

NATIONAL TRANSPORTATION SAFETY BOARD

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



June 23, 2020

MATERIALS LABORATORY ADDENDUM REPORT

Report No. 20-014B

1. ACCIDENT INFORMATION

Place : Denver, Colorado
Date : December 22, 2019
Vehicle : Boeing 737-800, N87513
NTSB No. : DCA20LA047
Investigator : Dan Bower, AS-10

2. COMPONENTS EXAMINED

Remnants of a main landing gear trunnion pin

3. DETAILS OF THE EXAMINATION

On December 22, 2019, a Boeing 737-800 collapsed during a landing in Denver, CO. After examination, the left main landing gear assembly was found to have failed, and the left hand main landing gear aft trunnion pin was found fractured. The trunnion pin, P/N 161A1192-13 and S/N 65780-0066, exhibited a small thumbnail crack at the approximately 12 o'clock position (see Figure 1).

The thumbnail crack exhibited distinct regions, which were measured as annotated in Figure 2. As detailed in the Materials Laboratory Factual Report (20-014), the thumbnail crack mostly exhibited striations, consistent with fatigue crack propagation. This fatigue cracking occurred prior to the accident, and its total depth was 0.154 inch (3.91 mm). The initial 0.0164 inch (415 μm) portion of the crack consisted of the outer 0.006 inch (152 μm) chromium electroplated layer and an internal region of intergranular fracture. The 0.105 inch (2.67 mm) portion of the crack exhibited fatigue striations, but exhibited a darker color visually. The remainder of crack exhibited fatigue striations (with isolated overstress bands typified by dimpled rupture) but was not discolored.

In order to better understand how long the fatigue crack had been present, a fatigue crack growth rate analysis was performed by counting striations at intervals along the crack depth. The fatigue striation counts were taken at over 30 random, unique, and non-duplicated places on the fracture surface, with the distances from the initiation site recorded. The initiation site was labeled from its location on the specimen stage, 49.932 mm in the X-direction and 61.903 mm in the Y-direction. The distances were measured via a calibrated stage on a field emission scanning electron microscope (FESEM). These

locations and the measurements are shown in Figure 4 through Figure 33. No measurements were taken in any overstress 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 particular crack depth, the fracture surface was flat, and that the fatigue striation spacing increased with crack depth. The summary of the results is tabulated in Table 1.

Of note from the data in Table 1 were the following highlights:

- The total number of cycles from the intergranular initiation site to the end of the crack was 6225.
- The total number of cycles from initiation to the end of the discolored portion of the crack was 4150.
- Therefore, the number of cycles at the end of the crack, or the non-discolored portion was 2075.

The number of landings since the last overhaul at United Airlines (UAL) was 2309 cycles. This number of landings was similar to the number of cycles in the non-discolored portion of the fatigue crack. Assuming the number of cycles counted in the non-discolored region was related to the number of landings since the last overhaul, the crack had been present for at least 4150 cycles prior to the last (UAL) overhaul. For comparison purposes, the overhaul previous to the one at UAL, performed at Goodrich, was 12922 cycles prior to the accident, with 10613 landings having occurred between the two overhauls.

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 (4 through 34), in US customary units.

Photo File #	Location #	Increment (in)	Depth (in)	Striation Count	Distance (um)	Distance (in)	da/dN (in / cycle)	Cycles / in	Cycles from Origin
9	1	0.003	0.001	10	10.97	0.00043	4.32E-05	64.43	64.43
13	2	0.004	0.003	9	17.82	0.00070	7.80E-05	61.18	125.61
16	3	0.005	0.006	11	29.18	0.00115	1.04E-04	52.38	177.98
55	16	0.005	0.008	8	29.21	0.00115	1.44E-04	43.96	221.95
19	4	0.007	0.012	7	7.891	0.00031	4.44E-05	71.24	293.18
22	5	0.007	0.015	6	11.22	0.00044	7.36E-05	118.36	411.55
46	13	0.007	0.019	13	19.15	0.00075	5.80E-05	112.00	523.55
49	14	0.008	0.023	16	16.15	0.00064	3.97E-05	165.45	689.00
43	12	0.009	0.027	10	7.511	0.00030	2.96E-05	247.08	936.08
25	6	0.009	0.032	13	14.06	0.00055	4.26E-05	241.42	1177.50
28	7	0.009	0.036	11	12.17	0.00048	4.36E-05	211.30	1388.79
32	8	0.009	0.041	10	8.498	0.00033	3.35E-05	237.13	1625.92
67	20	0.009	0.045	15	11.61	0.00046	3.05E-05	287.11	1913.04
70	21	0.009	0.050	11	21.07	0.00083	7.54E-05	173.87	2086.91
52	15	0.009	0.055	7	29.25	0.00115	1.65E-04	78.39	2165.30
64	19	0.011	0.060	11	10.88	0.00043	3.89E-05	112.11	2277.40
58	17	0.011	0.066	15	46.04	0.00181	1.21E-04	142.89	2420.29
35	9	0.012	0.072	7	8.601	0.00034	4.84E-05	139.63	2559.92
73	22	0.012	0.078	11	12.59	0.00050	4.51E-05	253.91	2813.83
77	23	0.013	0.084	13	11.86	0.00047	3.59E-05	317.43	3131.26
38	10	0.013	0.091	7	6.561	0.00026	3.69E-05	366.95	3498.22
80	24	0.013	0.098	10	10.9	0.00043	4.29E-05	335.12	3833.34
89	27	0.014	0.105	14	17.14	0.00067	4.82E-05	317.28	4150.62
62	18	0.015	0.112	27	23.92	0.00094	3.49E-05	350.24	4500.87
83	25	0.015	0.120	12	9.778	0.00038	3.21E-05	451.69	4952.56
98	30	0.015	0.127	9	17.55	0.00069	7.68E-05	283.53	5236.09
40	18	0.015	0.135	10	16.33	0.00064	6.43E-05	219.56	5455.65
92	28	0.017	0.144	13	10.46	0.00041	3.17E-05	356.39	5812.04
95	29	0.018	0.152	12	16.33	0.00064	5.36E-05	413.39	6225.43

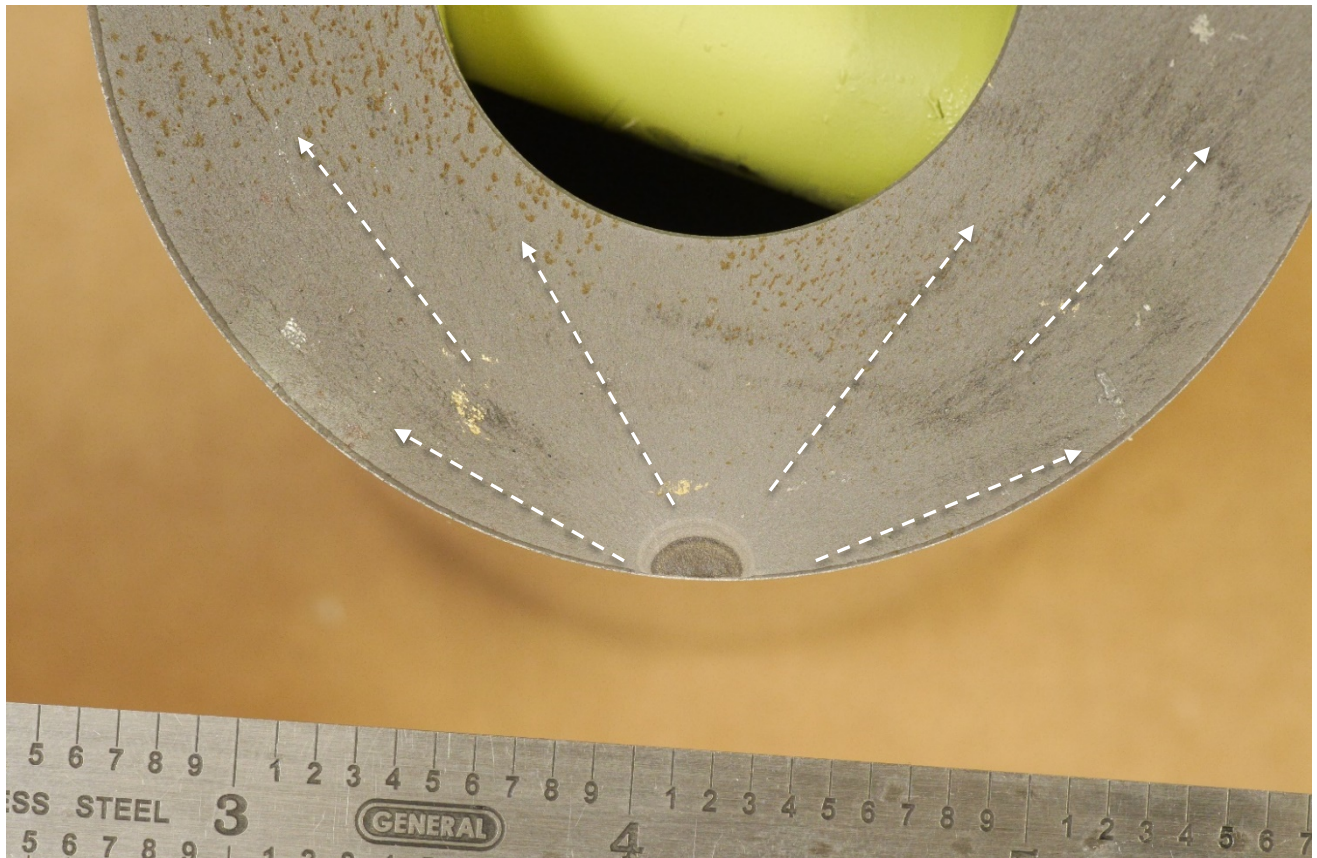


Figure 1 – Fracture surface of the forward pin fracture surface, showing a thumbnail crack at the 12 o'clock position. White dashed arrows denote the fracture direction from the thumbnail.

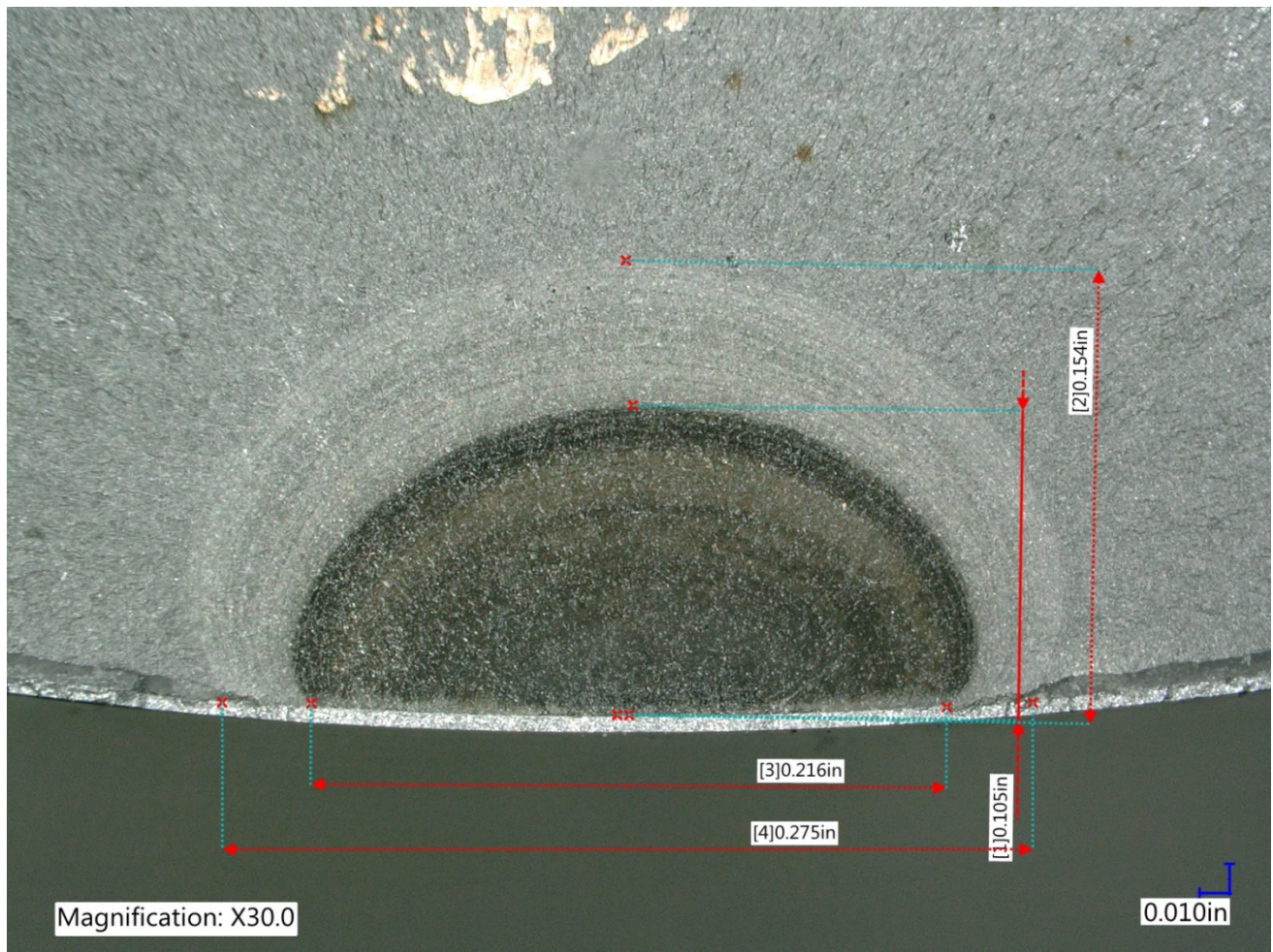


Figure 2 – Microscopic view of the thumbnail crack in Figure 1, annotated to show various dimensions.

