M.I.T

Magnetic-field-induced strain in Ni-Mn-Ga

Sponsorship: DARPA, ONR
PIs: Bob O'Handley, Sam Allen
RAs: Steve Murray*, Miguel Marioni, Chris Henry, Marc Richard
Postdocs: Hans Nembach, Pablo Garcia Tello, Kee Ahn Lee
Undergrads: Amy Kulkla, Josh Robinson, Jimmy Jia, Sarah Barron
Collaborator: Tom Lograsso, Ames Laboratory, David Bono, M.I.T.

*Present address: Midé Corporation, Cambridge, MA

Objectives

DARPA: Understanding and Exploiting Giant field-induced shear strains

- Crystal growth, orientation, cutting
- Test fixture for $e(s,H)$,
- Measure $M(H,T)$, $e(s,H)$

ONR: Magnetic Shape Memory Alloys for Sonar Transducers

Scientific basis for high twin boundary mobility

- Crystal growth, orientation, cutting
- Heat treatment, ordering
- AC measurements of $e(s,H)$

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Schedule

Month:	0	3	6	9	12	Done
DARPA						
(3/99 - 2/2000) Crystal growth, orientation, cutting, annealing					"	
Test fixture for $e(s,H)$					"	
Measure $M(H,T)$, $e(s,H)$						"
ONR						
(3/99 - 2/2002) Crystal growth, orientation, cutting, annealing					"	
Heat treatment, ordering					"	
Measure AC $e(s,H)$						
Sample to NUWC						

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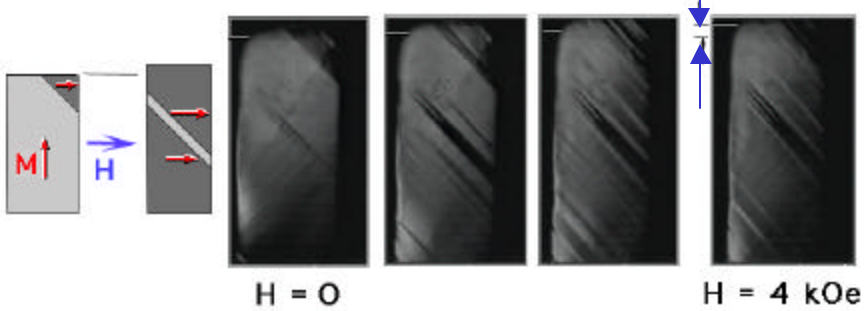
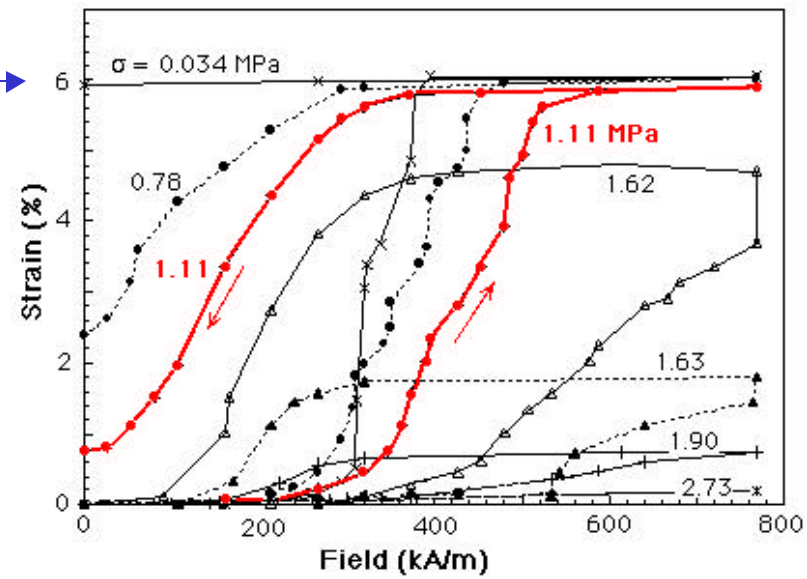
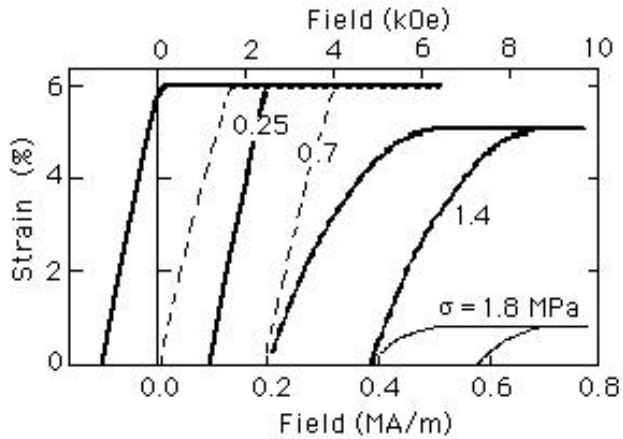
Overview of major accomplishments

