NANOVEA

METALLURGY STUDY OF MULTIPHASE MATERIAL

USING NANOINDENTATION

Prepared by

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INTRODUCTION

Metallurgy studies the physical and chemical behavior of metallic elements, as well as their intermetallic compounds and alloys. Metals that undergo working processes, such as casting, forging, rolling, extrusion and machining, experience changes in their phases, microstructure and texture. These changes result in varied physical properties including hardness, strength, toughness, ductility, and wear resistance of the material. Metallography is often applied to learn the formation mechanism of such specific phases, microstructure and texture.

IMPORTANCE OF LOCAL MECHANICAL PROPERTIES FOR MATERIALS DESIGN

Advanced materials often have multiple phases in a special microstructure and texture to achieve desired mechanical properties for target applications in industrial practice. Nanoindentation is widely applied to measure the mechanical behaviors of materials at small scales[i] [ii]. However, it is challenging and time-consuming to precisely select specific locations for indentation in a very small area. A reliable and user-friendly procedure of nanoindentation testing is in demand to determine the mechanical properties of different phases of a material with high precision and timely measurements.

MEASUREMENT OBJECTIVE

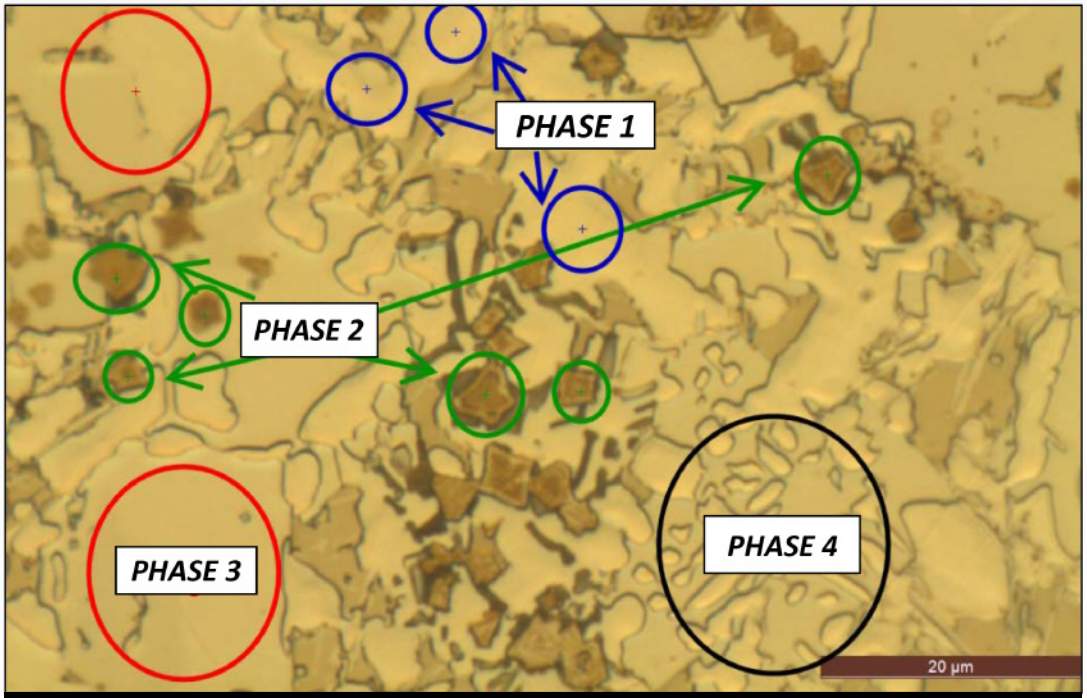
*In this application, we measure mechanical properties of a multiphase metallurgical sample using the Most Powerful Mechanical Tester: the **NANOVEA** PB1000.*

Here, we showcase the capacity of the PB1000 in performing nanoindentation measurements on multiple phases (grains) of a large sample surface with high precision and user friendliness using our Advanced Position Controller.

NANOVEA
PB1000

TEST CONDITIONS

In this study, we use a metallurgical sample with different phases. The sample had been polished to a mirror-like surface finish before the indentation tests. Four phases have been identified in the sample, namely ***PHASE 1***, ***PHASE 2***, ***PHASE 3*** and ***PHASE 4*** as shown below.



METALLOGRAPH UNDER THE OPTICAL MICROSCOPE

The patented ***Advanced Stage Controller*** is an intuitive sample navigation tool which automatically adjusts the speed of sample movement under the optical microscope based on position of the mouse. The further the mouse is away from the center of field of view, the faster the stage moves toward the mouse's direction. This provides a user-friendly method to navigate the entire sample surface and select the intended location for mechanical testing. The coordinates of the test locations are saved and numbered, along with individual test setup, such as loads, loading/unloading rate, number of tests in a map, etc. Such a test procedure allows users to examine a large sample surface for specific areas of interest for indentation and perform all the indentation tests at different locations in one time, making it an ideal tool for mechanical testing of metallurgical sample with different phases.

