Funding Authority

Romanian National Authority for Scientific Research

CNCS – UEFISCDI

Host Institution: Politehnica University of Timisoara

PROJECT OUTLINES

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ESOP

Exploration System for Optimization of Shape Memory Actuation in Compositional Spreads

Project No.PN-II-ID-PCE-2011-3-0837
Contract no.166/2011

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ESOP

The project has as main fundamental objectives the development of an exploration system that would allow:

- a combinatorial optimization of actuation using the sputtering technique to generate compositional spreads; -
- the development of models for combinatorial systems adapted for investigation of actuation;
- the implementation of the combinatorial exploration system for the case of intelligent materials, with focus on shape memory alloy families;
- the development of microactuators with controlled and optimized functionality;
- the investigation or modelling of systems for the exploration, and
- the microfabrication of materials with "on demand" properties, adapted for applications in microsystem engineering.

Several experimental objectives have been defined:

- identification of specific design requirements for a system dedicated to generating combinatorial libraries of metallic materials;
- design of an exploration path for specific functionalities;
- design and fabrication of an exploratory system that allows sputtering of compositional spreads;
- design and microfabrication of substrates for the investigations of functional libraries;
- microfabrication of sputtered compositional spreads based on shape memory alloy compostions;
- microstructural-compositional characterization of libraries;
- design of an actuator based on thin film microfabrication.

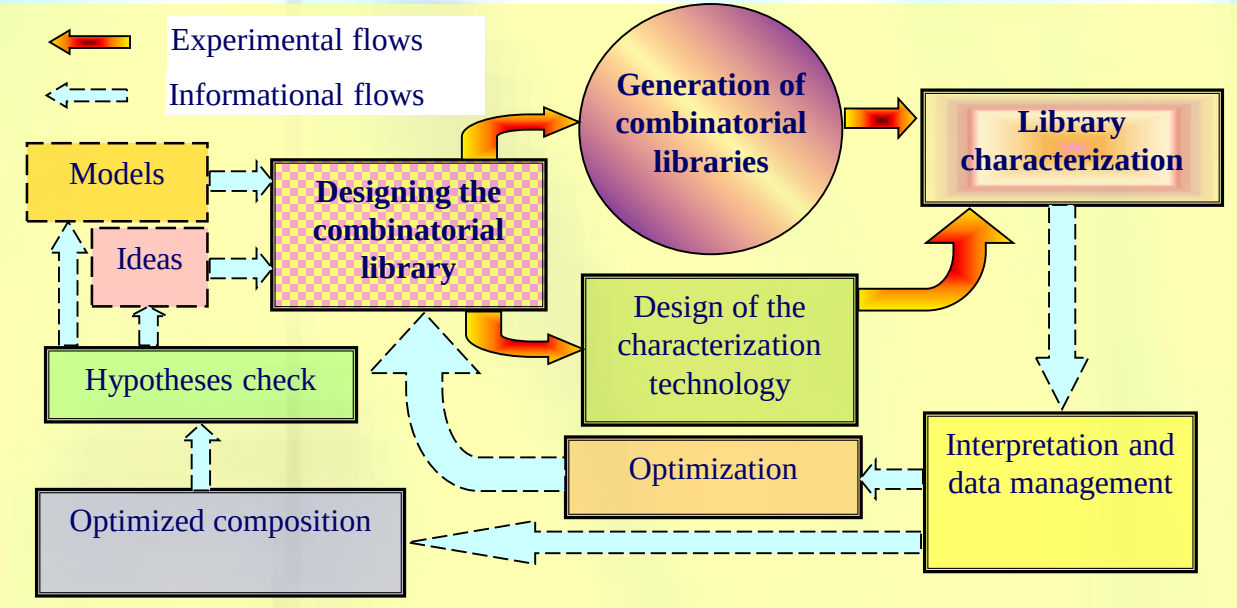
The exploratory system aims to accelerate the innovation process in the fabrication of micro sensors and actuators.

ESOP

The project aims to design, fabricate and develop a combinatorial exploration system for optimization of microactuation using the sputtering technique of thin film compositional spreads.

Objectives

- the development of a method that allows the combinatorial approach of materials functionality by microfabrication via thin film sputtering.
- the development of models for combinatorial systems, adapted for the investigation of the functional properties of metallic materials, especially actuation.
- the implementation of the combinatorial exploration system focused maximizing the actuation of shape memory alloys.



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ESOP 2011 Objectives & Results

Exploration paths for the investigation
of shape memory alloys actuation

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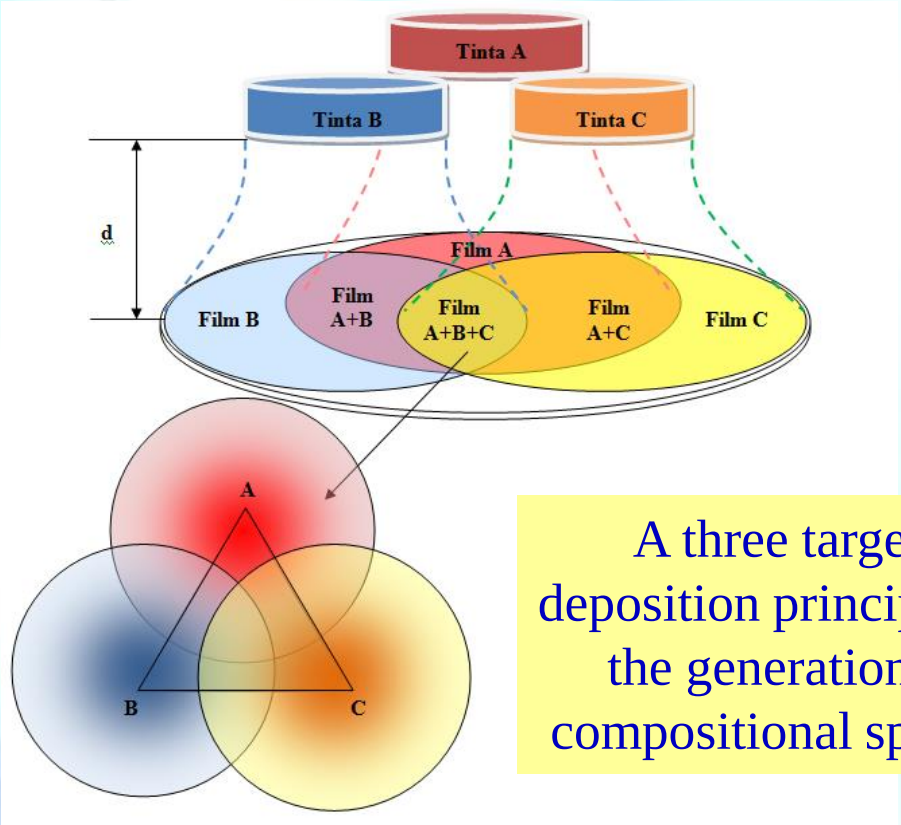
Thin film investigation path



A three targets deposition principle for the generation of compositional spreads

Continue **2011**

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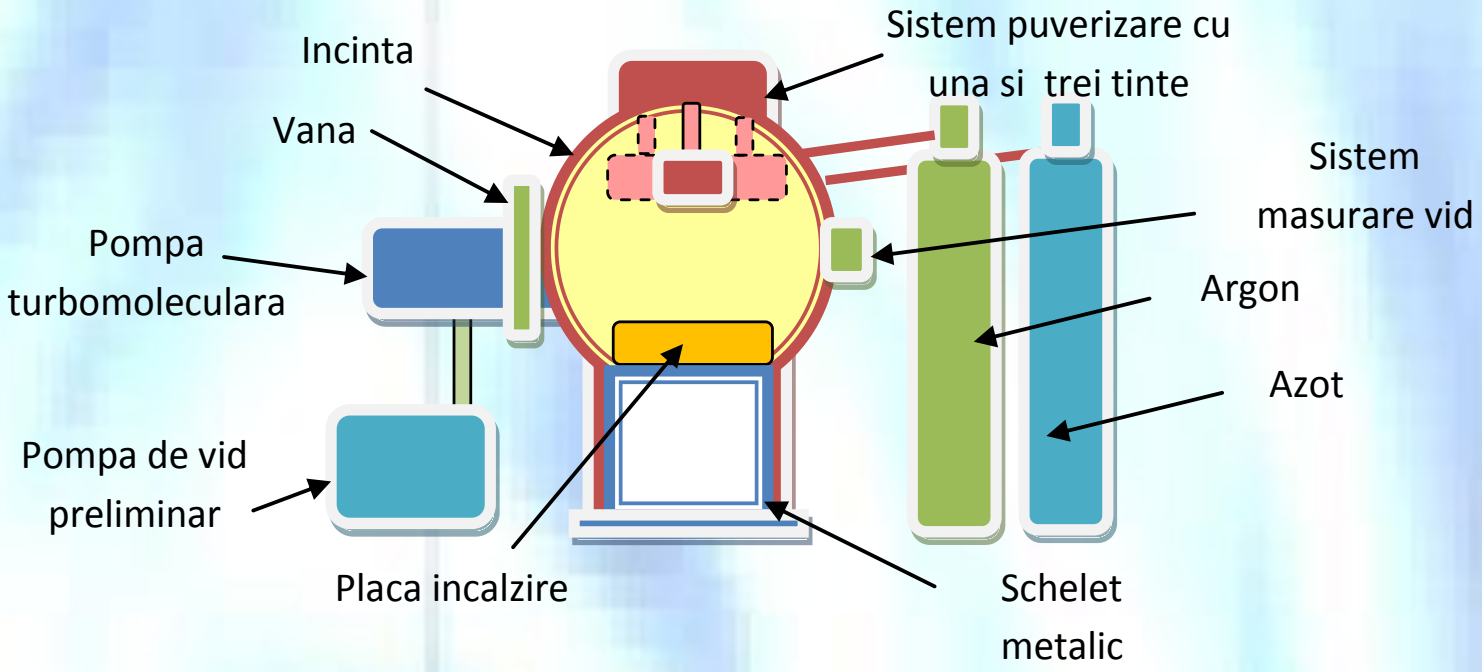
ESOP 2011

