

NATIONAL TRANSPORTATION SAFETY BOARD

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



July 27, 2021

MATERIALS LABORATORY FACTUAL REPORT

Report No. 21-044

1. ACCIDENT INFORMATION

Place : Lake Tahoe, California
Date : July 7, 2020
Vehicle : Cessna 172N, N6328D
NTSB No. : WPR20LA212
Investigator : Maja Smith, AS-WPR

2. COMPONENTS EXAMINED

Remnants of a spark plug
Remnant of an electrode

3. DETAILS OF THE EXAMINATION

On July 7, 2020, about 1523 Pacific daylight time, a Cessna 172N airplane was substantially damaged when it was involved in an accident near South Lake Tahoe, CA. The pilot sustained fatal injuries, and the passenger sustained serious injuries to which she succumbed 5 days later. A witness reported hearing the engine losing and gaining power during flight prior to the accident. The airplane wreckage was discovered about 2.5 nautical miles southwest of the departure end of the airport of origin. A spark plug and separated center electrode tip from the #4 cylinder of the Lycoming O-320 series engine were recovered and sent to the NTSB Materials Laboratory for examination.¹

Figure 1 and Figure 2 show the spark plug as received, viewed from the side and firing head respectively. Not pictured was the separated center electrode tip, shown absent in Figure 3. The markings on the side of the spark plug housing indicated the part was a Tempest URHM38S iridium fine wire spark plug.² A remnant of the spark plug ignition wire was still inserted into the plug terminal well barrel, and the rubber coated wire exhibited a flat, angled appearance, consistent with having been cut or sectioned.

¹ The Lycoming O-320 is a family of naturally aspirated, air-cooled, four-cylinder, direct-drive engines produced by Lycoming Engines, headquartered in Williamsport, PA.

² Tempest Aero Group is a manufacturer of original OEM (original equipment manufacturer) aircraft products, headquartered in Burlington, NC.

According to the manufacturer's specification sheet, this spark plug, P/N 08-1232, was a shielded 0.75 inch / 20 thread all weather plug, with an 18 mm mounting thread, 0.5 inch reach, and a 0.875 inch hex size for installation. The spark plug had a single nickel alloy ground electrode offset from center, with a fine wire iridium center electrode tip welded to the copper-core nickel electrode.

Figure 3 shows an angled view of the firing head of the spark plug, demonstrating the offset of the ground electrode. As shown in this figure, the center electrode tip was no longer attached. All these surfaces exhibited a thick layer of deposits and compounds, consistent with combustion products from inside the cylinder. The deposits were thick enough that they had begun to crack and spall from the spark plug surfaces that had been inside the combustion chamber (see Figure 4 and Figure 5). The deposit thickness was measured up to 0.01 inches.

The ground electrode, shown in a side profile in Figure 5, did not exhibit any upward or downward deformation. Likewise, the position shown in Figure 3 and Figure 4 were consistent with the offset shown in the manufacturer's exemplar catalog and was inconsistent with plastic deformation that would have indicated movement of the subcomponent.

The loose and separated center electrode tip was recovered and was shown from opposite sides in Figure 6. The electrode tip was almost completely covered in dark, reflective compounds, consistent with deposits from the engine combustion. The upward face of the tip surface is positioned to the right in the figures, and the inward facing base surface faces towards the left. The middle of the electrode exhibited a circumferential tapered protrusion, consistent with the position of the weld material where the part had been affixed to the electrode body.

To examine the electrode tip, the part was repeatedly cleaned in an ultrasonic bath using acetone, then Alconox, and then Evaporust.^{3,4} While this successive cleaning process removed some of the deposits, much of the surfaces were still coated in external compounds.

The electrode tip was examined using a scanning electron microscope (SEM). Figure 7 and Figure 8 show backscattered and secondary electron micrograph montages, respectively, of the electrode tip.⁵ As shown in Figure 7, the tip exhibited different contrast intensities, consistent with different chemical compositions. The different areas of the tip were examined using energy dispersive x-ray spectroscopy (EDS) to determine the

³ Alconox is a powdered cleaning detergent, containing primarily sodium bicarbonate and sodium alkylbenzene sulfonate, manufactured by Alconox, Inc., White Plains, NY.

⁴ Evapo-Rust is a commercially available chelating rust stripper manufactured by Harris International Laboratories, headquartered in Springdale, AR.

⁵ Backscattered electrons: SEM micrographs produced using backscattered electrons display contrast that is associated with the atomic numbers of the elements in the micrograph. Materials containing elements with higher atomic numbers visually appear lighter relative to other materials containing elements with lower atomic numbers.

different chemical compositions. As illustrated using x-ray maps in Figure 9, different areas corresponded with heavier and lighter concentrations of various elements.

The exposed tip surface exhibited a composition of a nearly pure iridium (Ir) alloy, with minor additions of nickel (Ni), as indicated in Figure 10. The welding material was a Ni alloy with major concentrations of iron (Fe) and chromium (Cr), along with minor amounts of oxygen (O). The darker deposits were found to exhibit high amounts of lead (Pb), bromine (Br), and oxygen (see Figure 11). This composition was consistent with compounds produced from the combustion of brominated tetraethyl lead additives used in avgas. Carbon (C) and sulfur (S) were also found on much of the contaminated areas of the electrode.

Figure 12 and Figure 13 show the upward face of the electrode tip, which functioned as a surface to create an arc between the lower surface of the ground electrode. The edges of the tip had been rounded upward, along with parallel longitudinal markings. These features were consistent with a machined tapering, visible in the side profile seen in Figure 8. Figure 13 also demonstrates the thickness of the remaining lead oxide deposits on the tip. Figure 14 and Figure 15 show a closer view of the tip upper surface. This surface exhibited equiaxed rounded features, with small cracks between them. These features were consistent with the sintered manufacturing process of iridium parts, as the high melting point makes its alloys difficult to forge or cast. While there was some rounding of the surface features, there were no large divots or spherical deposits suggestive of electrical arcing damage. No indications of Ni deposits were found on this surface, which would have been indicative of arcing. No indications of features consistent with fractures were observed.

Figure 16 and Figure 17 show the base or inner surface of the electrode tip. Like the other areas of the electrode tip, this area exhibited lead oxide and carbon deposits. A closer view of the surface of the base is illustrated in Figure 18. This surface also exhibited multiple rounded protrusions, consistent with the surface morphology observed on the outward facing tip surface. The base surface did not exhibit comparable shallow cracking as seen on the opposite surface in Figure 15. No indications of fracture features were observed on this surface or along the edges of the base.

Figure 19 and Figure 20 shows the underside of the welding material remnant located along the middle of the electrode tip cylindrical surfaces. As shown from the electron charging in Figure 20, and the high oxygen content in Figure 9, much of the surfaces of this material had been oxidized and were non-conductive. The lower surface of the welding material was generally flat in orientation and protruded outward perpendicular to the electrode tip. The upper surface was tapered upward toward the electrode tip cylindrical exterior. These features were typical of a fillet weld process that would have been used to join the tip to the electrode base.

The underside of the weld material exhibited features consistent with fracture. The surface was generally rough in texture. However, the oxidation of the material obscured many of the features, as demonstrated by the lack of light areas in Figure 22. The fracture

features that were able to be examined exhibited faceted features, as illustrated in Figure 23.

Erik M Mueller
Materials Research Engineer



Figure 1 – View of the spark plug and wire remnant, as received.

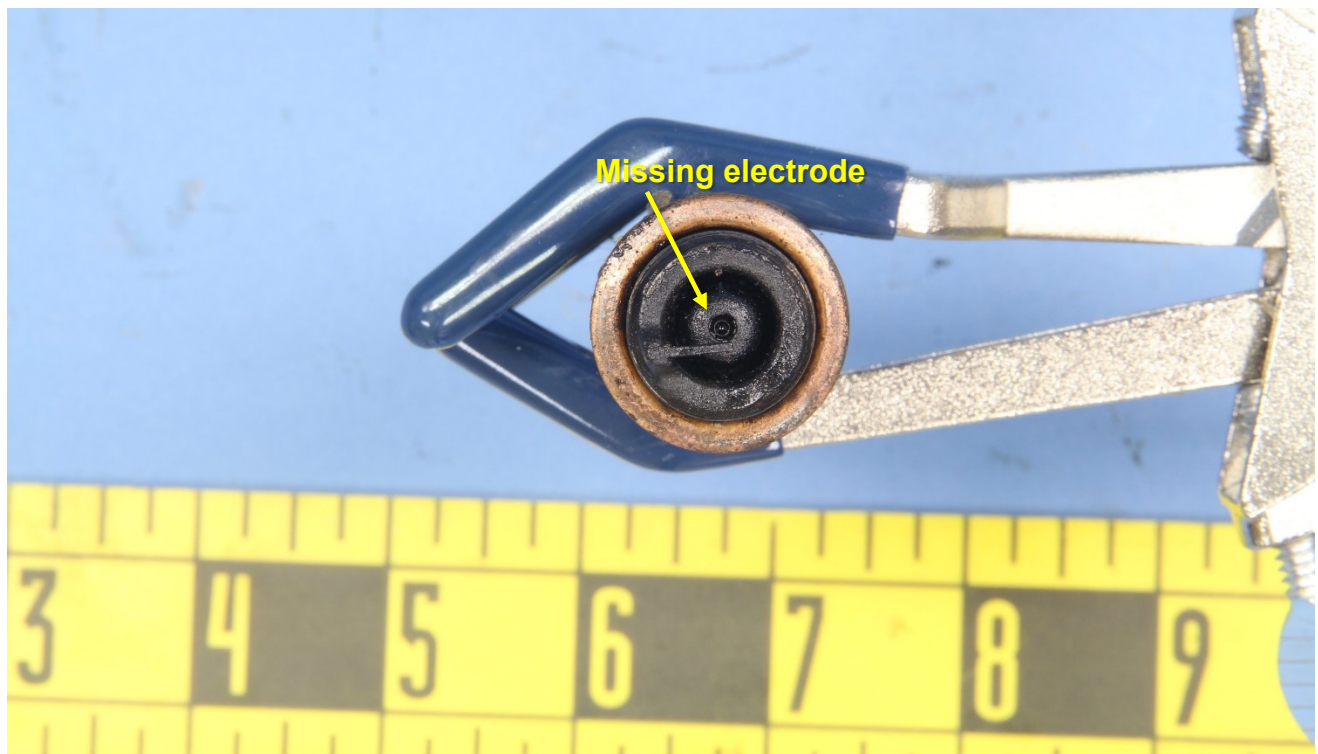


Figure 2 – View of the spark plug head, showing the lateral electrode and the empty slot with the missing central electrode.

