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Metallographic Procedures and Analysis – A review

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Abstract

The purpose of this research is to give readers general insight in what metallography generally is, what are the metallographic preparation processes, and how to analyse the prepared specimens.

Keywords: metallography; metallographic specimens; metallographic structure

1. Introduction

Metallography is the study of the microstructure of various metals. To be more precise, it is a scientific discipline of observing chemical and atomic structure of those materials, and as such is crucial for determining product reliability.

Not only metals, but polymeric and ceramic materials can also be prepared using metallographic techniques, hence the terms plastography, ceramography, materialography, etc.

Steps for preparing metallographic specimen include a variety of operations, and some of them are: documentation, sectioning and cutting, mounting, planar grinding, rough polishing, final polishing, etching, etc.

1.1. Documentation

As previously mentioned, metallographic analysis is very valuable. If the analysis is properly conducted, it can provide a researcher with high quality control, and can serve as an investigative tool.

2. Metallographic Procedures

2.1. Sectioning and cutting

Most of the metallographic samples need to be sectioned for easier handling. The way of sectioning depends generally on the type of material, and so you can clearly differentiate abrasive cutting (metals), thin sectioning with a microtome (plastics), and diamond wafer cutting (ceramics).

These processes are mostly used in order to minimize the damage which could alter the microstructure of the material, and the analysis itself.

2.2. Mounting

This process protects the material's surface, fills voids in damaged (porous) materials, and improves handling of irregularly shaped samples. There are plenty of ways to conduct this operation, and all of them depend on the type of material that is being handled. So, there are: compression mounting used for metals, and castable mounting resins used for electronics or ceramics.

2.3. Planar grinding

This operation is mainly used to reduce the damage caused by previously done sectioning. Generally talking, this means reducing the size of the particles in such way that the surface of the material is ready for polishing. It goes without saying that, in this step, it is necessary to be cautious in order not to produce greater damage than the one caused by cutting.

2.4. Rough polishing

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The purpose of this process is to remove the damage caused by cutting and planar grinding. This is usually done using diamond abrasive because of its multiple smaller cutting edges which produce minimal surface damage. If done right, rough polishing serves as a reason to spend minimal amount of time on further (final) polishing.

2.5. Final polishing

Final polishing is used to remove the surface damage, and not the damage caused by cutting and/or planar grinding. If the damage from those two steps is not removed completely, the rough polishing should be repeated before moving on to the final polishing step.

2.6. Etching

The reason why etching is done is to optically enhance microstructural features of the material (grain size, phase features, etc.). The most common technique used is chemical etching, but other techniques include: molten salt, electrolytic etching, thermal etching, and plasma etching.

3. Metallographic analysis

The metallographic analysis provides the scientist with information about grain size, phase structure, solidification structure, etc. For example, Fig. 1 shows how the grain size of the tough pitch copper, while the Fig. 2 represents aluminum and titanium couple bonded by diffusion welding method.

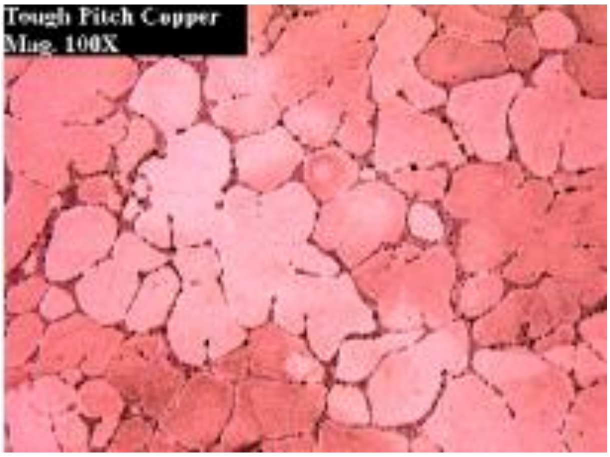

Figure 1. Tough pitch copper

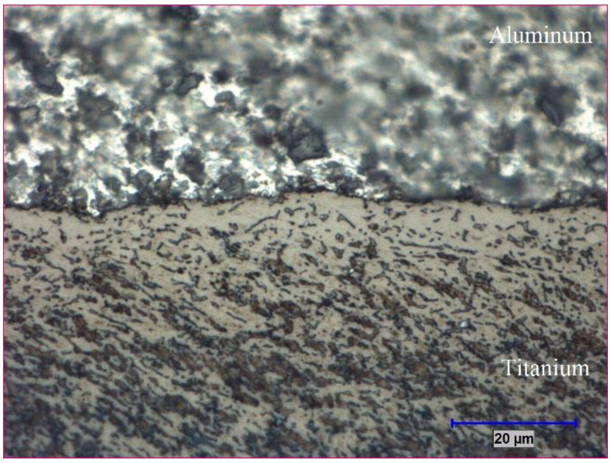

Figure 2. Aluminum-titanium diffusion couples

4. Microscopic analysis

The most common way of conducting the metallographic analysis.