In this study, we use a metallurgical sample with multiple phases. The sample had been polished to a mirror-like surface finish before the indentation tests. Four phases have been identified in the sample, namely ***PHASE 1***, ***PHASE 2***, ***PHASE 3*** and ***PHASE 4*** as shown below.

TEST CONDITIONS

of the nanoindentation

MAXIMUM FORCE ..... 50 mN
LOADING RATE ..... 100 mN/min
UNLOADING RATE ..... 100 mN/min
CREEP ..... 5.0 s
COMPUTATION METHOD ..... ASTM E-2546 & Oliver & Pharr
INDENTER TYPE ..... Berkovich

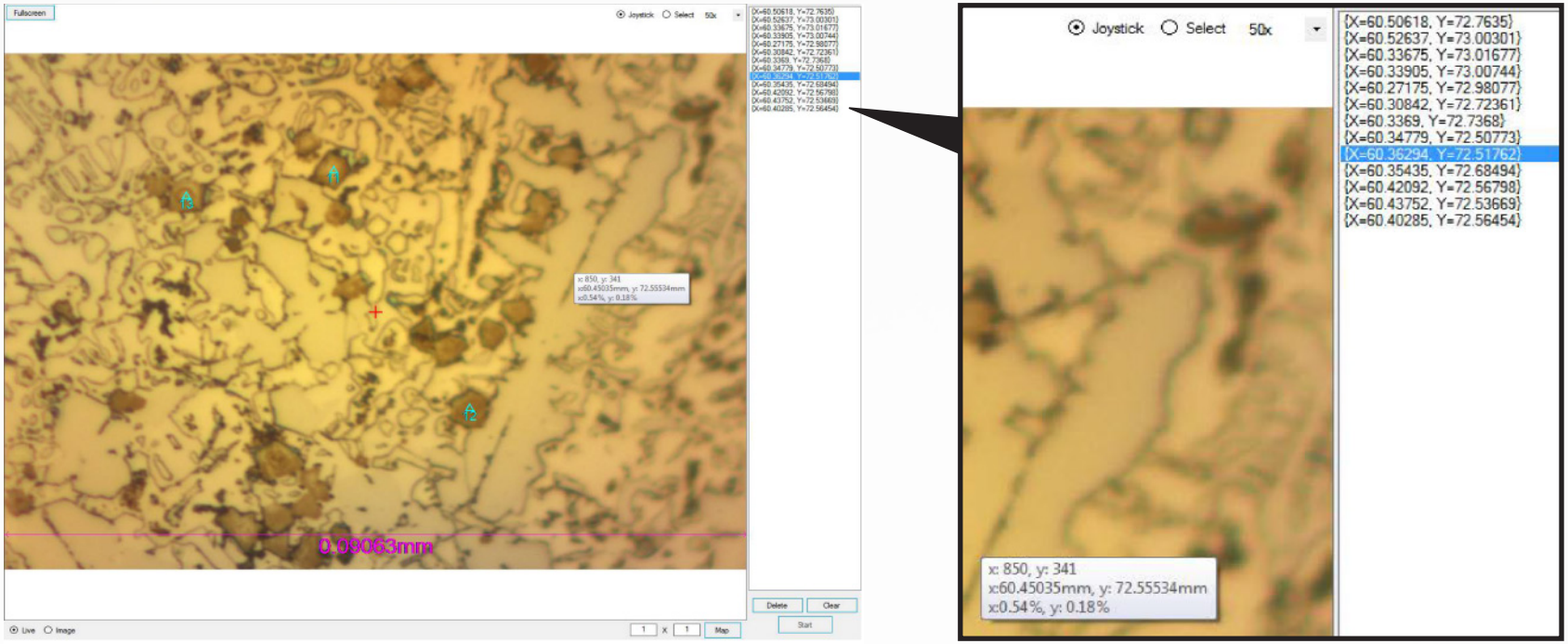
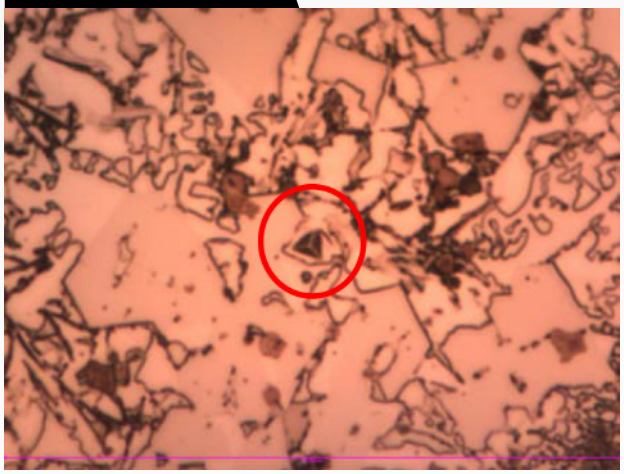


FIGURE 1: SELECTING NANOINDENTATION LOCATION ON THE SAMPLE SURFACE.