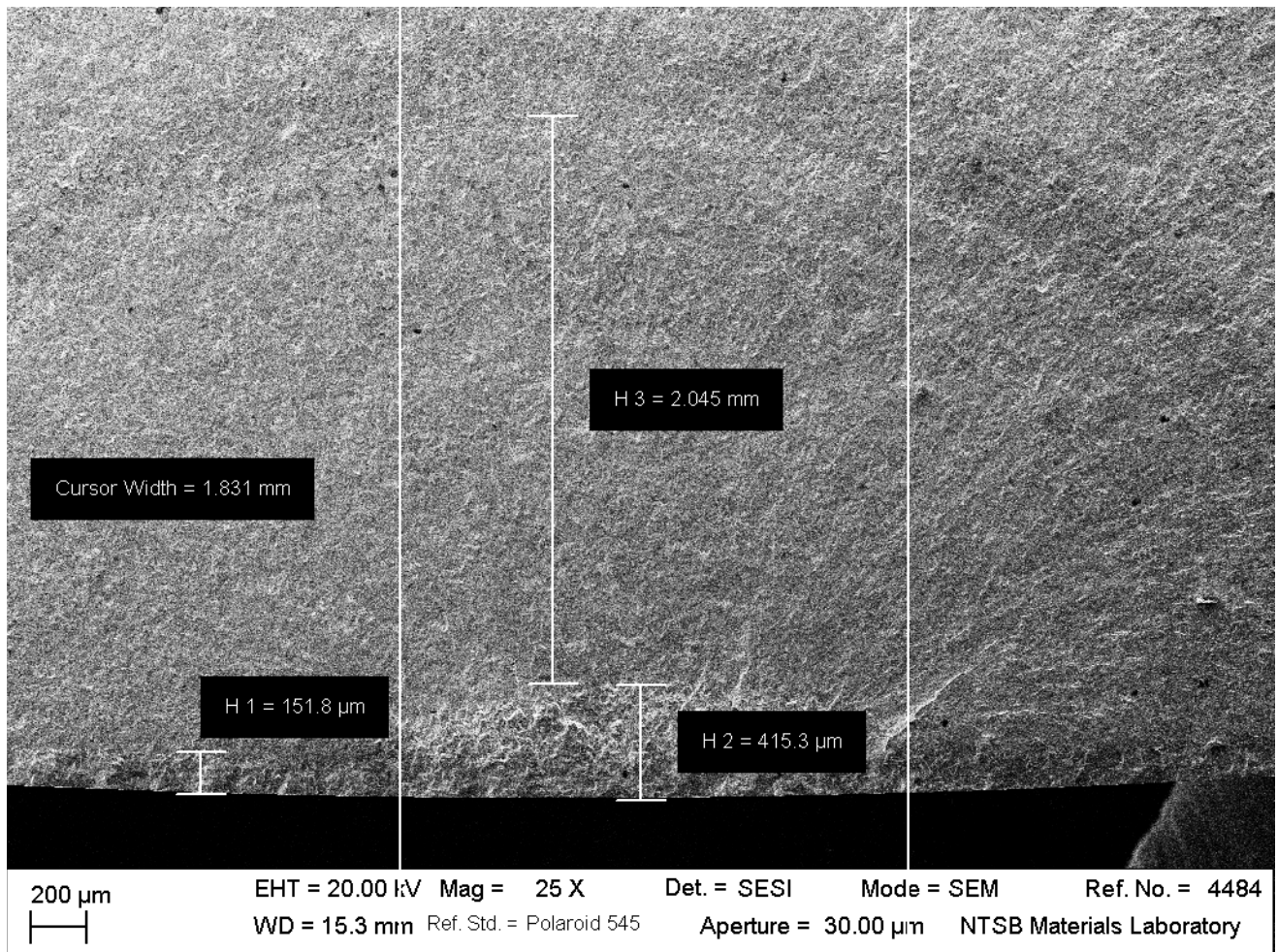


Figure 3 – Secondary electron (SE) micrograph of the overall view of the thumbnail crack, annotated to show various measurements.

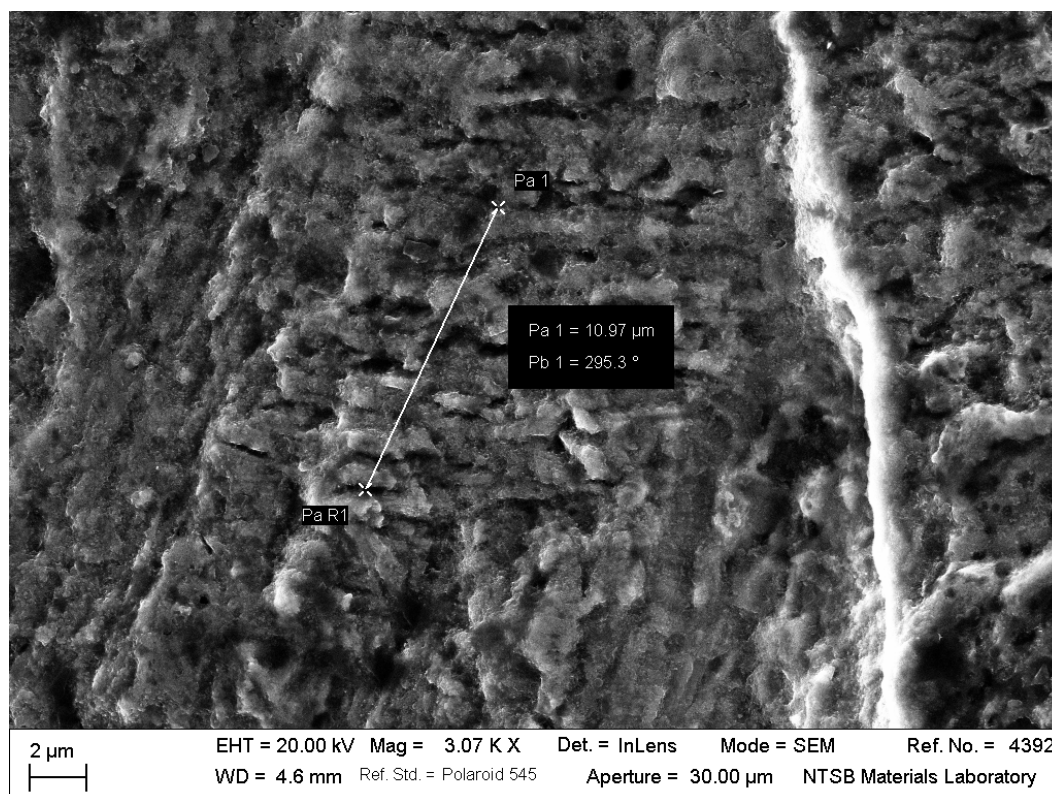


Figure 4 – SE micrograph of spot 1 and the length used in striation counting.

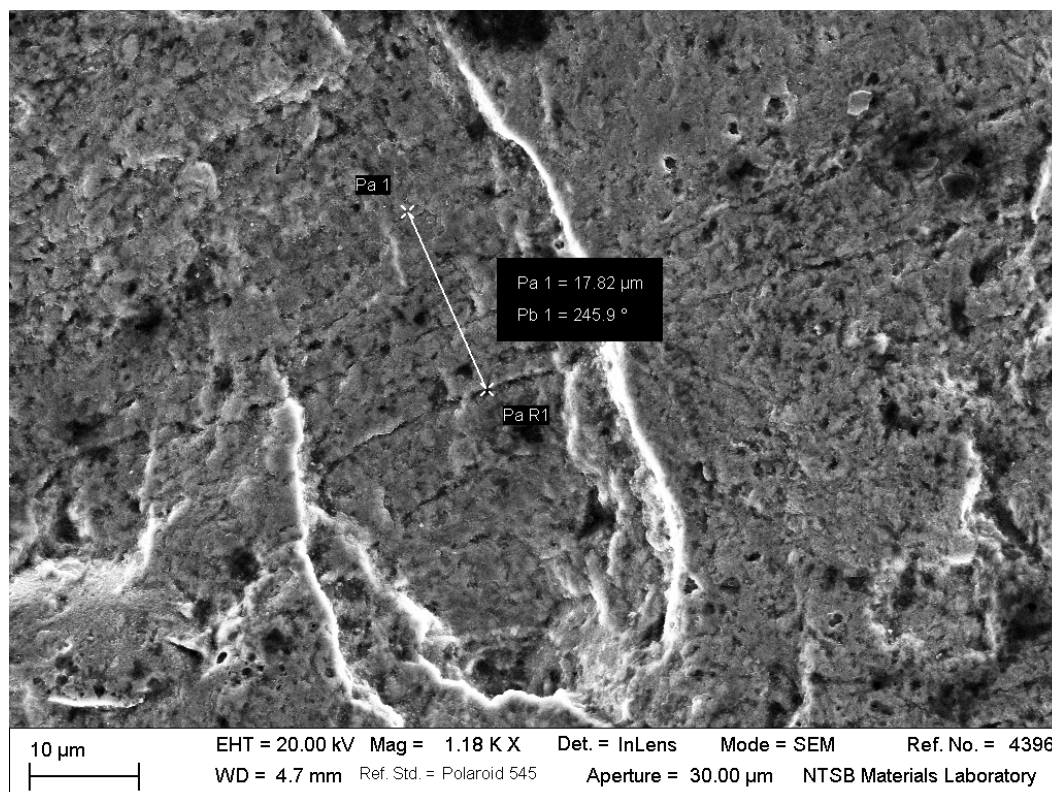


Figure 5 – SE micrograph of spot 2 and the length used in striation counting.

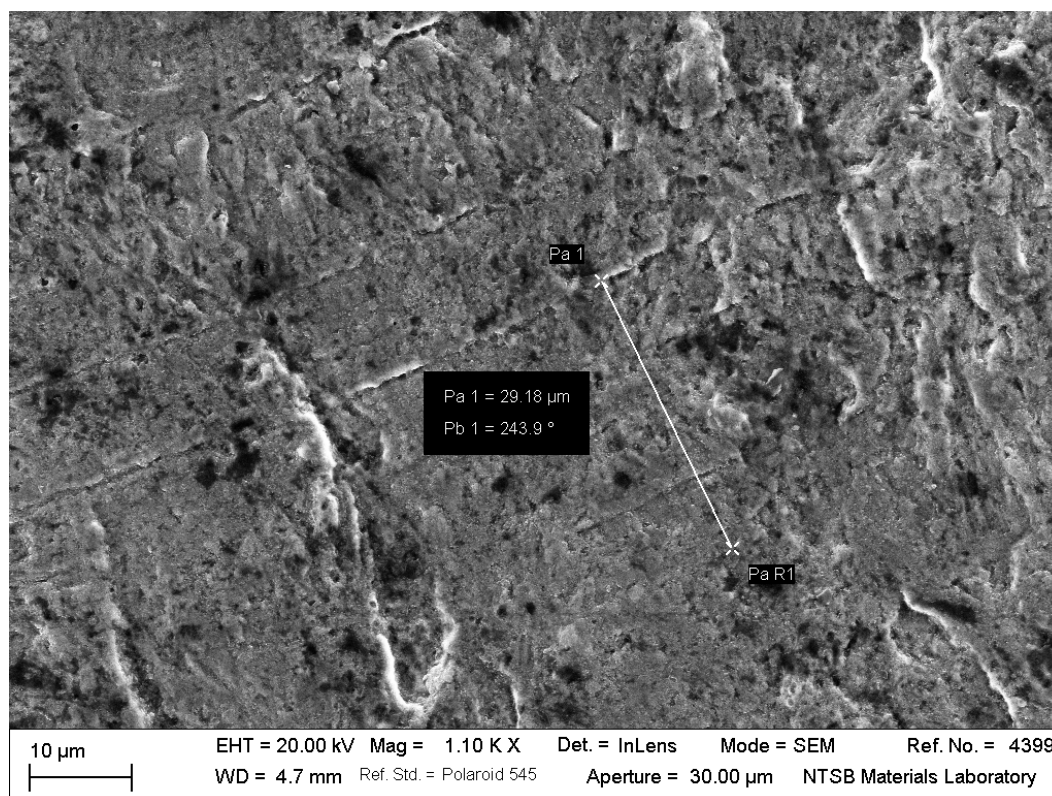


Figure 6 – SE micrograph of spot 3 and the length used in striation counting.

