Selecting a Probe Station Microscope and Lighting Method

Introduction

Lake Shore cryogenic probe stations are available in a wide range of models and capabilities. These instruments empower scientists and researchers to investigate a wide range of materials in extreme environments. An optical microscope provided with the probe station allows viewing and placement of the probe tips on the sample contacts. This note describes the selection of probe station microscope options available and briefly discusses factors researchers should consider when selecting a microscope option.

Microscope specifications will be reviewed and related to image quality. The selection of light source options will be examined, and guidelines based on sample surface properties will be presented. Finally, we will present a set of microscope and probe station dimensions with which users can develop their own optical interfaces.

For more information on general microscope operation and background material, see http://www.microscopy.fsu.edu/primer/index.html.

Microscope Options

Lake Shore offers four different microscopes for use on cryogenic probe stations. There are two different zoom options, each with two choices of lighting. Zoom is the ratio of the magnification change available for the microscope. The two available are Zoom 70 (7:1 ratio) and Zoom 160 (16:1 ratio). The two lighting options are a ring light (figure 1) or coaxial lighting (figure 2).

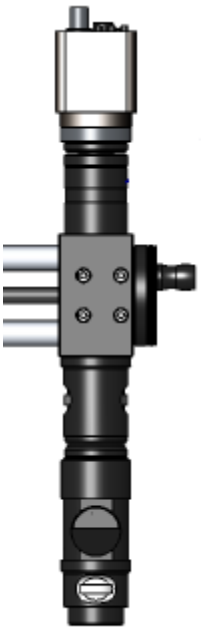

Figure 1 *Zoom 70 with ring lighting option*

Figure 2 *Zoom 160 with coaxial lighting option*

The working distance of a microscope is the distance from the last optical element to the focal plane. The microscope is outside the vacuum chamber of the probe station. The focal plane must be on the sample stage, so the working distance of the microscope must be large. The working distance for all probe stations except the horizontal field superconducting magnet probe station and the electromagnet probe station is 89 mm for coaxial lighting options. For the ring lighting options, the working distance is increased to 114 mm to accommodate the additional space needed to mount the ring light. For the horizontal field superconducting magnet probe station and the electromagnet probe station the working distance is increased to 181 mm for both lighting sources. This is necessary because of the increased chamber height of these two probe stations. The effect of the large working distance is the magnification limitation of the microscope. In the next section, the detailed specifications of the microscopes are summarized.

The coaxial light source is designed to illuminate the sample with light perpendicular to the sample. If the sample is highly reflective, nearly all the light reflects from the surface back into the microscope. Compare this to reflection from a diffuse surface. The light is reflected in all directions (the cosine law), and little of the reflected light finds its way back into the microscope. The light reflected from the diffuse surface is overwhelmed by the reflected light from the windows of the probe station. The image of diffuse surfaces with coaxial light source lacks contrast.

Just the opposite applies to the ring light. The light source is a ring mounted around the microscope. On highly reflective surfaces, the reflected light from the ring misses the microscope elements. The image of highly reflective surfaces is dark with the ring light. However, from diffuse surfaces, the scattered light reflects in all directions. The reflections from the windows mainly miss the microscope, giving good images of diffuse surfaces with the ring light. Use of the ring light on diffuse surfaces also gives shadows and a 3D image effect.

Each microscope is supplied with a CCD camera (which mounts on the microscope with a standard C mount) and monitor.

Microscope Specifications

The optical specification for each of the microscopes is summarized in figure 3. The magnification specification is the optical magnification of the microscope and does not include the magnification of the CCD camera. The field of view, numerical aperture, and depth of focus depend on the zoom setting of the microscope. The table lists the values at minimum magnification (zoom) and at maximum magnification (zoom). These variables vary continuously with the zoom from minimum zoom to maximum zoom.

For all models except CPX-HF, EMPX-HF, and FWPX										
Scope	WD (mm)	Minimum Magnification				Maximum Magnification				
		Magnification	Field of View (mm)	Numerical Aperture	Depth of Focus (mm)	Magnification	Field of View (mm)	Numerical Aperture	Depth of Focus (mm)	Resolution* (µm)
Z70-CL	89	1.5	2.4 × 3.2	0.024	0.95	10.5	0.34 × 0.45	0.08	0.085	4
Z70-RL	114	1.1	3.2 × 4.2	0.018	1.7	7.9	0.45 × 0.61	0.06	0.15	4
Z160-CL	89	1	3.6 × 4.8	0.009	6.8	16	0.22 × 0.30	0.15	0.024	4
Z160-RL	114	0.75	4.8 × 6.4	0.0068	12.1	12	0.30 × 0.40	0.11	0.043	4