The basic idea for the deposition system



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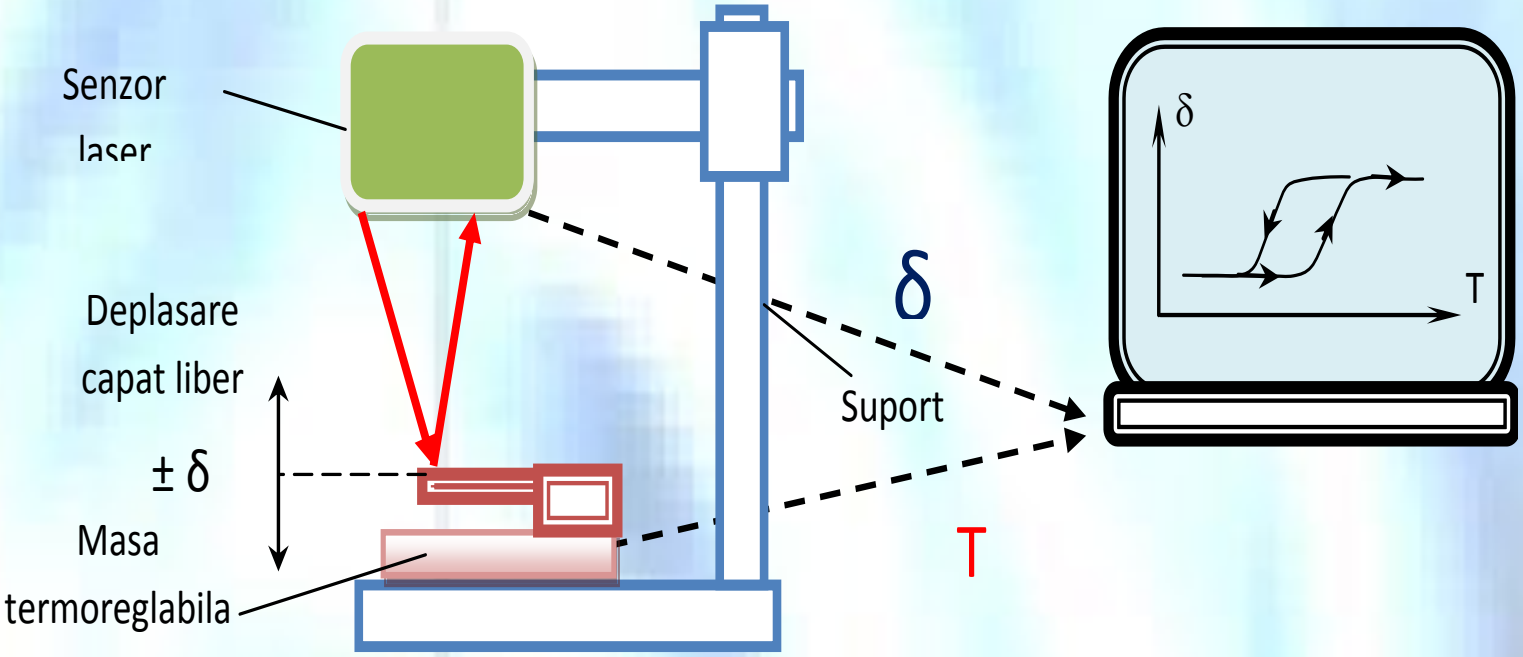
ESOP 2011

Principle of a laser actuation microscope for cantilever-type samples



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ESOP 2012 Objectives & Results

Modelling and design of manufacturing exploration system

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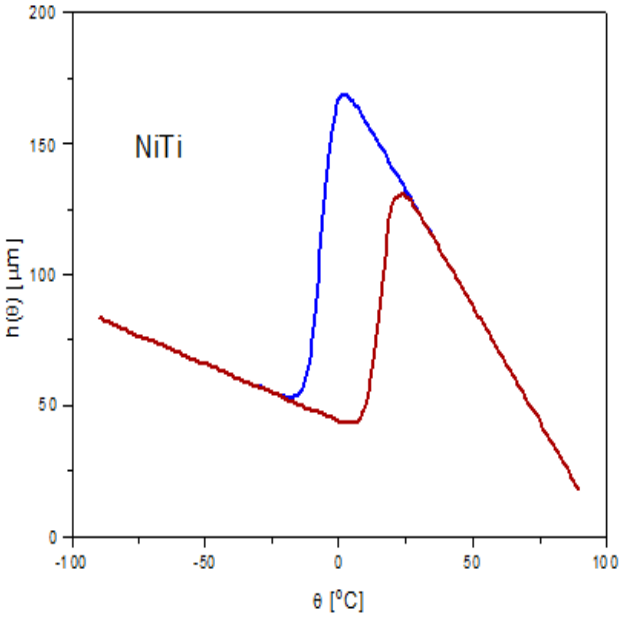
Actuation prediction in bimorphs based on shape memory alloy films

$$\rho(\theta) := \frac{1}{3\cdot\Delta T(\theta)}\cdot\frac{2\cdot\left(\gamma(\theta)\cdot\beta^2\cdot d_s + d_f\right) + 3\cdot d_b(\theta)\cdot\left(\gamma(\theta)\cdot\beta^2 - 1\right)}{\delta_f(\theta)\cdot\left(\gamma(\theta)\cdot\beta^2 - 1\right) - \left(\gamma(\theta)\cdot\beta^2\alpha_s - \alpha_f(\theta)\right)}$$

$$h(\theta) = \rho(\theta)\cdot\left(1 - cos\left(\frac{Lo}{\rho(\theta)}\right)\right)$$



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ESOP 2012

Deposition system with three targets

Acquisition
Electron Microscope TESCAN VEGA 3 LMU
with Bruker EDX Quantax

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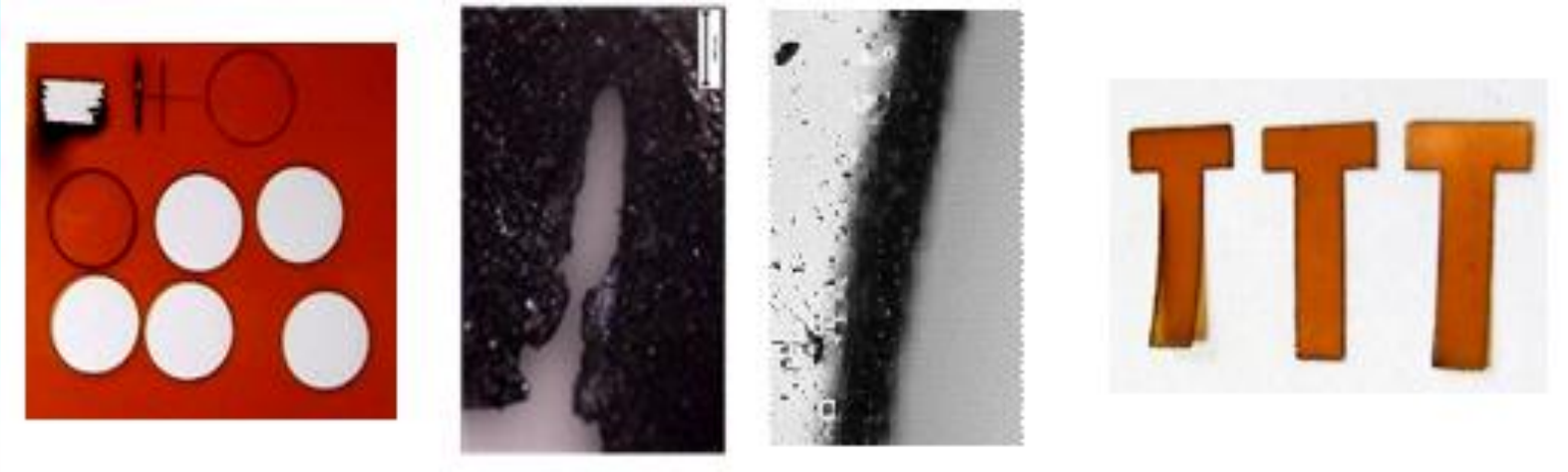
ESOP 2012

