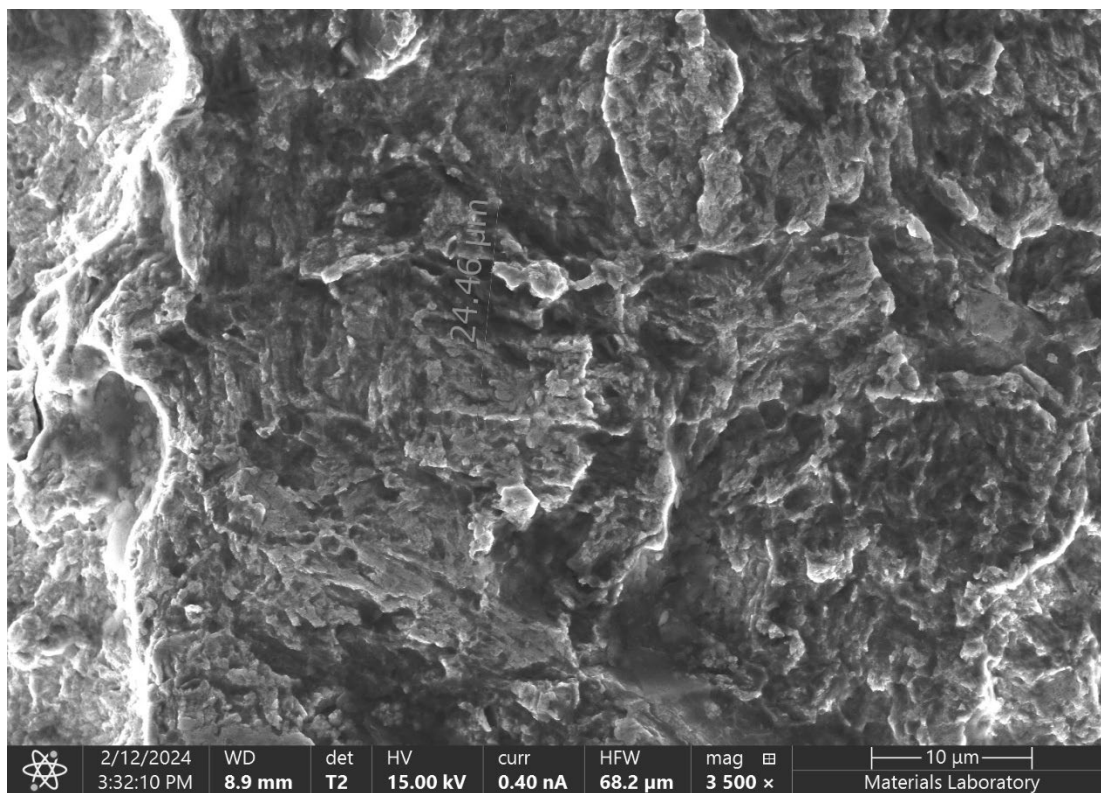


Figure 7. SE micrograph of spot 1 and the length used in striation counting.

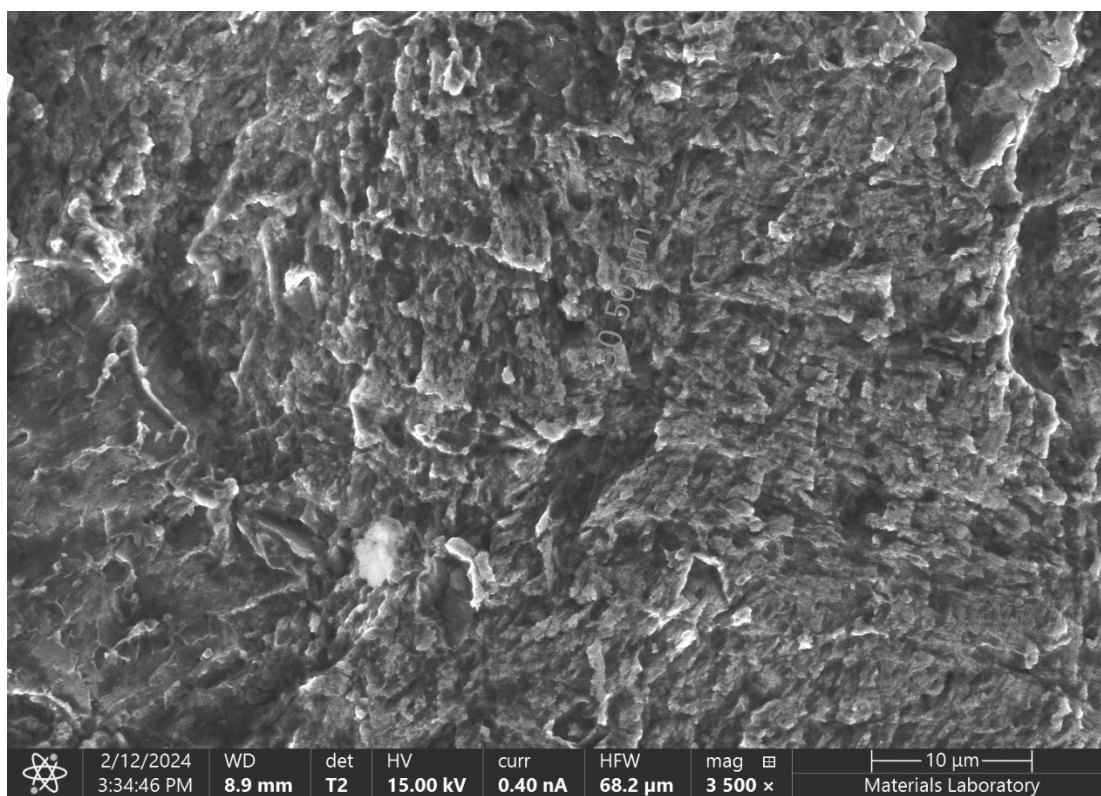


Figure 8. SE micrograph of spot 2 and the length used in striation counting.

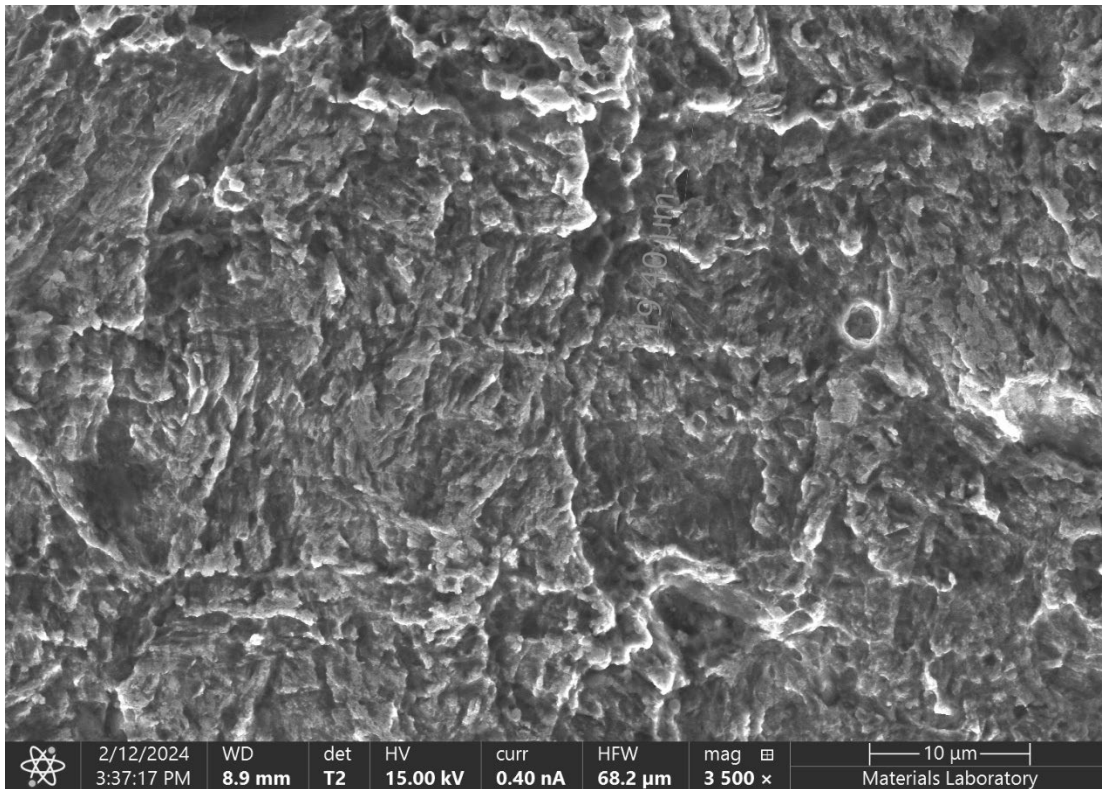


Figure 9. SE micrograph of spot 3 and the length used in striation counting.

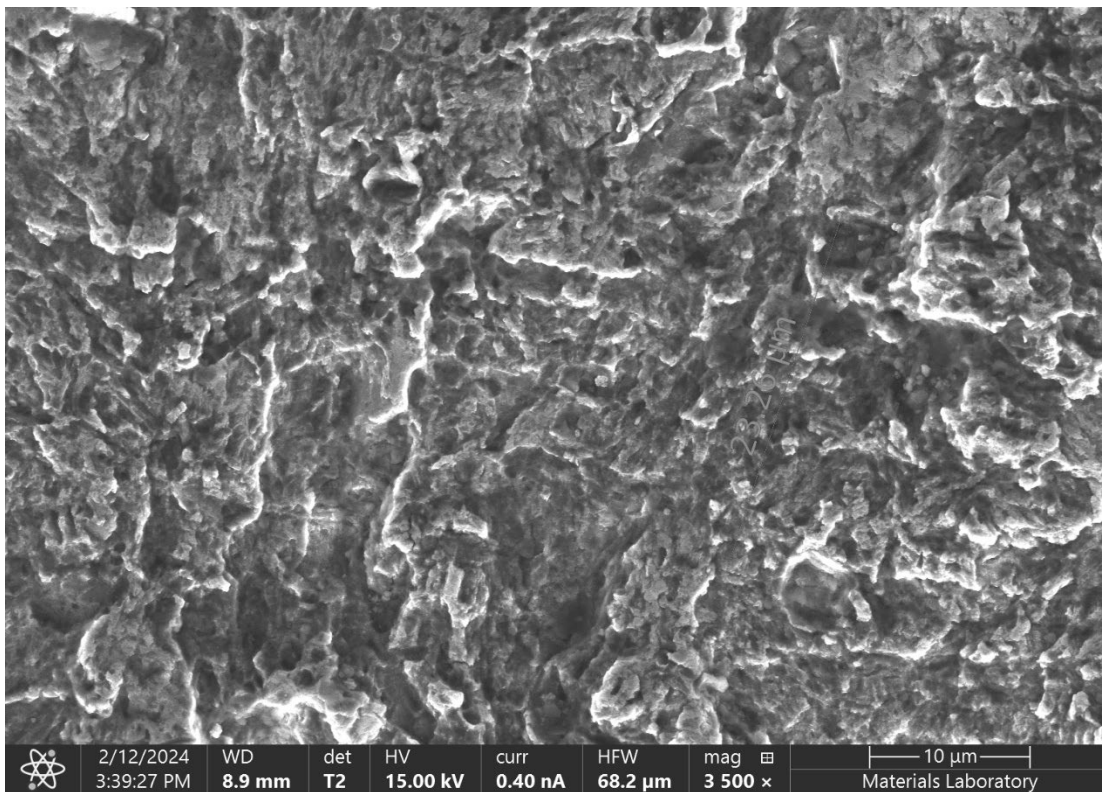


Figure 10. SE micrograph of spot 4 and the length used in striation counting.

