

National Transportation Safety Board

Office of Research and Engineering

Washington, DC 20594



WPR23FA256

MATERIALS LABORATORY

Factual Report 24-076

October 22, 2024

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A. ACCIDENT INFORMATION

Location: St. Maries , ID
Date: July 6, 2023
Vehicle: Cessna 182N N703Z
Investigator: Contessa Blum, AS-30

B. COMPONENTS EXAMINED

Cylinder 3, failed exhaust valve and guide

C. EXAMINATION PARTICIPANTS

Specialist Edward Komarnicki
NTSB
Washington, DC

D. DETAILS OF THE EXAMINATION

Figure 1 is an as-received photo showing all of the parts received for this case. The parts focused on in this examination were the fractured exhaust valve, the valve guide and cylinder 3. The exhaust valve fractured at the neck where the head meets the stem and both pieces are highlighted by the yellow box in the photo. Yellow arrows point to the general location of the exhaust valve guide. The fracture surfaces of the head and stem were documented before and after cleaning with an anionic detergent. The intake valve push rod along with its tube and spring are highlighted by the dashed yellow box. To the left of the yellow dashed box is the exhaust valve push rod with its corresponding tube and spring. Red arrows point to the recovered piston pieces. Both piston pieces were examined for fracture features, but none were found as the surfaces were too damaged.

Figure 2 shows the valve head (face and neck) after cleaning. Cleaning with detergent and later acetone had no effect on revealing fracture features. As can be seen, the valve head fracture surface is completely obliterated, and no fracture mechanism information could be obtained.

Figure 3 is a top view of the fractured stem before and after cleaning. With scrubbing and ultrasonic cleaning, the stem fracture surface revealed an intergranular fracture surface subject to further examination. Before and after cleaning side views of the thermally discolored and carbon buildup of the fractured exhaust valve stem are shown in figure 4. Vigorous cleaning did not remove the discoloration. A few small gouges were found on the exhaust valve stem surface near the rotocoil. Images in figure 5 are backscattered electron (BSE) images of couple of these gouges. The top of both valve stems where the rocker arms come in contact were examined for

wear markings. While the top of the intake valve showed no visible wear marks, the top of the exhaust valve showed significant wear in the form of material deformation cupping over to the outside surface of the chamfer. Scanning electron microscope (SEM) images of the deformation are shown in figures 6 and 7.

Before and after cleaning of the top of the engine exhaust valve guide are shown in figure 8. No cracking was found at the top of the guide after cleaning. Figure 9 shows exhaust valve guide images taken using a borescope before (left) and after (right) cleaning. The top images in figure 9 were taken near the top of the guide while the bottom images were taken near the bottom of the guide. No cracking or scoring marks were observed in the guide shaft. The average outside (OD) diameter of the exhaust valve stem was determined to be 0.431 inches while measurements of the inside diameter (ID) of the exhaust valve guide was taken at four different locations and are shown in Table 1 below.

Table 1 - Valve Guide ID Measurements

<u>Location</u>	<u>inches</u>
near Top	0.442
center near top	0.448
center near bottom	0.451
near bottom	0.469

Using an alloy analyzer, the valve material was determined to be Nimonic 80A with the composition shown in Table 2 below.

Table 2 - Chemistry

<u>Element</u>	<u>Percent Composition</u>
Cr (Chromium)	18.47
Ti (Titanium)	2.40
Al (Aluminum)	1.79
Fe (Iron)	0.55
Mn (Manganese)	0.53
Si (Silicon)	0.15
Zr (Zirconium)	0.043
Ni (Nickel)	Balance

Sections of the valve stem were cross-sectioned both radially and axially to examine the microstructure and perform Vickers (HV) microhardness testing. Specification calls for a minimum hardness of 300 HV using a 500-gram load. The average hardness of the axial section was 382.4 HV while the average hardness of the radial section was 381.7 HV. Microstructural images taken using a metallograph and

SEM are documented in Figures 10 - 12. Figure 10 shows the core grain structure of both the radial and axial sections. Figure 11 is a radial metallographic image of the stem edge showing a coating on the outside of the stem. The coating was determined to be chromium using energy dispersive spectroscopy (EDS). The coating thickness was measured to be 0.00003 inches (0.762 microns) and is relatively uniform in thickness and continuous in this area. The SEM images in figure 12 show the edge coating at two different magnifications. The yellow arrows in the images point to the chromium coating at the edge. The lower magnification top image shows the coating is non-uniform in thickness and non-continuous in some areas. The higher magnification bottom image shows coating thickness measurements at two different locations. The thicker coating area is 1.196 microns (0.00005 inches) while the thinner coating area is 0.5061 microns (0.00002 inches). Note that in both images the coating is non-uniform and non-continuous. No chromium coating was present on either edge of the radially cross-sectioned valve stem during microscopic examination.

Figure 13 is a montage SEM image of the exhaust valve stem fracture surface from a top view. The green curved line on the right side of the image identifies the shear lip along half of the circumferential edge of the fracture surface. Cyclic overstress features were observed in many areas just inside and along the shear lip. The solid and dashed yellow boxes in the image are two locations where higher magnification images were acquired. These are shown in figures 14 and 15. Figure 14 shows an area where mixed mode fracture features were observed. It is the only area where micro-void coalescence (MVC) or dimple overstress was observed and is identified by the yellow arrows in the image. Cyclic overstress features were observed near or just inside along the shear lip and nowhere else. One such area is pointed out in figure 14 by the yellow arrow. The arrows in figure 15 point to more of these cyclic overstress features. A side view of the fracture surface is shown on the cleaned valve stem in the right image of figure 4. The overall fracture mode is brittle overstress appearing to initiate at the core.

