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2007-2013

Romania - Republic of Serbia
IPA Cross-border Cooperation Programme

From actuation control to ferromagnetism and biocompatibility in shape memory alloys

Universitatea Politehnica Timişoara

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Shape memory & Actuation

Can we try to outsmart Smart materials !?

…via design of actuators with enhanced output

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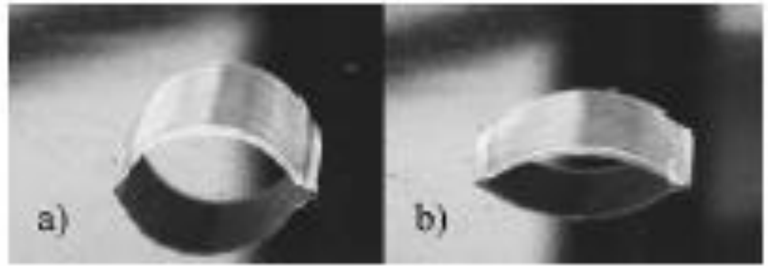
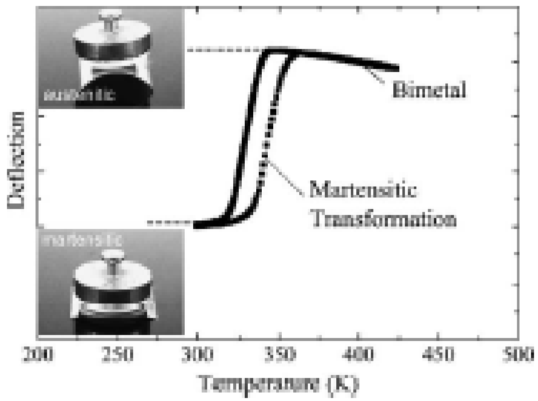
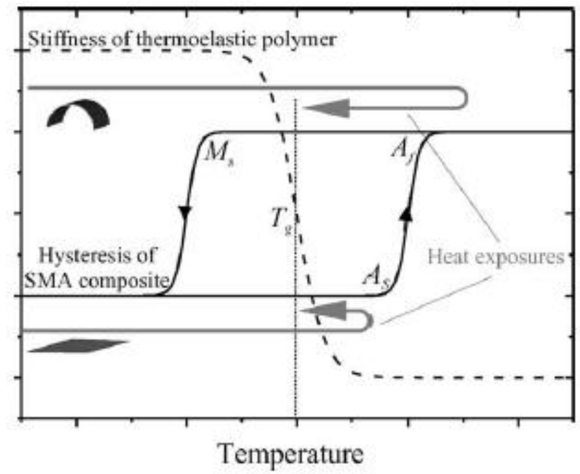
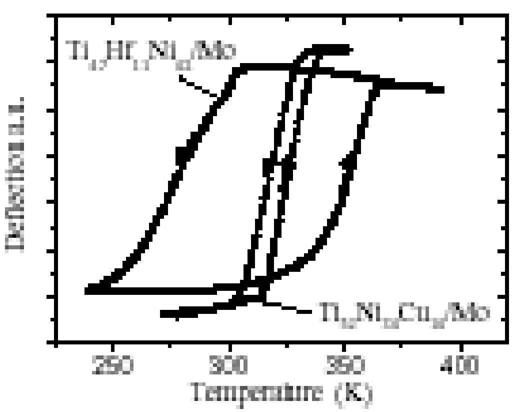


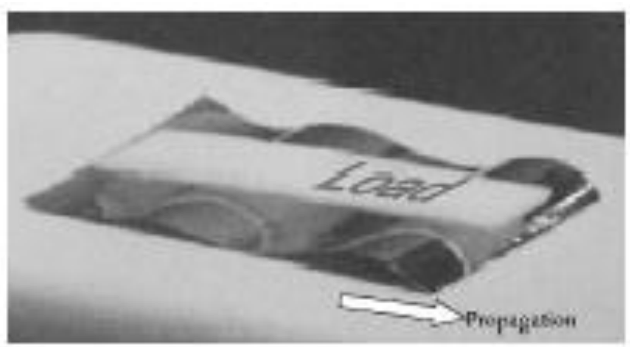


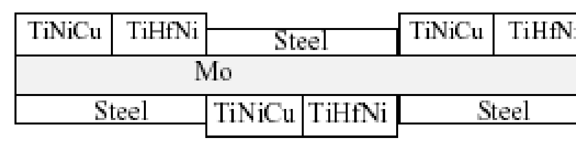
Embeeded dissimilar transformations



Embeeded SMA transformations



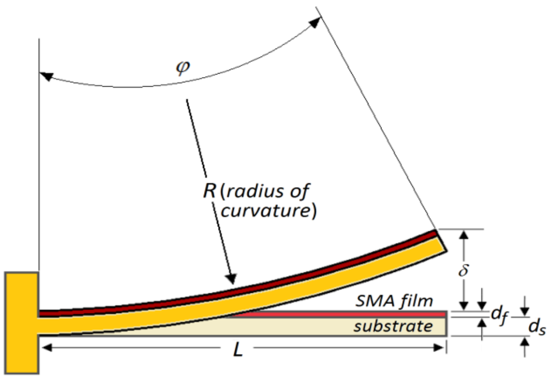




B. Winzek et al. Materials Science and Engineering 2004

Factors to play [smart] with:

Composition
Stress
Microstructure

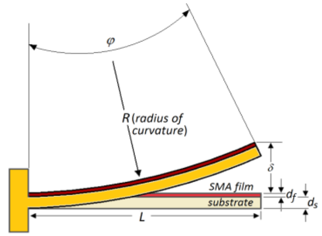


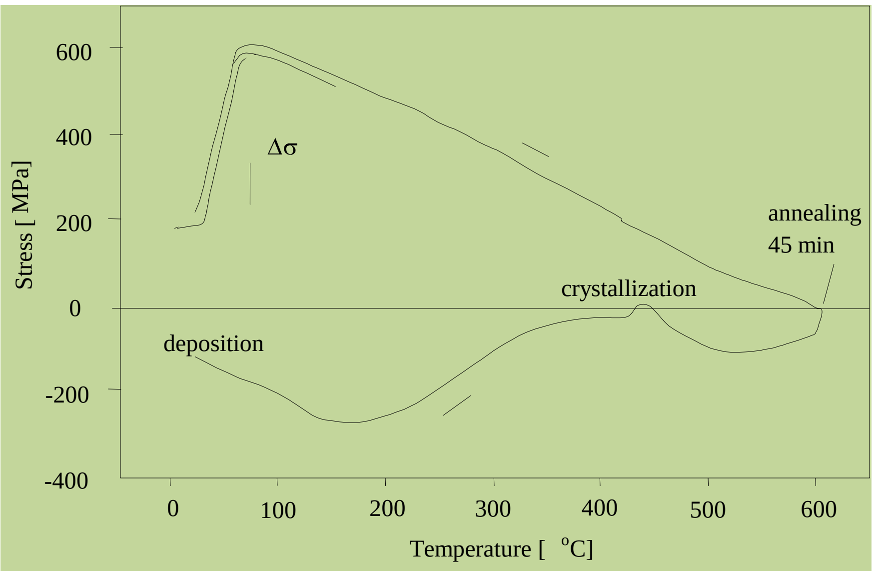
Ways to play [smart] with:

- by generating architectures based on thin films that would allow the maximization of the properties (actuation) via
  - substrate's reinforcement
  - layering the films
  - grading the film
  - modulating the actuation response

