Element Materials Technology
Zekeringstraat 33
1014 BV Amsterdam NL

P + 31 (0) 20 556 35 55
F + 31 (0) 20 556 35 56
info.amsterdam@element.com
element.com

Bank ABN AMRO, Amsterdam
Acct 54.02.65.659
BTW NL0086.06.754.B01
KvK 33194077

Report

INVESTIGATION OF A BROKEN HYDRAULIC SWIVEL

Customer	: Dutch Safety Board Anna van Saksenlaan 50 2593 HT Den Haag	
Reference Customer	: -	
Project Element	: EAM017776P	
Report	: EAM017776-1 Rev. 2	
Author	: A. Bank	
Date Report	: March 2, 2016	
Number of Pages	: 20	
Classification	: n.a.	
Distribution	: Dutch Safety Board	1x
	Files Element Amsterdam	1x

1 INTRODUCTION

On the 4th of February 2016, Element Amsterdam received from Dutch Safety Board the request to investigate a broken hydraulic swivel. The swivel concerns a part of the hydraulic system of the downlock system of the landing gear of a SAAB 340.
The received swivel was delivered at Element with the remark: “Loganair Saab 340 onderzoek, Rotterdam 30-09-2015”.

The goal of the investigation was to determine the failure mechanism and the initiation point of the fracture. The results of the investigation are compared with the failure causes of broken hydraulic swivels as reported in Service Bulletin 340-32-142. The swivels, mentioned in this Service Bulletin, were broken due to fatigue.
The investigation was carried out in the laboratory of Element Amsterdam in the month February 2016. All results and conclusions mentioned in this report are applicable to the investigated swivel only. This report contains one appendix.

To perform the investigation Element received the following:

- The broken hydraulic swivel;
- Service Bulletin 340-32-142.

2 SCOPE OF WORK

The swivel is first visual investigated. Subsequently, the fracture surfaces are investigated by using a scanning electron microscope (SEM).

3 RESULTS

3.1 Visual examinations

The swivel consists of an aluminum block with an aluminum hollow axle. The figures **1**, **2** and **3** show the swivel in the as received condition. At the identification plate the following data was present:
p/n : L387-10 SA
s/n : 1094
Date : 12-87

Through the block and the hollow shaft, the hydraulic oil flowed. The hollow shaft turned in the steel block of the swivel. The hollow shaft is broken at the radius from shaft to collar. At this position the bore of the shaft comes through the outer shaft diameter.
The fracture surface shows one position, which is mechanically damaged. The damage is only present on the fracture surface of the shaft part. At the fracture surface of the collar part the mechanical damage is not present.
The major part of the fracture surface exhibits a sparkling appearance. Opposite the hole of the bore the fracture surface shows a visually small area with a dull appearance. The figures **4** up to and including **11** show the fracture surface.

3.2 SEM examinations

With use of a SEM the fracture surfaces are investigated to reveal specific fracture characteristics. During these investigations it is observed that the visually sparkling part of the fracture surface is showing fatigue striations. The visually dull area is showing features of a tough overload fracture

such as dimples and plastic deformed aluminum. These characteristics indicate that this area is the final fracture.
The visually sparkling area is investigated in detail with the SEM. During these investigations the following is found:
At the outer diameter (radius) where the bore comes through the shaft surface the striations are very difficult to reveal due to chemical attack of the aluminum. These two positions are pointed as C1 and C2 in figure **12**. In the direction to the final fracture, more striations are clearly visible and the striation distance increase. In figure **12** the positions of the detailed investigated fracture surface are noted in red. The yellow lines in this figure indicate the crack grow direction from the corners C1 and C2 to the final fracture. The figures **13** up to and including **27** show the detailed investigated positions.

3.3 Service Bulletin

In the Service Bulletin 340-32-142, failure of a same type of swivel is reported. In this Service Bulletin the failure cause is attributed to fatigue in the aluminum part of the swivel.
The Service Bulletin describes the procedure to replace the swivels for a swivel type which is completely from steel.
In paragraph 1.D COMPLIACE the status "Recommended" is given.
The Service Bulletin is shown in appendix 1.

4 DISCUSSION

Element Amsterdam had investigated a broken swivel to determine the failure mechanism of a broken shaft from a hydraulic swivel. This swivel shaft is manufactured from aluminum. During the investigation, it was found that the shaft was broken due to fatigue. The fatigue is initiated in the radius between the shaft and collar where the bore of the shaft was come through the shaft surface. At the initiation positions, the striations were very slightly visible due to chemical attack of the aluminum. The outer shaft surface is not chemical attacked. This surface is protected by an anodizing layer. The fracture surface is completely unprotected after fracturing. Due to the absence of oxygen in the hydraulic oil, the aluminum at the fracture surface cannot passivate. This resulted in a high sensitivity for chemical attack of the aluminum.
More close to the final fracture the striation distance has increased and more clearly visible due a decrease of the chemical attack. This proves that the fracture is time depended and is caused over a longer time.
The direction of the crack grow indicate that the fatigue is caused due to alternated tensile loads in the shaft. Indications of alternated torsion loads are not found.

For aluminum, it is known that it has no fatigue strength[1]. The swivels are present in the airplane since delivery of the airplane. For the investigated swivel, this is since 1987. This represents 29 years.
At Element, the life time of the failed swivel is not known. However, when an aluminum component is failed after many years due to fatigue it can be expect that the fatigue strength of the aluminum is

[1] **Fatigue strength**, **endurance limit**, and **fatigue limit** are all expressions used to describe a property of materials: the amplitude (or range) of cyclic stress that can be applied to the material without causing fatigue failure. Ferrous alloys and titanium alloys have a distinct limit, amplitude below which there appears to be no number of cycles that will cause failure. Other structural metals such as aluminum and copper, do not have a distinct limit and will eventually fail even from small stress amplitudes. In these cases, a number of cycles (usually 10^7) is chosen to represent the fatigue life of the material.

reached. This means that all aluminum shafts of comparable swivels, operated at comparable circumstances, are possible risks.

5 CONCLUSION

Element Amsterdam received from Dutch Safety Board a broken hydraulic swivel to investigate. It is concluded that the swivel is broken due to fatigue as result of alternated tensile loads in the shaft.

Element Materials Technology Amsterdam

Authorised: J. Rademaker
Sr. Adviseur Materiaalonderzoek

Author: A. Bank

Furthermore, we inform you that we will keep the investigated objects, as far as they are important to the judgment of the results of the investigation, for a period of at least six months. If we have not received other instructions from you before the ending of this period, we assume Element can destroy these objects after that period, at a time that suits us.

Figure 1. The broken swivel in the as received condition.

Figure 2. The identification plate of the swivel.

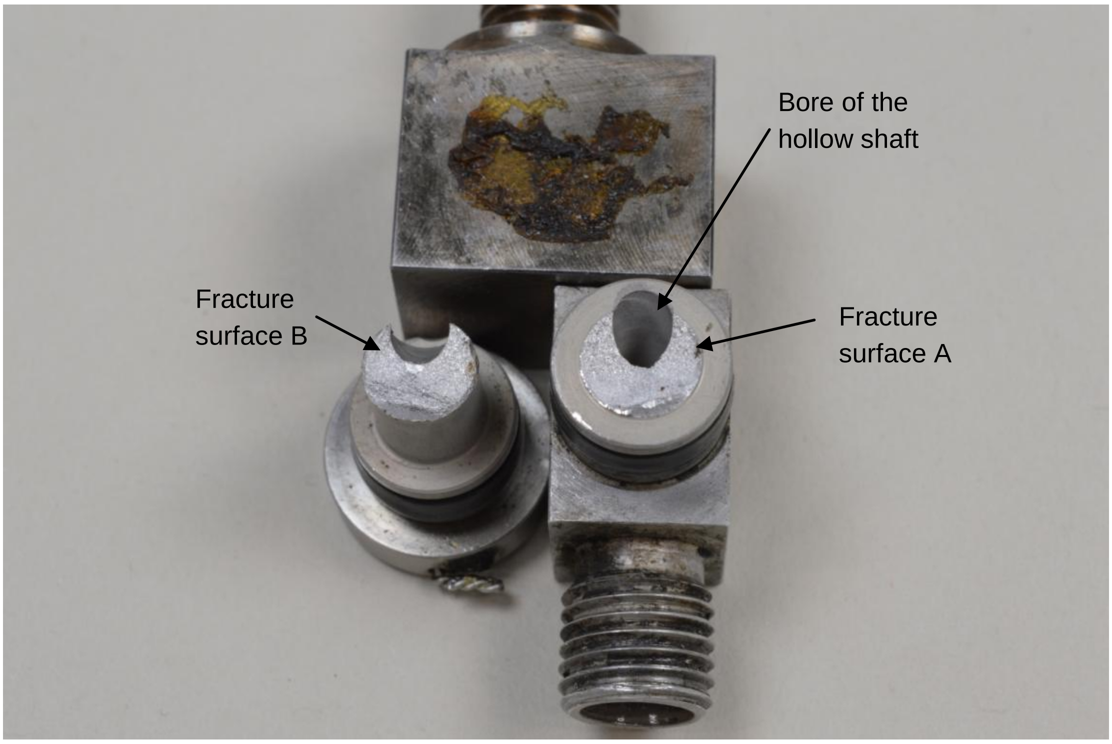

Figure 3. The two fracture surfaces (A and B). Bore of the hollow shaft.