Kapton substrate laser manufacturing



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ESOP 2013 Results

Equipment fabrication and preliminary tests

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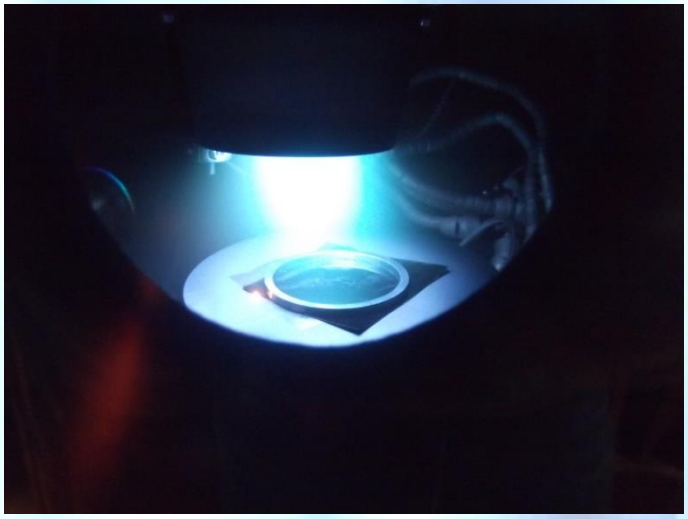
Developed and tested sputtering equipment

Plasma deposition of NiTi film on kapton substrate



Continue **2013**

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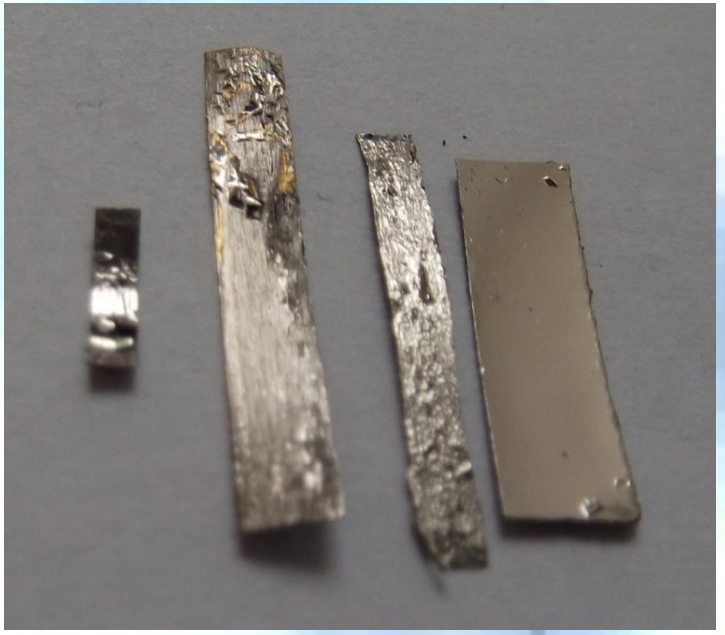
ESOP 2013

Equipment fabrication and preliminary tests

Test on bimorph architectures with NiTi film deposited on:

-Ni-TiCu ribbon

- Cu-Zn-Al porous ribbon
- Cu-Al-Ni ribbon
- Kapton foil



Test on deposition parameters

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ESOP 2014 Results

Exploration of compositional spreads

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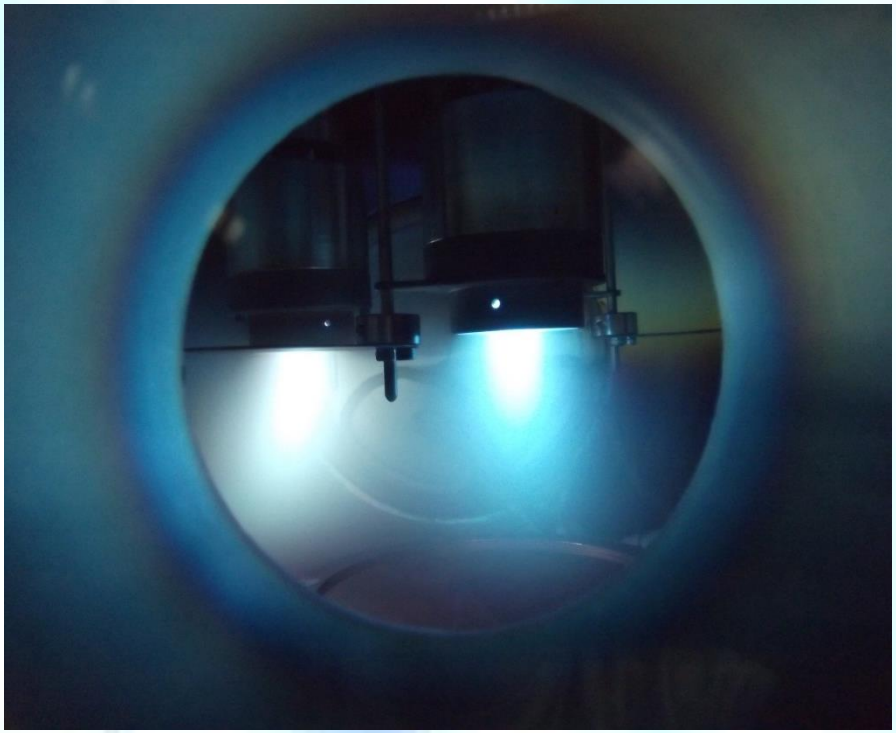
Test on two targets deposition



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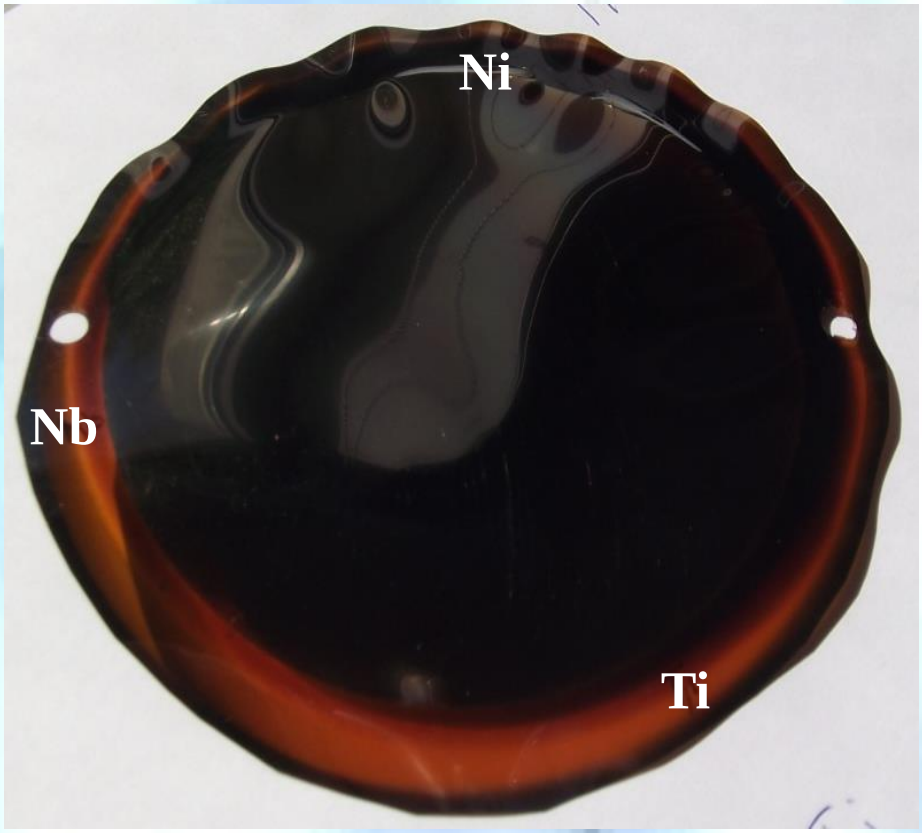
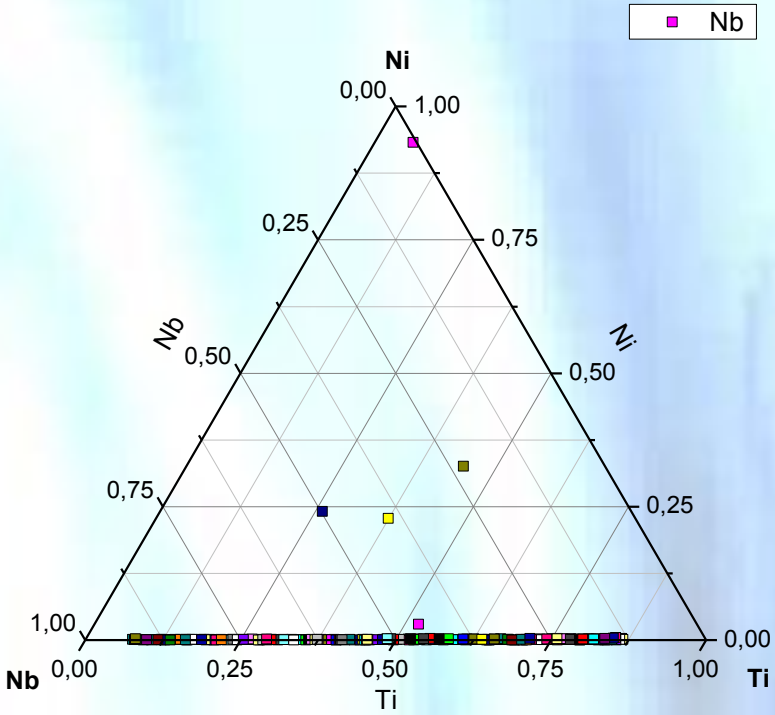
ESOP 2014

