The Role of a Compact Low Voltage FE-SEM in the Analysis of AFM Cantilevers

Application Note

Introduction

The atomic force microscope (AFM) has become a powerful tool for investigating surfaces on an atomic or nanometer scale. An AFM consists of a sharp cantilevered tip that is raster-scanned with sub-nanometer precision over a surface. The interaction forces between the tip and sample cause a minute cantilever deflection, which is sensed by optical deflection to produce a topographical map of the surface on the nanometer or atomic scale. Since its invention, the AFM has been used not only to view surface structures, but also to probe electrical, magnetic, van der Waals, adhesion, and chemical interactions between the tip and surface. The sharpness of the tip is often a fundamental resolution-limiting parameter. When the tip and sample are in contact, the contact area increases with the radius of curvature of the tip. Furthermore, the sample features appear widened or convoluted by the tip. In addition to tip sharpness, understanding wear and tip surface structure for magnetic or electrically coated cantilevers is also important. Although not commonly thought of as a MEMS device, AFM cantilevers are microfabricated using standard MEMS processing.

Of the multitude of scientific instrumentation used to characterize MEMS, SEM is one of the most common instruments. Because of the ubiquitous need for SEM images in AFM cantilever analysis, a new breed of instruments, the compact or bench top SEM, is garnering attention. These smaller SEMs will not replace the full suite of analytical capabilities of the full-size instruments; however, their ease of use and quick, high resolution images allows for operators with a wider range of SEM skill level. The compact SEM improves overall efficiency and analysis time, allowing researchers to quickly image the cantilevers when only an image is needed to guide further analysis.

Agilent's 8500 compact FE-SEM is a low voltage, field emission SEM which employs a novel electrostatic lens design. This innovative design allows for high resolution imaging of AFM cantilevers, typically without the need for metal coating to mitigate charging in the SEM. The 8500 FE-SEM was used to image 11 different types of atomic force microscope (AFM) cantilevers.

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1. Cantilever for KFM

This type of cantilever is for KFM (Kelvin force microscopy) and has a unique conductive alloy tip.

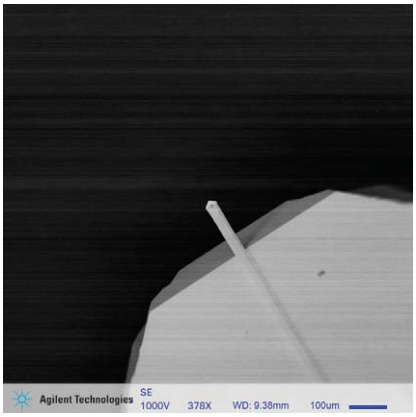


Figure 1.

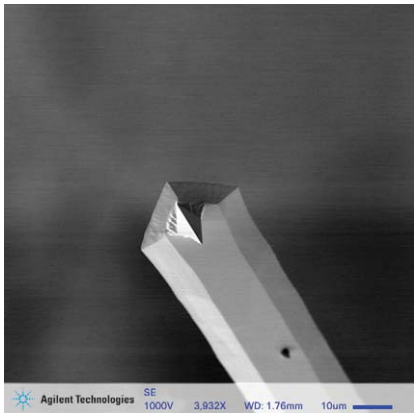
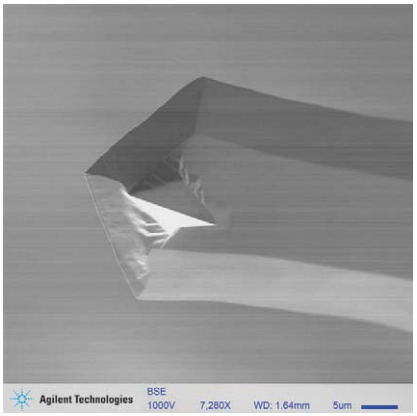


Figure 2.