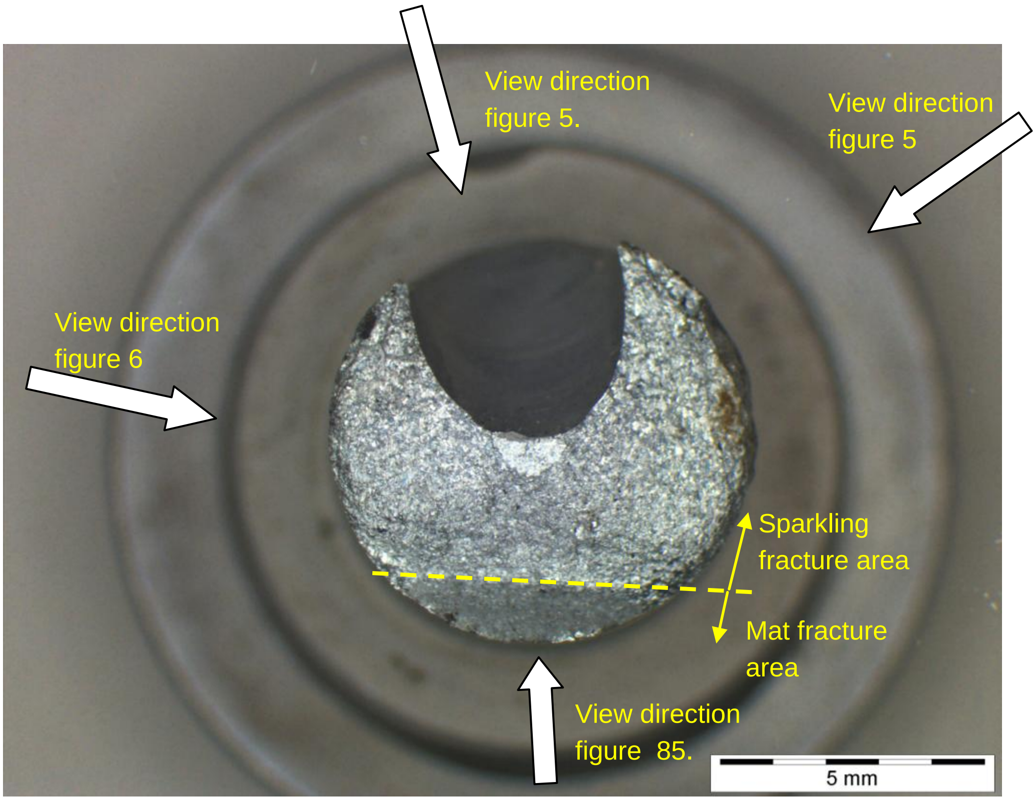

Figure 4. Fracture surface B.

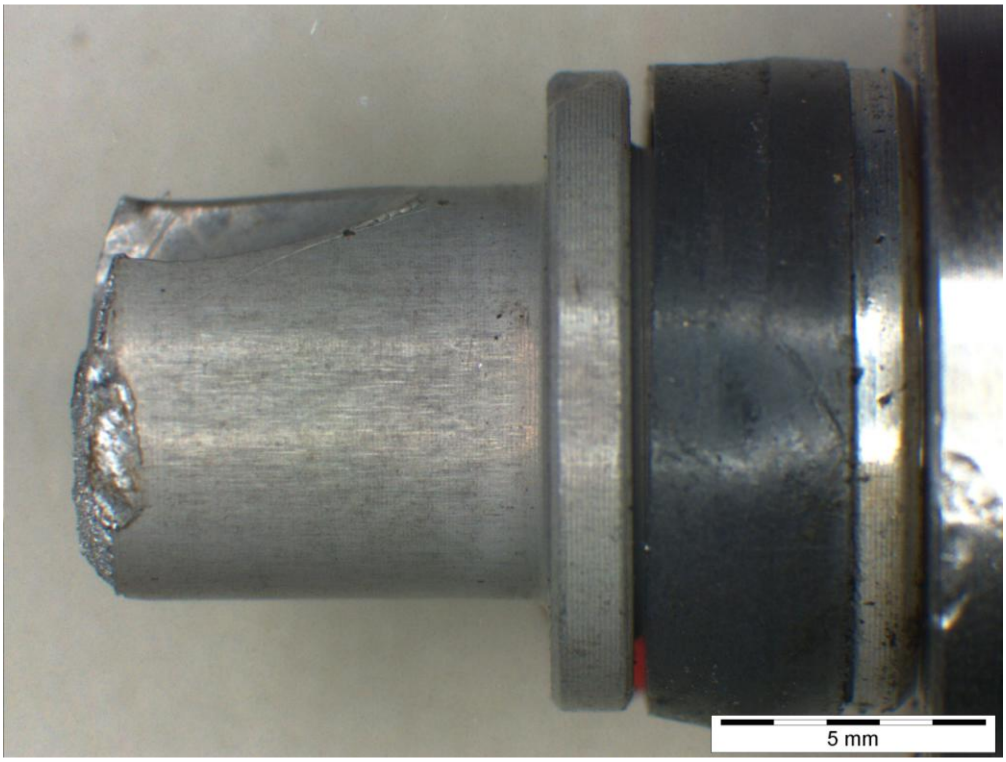

Figure 5. Fracture part B; Side view. At the edge the fracture surface is mechanical damaged.

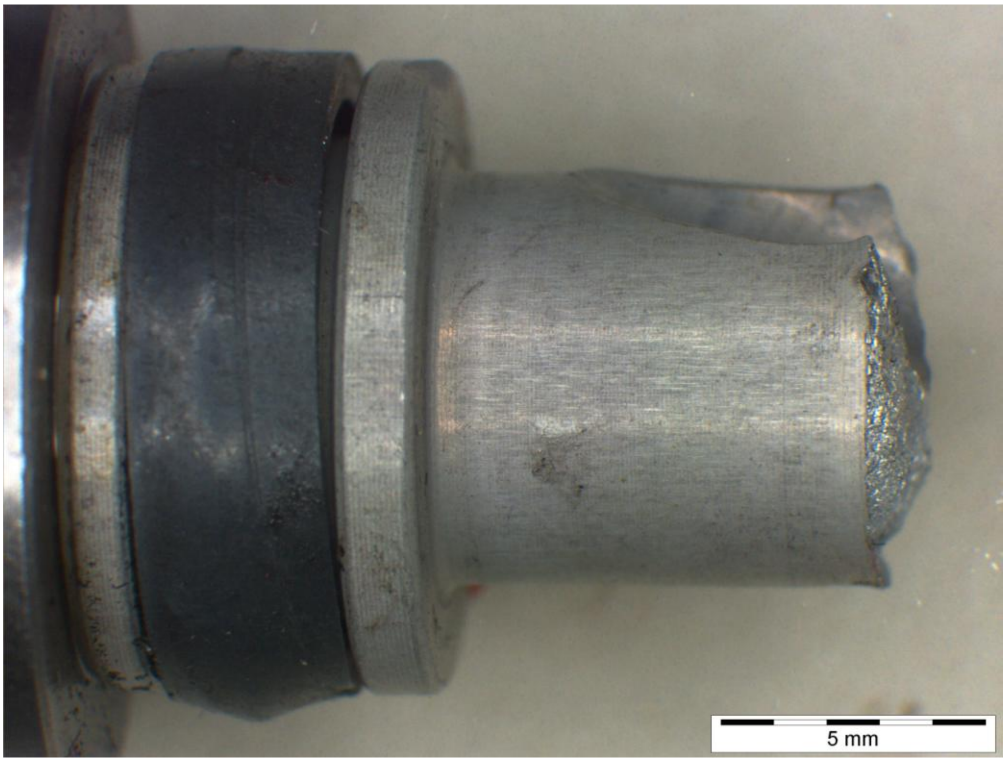

Figure 6. Fracture part B; Side view.