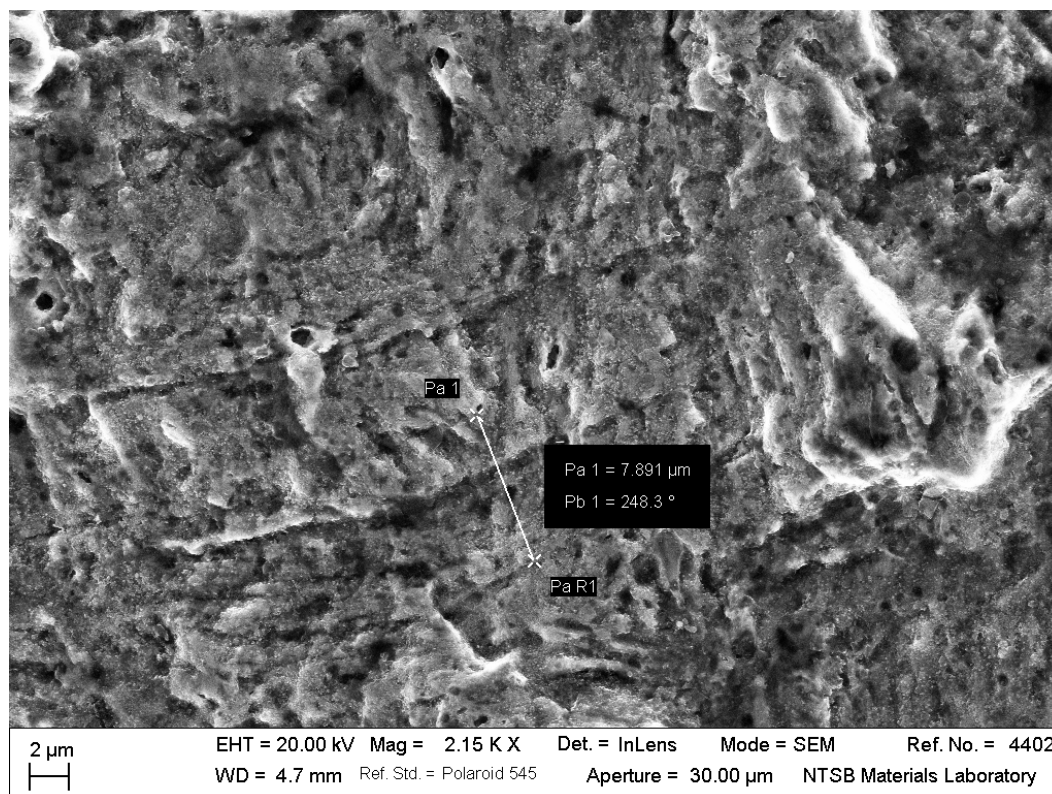


Figure 7 – SE micrograph of spot 4 and the length used in striation counting.

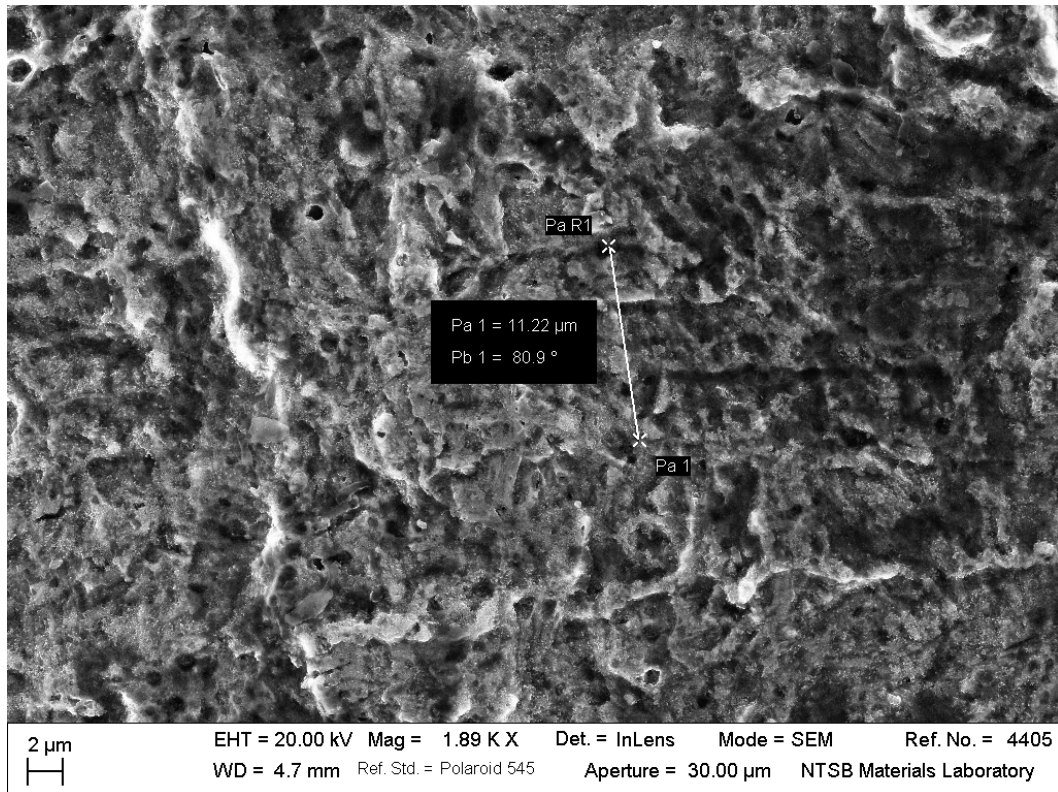


Figure 8 – SE micrograph of spot 5 and the length used in striation counting.

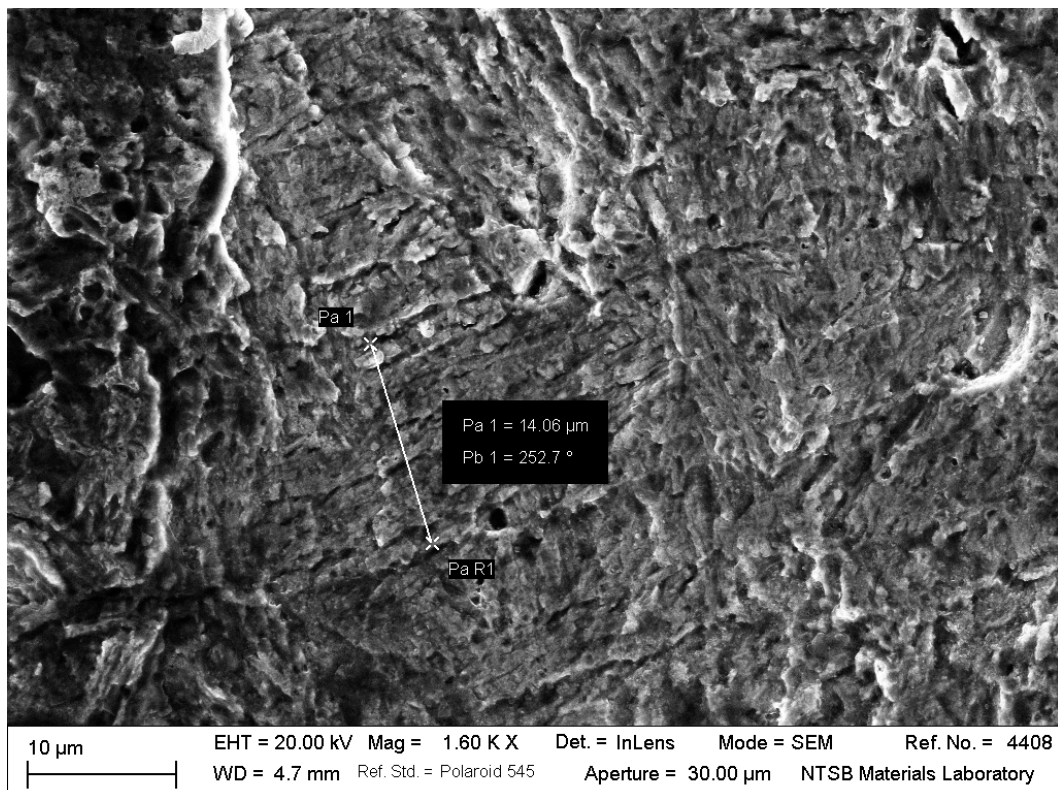


Figure 9 – SE micrograph of spot 6 and the length used in striation counting.

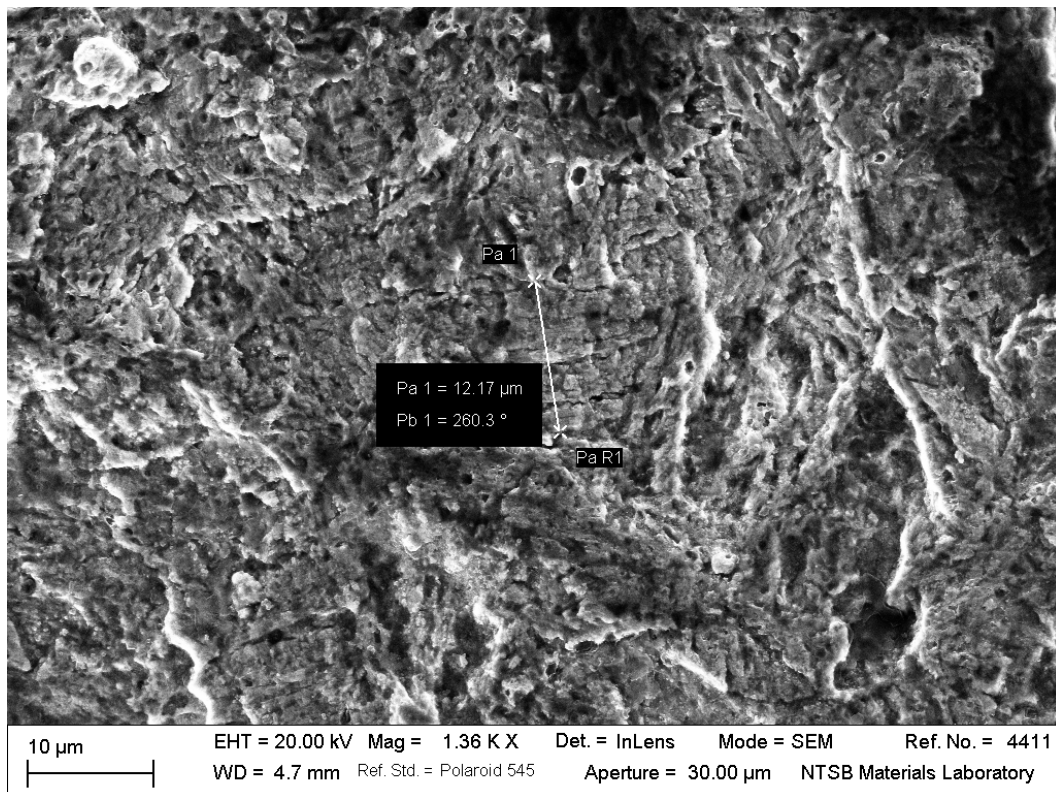


Figure 10 – SE micrograph of spot 7 and the length used in striation counting.

