

APPLICATION NOTE

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NANOINDENTATION OF A MULTIPHASE COMPOSITE WITH THE NANO VISION™ OPTION

innovation center

APPLICATION

AUTHOR

INTRODUCTION

MTS Nano Instruments has a strong history of accurately determining the mechanical properties of materials using nanoindentation experiments. Today, materials engineers actively create materials with very fine microstructures. In the case of multiphase composites, mechanical properties of each phase will affect the overall performance of the material, placing importance on the ability to accurately locate and test a phase. Using the NANO **Vision™** option and the capabilities of the **DCM** indentation head, a multiphase material has been tested to determine the hardness and modulus of each phase present.

IMAGING THE SAMPLE

The NANO **Vision** option available from MTS NANO utilizes an x-y sample scanning system with high resolution (0.5 nm) capacitive displacement gauges for closed-loop control. The sample was scanned while in contact with a well-characterized Berkovich diamond tip to obtain a quantitative topographical image of the sample. A small load is applied while translating the stage in the X and Y directions to keep the tip in contact with the sample. The changes in displacement resulting from the topology of the surface and a constant load application produce the image.

THE SAMPLE

The sample, obtained from Oak Ridge National Laboratory, is a lamellar eutectic alloy. The sample was directionally solidified to achieve the elegant microstructure.

The primary phase is chromium silicide, Cr₃Si, and the secondary phase is a chromium-rich solid solution [1].

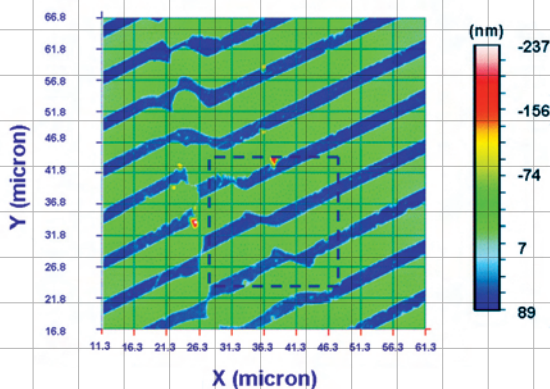


Figure 1: A 50 x 50 μm scan of the multiphase material.

The image in figure 1 is a 50 x 50 μm scan of the multiphase composite. The boxed area in figure 1 was rescanned to produce a more detailed image of the phases, as seen by figure 2. From figure 2, four different locations in each phase were selected to determine mechanical properties via nanoindentation.

INDENTATION

The first four indents were made in the chromium silicide phase of the material, two indents per band for two bands. The second four indents were made in the chromium-rich solid solution phase. All of the images shown were produced with the same Berkovich diamond tip in a **DCM** head that was used to indent the material. The material was loaded to a maximum load of approximately 18 mN at a prescribed indentation strain rate of 0.20 s⁻¹. Figure 3

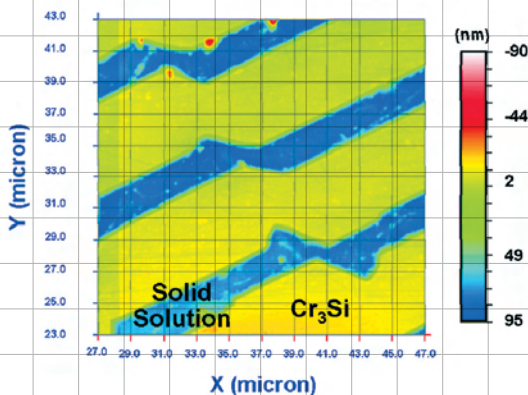
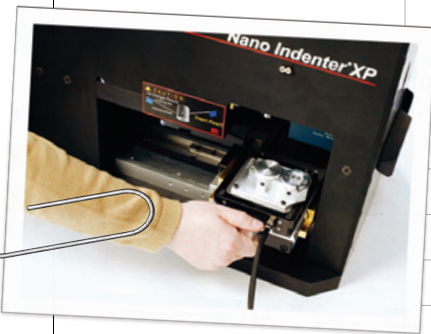


Figure 2: A 20 x 20 μm scan of the multiphase material.



RELATED PRODUCTS:



shows the surface of the sample, with the same dimensions as **figure 2**, after the eight indents have been made.

The very high resolution and accuracy of indent placement that **NANO Vision** provides is clear in this image.