Stress -related observations

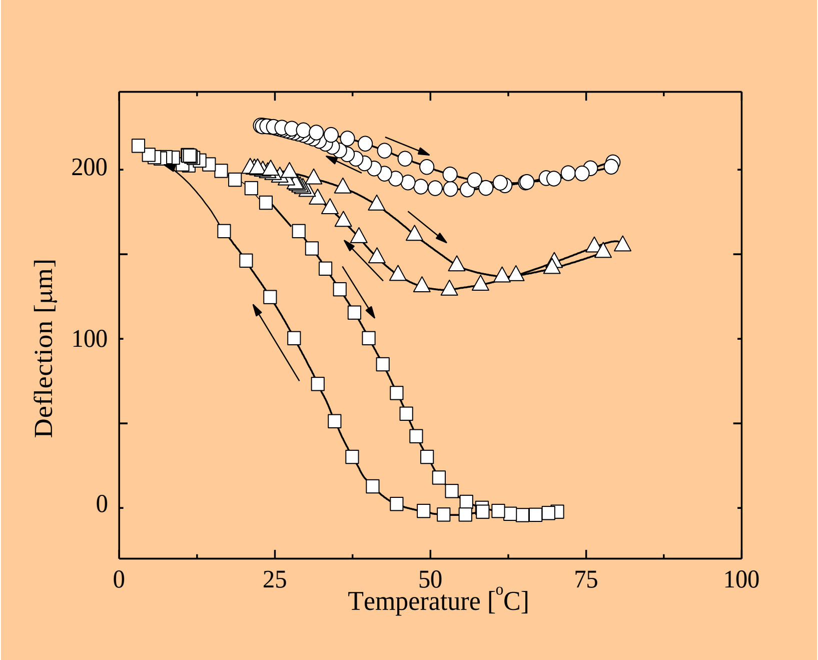
Bimorph cantilever





$(TiPd)_{50}(TiNi)_{50}$

S.Mathews, J.Li, Q. Su, M. Wuttig Philosophical magazine letters



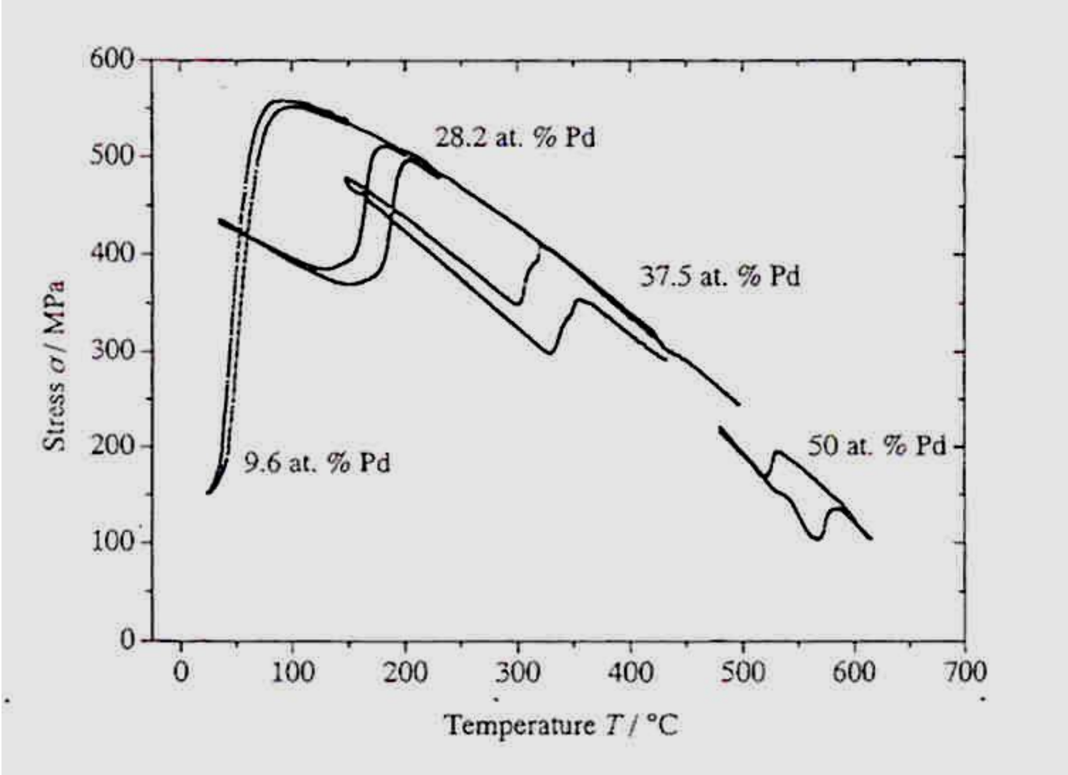
$Ni_{50}Mn_{28}Ga_{22}$ /Si

annealed at 400 (o), 500(Δ) și 600 ( ) °C

C. Crăciunescu, Y. Kishi, L. Saraf, R. Ramesh and M. Wuttig, MRS Proceedings vol 687

Composition-related observations

Ti-Ni-Pd system



B. Winzek and E. Quandt, Zeitschrift fuer Metallkunde

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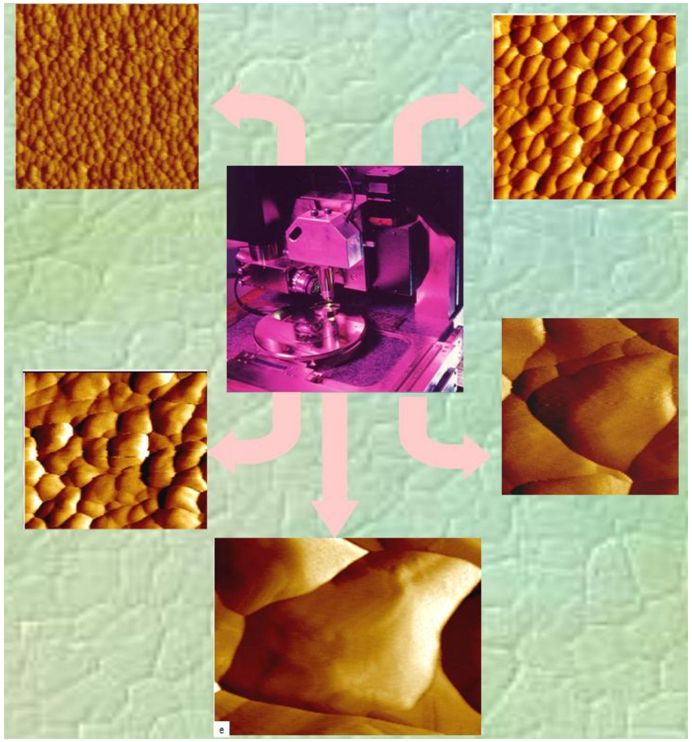
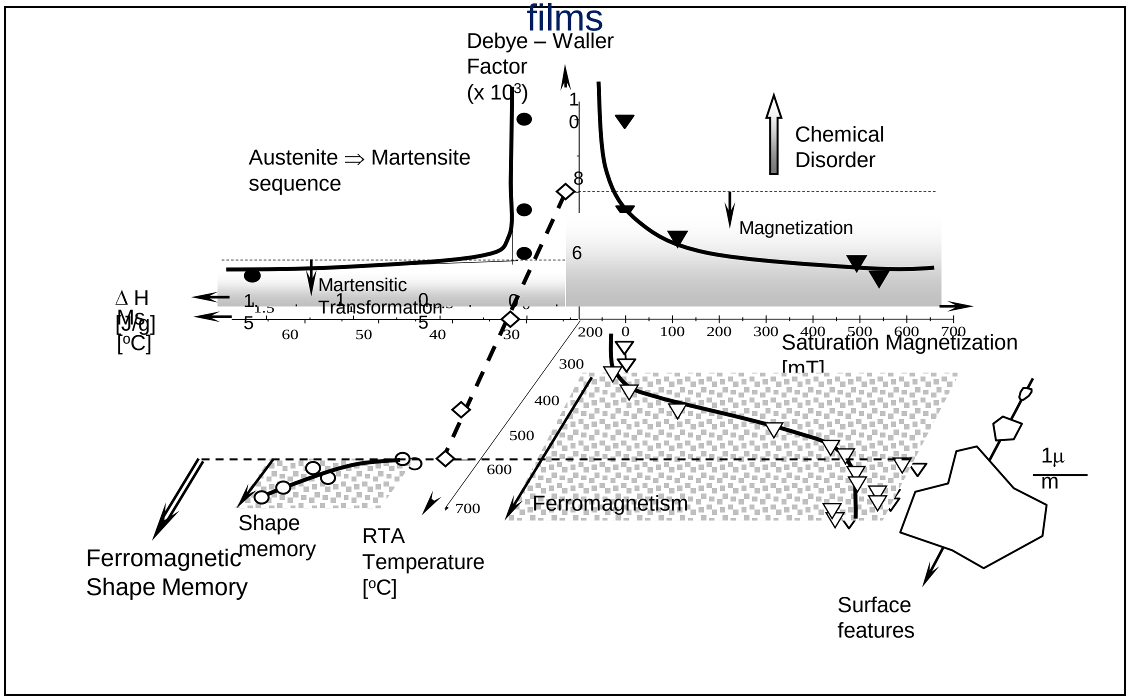
Microstructure-related observations



C.M. Crăciunescu, J.Li si M.Wuttig, Thin Solid Films

Successive occurrence of ferromagnetic shape memory properties during crystallization of rapid annealed free-standing films



H. Rumpf, C.M. Craciunescu et all. – JMMM

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Main question

How to play smart with thin film opportuntities and to generate a new and controlable space for microactuation

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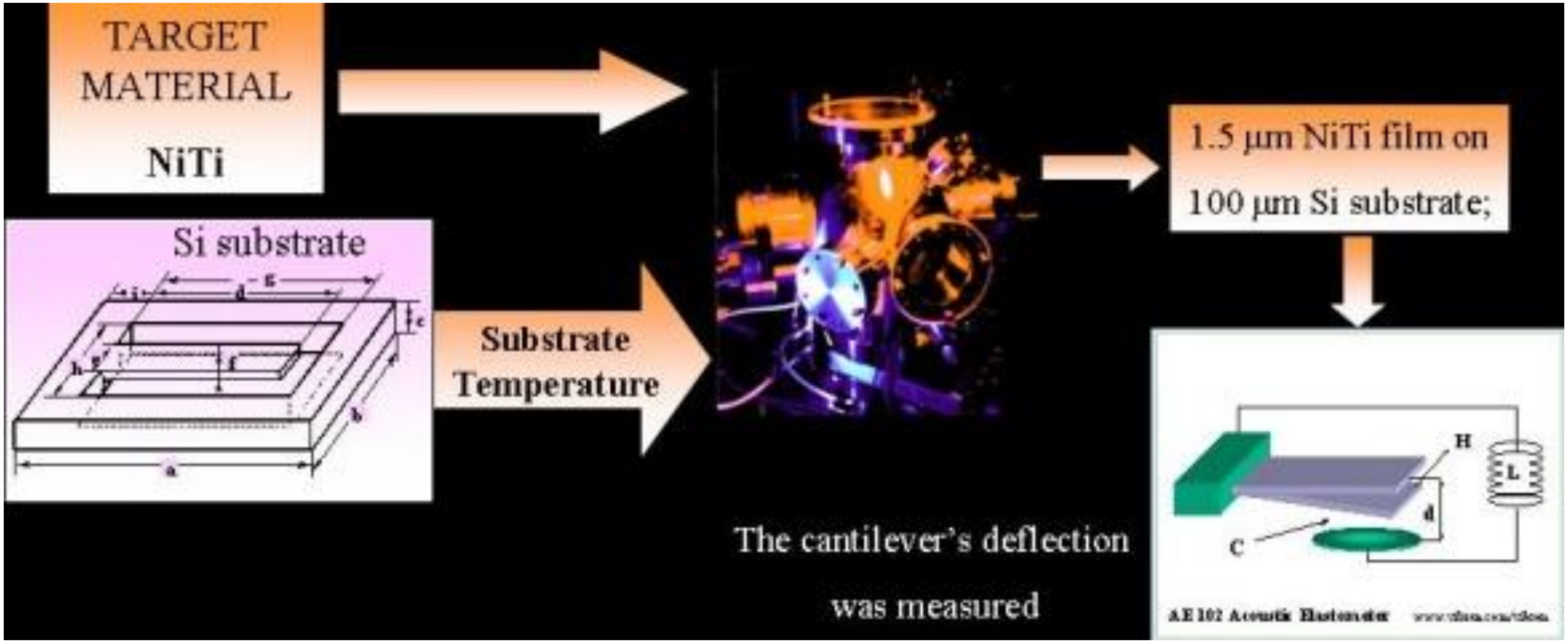
Experimental set up

