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SOME CHALLENGES IN MEASURING THE MICROHARDNESS OF METALLIC GLASSES

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ABSTRACT
Measuring the material's microhardness is generally easy and quick. However, since the operator reads the dimensions, i.e., the ends of the imprint formed in the material, the measurement result is greatly influenced by the operator's assessment.
We present the research results in which three operators measured Vickers microhardness on the same impression by reading the dimensions in two ways: on the instrument's eyepiece and using a CCD camera connected to a computer. Three samples of metallic glasses from the same system, with similar properties but significantly different thicknesses (approximately 20, 50, and 90 μm), were used. We made 20 impressions on each sample and compared and discussed the results.

1. INTRODUCTION

The (micro)hardness of the material (*Hv*) is generally defined as the ability of the material to resist plastic deformation due to the action of some force on it [1]. It is measured by loading a known force into the material for a certain time and calculating *Hv* from the dimensions of the resulting impression. When measuring *Hv*, several things should be considered that can introduce errors into the result, namely: precision, operator's experience, choosing the appropriate force, etc [2]. A special challenge for measuring *Hv* is thin materials because care must be taken that the indenter does not penetrate deeper than 2/3 of the thickness of the tested sample, and therefore low indentation forces are used [3]. Metallic glasses are disordered, metastable and usually thin materials. If they are produced by melt spinning technique, they are in the form of a ribbon with a width of approximately 1 mm and a thickness of several tens of micrometers.

We have previously researched and published results on how to optimize the *Hv* measurement process on these materials [4]. We continue the research using the same samples, but examine how much the precision and accuracy of the *Hv* measurement are affected by the experimental setup which uses a Charge-Coupled Device (CCD camera) connected to the *Hv* measuring device and a computer.

Usually, the operator marks the impression left by a loading force on the sample using the device's eyepiece and measures its dimensions. Based on these measurements, *Hv* is displayed on the device's screen. If a CCD camera is used, the operator measures the dimensions of the impression on a computer monitor. The use of a CCD camera, along with a

computer and the necessary software, represents an upgrade to the basic instrument, and these upgrades can often be even more expensive than the original device itself.
Finally, it is important to emphasize that measuring *Hv* is a subjective method since it depends heavily on the judgment and skills of the operator performing the measurement. We will discuss this.

2. EXPERIMENT

Three samples of metallic glasses from the CuZrAl system are used for the measurement. Their structural, thermal, and electrical properties have been previously determined [5,6]. The notation and approximate thicknesses of the samples are given in the table 1.

Table 1. Notation and thickness of the samples

Sample	Thickness (μm)
A	90
B	50
C	20

The measuring system consists of a Vickers hardness tester model DHV-1000Z equipped with a diamond pyramid with an angle of 136° as an intender, a 1.3-million-pixel CCD camera, a computer and software. The setup is shown in Figure 1.

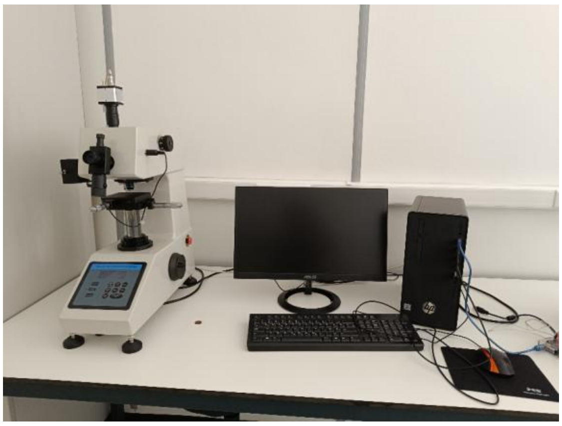

Figure 1. Experimental setup

The measurements were performed by three operators, designated as 1, 2, and 3, who had undergone identical training.
The measurement procedure was:

- On the platform of the device, a sample of metallic glass was placed, previously glued to the microscope slide.
- The measurement was conducted by applying a loading force of 0.00981 N for 10 seconds.
- All operators measured the same impression on the eyepiece and recorded the results displayed on the device screen.
- Then, on the same impression, all operators determined *Hv* using the software and the image on the computer monitor obtained by the CCD camera.
- The measurement was done in another place of the same sample, and the whole previous procedure was repeated.
- A total of 20 measurements were taken for each sample.