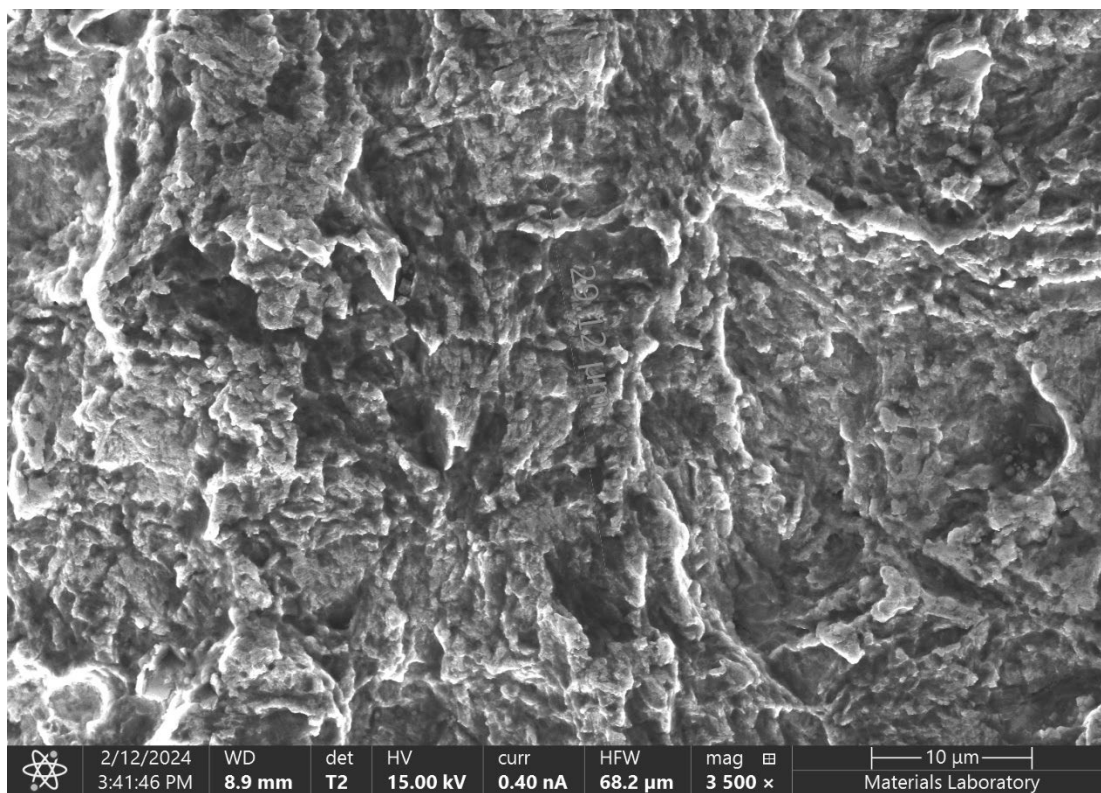


Figure 11. SE micrograph of spot 5 and the length used in striation counting.

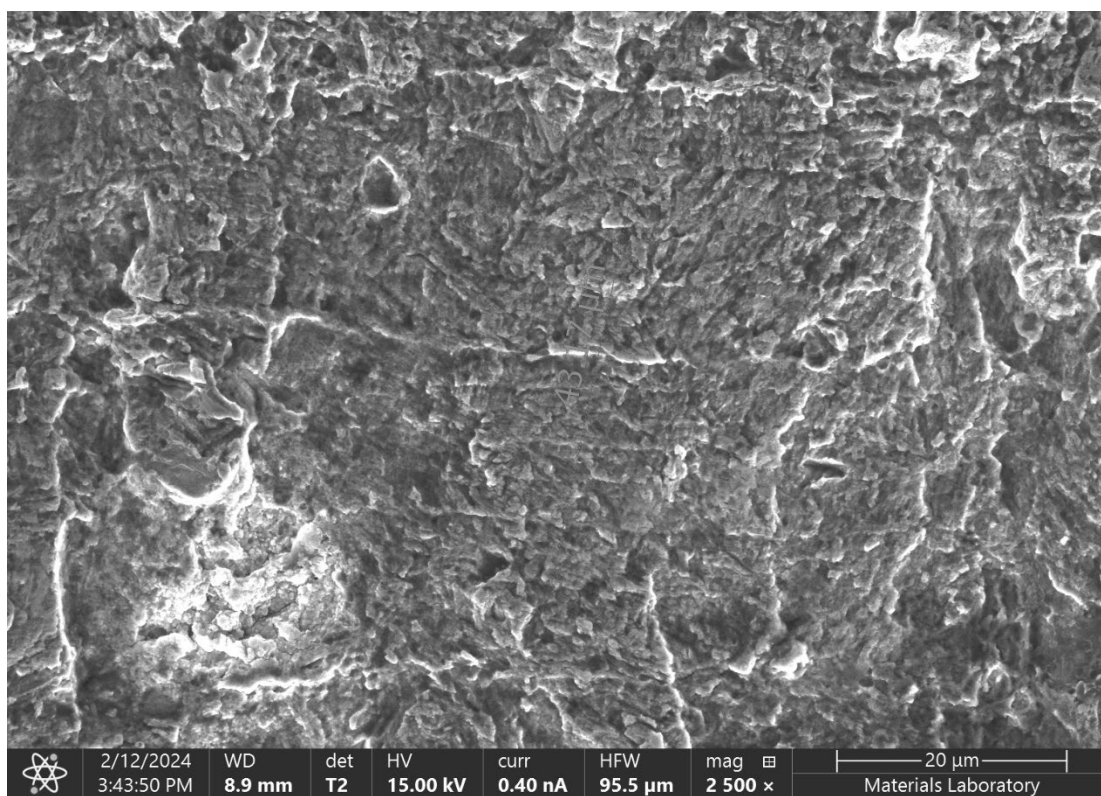


Figure 12. SE micrograph of spot 6 and the length used in striation counting.

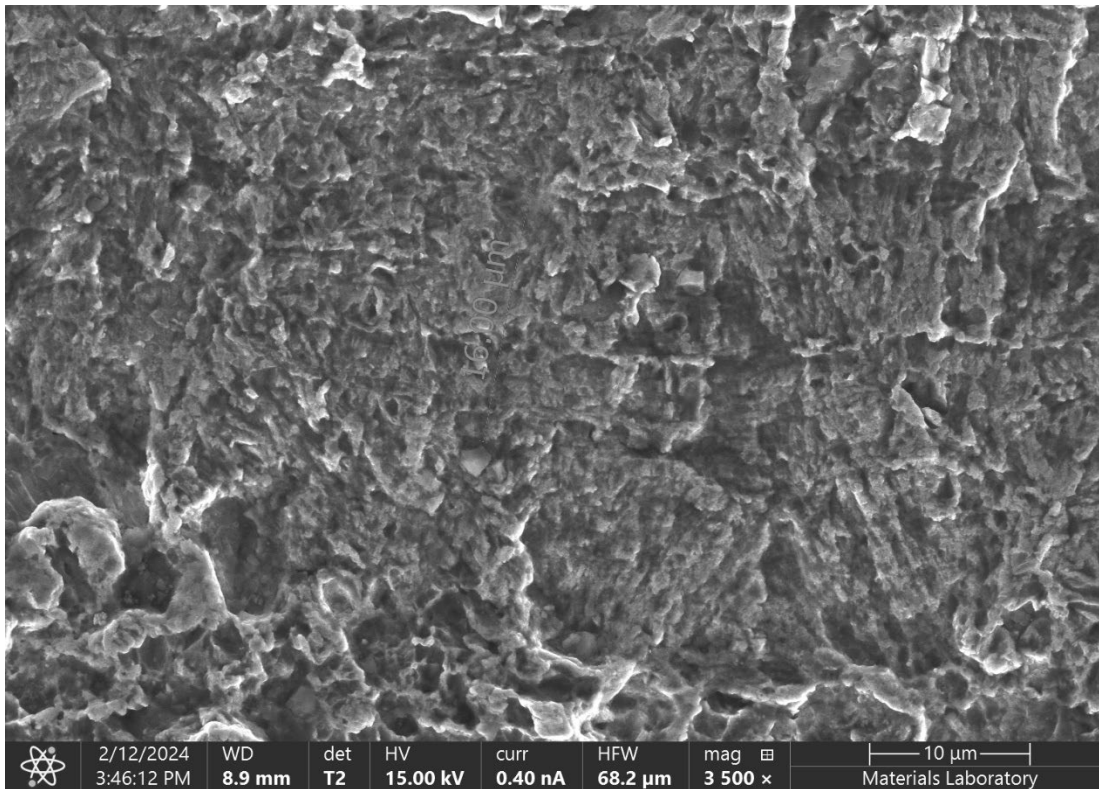


Figure 13. SE micrograph of spot 7 and the length used in striation counting.

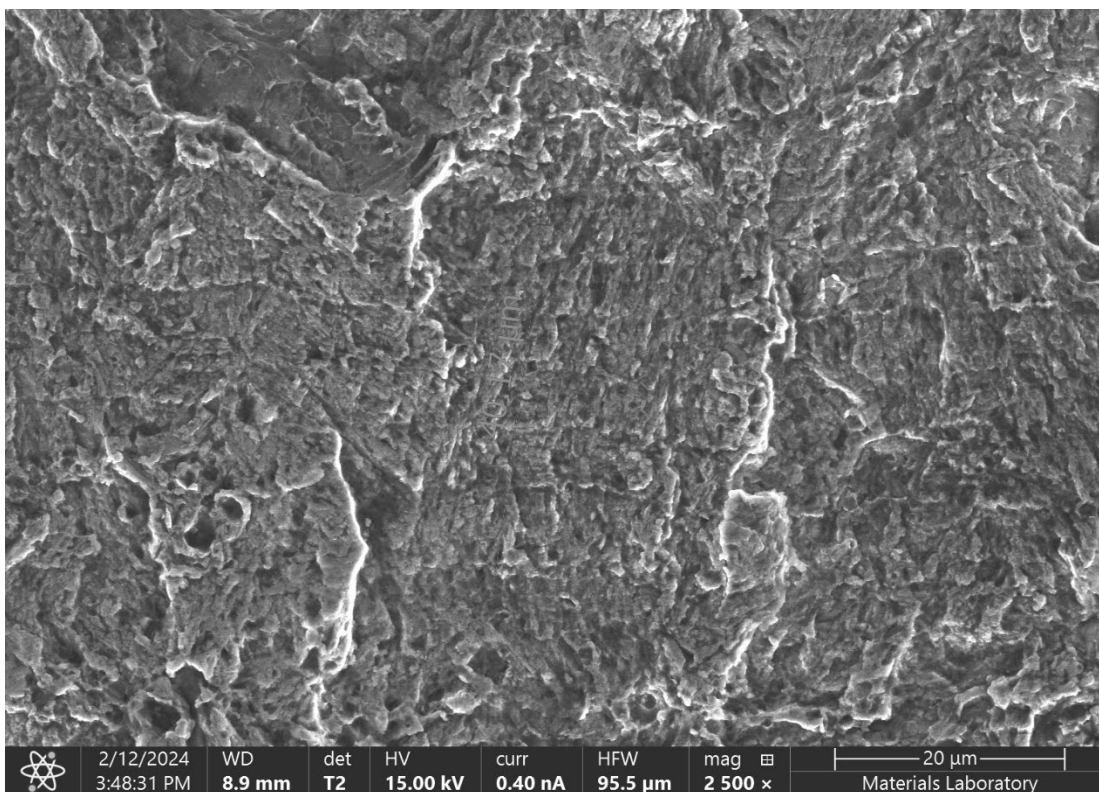


Figure 14. SE micrograph of spot 8 and the length used in striation counting.