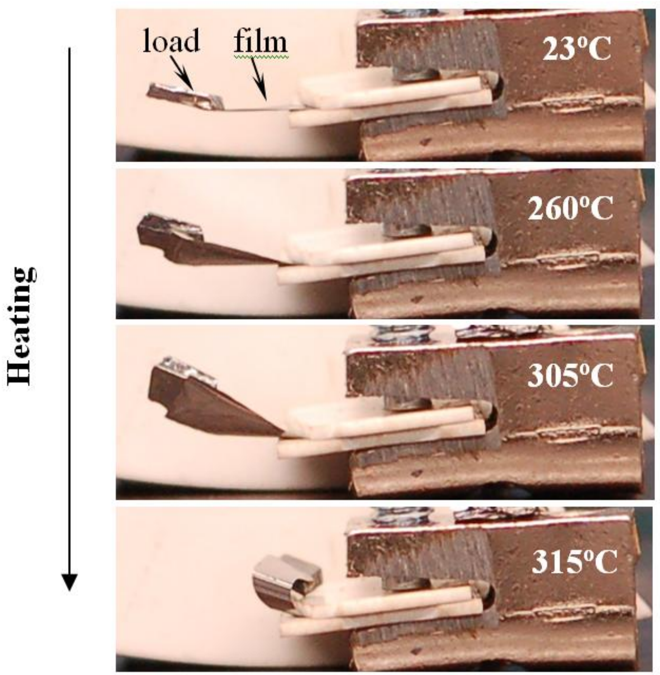


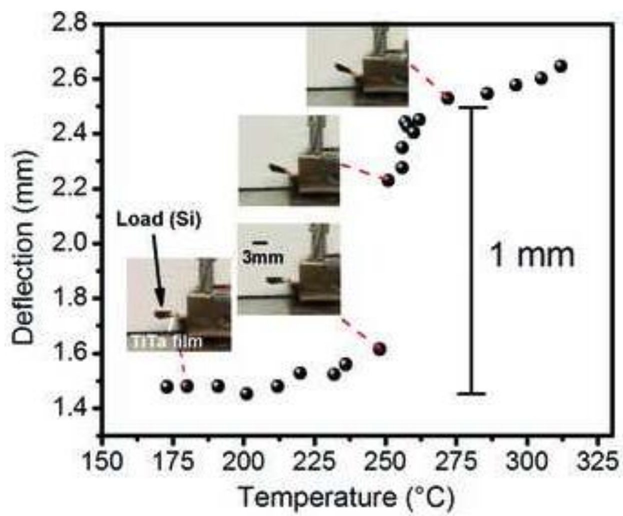
Free standing films

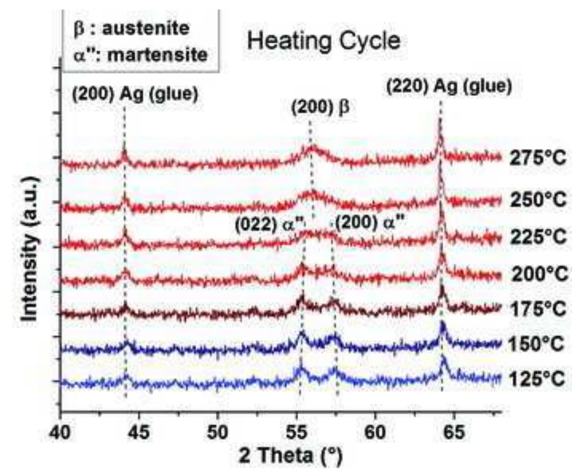
Ti-Ta HTSMA films

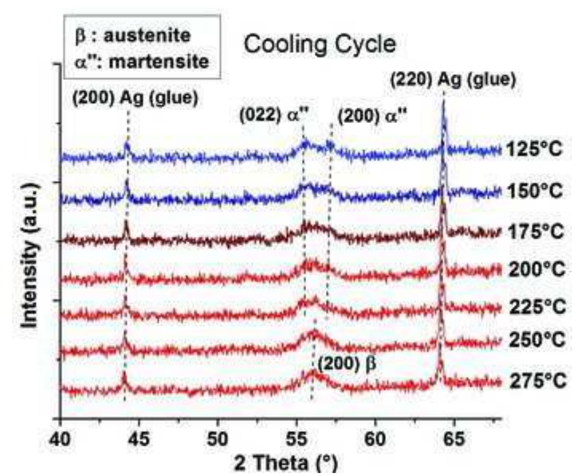
RT deposition !!!

Opens new opportunities !









Y. Motemani, P. J. Buenconsejo, C. Craciunescu, and A. Ludwig – Advanced Materials and Interfaces

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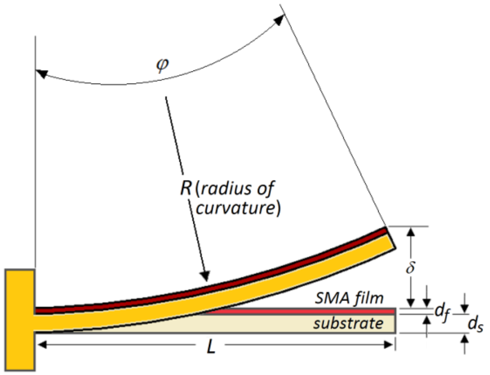
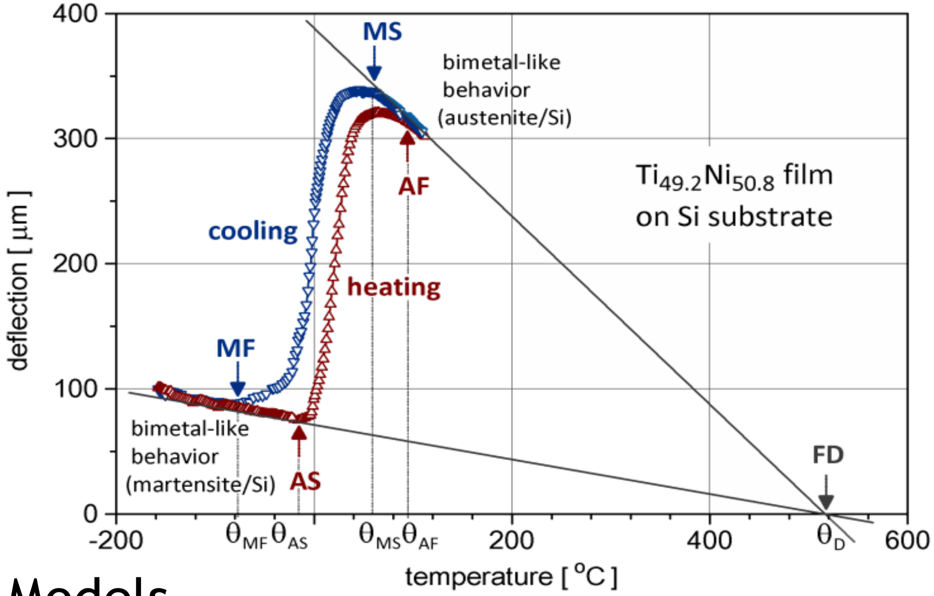
Bimorphs

