Local characterization of austenite and ferrite phases in duplex stainless steel using MFM and nanoindentation

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1. Abstract

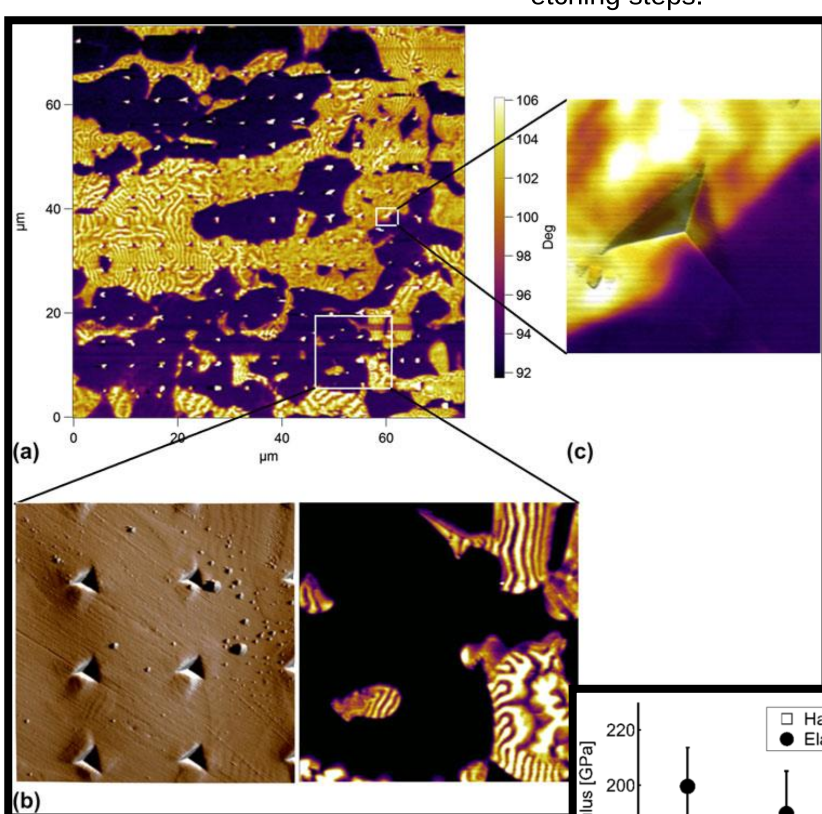
The local mechanical properties of ferritic and austenitic domains in a duplex stainless steel are locally studied by nanoindentation. The elastic and plastic properties of the two phases are determined. Without any specific surface treatment (chemical or electrochemical), the austenitic and ferritic domains present in the duplex stainless steel are distinguished using magnetic force microscopy. The magnetic scans allow nanoindentation results to be assigned to the respective phase, yielding the local mechanical properties of the duplex steel. The magnetic scans also show a sharp transition between the phases that is maintained even inside indentations. The ferrite phase is found to supersede austenite in the elastic modulus, hardness, and strain-hardening exponent, while both phases possess similar yield strength. Interface properties are a weighted average of the phase properties.

2. Introduction

Duplex stainless steel is a class of materials that attracts great interest due to its improved resistance to general and localized corrosion, stress corrosion cracking, abrasion, and wear.

Studying the microstructure of duplex stainless steel is traditionally performed through chemical etching to identify the ferritic and austenitic phases. Such approach is nontrivial, requiring skill and experience in sample preparation as well as analysis.

Magnetic force microscopy (MFM) provides a valuable alternative to locally identify the phases without the need for specific surface treatment that may alter the surface. The technique exploits the difference in the magnetic characteristics of the phases (α is ferromagnetic and γ is paramagnetic) to unequivocally distinguish the phases with high resolution.



3. Experimental

A commercial austenitic–ferritic duplex stainless steel sample (Uranus 50) is examined throughout the course of this work. The sample is subjected to mechanical testing using nanoindentation followed by a magnetic force microscope scanning to the indented area.

Nanoindentation experiments are performed using MFP Nanoindenter (Asylum Research) with a Berkovich tip.

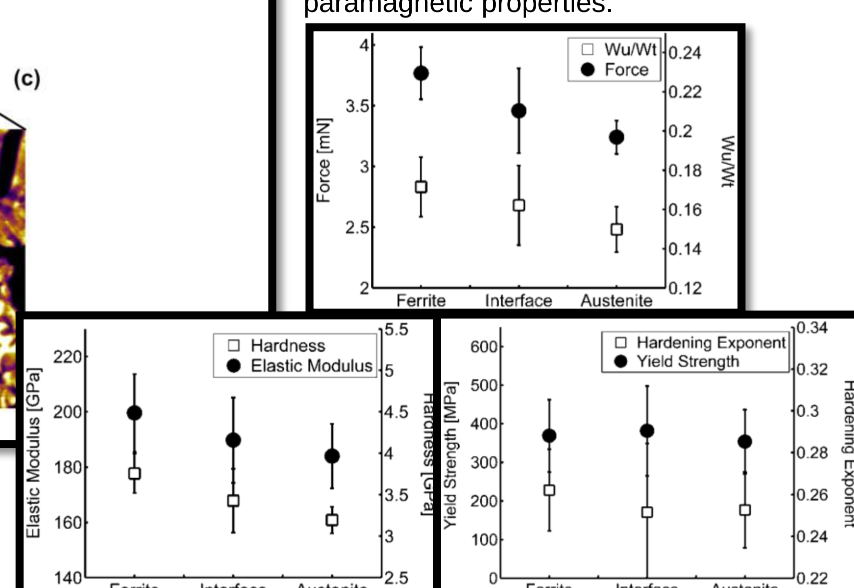
MFM scans are conducted using MFP three-dimensional atomic force microscope (Asylum Research) using a CoCr coated tip. The tip is magnetized along its axis before scanning.

4. Discussion

Clear magnetic domains with their wormlike shapes can be easily distinguished in a 75*75 μm^2 phase plot from the MFM scan. MFM show the distribution of the ferromagnetic ferrite within the paramagnetic austenite without the need to perform any chemical etching steps.

The topography map does not provide any information on what the phase presents.

The deformation of the material under the indentation load has no visible effect of the separation between the two domains. In our range of indentation (200nm max), the plastic deformation in the austenite did not result in any martensitic transformation and the material kept its paramagnetic properties.



5. Conclusion

MFM is accurately capable to identify austenitic and ferritic phases in duplex steel. The magnetic scans show very sharp boundaries between the domains. No clear phase transformation is observed in the austenite. The sharp transition between phases was maintained through indentations.

The combination of MFM and nanoindentation provides a relatively easy and fast method to conduct and distinguish large number of indentation experiments and obtains a statistical characterization of the local mechanical properties of duplex steel.

1 . Oliver W and Pharr G Measurement of hardness and elastic modulus by instrumented indentation: Advances in understanding and refinements to methodology *J. Mater. Res* **19** 3-20 (2004)

2 . A. Dias and M.S. Andrade: Atomic force and magnetic force microscopies applied to duplex stainless steels. *Appl. Surf. Sci.* 161 (1–2), 109–114 (2000).

3 . X.F. Wang, X.P. Yang, Z.D. Guo, Y.C. Zhou, and H.W. Song: Nanoindentation characterization of mechanical properties of ferrite and austenite in duplex stainless steel. *Adv. Mater. Res.* 26, 1165–1170 (2007).

4. I. Serre, D. Salazar, and J.B. Vogt: Atomic force microscopy investigation of surface relief in individual phases of deformed duplex stainless steel. *Mater. Sci. Eng.*, A 492(1–2), 428–433 (2008).

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