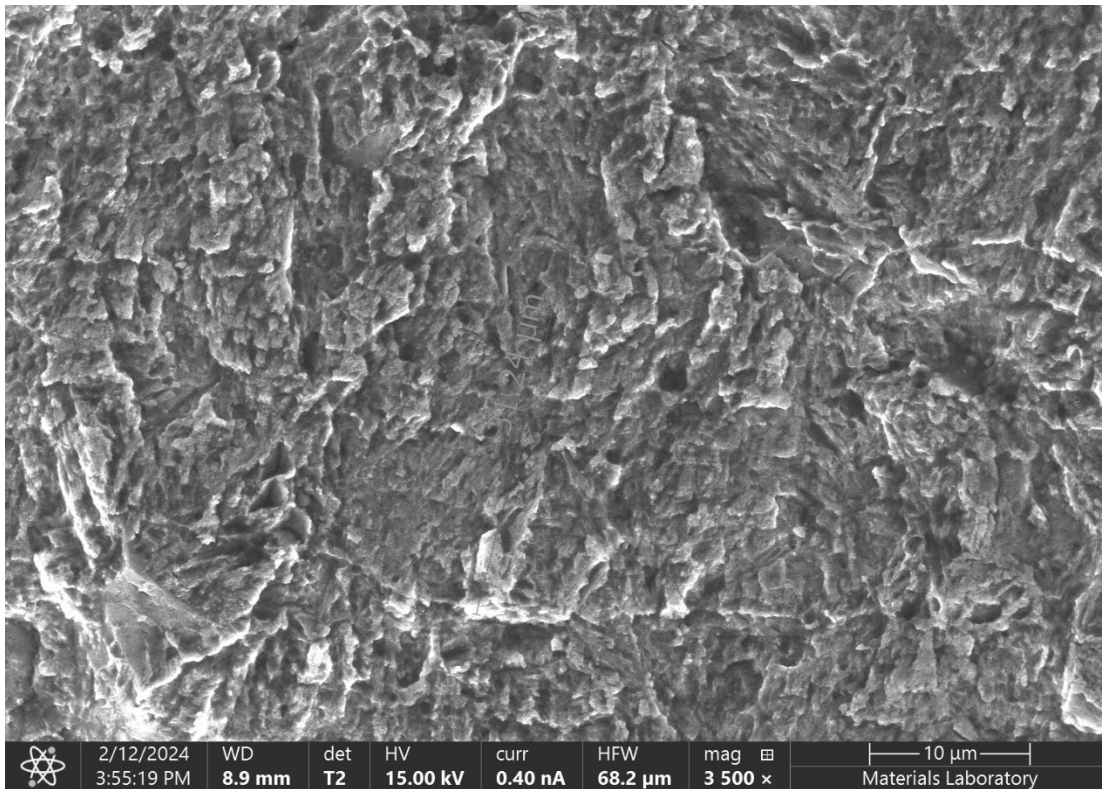


Figure 15. SE micrograph of spot 9 and the length used in striation counting.

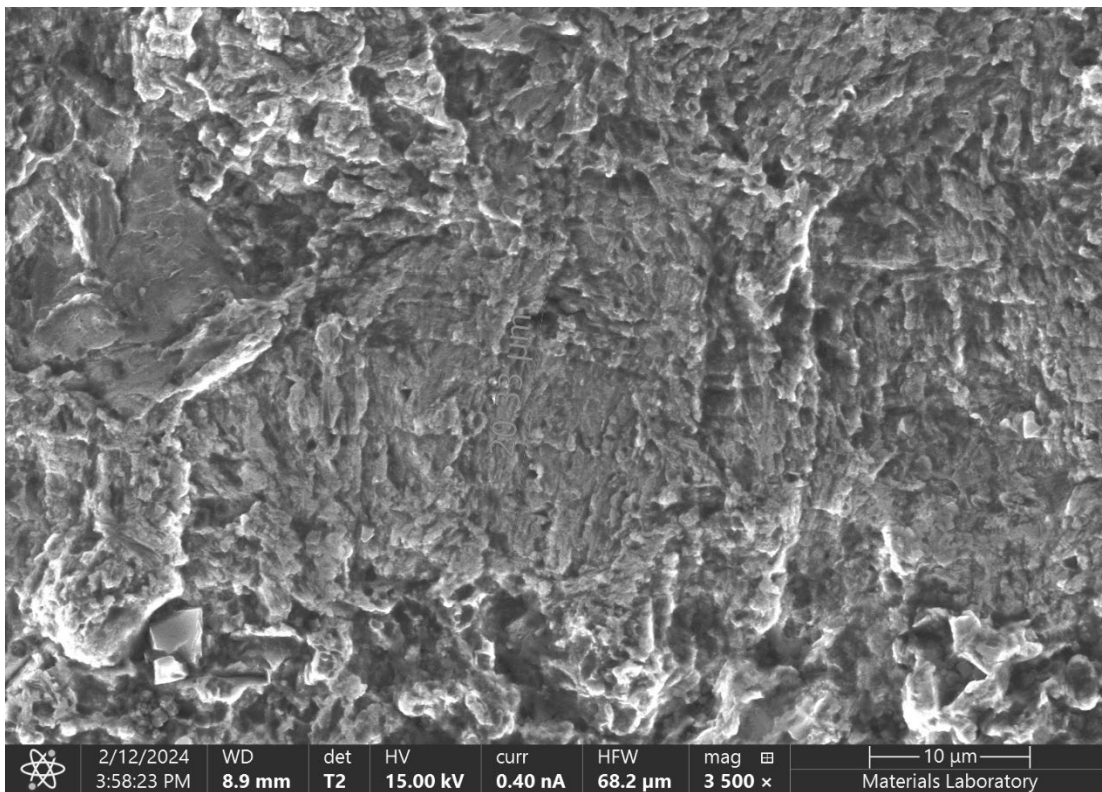


Figure 16. SE micrograph of spot 10 and the length used in striation counting.

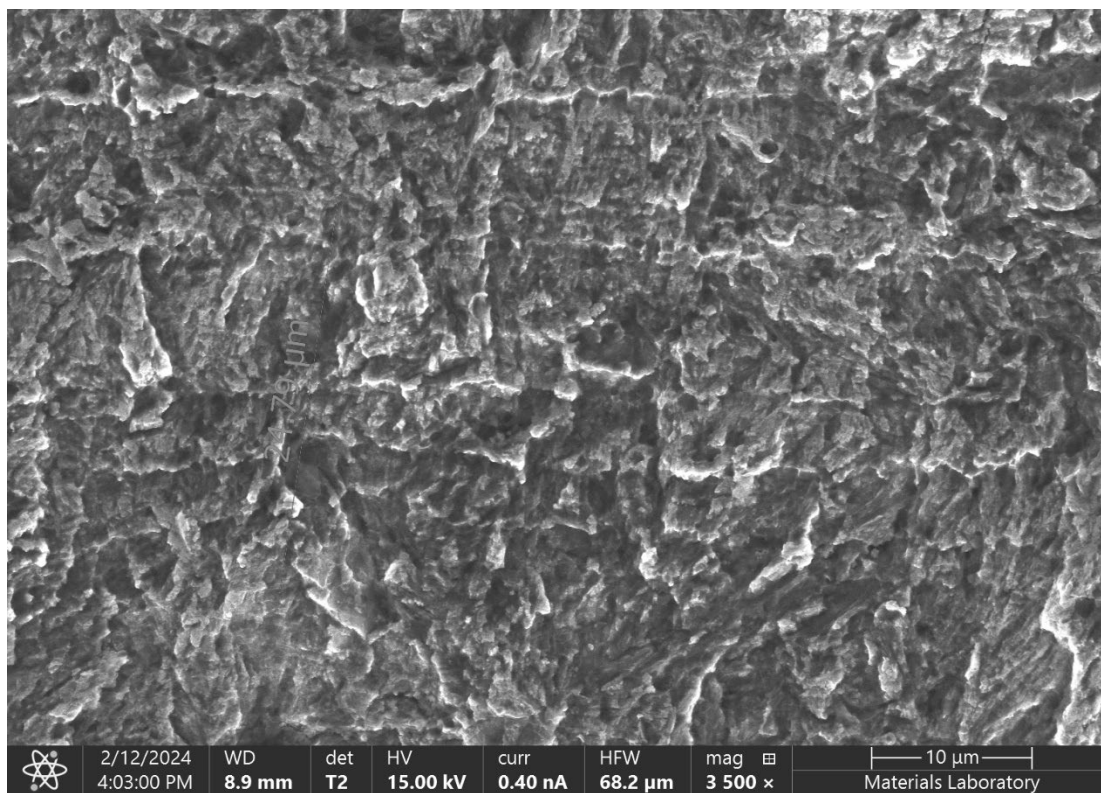


Figure 17. SE micrograph of spot 11 and the length used in striation counting.

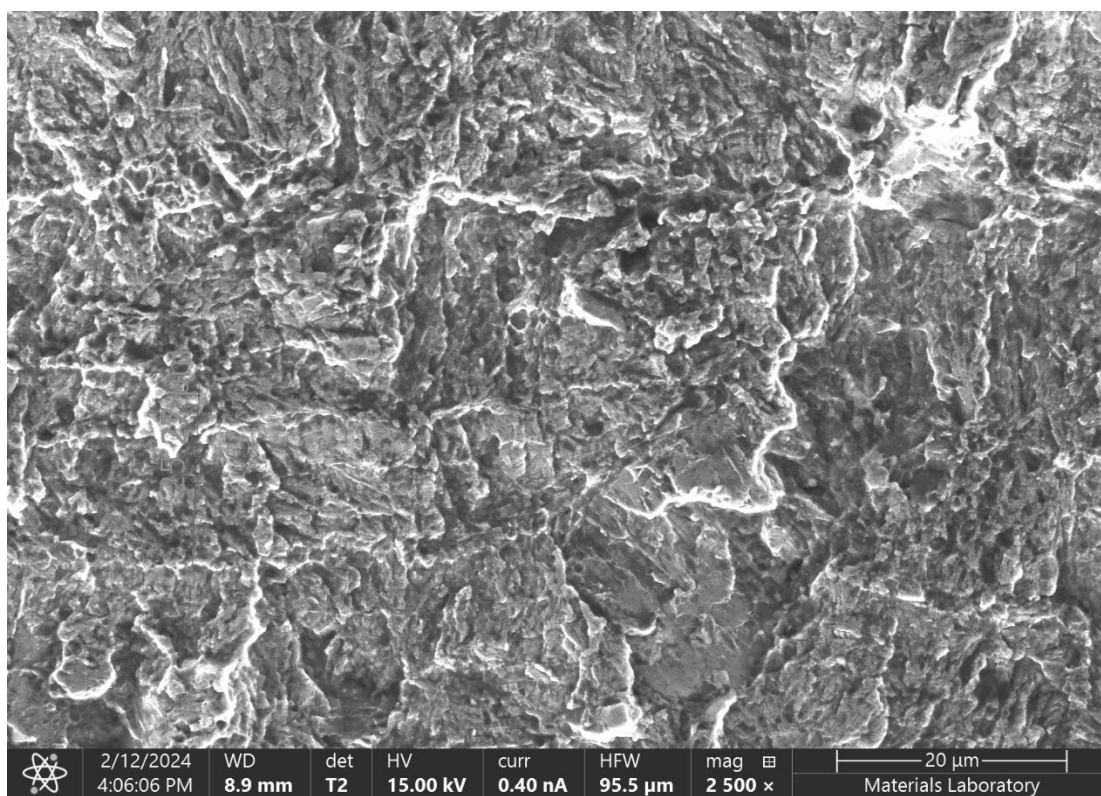


Figure 18. SE micrograph of spot 12 and the length used in striation counting.