Exploration of compositional spreads

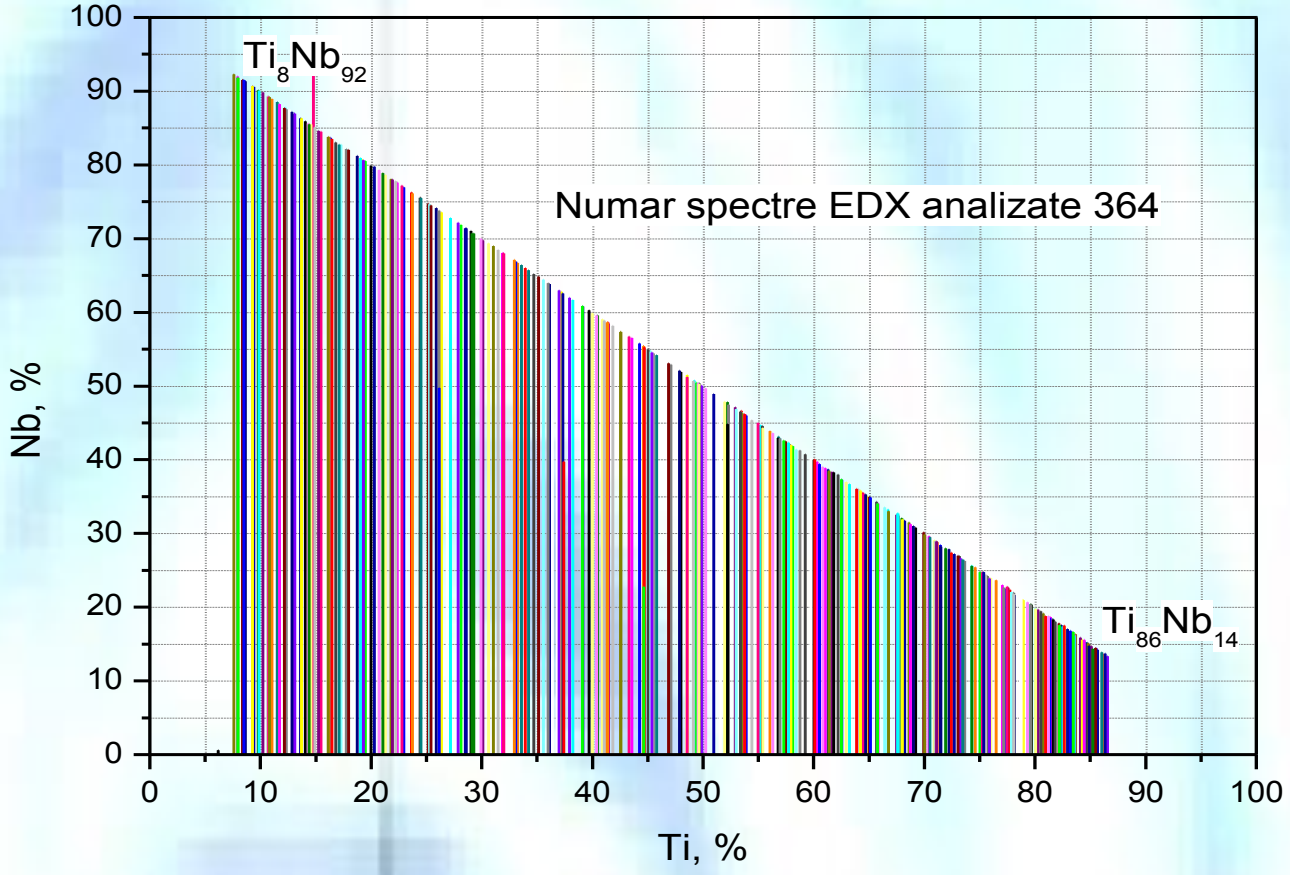
Ni-Ti-Nb compositional spread



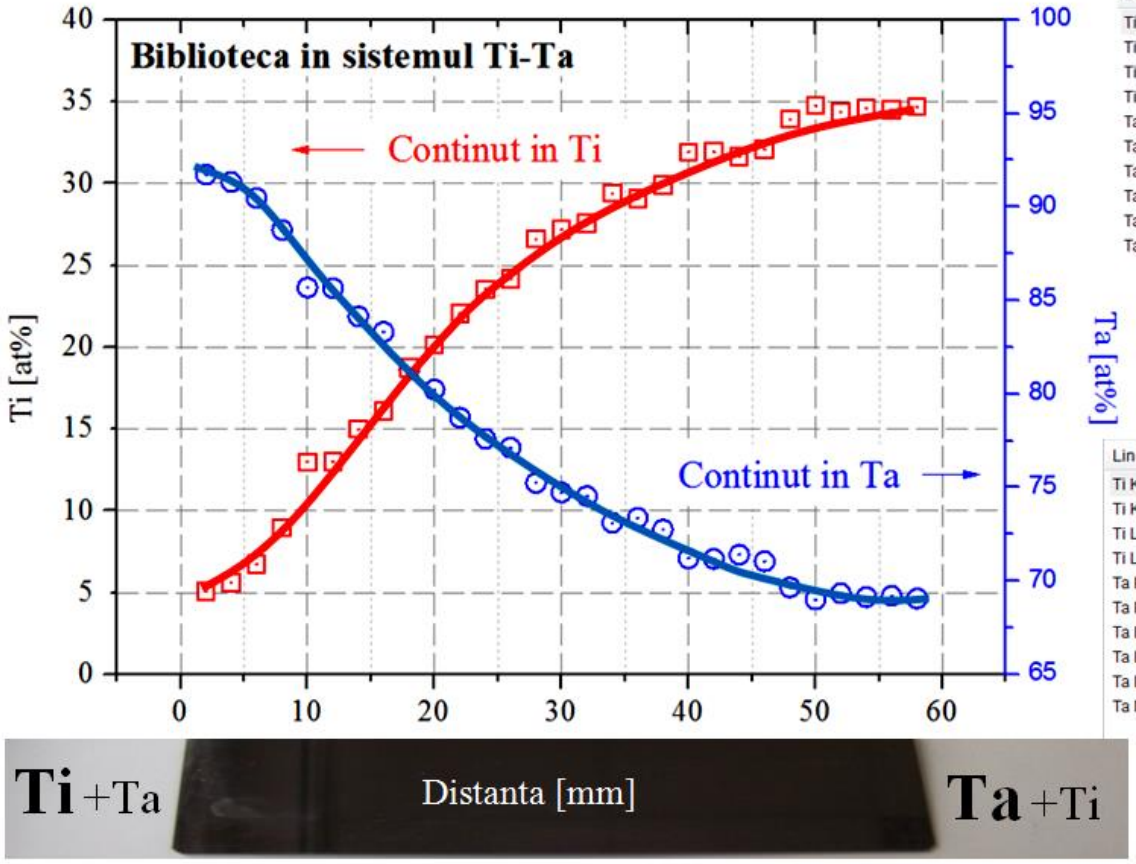


ESOP 2014

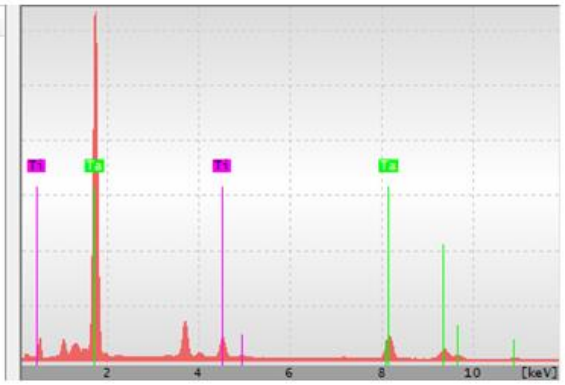
Exploration of compositional spreads



Ti-Ta library



Line	keV
Ti Kα1	4.511
Ti Kβ1	4.932
Ti Lα1	0.452
Ti Lβ1	0.458
Ta Kα1	57.532
Ta Kβ1	65.223
Ta Lα1	8.146
Ta Lβ1	9.343
Ta Lγ1	10.895
Ta Mα1	1.710



