Miscrostructural Analysis Of Ores Using USB and Metallurgical Microscopes

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***Abstract*— In this paper, Metallurgical and USB microscopes are used to analyze the microstructure of different materials. Examining the interior structures of samples—with an emphasis on grain boundaries and sizes—and talking about how these microstructures affect material properties are its main objectives. Important results show that material qualities like strength, toughness, ductility, hardness, and diffusion rates are strongly influenced by microstructure. The study emphasizes how using a variety of imaging techniques is essential to gaining a thorough grasp of material properties because each technique displays distinct microstructure features. Finally, the findings highlight the significance of microstructural analysis in the fields of materials theory and engineering.**

Keywords*— *Microstructure, Grain Boundaries, Metallurgical Microscope, Diffusion, Surface energy, Magnification

I. Introduction

Microstructure is the very small-scale structure of a material, defined as the structure of a prepared surface of material as revealed by an optical microscope that ranges between 1000-2000× magnification. The microstructure of ceramic materials can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, or wear resistance [1]. It might not seem like much, but from observation, a proper analysis of the tiny visible part of the surface of materials, under a microscope, reveals a lot about the nature of a given material. From the grain size to grain boundaries to defects and impurities. This experiment seeks to inspect and analyze the microstructure of some given materials using a metallurgical microscope and a USB microscope.

A. Objectives of the experiment:

This experiment seeks to inspect the internal structure (Microstructure) of the given samples using the metallurgical microscope and the USB microscope. Inspect the internal structure (Microstructure) of the given samples using the metallurgical microscope and the USB microscope. This experiment also seeks to determine the grain size and grain boundaries of the given samples and discuss the implications of microstructures on the materials properties.

B. Apparatus Used:

- Metallurgical microscope
- USB microscope
- 1 gram of Porous PDMS scaffolds
- 1 gram of PDMS coated with Ti-Au substrates
- 1 gram of PLA-PEG-Fe_3O_4 Nano particles
- Fossil Limestone sample
- PLA sample

C. Ores Used:

- Bauxite
- Banded iron formation
- Charcoal pyrite
- Dolomite
- Malachite
- Rhodonite
- Chrysocolla
- Pyrolusite
- Pyrite
- Cassiterite
- Hematite
- Sphalerite
- Magnetite
- Molybdenite
- Limonite

D. Hypothesis Made:

The USB optical microscope has a low magnification and does not clearly reveal the grain boundaries in the ores (Salem & Maher, 2022). USB optical microscope has a low magnification and does not clearly reveal the grain boundaries in the ores.

Coated PDMS would have more defined grain boundaries than uncoated PDMS. Materials with rougher surfaces are more wettable. Materials with rougher surfaces have less surface energy.

II. PROCEEDURE: IMAGING WITH THE USB MICROSCOPE

The sample stage was cleaned to remove dust and foreign materials that would interfere with a clean viewing of the specimen. The USB microscope as seen in Figure 1 was connected to a laptop, and the camera application was opened and reversed to view the sample. The microscope was adjusted until the best focus was obtained using the micrometer calibration ruler. The images were captured using the camera application and saved. The images were later studied and analyzed for grain formations, and any further microstructural analysis. The images studied include all the ores and specimen mentioned in section IV "Ores used".

Figure 1: A picture of the USB microscope

A. Imaging with the metallurgical microscope

Place the sample on the sample state and turn the head to focus the illuminator on the specimen. Turn the focus control till a clear image is observed on the screen. Take a picture of the image for further analysis. The procedure can be seen in figure 2 below.

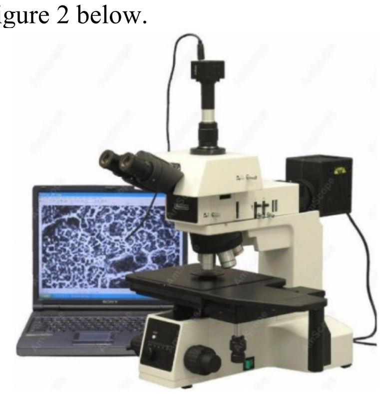

Figure 2: A picture of the metallurgical microscope set up

III. ANALYSIS OF RESULTS:

Generally, the USB microscope gave a clearer structural make up, showing the colors of each ore, but didn't reveal the crystallography and grain boundaries in the various ores. However, the grains were irregularly shaped. The Cassiterite, Sphalerite, Pyrite and Magnetite ores were easy to image under the microscope as seen in figure 3 and Figure 4. This is as a result of the visibility of the grain boundaries in the ores. The Sphalerite's porosity was revealed through the USB microscope.