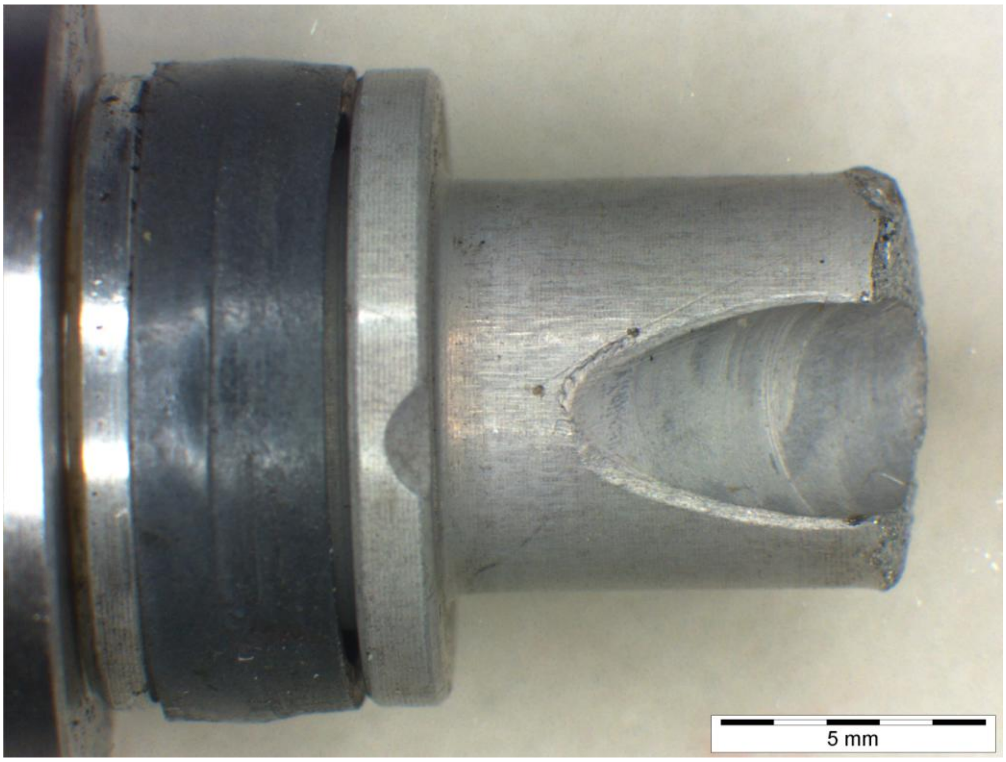

Figure 7. Fracture part B; Top view. The end of the bore is present in this shaft side.

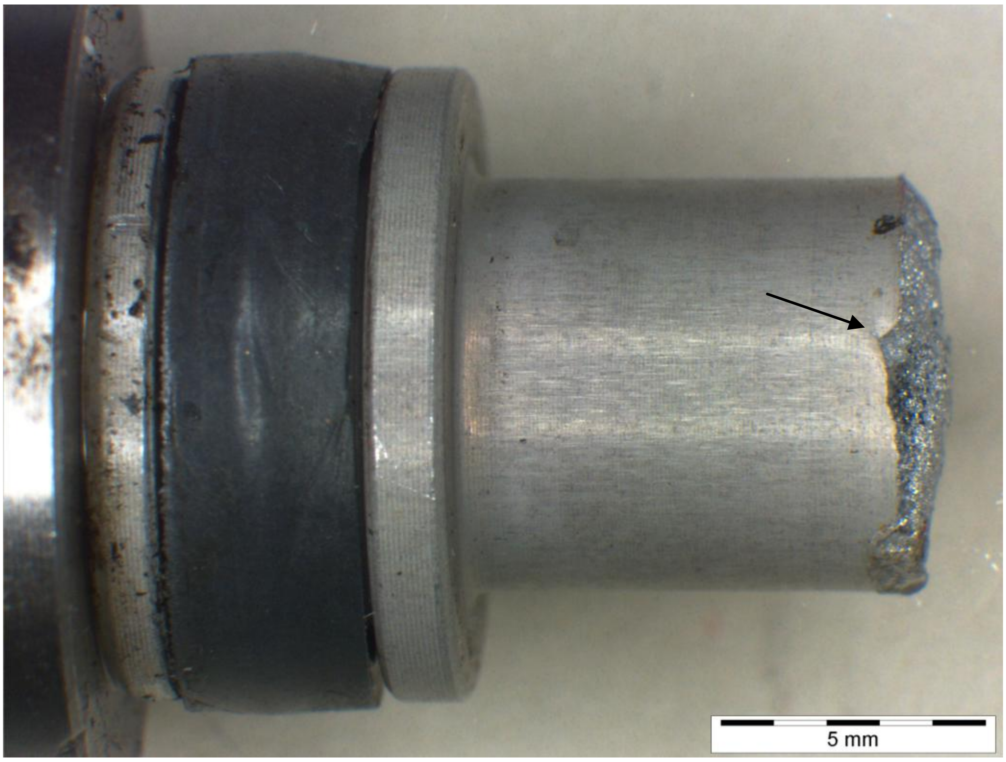

Figure 8. Fracture part B; Bottom view. The deformation from the final fracture is visible at the edge of the fracture surface (arrow).

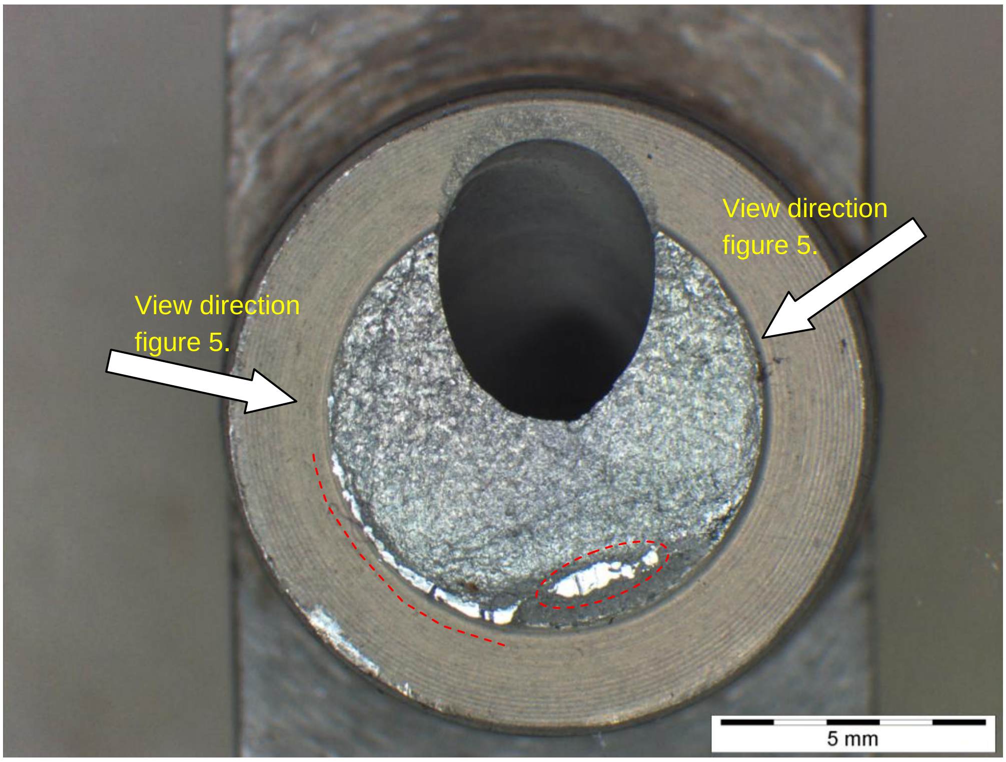

Figure 9. Fracture part A; The shaft is fractured in the radius from collar to shaft. The blinking areas (red markings) represents mechanical damaged fracture surface.