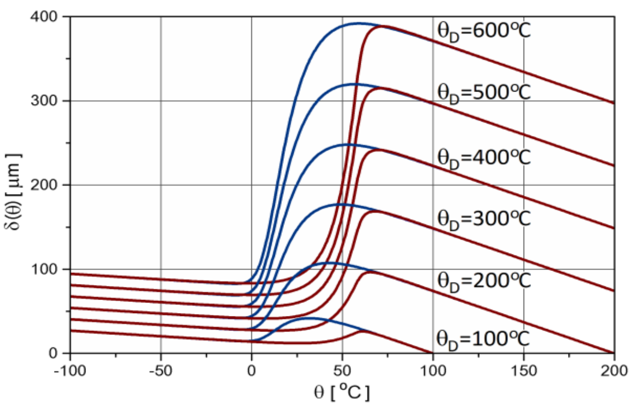
with homogenous films, one transition

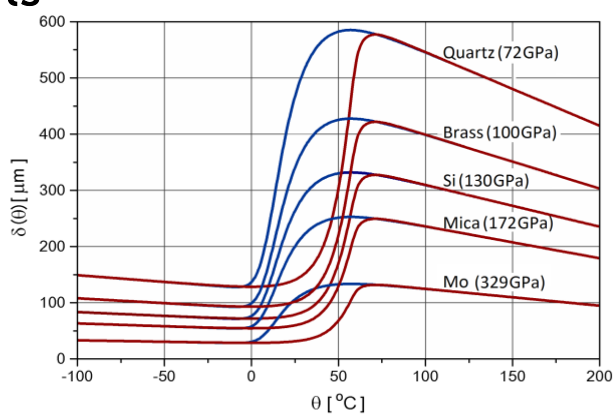




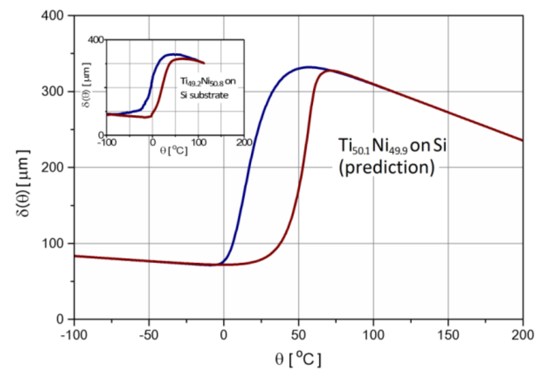
Experimental observation

Models





C. Craciunescu, A. Ercuta – Smart Mater. Struct



Validation

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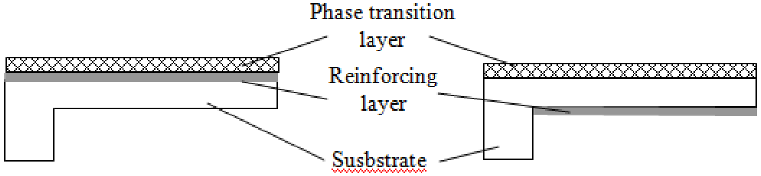
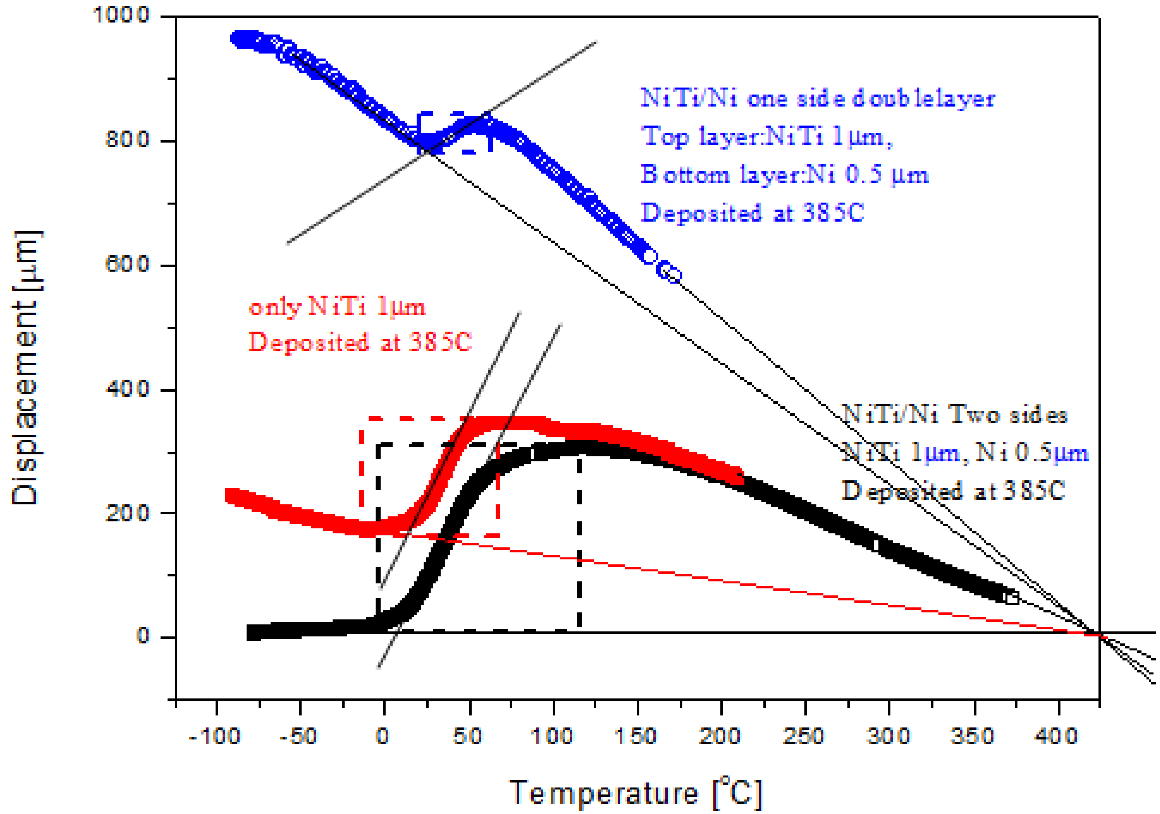
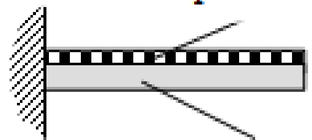
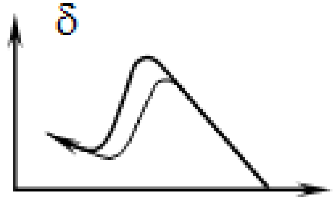
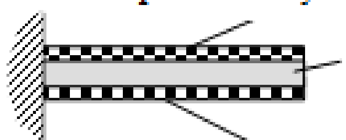
Bimorphs
with additional stress control layer





Bimorphs → Trimorphs

Architectures	Bimorph			Controlled by thermoelastic stresses
	Trimorph		?	Influenced by the nature of the films and the deposition sequence

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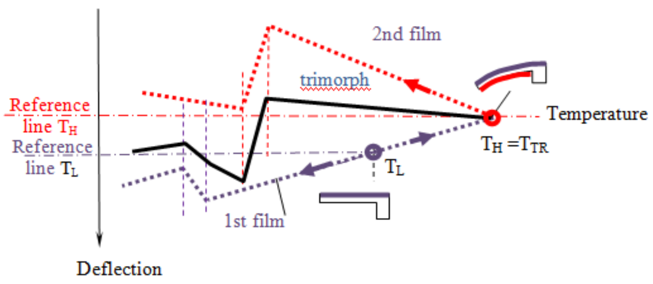
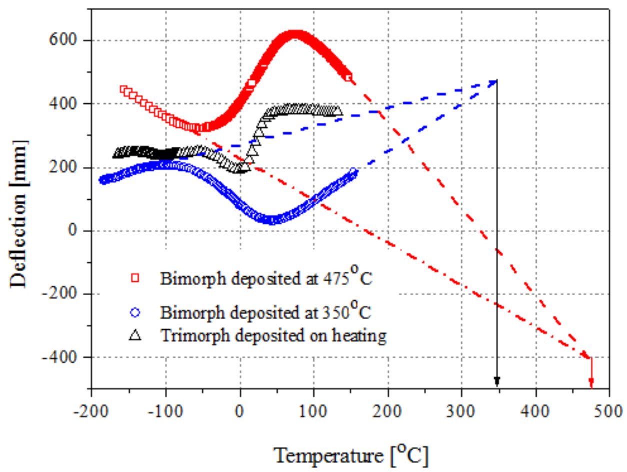
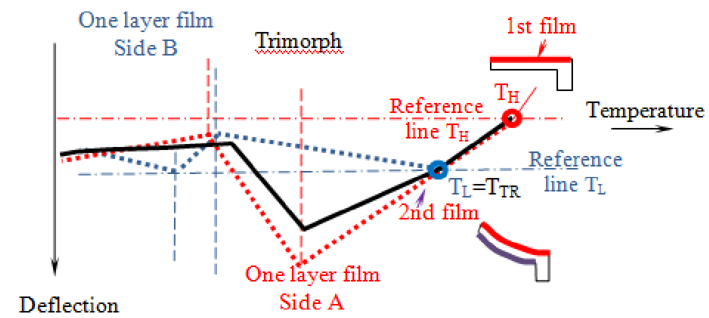
Trimorphs

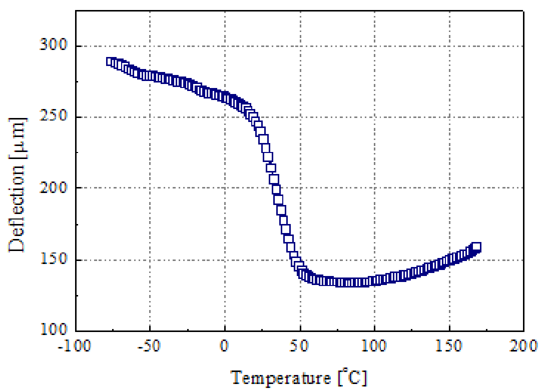
on heating





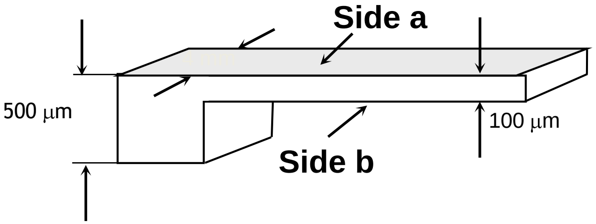
on cooling

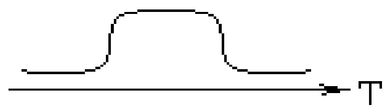
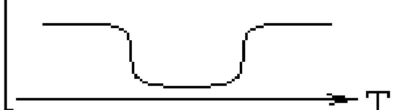
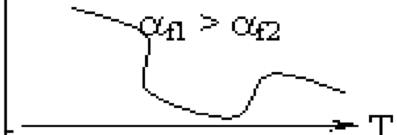
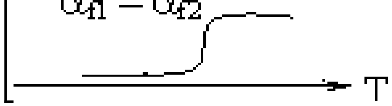




Trimorphs

Modulating the actuation response



Thermal Actuation Profile	Sequence of transformations on cooling	
	Film a (α_{f1})	Film b (α_{f2})
	II	I
$\alpha_{f1} = \alpha_{f2}$ 	I	II
$\alpha_{f1} > \alpha_{f2}$ 	I	II
$\alpha_{f1} < \alpha_{f2}$ 	I	II
$\alpha_{f1} = \alpha_{f2}$ 	I	no transformation