3. RESULTS

Figure 2 illustrates a typical display that the operator sees on the computer monitor via the CCD camera (a) and through the device's eyepiece (b).

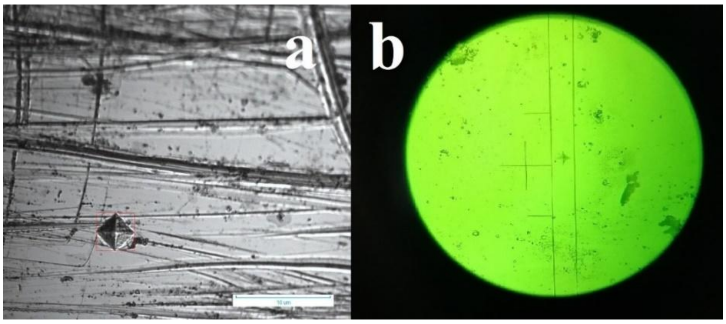

Figure 2. Typical impression (a) with CCD camera, (b) on the eyepiece without CCD camera.

All measurement results are shown in Figure 3. We calculated the mean values and mean absolute errors for each sample and each operator, including both procedures with and without a CCD camera.

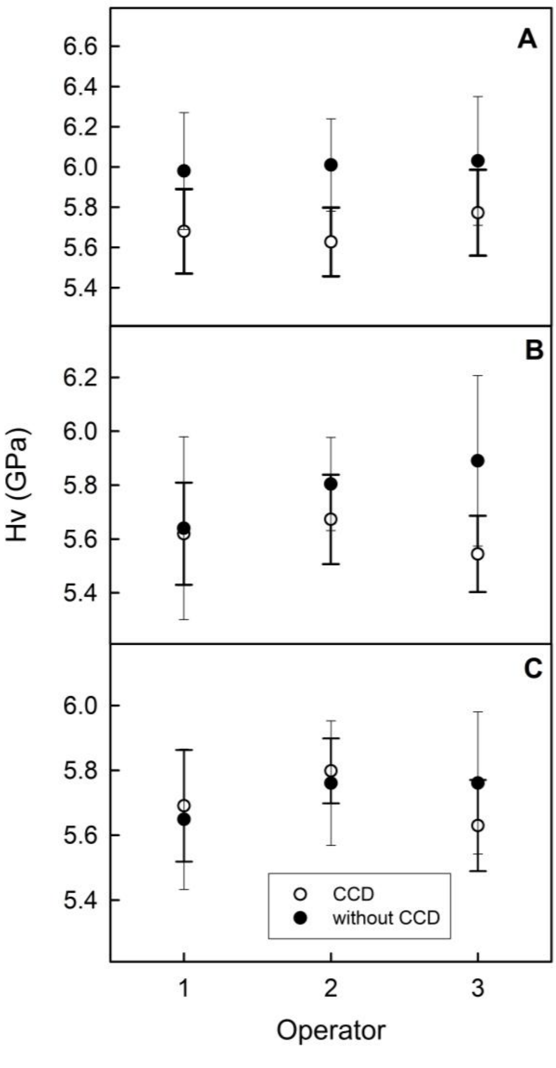

Figure 3. Results of Hv including mean values and mean absolute errors represented as error bars.

4. DISCUSSION AND CONCLUSION

After conducting the research and analyzing the results, we can draw several conclusions.

- In general, slightly higher mean values and mean absolute errors of *Hv* are observed when measurements are taken without the CCD camera. This outcome is anticipated. Figure 2 clearly shows that the magnification of the impression is higher when a CCD camera is used, resulting in improved accuracy for measuring its dimensions. However, the mutual deviations between the mean values obtained with and without the CCD camera do not exceed 10%. The relative measurement errors range from 5% to 10%.
- Significant differences between the samples were not observed.
- Additionally, the operators demonstrated consistent performance, with their errors being relatively similar.
- The key conclusion is that with careful measurement, comparable results can be achieved both with and without a CCD camera. This suggests that the use of such an expensive accessory is not always mandatory.

5. ACKNOWLEDGMENTS

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