Metallography—Imaging of topographical or microstructural features on polished or polished and etched surfaces of metals and other materials

Metallography—Versatile Technique Solves, Prevents Problems

Case 1
You-Call-We-Haul Pipe and Tube, a metal distributor, had just nailed down a great contract. They were to provide chrome-plated steel tubing to be used as trapeze bars for the Flying Fellinis. But there was a problem—tests of the tubing showed that the parts were too brittle. Not wanting to let the Fellinis down, You-Call-We-Haul looked for help.

Case 2
Seafront Sands Hotels had just completed a new oceanside resort. But, only weeks after the grand opening, a sun awning with a high-strength aluminum frame collapsed on a package tour group from Winnipeg. The dry cleaning bills to remove Mai Tai and Piña Colada from flowered shirts were staggering. Who will pay: the contractor, the aluminum supplier, or the architect?

Case 3
Scientists recently discovered that vampires can see themselves reflected in metal—even though they’re invisible in a glass mirror. Sensing new market opportunities, Magic Mirror Manufacturing started making steel mirrors for export to Transylvania. Trouble is, the electroplated nickel surface, intended to be as smooth as glass, looked like the face of the moon. What can be done?

Finding the solution to each of these somewhat whimsical problems will most likely involve metallography.

Metallography is a method of examining the underlying structure of a material—examining a prepared specimen with a microscope. Specimens are prepared by cutting, grinding, and polishing. Sometimes the polished surface is examined. In other cases the polished surface is etched with chemicals first to highlight certain features.

The most common type of metallography is optical metallography. Examination is done with an optical microscope at magnifications of 1500X and below.

A related technique, scanning electron microscopy, uses the scanning electron microscope to achieve higher magnifications. SEM is also useful in some cases because it allows chemical analysis of microstructural phases or other features.

A third process included in metallography is macroetching. In this process, specimens are not polished, but are deeply etched. They are then examined at very low magnification or with the unaided eye.
Using Metallography

Our three “cases” can serve to illustrate some of the uses of metallography.

In Case 1, material evaluation was needed. You-Call-We-Haul’s problem with brittle tubing sent them running to the nearest metallurgist. He promptly recommended metallography to evaluate the steel tubing to find out why it was too brittle.

After preparing the specimen by cutting, grinding, polishing, and etching, he began examination under the microscope. What he found was carburization on the outside surface of the tubing (See Figure A). The hardened carburized surface picked up hydrogen from the subsequent plating and the material cracked when loaded.

The carburization problem was eventually traced to improper control of the heat-treating process. By controlling the process and adding a baking step after plating, the brittleness problem was solved. The Fellinis were off and flying, and You-Call-We-Haul kept the contract.

In Case 2, failure analysis was required. The collapsed awning had been built with a high-strength aluminum frame, and should have been able to withstand any stresses placed on it in service. The metallurgical firm called in to determine the cause of the failure had to find out if the fault was in the material itself, the construction process, or the way the awning was used.

Choosing and Preparing a Metallography Specimen

The old saw, “You can’t get the right answers if you don’t ask the right questions,” applies to metallography. If you don’t choose and prepare the sample correctly, you can’t find out what you need to know.

How you choose the sample depends on what you are trying to find out. A material evaluation, for example, might call for samples from two or more different lots of the same material. A failure analysis of a cracked piece might require samples from the area of the crack itself, the region near the crack, and a control sample taken far from the crack. Quality assurance testing might mean using statistical techniques to tell you how often samples must be taken from the manufacturing line.

Once the samples are chosen, proper preparation begins. The objective of the preparation process, which can be lengthy, is to remove any surface damage to the material so that the underlying structures become clear. The typical preparation process has these steps:

**Cutting**—This is often done with a water-cooled abrasive, cut-off to minimize damage; although motorized band saws and even hand hacksaws are sometimes used.

**Grinding**—This is typically done with silicon carbide abrasive papers and water coolant. Successive steps using finer and finer abrasives remove any damage done in the previous step.

**Polishing**—Diamond and aluminum oxide are commonly used to polish the sample. Like grinding, a number of steps using finer and finer abrasives are completed.

**Etching**—Not all samples are etched. Those that require etching are treated with chemicals to bring out the details of the structure. A variety of chemicals are used, depending on the material and the structures to be studied.

Different techniques might be necessary if non-destructive testing is required. One technique uses cellulose acetate tape to “replicate” the microstructure. The piece to be examined is ground, polished, and etched in place. The surface is then “transferred” to the tape, which can be taken back to the laboratory for examination.
Metallographic examination of the frame members showed a pattern of cracks along the grain boundaries (See Figure B). This type of cracking indicated stress corrosion as the probable cause.

High-strength aluminum alloys are very susceptible to stress corrosion cracking, especially in environments of moist marine air. The architect who specified the high-strength alloy may have to dig deep to pay the cleaning bill.

In Case 3, the manufacturing process needed to be examined. Somewhere along the production line, Magic Mirror was doing something wrong. The plant metallurgist decided metallography could help determine just where on that production line the problem occurred.

Metallography quickly discovered not one, but two problems. First, the nickel plating was not uniform: it was thick in some areas and thin in others. Second, the underlying surface was found to be extremely porous (See Figure C).

Eventually, Magic Mirror found that a carbonitriding process, done before plating, caused the surface voids. Controlling that process eliminated the voids. This made sure that the plating solution was not trapped beneath the surface and eliminated the nonuniform plating problem. Now, the metal surface has no voids and the plating layer is uniform (See Figure D). The mirrors can be shipped.

**Gaining in Importance**

Even though metallography is an old science—it has been around for about 100 years now—it is becoming more and more important, in large part because of its versatility.

Metallography can predict the properties and performance of a material or process. It can also recreate the manufacturing and service history of a component or product.

If you have questions about metallography, please contact us at Engel Metallurgical. We'd be happy to tell you more about this useful and versatile process.

**Before the Fact or After the Fact?**

One of the advantages of metallography is its usefulness both before and after the fact—before the fact to predict the performance of a material or process; after the fact to reconstruct the manufacturing and use of a material.

In fact, in recent years, the ability of metallography to predict the performance of a material has become increasingly important because of new, high-performance metal alloys, ceramics, and composite materials. Metallography gives a method of predicting their performance in high-reliability applications before expensive and time-consuming prototype work begins.

After the fact, metallography finds extensive use in failure analysis. Some of the ways it is used are:

- Evaluating the properties of the component material
- Verifying the manufacturing and processing parameters
- Determining the failure mechanism
- Identifying local material discontinuities
- Reconstructing the failed part's service history
Recent Projects at Engel Metallurgical

★ Microstructure evaluation of wire used for implanted medical devices
★ Failure analysis of plumbing fittings
★ Metallurgical evaluation of heat-treated blades used in scraping tools
★ Failure analysis of 6-foot aluminum step ladder
★ Elevated temperature corrosion testing of medical implement
★ Strength analysis and reinforcement recommendations for a personnel lifting cage
★ Analysis of parts from a helicopter involved in a crash

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