TECHNICAL REPORT

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MEE Project: AB0004
Sample ID: Fractured Wire

PROJECT TITLE: Evaluation of Device Wire Fracture

INTRODUCTION

A failed device wire was examined using scanning electron microscopy (SEM) to characterize the fracture. Following the SEM examination, fractographic interpretation was requested to determine the failure mode for the wire and evaluate whether pre-existing cracks contributed to the failure.

The wire material is type 304 stainless steel. The wire diameter at the fracture location has been reduced using centerless grinding. The device reportedly failed during use such that the reduced diameter tip separated from the rest of the wire during a procedure.

DISCUSSION AND CONCLUSIONS

Only one side of the fractured wire was available for evaluation. The fracture surface exhibited three distinct fracture regions. Two fracture zones on opposite sides of the wire exhibited features characteristic of fatigue fracture. Ratchet marks along the wire surface indicated multiple fatigue fracture initiation sites at the wire surface for each of the two fatigue fracture areas.

The third fracture zone was a thin band across the center of the wire between the first two zones. The features in this zone were characteristic of a ductile fracture mode, which indicated that this center zone was the last portion of the cross section to fail.

The submitted wire section had a distinct bend in the wire at the fracture. The fracture origins for the two fatigue areas were located at the inside and outside of the bend, which would be consistent with fracture due to reversed bending in the direction of the permanent bend. This bend indicated that the wire had been bent sufficiently that the maximum stresses in the wire were beyond the elastic limit of the wire material. Cyclical bending at this magnitude could readily initiate and propagate the observed fatigue cracks. A permanent bend in the wire may also increase the potential for additional bending of the wire during subsequent manipulation and flexing of the device.

The texture of the original wire surface adjacent to the fracture was rough and somewhat smeared. The appearance and circumferential orientation of the surface texture was typical of centerless ground stainless steel wire. The circumferential grooves from centerless grinding create stress concentration sites that will accelerate the initiation of fatigue fracture in the wire. The grinding grooves are quite coarse relative to the small diameter of the wire, which creates a substantial concentration for bending and tensile stresses.

In summary, the failure mode for the submitted device wire was fatigue fracture. The fracture configuration indicated that the failure stresses were due to reversed bending. A permanent bend in the wire further indicated that the device had been subjected to substantial bending deformation at the failure location. Cyclic bending in the direction of the permanent bend could have created the observed failure. The rough surface texture from centerless grinding created stress concentrations in the wire surface, which would accelerate the initiation of fatigue fracture.

The fatigue fracture mode is a progressive failure mode that requires multiple stress cycles. The width of the fatigue striations on the fracture surface was consistent with a low-cycle fatigue fracture, i.e. the number of cyclical stress cycles to failure ranging from about one hundred to a few hundred. It cannot be conclusively determined from the features of this failure whether the stress cycles that initiated and propagated the fatigue cracks occurred prior to the procedure, during the procedure, or both. Further review of the details of the procedure is recommended to determine when the permanent bend was created and whether a sufficient number of stress cycles could be accumulated during the procedure to have initiated and propagated the fatigue fractures. Review of the manufacturing process for potential sources of cyclical stresses, including the grinding process and turbulent cleaning procedures, is also recommended.

TEST PROCEDURES

The fracture and wire surface within about 1 in. of the fracture were examined using scanning electron microscopy (SEM). Micrographs were obtained to document representative features observed in the examination.

RESULTS

The wire had a distinct bend immediately at the fracture, Figures 1 and 2. The fracture was generally transverse to the wire's longitudinal axis. Other than the bend, there was no significant plastic deformation, such as necking or twisting of the wire, at the fracture.

The surface texture of the wire near the fracture consisted of circumferential grooves and smeared metal typical of the surface finish obtained by centerless grinding, Figure 1. No secondary cracks were detected in the wire surface near the fracture.

The fracture had three distinct zones, which are identified as A, B, and C in Figure 3. Zones A and B were relatively flat and located on the outside and inside of the bend in the wire. Striations and secondary cracking on the fracture surface in Zones A and B were characteristic of a fatigue fracture mode. Step-like features, i.e. rachet marks, in this region indicated multiple crack origins at the surface of the wire for each of the fatigue zones. The orientation of the striations and secondary cracking also indicated fracture propagation generally from the wire surface toward zone C, Figure 4.

Zone C was a narrow band across the wire section in the middle of the fracture between zones A and B. A dimpled fracture morphology in this region was characteristic of a ductile fracture mode.

SAMPLE DISPOSITION AND DATA STORAGE

The samples from this project were returned at the completion of SEM examination. All data will be kept on file, and additional report copies can be obtained upon request.