- 6% extensional strain







- Data modeled using measured parameters

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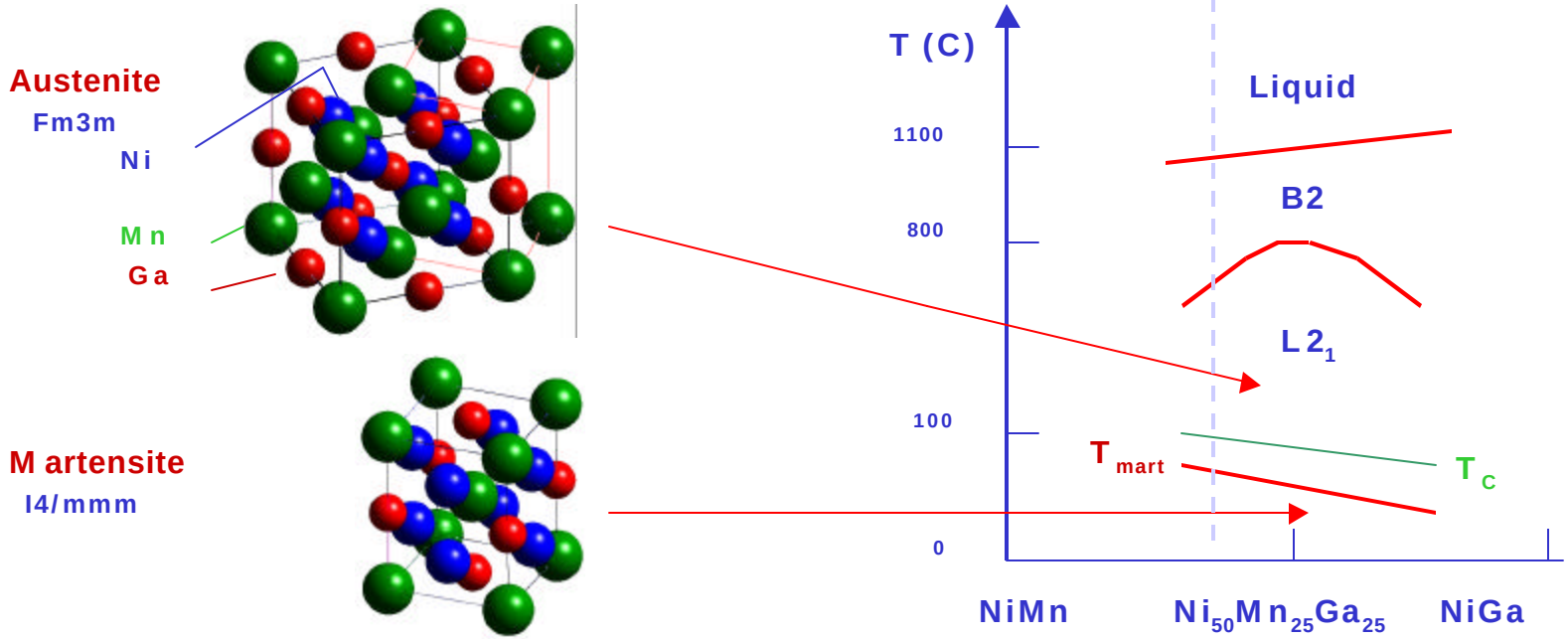
Magnetic-field-induced strain in Ni-Mn-Ga