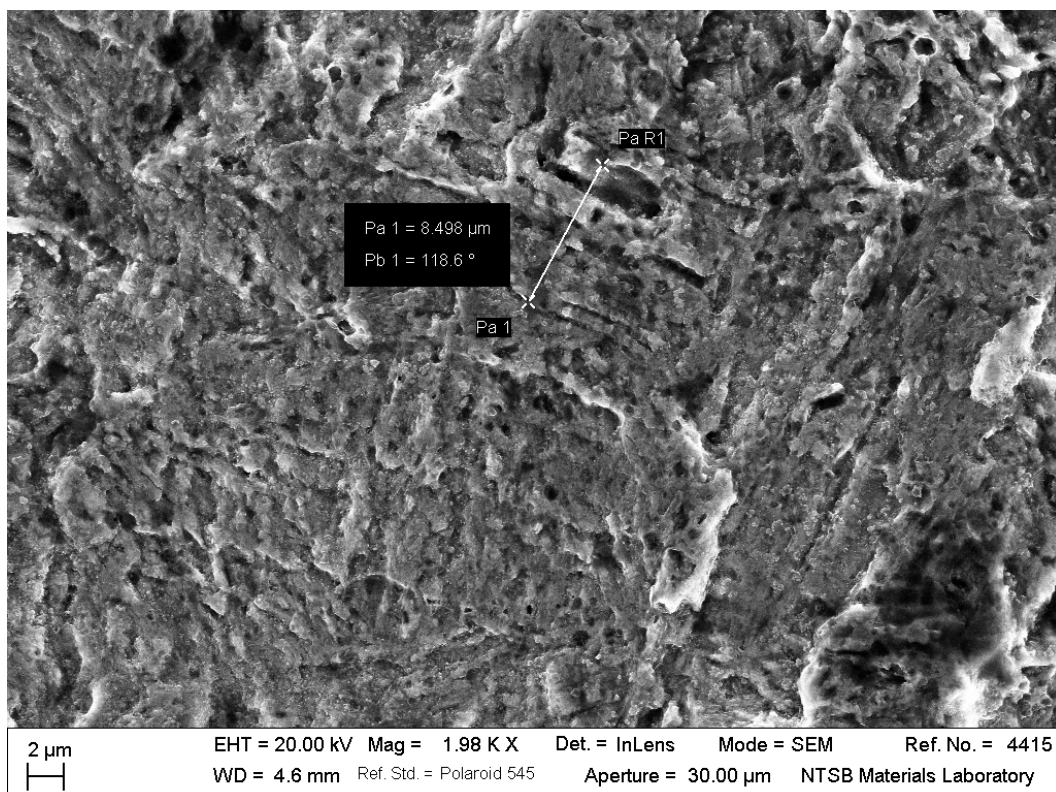


Figure 11 – SE micrograph of spot 8 and the length used in striation counting.

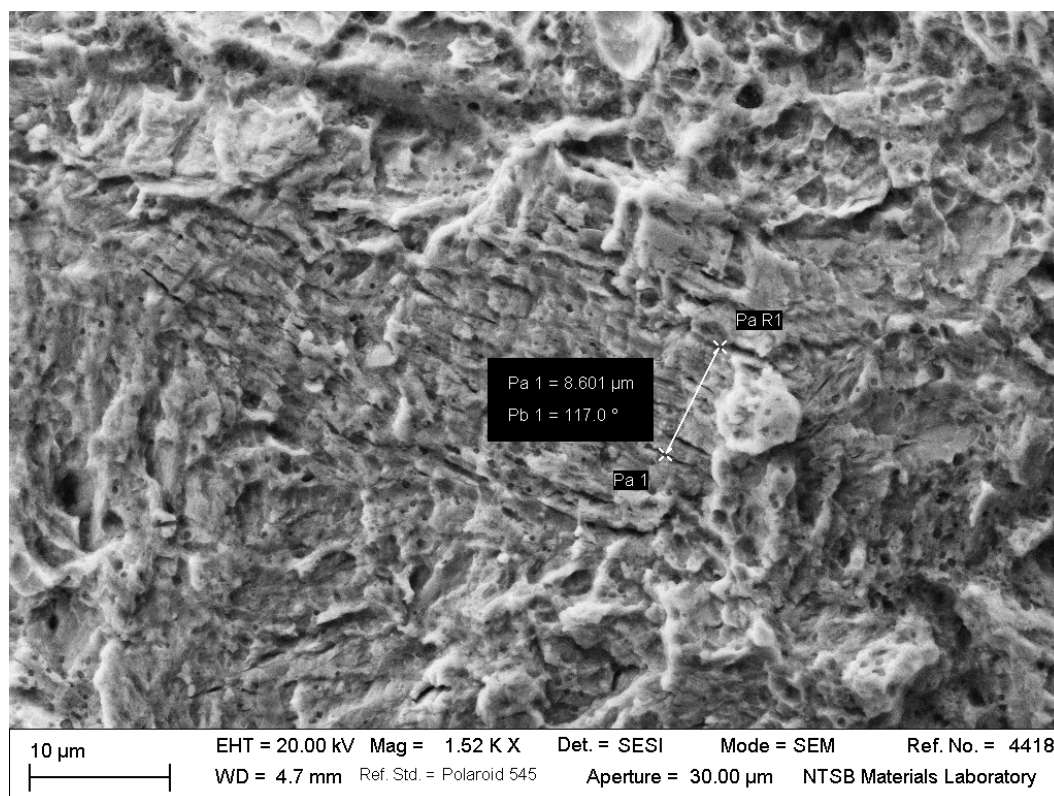


Figure 12 – SE micrograph of spot 9 and the length used in striation counting.

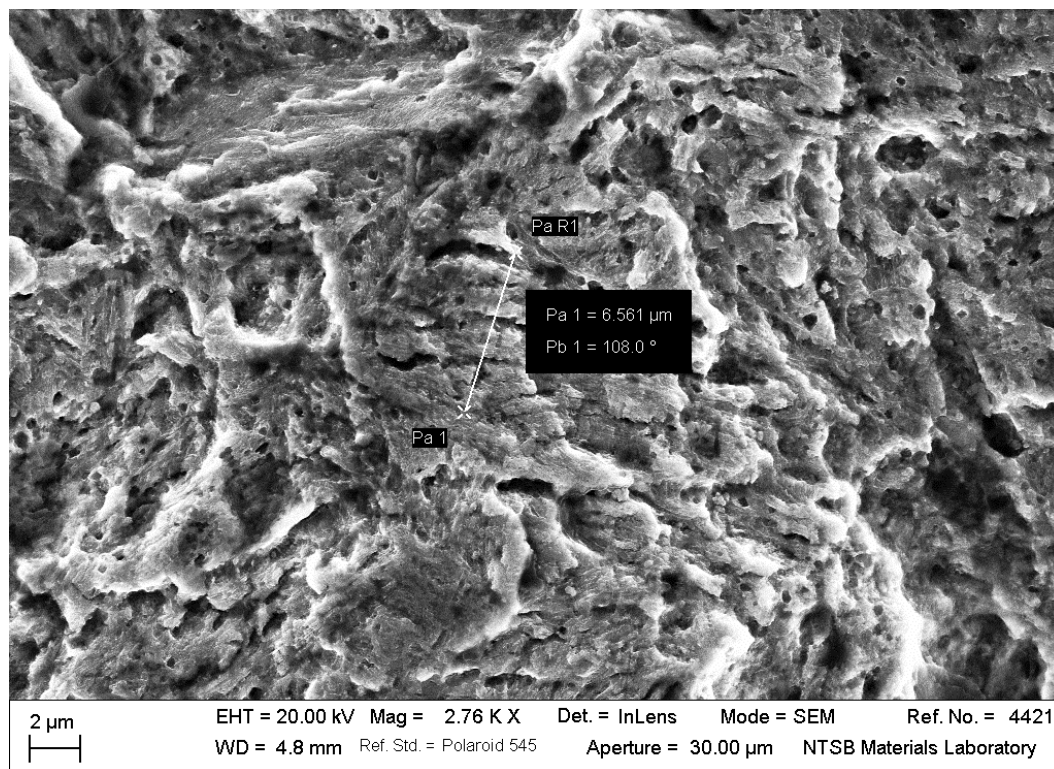


Figure 13 – SE micrograph of spot 10 and the length used in striation counting.

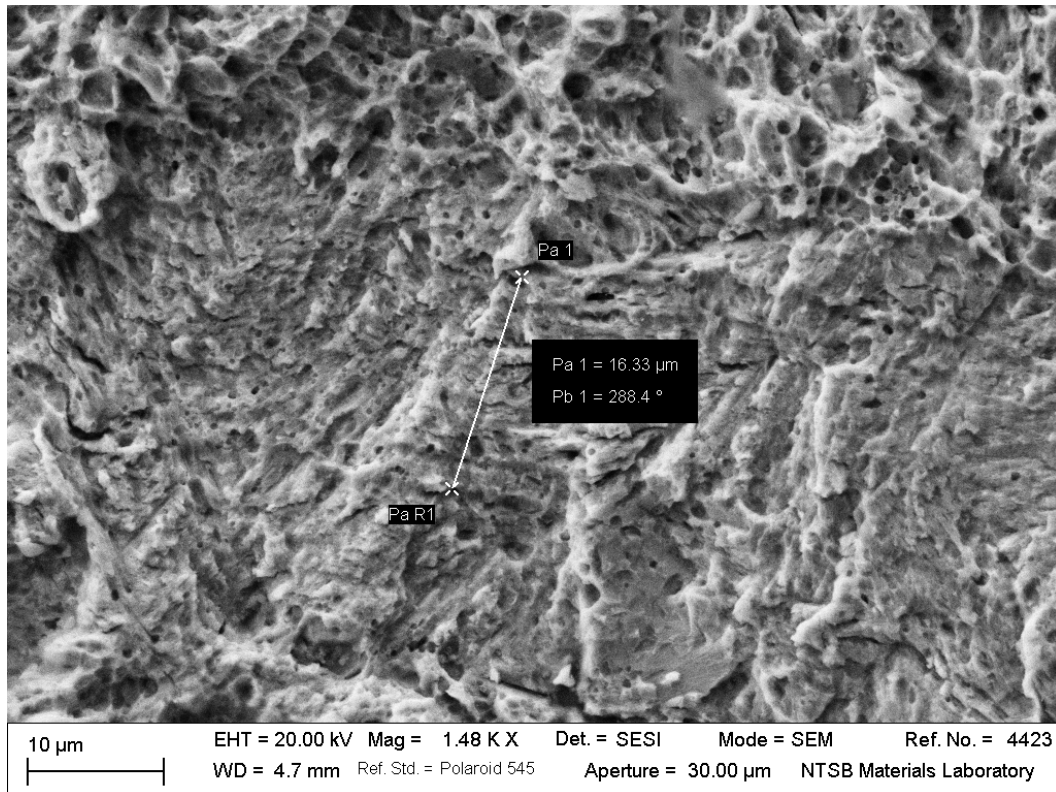


Figure 14 – SE micrograph of spot 11 and the length used in striation counting.

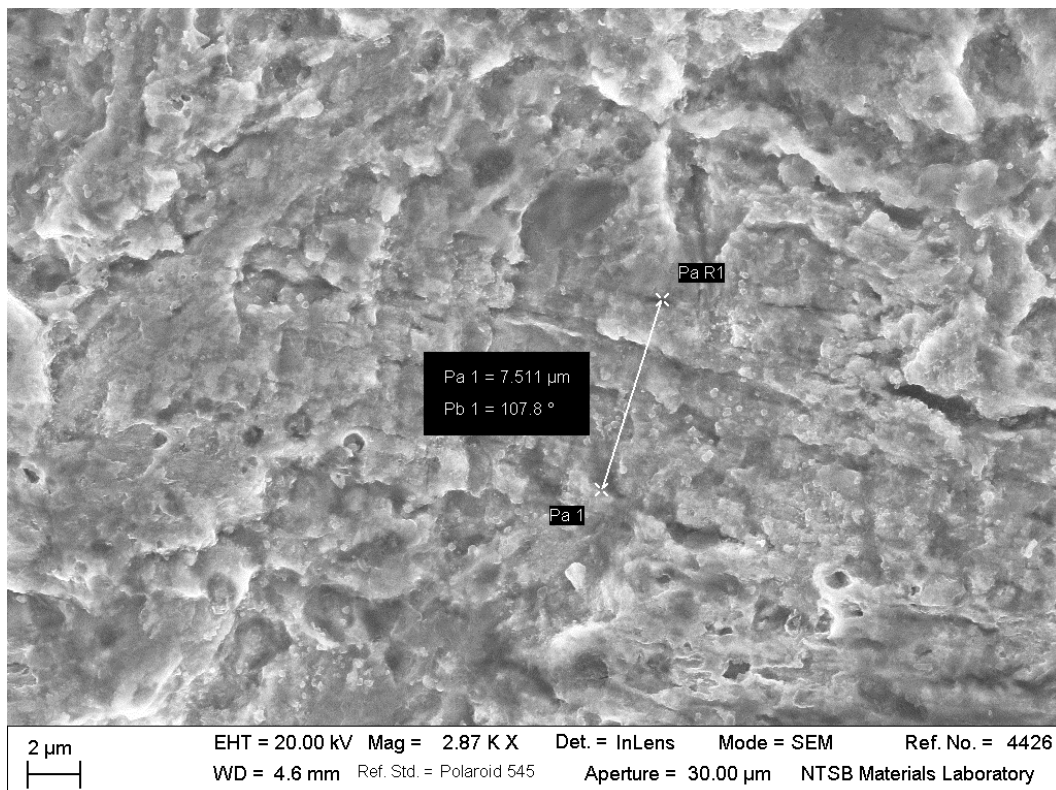


Figure 15 – SE micrograph of spot 12 and the length used in striation counting.