Submitted by:
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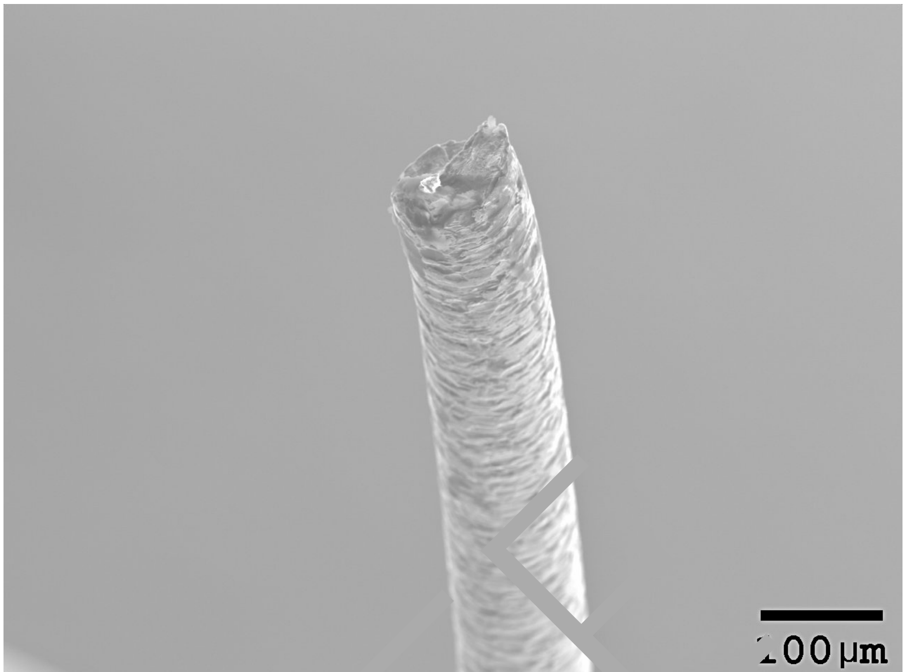

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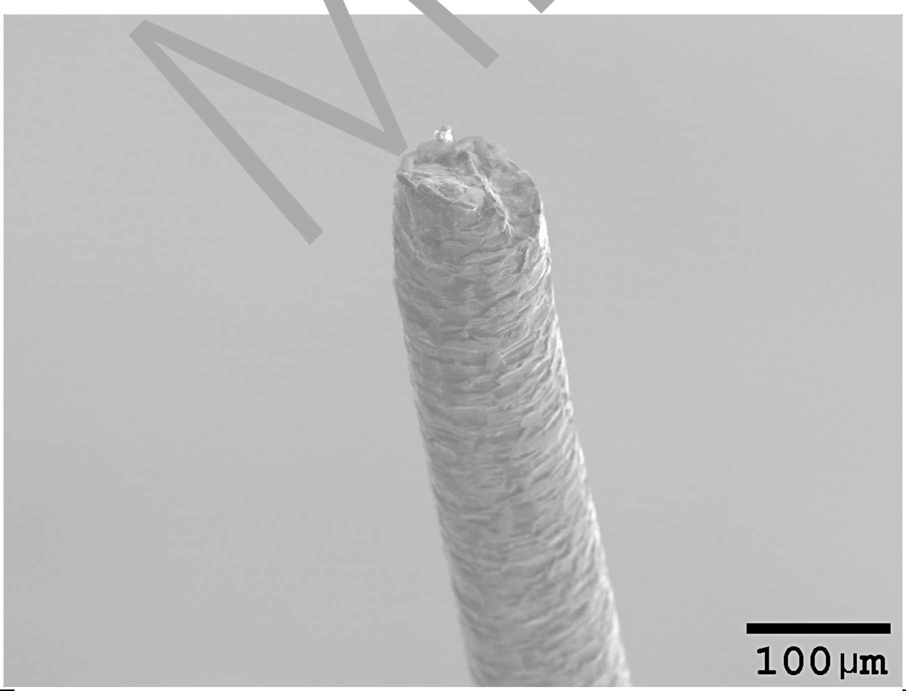