Submitted by:

Edward Komarnicki
Engineering Technician

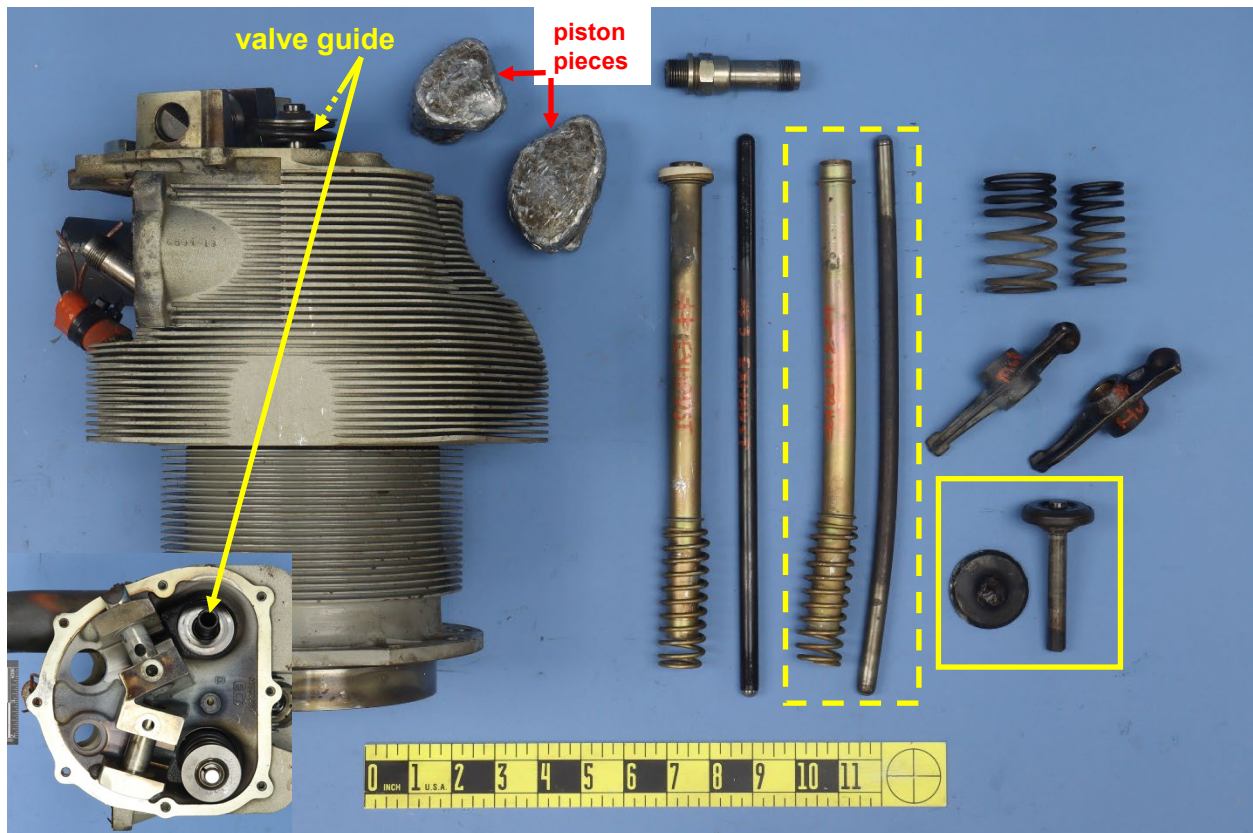


Figure 1. Photo of all parts received with the exhaust valve pieces highlighted within the yellow box and yellow arrows pointing to the valve guide location on the engine. The dashed yellow box encloses the bent intake push rod to the right of its mating tube and spring. The red arrows point to the recovered piston pieces.

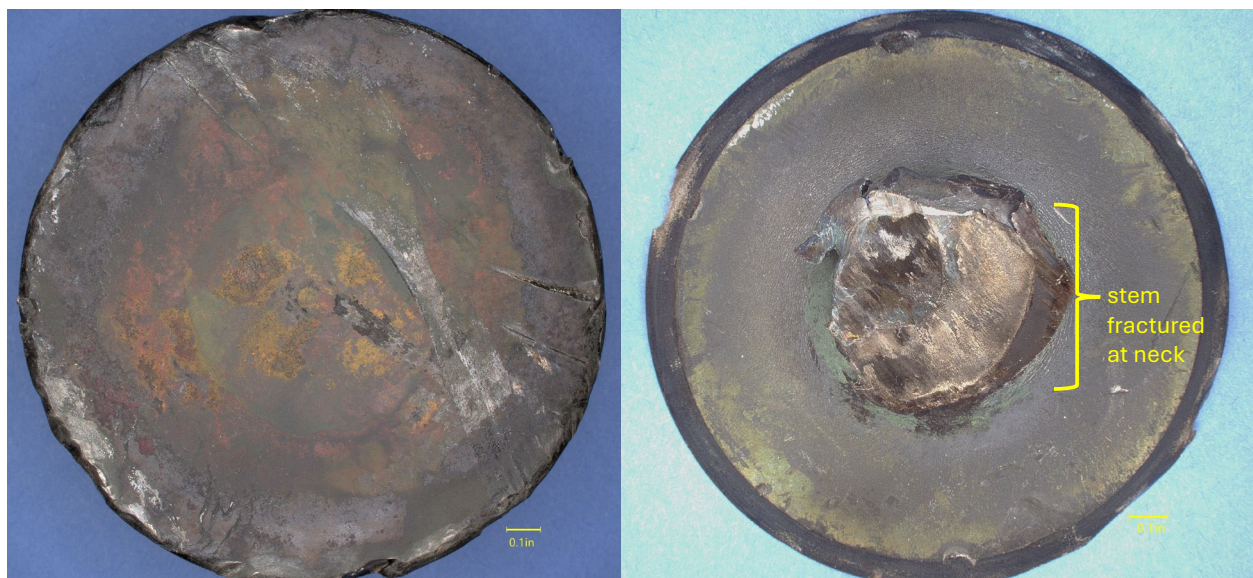


Figure 2. Images of exhaust valve head. The left photo shows the valve face while the right photo shows the fractured neck of the valve in the center.