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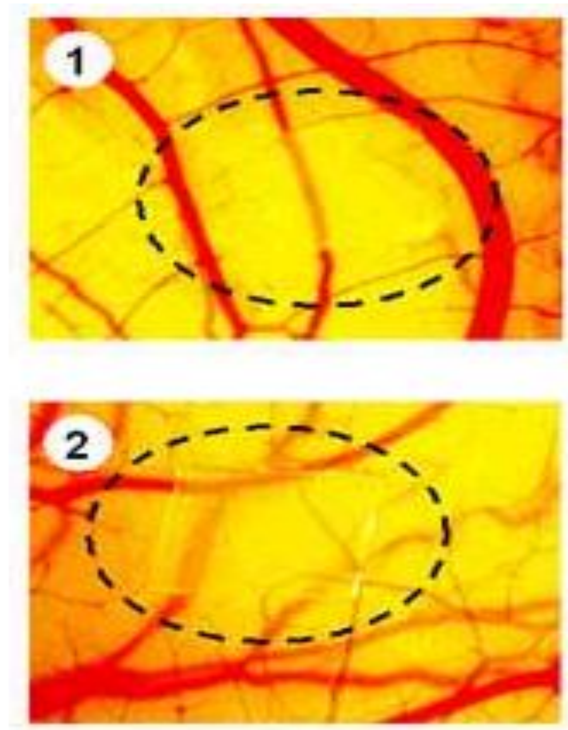
Shape memory & Biocompatibility

HET CAM TEST

HET-CAM



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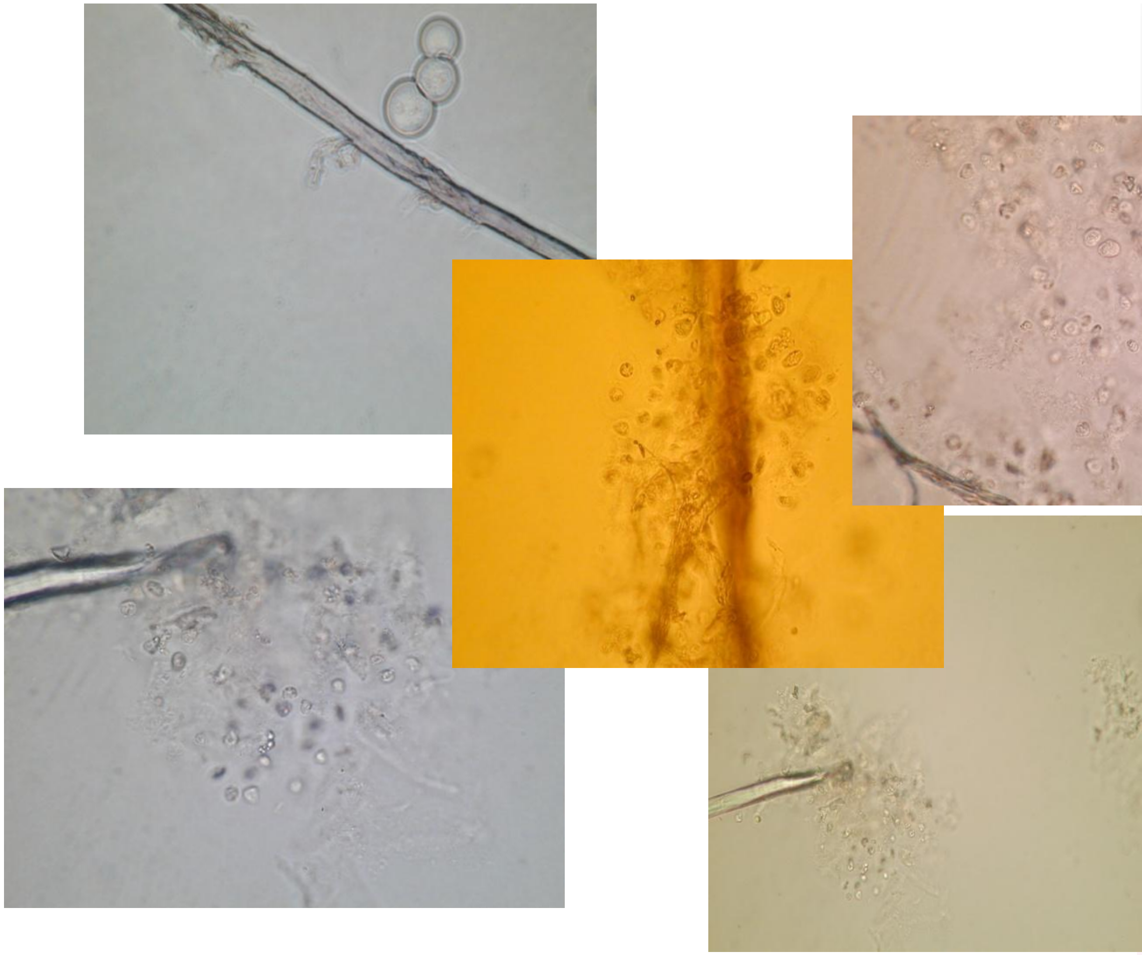
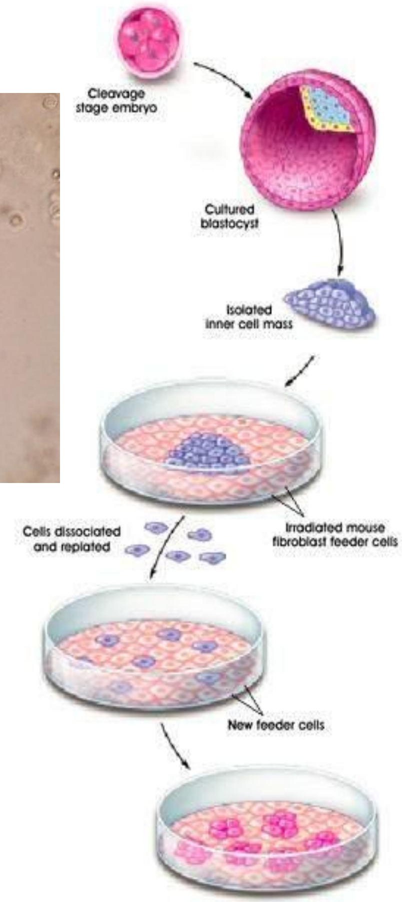
Assessment of biocompatibility *(in situ* experiments)





In collaboration with Universitatea de Medicina si Farmacie “Victor Babes” Timisoara

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Ferromagnetism & Shape memory

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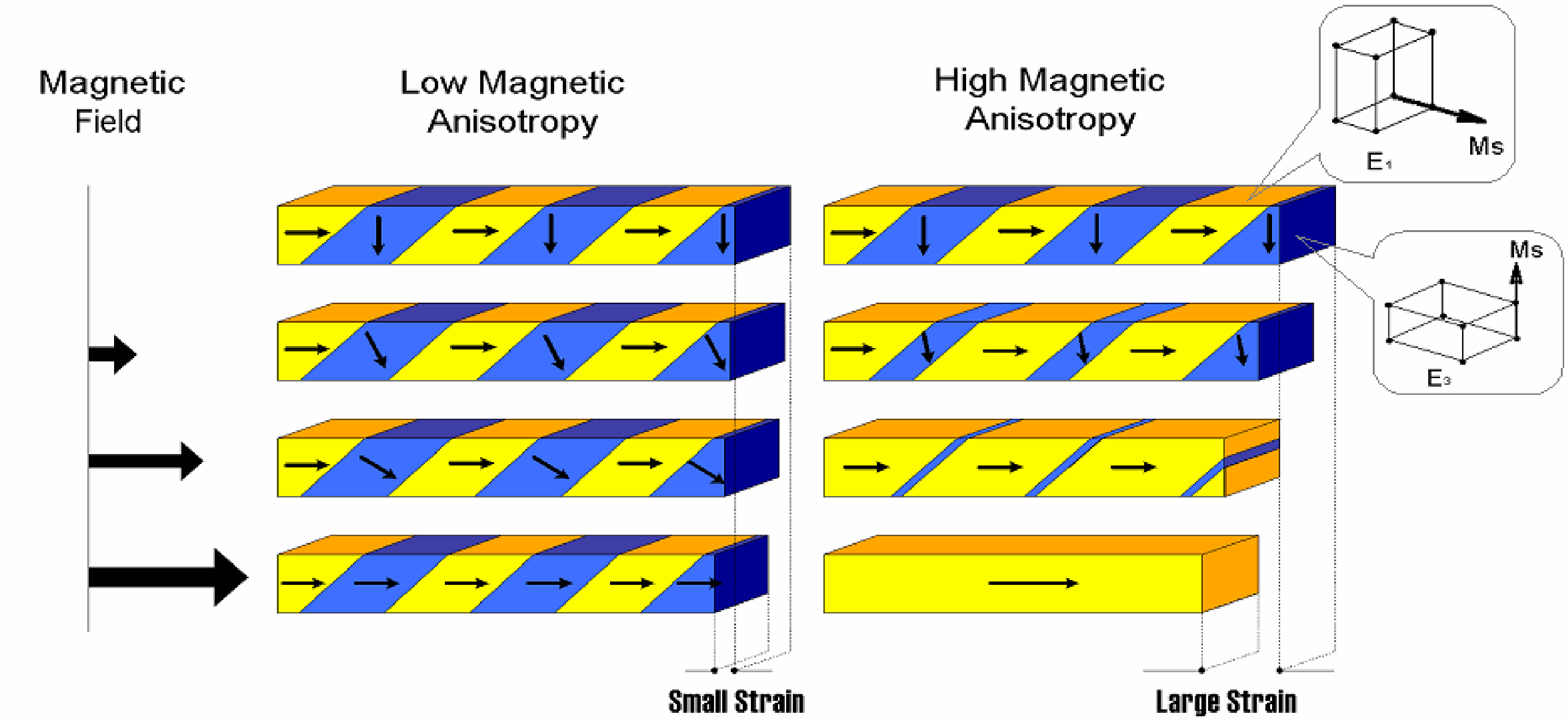
Magnetically controlled shape memory



