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Grain Growth Characterization of Ni_2MnGa

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Abstract

Project Overview:

- Magnetic shape memory alloys (MSMA) such as Ni_2MnGa possess a unique material property that allows them to strain up to 10% in an applied magnetic field.
- Strain is achieved through the magnetic-field-induced motion of twin boundaries.
- The highest reported strains have been found in single crystal MSMA but they are difficult and costly to produce.
- Polycrystalline materials are easier and more cost-efficient to produce than single crystals.
- Single crystals can be “cut out” from a polycrystalline material if individual grains are large enough.
- Very large grains may be formed via abnormal grain growth.

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Sample Preparation

- A Ni-Mn-Ga alloy with composition $Ni_{49.0}Mn_{31.0}Ga_{20.0}$ (errors were 0.2 for Ni and 0.1 for Mn and Ga) was made from nickel (3N, ESPI), manganese (3N5, Alfa Aesar), and gallium (6N, Atlantic Metals).
- The bulk materials were melted and mixed in an induction furnace and then cast into a copper block.

Imaging

- Images were taken using a Meiji Metallurgical Microscope model MT7100 using both the Infinity X-21 and the OptixCam model OCS5.0 camera to achieve a high resolution required for image analysis.
- Cross-polarized lighting was used to achieve grain boundary definition for as-cast images.
- Approximately forty images were collected in a sequential grid to ensure image overlapping which facilitates image stitching.

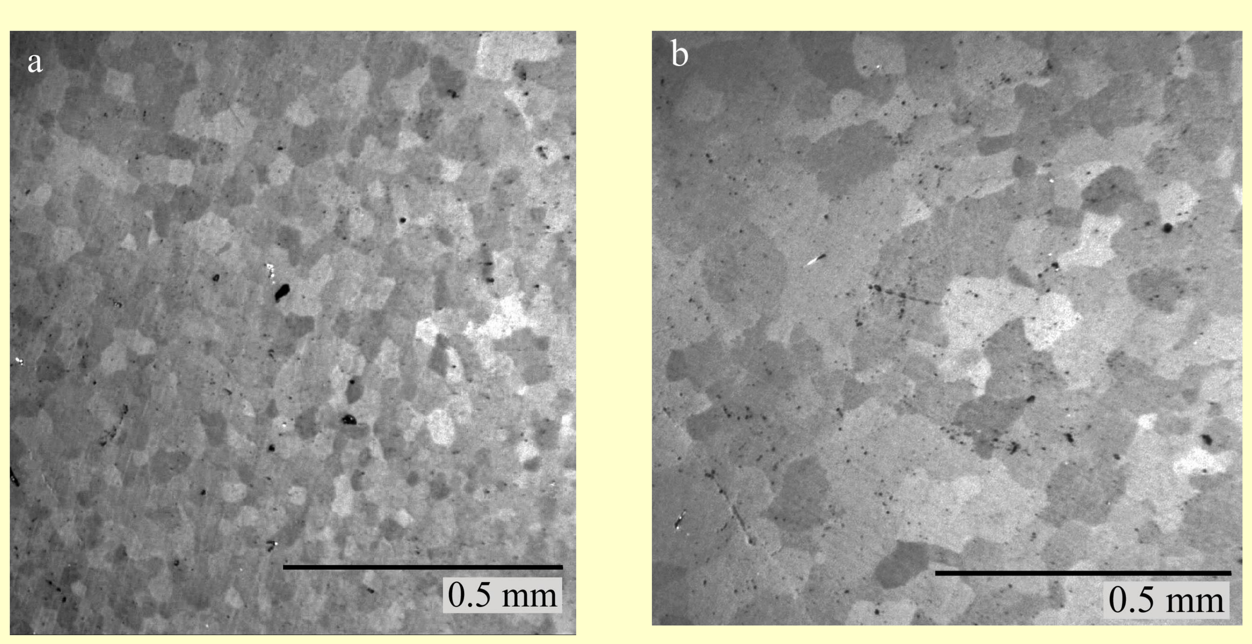

Figure 1: AR106-E as-cast ingot imaged with cross-polarized light. Near the edge (a) the grains are smaller than in the center (b) of the ingot.