Key ingredients

1. Ordered, oriented crystal
2. Mobile twin boundaries
3. Strong magnetic anisotropy

1. Ordered, oriented crystal, $Ni_{50}Mn_{28}Ga_{22}$



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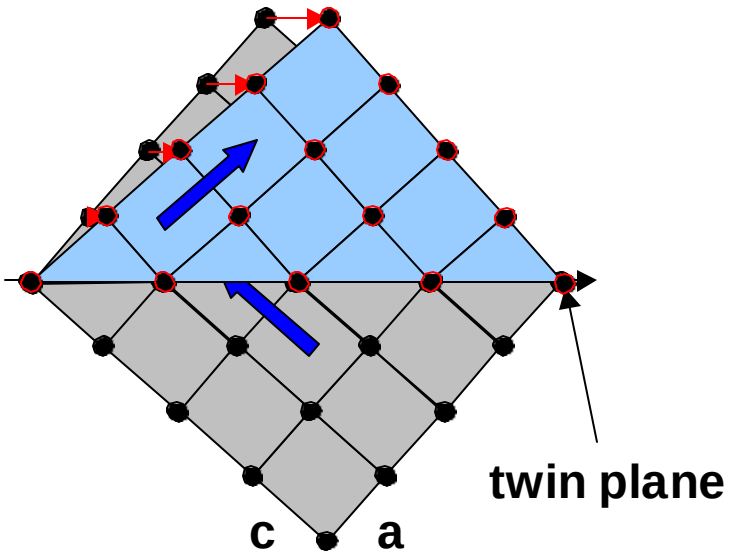
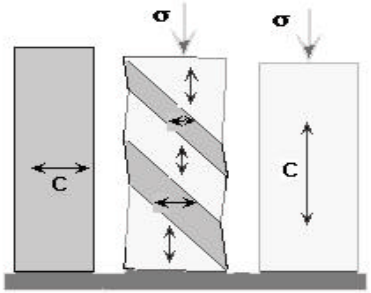
Magnetic-field-induced strain in Ni-Mn-Ga

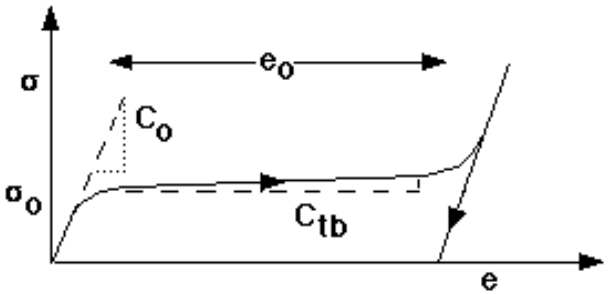
Key ingredients

1. Ordered, oriented crystal
2. Mobile twin boundaries
3. Strong magnetic anisotropy

2. Mobile twin boundaries







QuickTime™ and a
Sorenson Video decompressor
are needed to see this picture.

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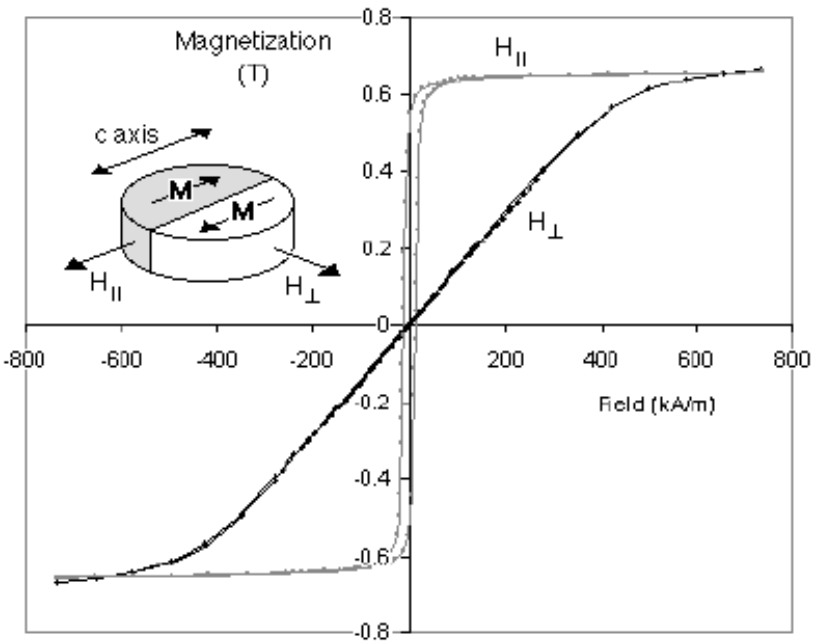
Magnetic-field-induced strain in Ni-Mn-Ga