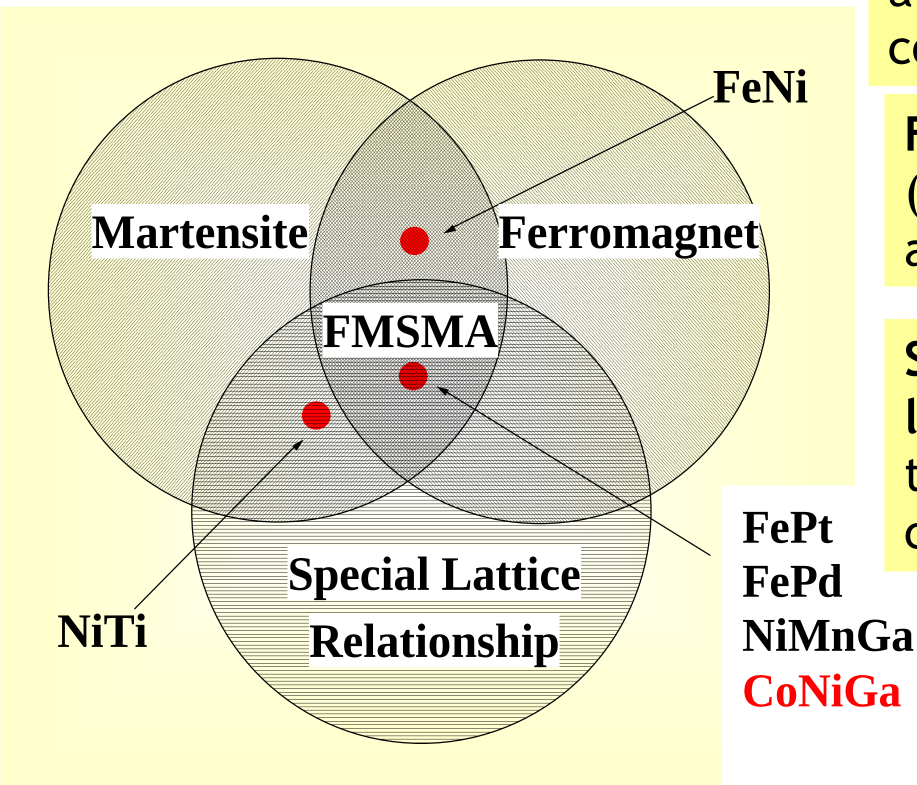
T. Kakeshita, K. Ullako –MRS Bull., vol. 27, No. 2, 2002

Magnetic and elastic domains

Independent

Interrelated

Where Ferromagnetic Shape Memory Alloys can be found?



Wuttig, Li, Craciunescu – Scripta mater

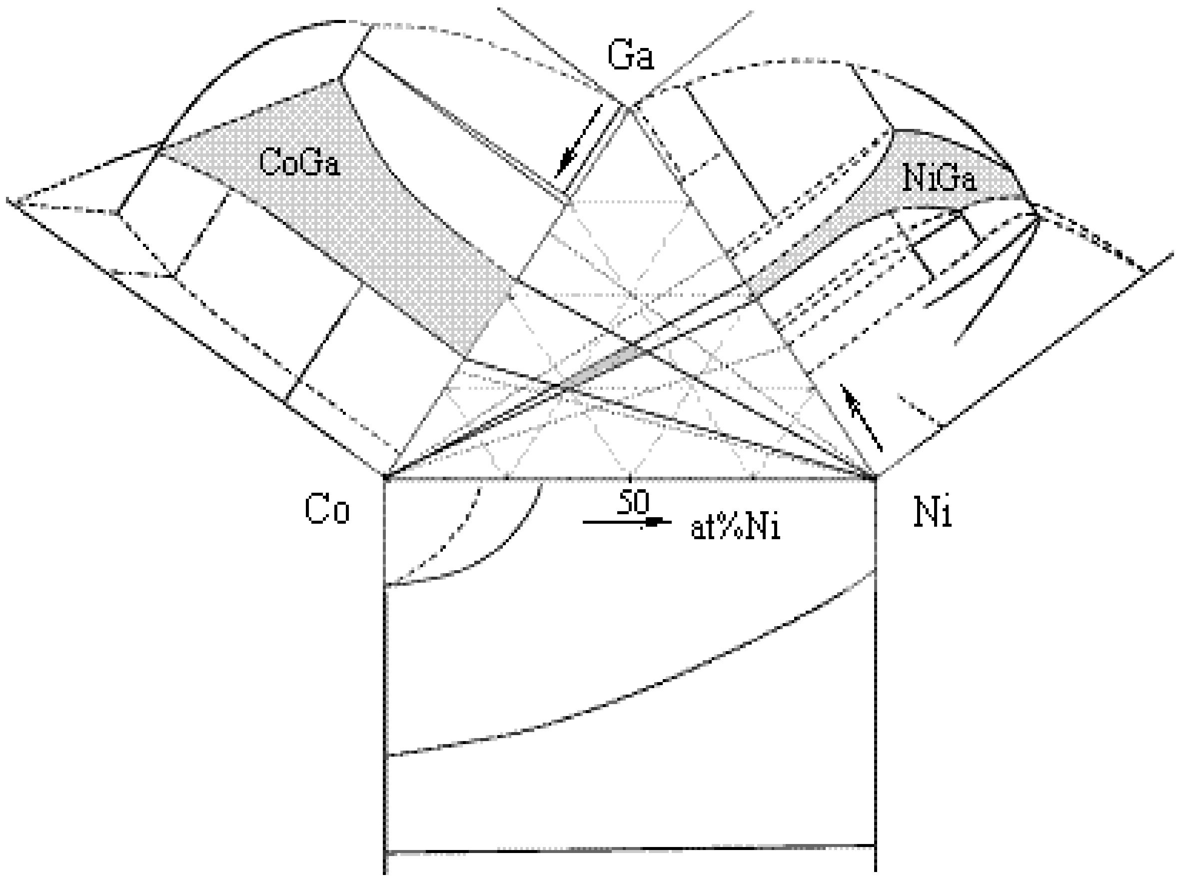
Martensitic phase changes - likely to occur at certain average valence electron concentrations.

Ferromagnetic martensites a certain (s+p+d) concentration and a ferro-antiferromagnetic transition.

Shape memory alloy require a **special lattice relationship** between high and low temperature phases to be structurally compatible.

Ferromagnetic shape memory alloys (FMSMAs) form when all three conditions are fulfilled.

Co-Ni-Ga ferromanetic shape memory system

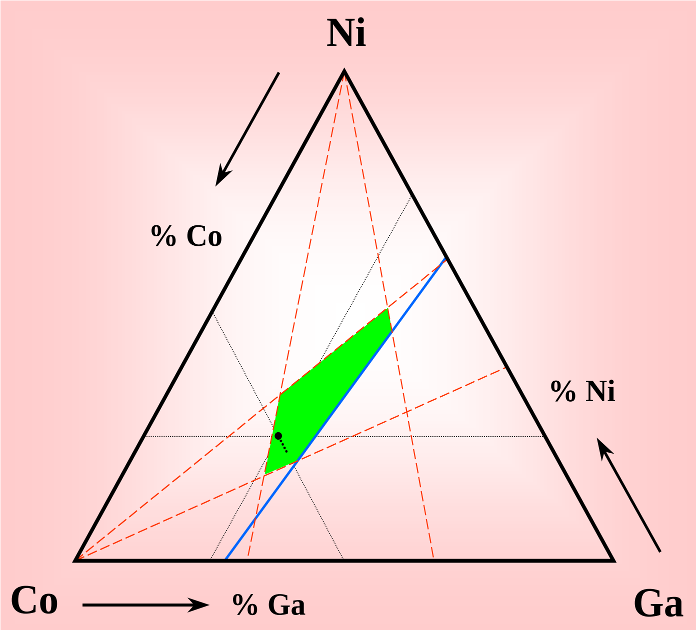


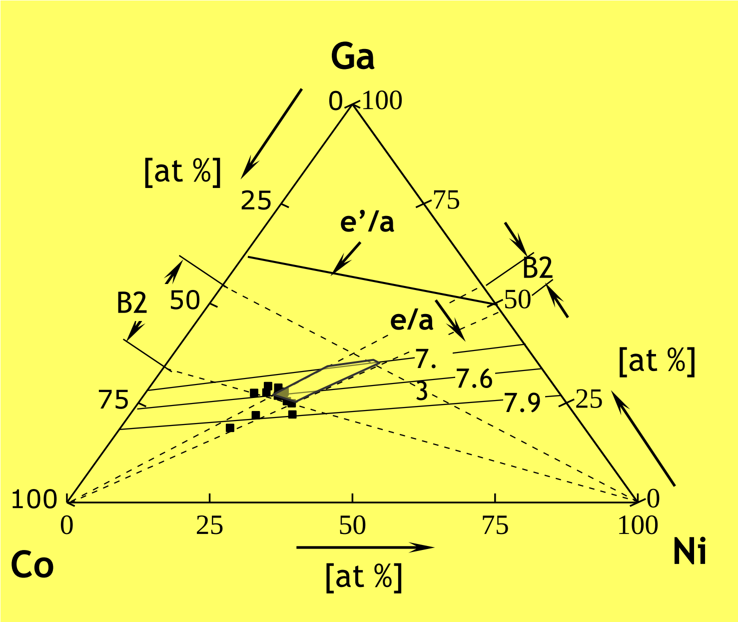
Craciunescu C.M., et all. SPIE Proceedings, vol.4699 (2002) 235-244