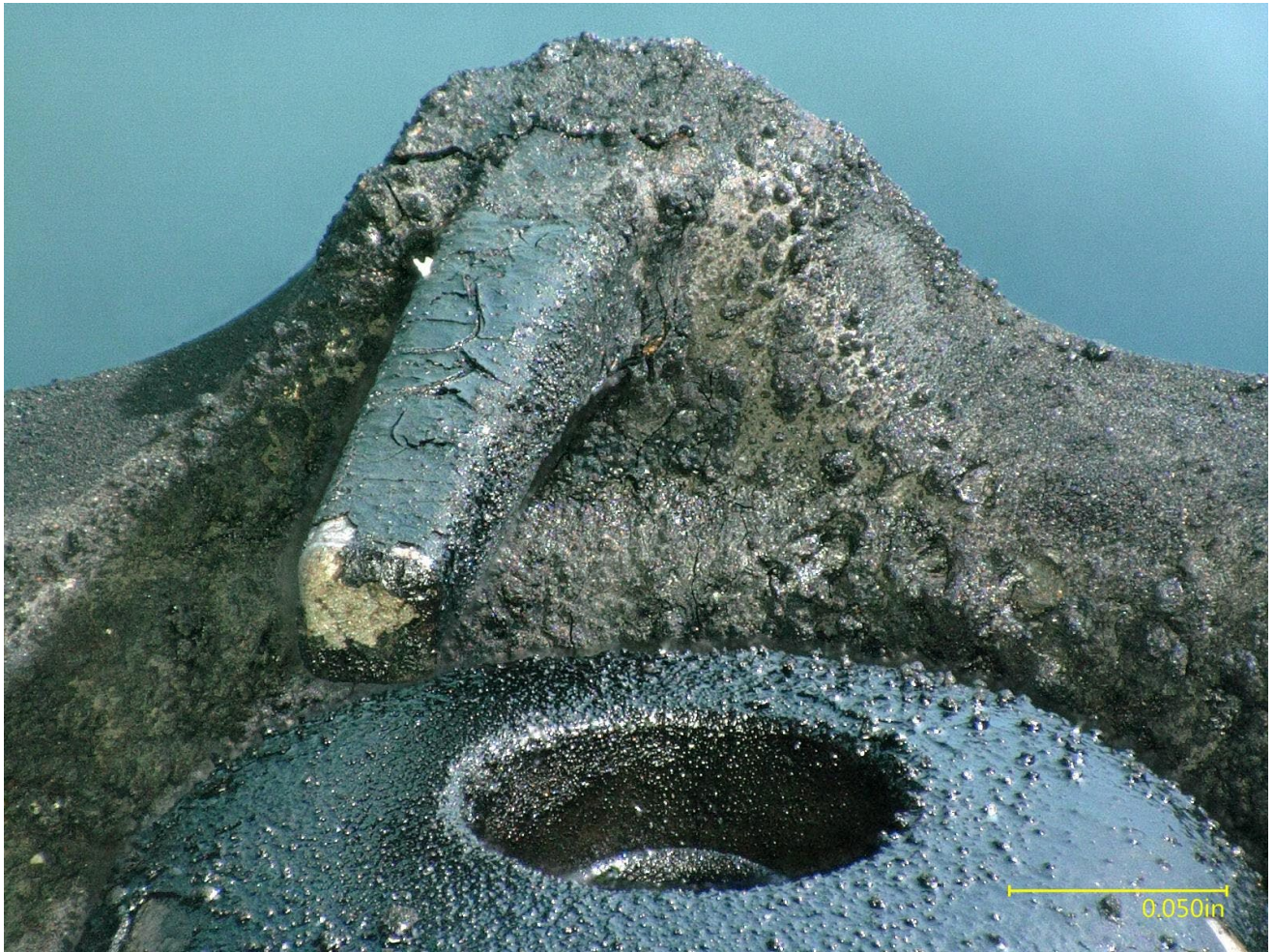


Figure 3 – Side view of the ground electrode of the spark plug head, showing its offset position.

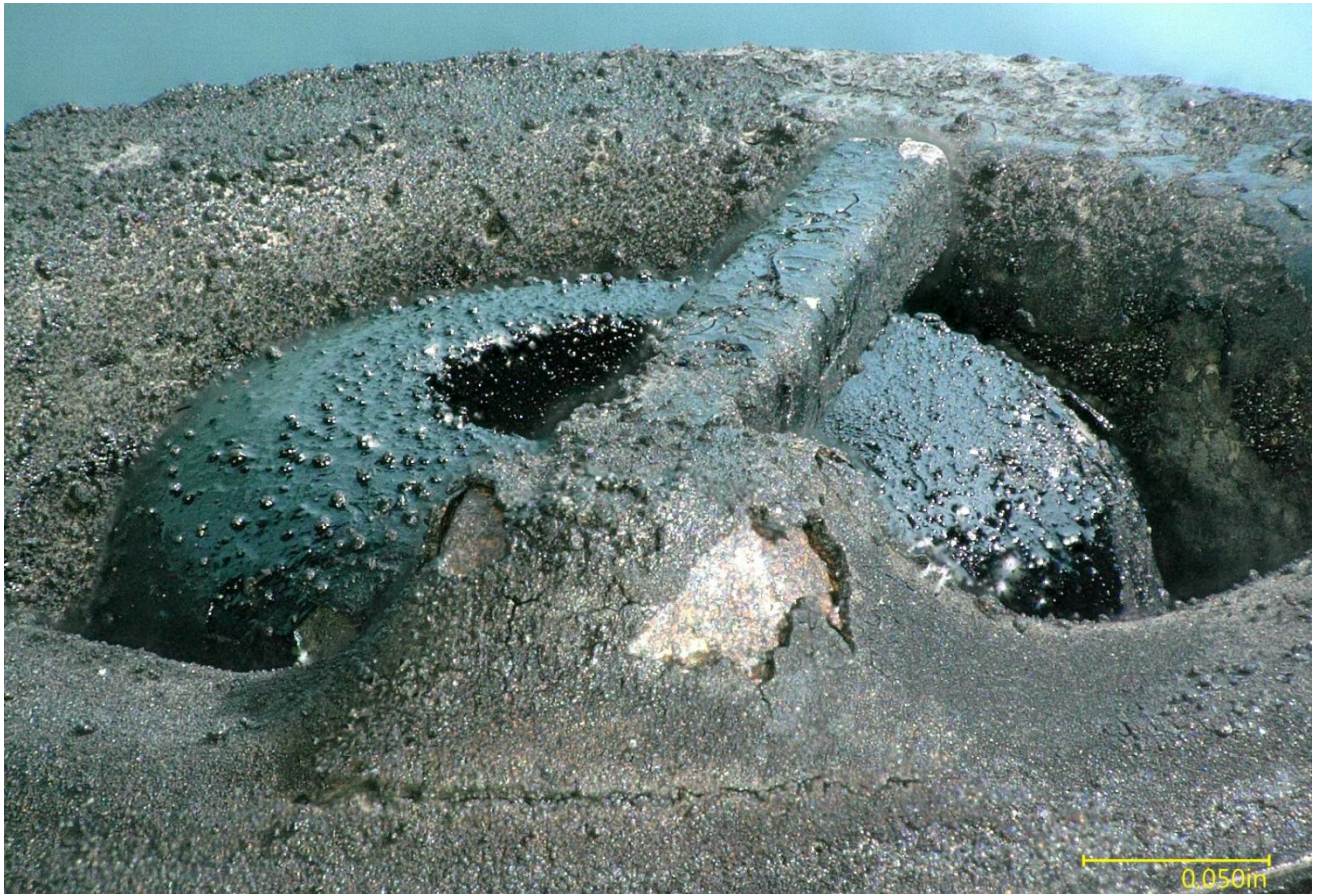


Figure 4 – View outside looking inward of the ground electrode, showing spalling of the deposits.

