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Guidance for Choosing When to Use Electron and/or Light Microscopy and Related ASTM E4 Standards

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Technical publications sometimes include scanning, or even, transmission electron images to characterize a microstructure, when the relevant structure could have very easily been illustrated using a simple light micrograph. When should one use a light generated image? What are the advantages/disadvantages of an electron-generated image? While there is some overlap in the capabilities of these imaging systems; in general, they are complimentary tools, each with their own uses. Standards under the jurisdiction of ASTM Committee E4 on Metallography offer guidance to both new and experienced users of both investigative techniques.

The most obvious and significant characteristic separating the two procedures is that of resolution. Based on the theories advanced by Rayleigh and Abbe, the resolvable separation between two objects in an image is known to be proportional to the wavelength of the image source. The harnessing of an electron beam, with its shorter wavelength, has made huge improvements in resolution allowing the illumination of matter on the atomic level [1]. However, resolution is not the only advantage of electron microscopy, and the improved resolution of electron microscopy does not make light microscopy obsolete.

The advantages of each imaging system, Table 1, will be addressed during the presentation. When approaching a new investigation, whether it is a failure analysis or material characterization, the investigator should employ the tools that will most efficiently achieve the goals of the project. Some different scenarios and uses for the two imaging systems will be presented. For example, when determining the volume percent pearlite in a steel sample, there is no need to employ electron microscopy, Figure 1. The volume percentage of pearlite can be determined more easily and quickly with a light microscope. Correspondingly, most fracture surfaces are more readily examined using a secondary electron image due to the superior depth of field of a scanning electron microscope. As will also be discussed in the presentation, many investigations will, ultimately, use both electron and light microscopy techniques in pursuing the goals of a particular study [2].

ASTM Committee E4 on metallography, which was created in 1916 in response to developments in the railroad and steel industry at the turn of the century, has the charge of ensuring that metallographic testing standards are kept current and of use to industry and academia. E4 has evolved into a Committee of approximately 140 members having jurisdiction over 35 standards covering sample preparation, etching, and quantitative methods for both light and electron microscopy. Table 2 lists the standards, under the jurisdiction of Committee E4, which apply to electron and light microscopy [3].

This presentation will offer some examples of investigations, in which, both electron and light microscopy were used and will offer guidance on why a particular imaging system was employed. The examples will also describe how the information available in metallographic standards under the jurisdiction of ASTM Committee E4 on Metallography facilitated the completion of these investigations.

References

[1] I. M. Watt, The Principles and Practice of Electron Microscopy, Cambridge University Press, Cambridge, 1985.
[2] G. F. Vander Voort, Metallography - Principles and Practices, McGraw Hill, New York, 1984.
[3] Annual Book of ASTM Standards, American Society for Testing and Materials International, Volume 03.01, W. Conshohocken, PA, 2002.
[4] The author would like to acknowledge Linford L. Hahn for his SEM images and expertise, and Richard L. Bodnar for his guidance and technical support for this presentation.

Table 1. Advantages of Imaging Sources

Electron Microscopy	**Light Microscopy**
Resolution	Relatively Easy Microstructural Characterization
Depth of Field	Ease and Accuracy of Calibration
Acquisition of Chemical Information	Larger area of sampling
Crystallographic Structure/Orientation Information	Facilitates Quantitative Metallography
Examination of as-received material	Cost of equipment
3D Appearance of Image	

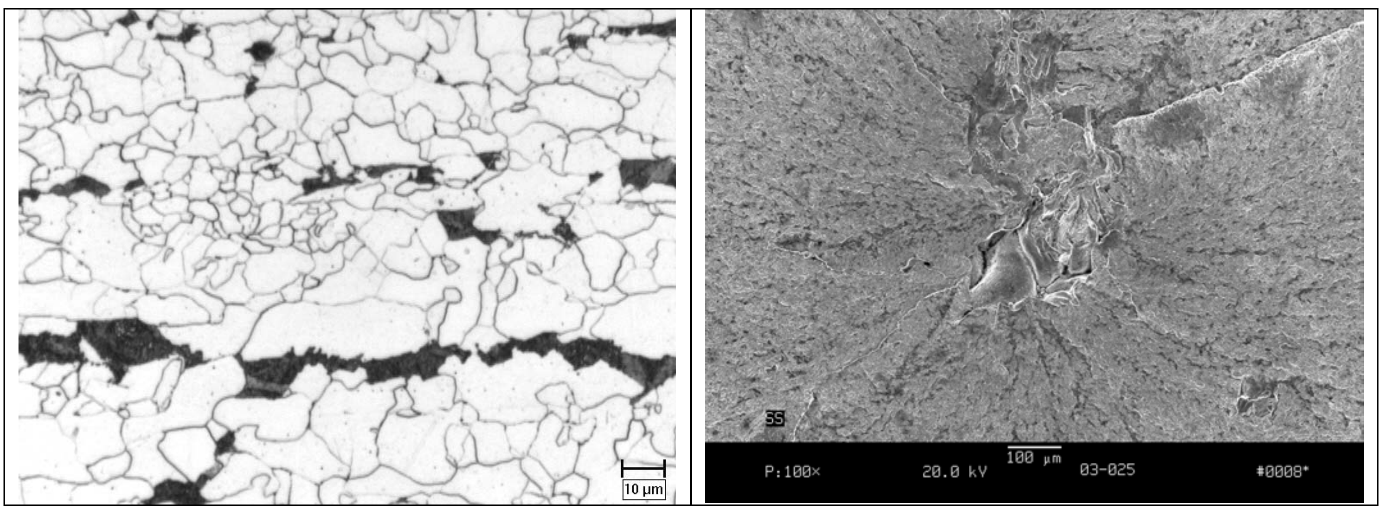

Fig. 1 Micrographs showing examples of the use of optimum imaging techniques.

Table 2. Pertinent ASTM standards.

Electron Microscopy	**Light Microscopy**
E1351 – Field Replicas	E3/E768/E1920/E2015 – Specimen Preparation
E766 – Calibrating SEM Magnifications	E407/E340/E381 – Specimen Etching
E986 – SEM Performance Characterization	E112/E1181/E1245/E930/E1382 – Grain Size
E1508 – EDS Quantitative Analysis	E45/E1122/E1245 – Evaluation of Inclusions
E2142 – Inclusion Ratings using SEM	E562/E2109 – Volume Fraction Determinations
	E1077/E1268 – Banding & Decarburization
	E1951 – Microscope Calibration

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