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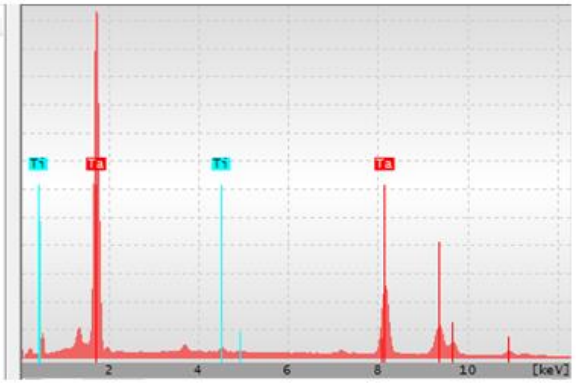
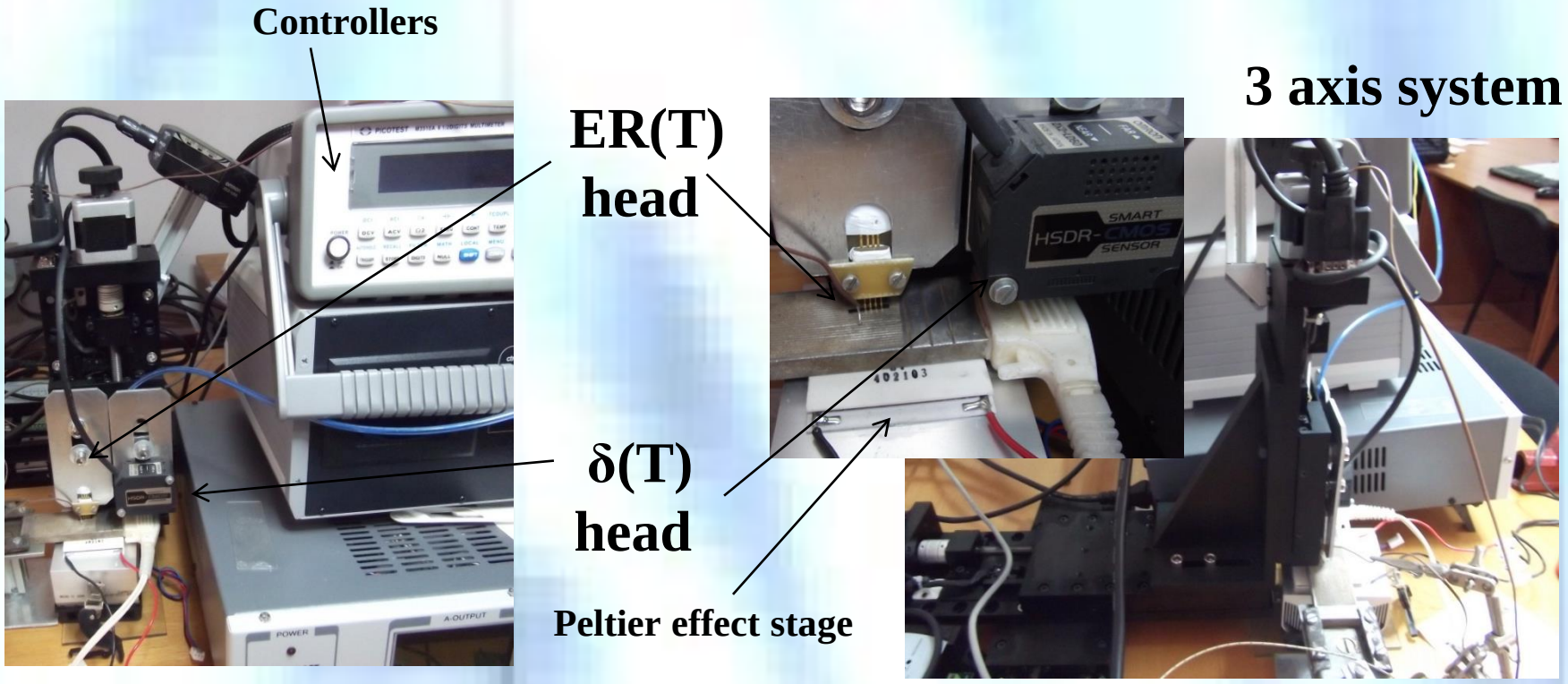


ESOP 2014

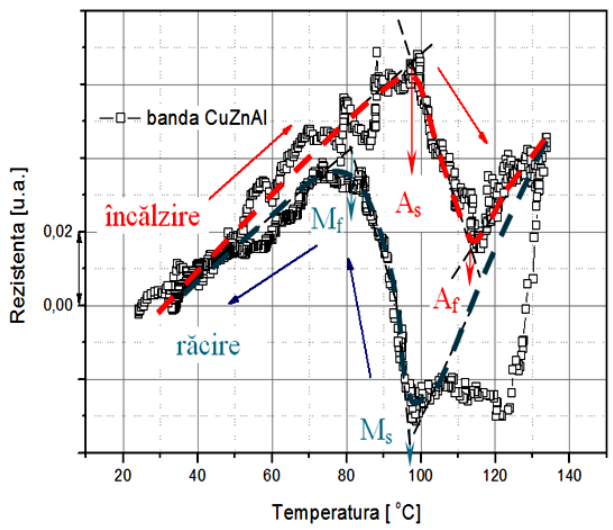
Development of a 3 axis Electric Resistance (ER) and deflection (δ) as a function of temperature (T) Measurement System

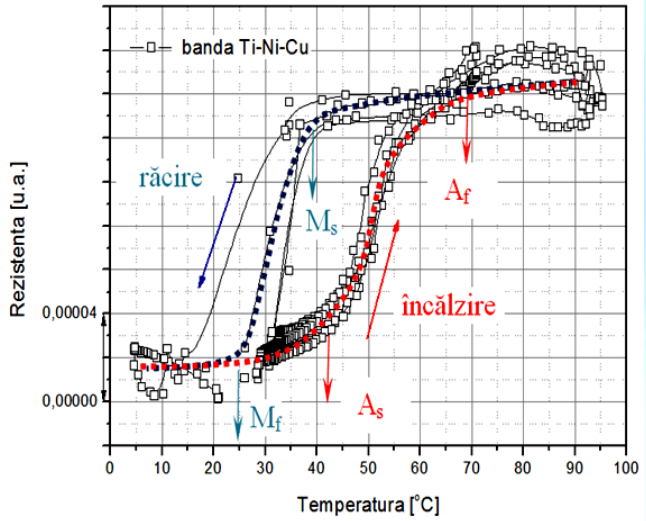


ESOP 2014

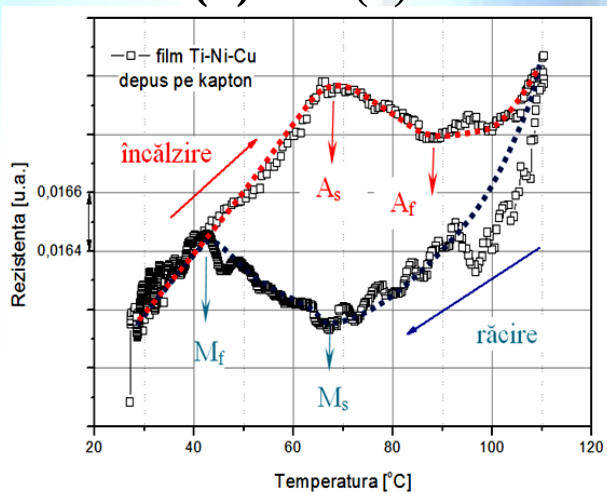
Tests on the ER(T) + δ(T) dependecies

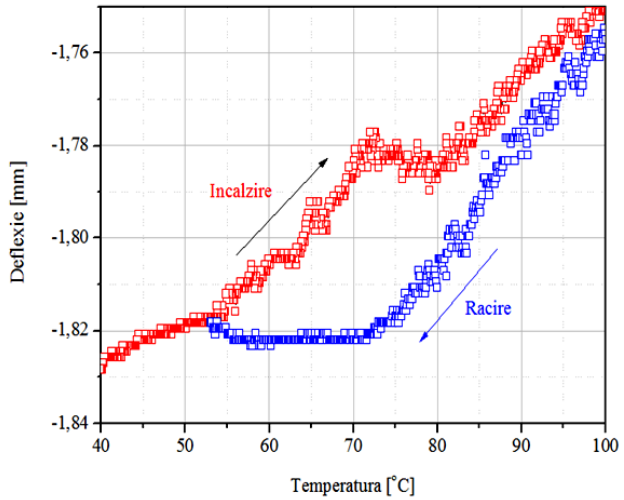
ER(T) for **Cu-Zn-Al and Ti-Ni-Cu ribbons**