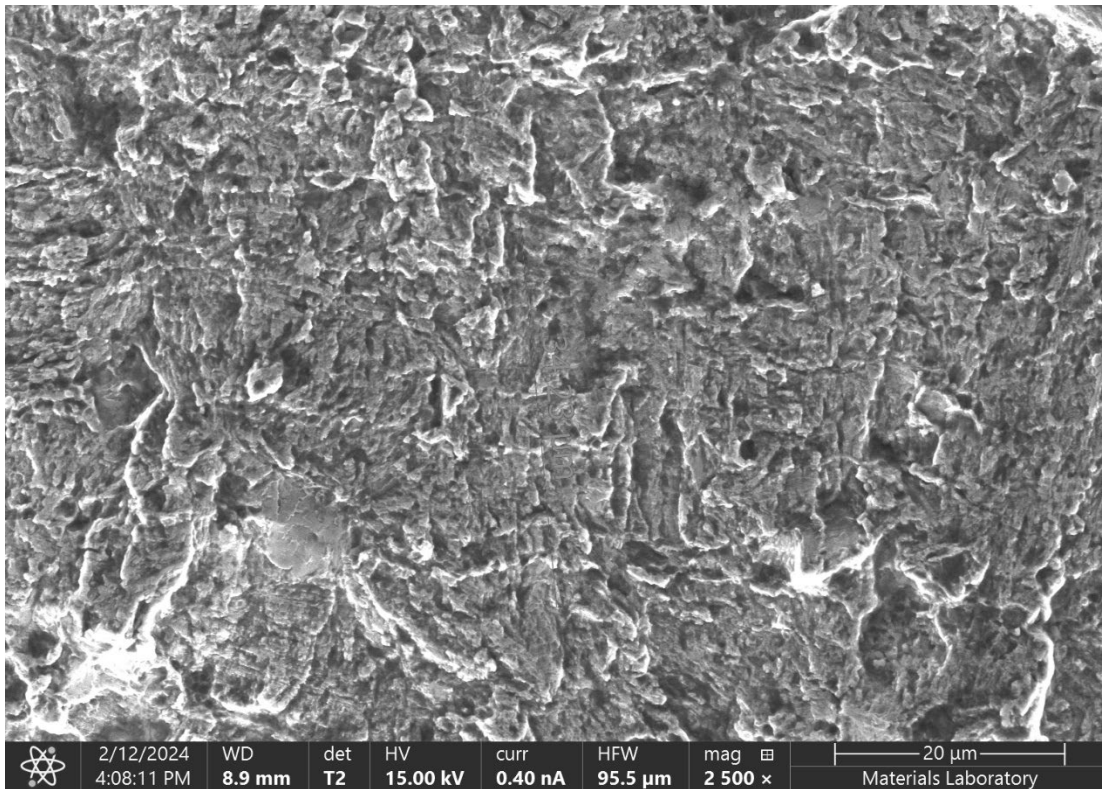


Figure 19. SE micrograph of spot 13 and the length used in striation counting.

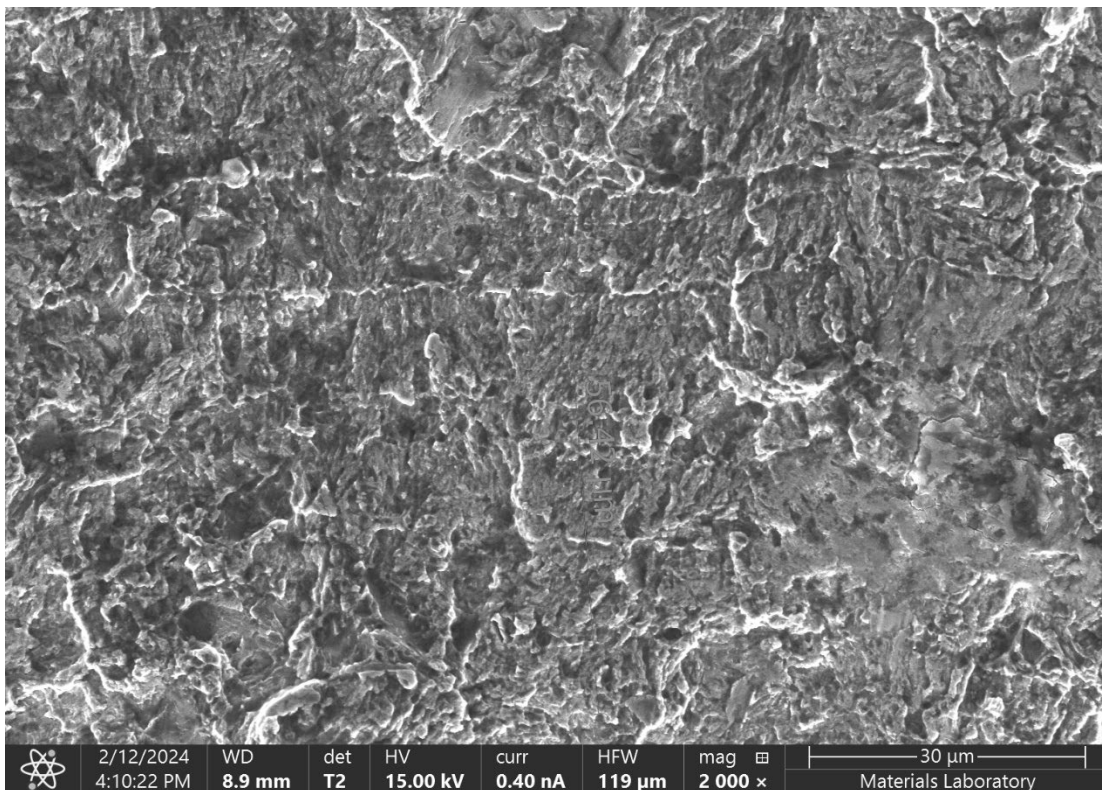


Figure 20. SE micrograph of spot 14 and the length used in striation counting.

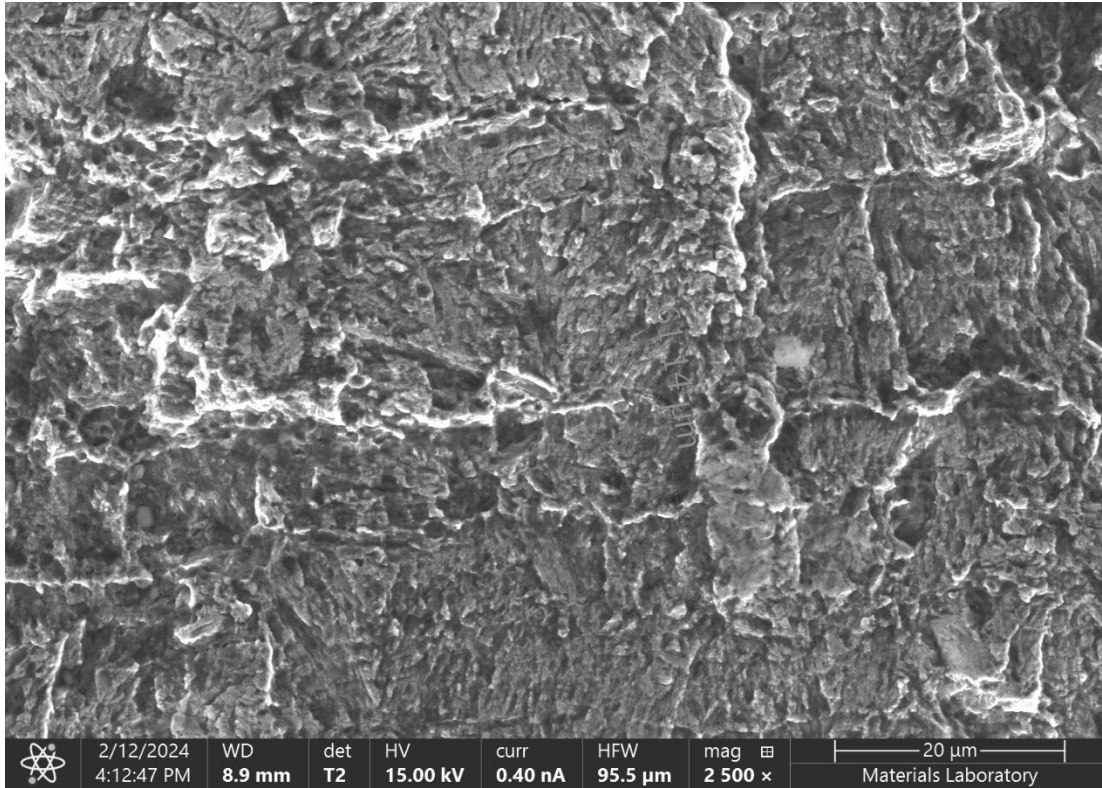


Figure 21. SE micrograph of spot 15 and the length used in striation counting.