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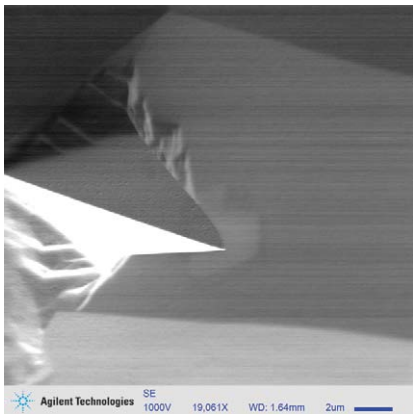

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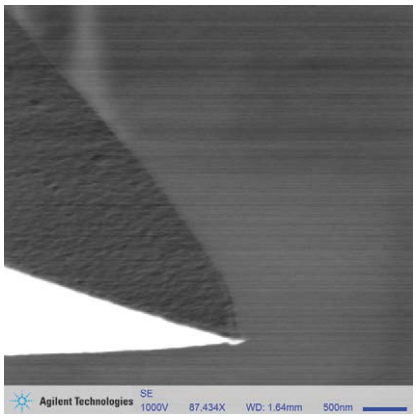

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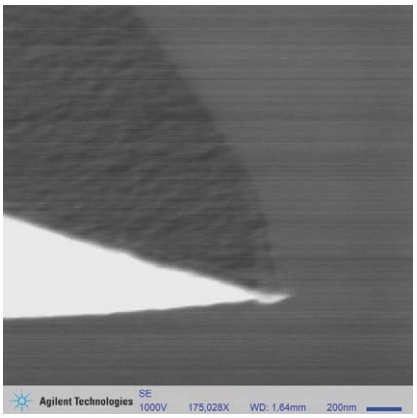


Figure 6.

2. Cantilever for Electrical Measurements

This type of cantilever is for electrical measurements and has a more traditional metal coating for electrical conductivity.

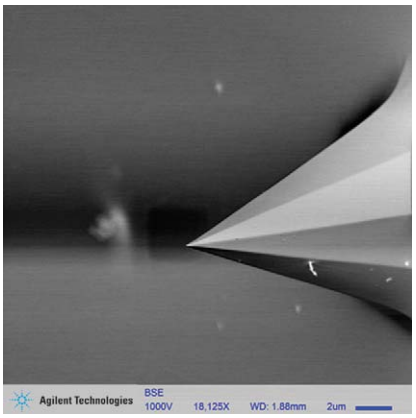


Figure 7.

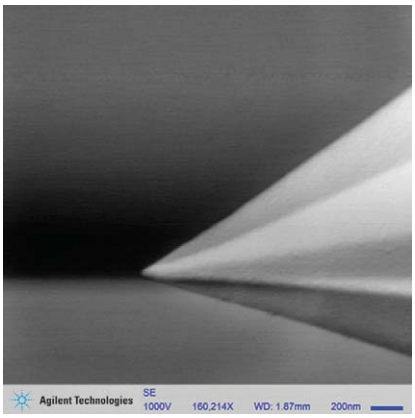


Figure 8.

3. Cantilever for Electrical Measurements with Metal Coating

This type of cantilever, also for electrical measurements, has a specialty metal coating that provides conductivity without adversely affecting tip sharpness.

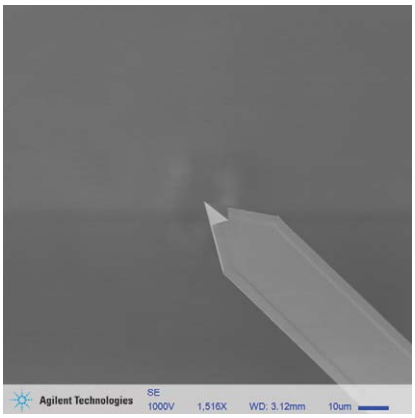


Figure 9.

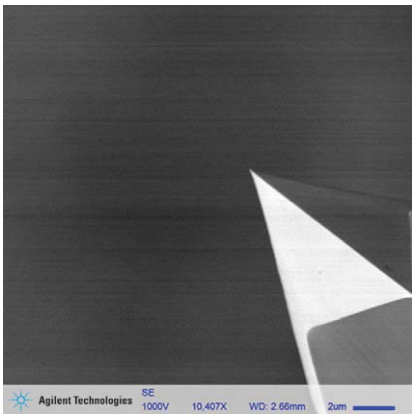


Figure 10.

