

# NATIONAL TRANSPORTATION SAFETY BOARD

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



June 7, 2017

## MATERIALS LABORATORY FACTUAL REPORT

Report No. 17-048

### A. ACCIDENT

Place : Cokeville, Wyoming  
Date : August 23, 2016  
Vehicle : Hiller UH-12D, N97TH  
NTSB No. : CEN16LA330  
Investigator : Craig Hatch, AS-CEN

### B. COMPONENTS EXAMINED

Pieces from a main rotor system control rotor cuff

### C. DETAILS OF THE EXAMINATION

On August 23, 2016, about 0745 mountain daylight time, a Hiller UH-12D helicopter impacted terrain near Cokeville, Wyoming. The commercial rated pilot received minor injuries and the helicopter was substantially damaged during the accident. The Federal Aviation Administration (FAA) inspector who was investigating stated that during the agricultural flight, a control rotor cuff separated from the helicopter when it was about 10-15 feet off the ground. The helicopter impacted terrain and came to rest on its side with the tail boom separated. The fractured cuff was located about 50 yards from the wreckage.

The mating fractured control rotor cuff sections of the cuff (P/N 36124) are shown in Figure 1, and a second sectioned intact control rotor cuff, which was opposite the fractured cuff, is shown in Figure 2. The cuff fragments in Figure 1 had fractured about the circumference of the outer shaft on the inboard bolt holes. This fracture surface exhibited a flat portion that was oriented perpendicular to the shaft direction, as shown in Figure 3. This flat portion was measured as 2.813 inches in circumferential length. The remaining portions of the fracture surface were more random in orientation, with a generally rougher texture.

The mating faces of the cuff fracture are shown from the inboard and outboard sides in Figures 4 and 5, respectively. The outboard fracture surface of the cuff shaft was separated from the remaining assembly and cleaned. Figure 6 illustrates the flat portions of this fracture surface. The flatter portion of the fracture surface exhibited crack arrest marks consistent with progressive crack propagation, later determined to be fatigue.

There were two fatigue cracks present on the cuff fracture surface: a larger one previously measured as 2.813 inches in length, and a smaller one located in the inside corner of the cuff bolt hole (upper left in Figure 6). The boundaries of the larger and smaller cracks are outlined in Figure 6, along with the crack growth direction (white dashed lines).

Figure 7 shows a closer view of the bolt hole, where both fatigue cracks initiated. The initiation site of the larger fatigue crack exhibited substantial smearing at the bolt hole edge. The undamaged features of the fatigue crack adjacent the smeared section were consistent with initiation at the middle of the bolt hole bore (Figure 8). In contrast, the smaller fatigue crack initiated at the surface corner of the inner shaft surface and the bolt hole.

The outboard fracture surface was examined using a scanning electron microscope (SEM). As typified in Figure 9, the larger fatigue crack exhibited fatigue striations. These striations were fine in size and erratically spaced, consistent with high cycle fatigue under spectrum loading. As previously observed in Figure 8, the initiation site of the larger fatigue crack had been obliterated by smearing (Figure 10).

The striations and other features of the fatigue crack were consistently present until the end of the crack, near the opposite bolt hole (See Figure 11). Outside the fatigue cracks, dimple rupture, consistent with overstress was observed (Figure 12).

The smaller fatigue crack is illustrated in Figure 13. This crack measured 0.105 inches (2.66 mm) on the bolt bore surface and 0.0932 inches (2.37 mm) on the shaft inner surface. The corner of the bolt hole and the inner shaft surface had been beveled. This smaller fatigue crack also exhibited fatigue striations, as typified in Figure 14. The crack initiation site of the smaller crack was located interior to the bolt hole bore or shaft surfaces (see Figure 15). A closer view of this crack initiation site is shown in Figure 16. This region exhibited an irregular jagged appearance, inconsistent with the surrounding fatigue striations. Examination of the site using energy dispersive x-ray spectroscopy (EDS) found it to have elevated levels of oxygen relative to the surrounding material.

The chemical composition of the control cuff was inspected using EDS and x-ray fluorescence. The cuff material was consistent with an AA 2024 aluminum alloy. The cuff was sectioned, mounted and polished. A typical area of the cuff microstructure is shown in Figure 17. The microstructure consisted of an aluminum-rich matrix, with aluminum-copper second phase precipitates dispersed throughout. No voids or non-metallic inclusions were observed in the microstructure.

The hardness the cuff was inspected per ASTM E18.<sup>1</sup> The hardness averaged 83 HRBW. The electrical conductivity was measured per ASTM E1004.<sup>2</sup> The conductivity

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<sup>1</sup> ASTM E18 – *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*. ASTM International, West Conshohocken, PA.

<sup>2</sup> ASTM E1004 – *Standard Test Method for Determining Electrical Conductivity Using the Electromagnetic (Eddy-Current) Method*. ASTM International, West Conshohocken, PA

averaged 36.0 %IACS. These hardness and conductivity data were consistent with a T6 or T8 temper for this aluminum alloy, per AMS 2658.<sup>3</sup>

Erik Mueller  
Materials Research Engineer

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<sup>3</sup> AMS 2658 – *Hardness and Conductivity Inspection of Wrought Aluminum Alloy Parts*. SAE International, Warrendale, PA.

