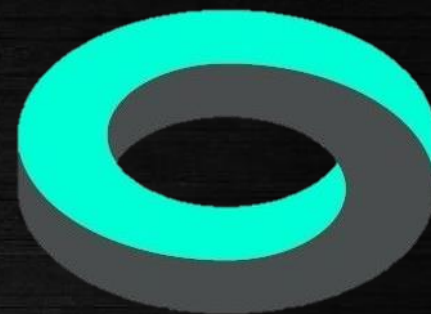




UNIVERZITA PAVLA JOZEFA ŠAFÁRIKA
V KOŠICIACH

Technologický a inovačný park UPJŠ

Centrum progresívnych materiálov

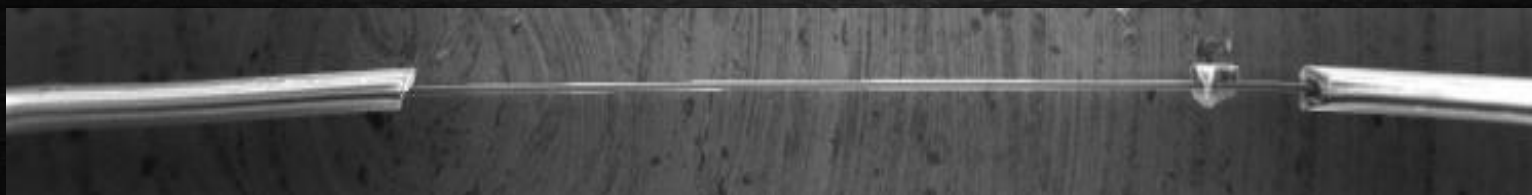


ANALÝZA MAGNETOKALORICKÉHO JAVU SKLOM POTIAHNUTÝCH MIKRODRÔTOV NA BÁZE HEUSLEROVÝCH ZLIATIN

Bc. Miroslav Hannel, 1FKLm

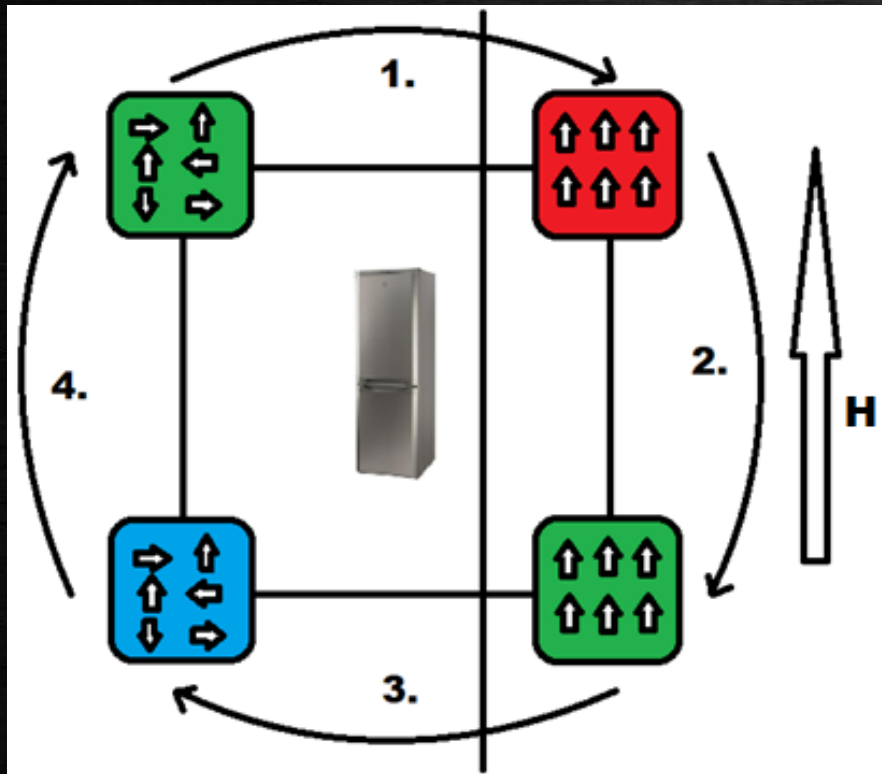
Školiteľ: RNDr. Ladislav Galdun, PhD.

Konzultant: prof. RNDr. Rastislav Varga, DrSc.



2020

Prečo MCE ?