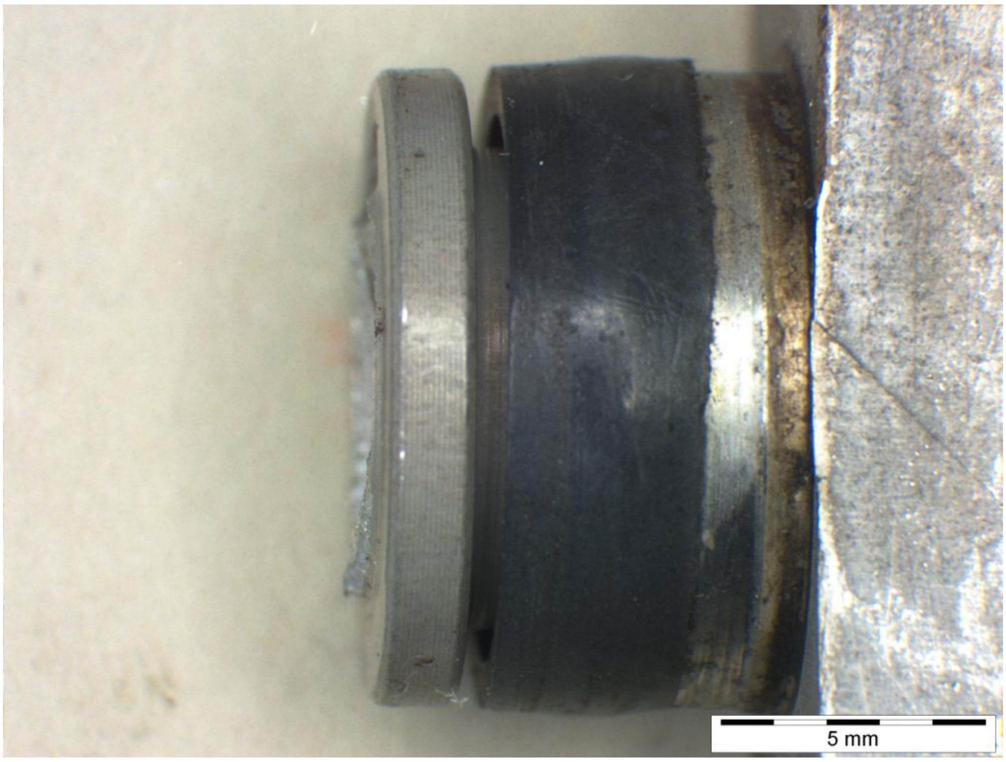

Figure 10. Fracture part A; Side view.

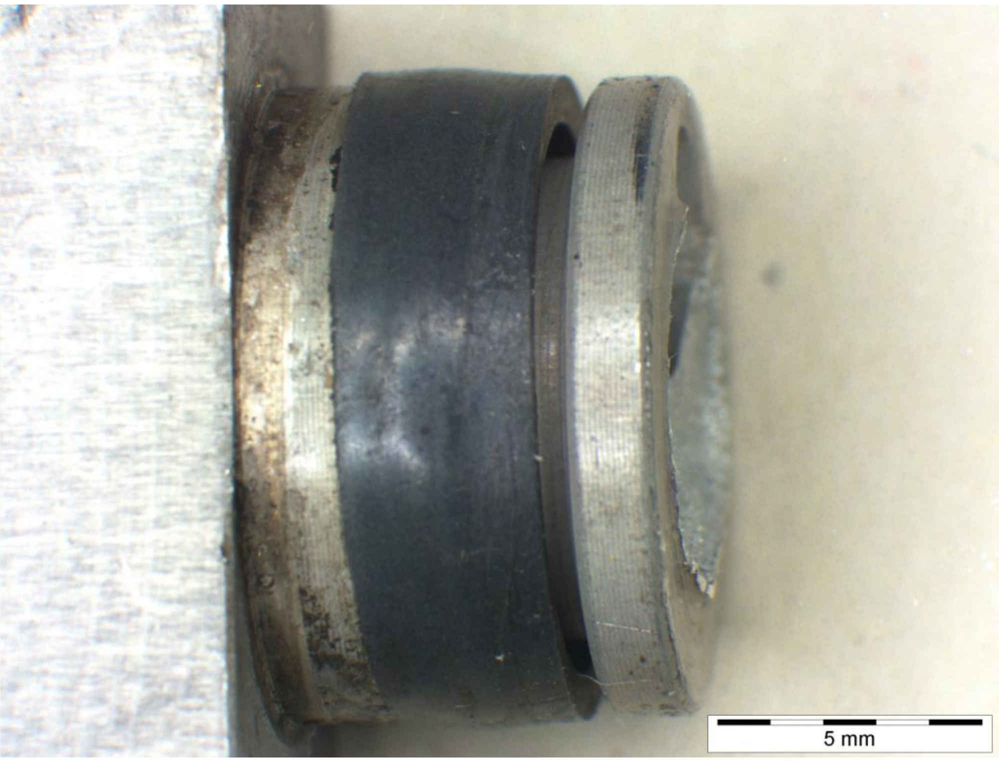

Figure 11. Fracture part A; Side view.

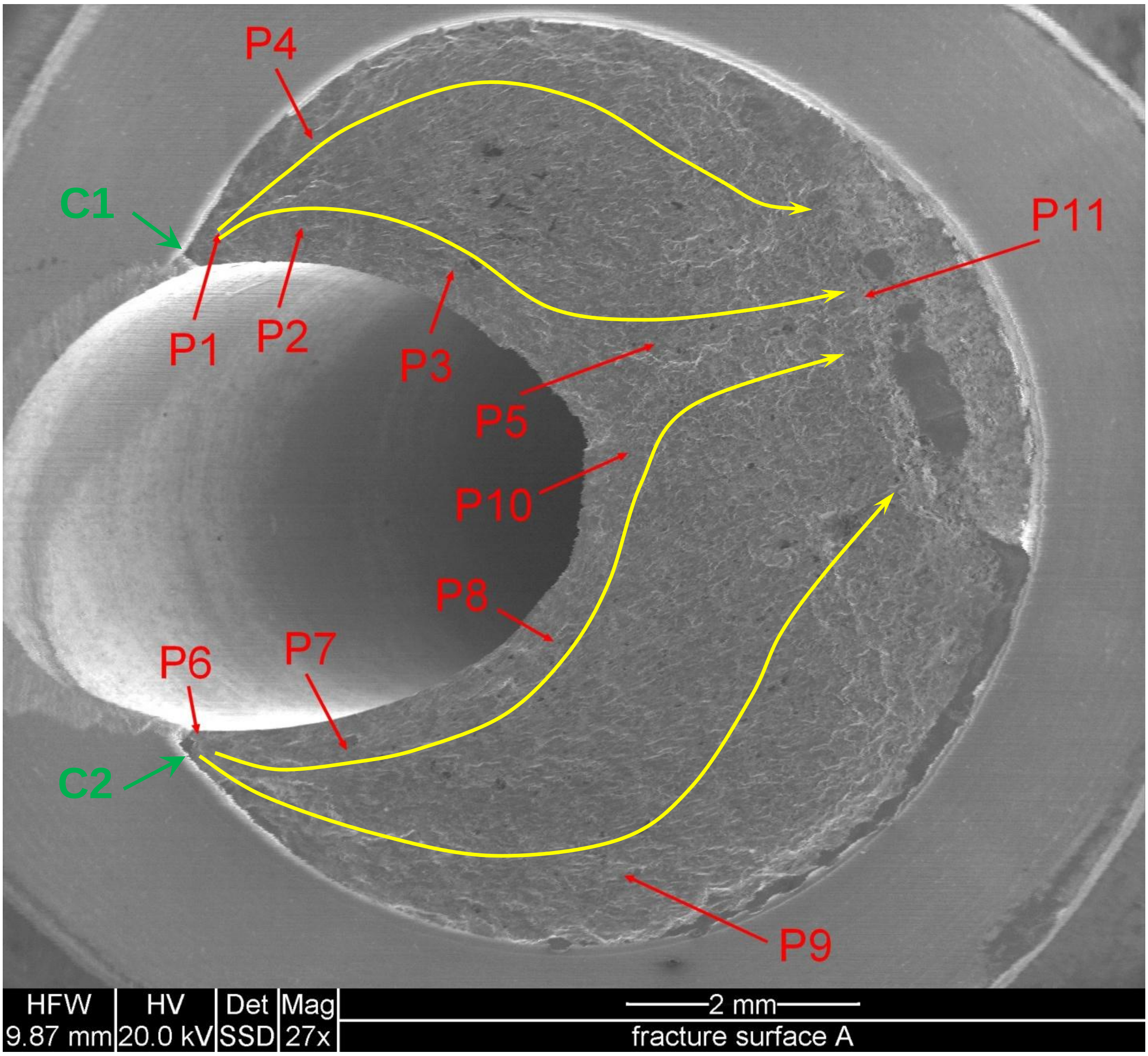

Figure 12. Fracture surface B. The red markings represent detailed investigated positions. The yellow lines indicate the grow direction of the fracture. The fracture is initiated in at the two positions C1 and C2.