Image Processing

- The MATLAB program is very sensitive to imaging artifacts such as inconsistent coloring, hard lines and holes in the images.
- Each sample was outlined by hand to disregard these artifacts.
- Accurate image stitching and outlining of the stitched image was crucial for achieving accurate grain size statistics.
- Grain growth is easily illustrated using a visual comparison between heat treatment steps.

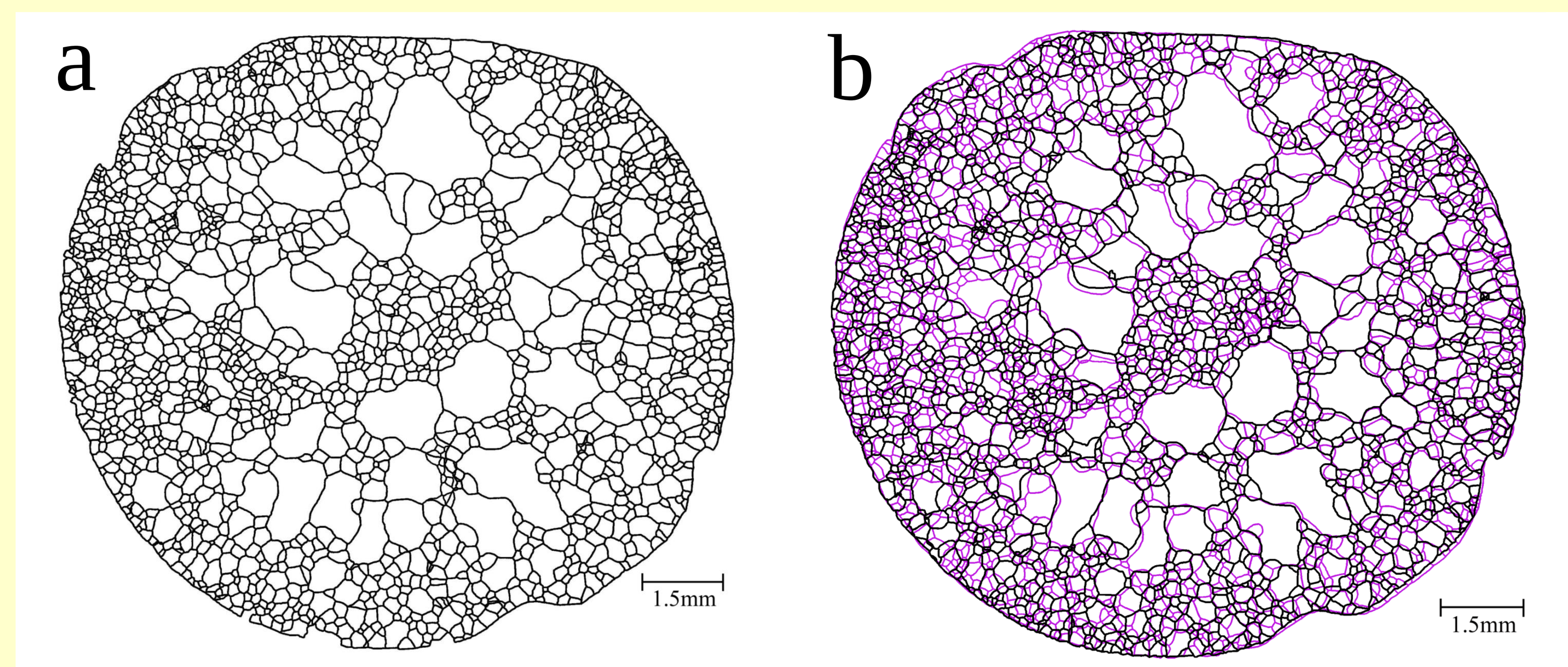

Figure 2: AR106-B (a) Outline of 12 Hr Heat Treatment (b) 12 Hr Heat Treatment (black) overlapped with 96 Hr heat treatment (purple)

Image Analysis

- A MATLAB program is in development to identify, count, and analyze grain size and distribution from a sample image.
- The MATLAB program uses the image created in Photoshop to determine grain growth statistics.