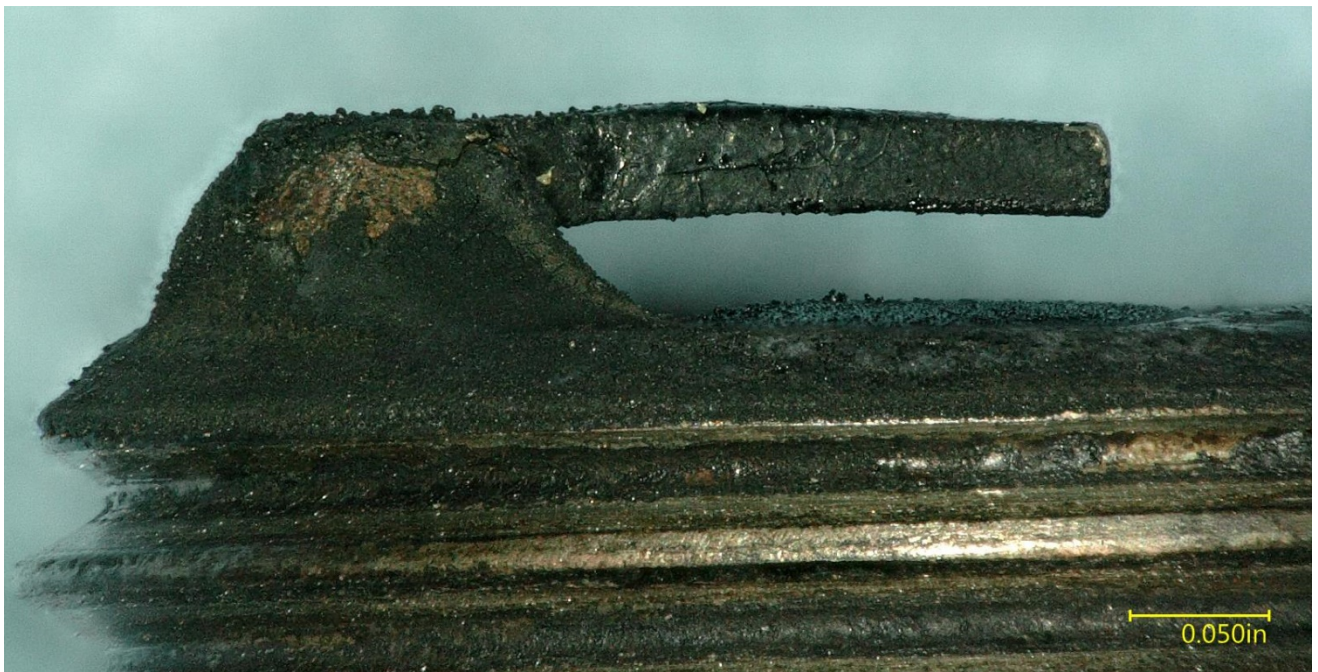


Figure 5 – Side view of the ground electrode.

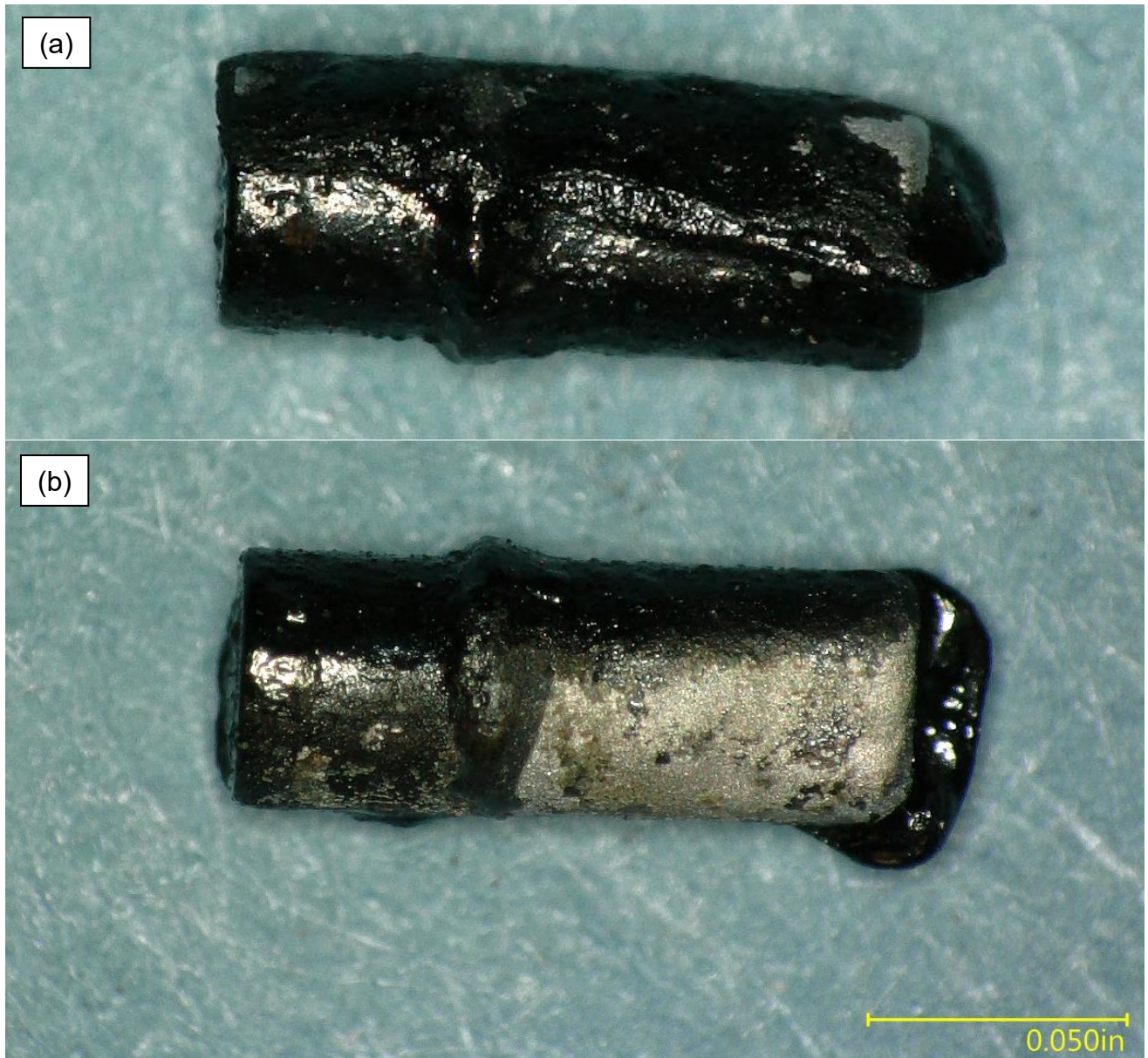


Figure 6 – View of the center electrode, found separated from the spark plug assembly, viewed from 180° rotations (a) and (b). The remnant was covered with dark, glassy deposits.

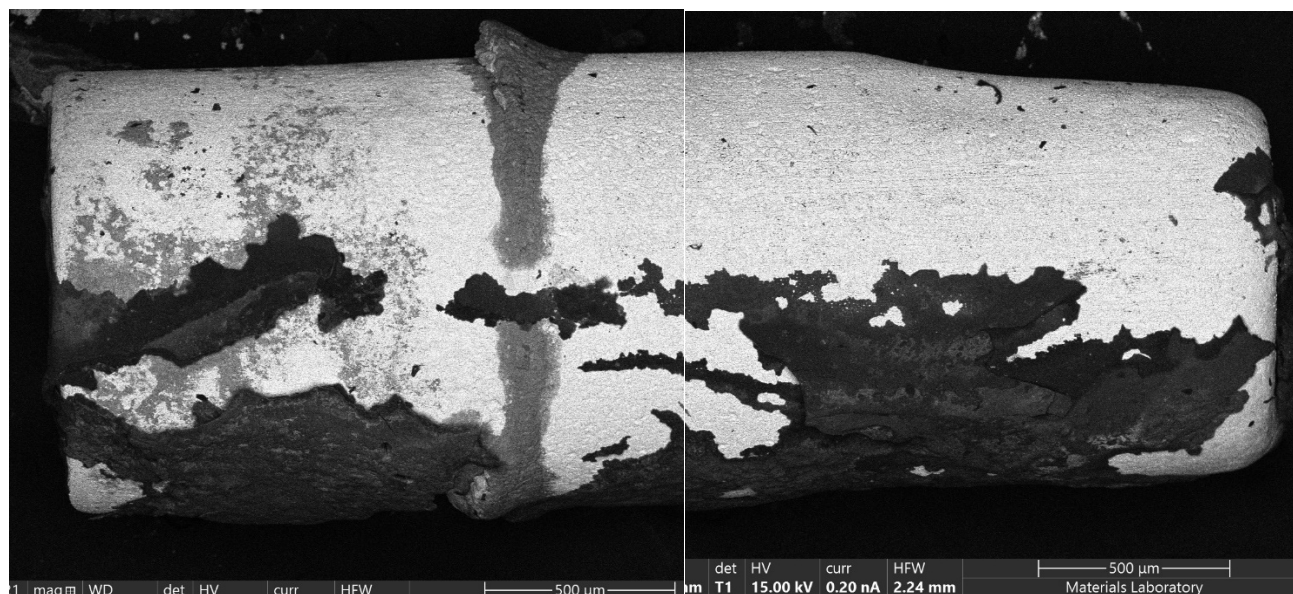


Figure 7 – Montage of backscattered electron (BE) micrographs of the center electrode remnant, after multiple cleanings (the inner surface is to the left).