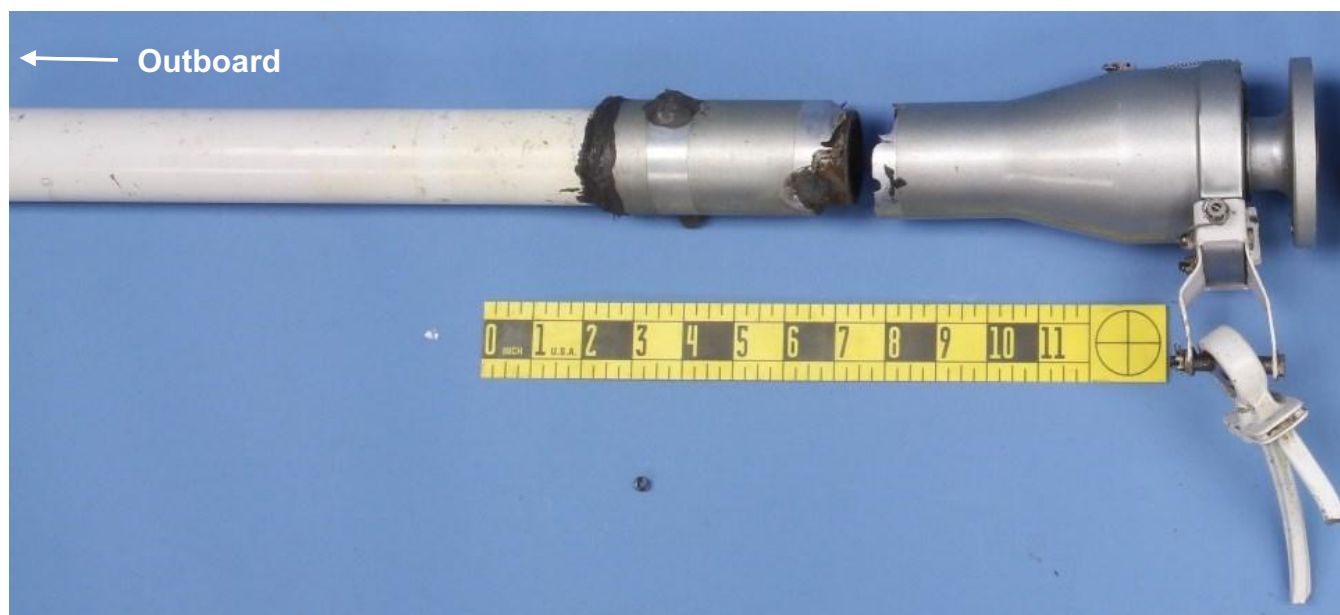


Figure 1 – The fractured portions of the control rotor cuff, as received. The fractured region is shown in Figures 3 through 5.



Figure 2 – The section of the intact control rotor cuff, opposite the fractured one in Figure 1, as received.

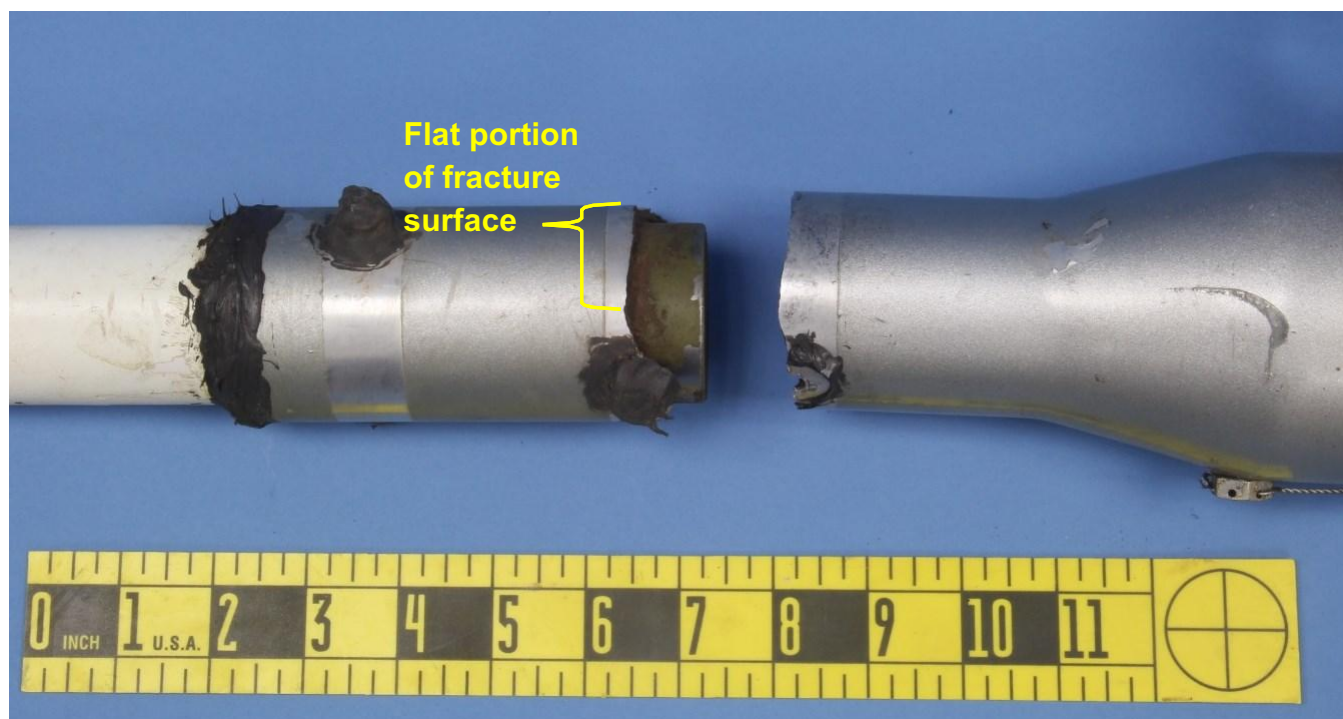


Figure 3 – Closer view of the control rotor cuff fracture, showing portion of the fracture surface oriented 90° to the shaft direction, with a relatively flat surface.