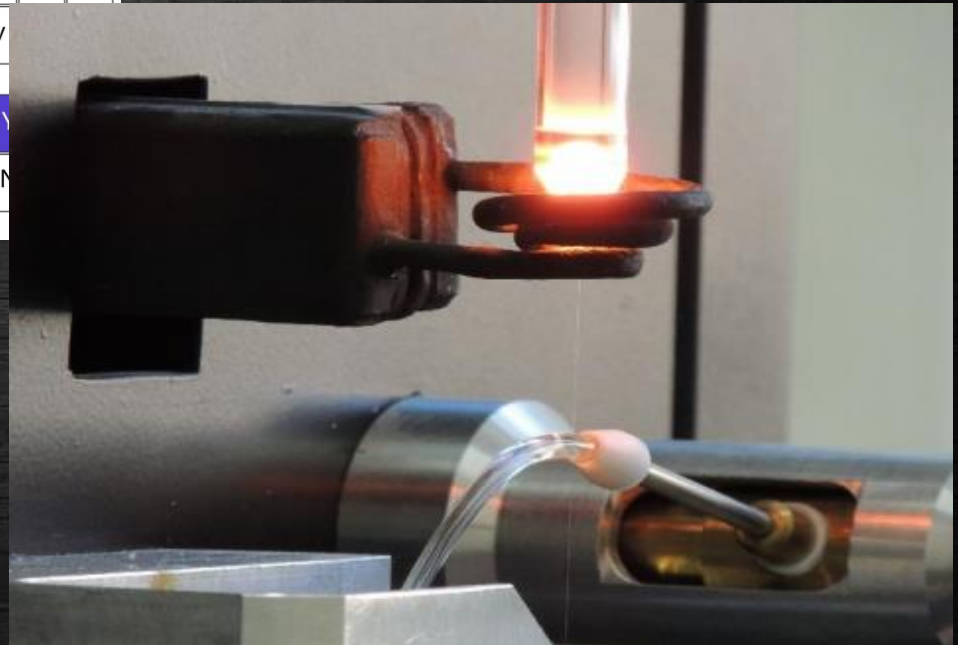


Od materiálu k aplikáciám

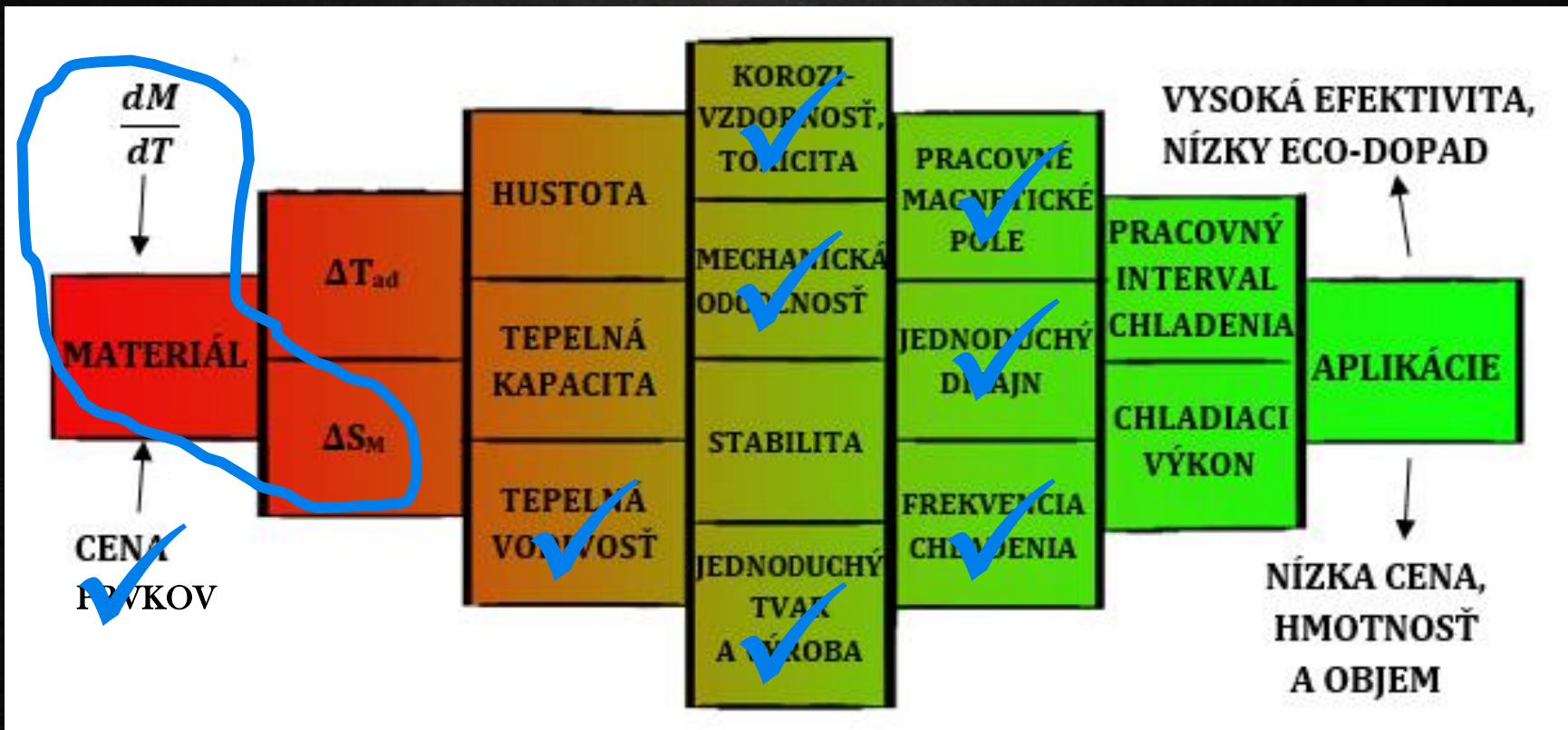


Prečo Heuslery a mikrodrôty ?

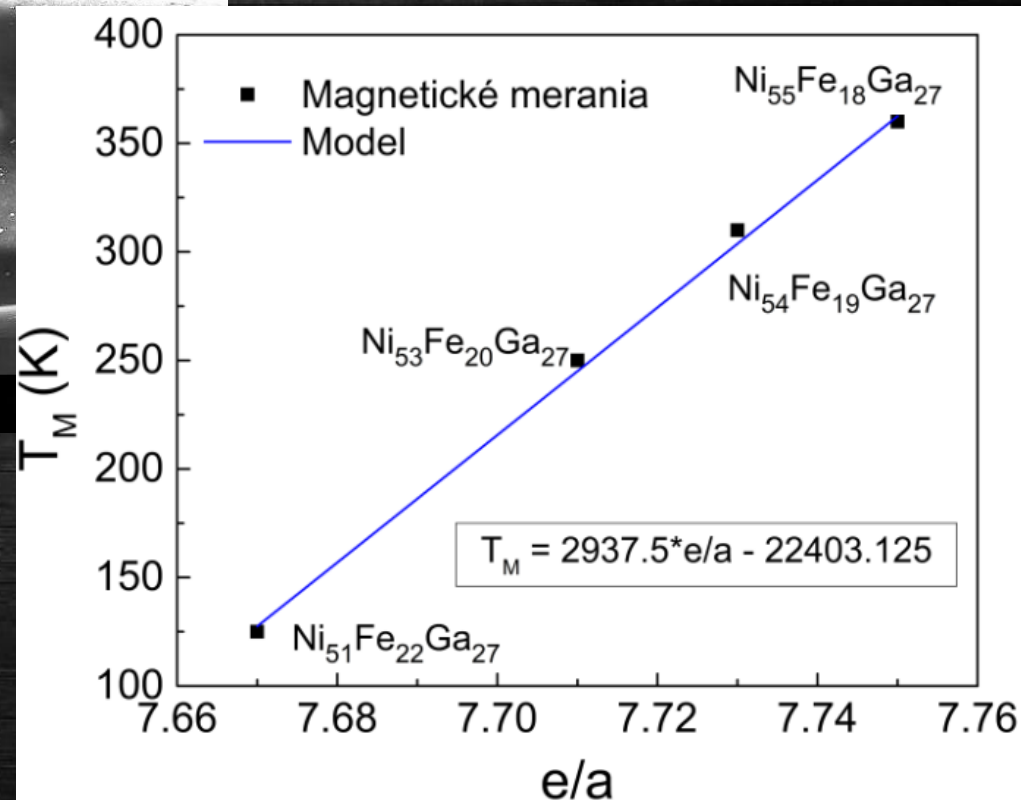
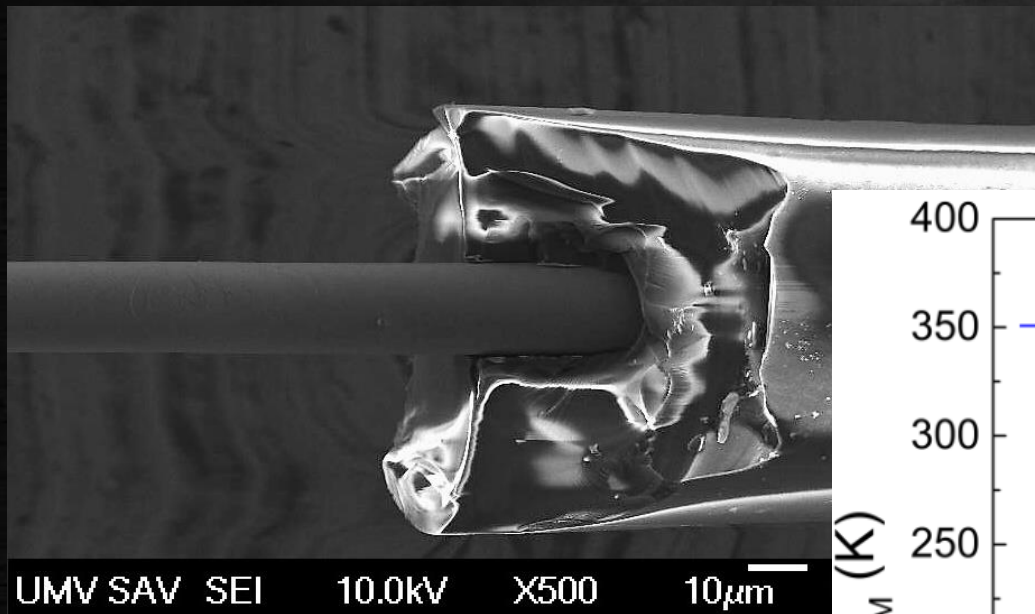
H																	He		
Li	Be	Full-Heusler X_2YZ								Half-Heusler XYZ				B	C	N	O	F	Ne
Na	Mg													Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn		
Fr	Ra	**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv				
		*	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Y			
		**	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	N			