Compositional range for ordered solid solution

e/a

in Co-Ni-Ga system





Wuttig, Li, Craciunescu – Scripta mater. 44

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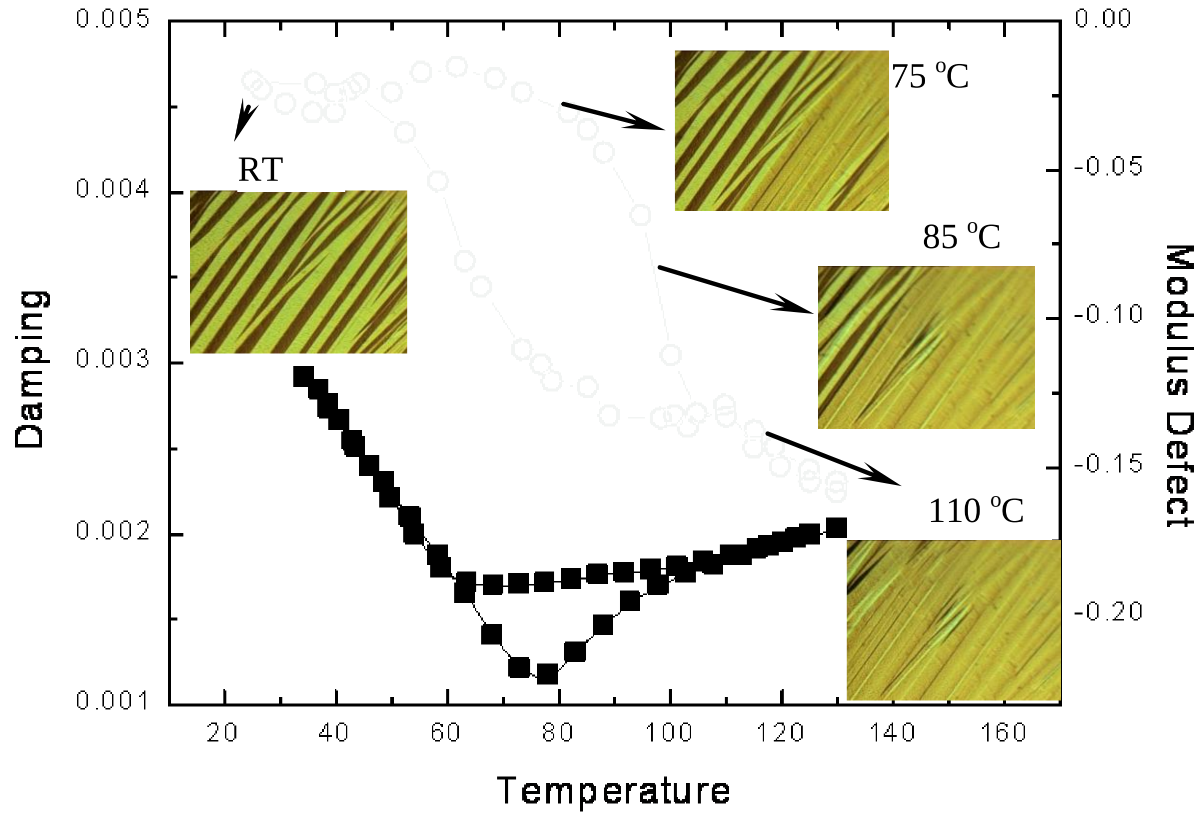
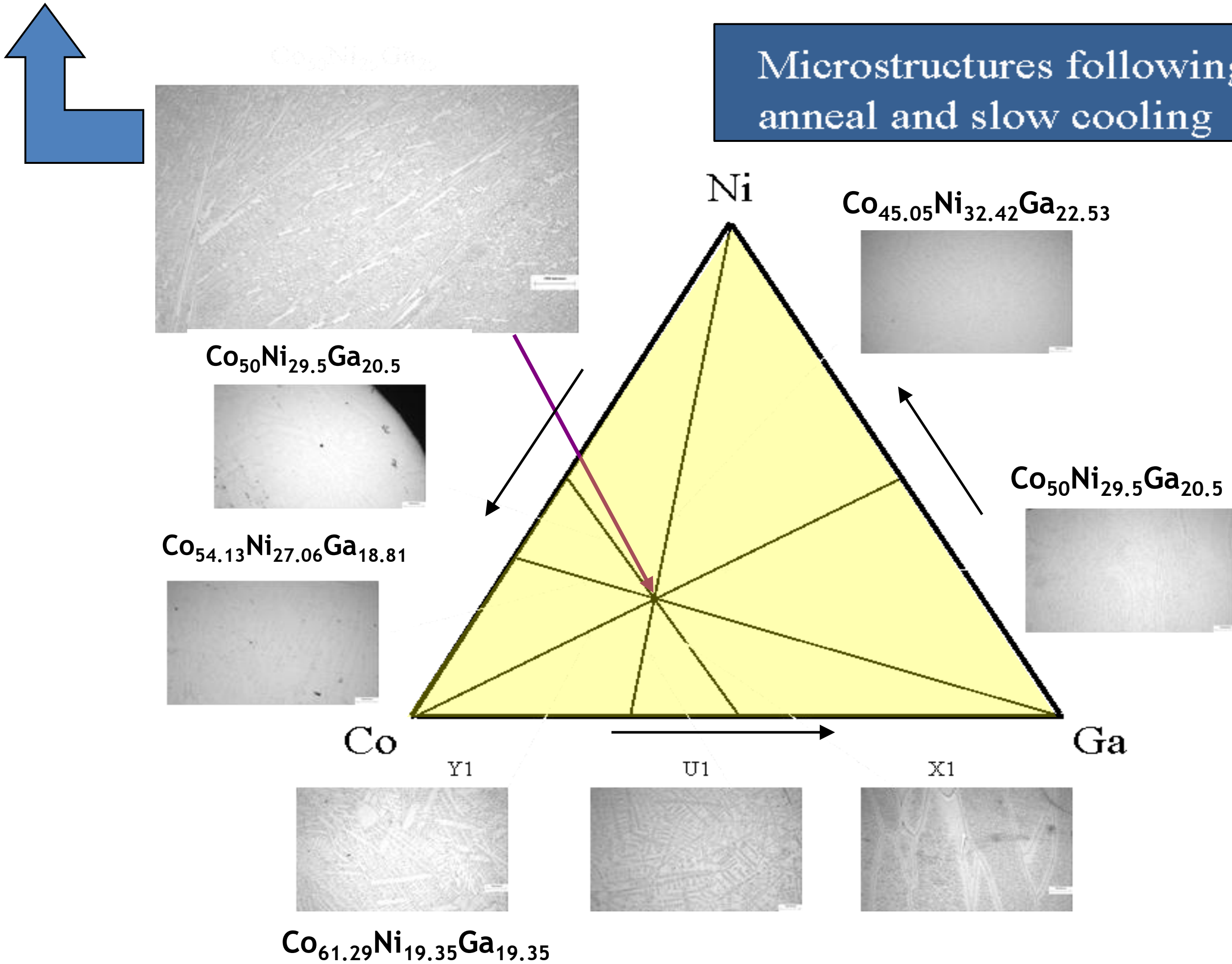


C.M. Craciunescu, Y. Kishi, M.Wuttig, Scripta Materiallia, vol 47/4

	Co	Ni	Ga
Dendrites	60.8	21.9	17.3
Matrix	42.9	28.1	29

Microstructures following 900 C anneal and slow cooling



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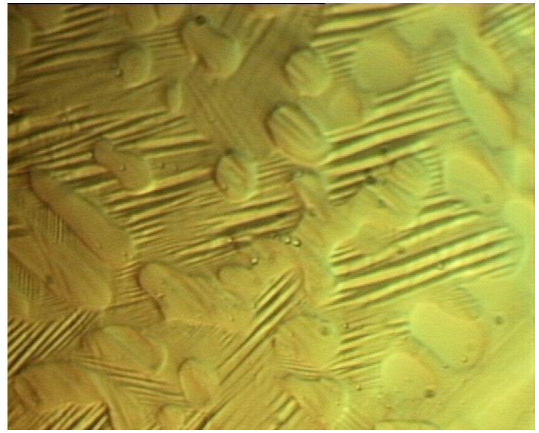
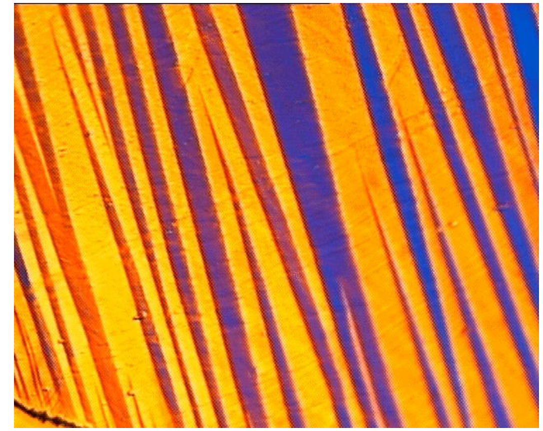
$Co_{58}Ni_{22}Ga_{20}$