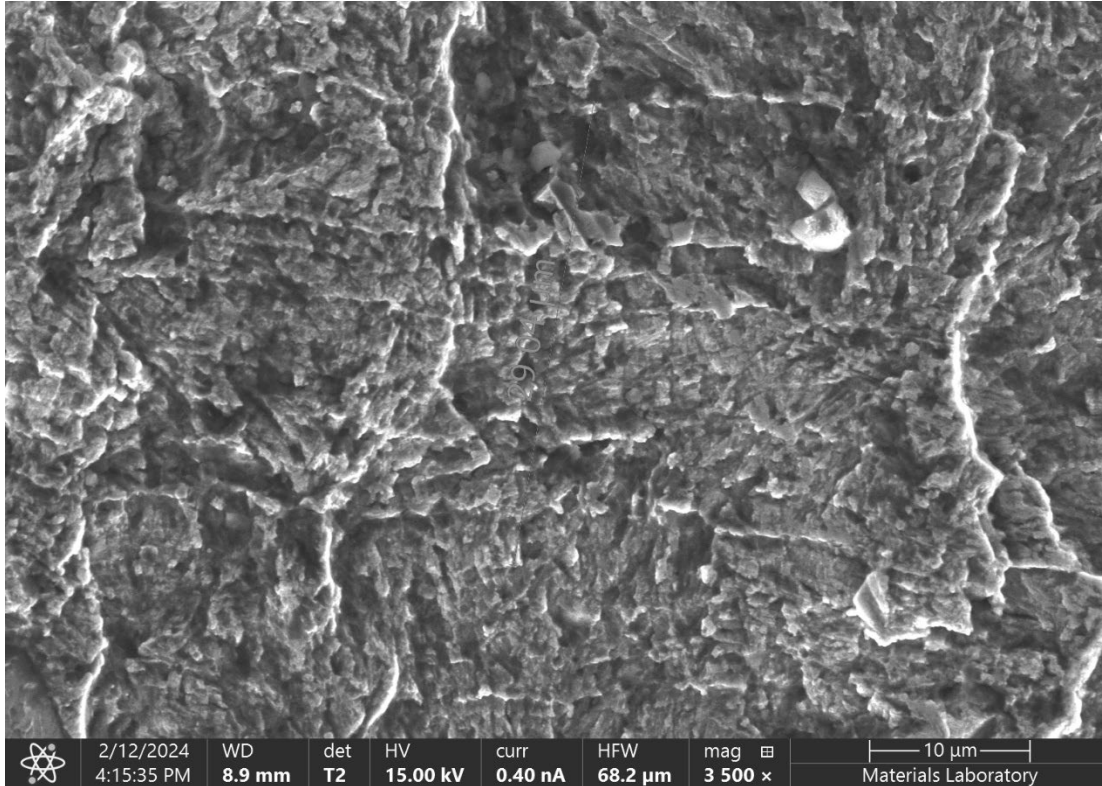


Figure 22. SE micrograph of spot 16 and the length used in striation counting.

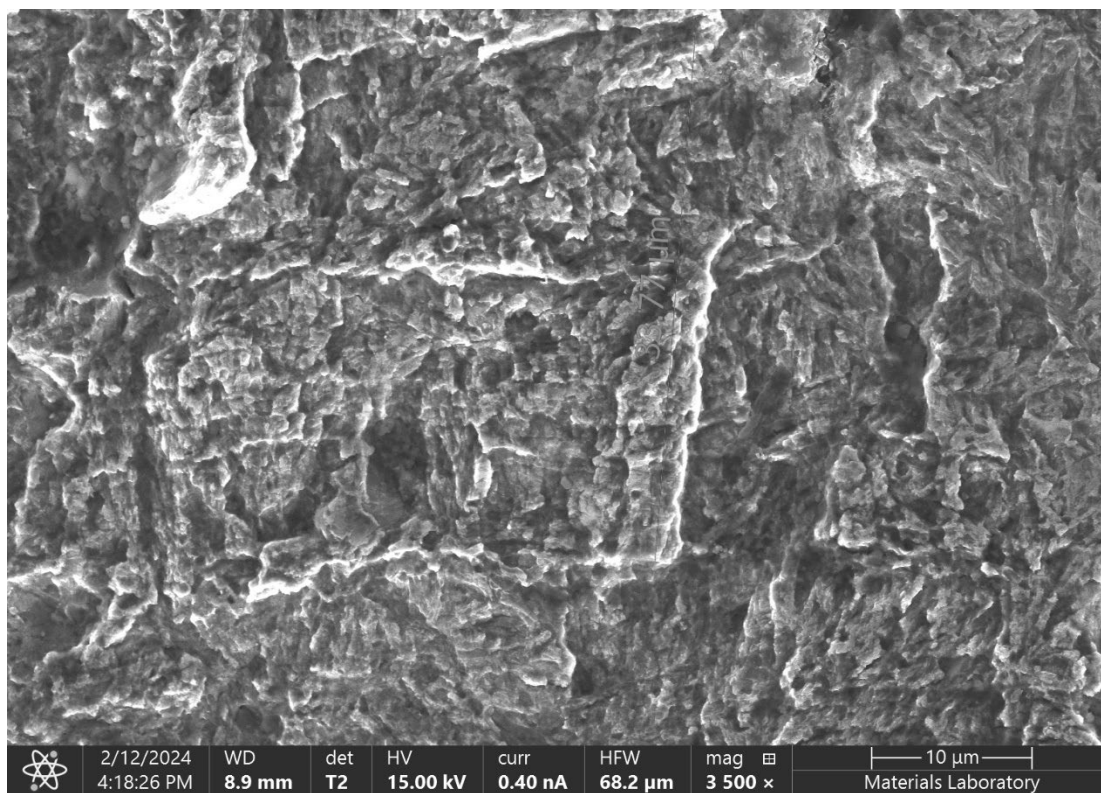


Figure 23. SE micrograph of spot 17 and the length used in striation counting.

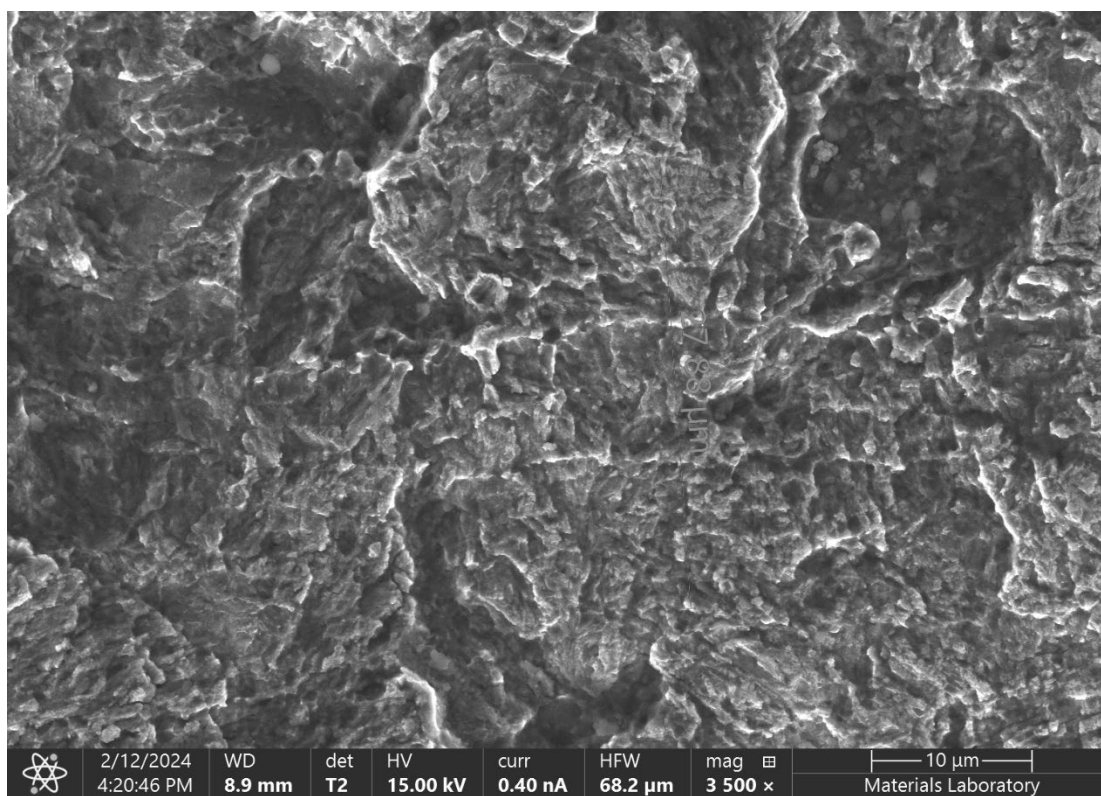


Figure 24. SE micrograph of spot 18 and the length used in striation counting.

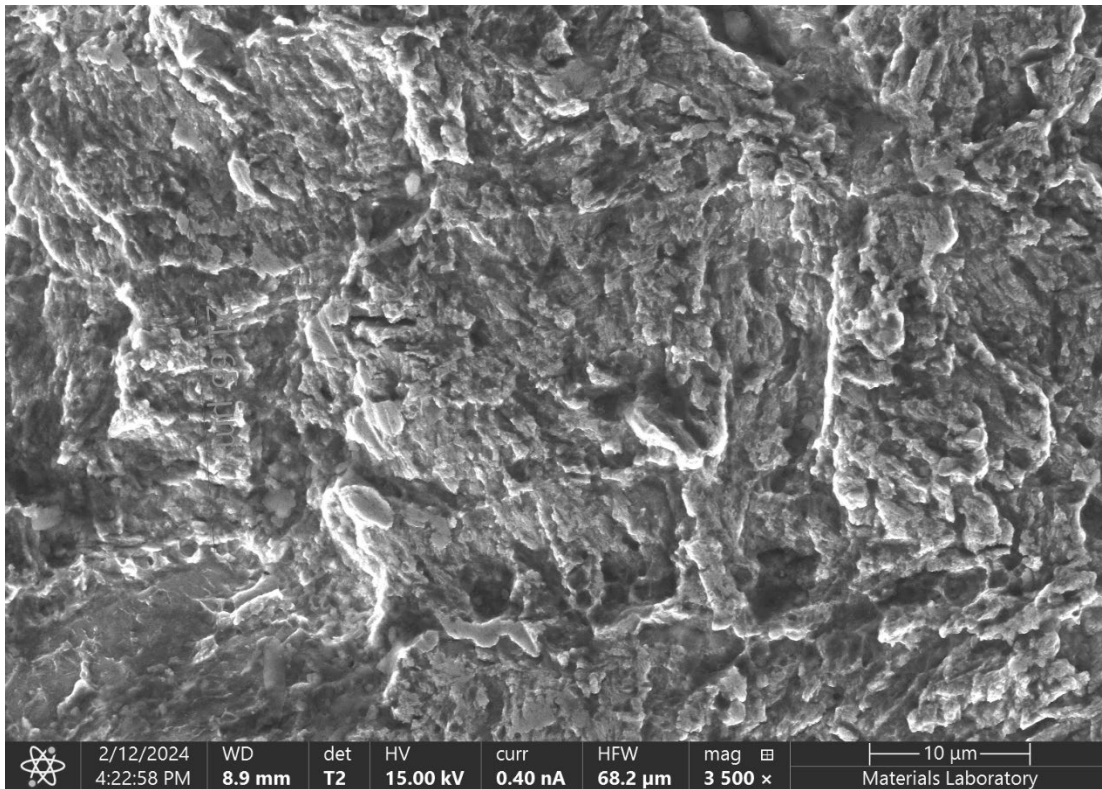


Figure 25. SE micrograph of spot 19 and the length used in striation counting.