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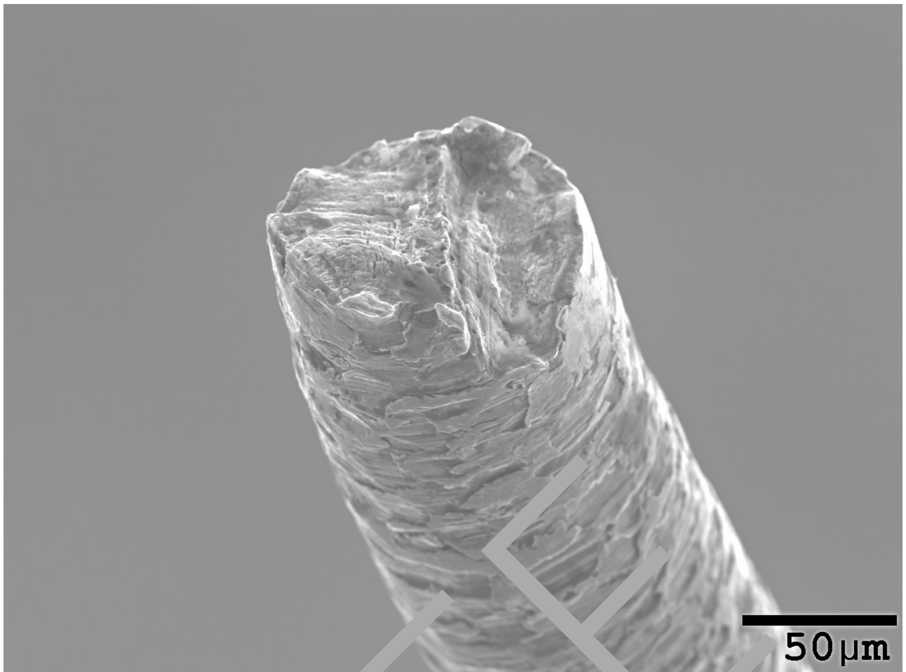
(b)

Figure 1 SEM images of the fractured end of the device wire.



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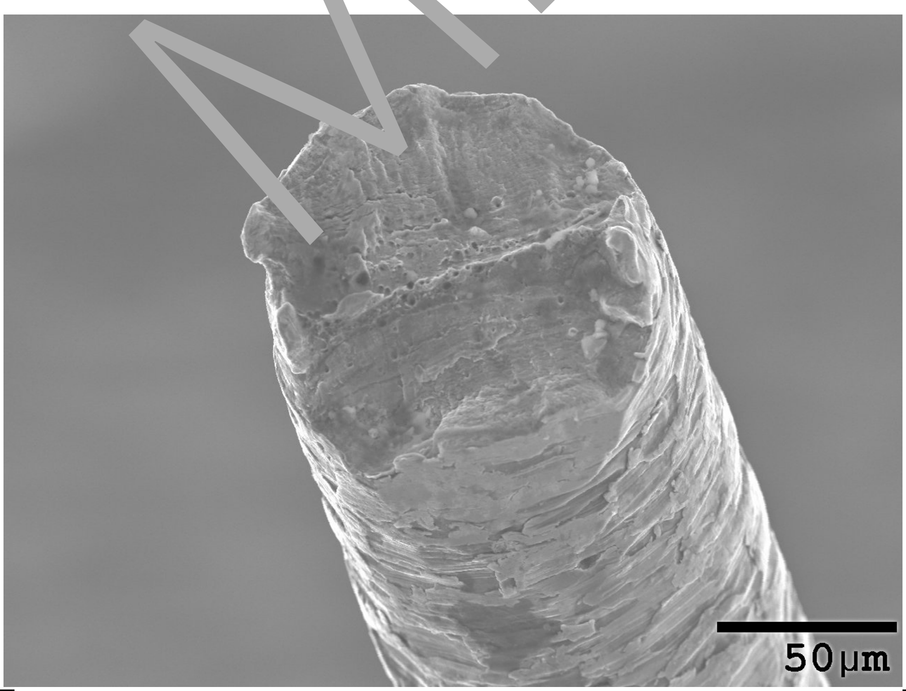

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(b)

Figure 2 SEM images of the fractured end of the device wire.