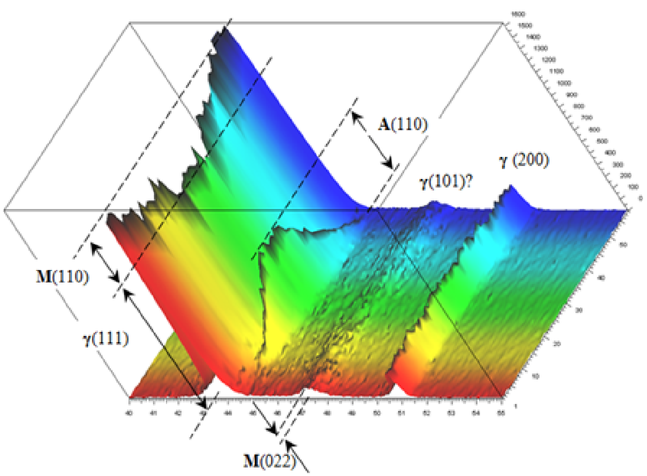
Martensitic matrix and non-martensitic precipitates



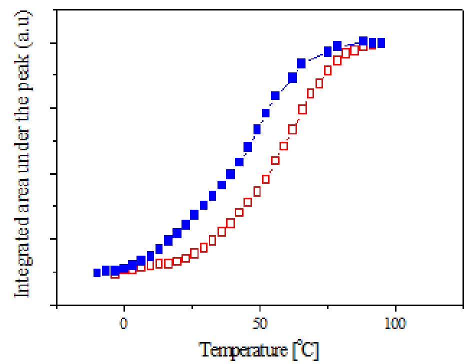


$Co_{50}Ni_{22}Ga_{28}$

Full martensitic structure

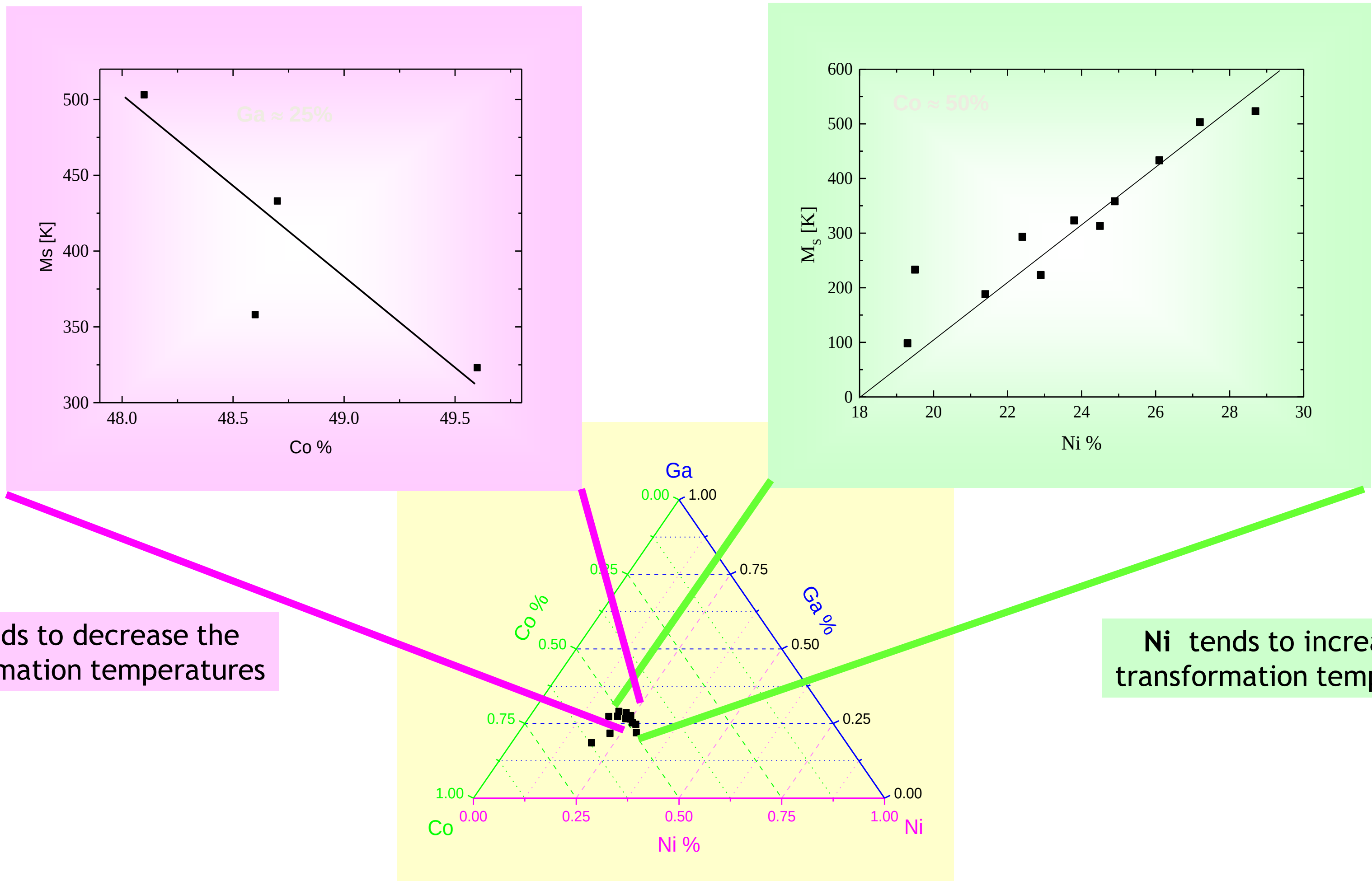


a. X-ray spectra on heating and cooling detailing the martensite M(110) peak disappearing on heating and reappearing on cooling, on top of the γ(111) peak.



b. integrated area under the A(110) peak describing the phase transition on heating (□) and on cooling (■).

$Co_{47.22}Ni_{22.44}Ga_{30.29}$



Co tends to decrease the transformation temperatures

Ni tends to increase the transformation temperatures

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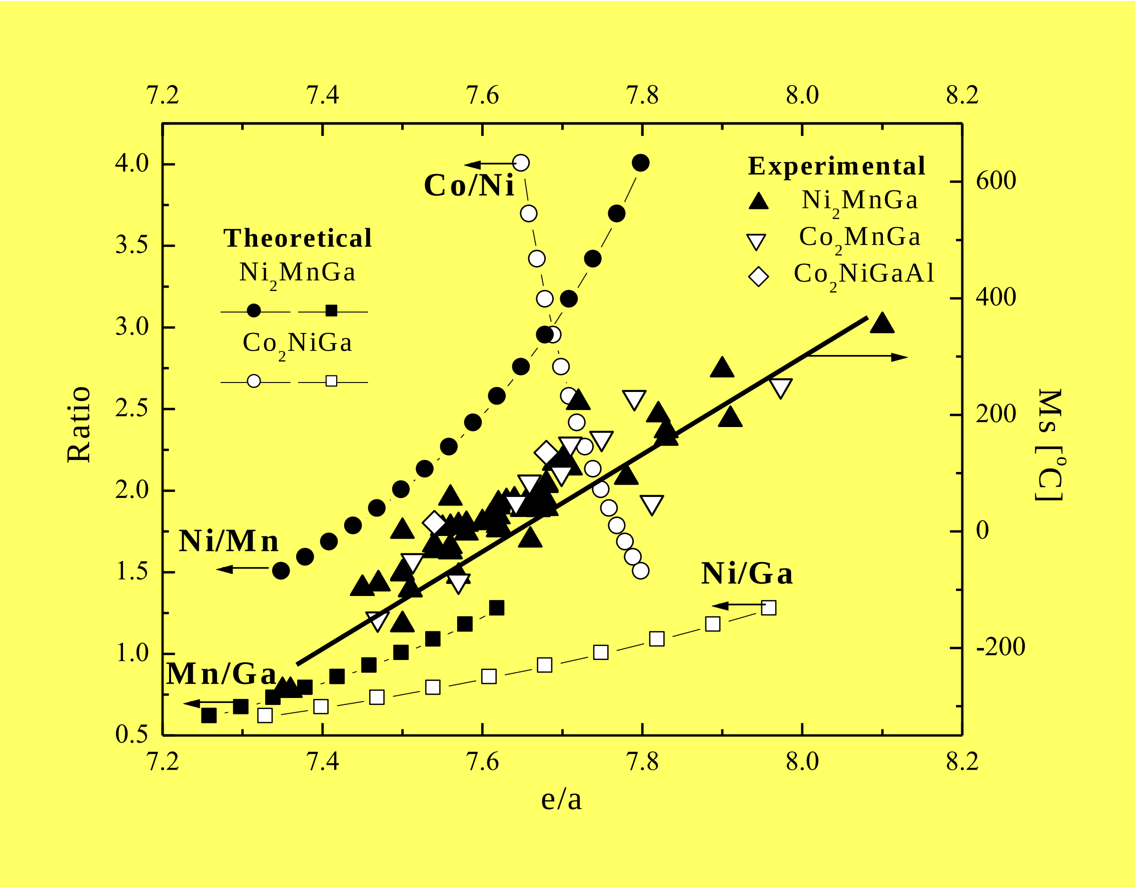

C.M. Craciunescu et all. -SPIE Proceedings

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Main Conclusions

- Enhancement of actuation is possible beyond the classical solutions
- Significant differences can be observed between bimorphs and trimorphs
- Signal modulation can be achieved in trimorphs by appropriately selecting the films transformation and their deposition sequence
- Assesment of biocompatibility via in situ tests
- Ferromagnetic shape memory alloys show martensitic phase transformation controlled by thermal and magnetic fields

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Goals within POCAL Project

- To manufacture shape memory alloys that are thermally and magnetically controlled
- To develop layered structures based on shape memory alloys
- To control the properties by nanostructuring via severe plastic deformation and rapid solidification

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