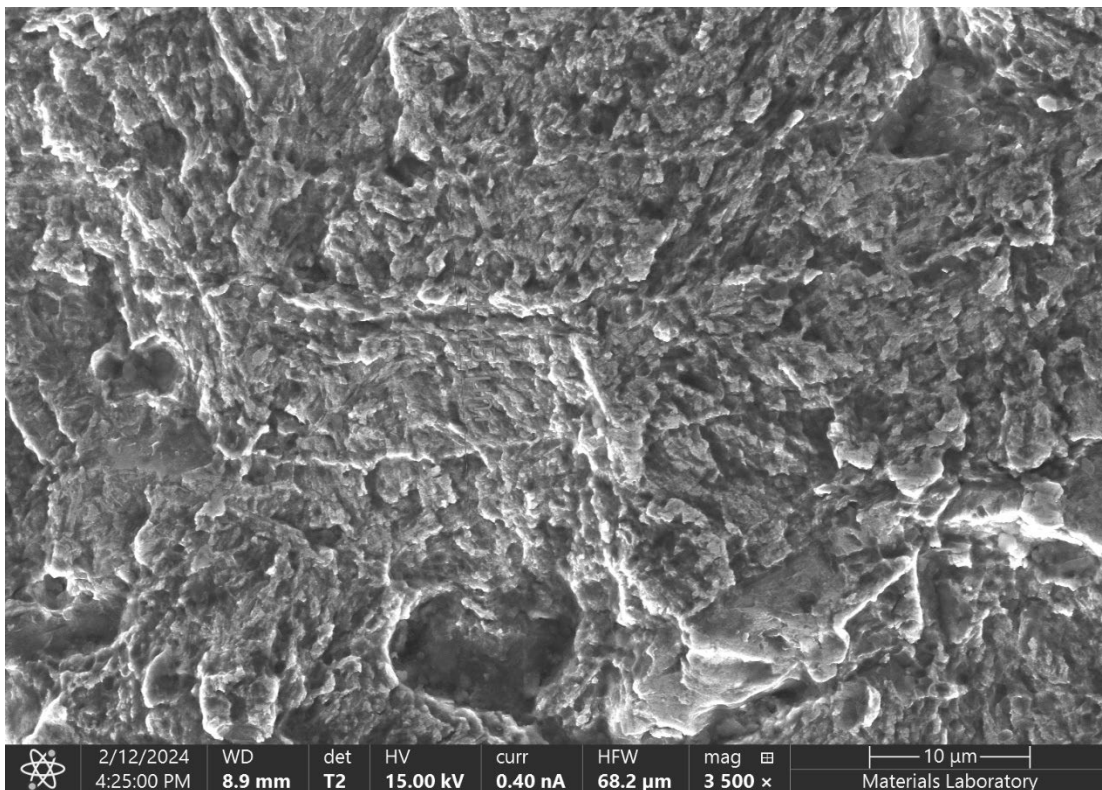


Figure 26. SE micrograph of spot 20 and the length used in striation counting.

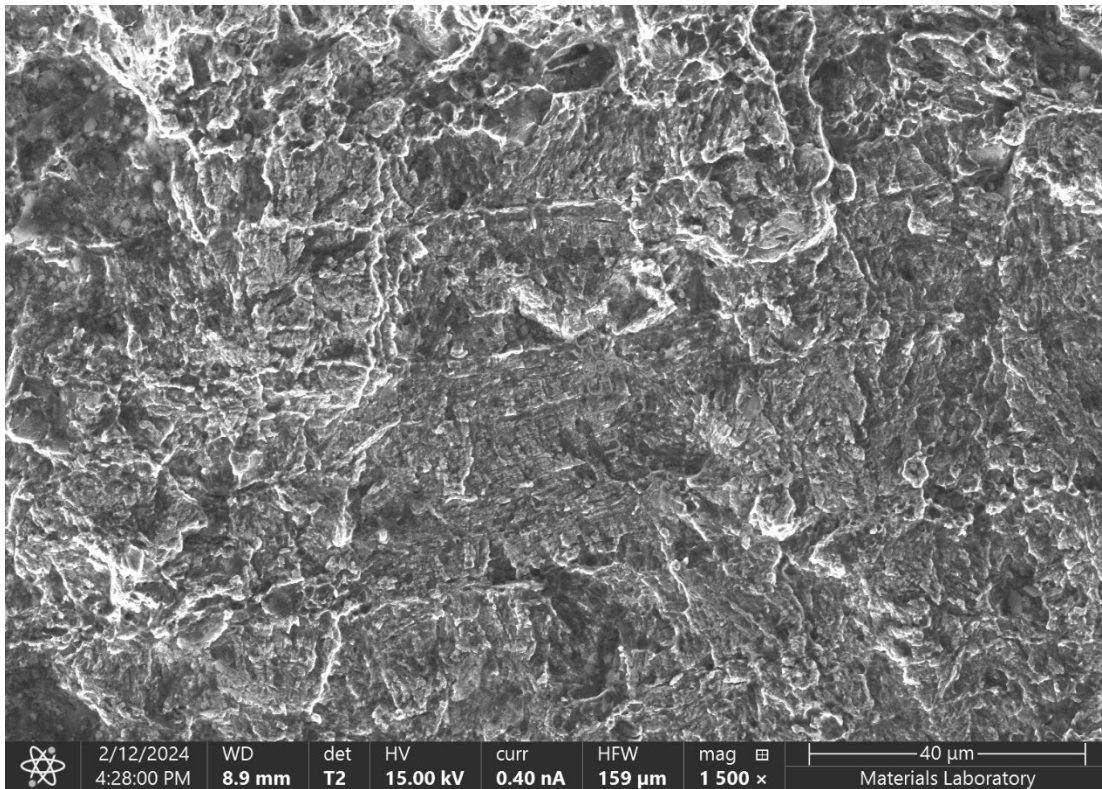


Figure 27. SE micrograph of spot 21 and the length used in striation counting.

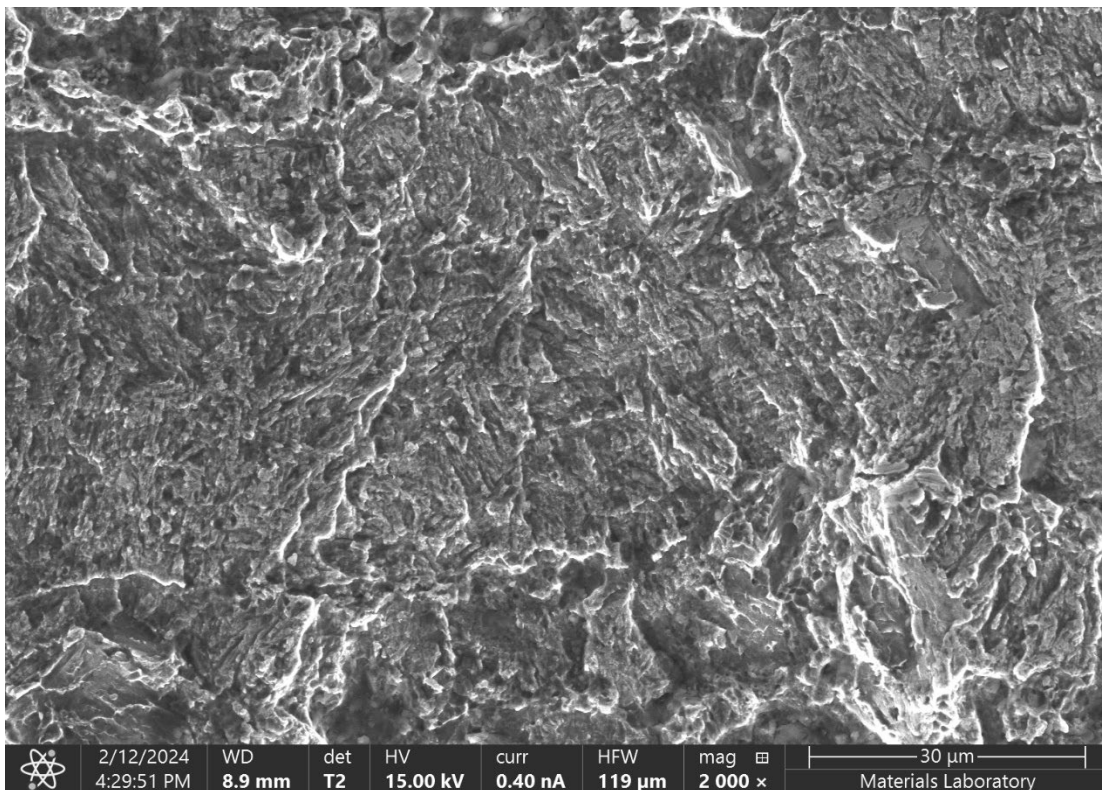


Figure 28. SE micrograph of spot 22 and the length used in striation counting.

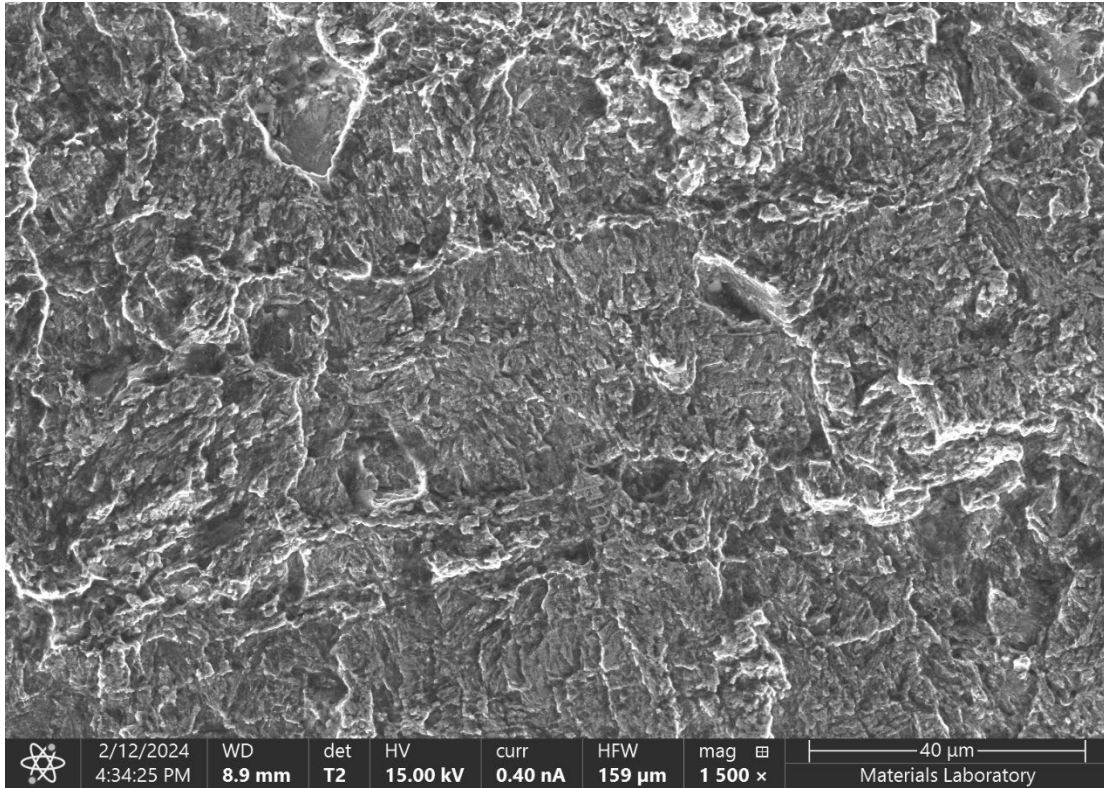


Figure 29. SE micrograph of spot 23 and the length used in striation counting.