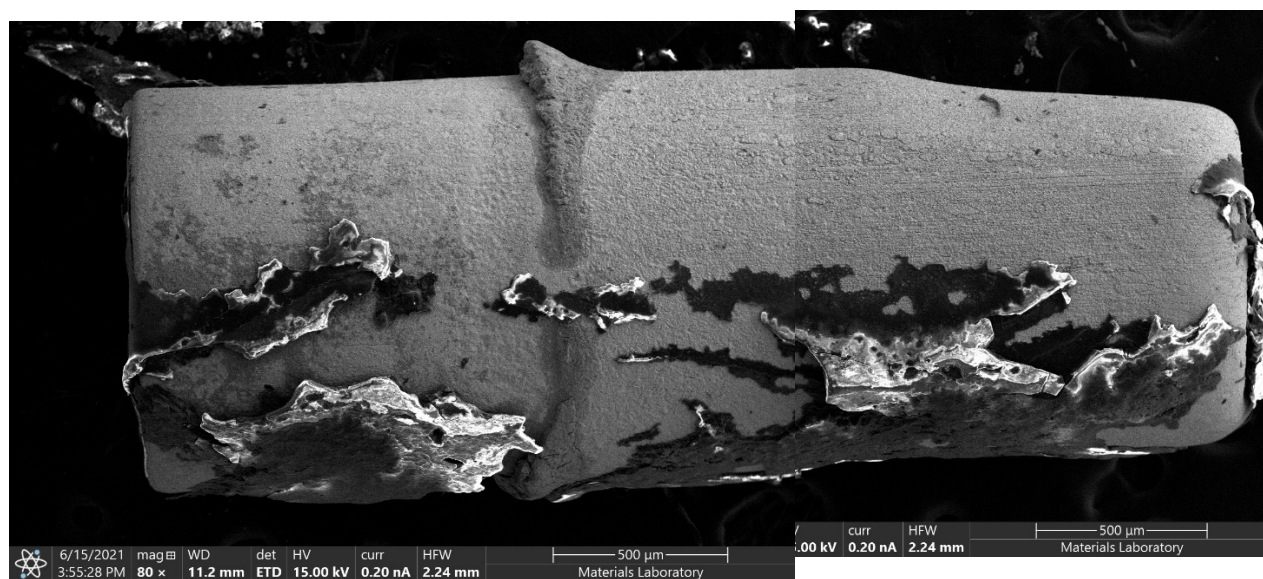


Figure 8 – Montage of secondary electron (SE) micrographs of the center electrode remnant, after multiple cleanings (the upward-facing tip is to the right).

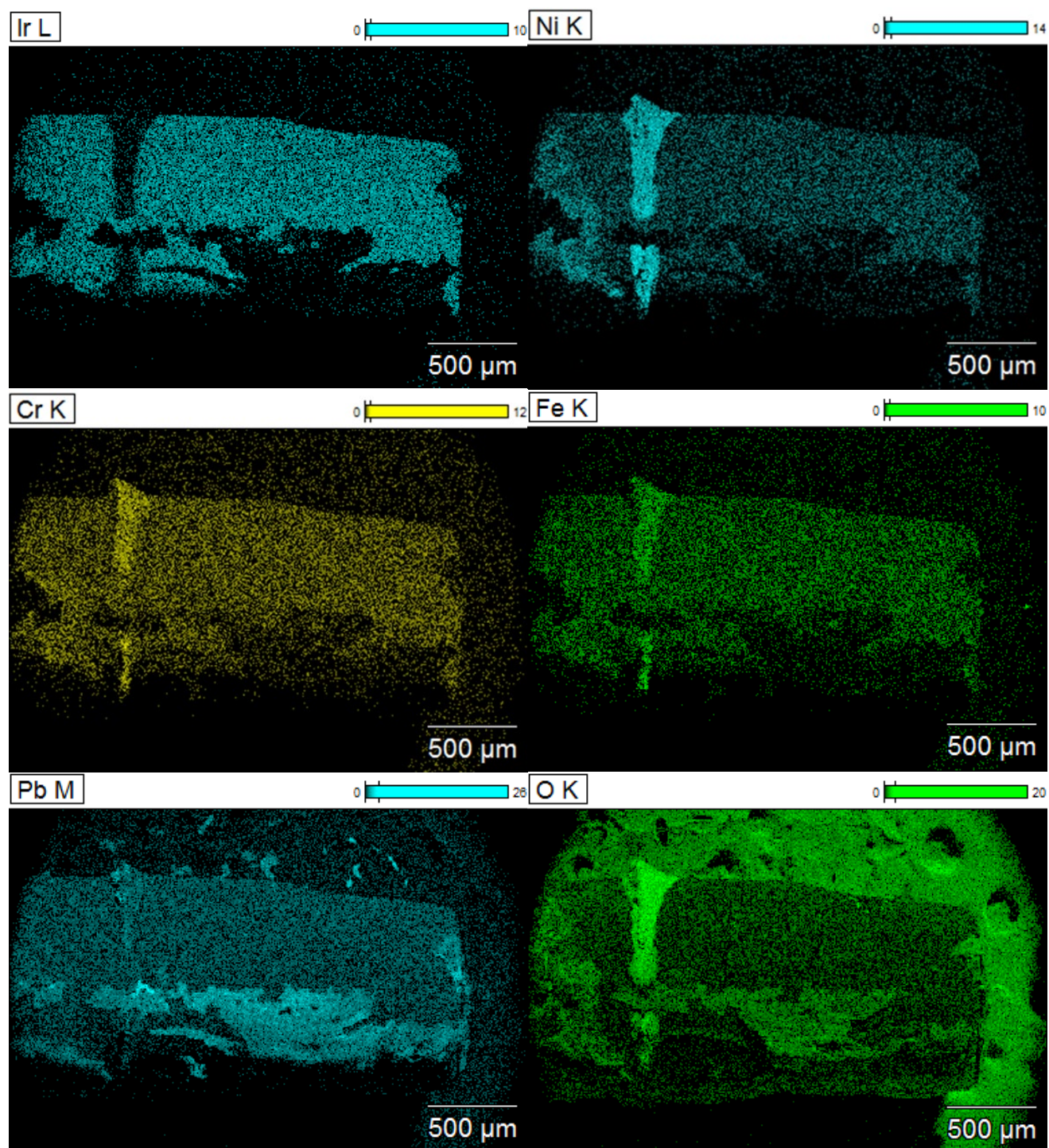


Figure 9 – X-rays maps of the upper half of the center electrode shown in Figure 7 and 8, displaying areas of concentrations of Ir, Ni, Fe, Cr, Pb, and O (brighter color equals higher concentration; darker color equals lower concentrations).

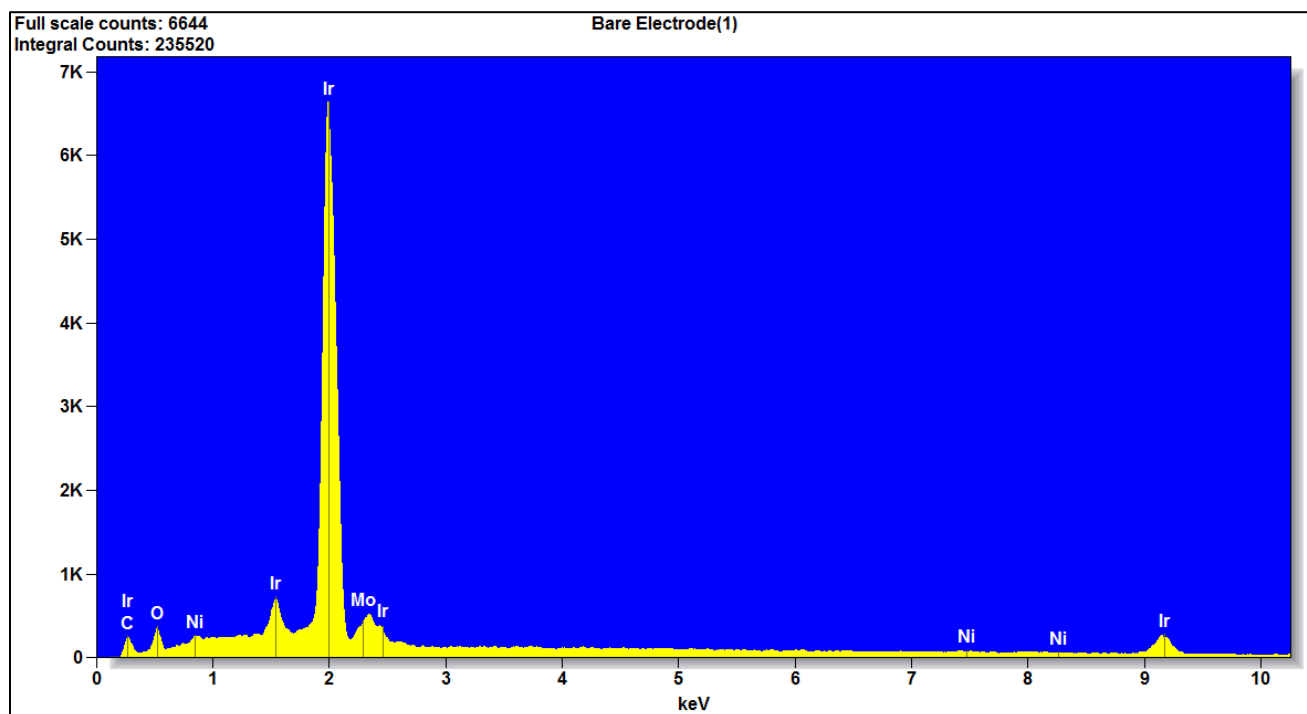


Figure 10 – EDS spectrum of the electrode tip material, consistent with an iridium alloy.