4. Non-Conductive Cantilever for Oscillatory Probe Mode Imaging

This type of cantilever is a non-conducting cantilever for typical oscillatory probe mode imaging of polymers.

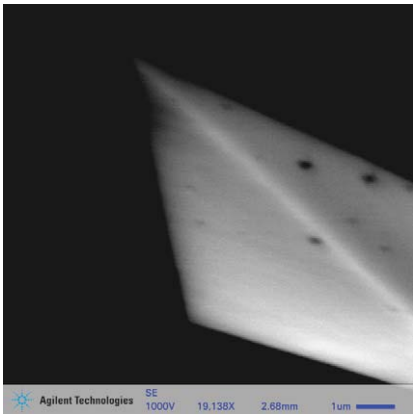
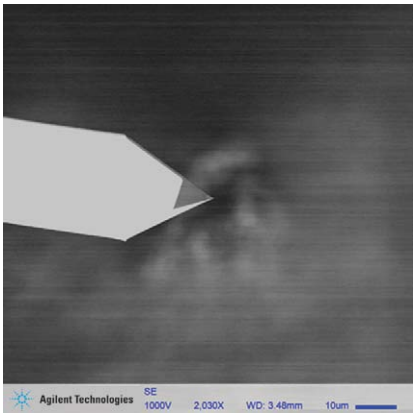


Figure 11.

5. Cantilever with a Hard Conductive Coating

This type of cantilever has a hard conductive coating.



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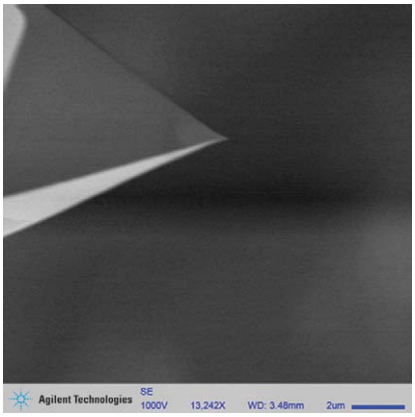

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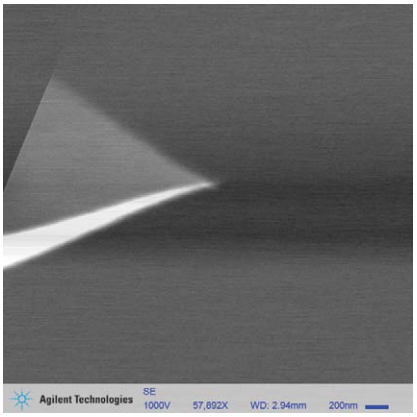
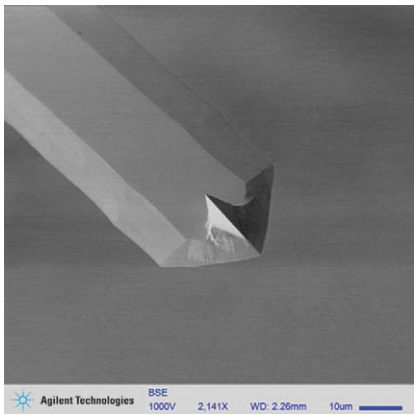


Figure 14.

6. Non-Conductive Cantilever for Oscillatory Probe Mode Imaging

This type of cantilever is also for oscillatory probe mode imaging of polymers but is made by a different manufacturer.



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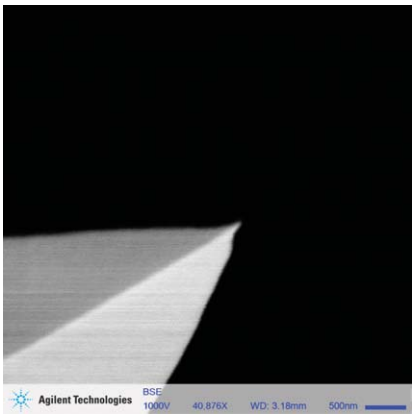


Figure 16.