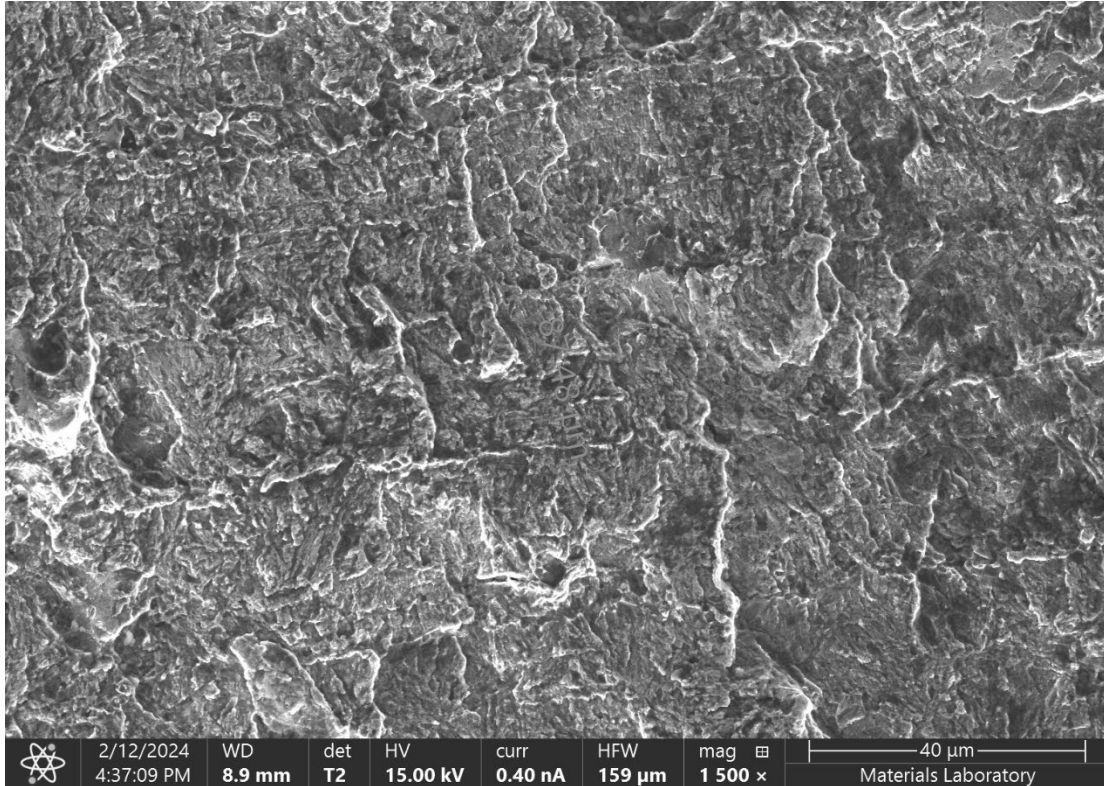


Figure 30. SE micrograph of spot 24 and the length used in striation counting.

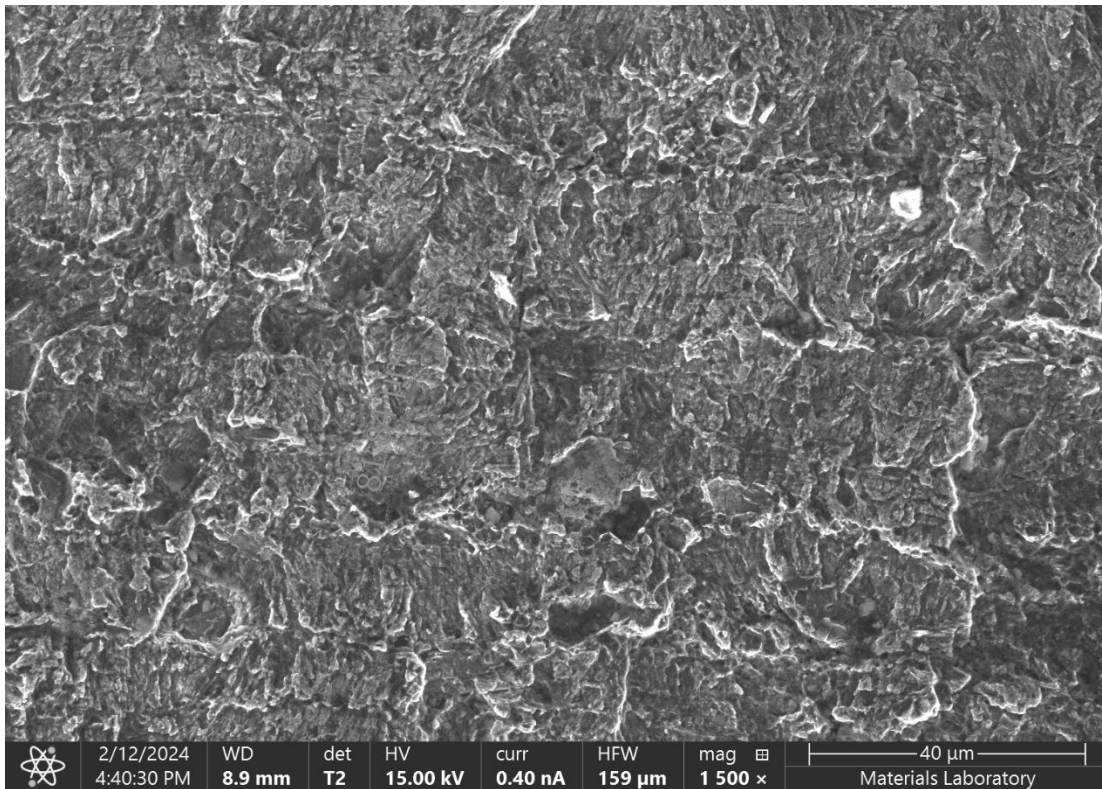


Figure 31. SE micrograph of spot 25 and the length used in striation counting.

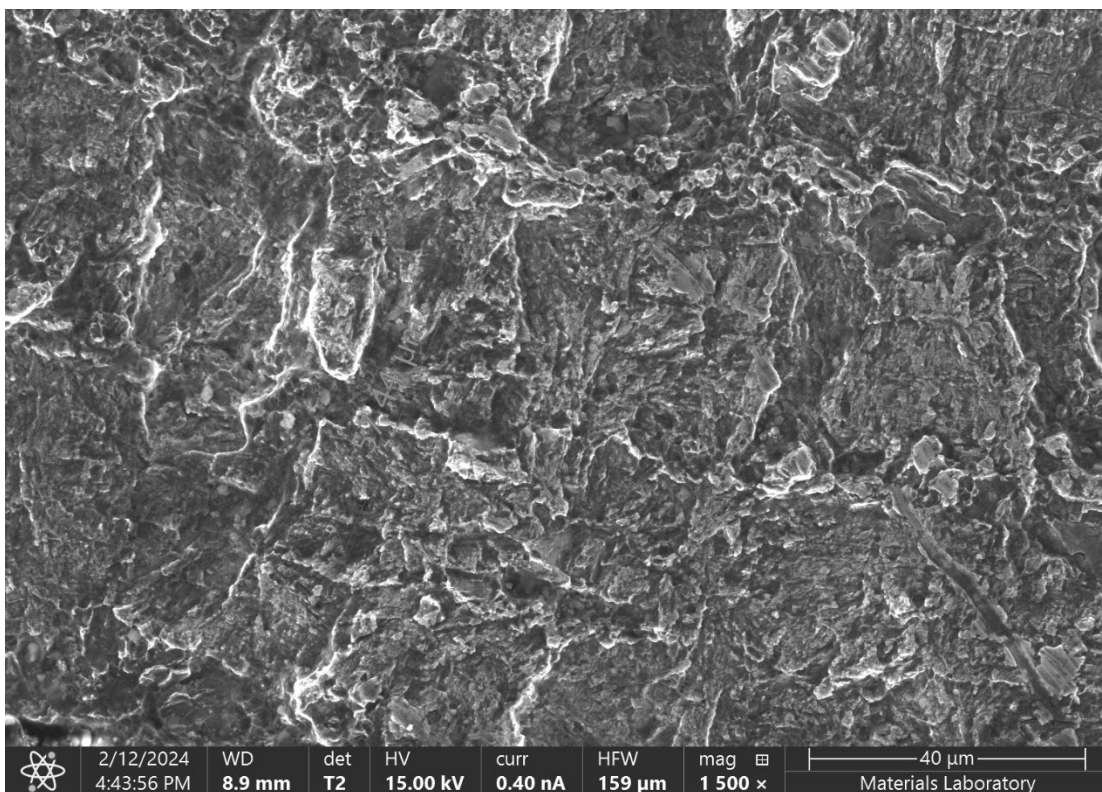


Figure 32. SE micrograph of spot 26 and the length used in striation counting.

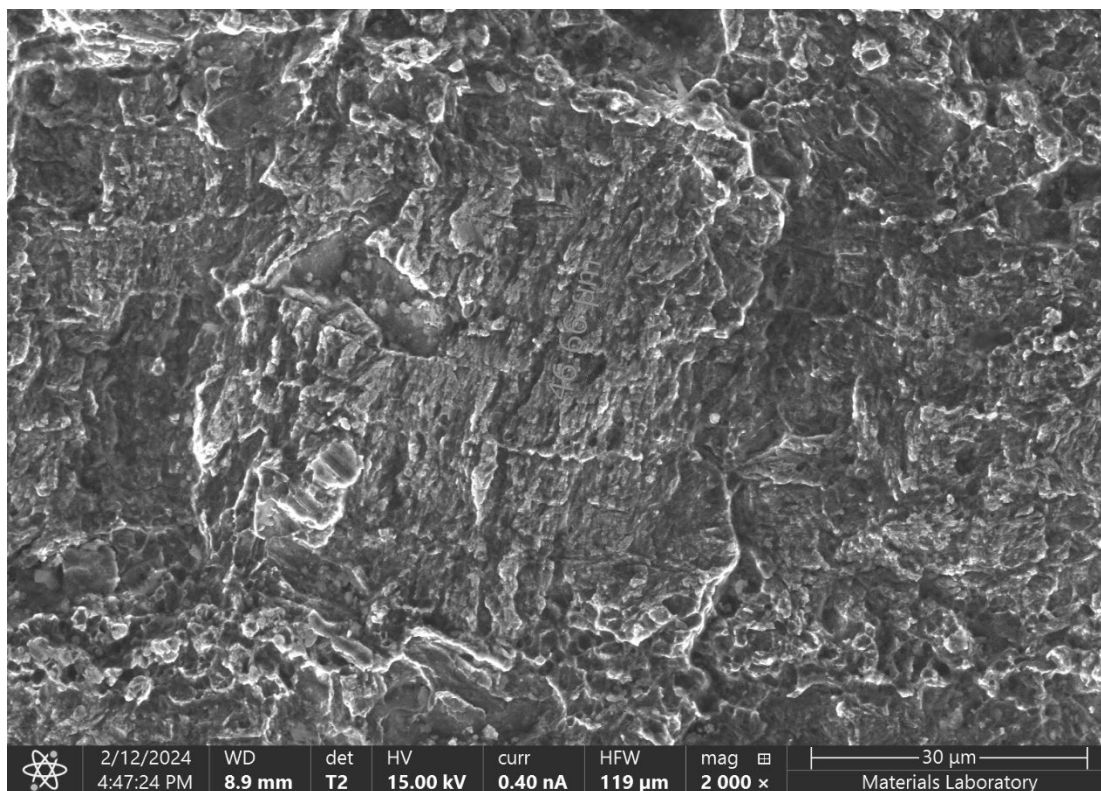


Figure 33. SE micrograph of spot 27 and the length used in striation counting.