For CPX-HF, EMPX-HF, and FWPX										
Scope	WD (mm)	Minimum Magnification				Maximum Magnification				
		Magnification	Field of View (mm)	Numerical Aperture	Depth of Focus (mm)	Magnification	Field of View (mm)	Numerical Aperture	Depth of Focus (mm)	Resolution* (µm)
Z70-CL	181	0.75	4.7 × 6.3	0.012	3.8	5.2	0.68 × 0.91	0.024	0.034	8
Z70-RL	181	0.75	4.7 × 6.3	0.012	3.8	5.2	0.68 × 0.91	0.024	0.034	8
Z160-CL	181	0.5	7.2 × 9.6	0.0045	27.1	8	0.45 × 0.60	0.076	0.1	8
Z160-RL	181	0.5	7.2 × 9.6	0.0045	27.1	8	0.45 × 0.60	0.076	0.1	8

**Typical — resolution is station configuration and operating condition-dependent*

Figure 3 *Summary of microscope specifications*

Highly Reflective Surface Images

The first example is a highly reflective surface of a magnetic tunnel junction. Figure 4 is the image through a zoom 70 microscope with coaxial lighting. The magnification is at the minimum value. The four gold circles are top side contacts. The diameters of the contacts are 100 µm, 50 µm, 25 µm and 10 µm.

Figure 5 is the same sample through a zoom 70 microscope with a ring light. Note that the image is much darker and the 10 µm contact is barely resolved. As the magnification is increased the lack of contrast of the topside contact gets worse.

NOTE: *Figure 4–7 images are best viewed in color. Color version available on www.lakeshore.com.*

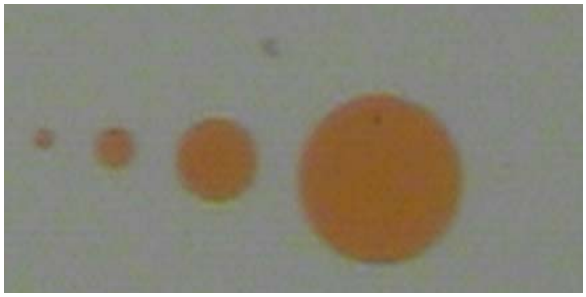

Figure 4 *Highly reflective surface through a zoom 70 with a coaxial light*

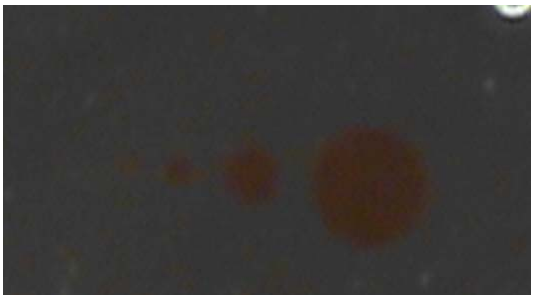

Figure 5 *Highly reflective surface through a zoom 70 with a ring light*

Diffuse Surface Images

Figure 6 is the image of a surface-mounted FET through a zoom 70 with a coaxial light. Figure 7 is the same FET with a ring light. Note that with the coaxial source the image lacks contrast and any color. With the ring light, the colors are rendered correctly with good contrast and shadows.

Figure 6

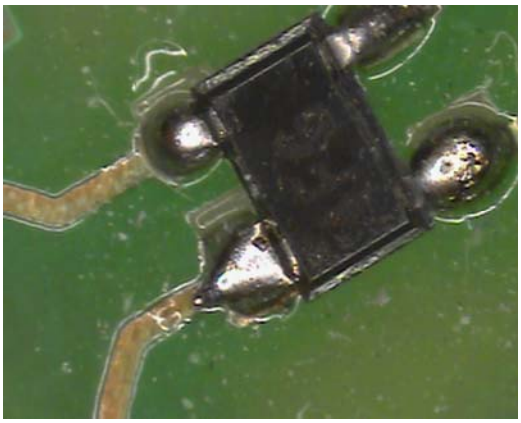

Figure 7

Resolution

The resolution of the microscope depends on a variety of parameters, including the vibrations of the probe station mounting, the exact microscope used, and the quality of the CCD camera, among others. Figure 8 is a picture of a USAF 1951 resolution test pattern showing groups 6 and 7. The spacing between the lines for group 6 runs from 7.3 µm to 4.3 µm. The spacing between the lines for groups 7 runs from 3.9 µm to 2.2 µm. This picture is through a zoom 70 at maximum zoom with a ring light. The resolution is about 4 µm. The pattern is a negative pattern (the lines are the glass region and between the lines is metal). Figure 9 is the same target using zoom 70 with a coaxial light. The resolution is about 3 µm. Figure 10 is the same target using a zoom 160 with a ring light. The resolution is about 4 µm. Figure 11 is the same target using a zoom 160 with a coaxial light. The resolution is about 2 µm.