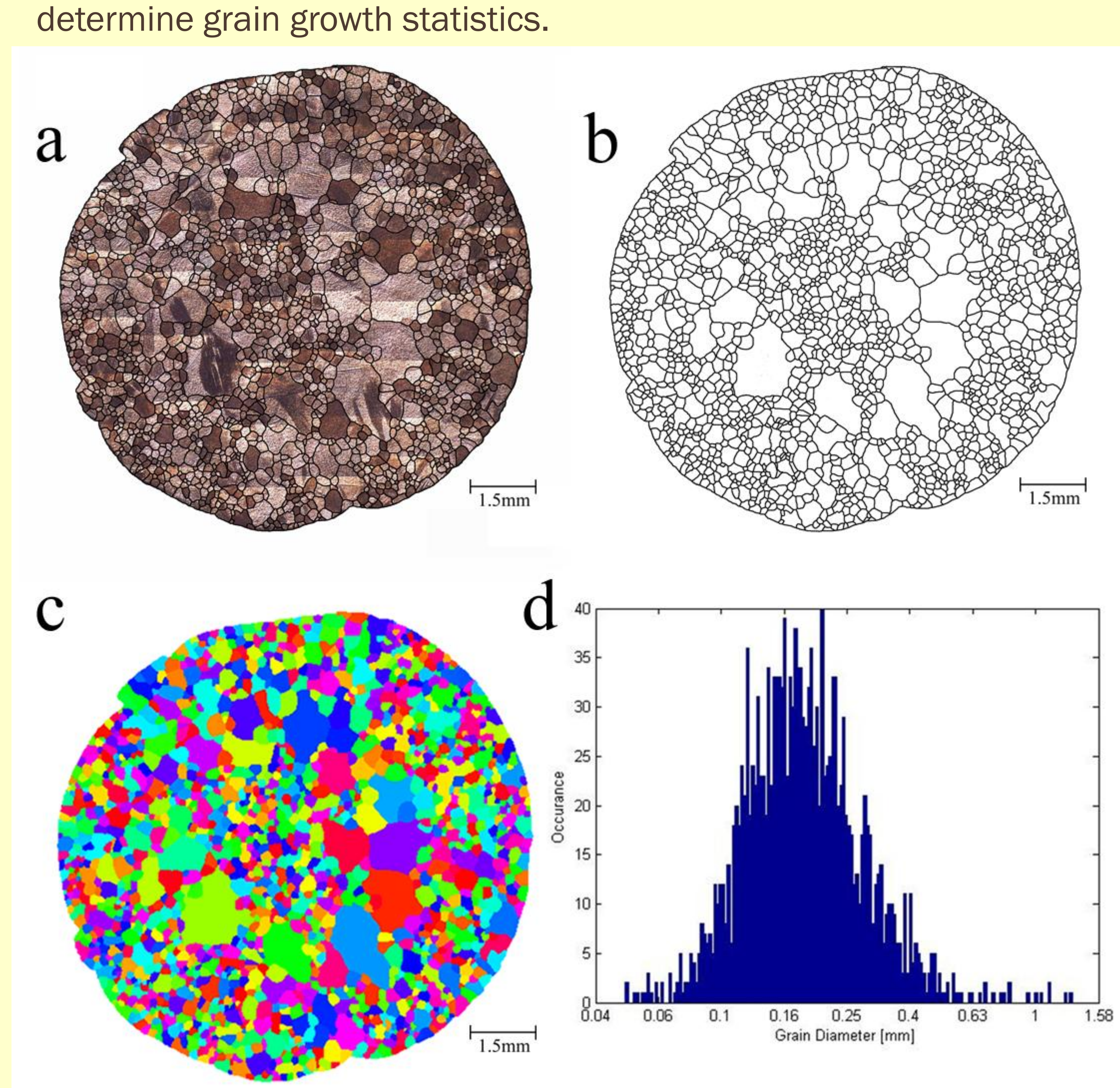

Figure 3: AR106-A(a) Outlined image fed into MATLAB Program (b) Outline of image after edge detection and filtering in MATLAB program (c) Resulting color image of grains with no outline (d) Distribution plot of grain diameter extruded from MATLAB

Texture Analysis

- X-Ray Diffraction texture analysis determines the orientation distribution of crystallites in a sample.
- Knowledge of the texture may provide a basis for understanding the mechanical, physical, or chemical behavior of the sample.
- The distribution of crystals narrows considerably after heat treatment.