4.1. Bright Field (BF) illumination

It counts as the most common illumination technique for metallographic analysis. The light path for BF illumination is from the source, through the objective lens, reflected off the surface, returning through the objective, and back the the eyepiece/camera. This way, non-flat surfaces (cracks, pores, etc.) appear darker compared to the flat surfaces which produce the bright background.

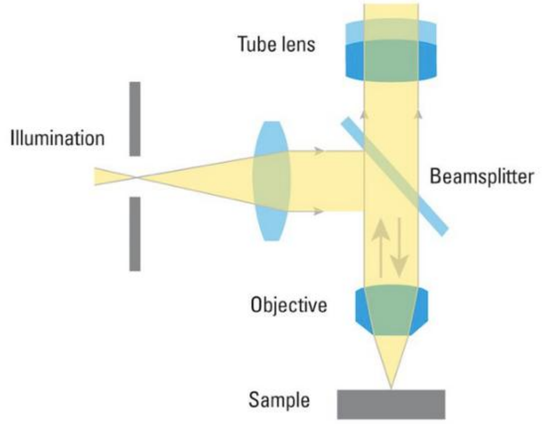

Figure 3. BF illumination

4.2. Dark Field (DF) illumination

This type of illumination is not as known as BF illumination, but nonetheless is a powerful illumination technique. The light path for the DF illumination is from the source, down the outside of the objective, reflected off the surface, returning through the objective, and back to the eyepiece/camera. What

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happens with this type of illumination is the exact opposite of the BF illumination, because here the flat surfaces serve as dark background to the non-flat surfaces which appear brighter.

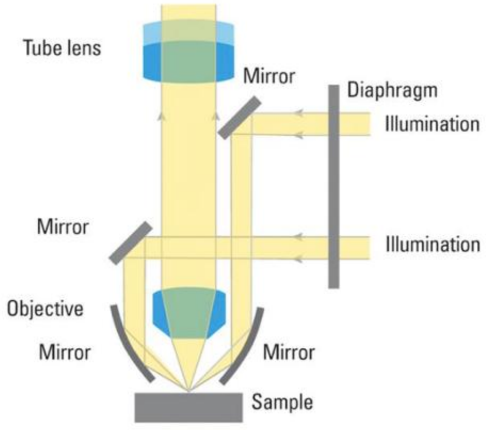

Figure 4. DF illumination

4.3. Differential Interference Contrast (DIC)

This type of microscopic analysis is also known as *Nomarski* Contrast. It helps to visualize small height differences on the surface of the observed material. The mentioned height differences are visible as variations in color and texture.

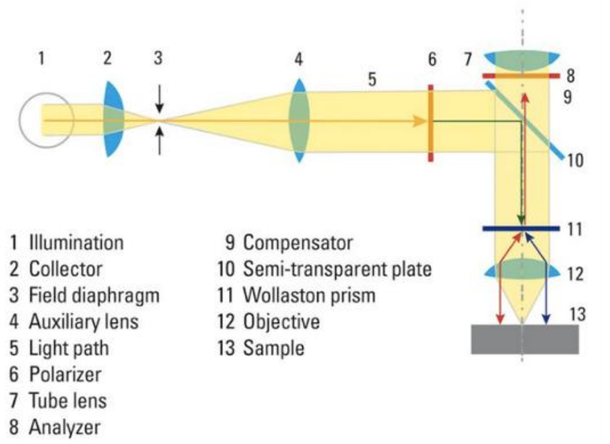

Figure 5. DIC

5. Hardness testing

This step provides the scientist with useful information which refer to the tensile strengtj, wear resistance, ductility and various other physical characteristics. Hardness testing is therefore very useful for monitoring quality control, and for the material selection process.

5.1. Microhardness

Microhardness is determined with Knopp hardness number (HK) and Vicker hardness number. It is used to determine the hardness of specific phases, small particles, etc.

5.2. Rockwell hardness (HR)

This type of harness is determined with a spheroconical penetrator (hard steel ball forced into the material surface).

6. Conclusions

Microstructural analysis is extremely important in today's day and age because materials such as metals, ceramics, polymers, and others are used to improve our everyday lives in terms of insuring reliability, safety, etc. In order to successfully conduct the microanalysis of the metallographic structures, it is necessary to do a proper specimen preparation. The key to the mentioned proper specimen preparation is knowing as much physical properties (hardness, fracture toughness, and other) of the observed material as possible. Generally, the point is to minimize the damage early in the microstructural preparation stage, and to follow the guidelines outlined in this paper with the goal of obtaining accurate results from the analysis.

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