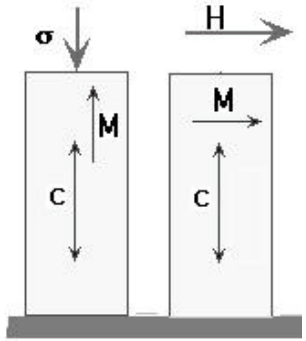
Key ingredients

1. Ordered, oriented crystal
2. Mobile twin boundaries
3. Strong magnetic anisotropy

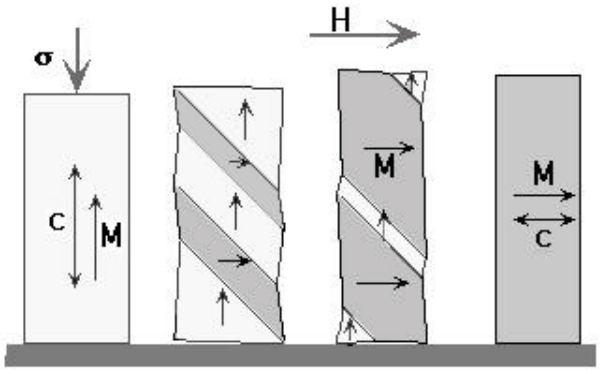
2. Strong magnetic anisotropy



Weak anisotropy
D// = 0



Strong anisotropy
$d_{31} > 0$



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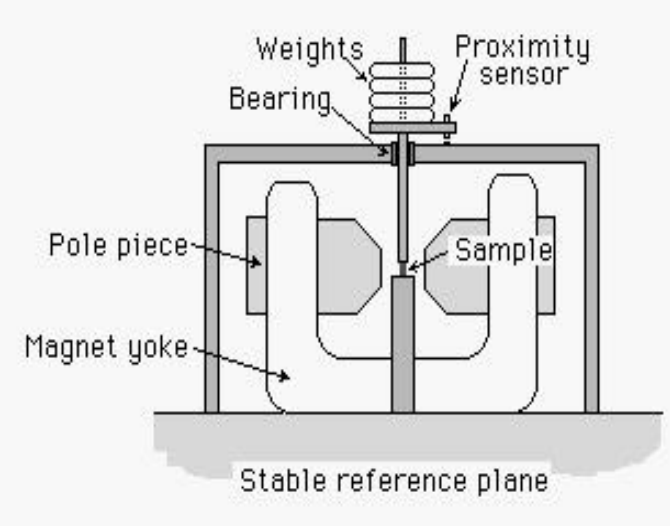
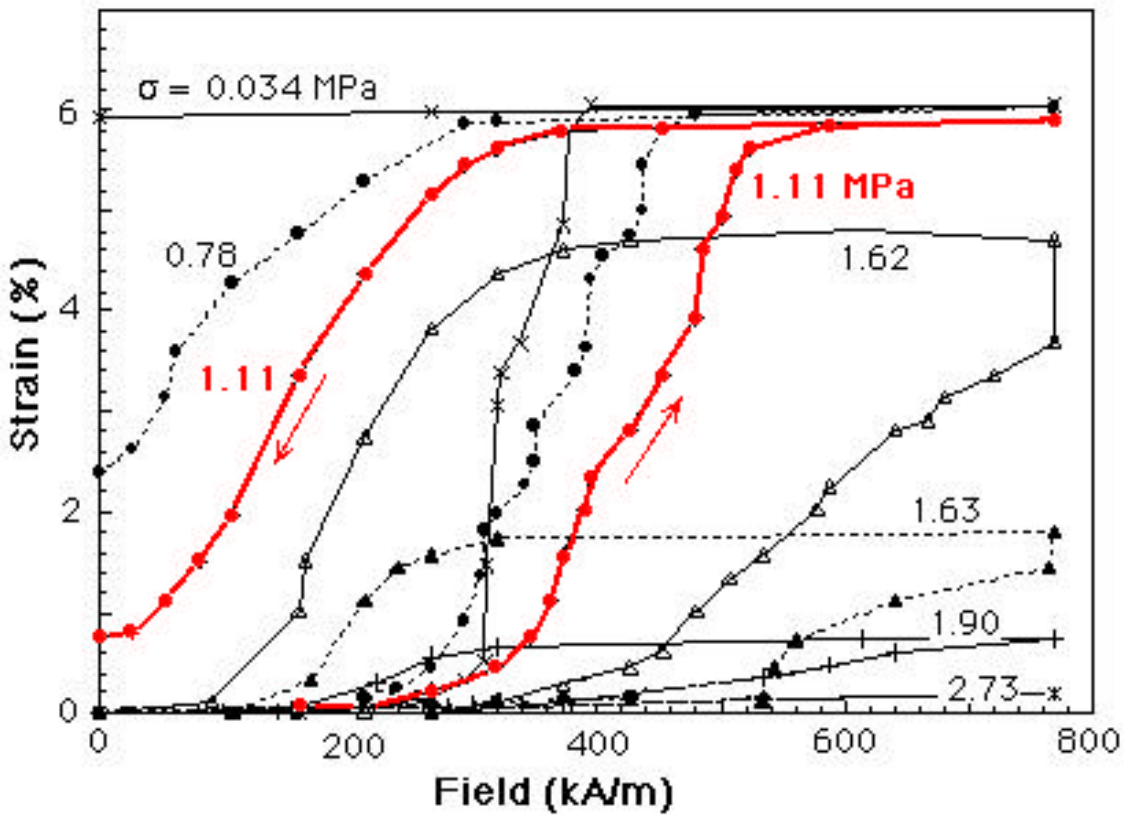
Magnetic-field-induced strain in Ni-Mn-Ga