RESULTS: NANOINDENTATIONS ON DIFFERENT PHASES

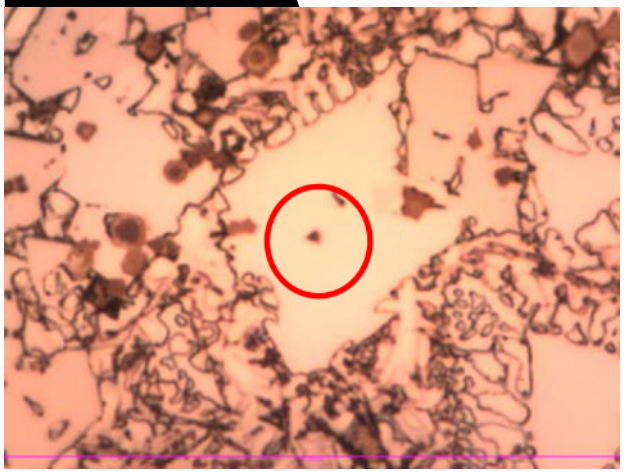
The indentations at the different phases of the sample are displayed below. We demonstrate that the excellent position control of the sample stage in the ***NANOVEA*** Mechanical Tester allows users to precisely pinpoint the target location for mechanical properties testing.

PHASE 1

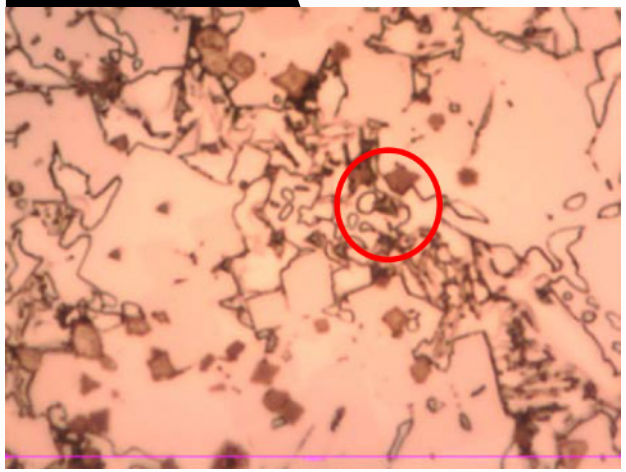


PHASE 2

PHASE 3



PHASE 4



The representative load-displacement curves of the indentations are shown in ***FIGURE 2***, and the corresponding hardness and Young's Modulus calculated using Oliver and Pharr Method[iii] are summarized and compared in ***FIGURE 3***.

The ***PHASES 1, 2, 3*** and ***4*** possess an average hardness of ~5.4, 19.6, 16.2 and 7.2 GPa, respectively. The relatively small size for ***PHASES 2*** contributes to its higher standard deviation of the hardness and Young's Modulus values.