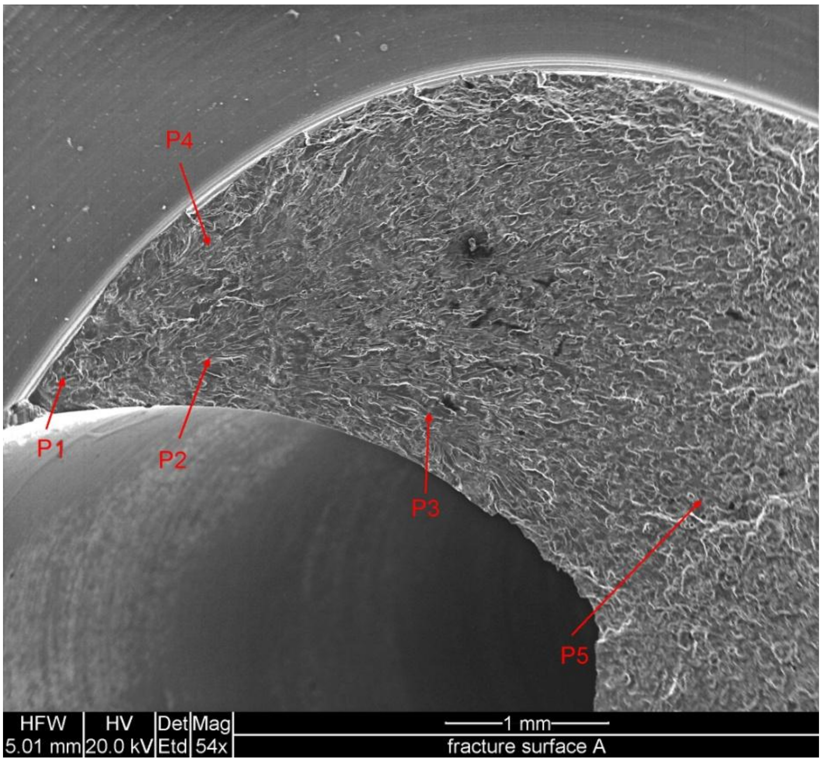

Figure 13. Detail of the figure **12**.

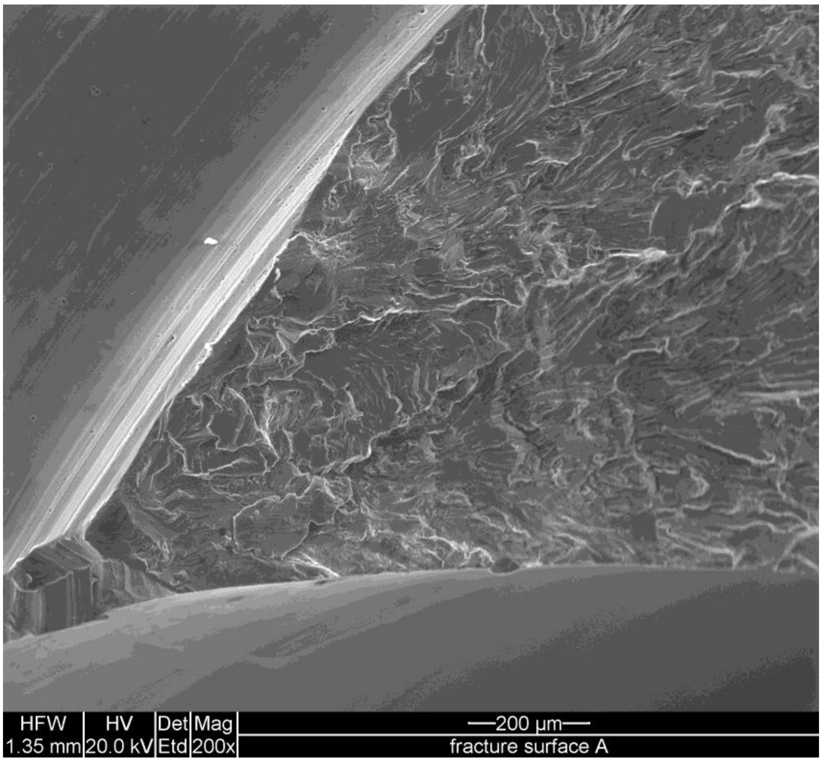

Figure 14. Detail of the corner C1.

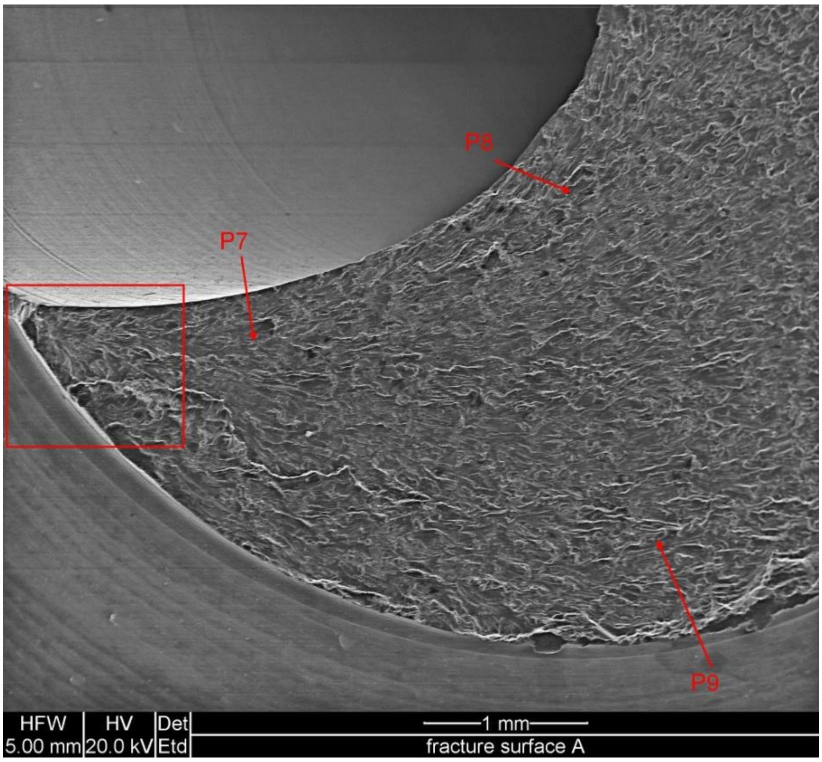

Figure 15. Detail of figure **12**.