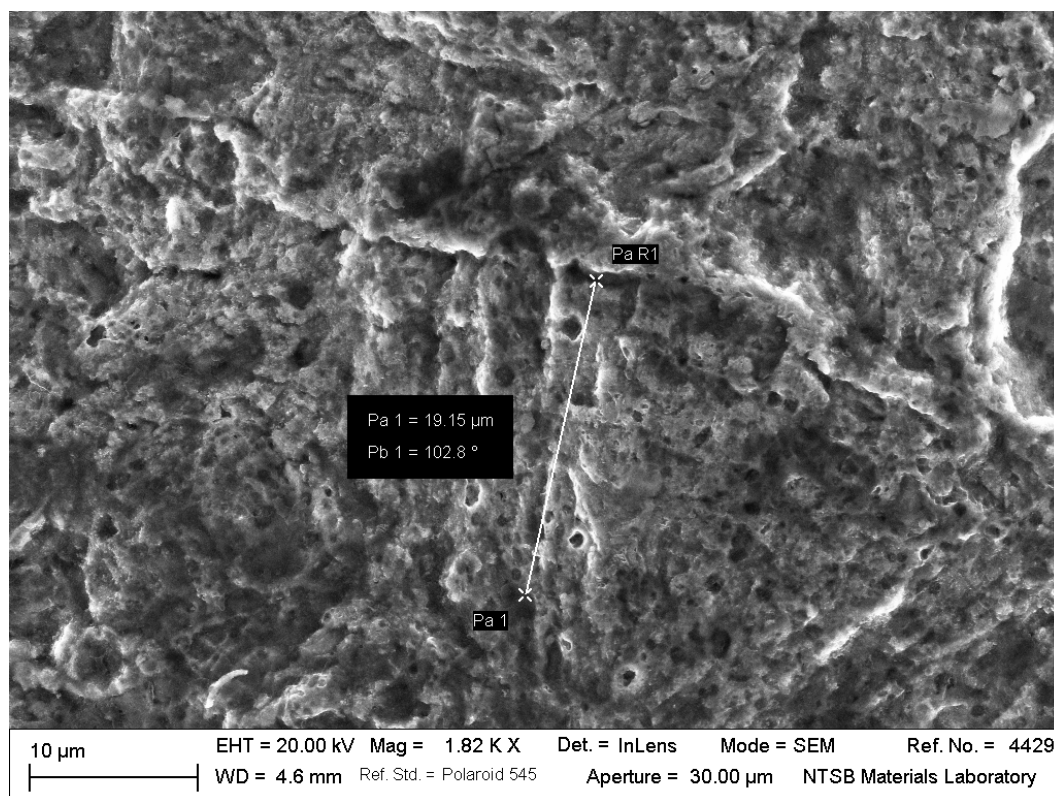


Figure 16 – SE micrograph of spot 13 and the length used in striation counting.

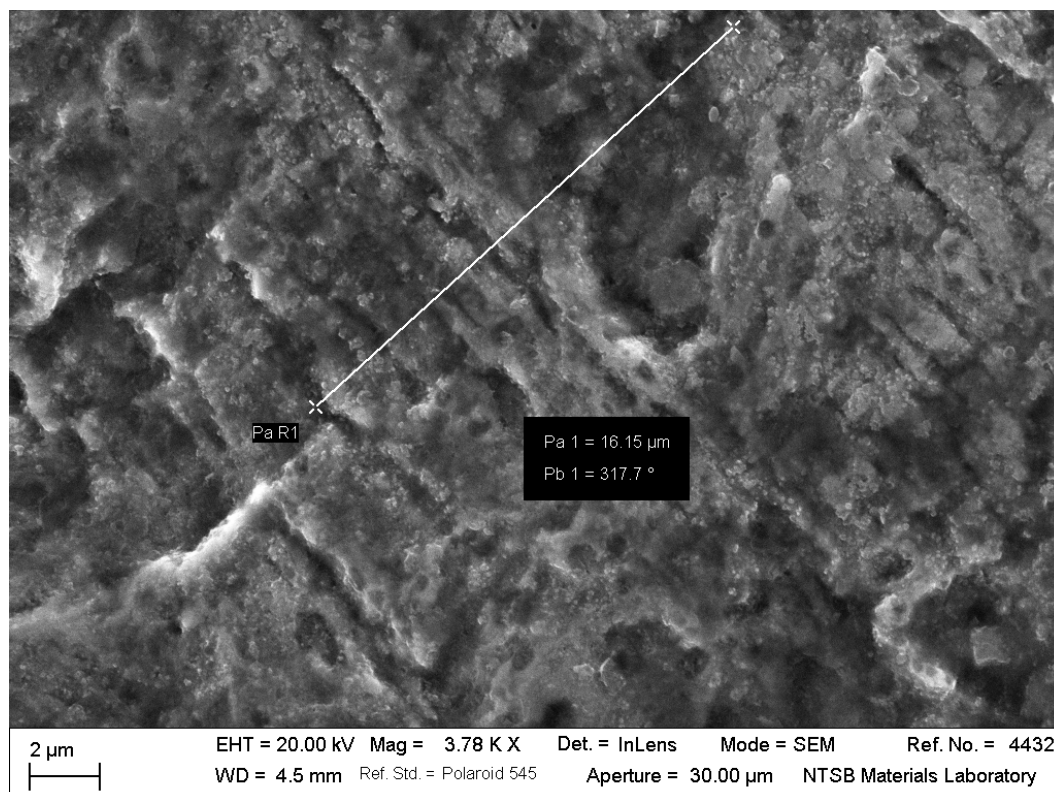


Figure 17 – SE micrograph of spot 14 and the length used in striation counting.

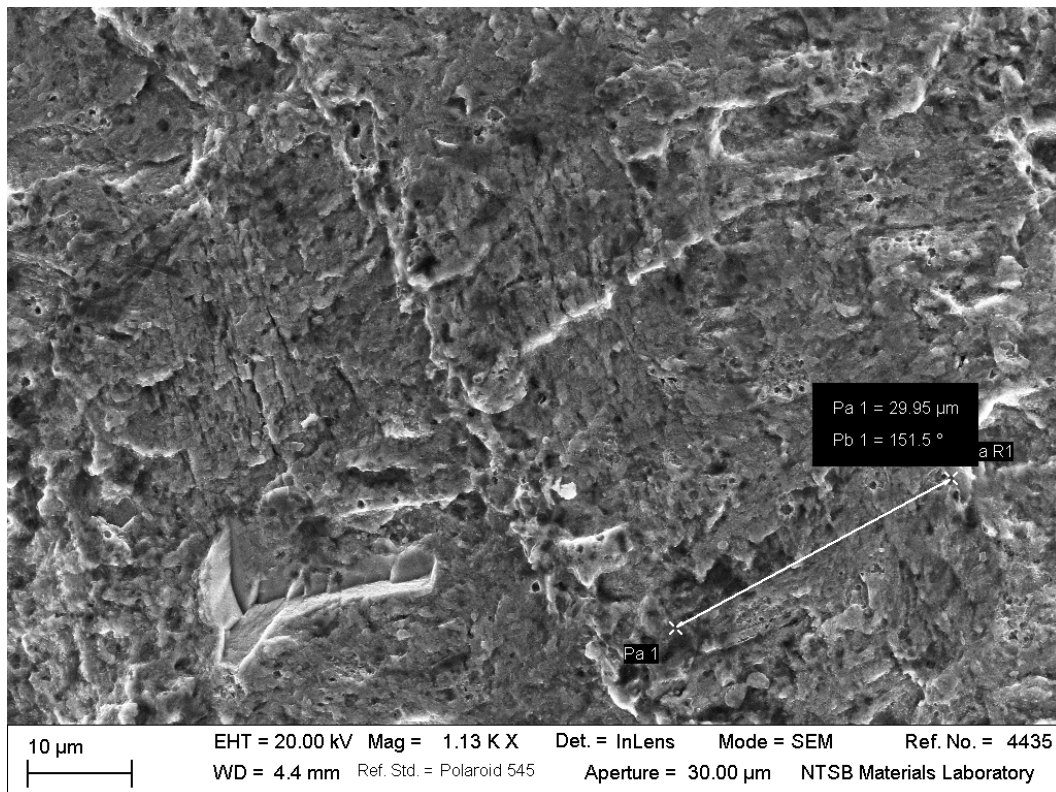


Figure 18 – SE micrograph of spot 15 and the length used in striation counting.

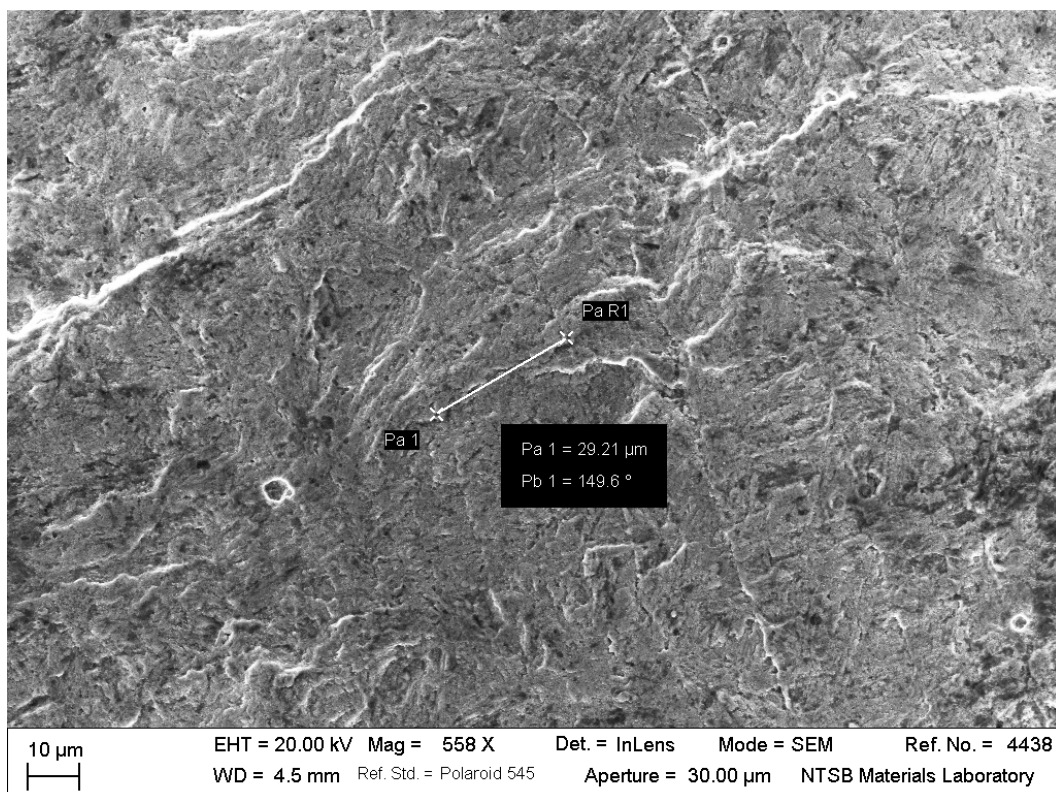


Figure 19 – SE micrograph of spot 16 and the length used in striation counting.