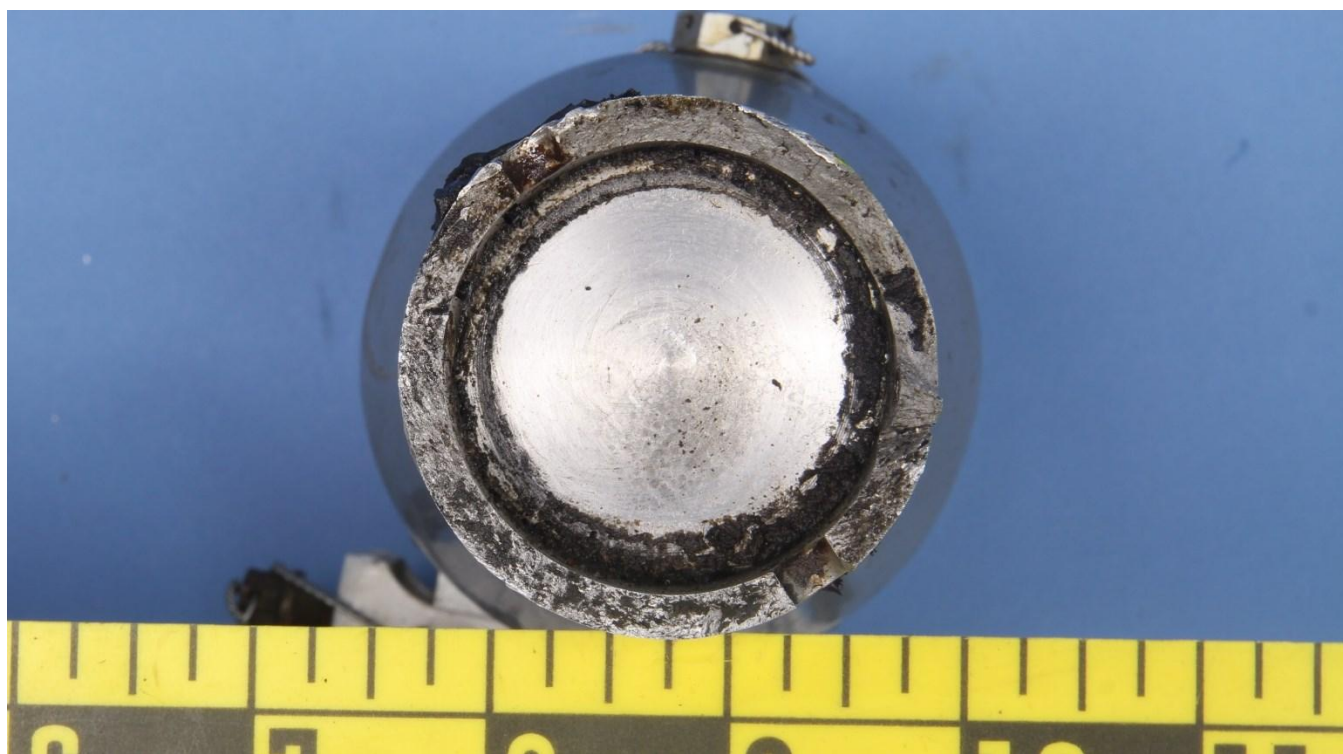


Figure 4 – The cuff fracture surface on the inboard side (looking inboard), as received.

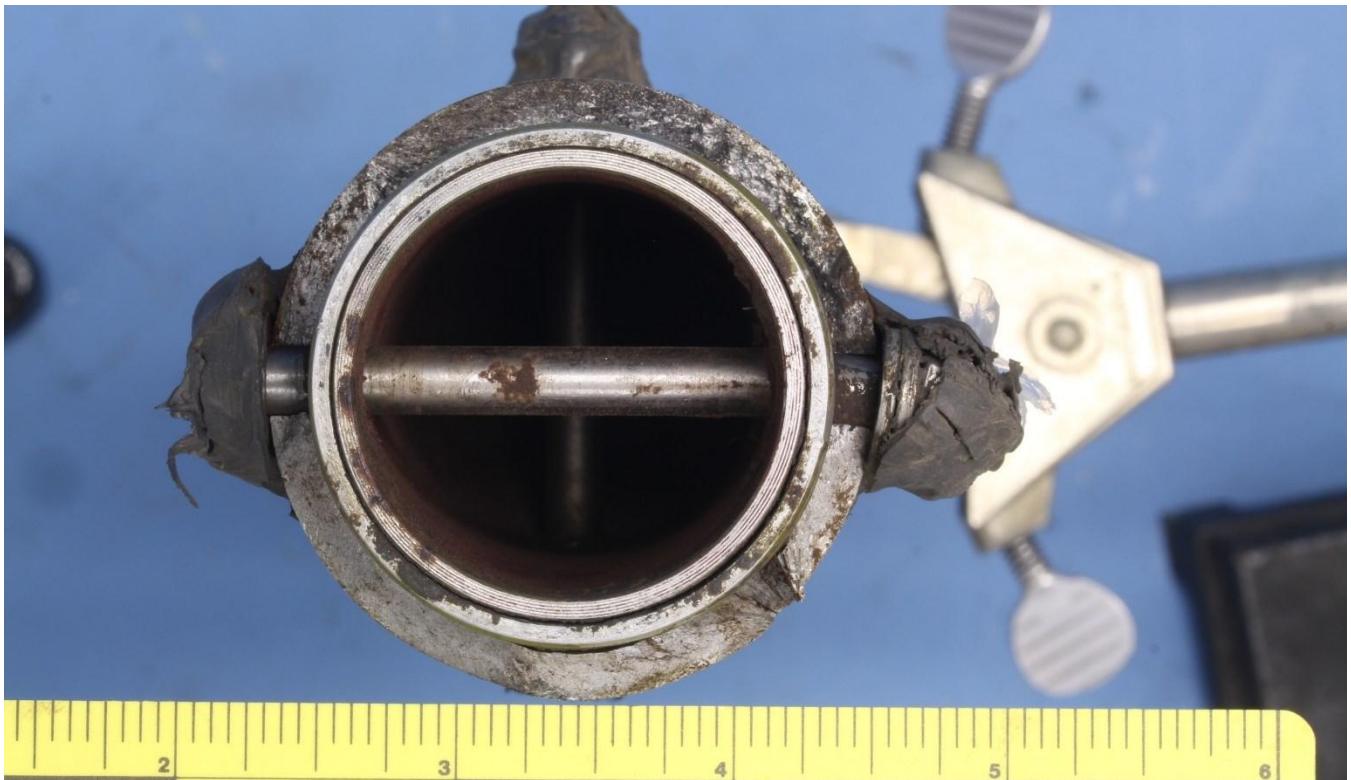


Figure 5 – The outboard side cuff fracture surface (mating that in Figure 4), as received.



Figure 6 – Closer view of the flat portion of the outboard fracture surface of the cuff (from Figure 5), after disassembly and cleaning. The progressive portions of the fracture surface are outlined and the crack direction is annotated.