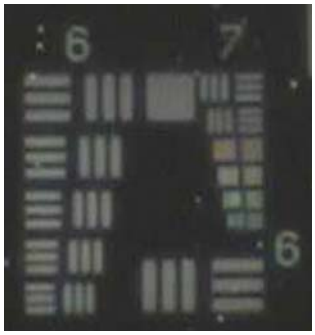

Figure 8 *USAF 1951 resolution test pattern showing groups 6 and 7 through a Z70 at maximum zoom with a ring light; the test pattern is a negative image*

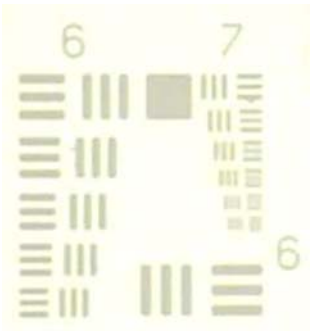

Figure 9 *USAF 1951 resolution test pattern showing groups 6 and 7 through a Z70 at maximum zoom with a coaxial light; the test pattern is a negative image.*

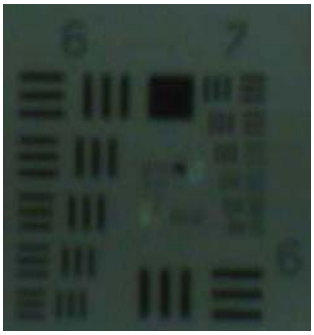

Figure 10 *USAF 1951 resolution test pattern showing groups 6 and 7 through a Z160 at maximum zoom with a ring light.*

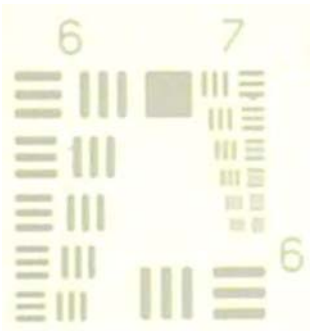

Figure 11 *USAF 1951 resolution test pattern showing groups 6 and 7 through a Z160 at maximum zoom with a coaxial light; the test pattern is a negative image*

Probe Station Dimensions

Figure 12 is a summary of the working height of the microscopes and the dimensions of the probe station chamber lid to sample stage. It may be helpful for researchers who want to design their own optical accessories.

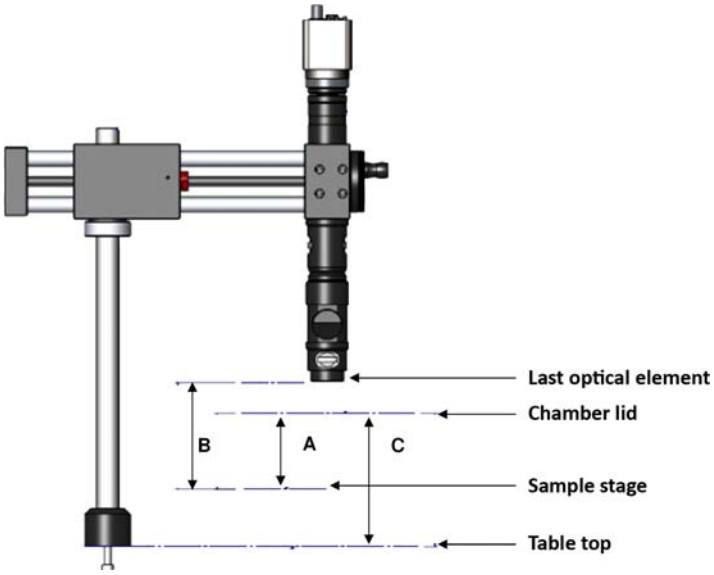

Figure 12

Scope	B — working distance (mm)	B — working distance (mm) HF
Z70-CL	89	181
Z70-RL	114	181
Z125-CL	89	181
Z125-RL	114	181
Z160-CI	89	181
Z160-RL	114	181

Model	A (mm)	C (mm)
TTPX	63	111
CPX	65	115
CPX-VF	82	131
CPX-HF	133	182
EMPX-HF	98	146
FWPX	99	181

Conclusion

This note has described the microscopes and options available for Lake Shore cryogenic probe stations. Guidelines and specifications for selecting a microscope and lighting options have been presented.

Acknowledgements

Lake Shore would like to thank Dr. John Xiao of the University of Delaware for providing the magnetic tunnel junction images used in this note.