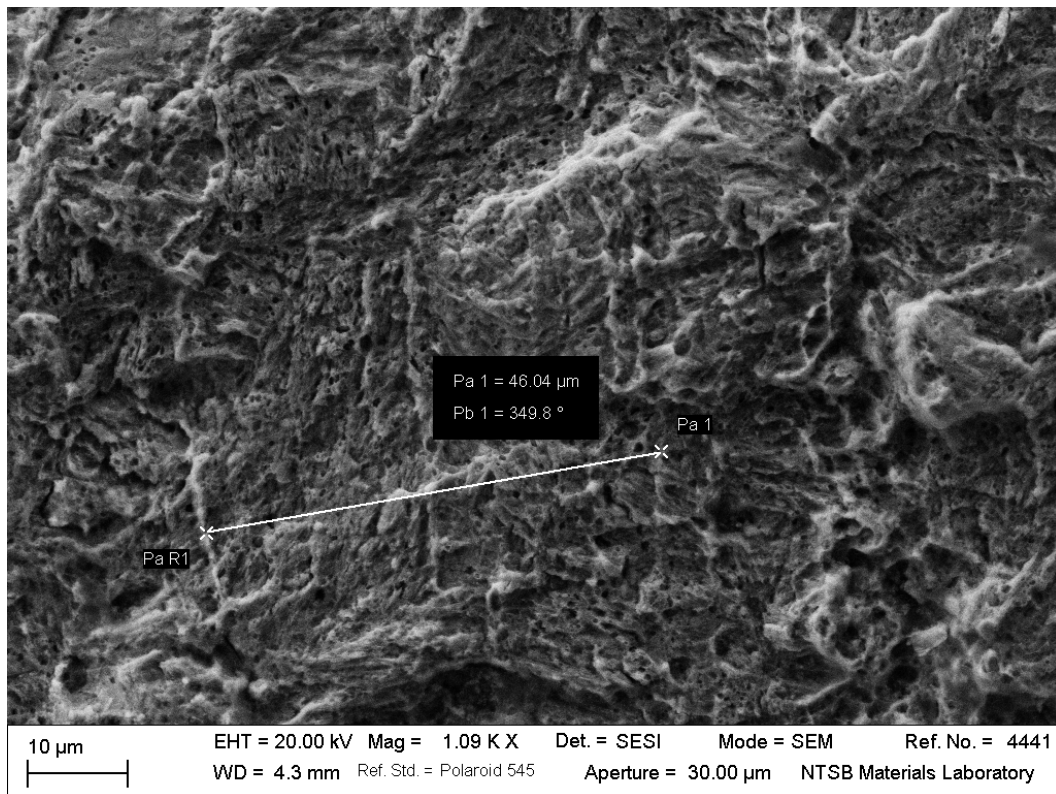


Figure 20 – SE micrograph of spot 17 and the length used in striation counting.

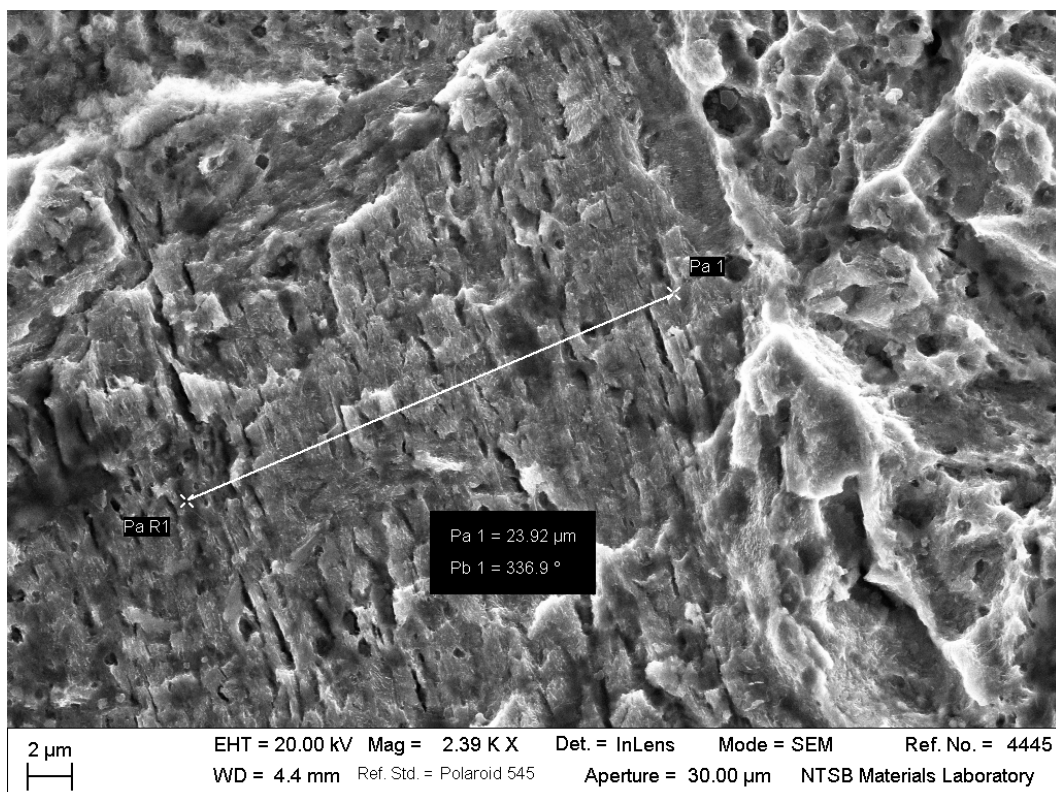


Figure 21 – SE micrograph of spot 18 and the length used in striation counting.

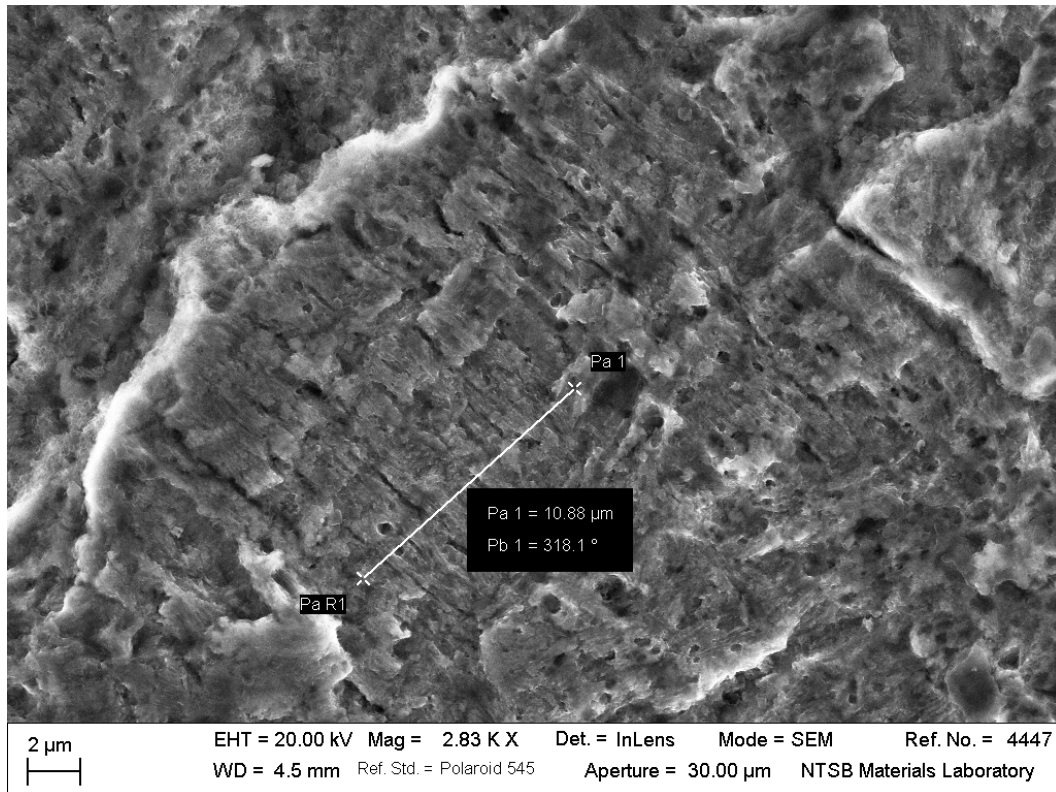


Figure 22 – SE micrograph of spot 19 and the length used in striation counting.

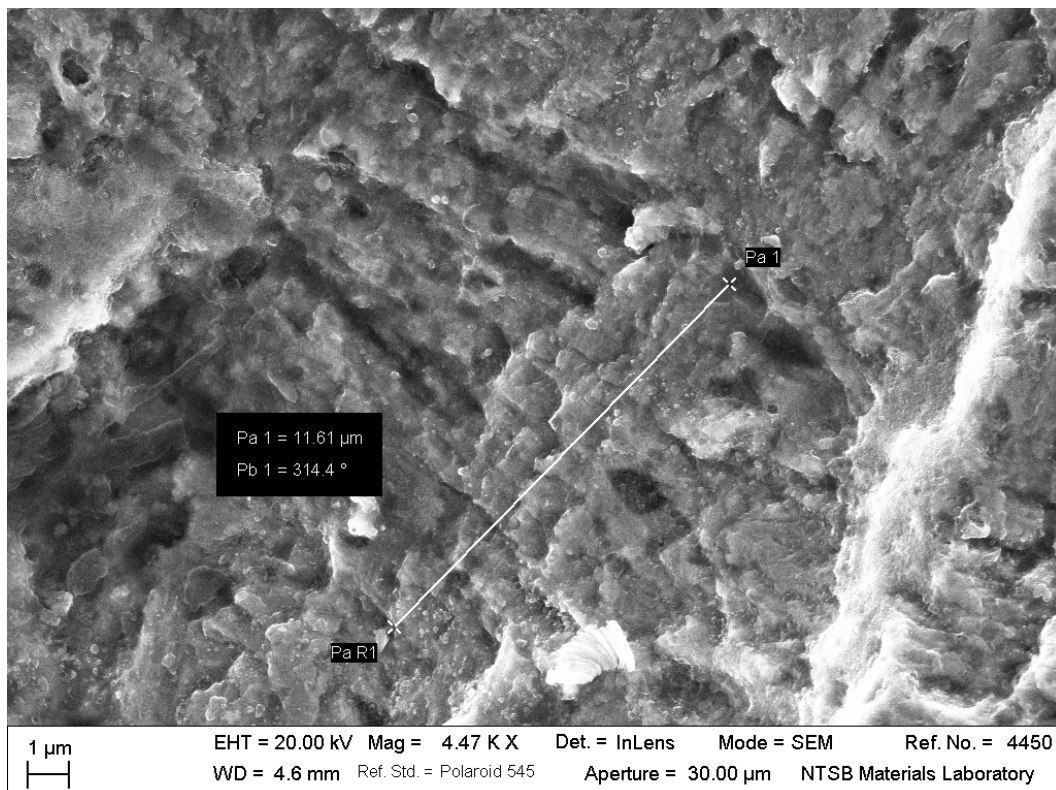


Figure 23 – SE micrograph of spot 20 and the length used in striation counting.

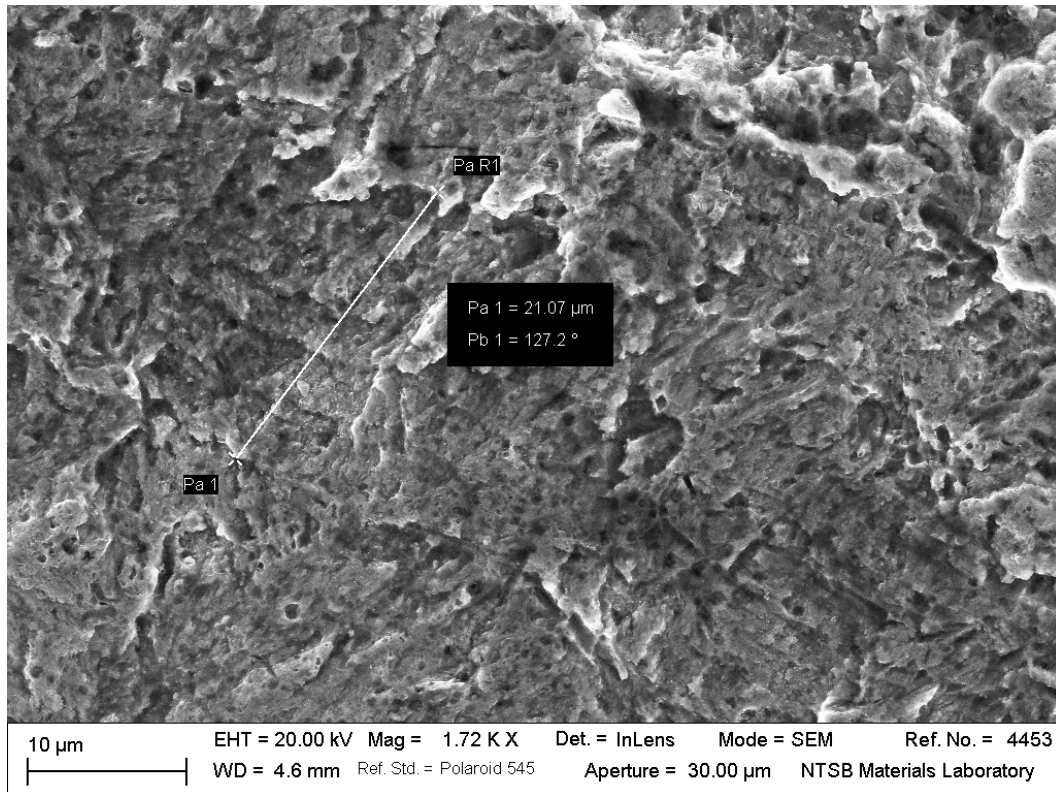


Figure 24 – SE micrograph of spot 21 and the length used in striation counting.