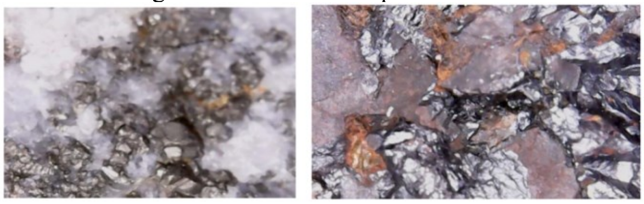

Figure 3: USB microscopic shot of the pyrite and magnetite ores on the left and right sides respectively.

Figure 4: USB microscopic shots of the cassiterite and sphalerite ores on the left and right sides respectively

A. Analysis on Viewing the Various Microstructures

Other structures apart from the coated PDMS such as porous PDMS were difficult to view on the metallurgical microscope because they did not have visible or clear grain boundaries compared to the PDMS coated with Ti-Au. The Ti-Au coating on the PDMS helps make the boundaries more visible since it is a metallic coating.

The metallurgic microscope works on the principle of reflection of light. "Metallurgical microscope is the optical microscope, differing from other microscopes in the method of the specimen illumination. Since metals are opaque substances, they must be illuminated by frontal lighting, therefore the source of light is located within the microscope tube. This is achieved by plain glass reflector, installed in the tube" [2]. The microscope picks up reflection from the metallic coating and this is what makes it more visible under the metallurgical microscope.

B. Comparison of Image Resolution Under Metallurgical Microscope and USB Microscope:

The metallurgical microscope and the USB microscope had a wide difference in magnification and as such, produced two completely different types of images. An example is shown below in figure 5 as a difference in picture quality taken of PLA mixed with magnetite, with the USB microscope picture on the right.

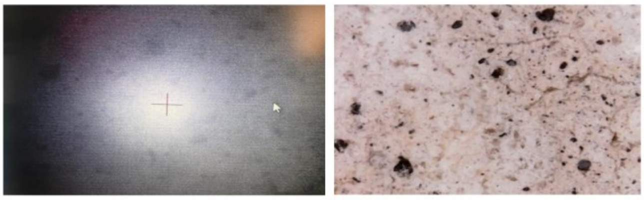

Figure 5: mages of PLA with magnetite viewed under the metallurgical and USB microscopes on the left and right sides respectively

C. Effects of Microstructures on Diffusion of Substances

According to Fick's Law [3] the net flux of atoms is given as :

$$J = -D\frac{d_x}{d_c}$$

Where, D is the diffusion coefficient and dx/dc is the concentration gradient of atoms, or atoms per cm3 . As such, a positive flux means that more atoms move or diffuse through the given substance and a negative flux means less atoms move or diffuse through the given material.

Through observations, the fossil limestone looked like it had a leaf-like microstructure and is a sedimentary rock, as seen in figure 6. Therefore, it will have a more positive flux due to a lower atomic concentration gradient. Porous PDMS, as the name suggests, will have a positive flux, meaning more materials will diffuse through it due to its porous nature. The coated PDMS will have a highly negative flux due to the formation of solid grains and grain boundaries, as seen in figure 7. This shows that the coated PDMS has a high atomic concentration gradient, and as such will have a more negative flux.

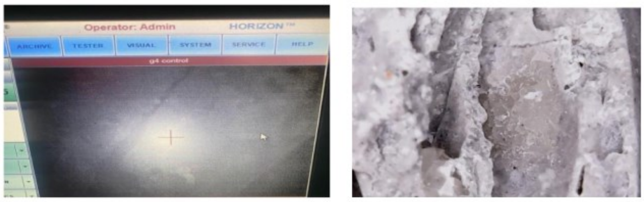

Figure 6: Images of fossil limestone viewed under the metallurgical and USB microscopes on the left and right sides respectively

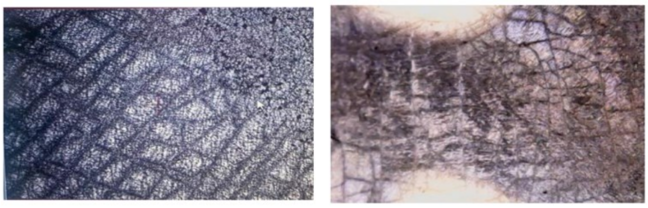

Figure 7: Images of PDMS coated with Ti and Au viewed under the metallurgical and USB microscopes on the left and right sides respectively

PLA will have a moderate concentration gradient of atoms due to the absence of visible grains and grain boundaries, as shown in Figure 8. This shows that the material has not formed any grains yet and the atoms are fairly dispersed in the material. As such, the atomic concentration gradient will not be high, meaning diffusion can take place through it.