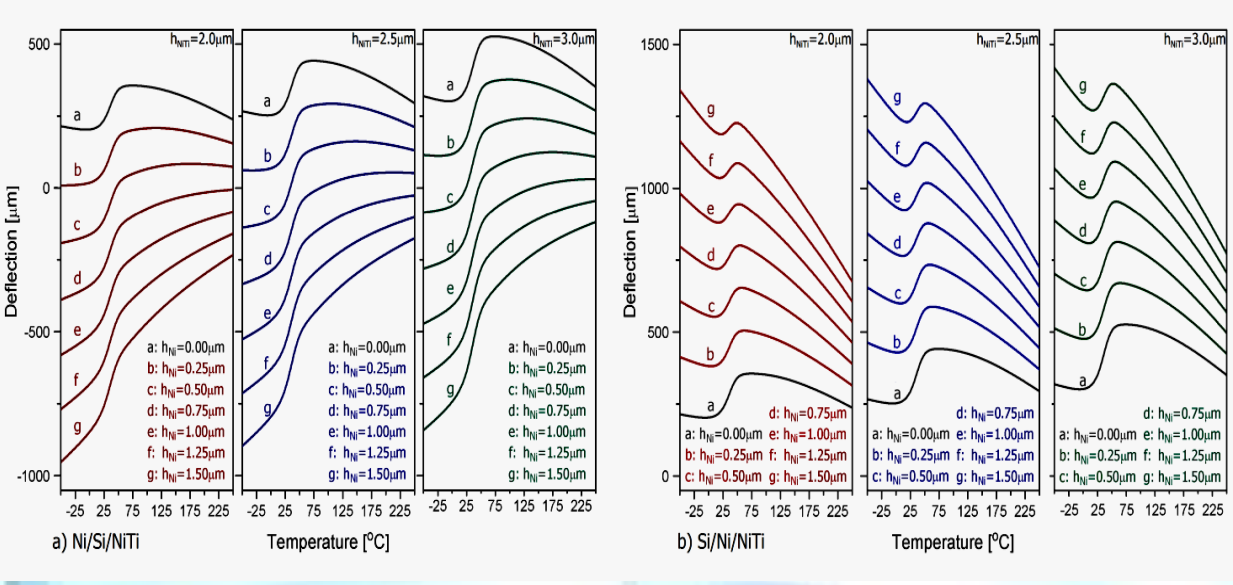
ER(T) and δ(T) for **Ti-Ni-Cu films deposited on kapton**

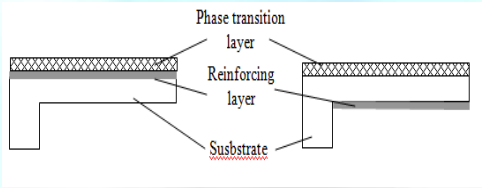




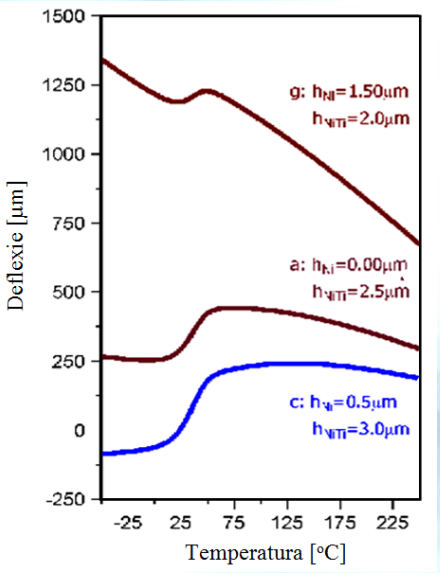
ESOP 2014

Optimization



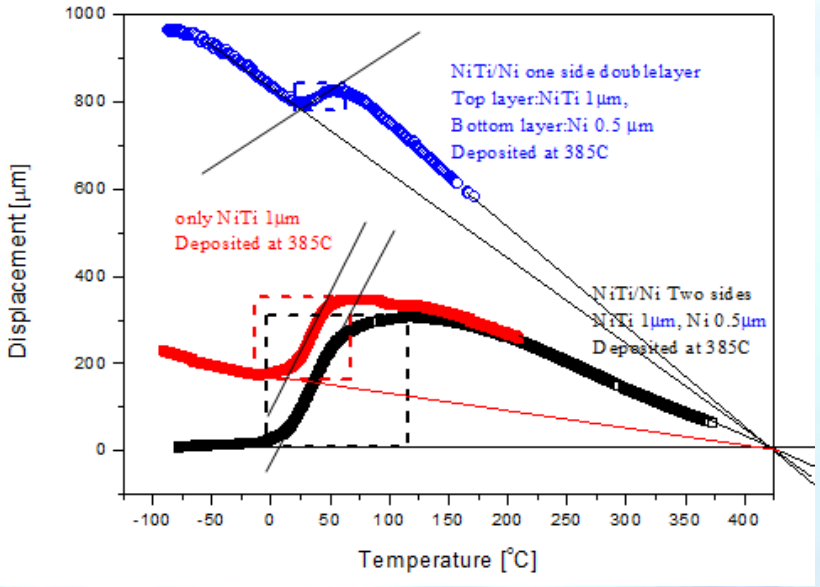


Models for actuators with reinforced substrate



Model

Experimental data



ESOP 2015

Fabrication of ternary library

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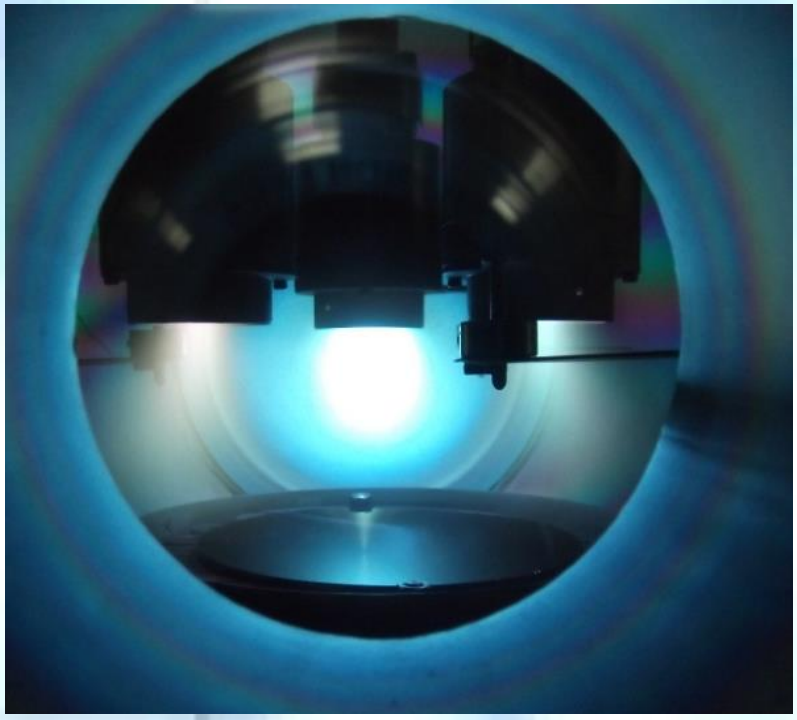
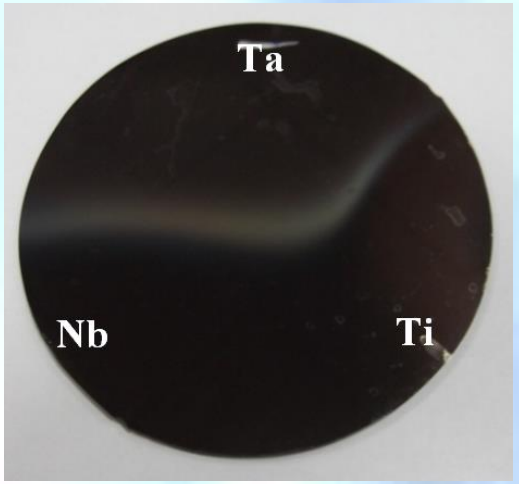
Three targets deposition