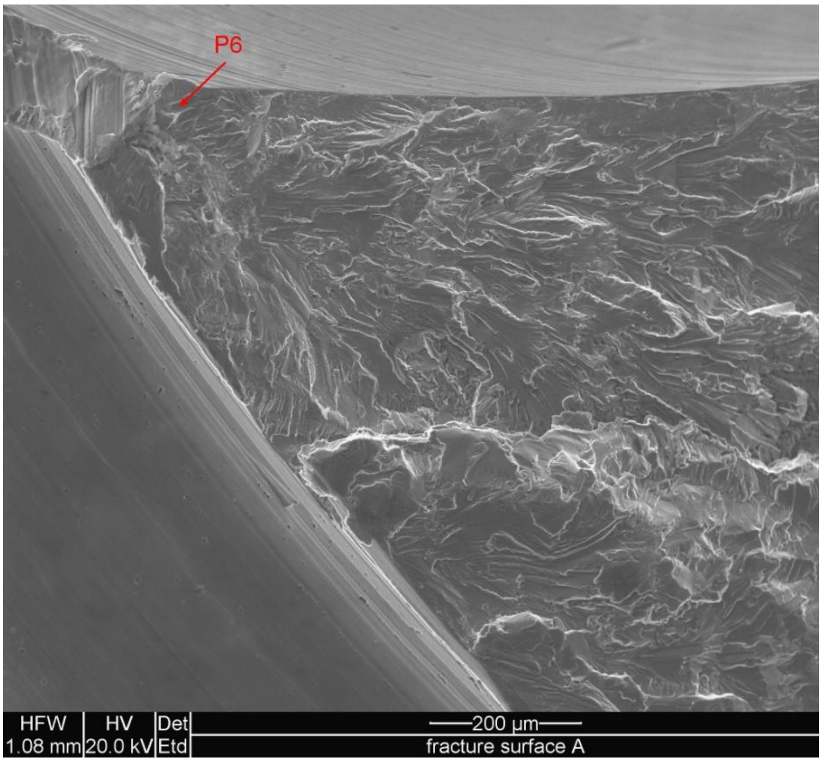

Figure 16. Detail of corner C2

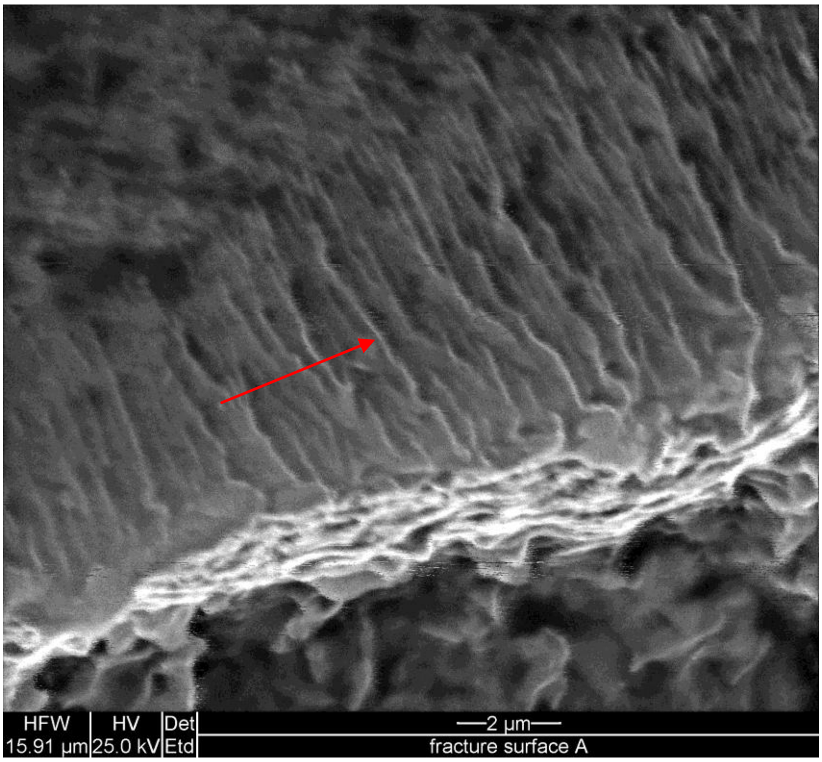

Figure 17. Position P1. Fatigue striations are present. The red arrow shows the crack growth direction.

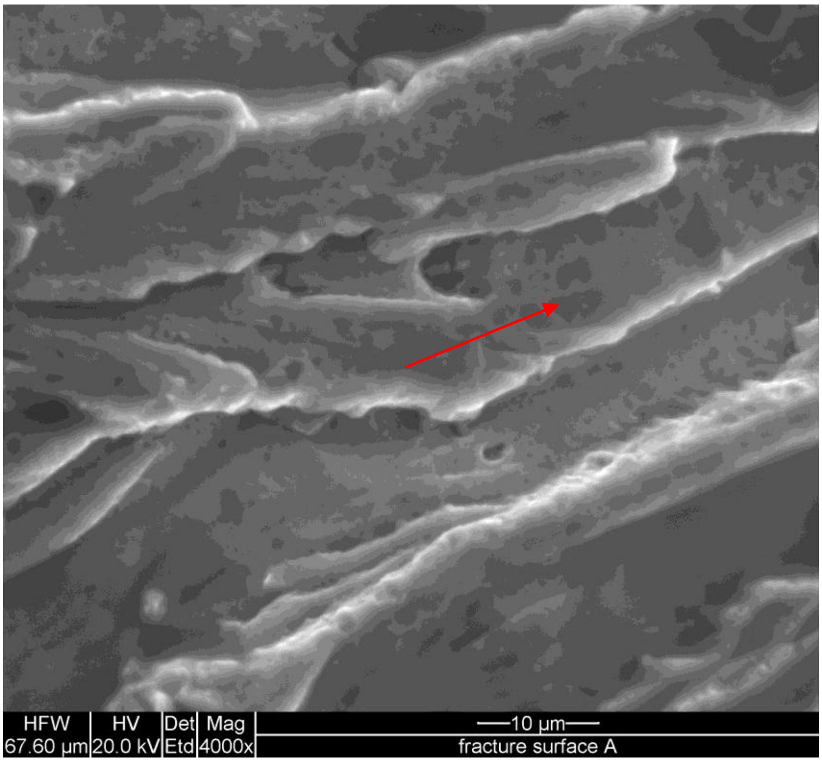

Figure 18. Position P2. Striations are not longer visible due chemical attack. The red arrow shows the crack growth direction.

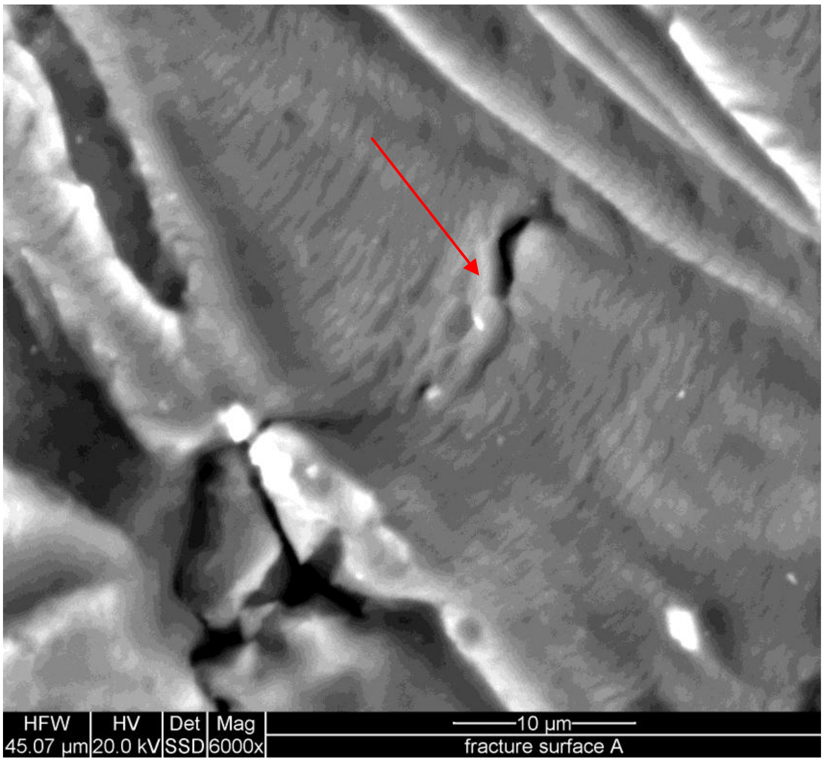

Figure 19. Position P3. Fatigue striations are present. The red arrow shows the crack growth direction.