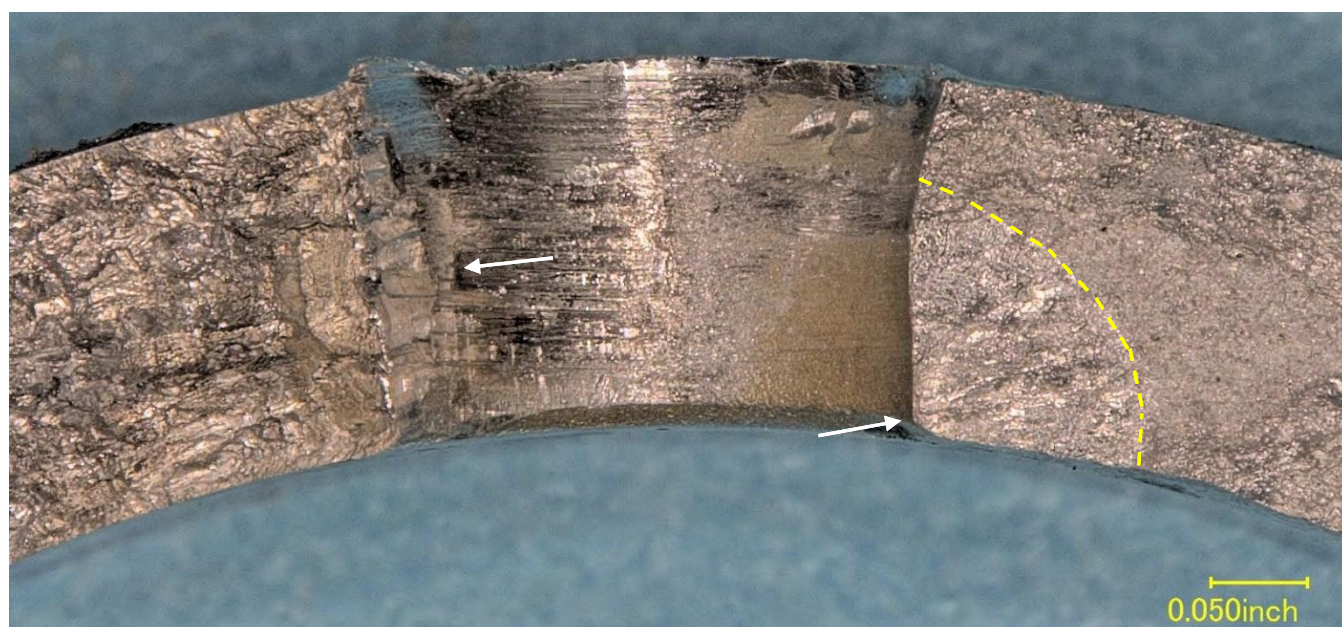


Figure 7 – Closer view of the fatigue crack initiation sites (denoted by arrows) about the bolt hole of the cuff. The smaller fatigue crack is outlined on the right.

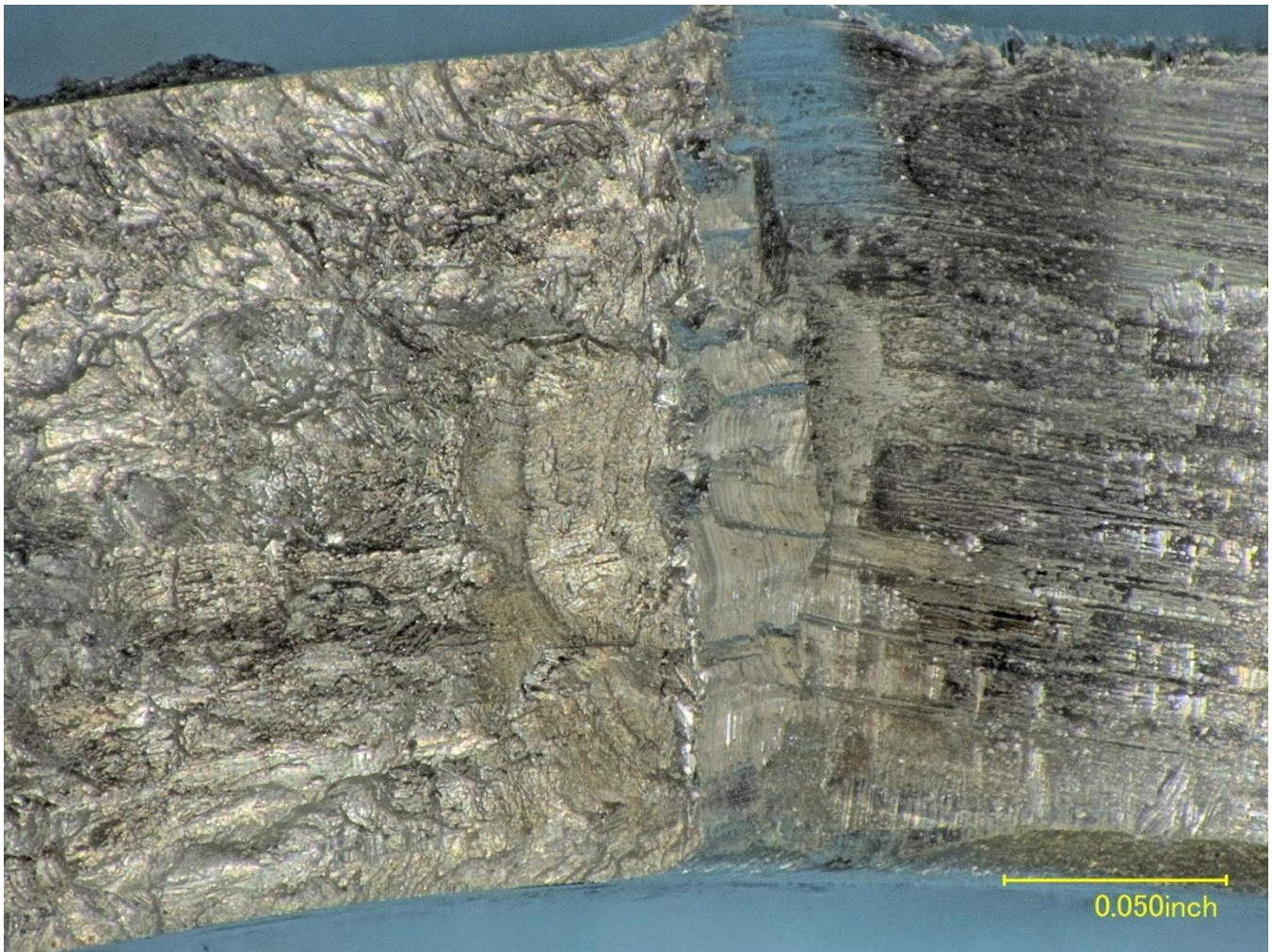


Figure 8 – Closer view of the major fatigue crack initiation site on the cuff fracture surface.