Figure 17.

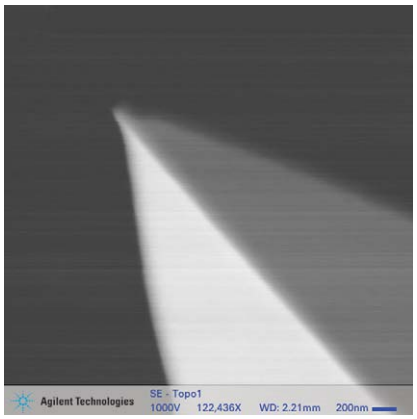
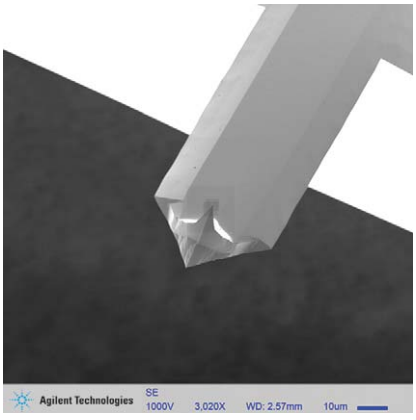


Figure 18.

7. Cantilever for Oscillatory Probe Mode Imaging of Polymers

This cantilever is also for oscillatory probe mode imaging of polymers.



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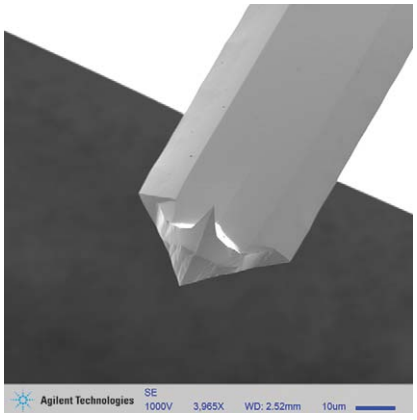

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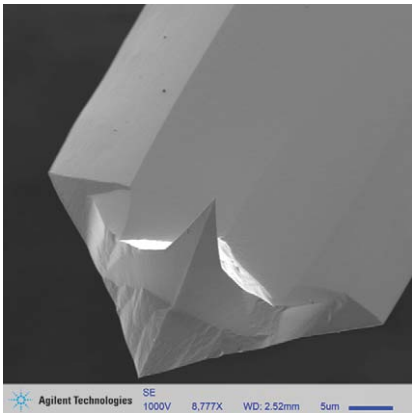
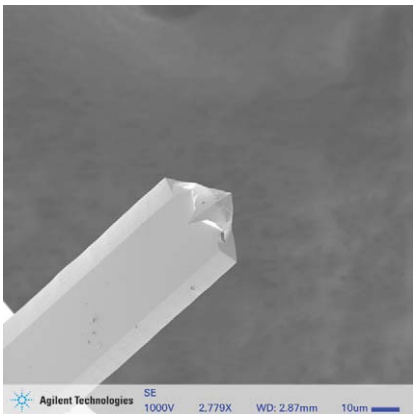


Figure 21.

8. Cantilever

The eighth type of cantilever, a specialty cantilever for electrical measurements.



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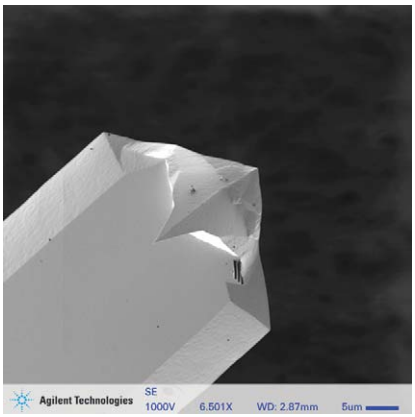