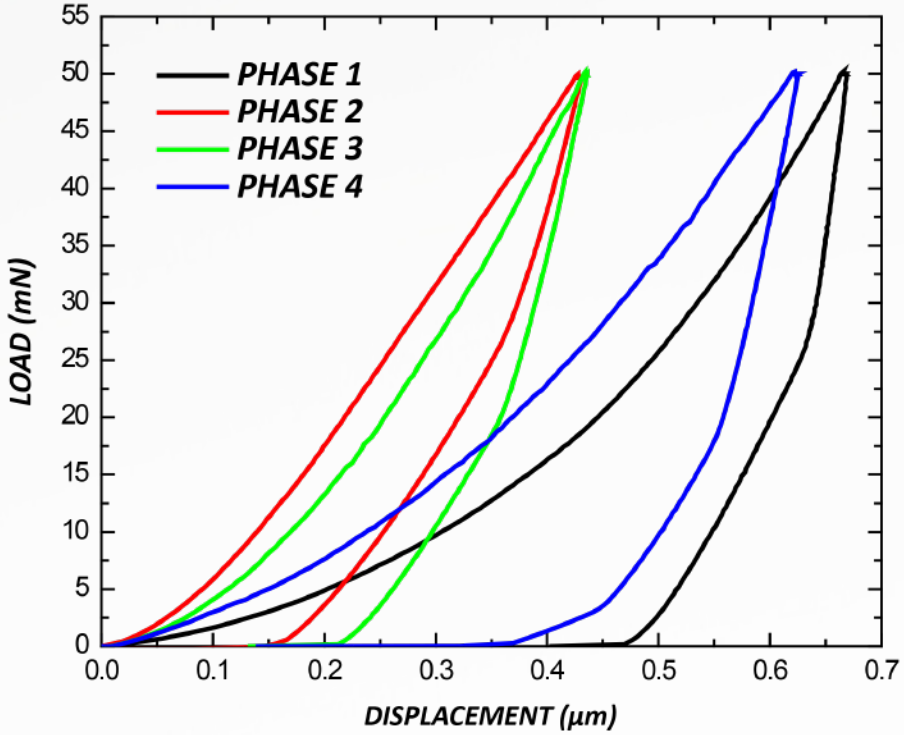


FIGURE 2. ***LOAD-DISPLACEMENT CURVES OF THE NANOINDENTATIONS***

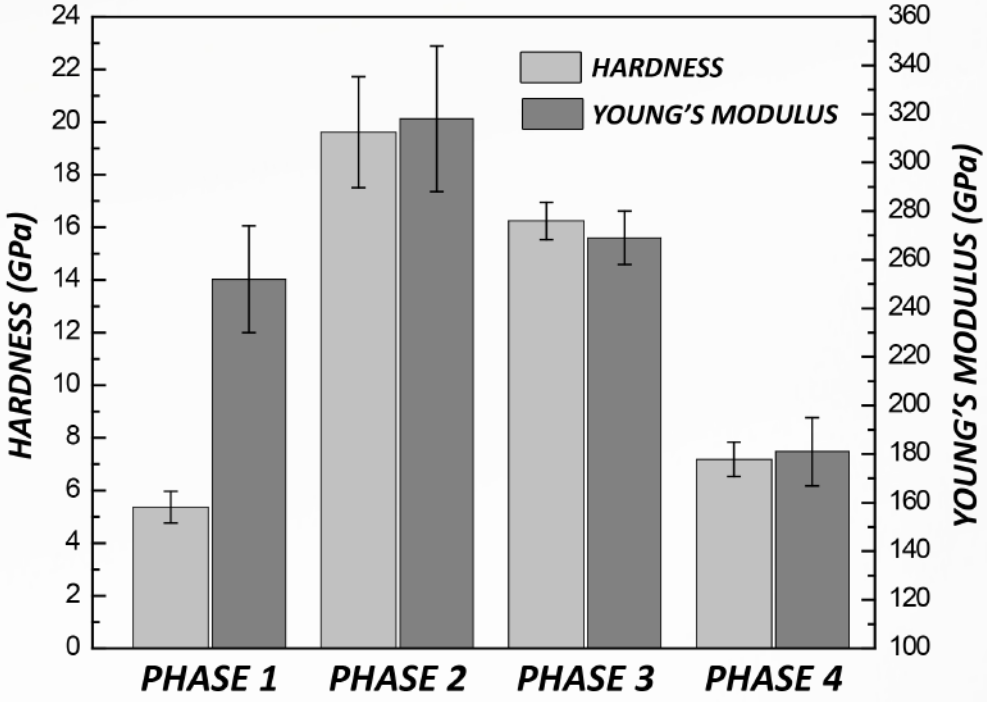


FIGURE 3. ***HARDNESS & YOUNG'S MODULUS OF DIFFERENT PHASES***

CONCLUSION

In this study, we showcased ***NANOVEA*** Mechanical Tester performing nanoindentation measurements on multiple phases of a large metallurgical sample using patented ***Advanced Stage Controller***. The precise position control allows users to easily navigate a large sample surface and directly select the areas of interest for nanoindentation measurements.

The location coordinates for the indentations are saved and all the indentation tests are performed at once. Such a test procedure makes measurement of the local mechanical properties at small scales, e.g. multi-phase metal sample in this study, substantially less time-consuming and more user friendly. The hard ***PHASES 2, 3*** and ***4*** improve the mechanical properties of the sample, possessing an average hardness of ~19.6, 16.2 and 7.2 GPa, respectively, compared to ~5.4 GPa for ***PHASE 1***.

The Nano, Micro or Macro modules of the instrument all include ISO and ASTM compliant indentation, scratch and wear tester modes, providing the widest and most user friendly range of testing available in a single system. ***NANOVEA***'s unmatched range is an ideal solution for determining the full range of mechanical properties of thin or thick, soft or hard coatings, films and substrates, including hardness, Young's modulus, fracture toughness, adhesion, wear resistance and many others.

[i] *Oliver, W. C.; Pharr, G. M., Journal of Materials Research., Volume 19, Issue 1, Jan 2004, pp.3-20*
[ii] *Schuh, C.A., Materials Today, Volume 9, Issue 5, May 2006, pp. 32–40*
[iii] *Oliver, W. C.; Pharr, G. M., Journal of Materials Research, Volume 7, Issue 6, June 1992, pp.1564-1583*