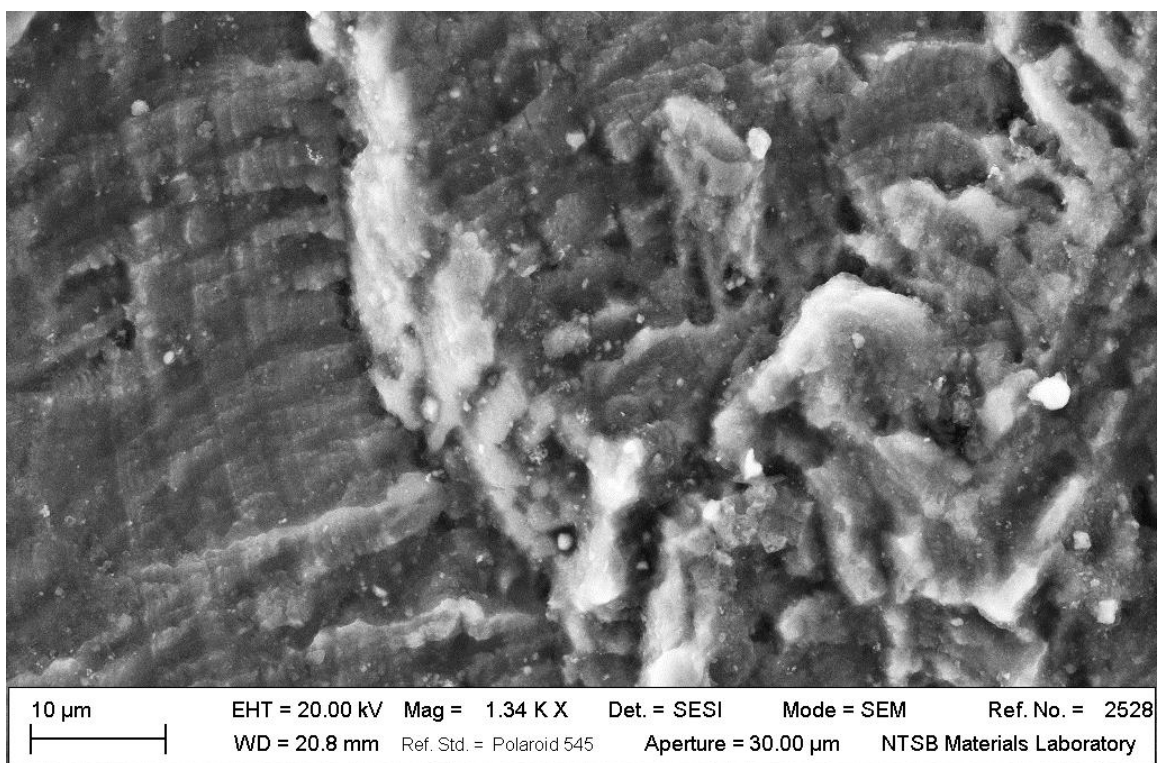


Figure 9 – Secondary electron (SE) micrograph of major fatigue crack, showing striations propagating from right to left.

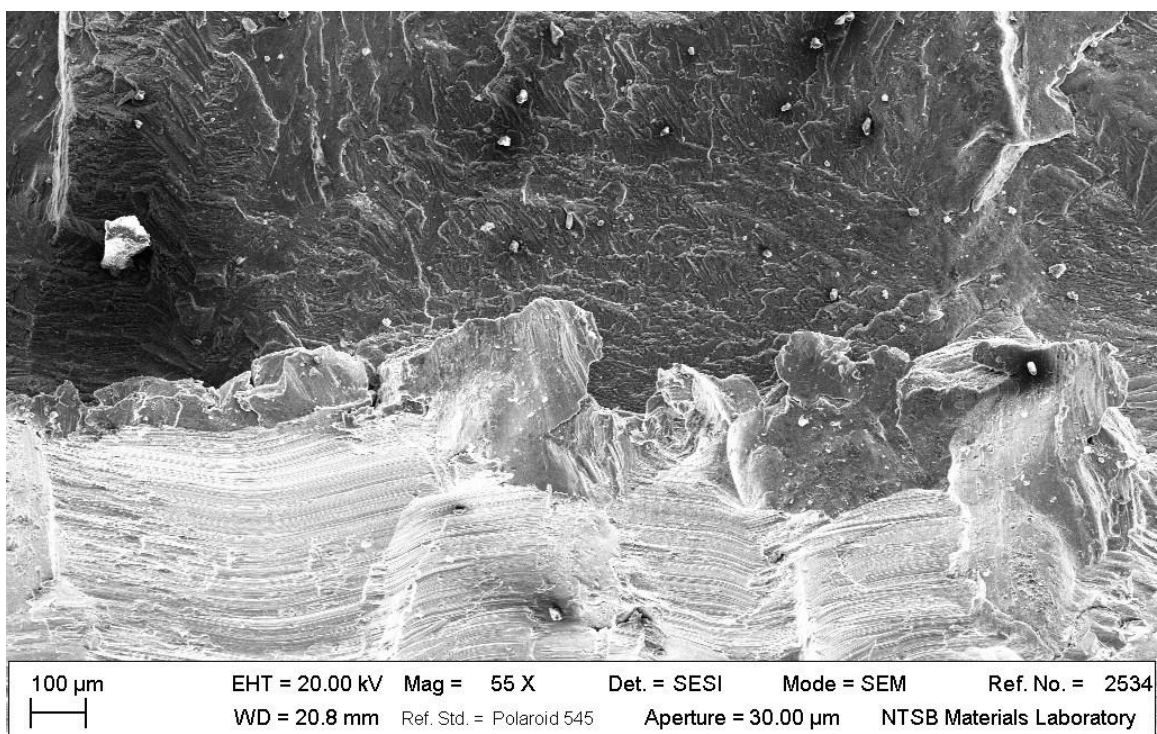


Figure 10 – SE micrograph of the major fatigue crack initiation site, showing smearing along the corner with the bolt hole.