Figure 8: Images of PLA viewed under the metallurgical and USB microscopes on the left and right sides respectively

For the PLA with magnetite, the grains are starting to form a bit but are not that visible or solid to create any grain boundaries, as shown in figure 5. As such, materials can diffuse through it fairly, but it will be more resistant to diffusion than the raw PLA.

D. IV. Comparison Between Images Under Metallurgical Microscope and USB Microscope

Metallurgical Microscope	USB Microscope
Captured images are blurry	Captured images are clear
Captured images are in black and white	Captured images are colored
Microstructural components and grain boundaries are less visible	Microstructural components and grain boundaries are more visible
Shows clearer images for Metals and reflective surfaces only	Shows clear images for all materials
Images are shown using a plain glass reflector	Images are shown using a camera lens

The samples in figure 7 were visible under both microscopes because of the metallic coating upon the PDMS sample. The metallic coating has very visible grain boundaries. The formation of these visible grain boundaries, and the metal coating make the sample easily visible under both microscopes. This is because the metallurgical microscope works on the principle of light reflection and shows clearer views on opaque materials which reflect light incidents on them.

The USB microscope works on the principle of light reflection also but has a very sensitive camera lens which picks up reflected light rays and brings up a clear image. On the other hand, samples with less visible grain boundaries and with poor refractive indexes looked quite blurry on the metallurgical microscope since the materials absorbed most light instead of reflecting it. Also, those materials remained clearer on the USB microscope due to the sensitive camera lens of the USB microscope. The rock samples had clear images under the USB optical microscope due to their highly defined edges and shiny surface.

E. The Need for Different Imaging Techniques for Different Samples.

The USB optical microscope produced clearer images of boundaries in ores and other samples. However, the metallurgic microscope produced images with far more detail and magnification than the optical microscope allowing us to see finer images of the grains themselves.

Therefore, from this discovery, it is therefore imperative that one uses both imaging techniques to see and study what images tell at specific levels of organization within structures of samples. The optical microscope was helpful in helping us picture and interpret boundaries in microstructures for each sample and the metallurgic microscope helped us further study the grains int the microstructures. As engineers, we must therefore use modalities (different types) to gather the right images for studying microstructures of samples for examination in order to paint the full picture of what sample is being studied, because the features observed at each level help determine the properties of the sample being observed and further lead to more accurate conclusions being drawn.

F. Effect of Microstructures on Cell Surface Interactions

The polymers with more grain boundaries on the surfaces have lower bonding energy and therefore less cell-surface interactions. PDMS coated with Ti-Au has distinct grain boundaries that would limit cell-surface interactions [4].

G. Effect of the Surfaces on Wettability or Surface Energy

The surface energy of polymers is dependent on the bonds present on the surface of the polymer. Microstructures with rough surfaces generally have lower surface energy. Due to this characteristic, they have more wettable surfaces as the adhesive forces between the liquids and the polymeric surfaces tend to increase. For higher surface energy in polymeric materials, wettability is reduced as the cohesive forces between the surfaces outweigh the adhesive forces between the liquids and the polymeric surfaces.

H. Comparison Between Images Obtained From the USB Microscope and the Metallurgical Microscope for the Different Sample.

Porous PDMS appear under the metallurgical microscope as scattered leaf-like structures that are not very visible. Under the UDB microscope, the microstructure is more visible and appears as closely packed layers. The fossil limestone, PLA, PLA with magnetite is more visible under the USB microscope compared to the metallurgical microscope. PDMS coated with Ti-Au is more visible under the metallurgical microscope with well-defined grain boundaries forming square-like structures. The same structure is observed under the USB microscope but with less defined grain boundaries.

IV. Conclusion

From this experiment, it is observed that the microstructure of materials is a huge determining factor on many material properties. Material microstructure strongly influences diffusion rate, ductility, hardness, toughness, and strength of the material. The metallurgical microscope and the USB microscope also provide different images because they work and operate on different principles.

Metals provide a better image quality under the metallurgical microscope due to their high refractive index and produce good results under the USB microscope but reflect some light back into the microscope camera lens. On the other hand, the USB microscope produces well-rounded images due to its sensitive camera lens.

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