Making Gems in Minutes

Single Crystal Casting

PRESENTER: **Zoe Hern**

INTRODUCTION

- Magnetic Shape Memory Alloy single crystals are flexible strips of metal, useful in solid-state devices such as micro-pumps.
- The Bridgeman-Stockberger method of growing single crystals is slow, wasteful, and creates chemical segregation.
- Our method involves casting Ni-Mg-Ga onto a seed crystal that sits on a cooled copper plate. This means nearly instant solidification.

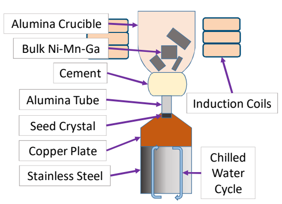

Figure 1. Casting setup cross-section.

Figure 2. Casting setup.

- Our method promotes directional solidification and consistent chemical composition in a short amount of time.

METHODS

Drop-Casting

- A polycrystalline Ni Mn Ga alloy is melted in an alumina crucible by heating inductively.
- The molten material is dropped into a heated ceramic mold that contains a water-cooled seed at the base.
- Solidification occurs as soon as the molten material contacts and partially melts the seed.

Instantaneous Melting-Solidification

- The same alloy is melted in alumina mold with a water cooled seed interfacing the bottom of the mold and melt.
- Solidification occurs as soon as the induction heating is turned off.

Characterization

- Optical Microscopy: grain boundaries (Fig. 3)
- Energy Dispersive X-Ray Spectroscopy: composition (Fig. 4-6, Tables 1 and 2)

RESULTS

- For instant melting-solidification (MT01) and a first casting experiment (MT02), optical microscopy revealed directional solidification and dendritic formations.
- Chemical segregation along the solidification direction was below the resolution of EDS – consistent composition means little waste.

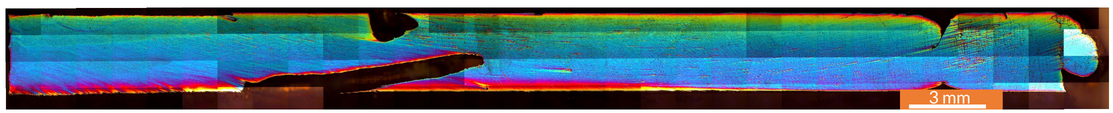

Figure 7. LEICA optical microscopy image of MT02. Grain boundaries, dendrites, and martensitic formations are evident.

Experimentation casting single crystals in **15 minutes** instead of growing them over days suggests **improved crystal quality.**

LEICA IMAGE of MT01, 5X

Figure 3. LEICA optical microscopy image of MT01. Directional solidification and dendrites are evident.

EDS LINE SCAN, MT01

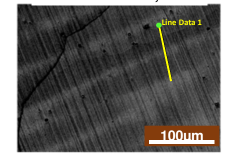

Figure 4. EDS line scan of MT01 across dendrites, showing the scan in relation to the larger sample.

EDS LINE SCAN, MT01

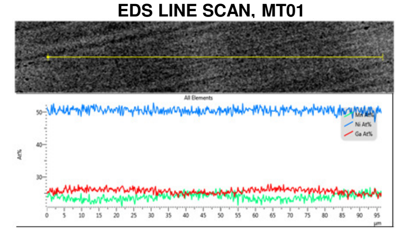

Figure 5. EDS line scan of MT01 dendrites. Lightly colored columns are higher in Mn composition, while darker colored columns are higher in Ga composition.

Table 1. Atomic percentage of composition from the Point and ID scan of MT01.

Spectrum Label	Mn	Ni	Ga
Spectrum 1	26.41	50.73	22.86
Spectrum 2	24.17	51.35	24.48
Spectrum 3	23.99	51.29	24.72
Spectrum 4	26.03	50.87	23.1

Table 2. Atomic percentage of composition table from the gradient EDS scan of MT02. The standard deviations are below the resolution of EDS.

Spectrum Label	Mn	Ni	Ga
Average	23.621	53.856	22.523
Standard Dev	0.2488	0.122	0.236

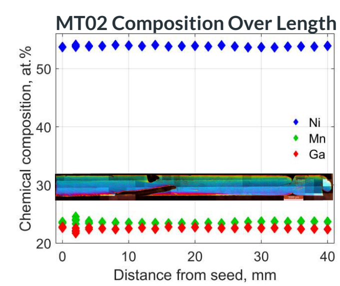

Figure 6. Atomic percentage of composition of MT02 from EDS data.. Chemical segregation is undetectable.

Zoe Hern[1,2], Ali Mustafa[2], Brent Johnston[2], Peter Müllner[2]

[1] The College of Idaho
[2] Boise State University

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