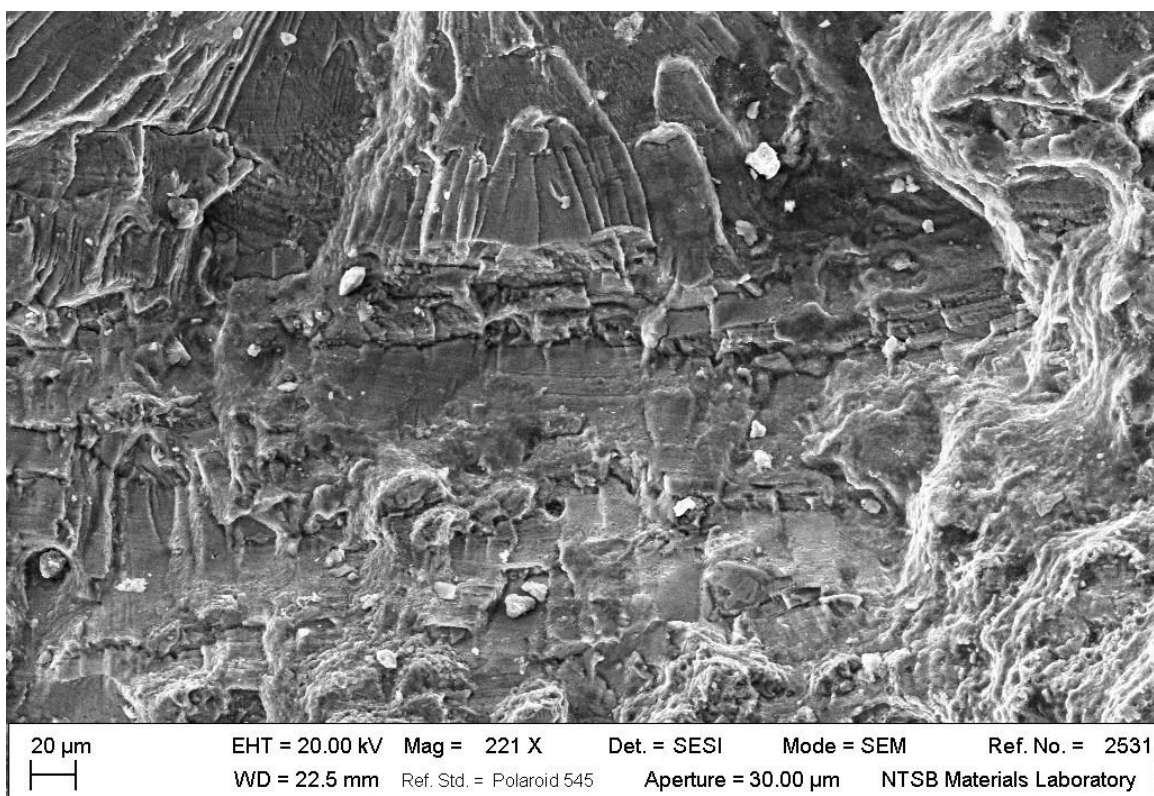


Figure 11 – SE micrograph showing the end of the major fatigue crack on the cuff fracture surface.

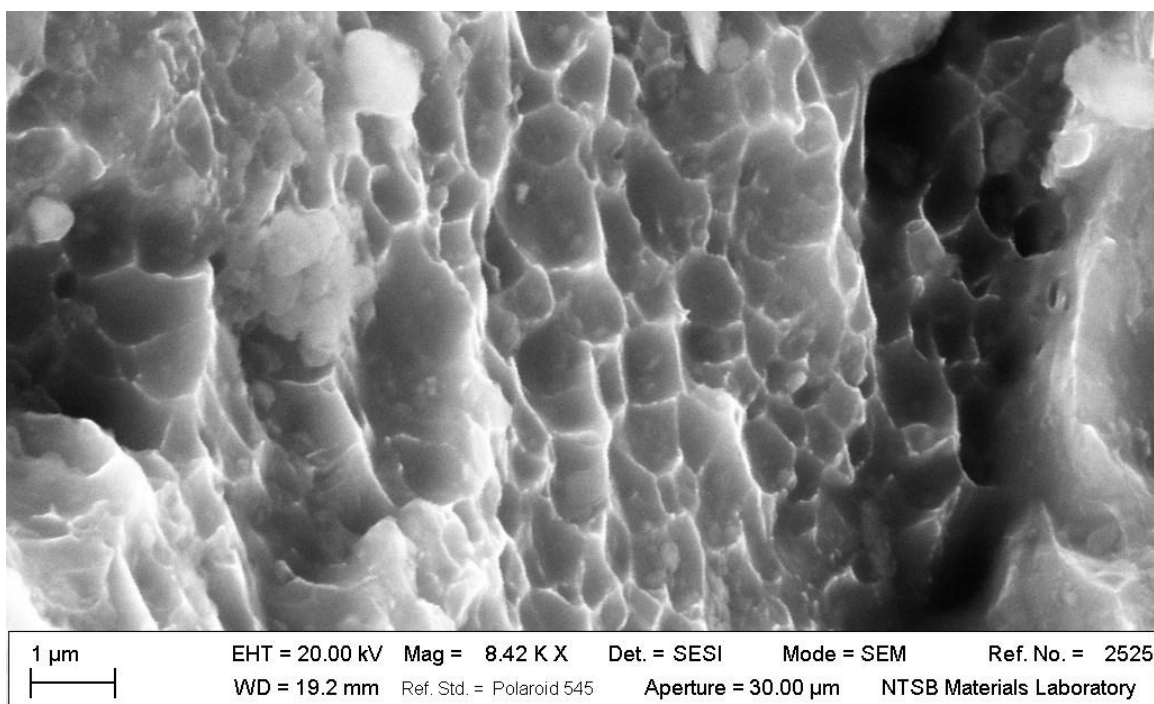


Figure 12 – SE micrograph showing dimple rupture on the portions of the fracture surface outside the fatigue features.

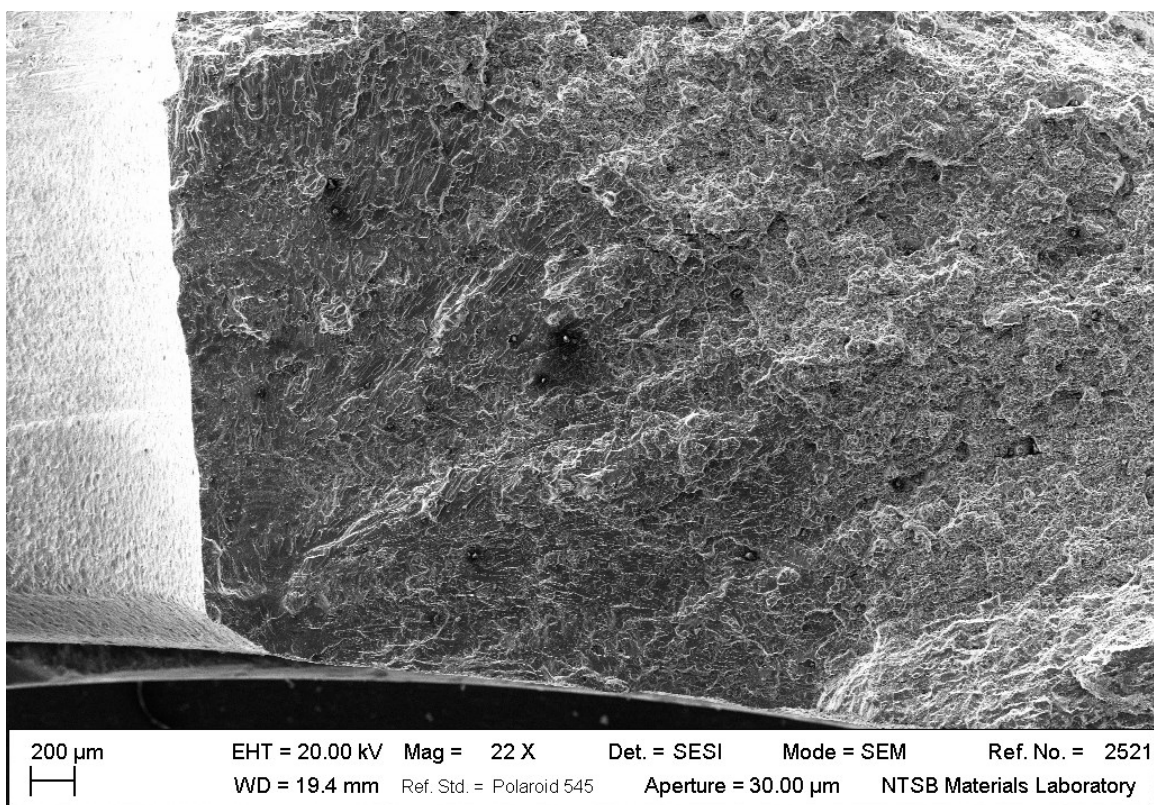


Figure 13 – SE micrograph showing the smaller fatigue crack, adjacent the bolt hole.