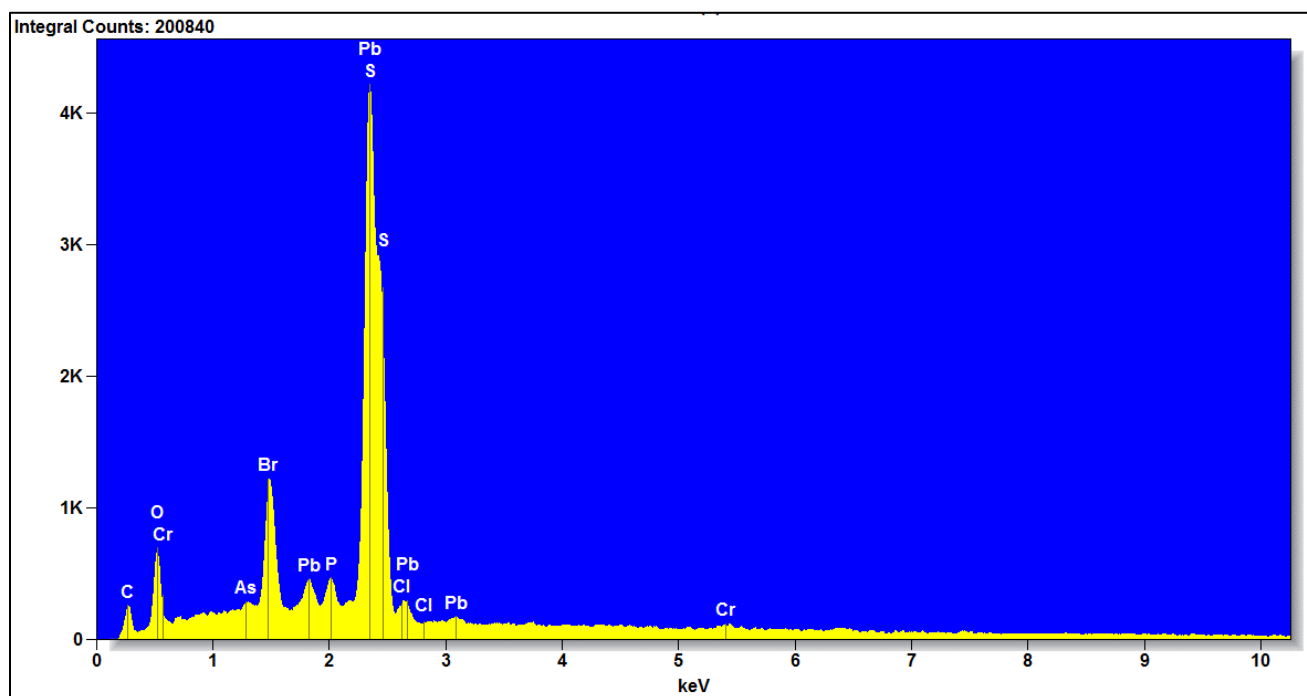


Figure 11 – EDS spectrum of the dark deposits, consistent with lead-based oxides.

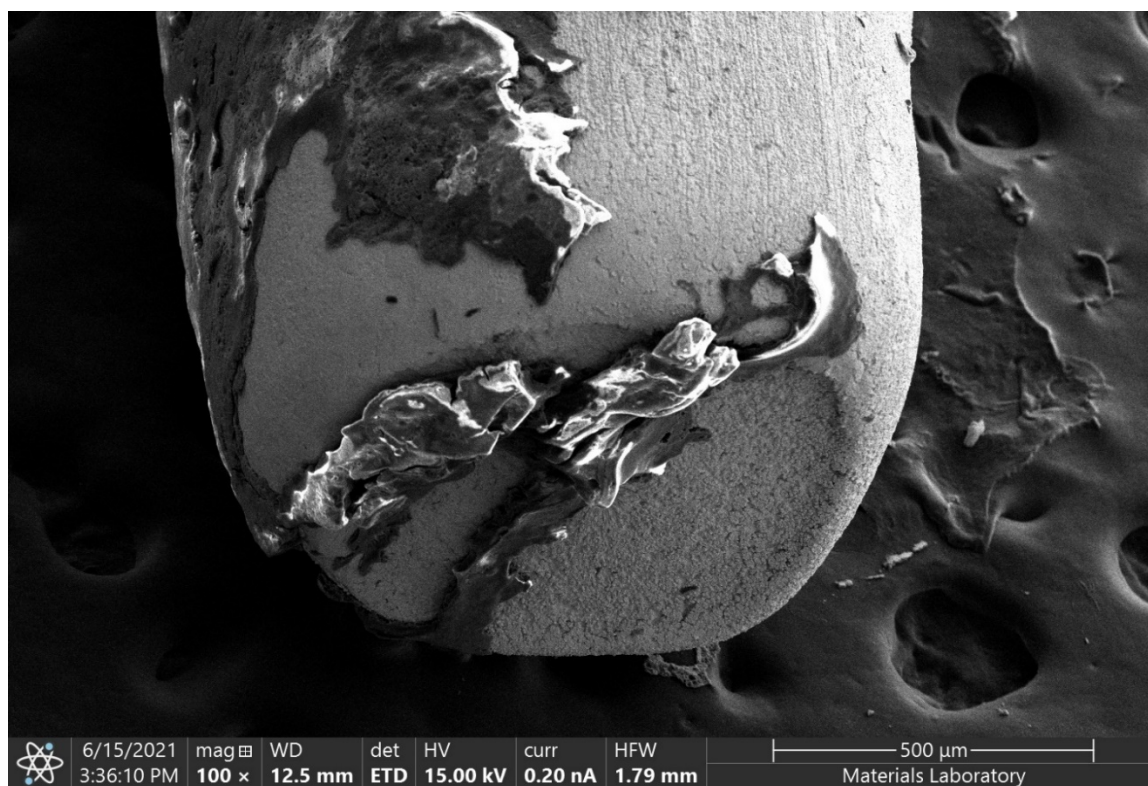


Figure 12 – SE micrograph of the electrode tip, after multiple cleanings.

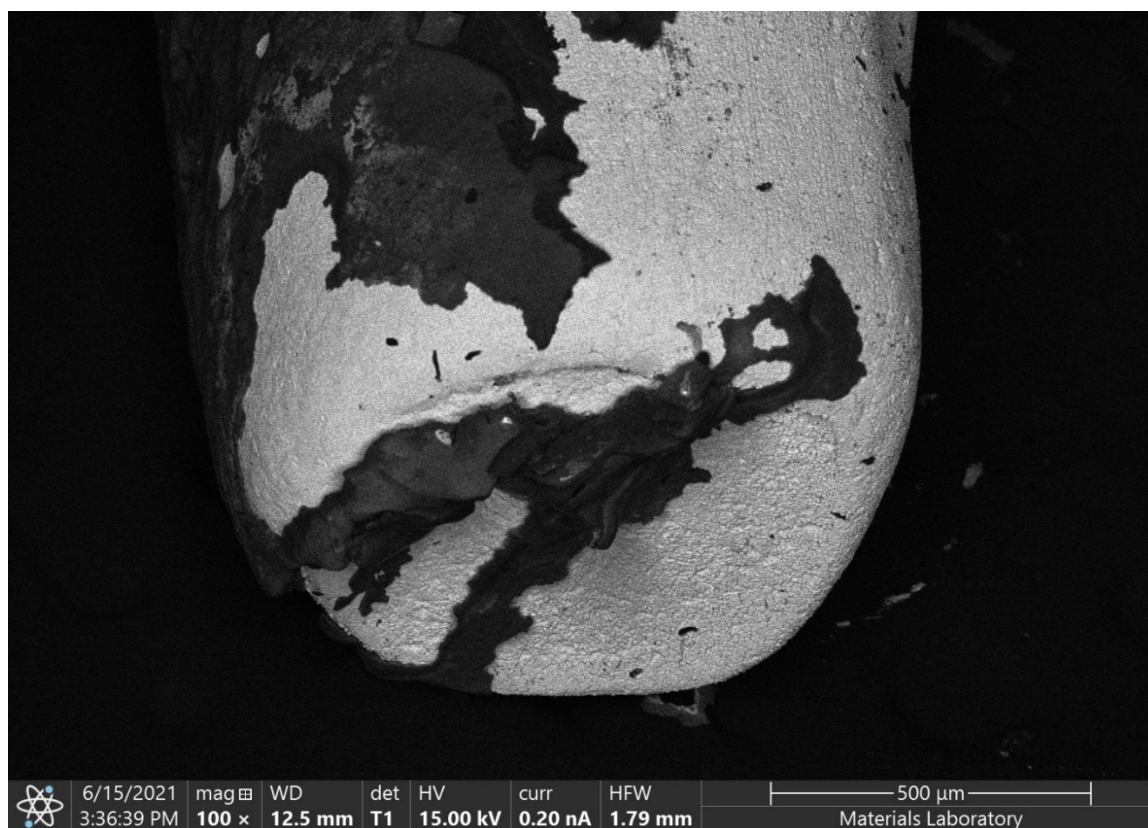


Figure 13 – BE micrograph of the electrode tip, after multiple cleanings.