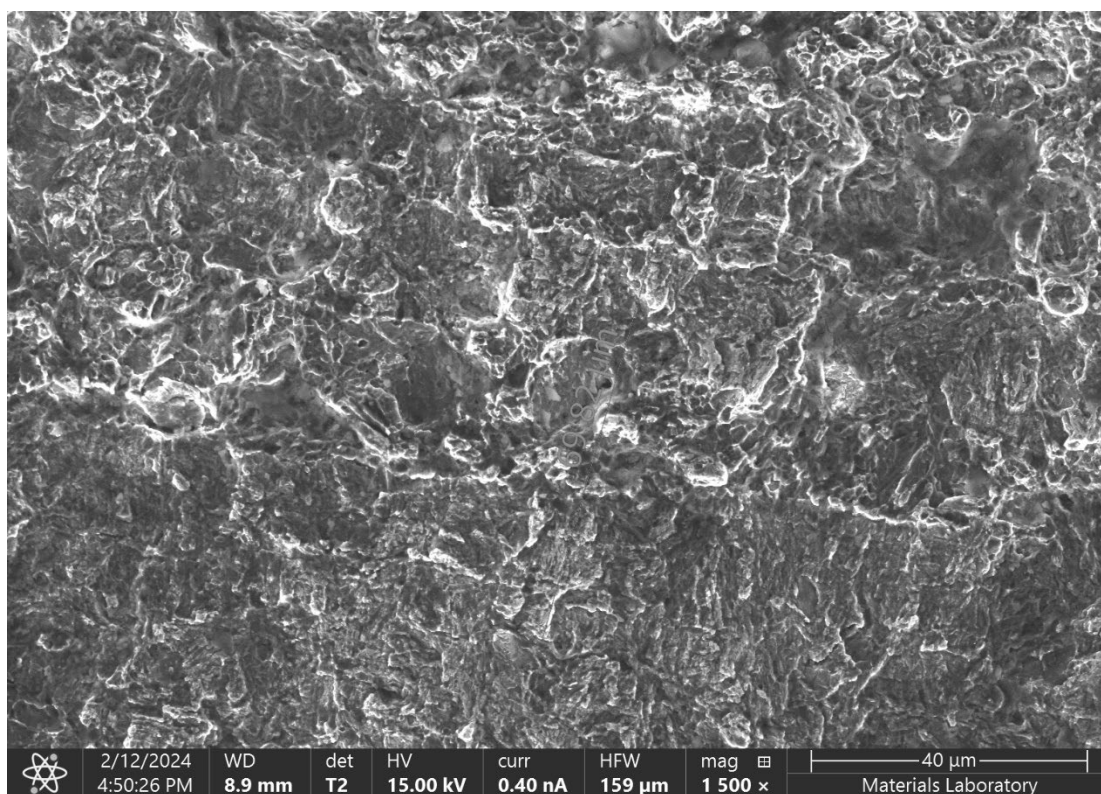


Figure 34. SE micrograph of spot 28 and the length used in striation counting.

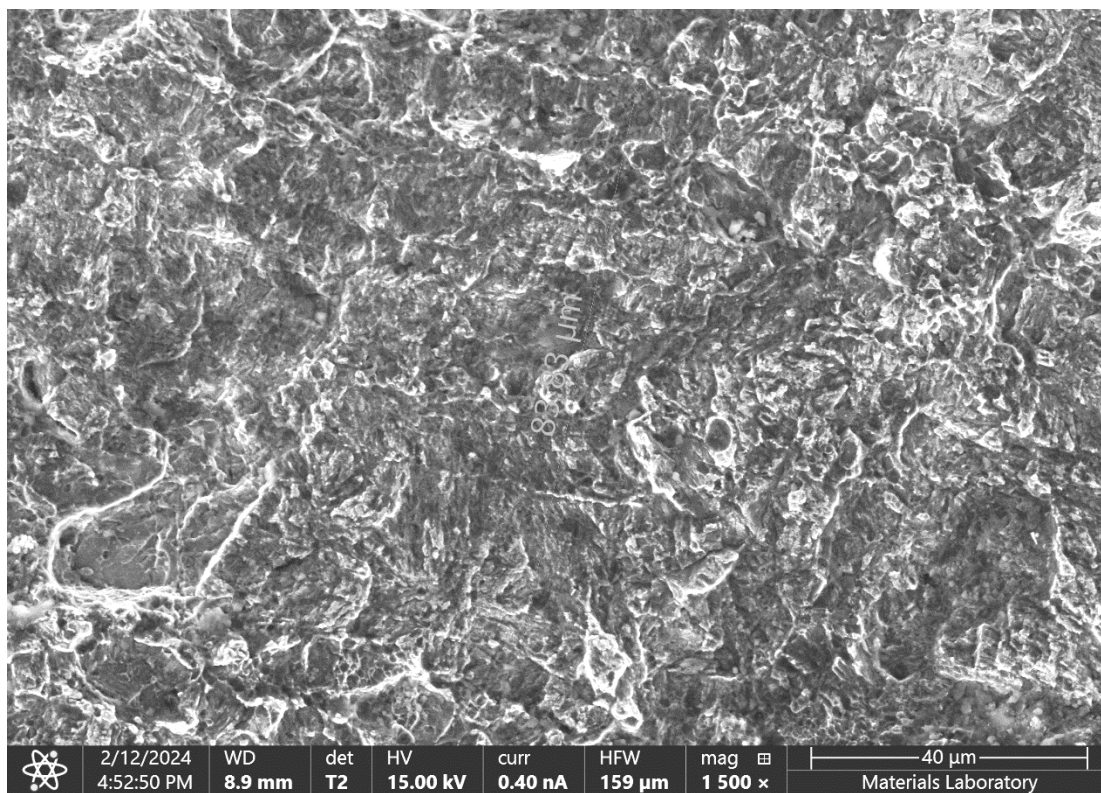


Figure 35. SE micrograph of spot 29 and the length used in striation counting.

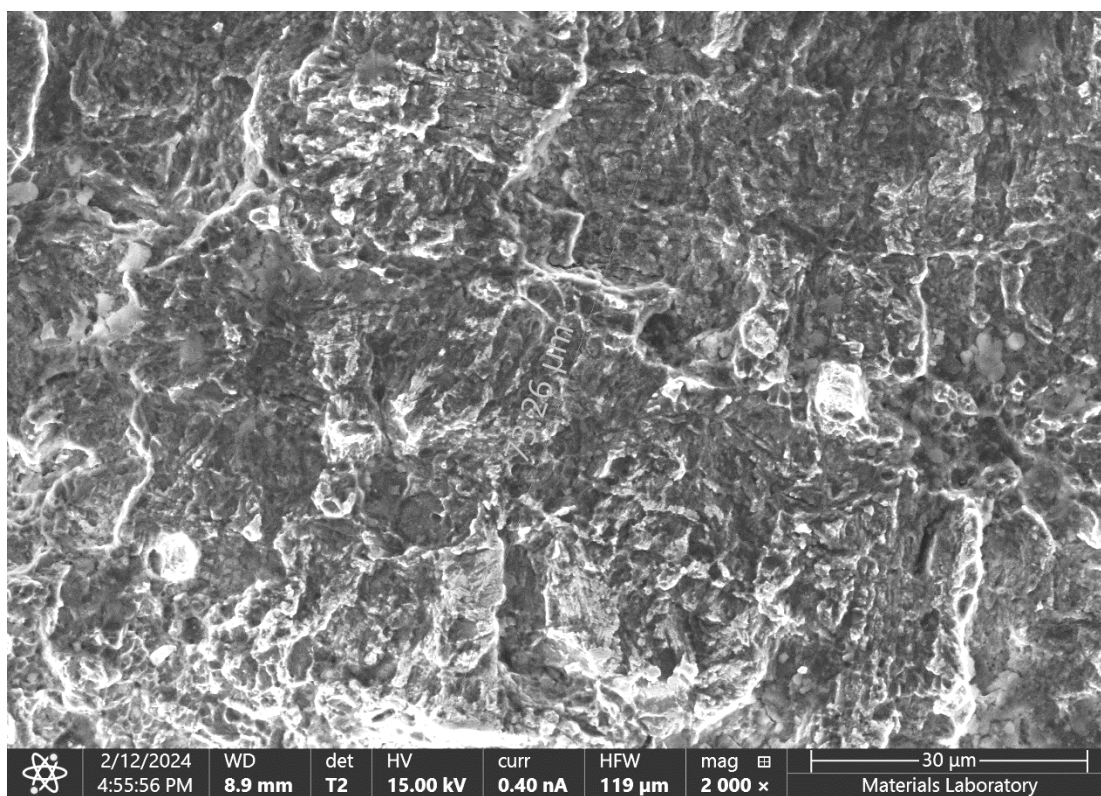


Figure 36. SE micrograph of spot 30 and the length used in striation counting.

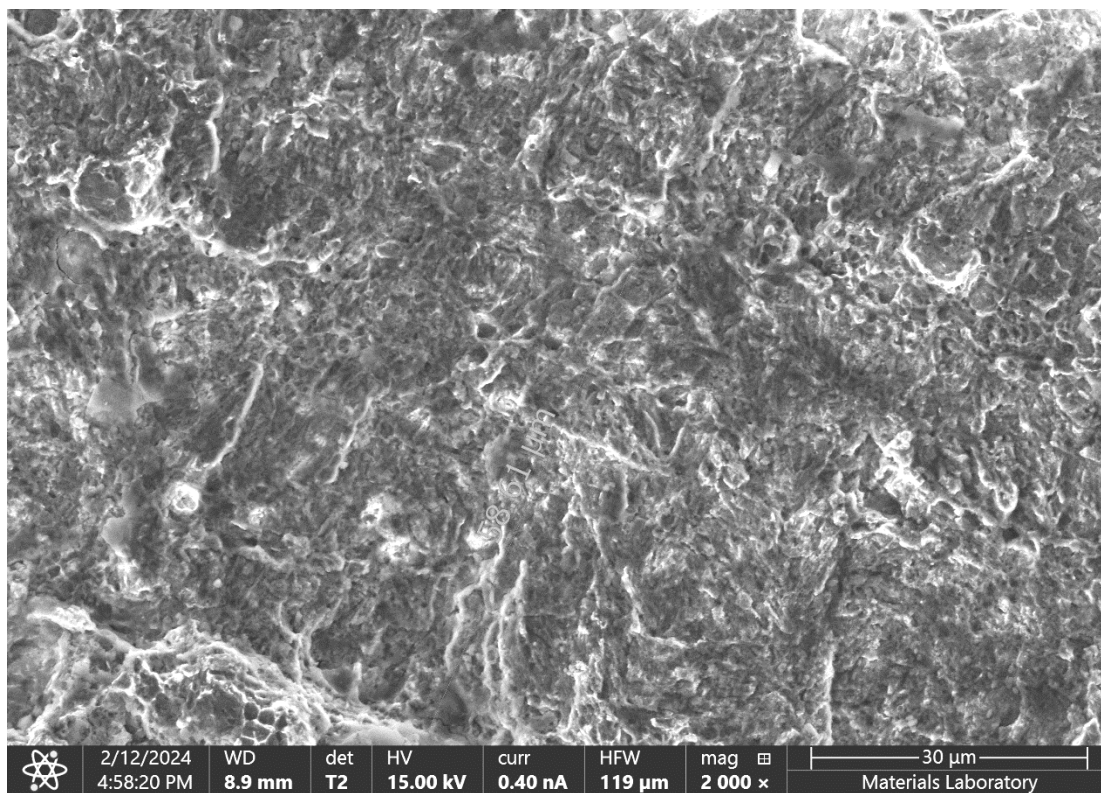


Figure 37. SE micrograph of spot 31 and the length used in striation counting.