Metallographer's Guide

Practices and Procedures for Irons and Steels

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Micrographs on cover:

Top, left: Annealed AISI/SAE 1005 steel showing equiaxed ferrite grains photographed using dark field illumination. Marshall's etch. 200×

Top, right: Annealing twins in AISI 347H austenitic stainless steel photographed using differential interference contrast (Nomarski). Electrolytically etched in 60% nitric acid in water. 5 volts, stainless steel cathode. 500×

Bottom, left: Partially spheroidized AISI/SAE 1060 steel photographed using bright field illumination. 4% picral etch. 500×

Bottom, right: Lath martensite in austenitized and quenched AISI/SAE 1040 steel photographed using bright field illumination. Etched in 2% nital. 500×

To Joan and Sandy for their enduring patience and encouragement.

Contents

Preface

This guide was prepared not only for the beginning metallographer but also for the experienced metallographer who may be looking for alternatives and new approaches to metallographic practice. For the beginning metallographer, little or no knowledge of steels and cast irons is necessary since the first three chapters provide the basic information needed to understand the various types of steels and cast irons available in the commercial world. These chapters also provide examples of the multitude of microstructures that the metallographer will encounter, how these microstructures are created, and how they can be altered by heat treatment and other means. Some metallographers may be working in a small laboratory where no metallurgical support is available. The authors feel very strongly that to be effective, the metallographer must understand as much as possible about the metallurgy of the material he or she is preparing. Without this knowledge, the metallographer can offer little interpretation of the microstructure he or she develops even after applying the best metallographic practices. Also, without a proper background in recognizing metallographic constituents, he or she may produce an artifact through improper specimen preparation that will lead to a totally inappropriate result. Thus, it is important that the metallographer read the first three chapters to obtain a basic understanding of steel microstructures before proceeding to the metallographic techniques chapters.

As part of this guide, the authors felt that a metallographer should know some of the history of metallography. In this new century, we have come a long way from the early days of Sorby and Widmanstätten who pioneered what we now know as metallography of steels and cast irons a century and a half ago. Chapter 4 gives a brief history of these early metallographers and defines the identity of a metallographer by comparing the vast amount of information gained from a metallographic analysis to that produced from a chemical analysis. The chapter also describes the types of things that a metallographer will encounter in a typical workday in a large metallographic laboratory in the research department of a large steel company and a small metallography laboratory associated with an iron foundry. Actual metallographic tasks in both situations are described in detail. Chapter 6 discusses some of the tools that are available beyond the typical metallographic laboratory. In today's world, there has been an explosion in technology to aid the metallographer. Not only can one reveal the microstructural constituents in a steel or cast iron, but also one can determine the chemical analysis of each constituent even on a nanometer scale. To be effective, the metallographer must be familiar with the capabilities of these modern-day instruments.

Since this guide concentrates on light (optical) metallography, Chapter 5 has been added to describe in detail how a metallurgical microscope works. This is the instrument located in all metallographic laboratories. The metallographer must have an intimate knowledge of the microscope to use it properly. An understanding of the different types of oculars (eyepieces) and objectives is important so that the microstructure can be revealed in its truest form. Knowledge of the various types of illumination (bright field, dark field, interference contrast, etc.) is important to enhance the image of the microstructural features. The metallographer also must know how to maintain and clean the microscope to keep it in the best condition possible.

Specimen preparation procedures were saved for Chapters 7 and 8. The procedures presented in this guide have proven to work effectively to prepare the specimen. However, the authors recognize that other procedures also can work as effectively. This book guides the metallographer through the specimen preparation procedures in a step-by-step manner. Various options are offered, and preferred methods are described in detail. The authors provide a basic understanding of how and why the methods work. As the metallographer becomes more experienced, he or she may develop his or her own adaptations of the procedures presented here. This guide will get the metallographer started with a sound procedure that works.

A unique feature of this guide is a separate and complete index of the various steels and cast irons used as examples throughout the book. The index makes the hundreds of micrographs essentially an Atlas of Microstructures, and it precedes Chapter 1.

Although this book is for the novice metallographer, an experienced metallographer may find it useful in that dozens of special metallographic tips are scattered through the chapters on specimen preparation and the art of revealing microstructure. This guide could be used as a university or technical school text to accompany the teaching of a laboratory course in metallography.

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Atlas of Microstructures

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