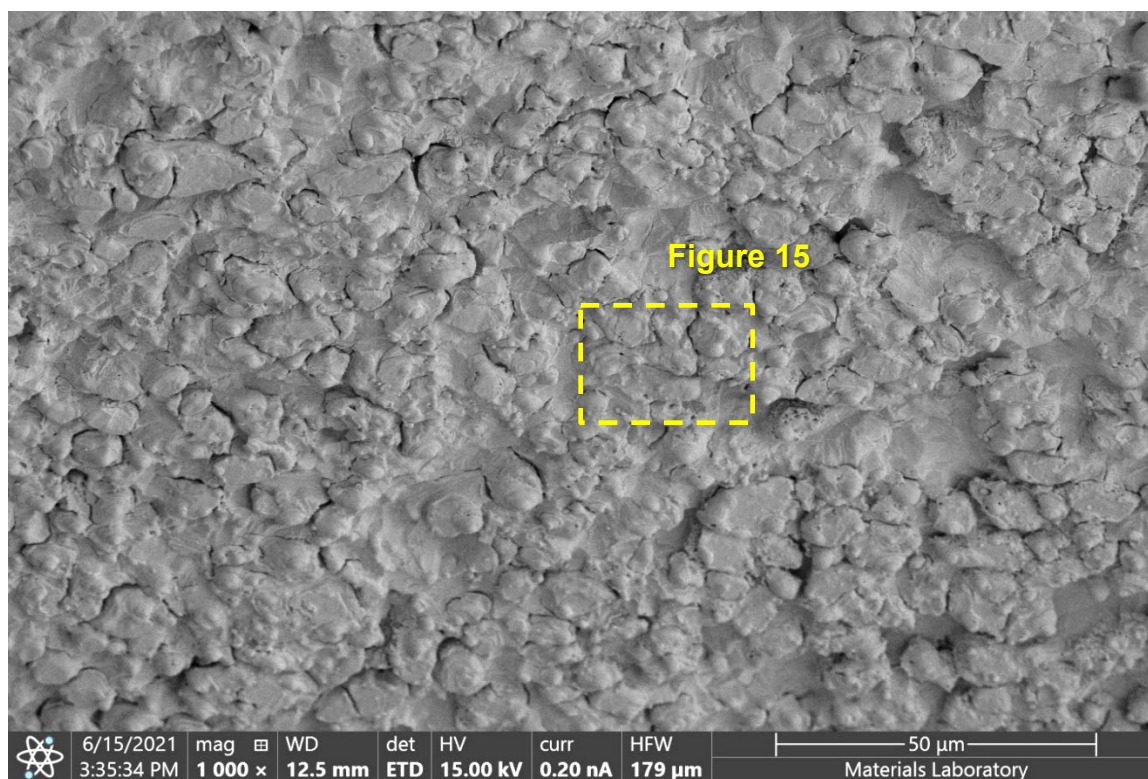


Figure 14 – SE micrograph showing a closer view of the electrode tip surface.

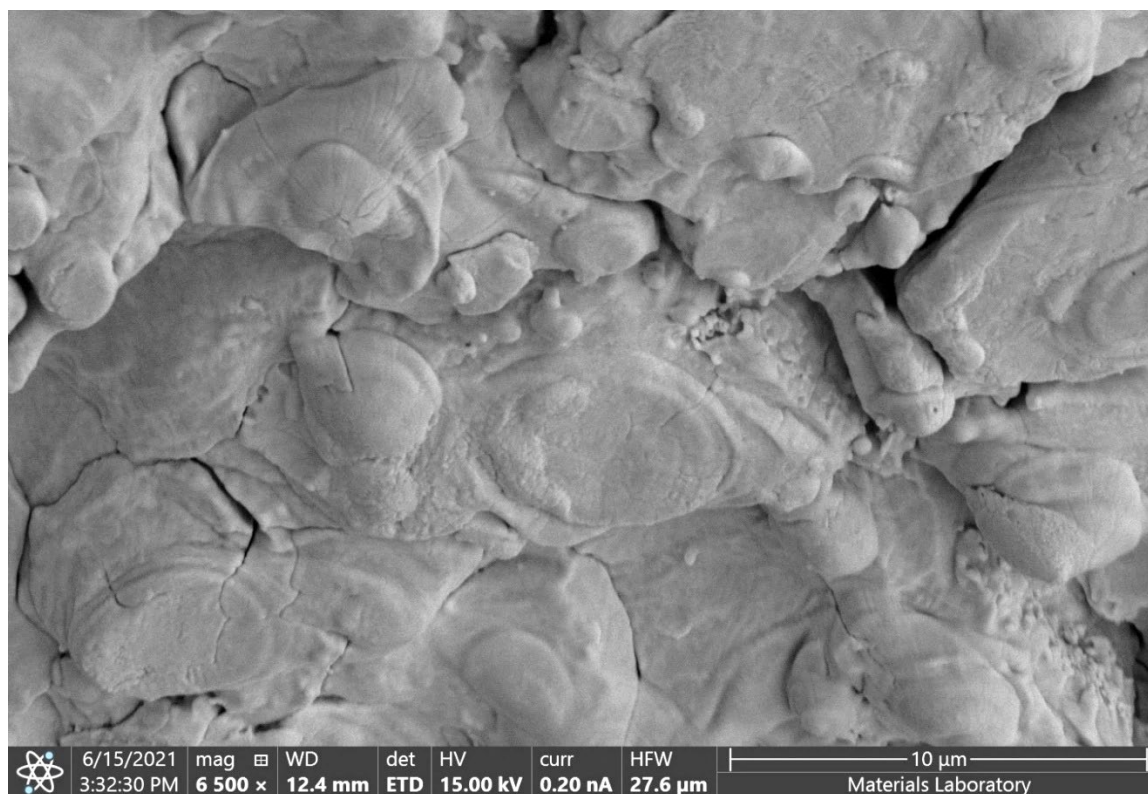


Figure 15 – SE micrograph of the boxed area in Figure 14, showing surface features.

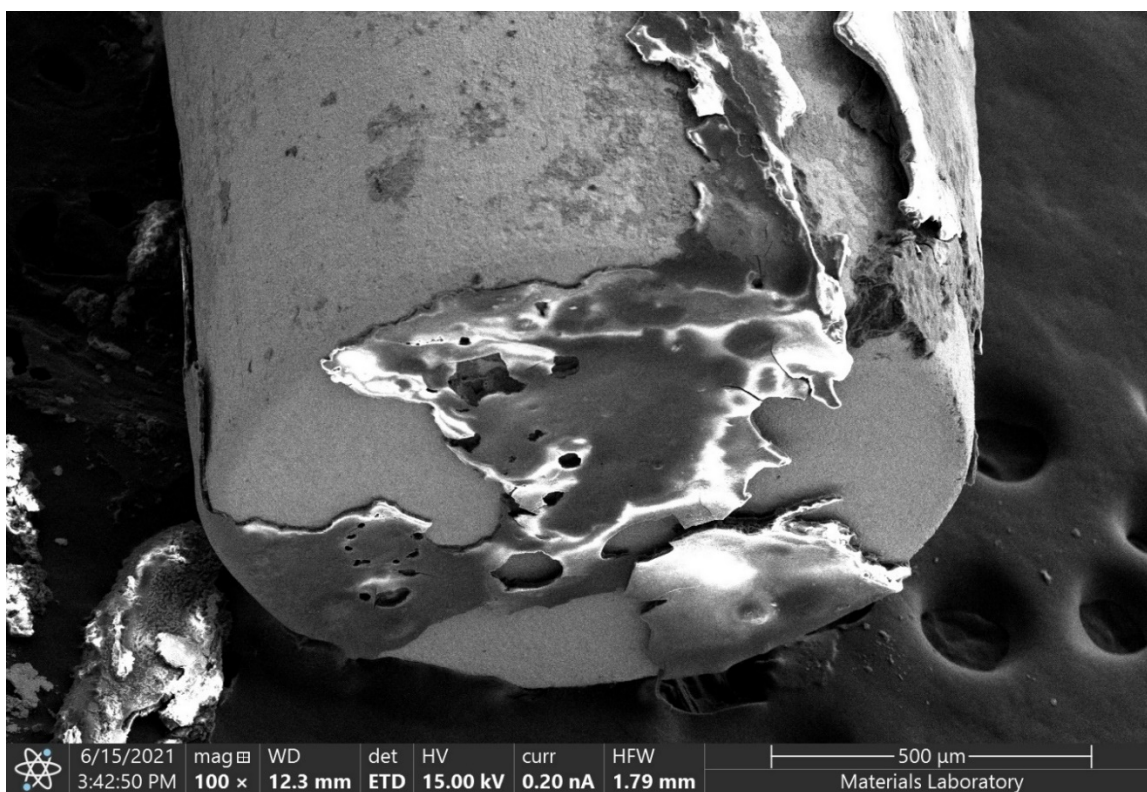


Figure 16 – SE micrograph of the electrode tip inner base surface, after cleaning.

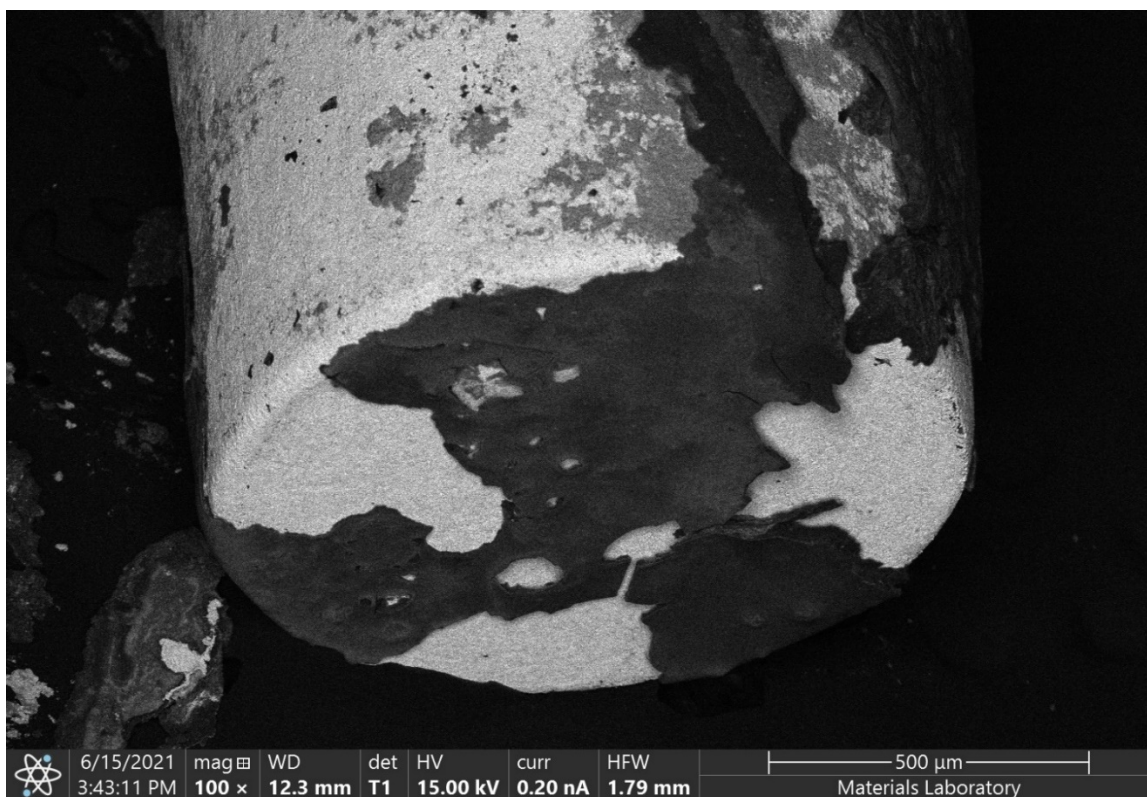


Figure 17 – BE micrograph of the electrode tip inner base surface, after cleaning.