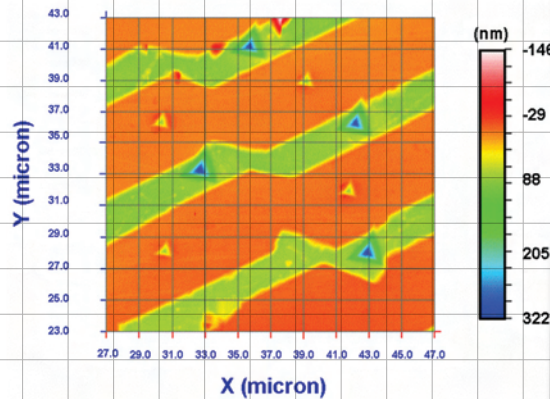
CONCLUSION

From the modulus and hardness curves as a function of indentation depth, **figure 4** and **figure 5**, respectively, the mechanical properties of the two materials are shown to be very distinct. The modulus of the chromium silicide phase is approximately 75 GPa higher than the modulus of the solid solution phase. Similarly, the hardness of the chromium silicide phase is approximately four times higher than the modulus of the solid solution. The differing hardness values can also be seen in **figure 3**: the depth of the indents in the chromium silicide is shallower due to the higher hardness of that phase. The results come directly from the **TestWorks®** review page and clearly show the repeatability of the instrument.

A point of interest is the sharp slope of the hardness curve followed by a drastic drop and

figure 3 (below): A 20 x 20 μm scan of the multiphase material after indentation.

figure 4 (right): The distinct modulus curves for the two different phases of the material.



then leveling of the hardness for two of the indents in the chromium silicide phase. Both of these indents were made in the same band. The sudden drop in hardness may be associated with initial yielding of the material. One possibility that has been used to explain such behavior is the lack of mobile dislocations in the vicinity of the indenter as the initial load is applied. Once the material yields, dislocations multiply and the strength, or hardness, drops [2].

Without the **NANO Vision** option and its closed-loop position control, the different phases of the material could not have been distinguished with such clarity and the probe could not have been placed as accurately. Since the two phases were made obvious from the image captured by the scan, they were able to be probed effectively, and repeatedly, to determine the mechanical properties of the distinct phases.

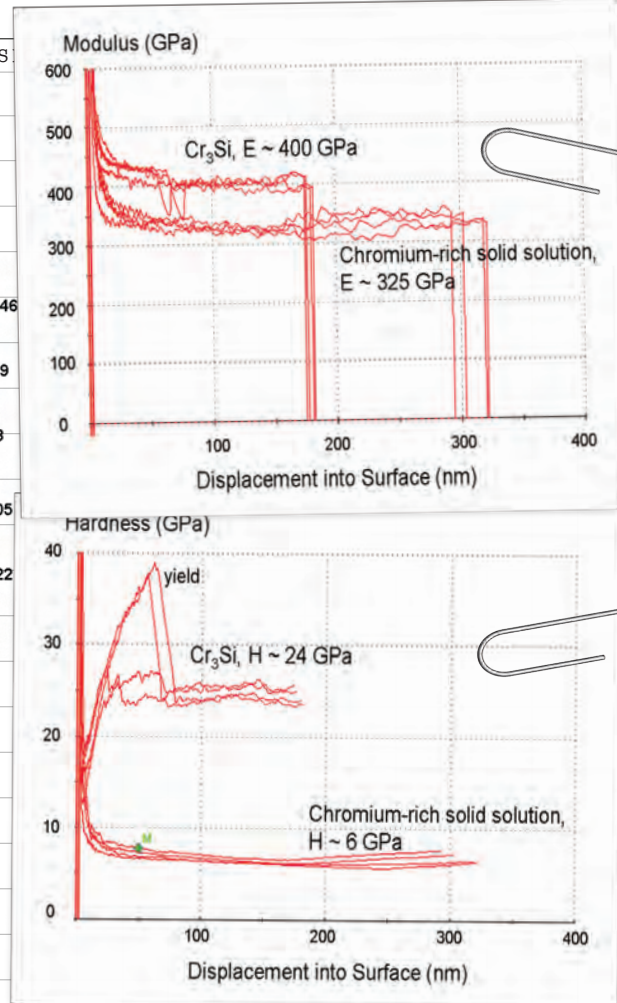


figure 5 (above): The distinct hardness curves for the two different phases of the material.

ACKNOWLEDGEMENTS

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NOTES

- [1] Bie, H., George, E.P., Kenik, E.A., and Pharr, G.M., (2003) Directional solidification and microstructures of near-eutectic Cr-Cr₃Si alloys, *Acta Materialia*, 51, 6241-6252.
- [2] Bie, H., George, E.P., and Pharr, G.M., manuscript in preparation.



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Inspired science.

Characterizing surfaces down to the level of a few nanometers has become increasingly important for a wide range of manufacturers and researchers. Properties at the nano scale can affect the performance of a variety of scientific and consumer products. **NANO Indenter** systems from **MTS NANO INSTRUMENTS** use the most advanced technology available to acquire fast, accurate mechanical data on a variety of surfaces at the submicron scale.