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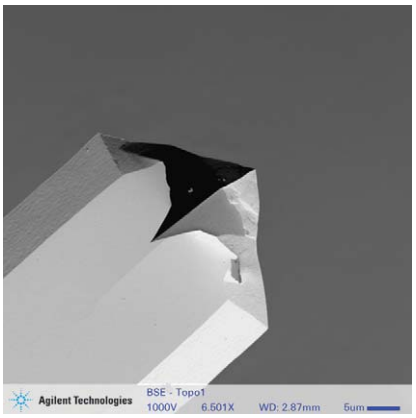

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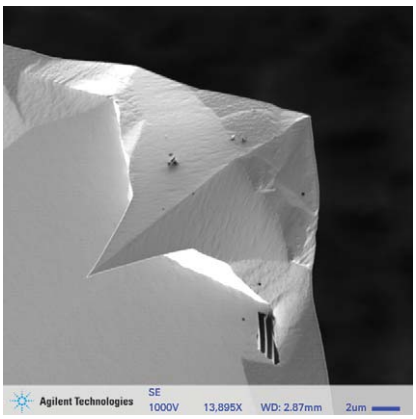

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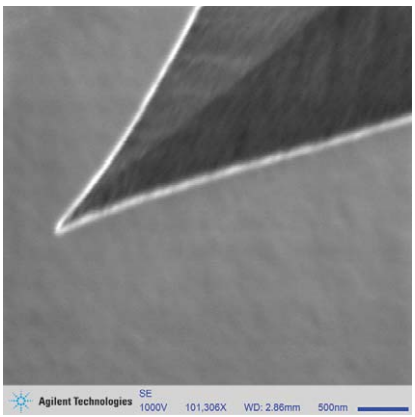
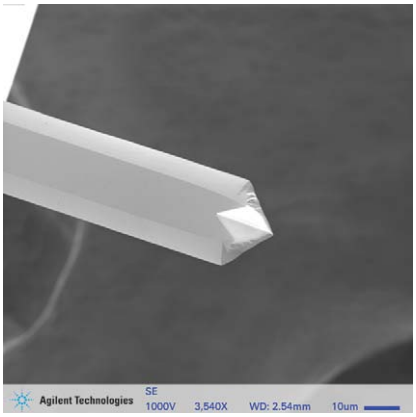


Figure 26.

9. Cantilever with Tip Wear

This cantilever is similar to the previous but shows tip wear after use.



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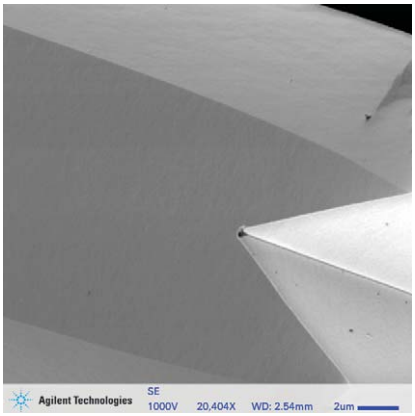

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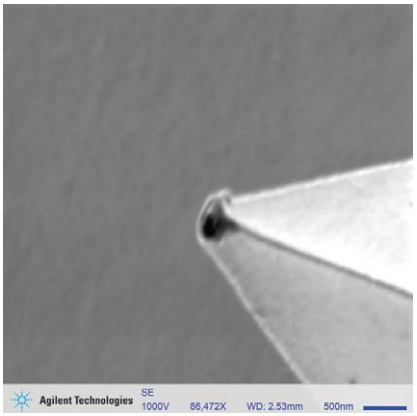
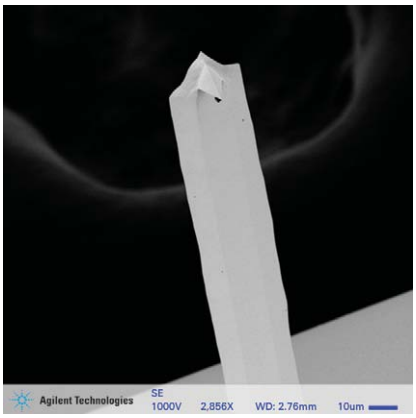


Figure 29.

10. Cantilever with Polymer Contamination on the Tip

This cantilever is similar to the ninth type of cantilever but shows polymer contamination on the tip as opposed to tip wear.