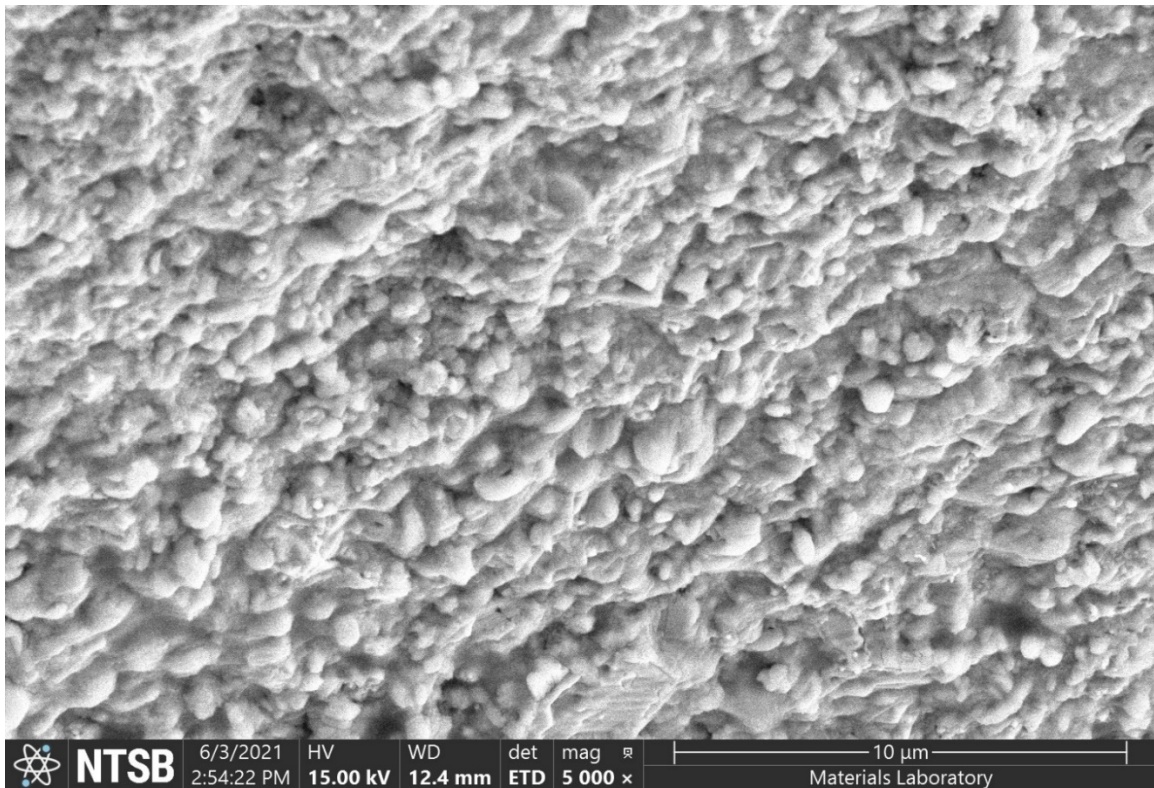


Figure 18 – SE micrograph of a closer view of the electrode tip base surface.

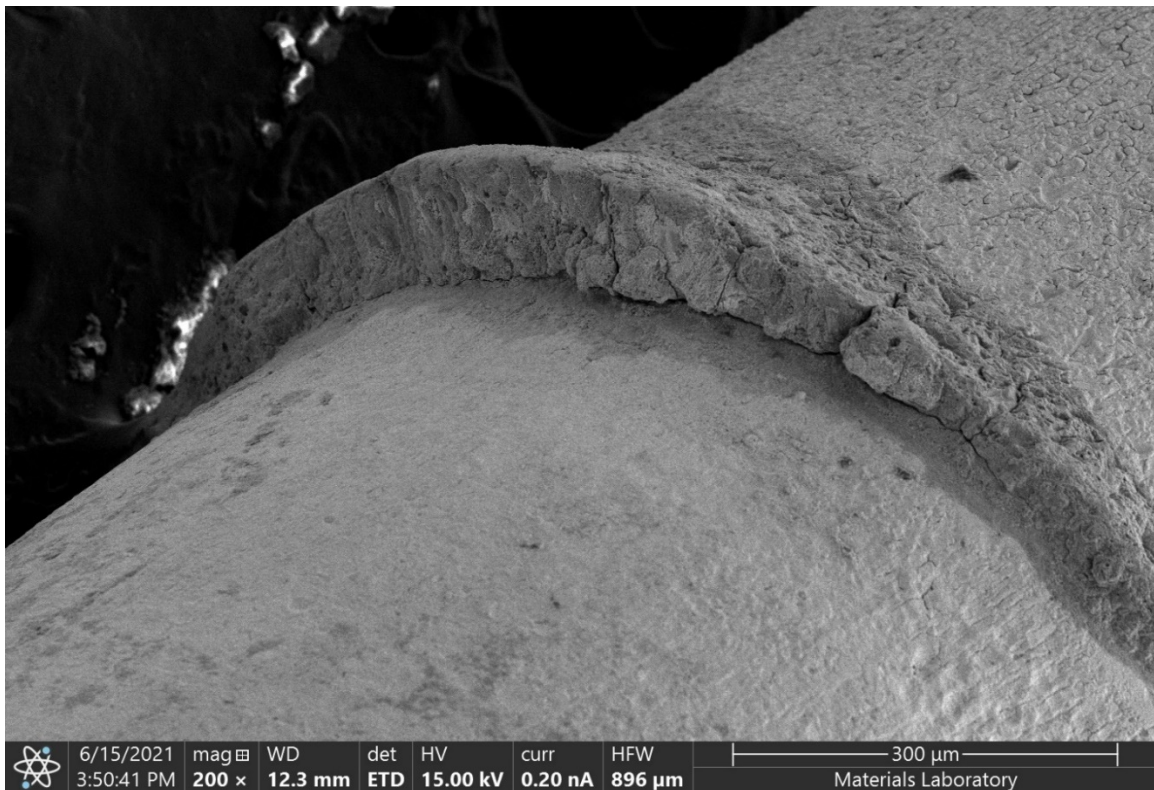


Figure 19 – SE micrograph of the fracture surface of the weld material underside on the middle of the tip cylindrical surface.

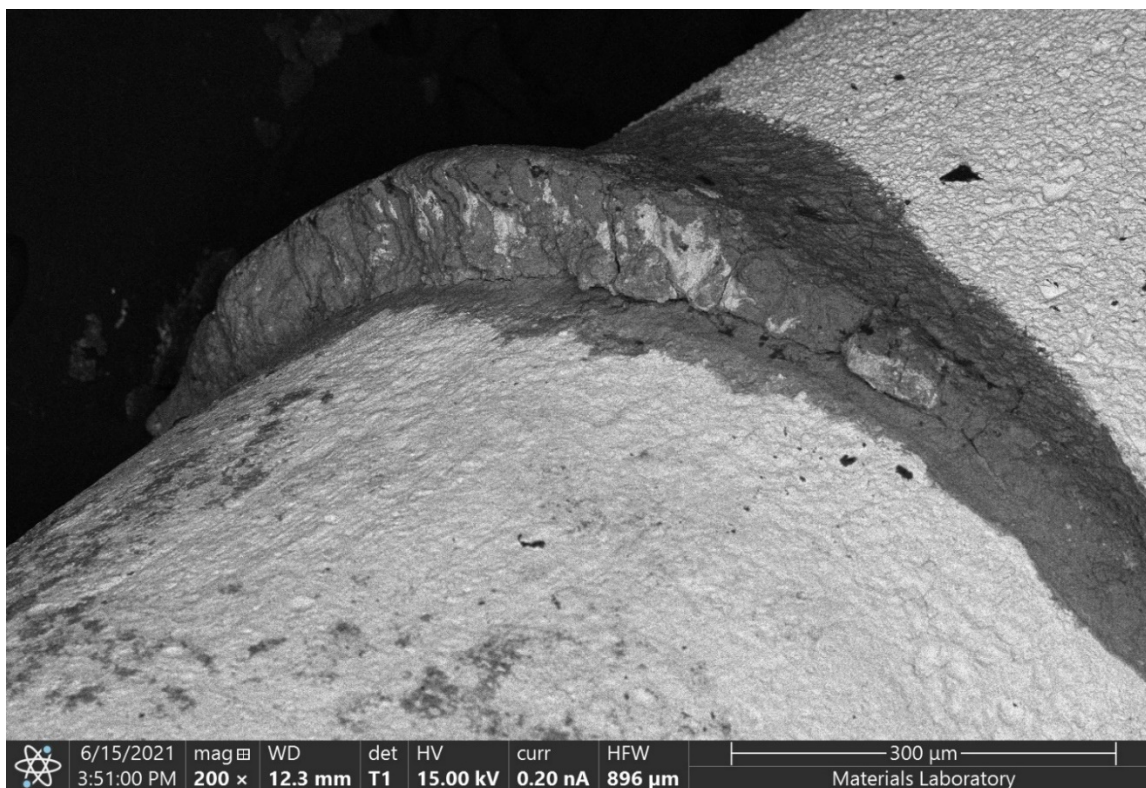


Figure 20 – BE micrograph of the underside of the tip weld material in Figure 19.