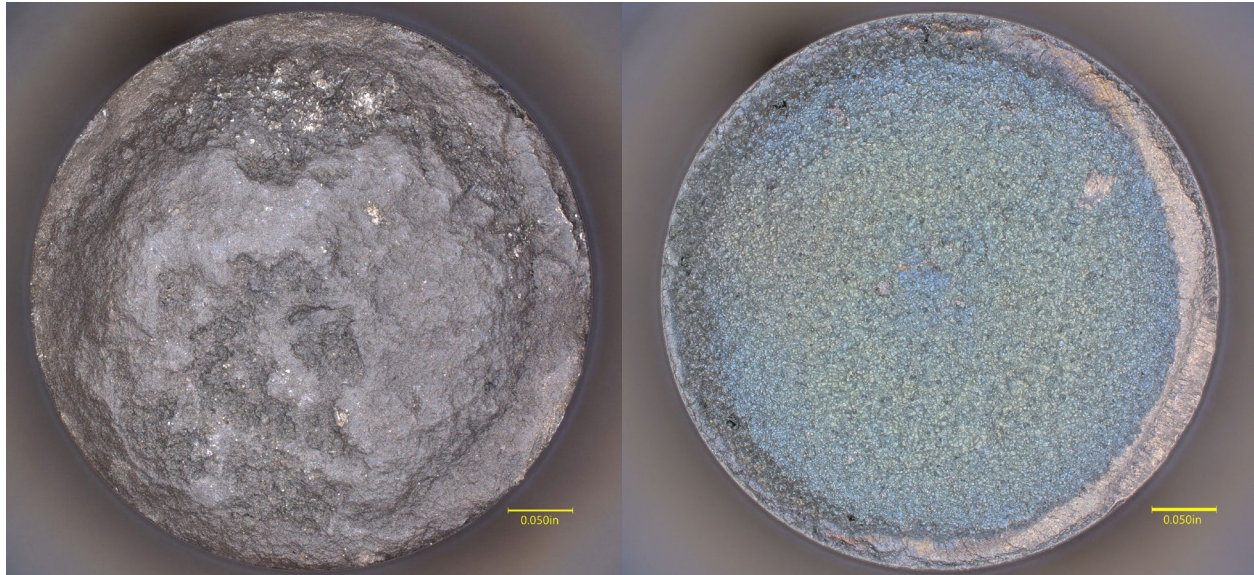


Figure 3. Top view images of fractured exhaust valve stem. The left photo is before cleaning while the right photo shows the fracture surface after cleaning.

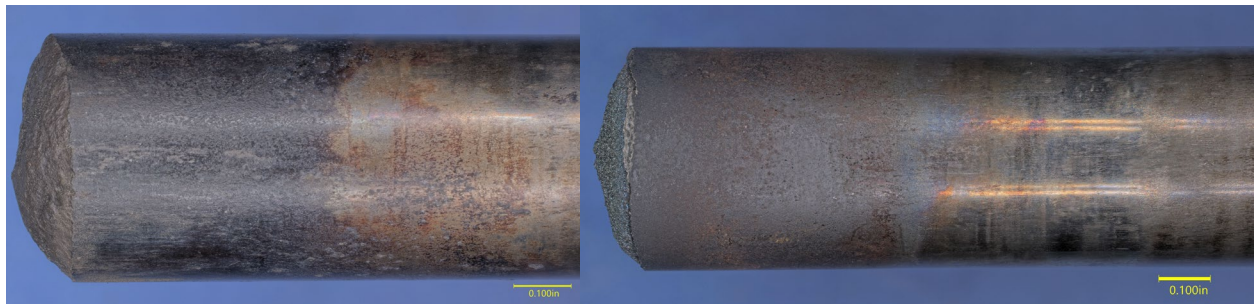


Figure 4. Side view images of fractured exhaust valve stem. The left photo is before cleaning while the right photo shows the fracture surface after cleaning.

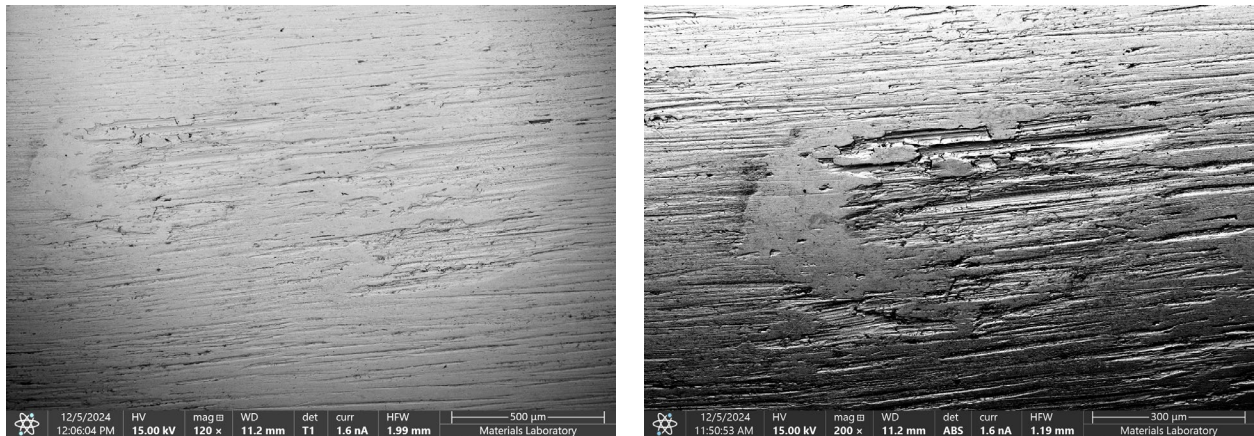


Figure 5. Left image shows two gouges next to each other on the stem surface near the top of the exhaust valve. The right image is a higher magnification view of the left-gouge in the left image.