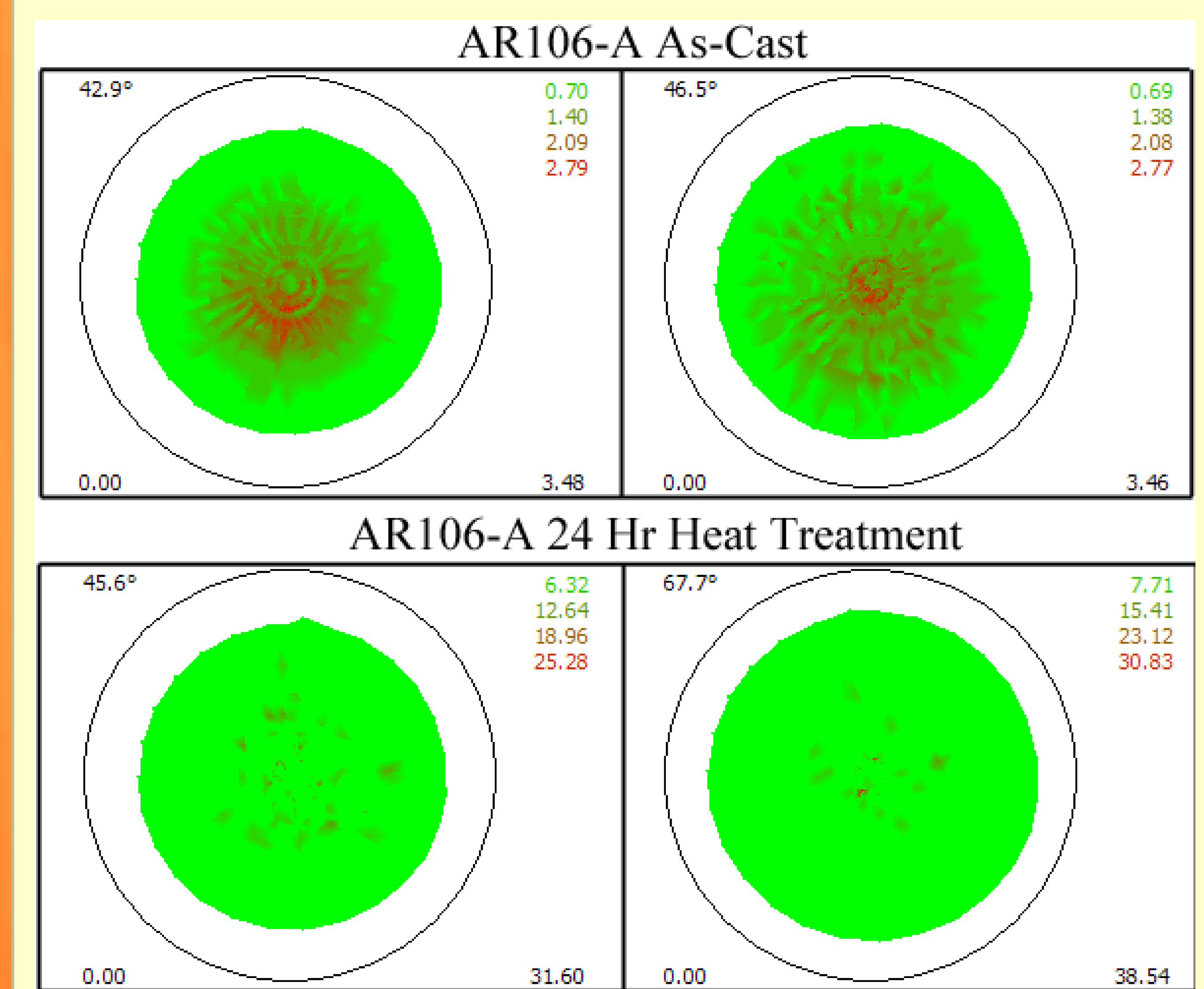

Figure 4: AR106-A Pole Figures (Top) As-Cast sample displays a random texture orientation. (Bottom) After a 24 Hr heat treatment the orientation displayed is still random but the pole figure exhibits a smaller number of randomly oriented crystals which implies grain growth.

Conclusions and Future Work

- Imaging techniques must be refined to reduce imaging artifacts.
- Further tests of the etchant must be done to ensure grain boundaries are defined with the least amount of surface pitting to facilitate automatic identification.
- XRD will be used on the sample after the final heat treatment to determine texture and final grain orientation.
- If abnormal grain growth occurs, the largest grain in the sample will be cut out as a single crystal.

Acknowledgements

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