Ti –Ta -Nb library

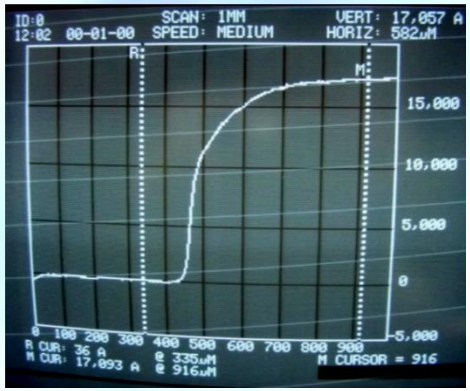


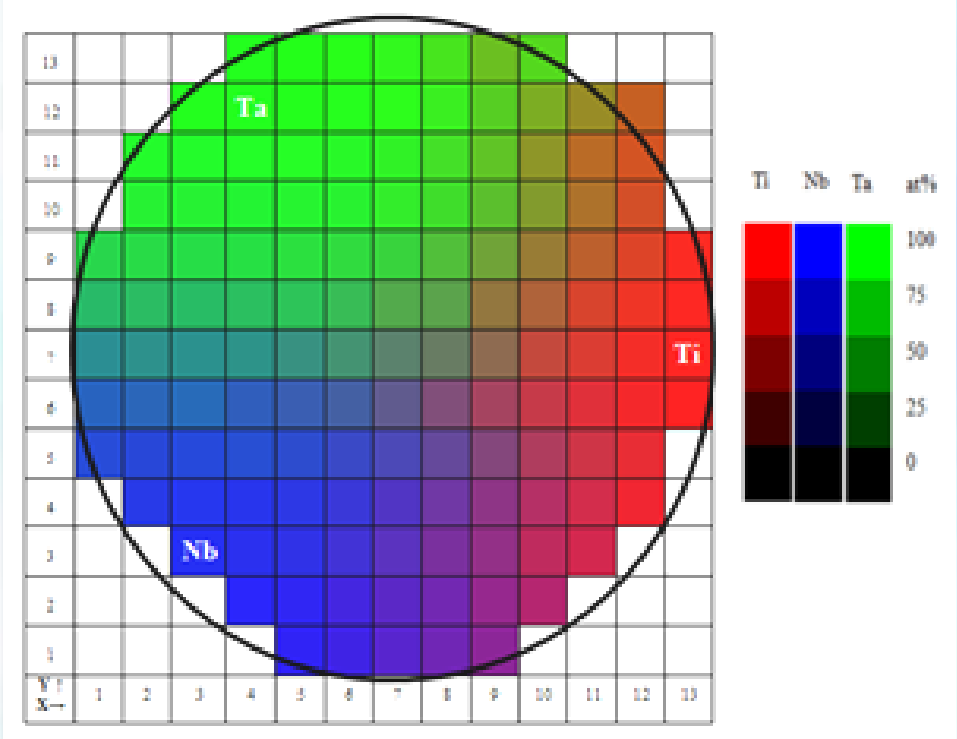
Continue **Collaborations**

ESOP 2015

Library characterization

1.7 µm thickness film

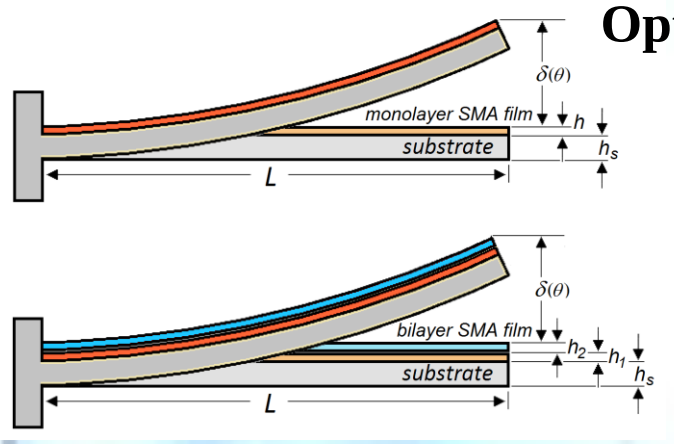




Ti-Nb-Ta compositional spread map

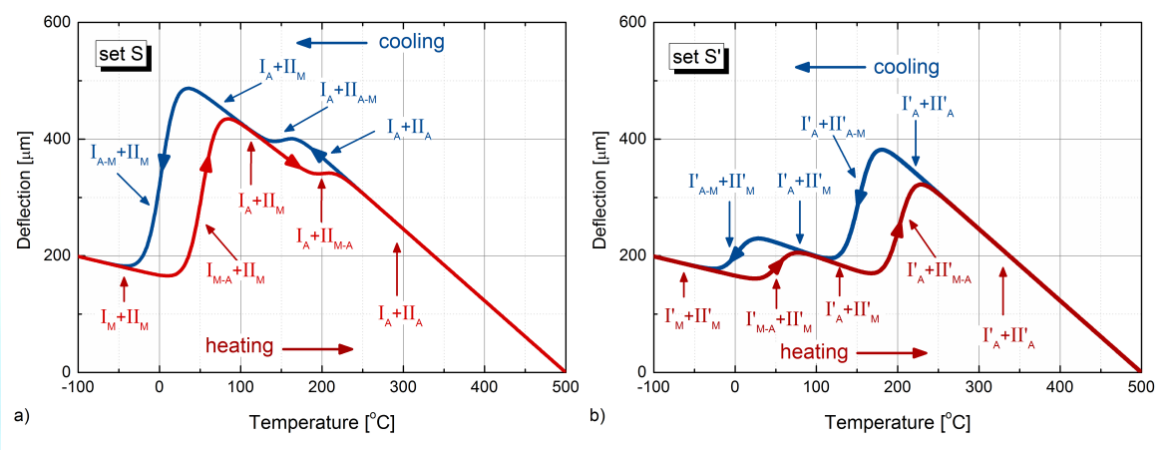
ESOP 2015

Optimisation of shape memory alloy actuating systems



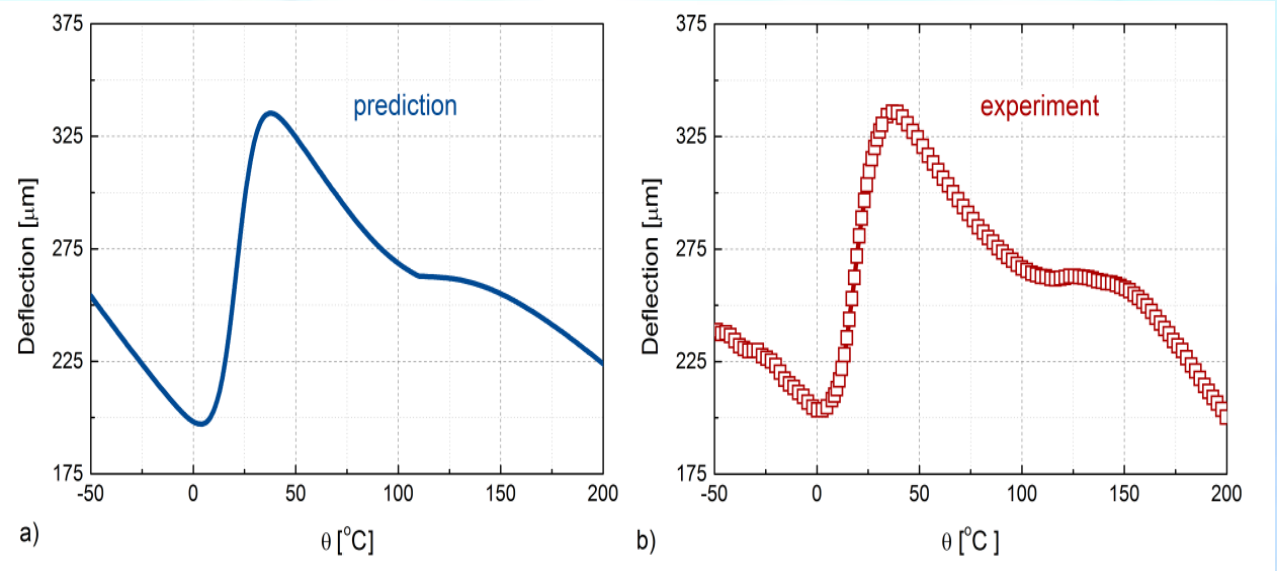
Bending on cooling from the deposition temperature θ_D of a cantilever beam made of a monolayer SMA film of thickness h deposited onto a substrate of thickness h_s (up), and of a cantilever beam consisting of two SMA layers of thickness h_1 and h_2, deposited onto a substrate of thickness h_s; in all cases, the films are assumed to exhibit thermal expansion larger than the substrate, and the beam is considered flat at θ_D.

Double layered active films



Comparative example of the predicted actuation (two layers of 0.5 μm each), deposited at the same temperature on a Si substrate. The two different actuators are designed with two layers as in the cases considered in Figs. 2.a and 2.b (zero deflection corresponds to the deposition temperature). Austenite and martensite phases are denoted by A and B, respectively

ESOP 2015



Comparison between the predicted and experimental deflection during the martensitic phase transformation for a bilayer film-based actuator made of two SMA films (1.5 μm NiTi and 1.5 μm NiMnGa) deposited at 450 °C on a 100 μm Si substrate

ESOP 2016

ESOP

Collaborations

Bochum University – Prof. Alfred Ludwig

Universidade Nova de Lisboa – Prof. Francisco Manuel Braz Fernandes

University of Debrecen – Prof. Beke Deszo

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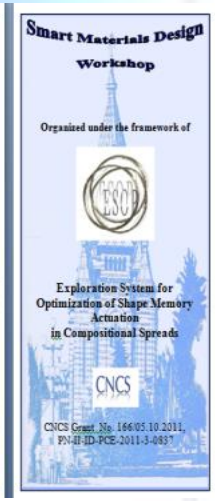
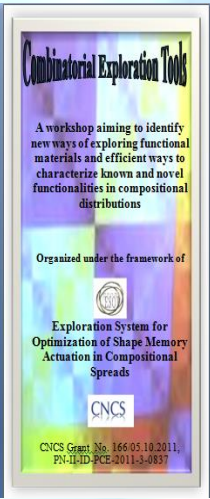
Events