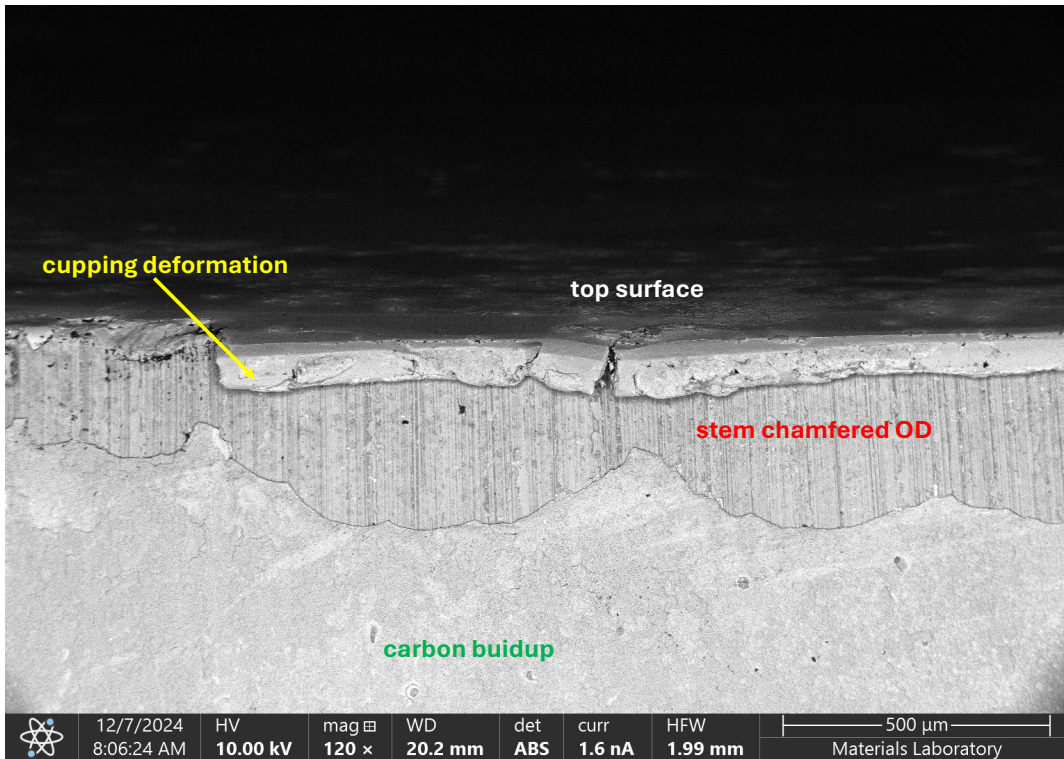


Figure 6. Side straight-on view of exhaust valve at the very top of the stem showing the cupping deformation wear.

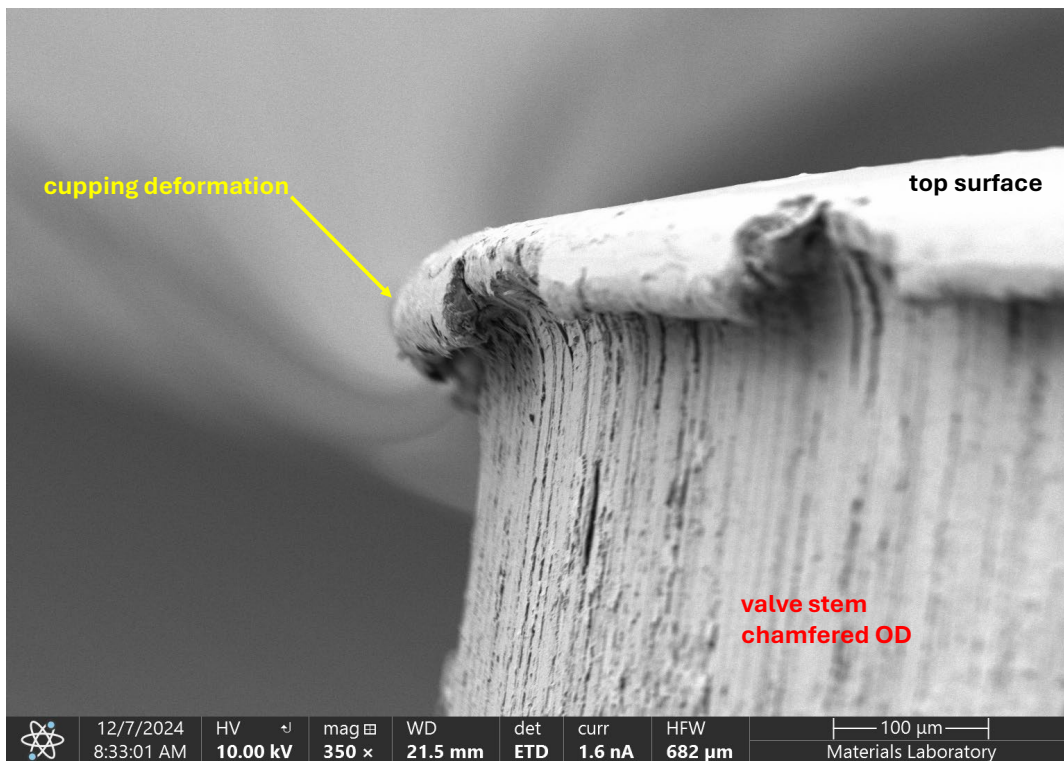


Figure 7. Corner side view of the exhaust valve at the very top of the stem showing the cupping deformation wear.

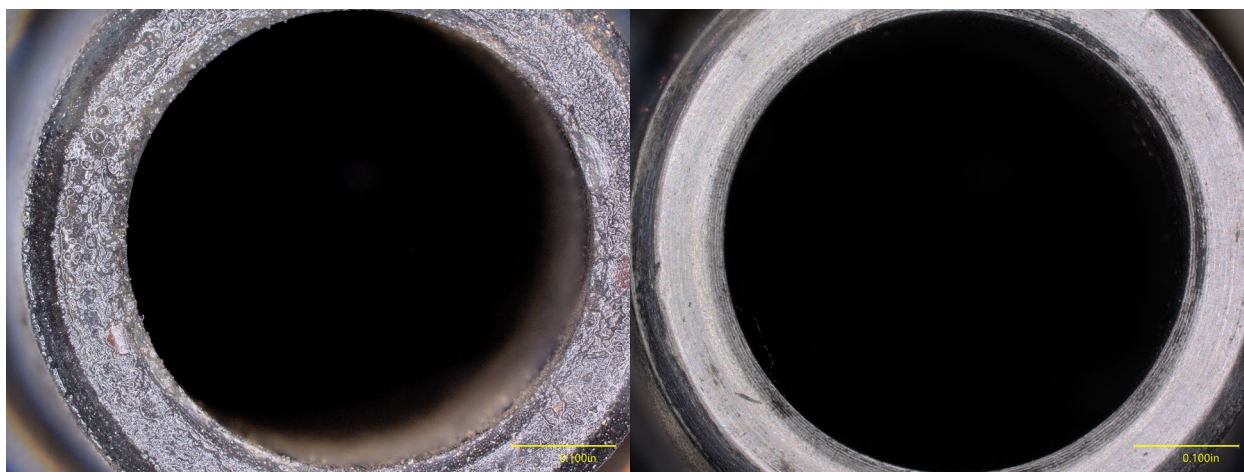


Figure 8. Top view images of exhaust valve guide showing no surface cracking around the top of the guide. The left photo is before cleaning while the right photo is after cleaning.