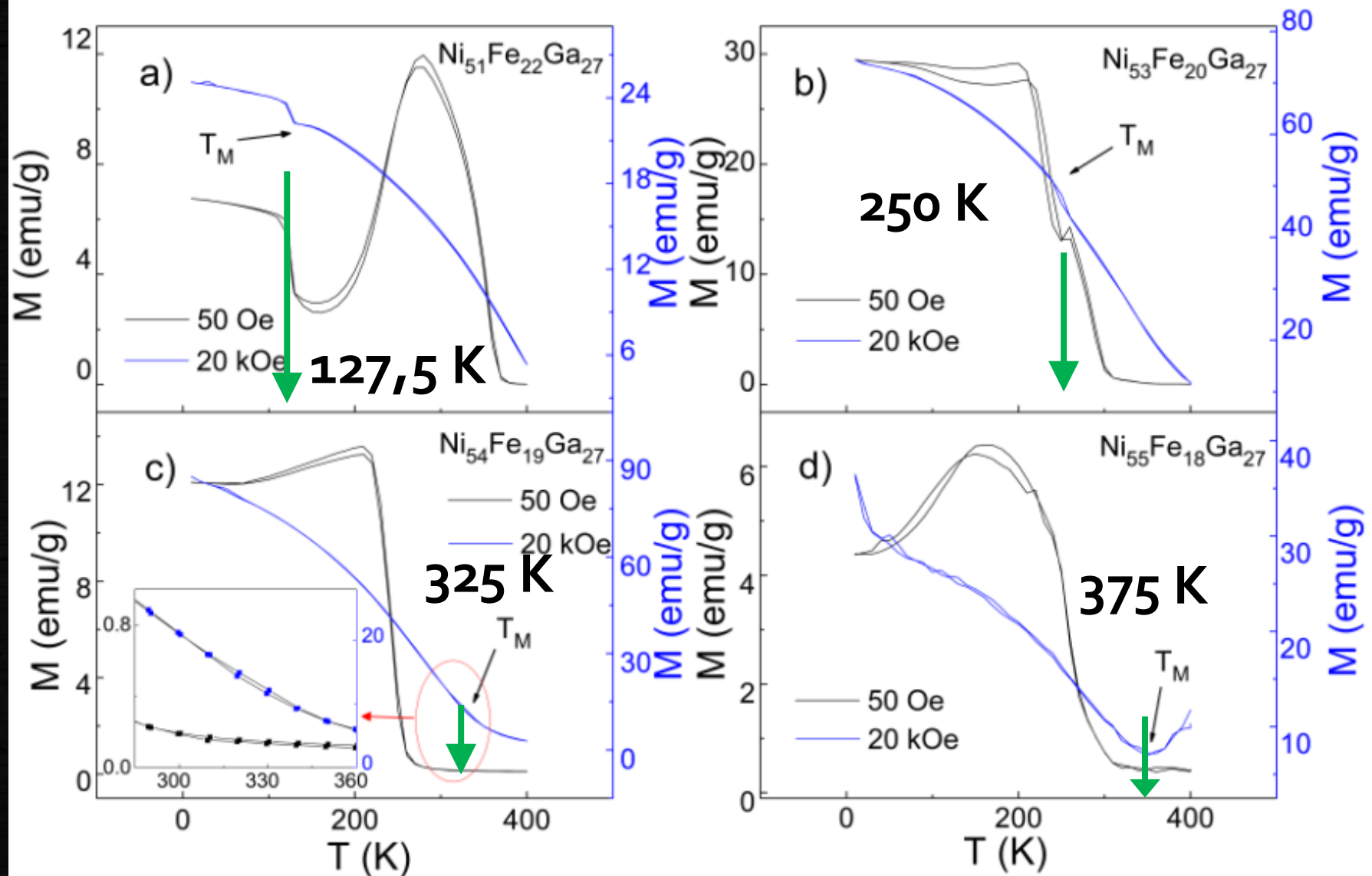
Od materiálu k aplikáciám