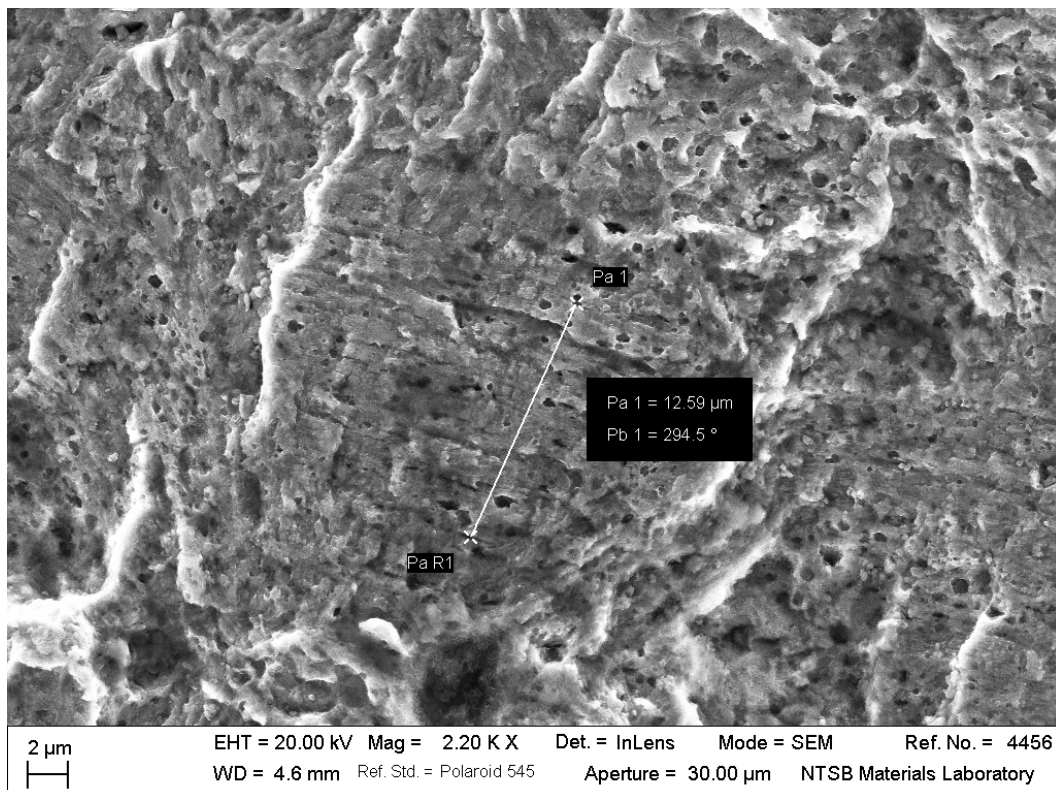


Figure 25 – SE micrograph of spot 22 and the length used in striation counting.

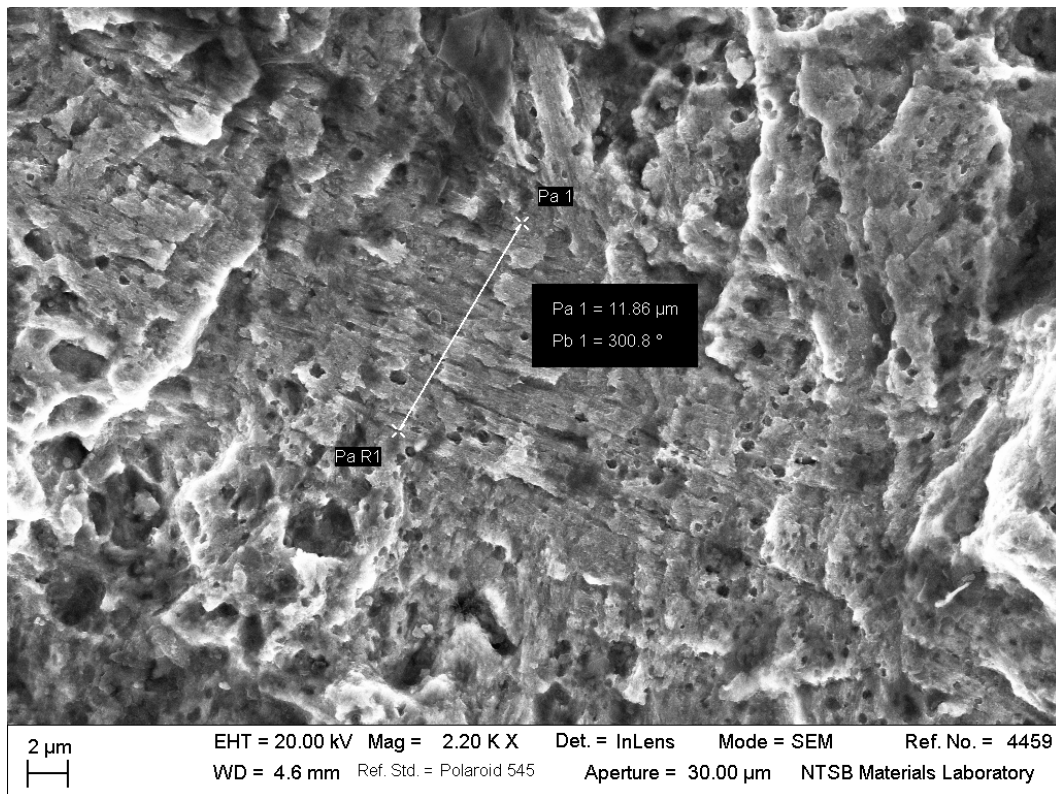


Figure 26 – SE micrograph of spot 23 and the length used in striation counting.

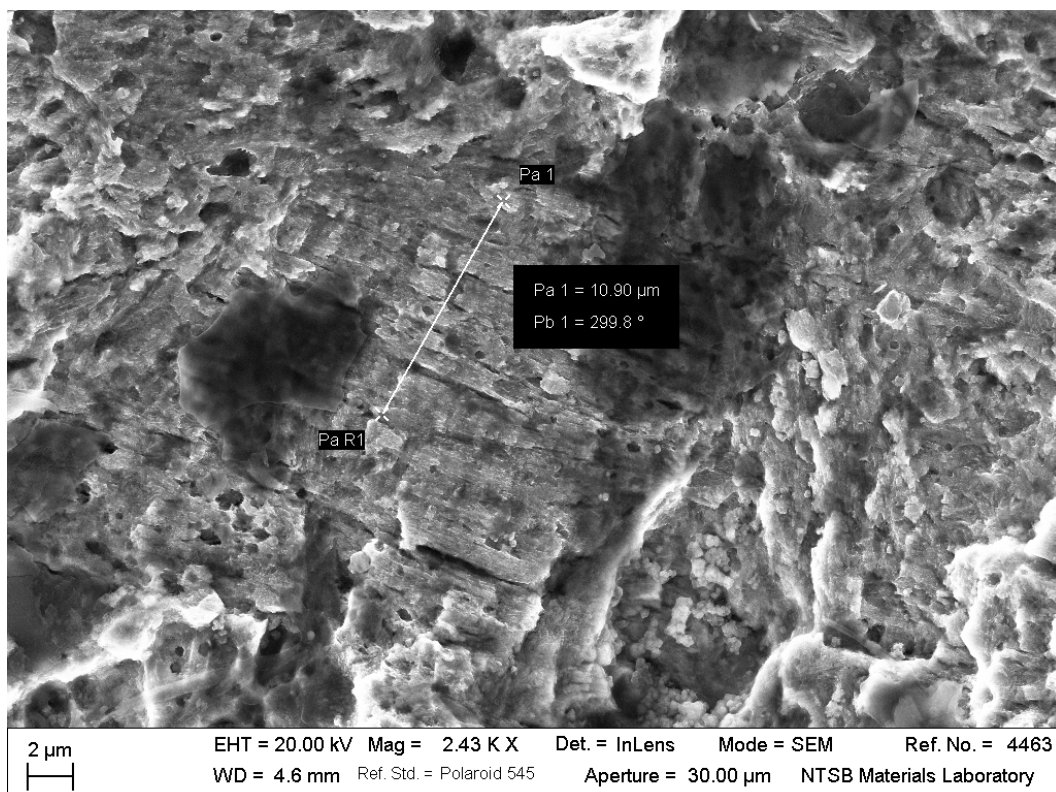


Figure 27 – SE micrograph of spot 24 and the length used in striation counting.

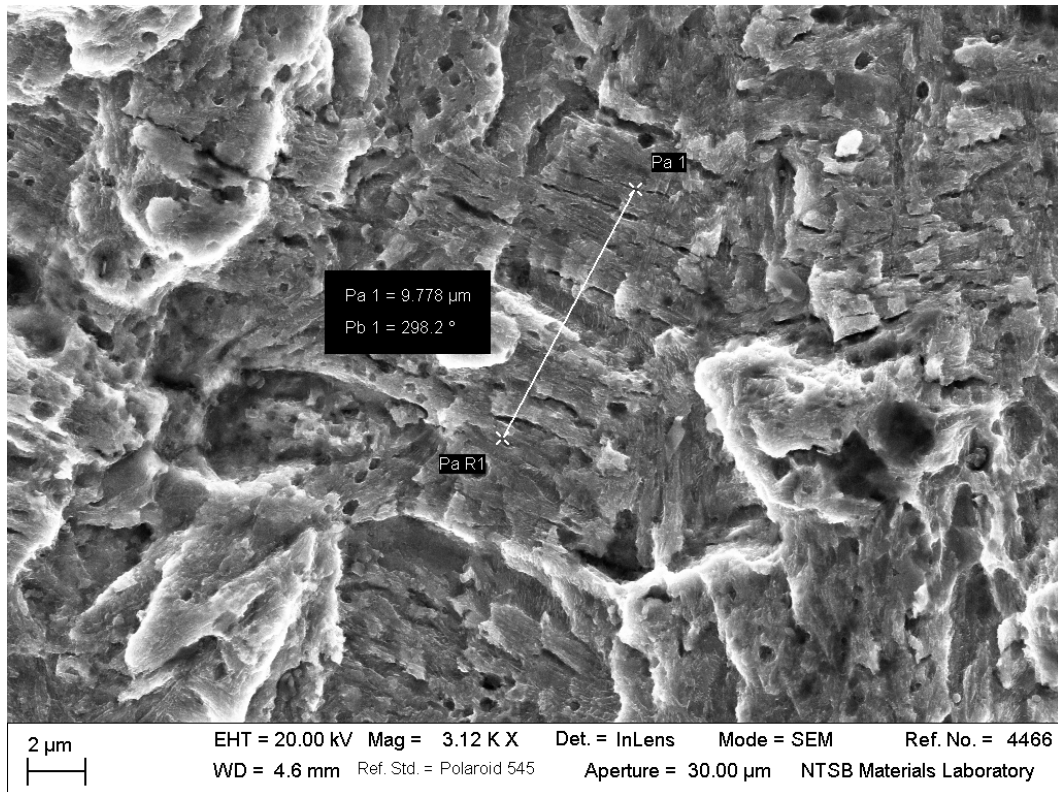


Figure 28 – SE micrograph of spot 25 and the length used in striation counting.