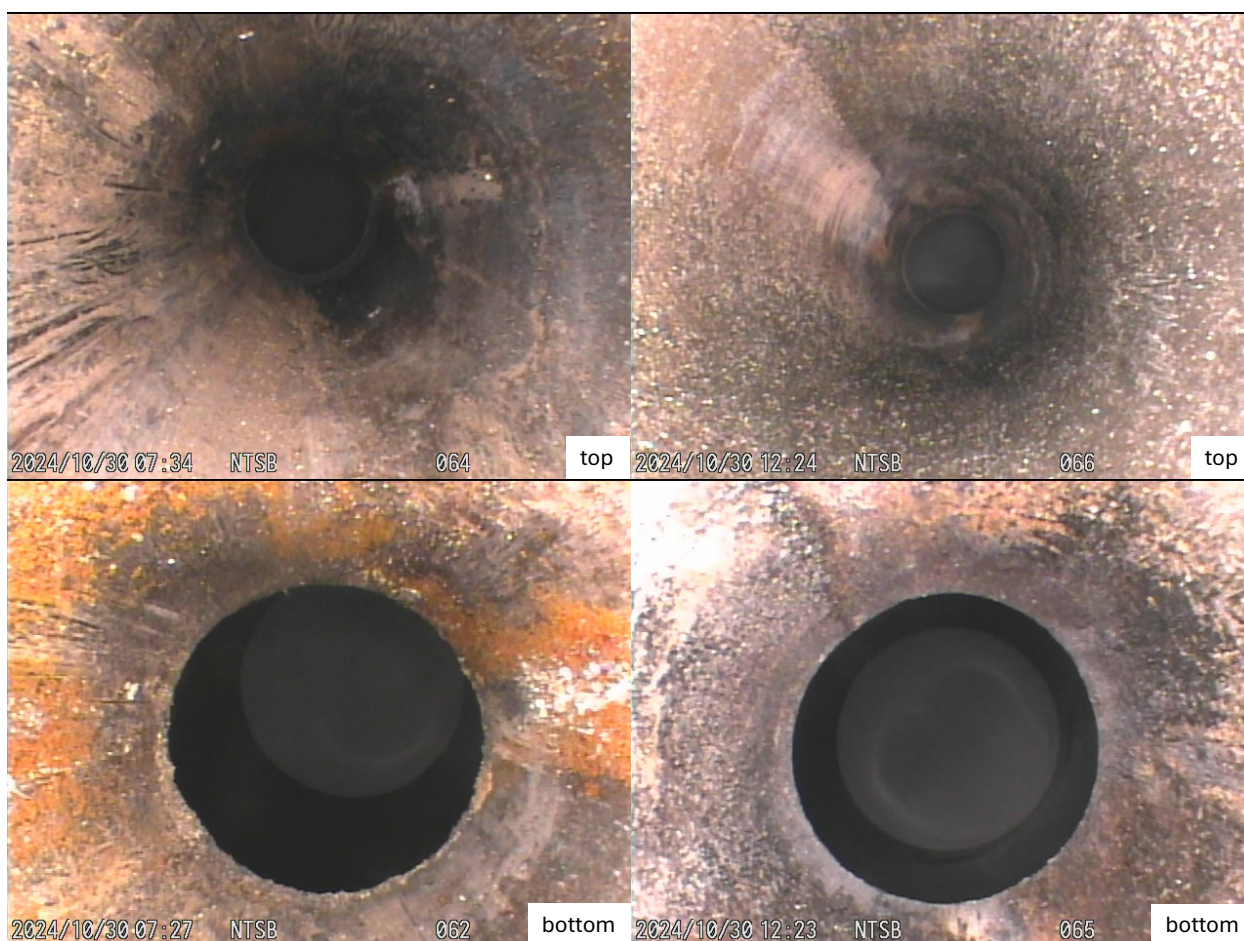


Figure 9. Borescope images of the exhaust valve guide before (left) and after (right) cleaning. Top images were taken near the top of the guide while the bottom images were taken near the bottom of the guide.

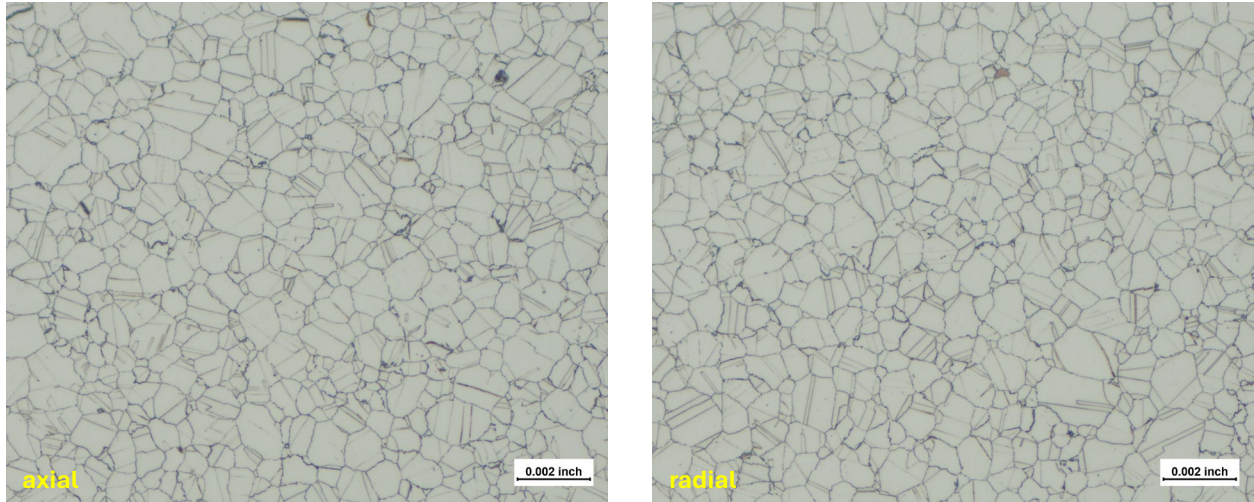


Figure 10. Metallographic microstructural core images showing the grain structure and are both at 200X magnification.

