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Grain Growth Characterization of Ni$_2$MnGa

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Project Overview
- Magnetic shape memory alloys (MSMA) such as Ni$_2$MnGa 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.

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.

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.

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.

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.

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.

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