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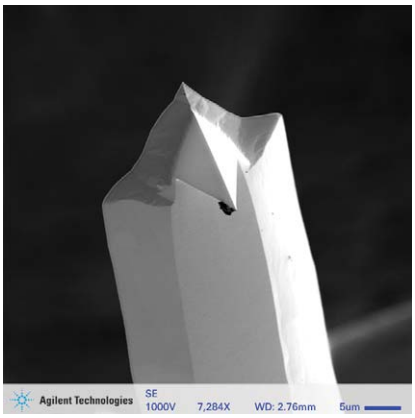


Figure 31.

Figure 32.

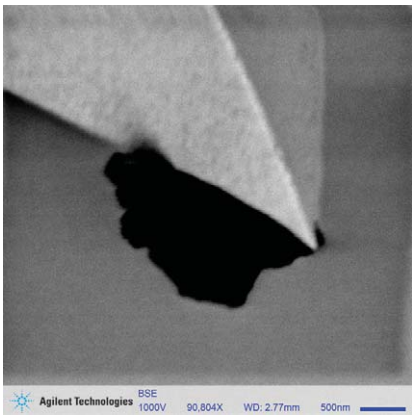
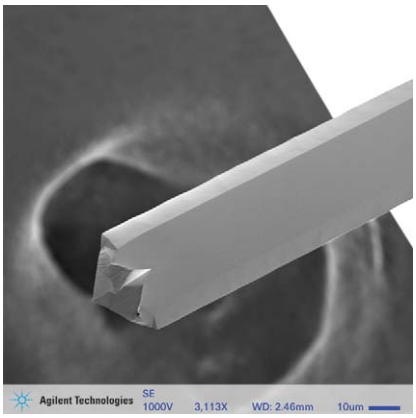


Figure 33.

Figure 34.

11. Cantilever with Conductive Tip

This type of cantilever has a unique conductive tip material.



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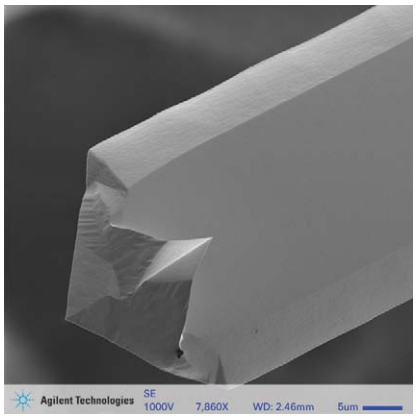

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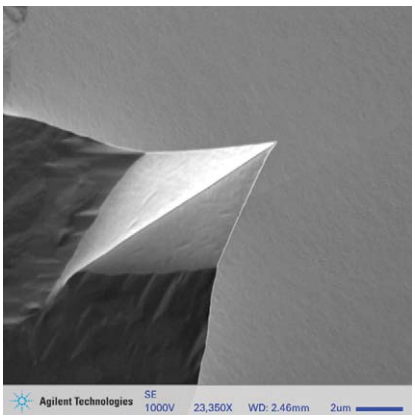

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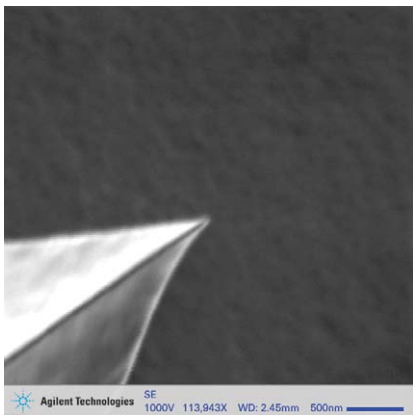

Figure 38.

Summary

Low voltage compact FE-SEM provides ease of use and a straightforward technique for high resolution imaging of AFM cantilevers. Although the application usage as well as the fabrication of the cantilevers examined spans many levels of sophistication in materials, design, and processing, the geometric and morphological features of interest and tip defects could easily be investigated with the Agilent 8500 FE-SEM.

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