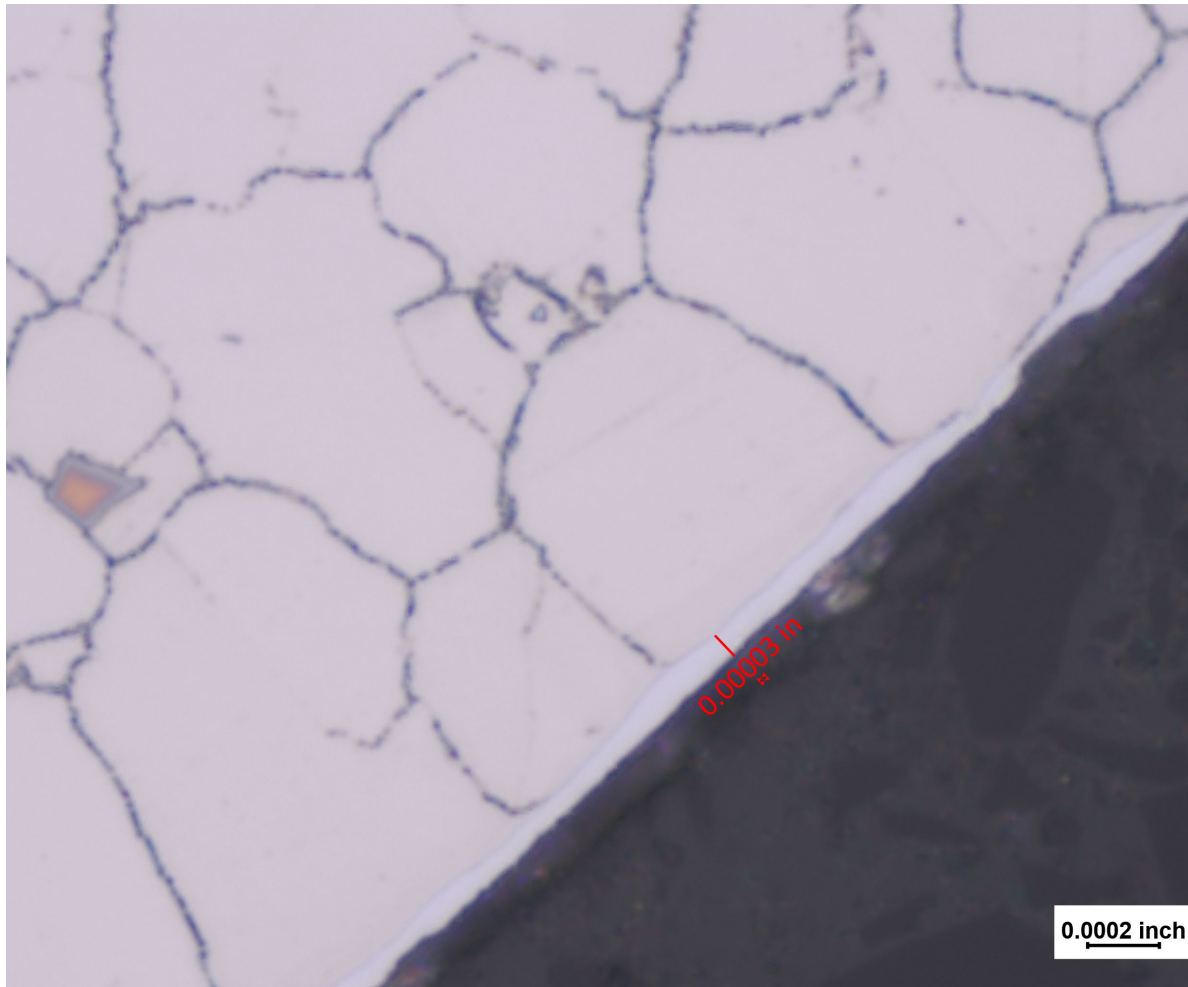


Figure 11. Metallographic image showing the edge coating on the radial cross-sectioned stem at 1000X magnification.