Major accomplishments

- New apparatus
- Field-induced strain under load





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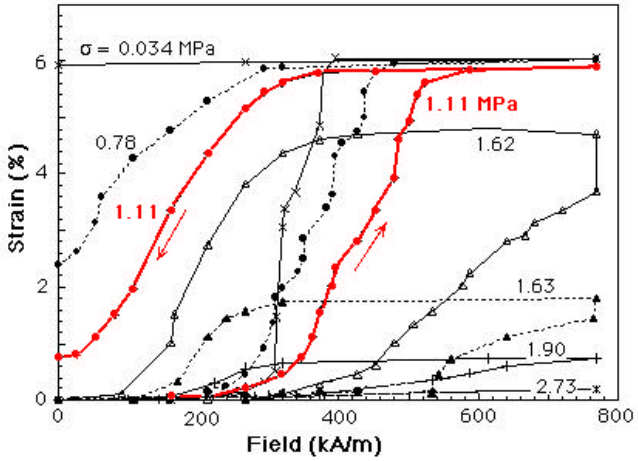
Magnetic-field-induced strain in Ni-Mn-Ga

Major accomplishments

- **Twin motion correlates with strain**



QuickTime™ and a
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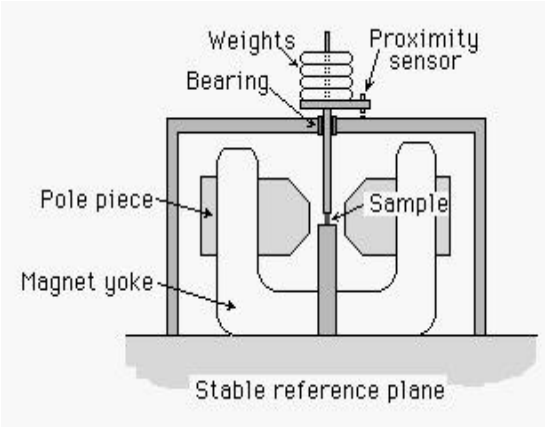
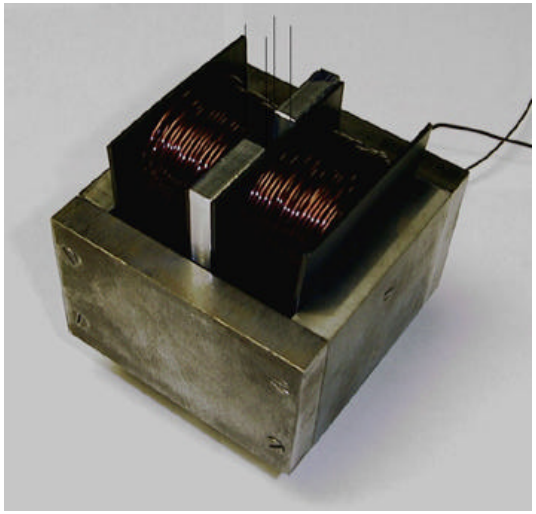
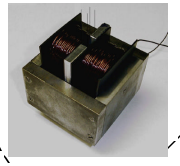
Magnetic-field-induced strain in Ni-Mn-Ga

Major accomplishments

- **Shrinking actuator**







$(50\ cm)^3$ → $(10\ cm)^3$ → $(4\ cm)^3$