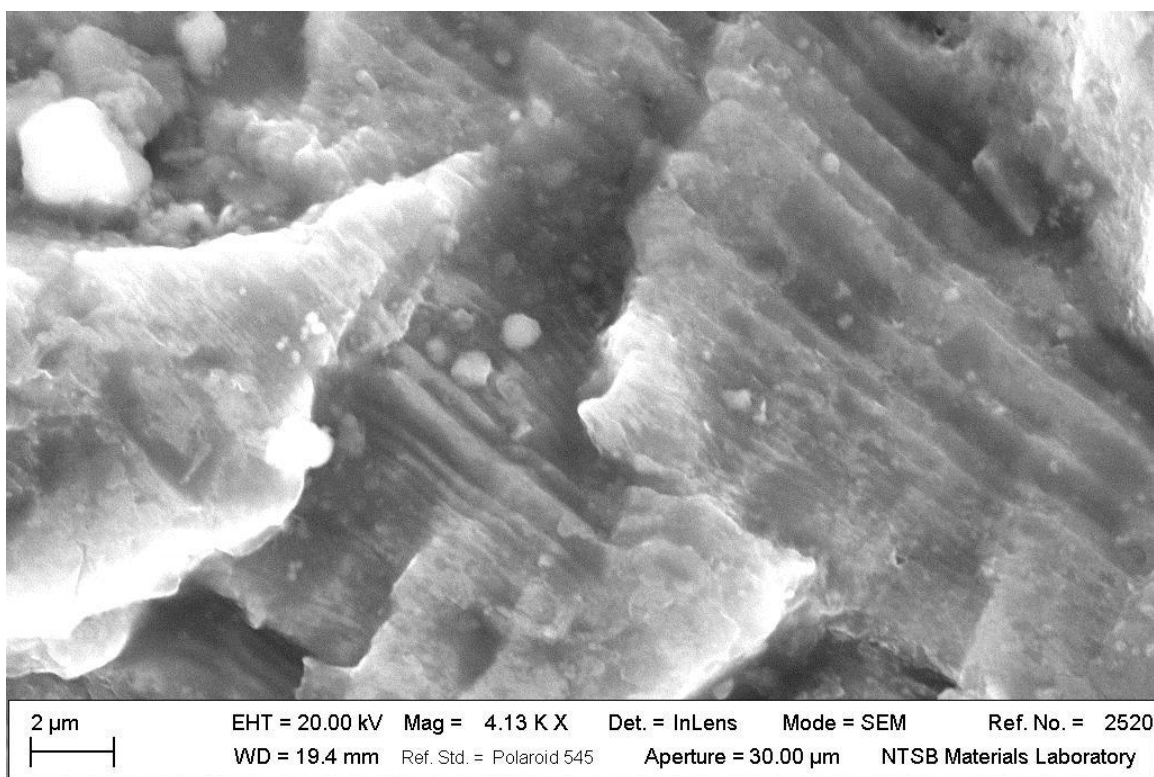


Figure 14 – SE micrograph of an area on the small fatigue crack striations.

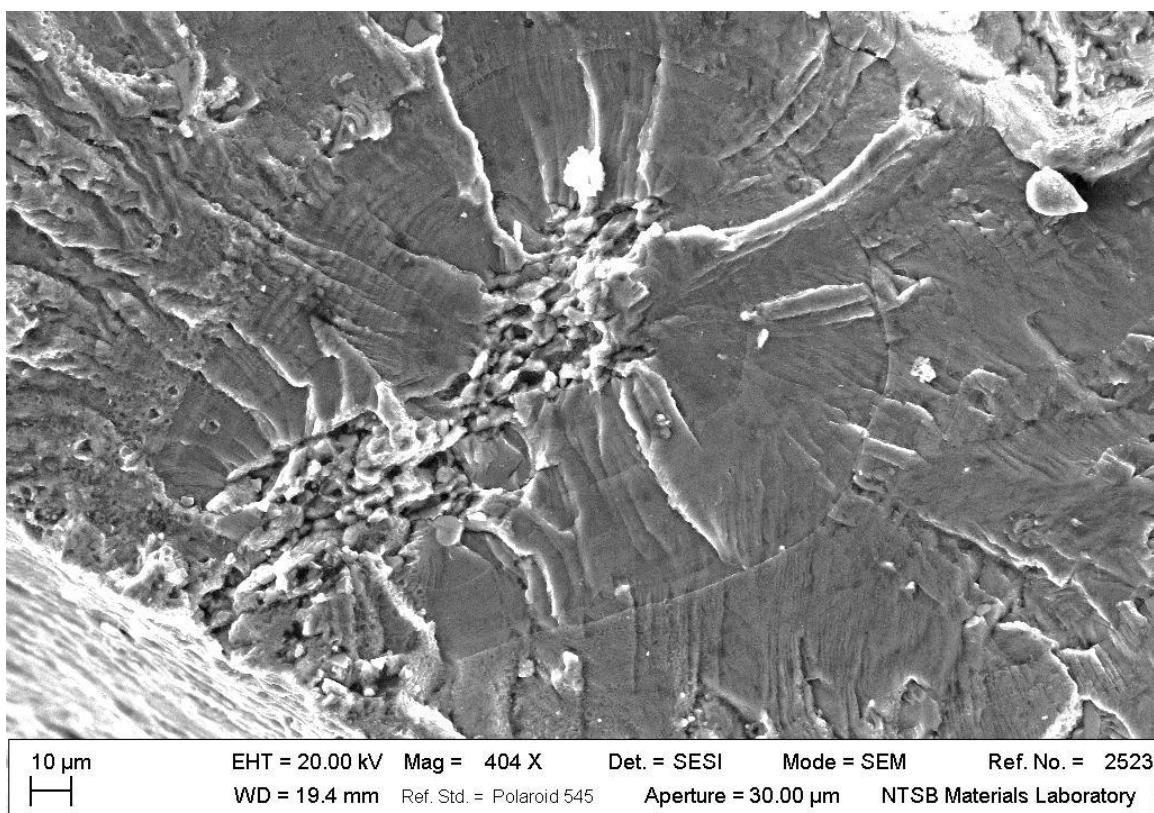


Figure 15 – SE micrograph showing the crack initiation site of the small fatigue crack.