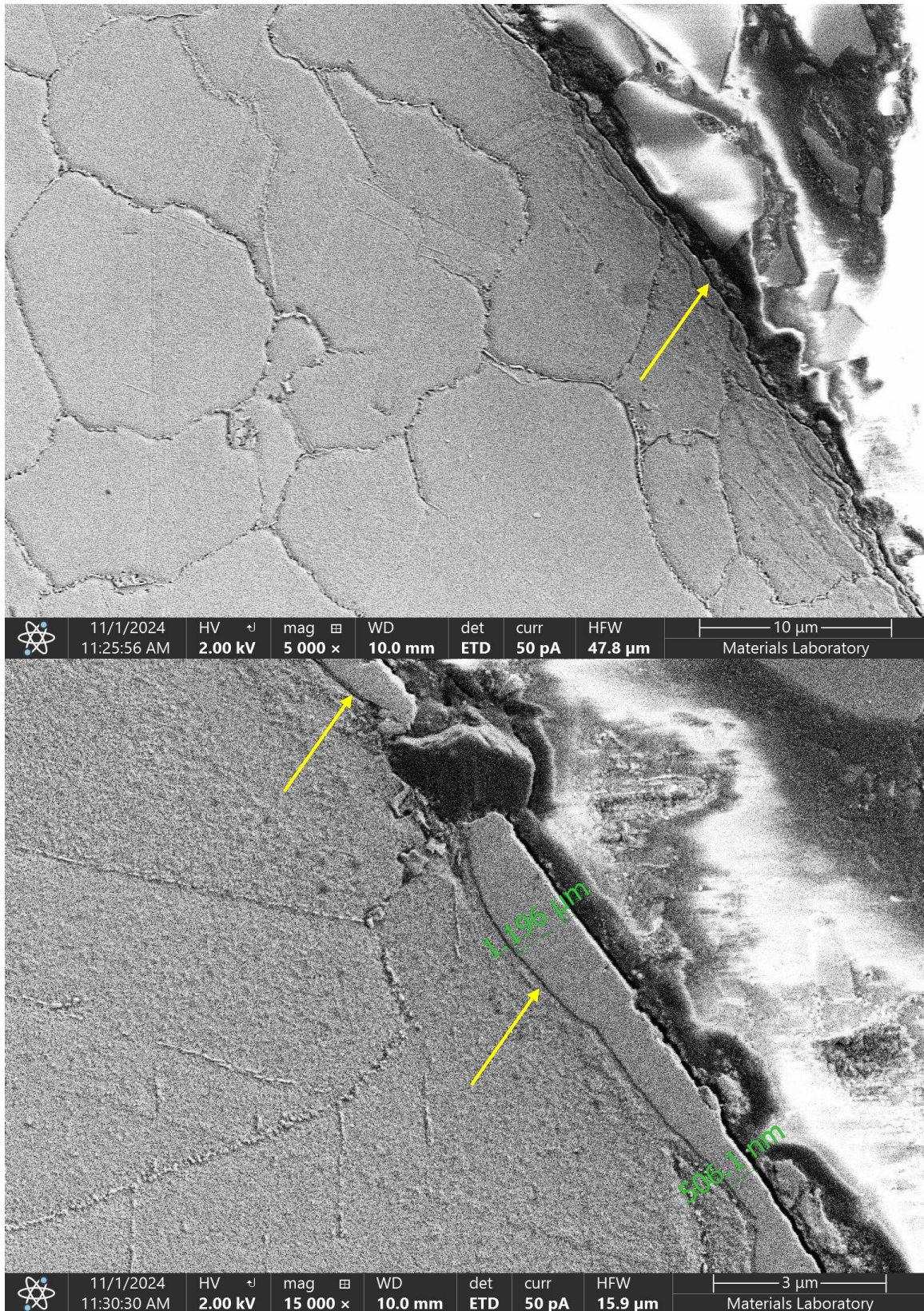


Figure 12. SEM images showing the edge coating on the radial cross-sectioned stem at 5000X and 15000X magnification. The yellow arrows point to the chromium coating.

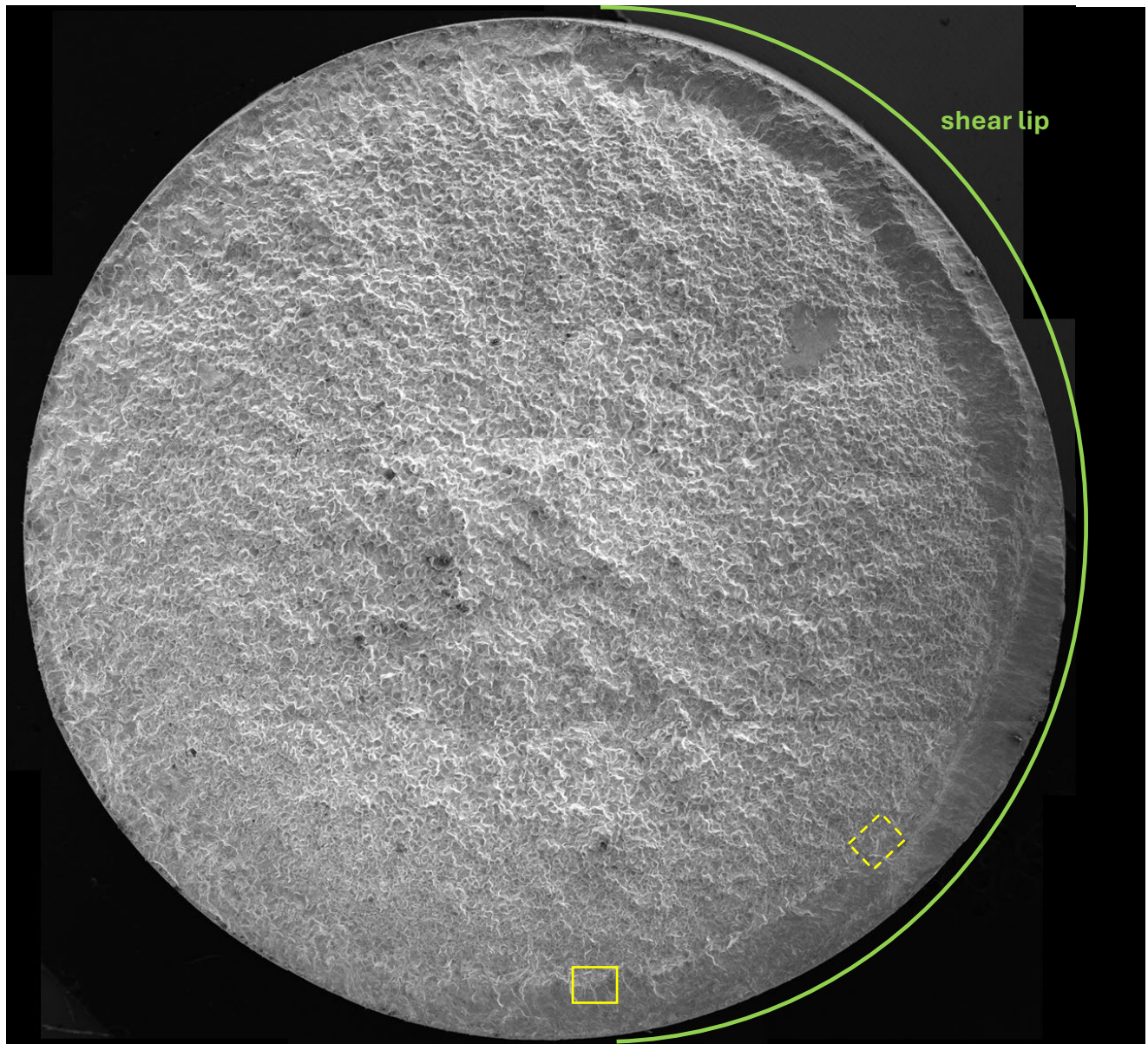


Figure 13. Montage SEM image of the exhaust valve stem fracture surface showing the shear lip along half of the circumferential edge of the fracture. The yellow boxes are where higher magnification images are shown in figures 14 and 15.