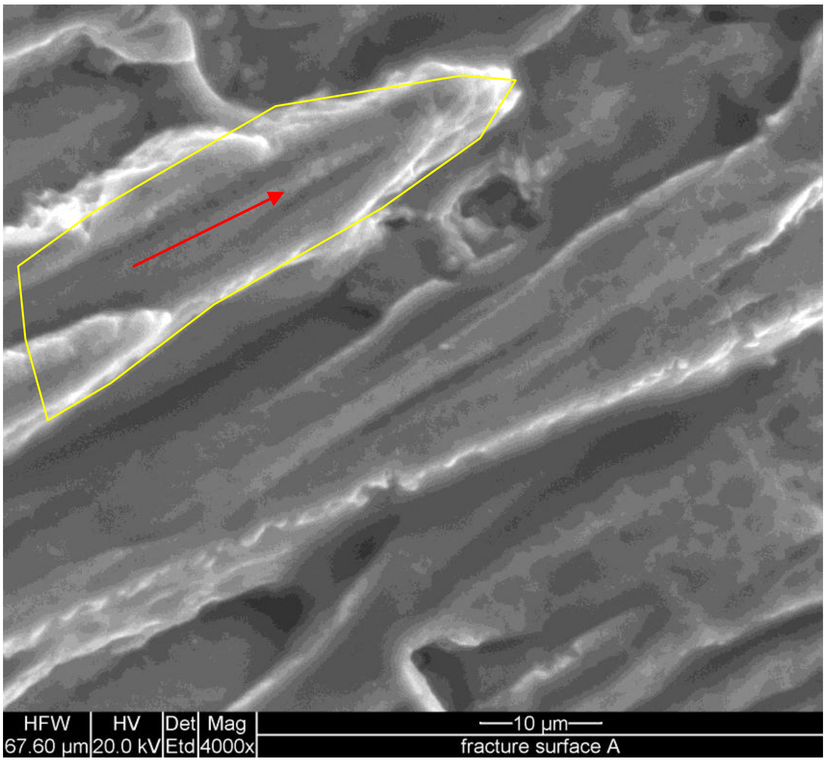

Figure 20. Position P4. Fatigue striations are hardly visible (yellow marking) due to chemical attack of the fracture surface.

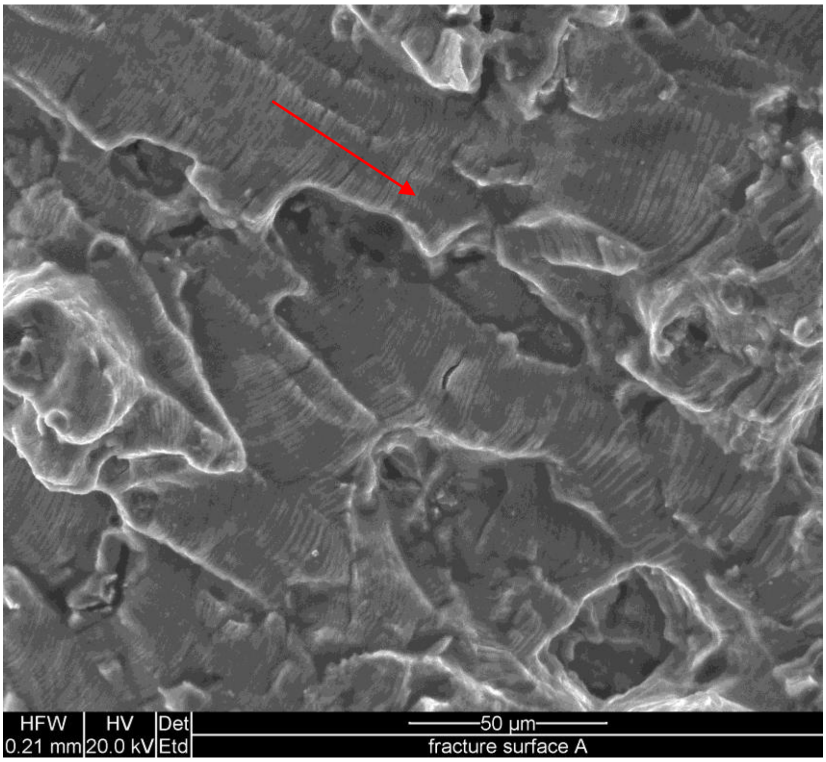

Figure 21. Position P5. Striations are clearly visible. The red arrow shows the crack growth direction.

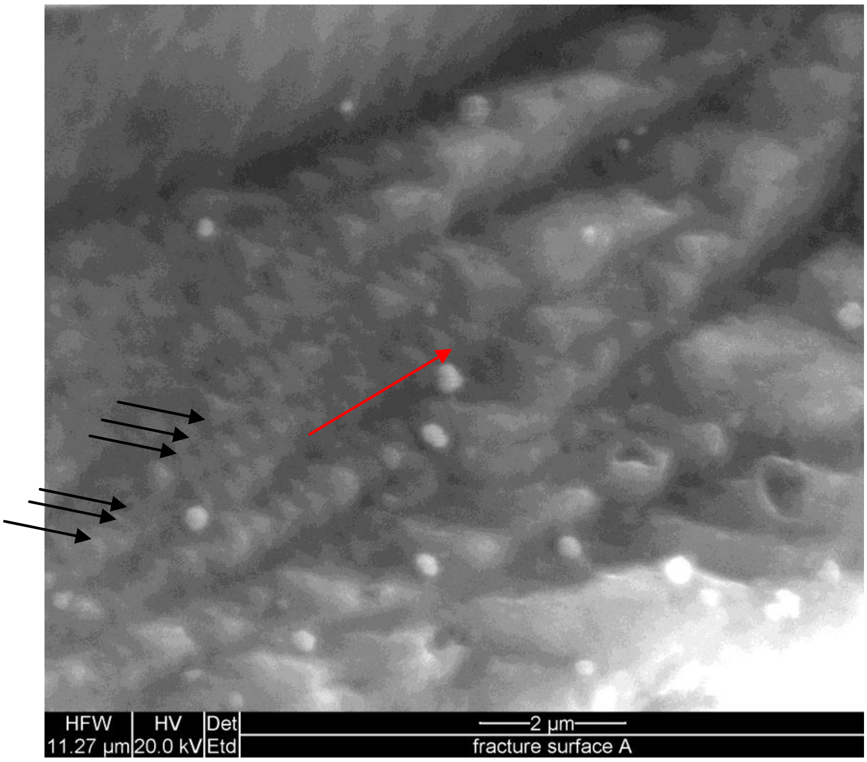

Figure 22. Position P6. Remnants of striations are present (black arrows pointed as example some striations). The red arrow shows the crack growth direction.

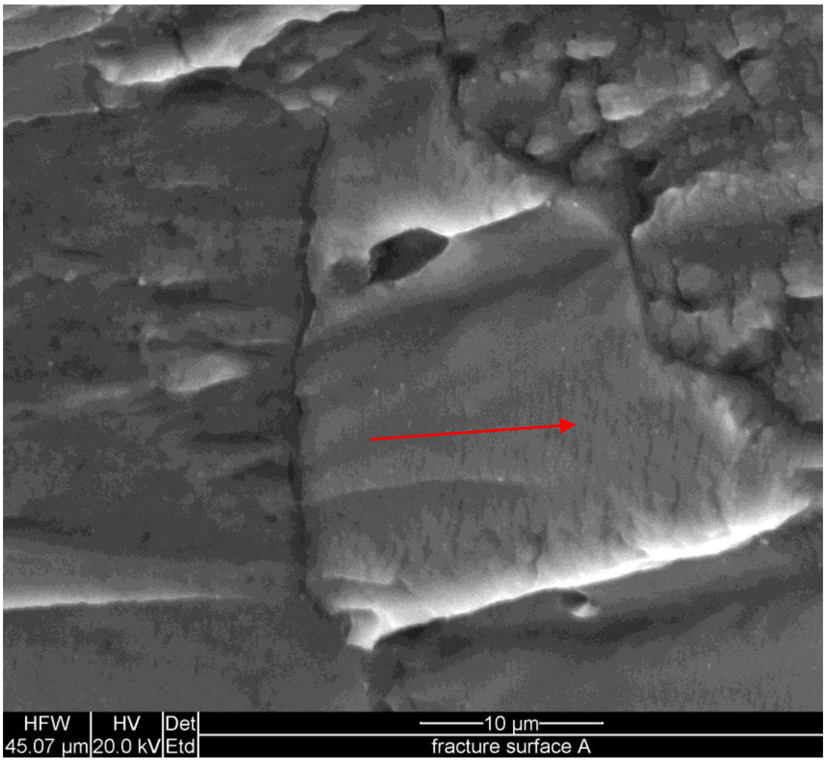

Figure 23. Position P7. Striations are present. The red arrow shows the crack growth direction.