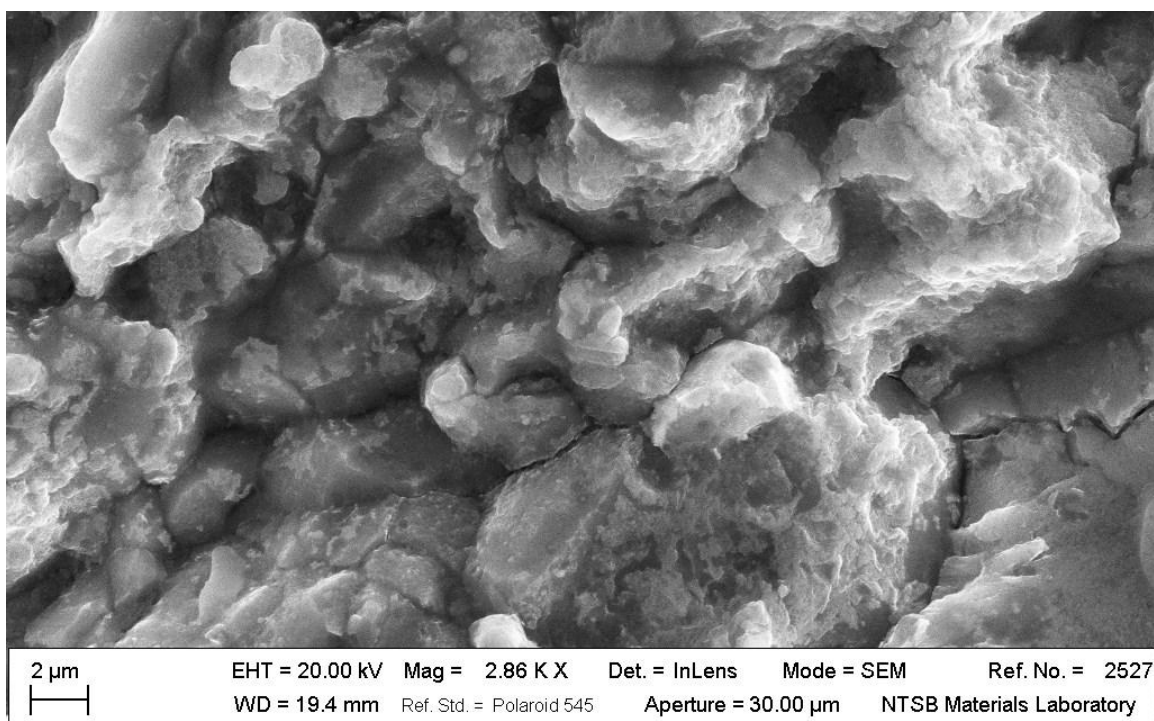


Figure 16 – SE micrograph closeup of the interior of the small fatigue crack initiation site.

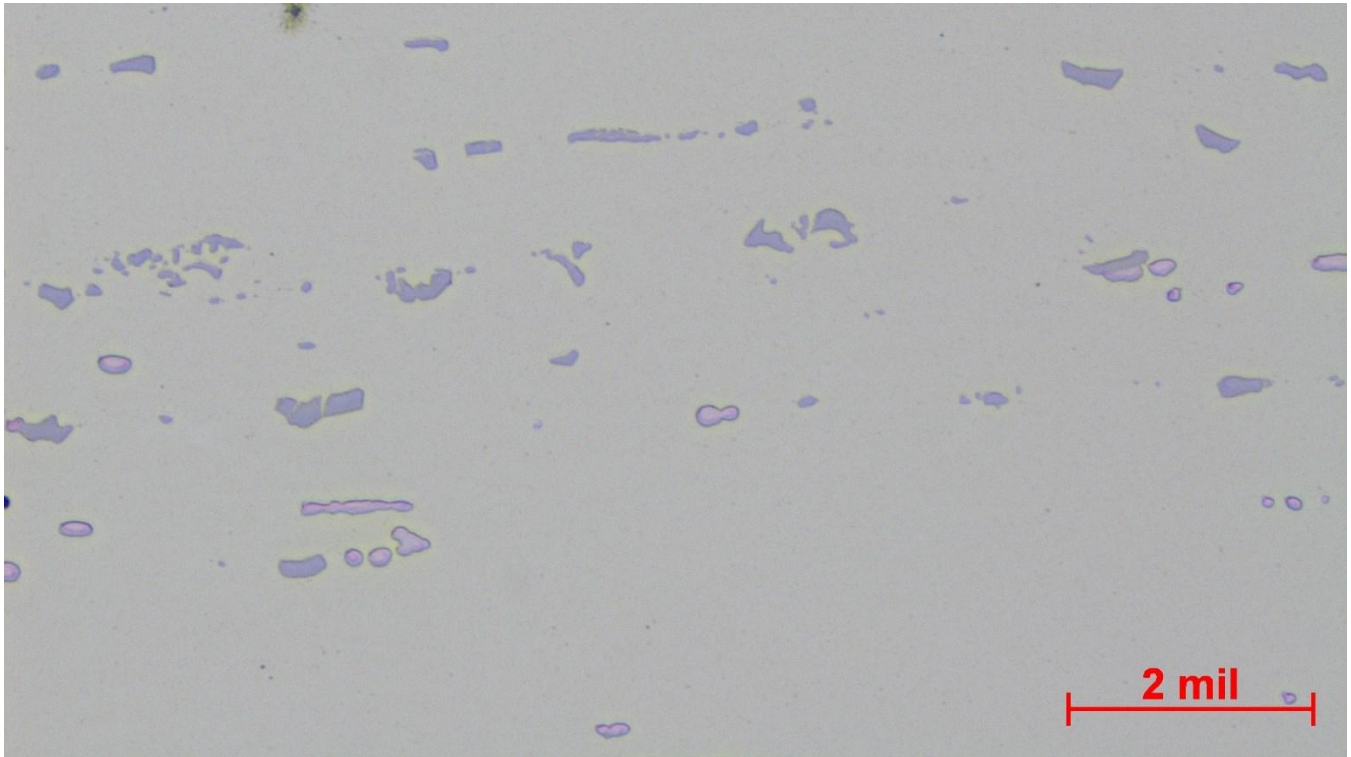


Figure 17 – Bright-field micrograph showing a typical area of the cuff microstructure, showing Al/Cu-based precipitates in the Al-primary matrix (~500X, as polished).