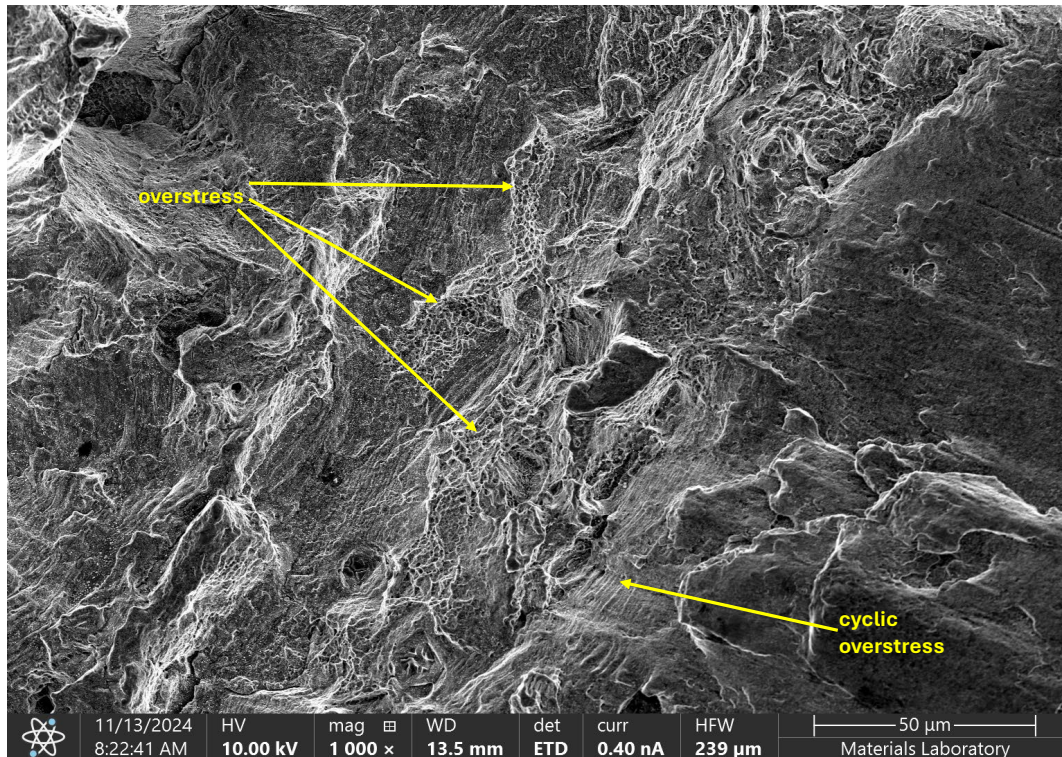


Figure 14. Higher magnification SEM image of the yellow dashed box area in figure 13 showing mixed mode fracture just inside the shear lip area.

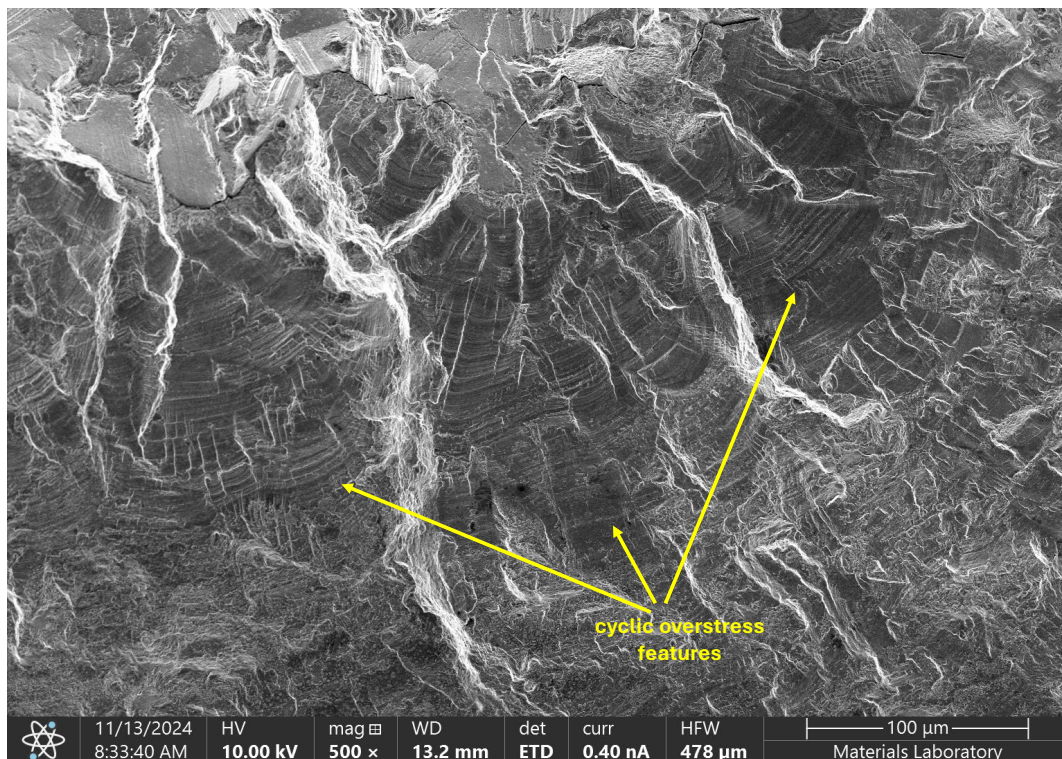


Figure 15. Higher magnification SEM image of the yellow box area in figure 13 showing cyclic overstress features found in areas along the inside of the shear lip area.