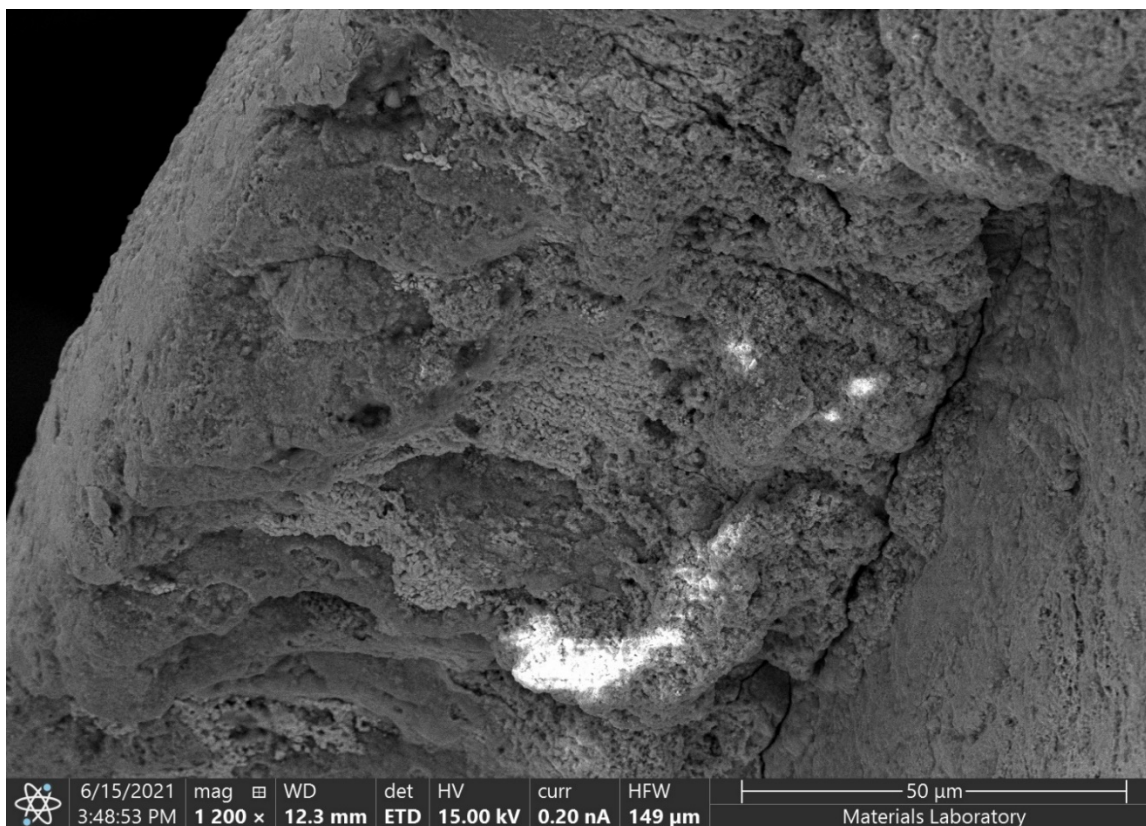


Figure 21 – SE micrograph of the weld material fracture surface.

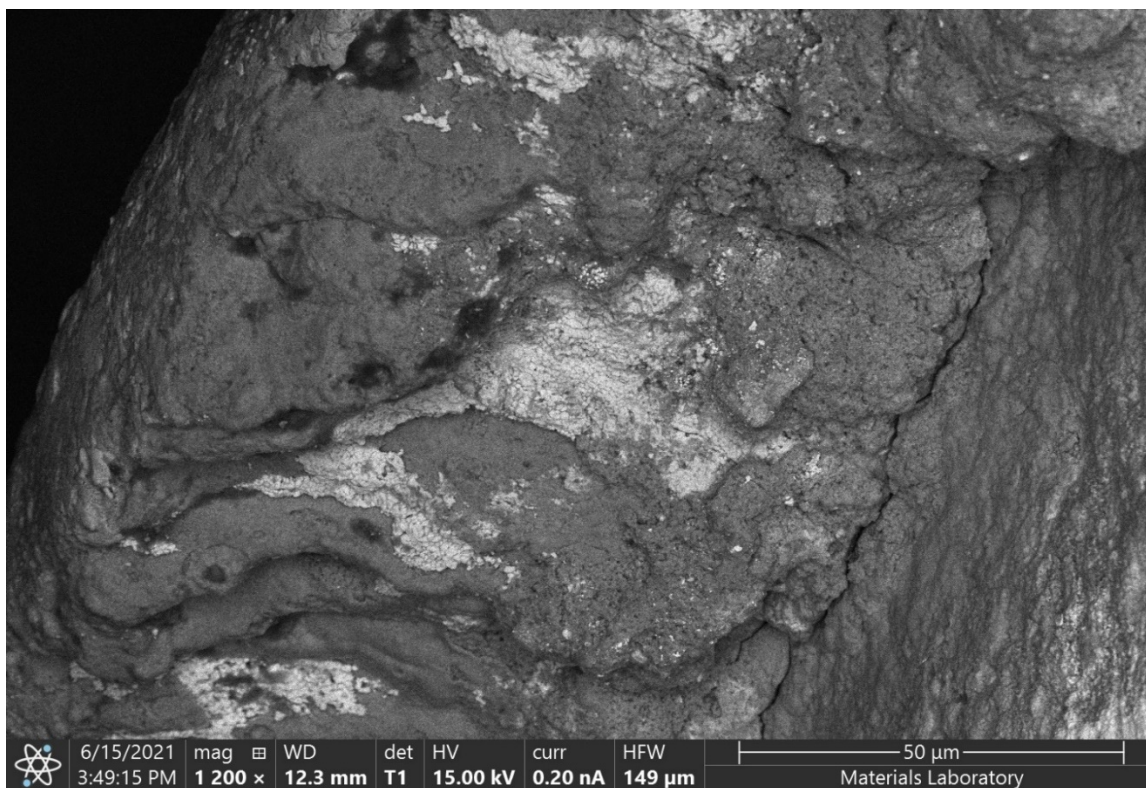


Figure 22 – BE micrograph of the underside of the weld material fracture surface.

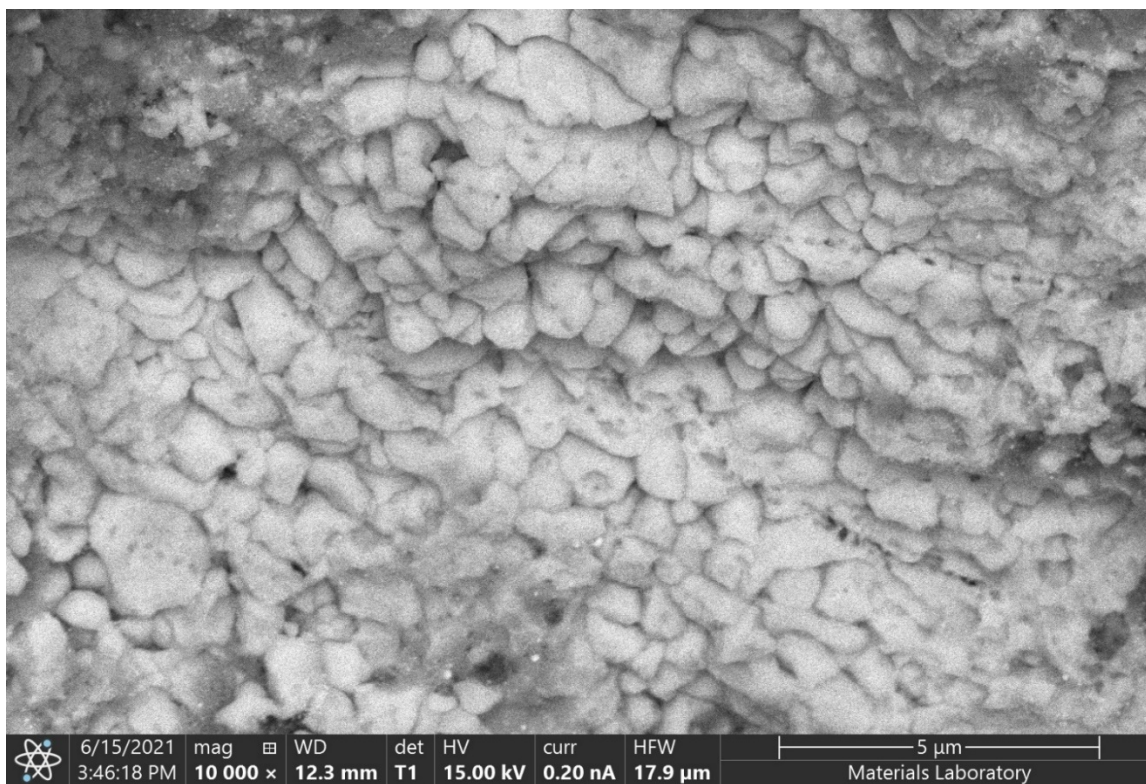


Figure 23 – BE micrograph of the weld material underside fracture surface.