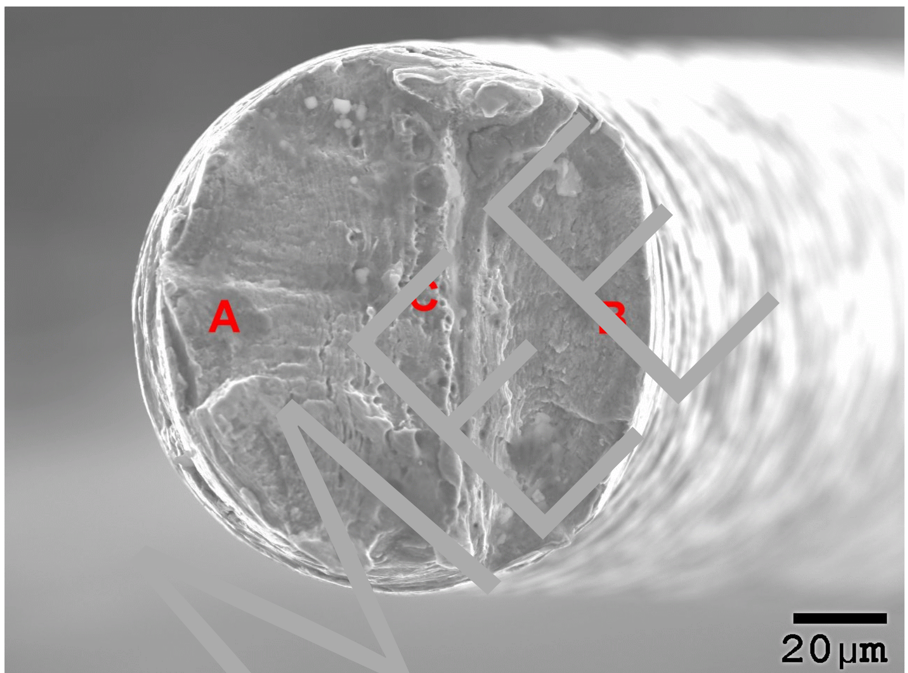

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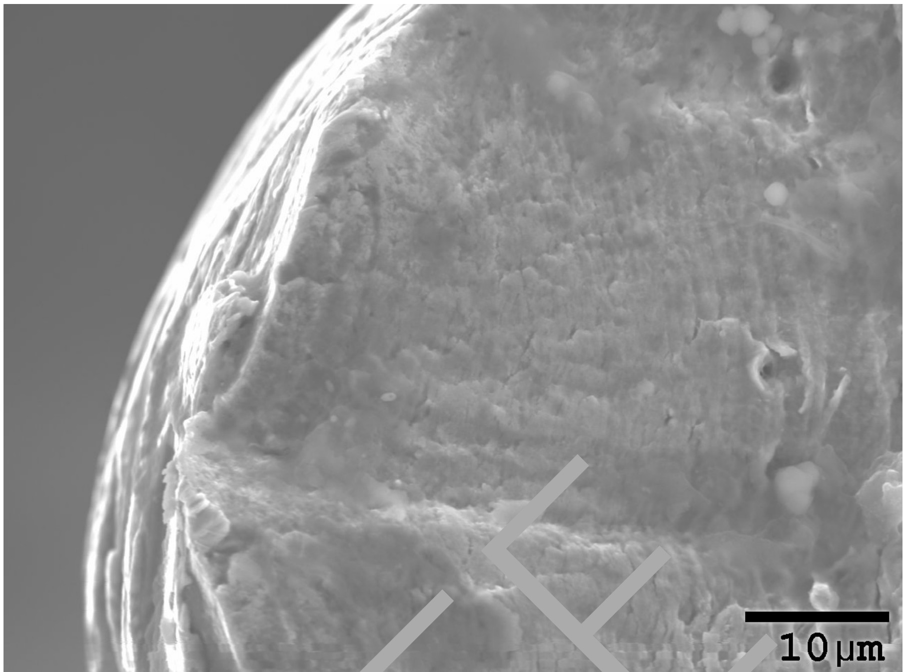
Figure 3 Fracture surface for the subject device wire.



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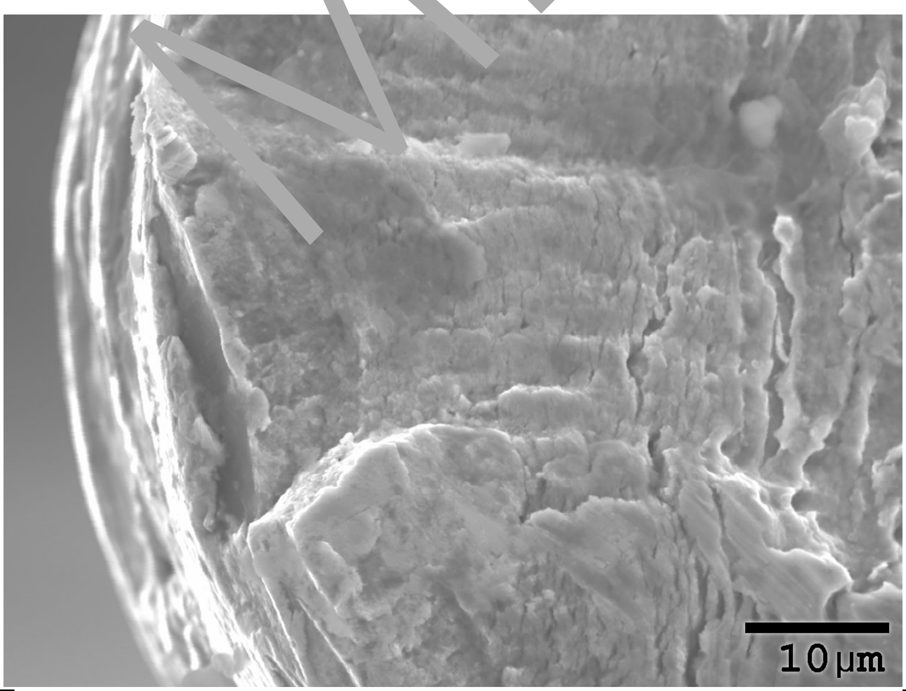
(a)



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(b)

Figure 4 Microscopic fracture features for Zone A of the fractured device wire.