Same field each case

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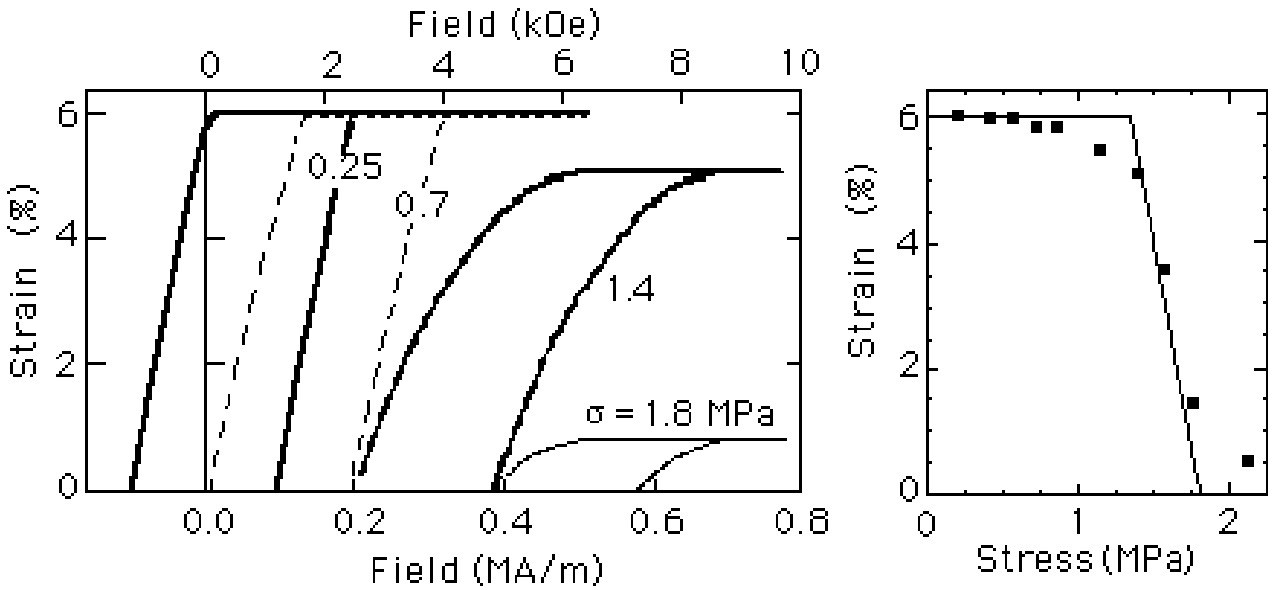
Major accomplishments

- Modeling advances

$$K_u > M_s H > s e_o > E_{tb}$$



All parameters measured independently from $M(H)$, $e(s)$ data

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Looking ahead

- **Reduce actuation field, coercivity**

  Control defects,

  heat treatment under σ, H

- **Characterize AC response**

  Apparatus under fabrication

  Power systems collaboration

- **Develop application-specific FSMAs**

  Pumps, valves, hybrid structures...