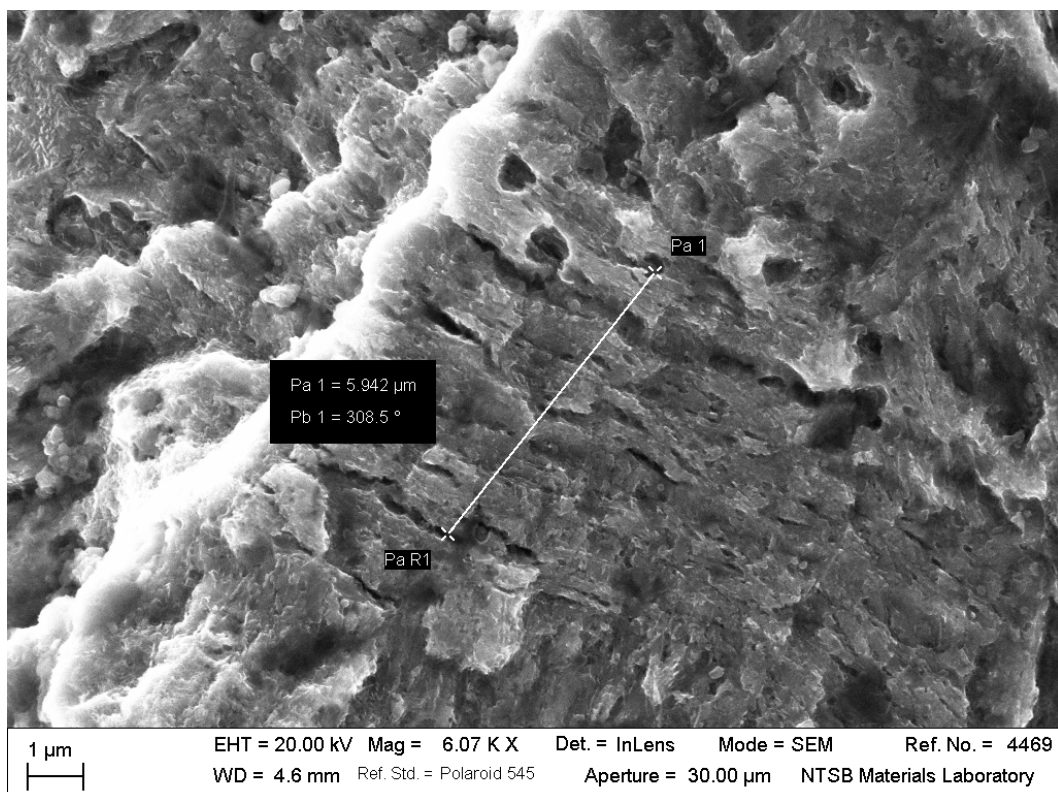


Figure 29 – SE micrograph of spot 26 and the length used in striation counting.

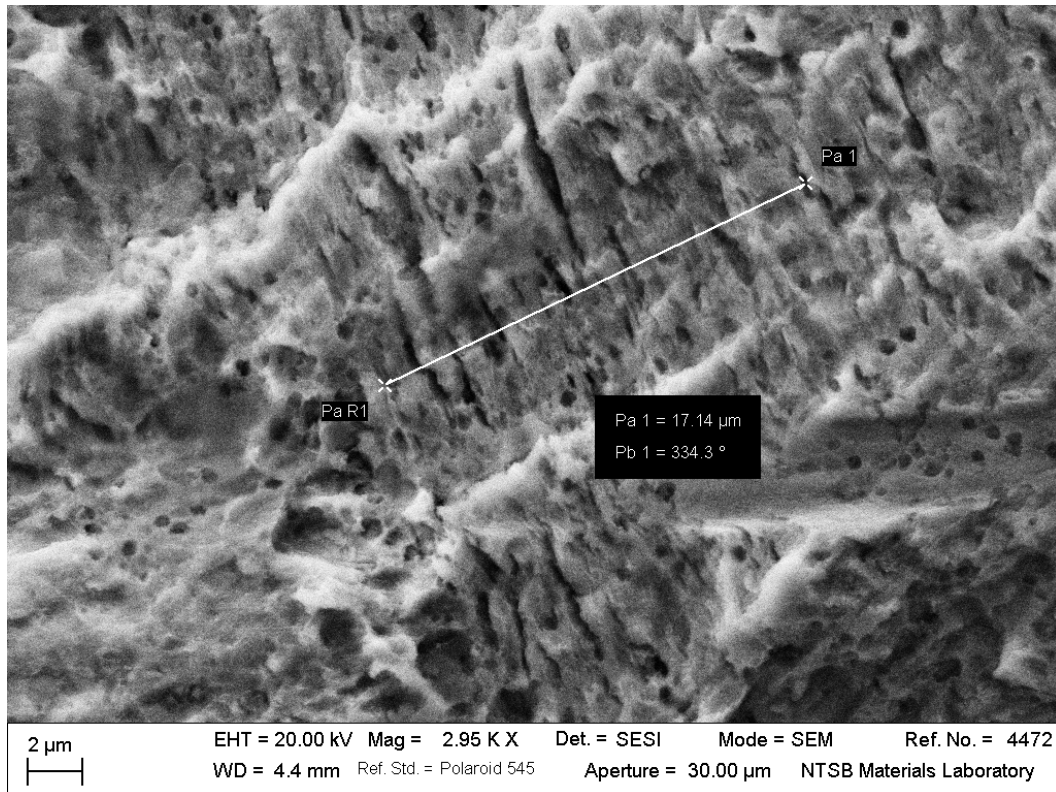


Figure 30 – SE micrograph of spot 27 and the length used in striation counting.

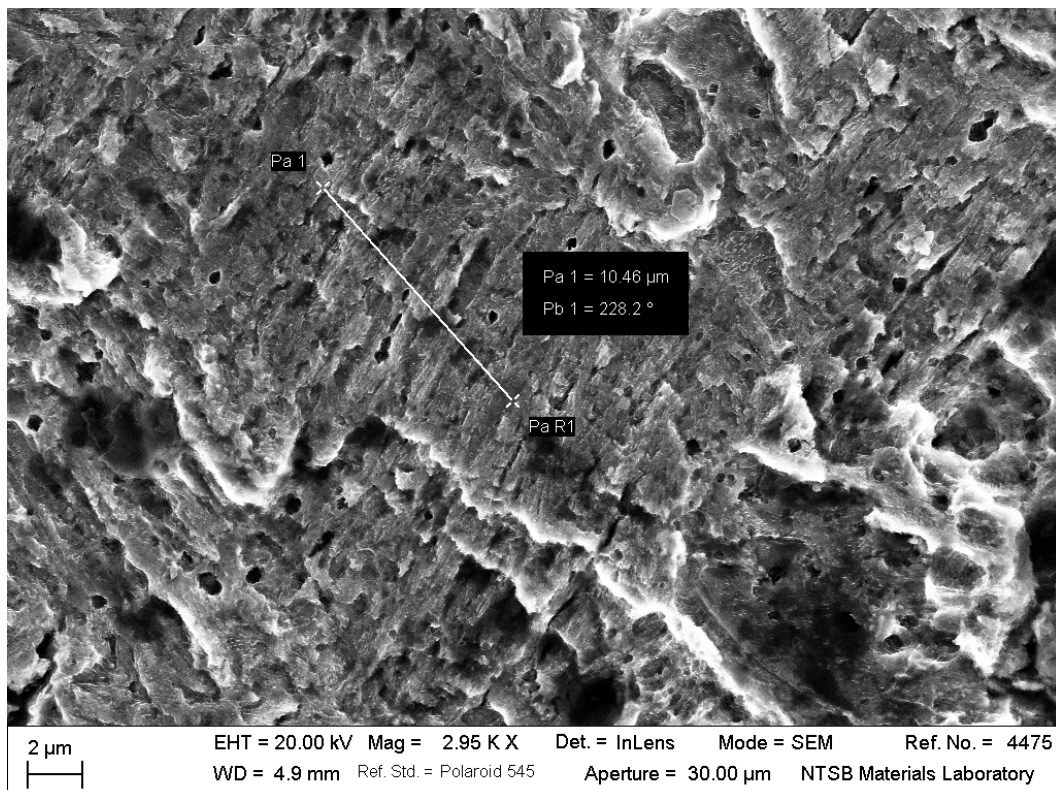


Figure 31 – SE micrograph of spot 28 and the length used in striation counting.

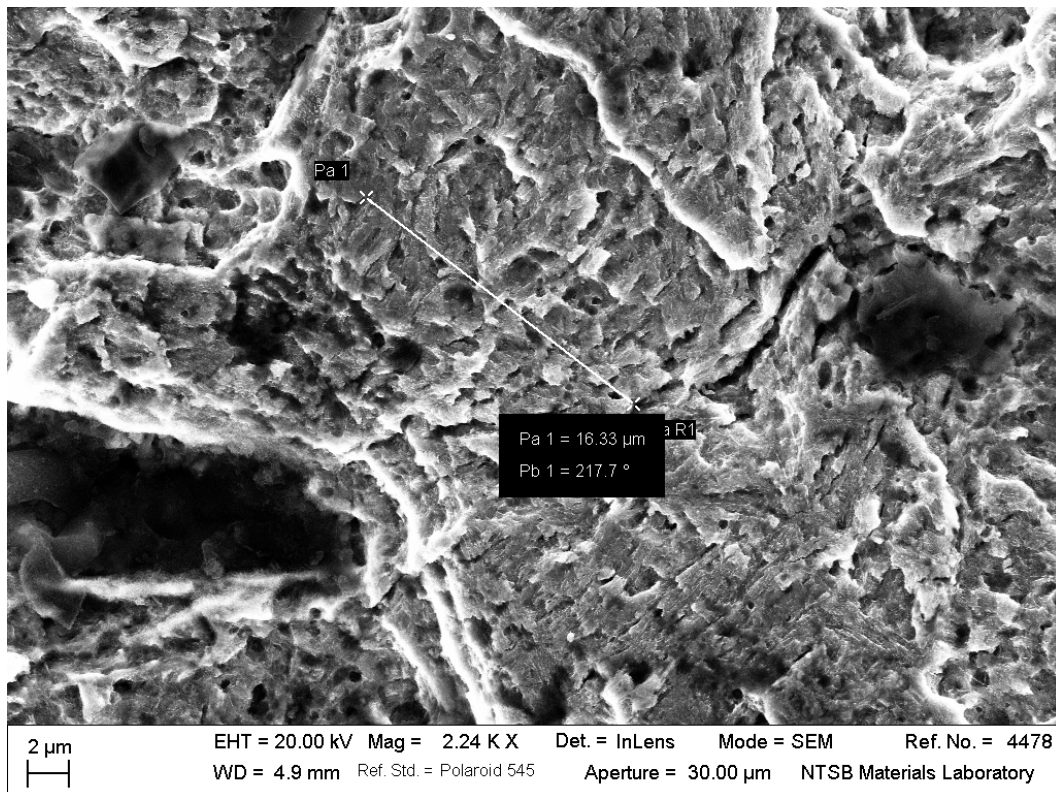


Figure 32 – SE micrograph of spot 29 and the length used in striation counting.

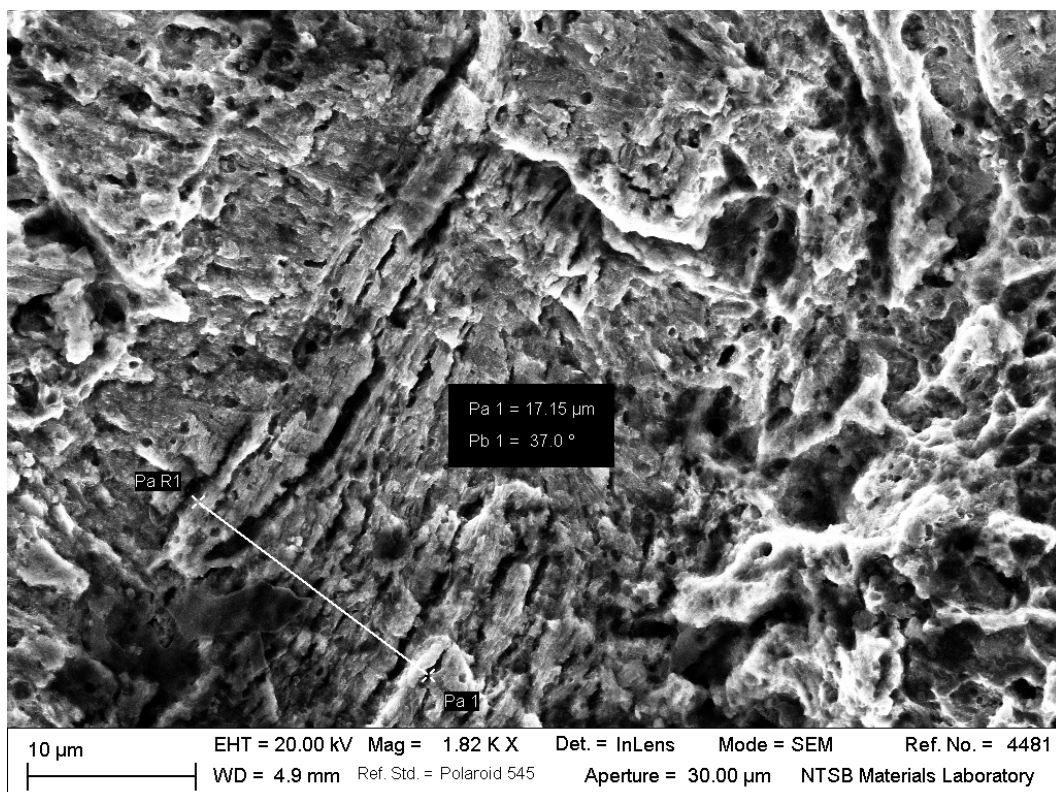


Figure 33 – SE micrograph of spot 30 and the length used in striation counting.