2011 Workshop “Smart Materials Design”

2012 Workshop “Combinatorial Exploration Tools”

2014 Presentation “Novel Materials Design”





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ESOP

Thesis defended

“Shape Memory Alloys Engineered from the Macro to the Nano Realm” - Habilitation Thesis

“Politehnica University of Timisoara, July 20, 2012

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International Grants Awarded

FP7 Grant awarded 2013 Competition

Proposal 612585 MIDAS FP7-PEOPLE-2013-IRSES

"Micro and Nanoscale Design of Thermally Actuating Systems"- MIDAS -

PARTICIPANTS

No.	Legal name	Short name	Principal Investigator	Country
1(CO)	Universitatea "Politehnica" din Timisoara	**UPT**	Corneliu M. Craciunescu	Romania
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3.	Universitat de les Illes Baleares	**UIB**	Eduard Cesari	Spain
4.	Cranfield University	**CU**	Stewart W. Williams	UK
5.	Laboratório Nacional de Energia e Geologia	**LNEG**	Filipe Neves	Portugal
6.	Universidade Federal Fluminense	**UFF**	Andersan dos Santos Paula	Brazil
7.	University of Waterloo	**WU**	Norman Zhou	Canada
8.	Indian Institute of Science	**IISc**	Satyam Suwas	India
9.	Russian Academy of Sciences	**RAS**	Victor V. Koledov	Russia
10	University of Science and Technology Beijing	**USTB**	Xingke Zhao	China

DAAD Grant awarded 2013

"Combinatorial exploration of functional alloy systems" CEFALS

DAAD Referat 322 A/13/03036

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Group Publications (with acknowledgements)

ISI Papers (published or accepted)

1. C.M. Craciunescu, F.M. Braz Fernandes - Graded transitions in Ni-Ti shape memory alloys processed by severe plastic deformation, **Functional Materials Letters** 05, 1250049 (2012) [4 pages] DOI: 10.1142/S179360471250049X.
2. I. Mitelea, V. Budau, Cl Dorohoi, C.M. Craciunescu -Experiments on the possibilities and limits of using conventional friction welding for joining dissimilar and graded materials, **Surface Engineering and Applied Electrochemistry**, February 2013, 49/1, pp 51-56, DOI10.3103/S1068375513010080.
3. Craciunescu, C. M.; Mitelea, I.; Sgavardea, Ghe., Microstructural observation of elastic domains in ferromagnetic shape memory alloys, **American Institute of Physics AIP Conference Proceedings** 2012, vol.1472, pp130-134 DOI: 10.1063/1.4748079
4. Craciunescu, Corneliu M.; Mitelea, I.; Budau, V., Actuation Micro-design based on Martensitic Phase Transformations in Shape Memory Alloys, **American Institute of Physics AIP Conference Proceedings** 2012, Vol.1472, pp135-140 , doi: 10.1063/1.4748080
5. I. Mitelea, C. Groza, C.M. Craciunescu, Copper interlayer contribution on Nd:YAG laser welding, of dissimilar Ti-6Al-4V alloy with X5CrNi18-10 steel, **Journal of Materials Engineering Performance** (accepted for publication)
6. I. Mitelea, C. Groza, C.M. Craciunescu, Pulsed Laser Processing of Dissimilar Ti-6Al-4V, and X5CrNi18-10 Joints, **Materials and Manufacturing Processes,**Volume: 29, Issue: 8, Pages: 975-979, DOI: 10.1080/10426914.2013.822978 Published: AUG 2014 ISSN (Print) 1042-6914
7. C. M. Craciunescu, A. Ercuta, I. Mitelea, V. Budau, Internal Friction and Actuation in Shape Memory Alloys. **American Institute of Physics AIP Conference Proceedings** (accepted for publication)
8. C. M. Craciunescu, A. Ercuta, Magnetic properties in Fe-Pd rapidly solidified ribbons, **American Institute of Physics AIP Conference Proceedings** (accepted for publication)
9. A. Ercuta, C.M. Craciunescu, A model for behavior in shape memory alloy based film / substrate cantilevers, **American Institute of Physics AIP Conference Proceedings** (accepted for publication)
10. C.M. Craciunescu, RJC Silva, F.M. Braz Fernendes, Fracture modes during severe plastic deformation of NiTi shape memory alloys, **The Physics of Metals and Metalography** (accepted for publication)

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ESOP

Group Publications (with acknowledgements)

ISI Papers (published or accepted for publication)

11. C.M. Craciunescu, F.M. Braz Fernandes - Graded transitions in Ni-Ti shape memory alloys processed by severe plastic deformation, **Functional Materials Letters** 05, 1250049 (2012) [4 pages] DOI: 10.1142/S179360471250049X.
12. Abdel Salam Maklouf and Corneliu Craciunescu, "The Effect of Copper Alloying Element on the Corrosion Characteristics of Ti-Ni and Ternary Ni-Ti-Cu Meltspun Shape Memory Alloy Ribbons in 0.9% NaCl Solution", **International Journal of the Electrochemical Society,** Volume: 8 Issue: 8 Pages: 10320-10334 Published: AUG 2013 WOS:000323548600016, ISSN 1452-3981
13. I.Mitelea, E.Dimian, I.Bordeaşu, C.Crăciunescu, Gas Nitriding Effects on Cavitation Behavior of Ti-6Al-4V alloys, **Ultrasonics sonochemistry,** published 2014
14. C.M. Craciunescu, A. Ercuta,, Prediction of Thermally-Controlled Actuation for Shape Memory Alloy Film-Based Bimorph Cantilever**, Smart Materials and Structures,** Volume: 23, Issue: 7,Article Number: 075025, DOI: 10.1088/0964-1726/23/7/075025, Published: JUL 2014
15. Aurel Ercuta, Corneliu Craciunescu - Microstructure Analysis of NiTi Films Deposited By Magnetron Sputtering, **American Institute of Physics AIP Conference Proceedings** accepted
16. I. Mitelea, C. Ghera, I.Bordeaşu, C. M. Crăciunescu - Ultrasonic cavitation erosion of a duplex treated 16MnCr5 steel, **International Journal of Materials Research** Vol. 106, Issue:4, pp. 391-397, Apr.2015, ISSN 1862-5282, ISI 0,64
17. I. Mitelea, I. Bordeaşu, M. Pelle, C. Crăciunescu - Ultrasonic cavitation erosion of nodular cast iron with ferrite - pearlite microstructure, **Ultrasonics sonochemistry**, 2015 Mar;23:385-90. Epub 2014 Nov 10. ISI
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Corneliu Crăciunescu, Aurel Ercuţa, Shape memory microactuation design by additional substrate's reinforcement layers, Mater & Design

Books

1. Corneliu M. Craciunescu - *Shape Memory Alloys Engineered from the Macro to the Nano Realm*, Editura "Politehnica", Timisoara 2013
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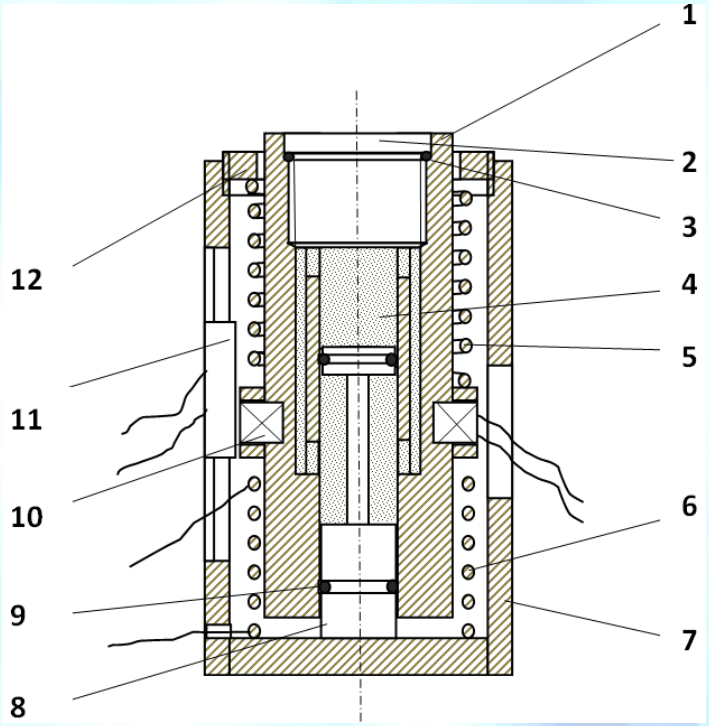
Patents

Patent applications:

- Actuator with thermal and magnetic control of position, OSIM Application No. **a 2012 00861/ 23.11.2012**
- Bilayer thermo-magnetic actuator, OSIM Application No. **a 2012 00862/ 23.11.2012**
- Bimorph actuator with reinforced substrate and shape memory film (submitted)



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