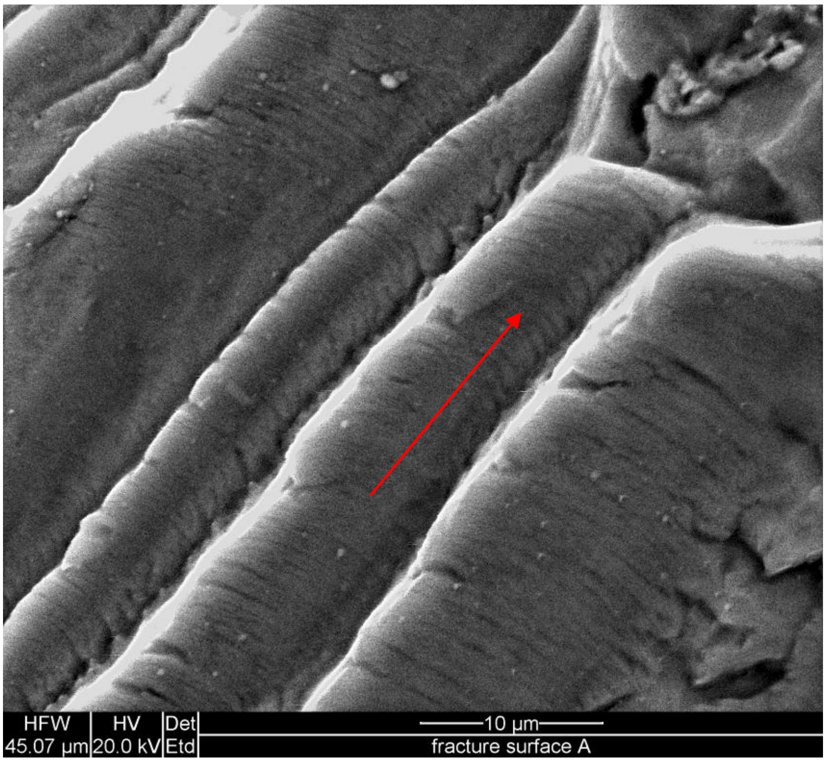

Figure 24. Position P8. Striations are present. The red arrow shows the crack growth direction.

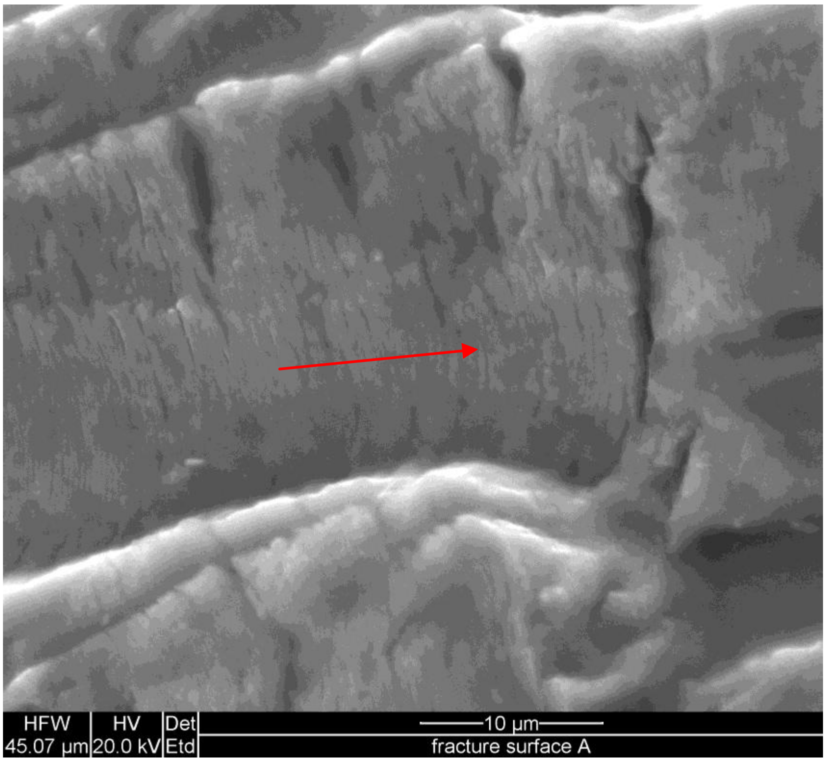

Figure 25. Position P9. Striations are present. The red arrow shows the crack growth direction.

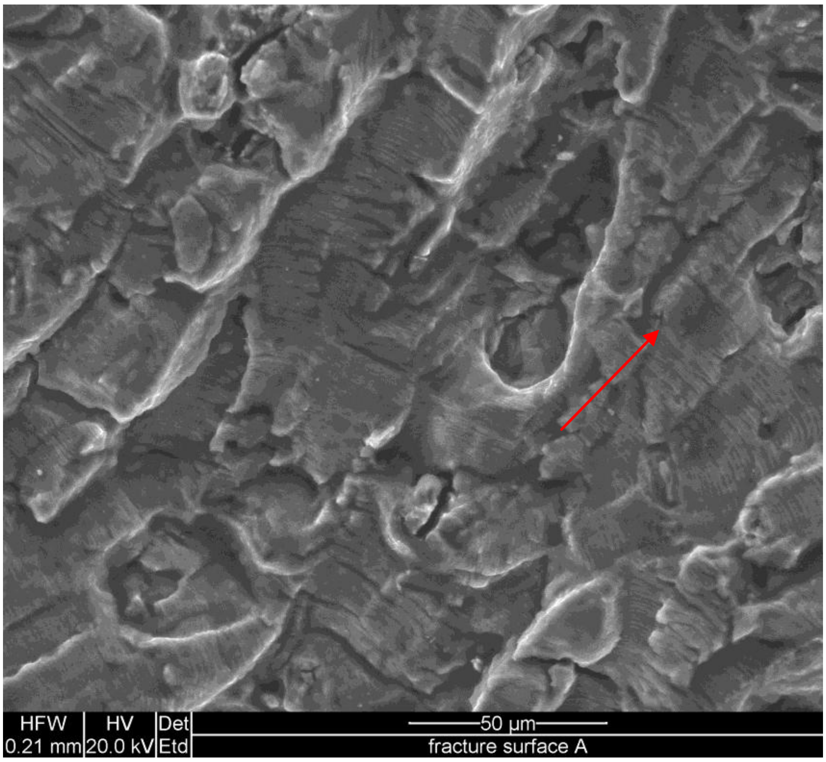

Figure 26. Position P10. Striations are present. The red arrow shows the crack growth direction.

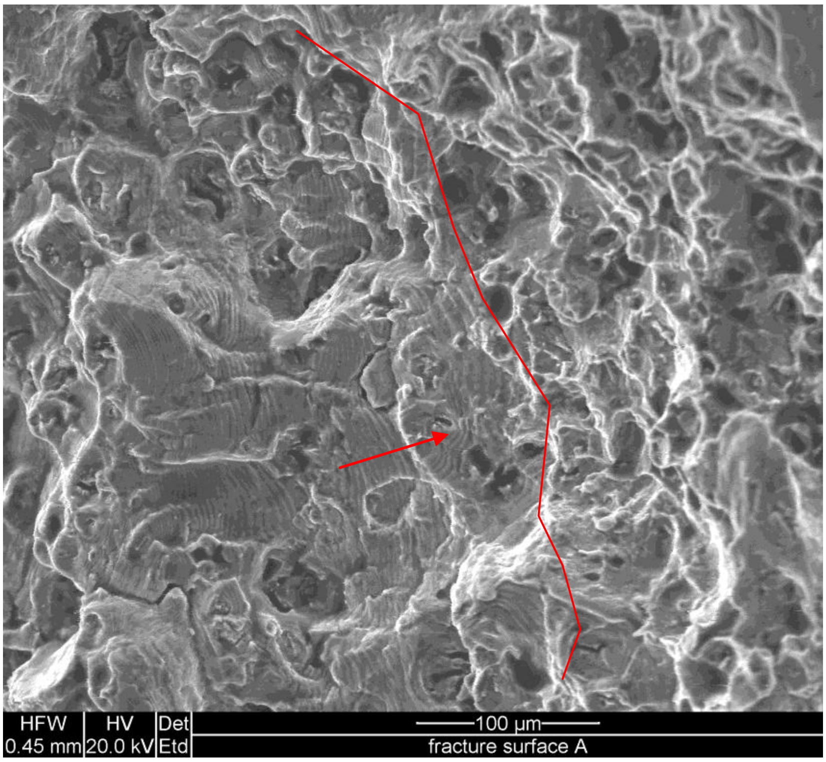

Figure 27. Position P11. Striations are present (to the left of the red line). The red arrow shows the crack growth direction. To the right of the red line the final fracture is present.