Doterajšie výsledky

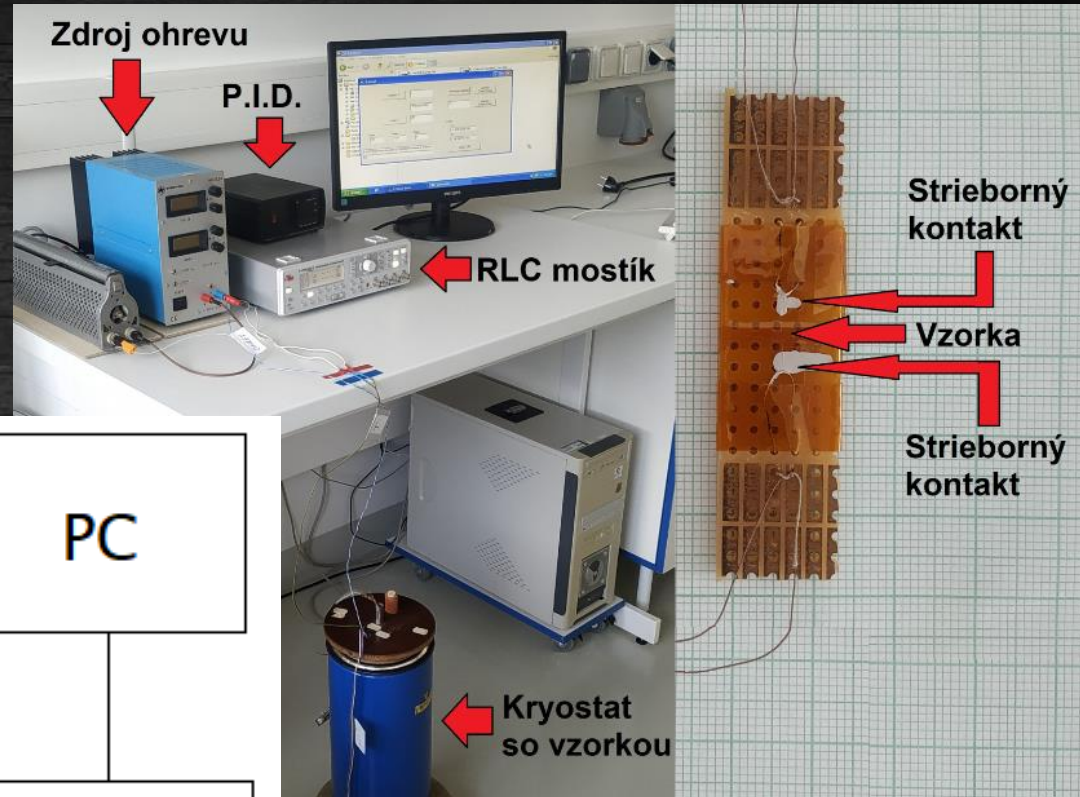
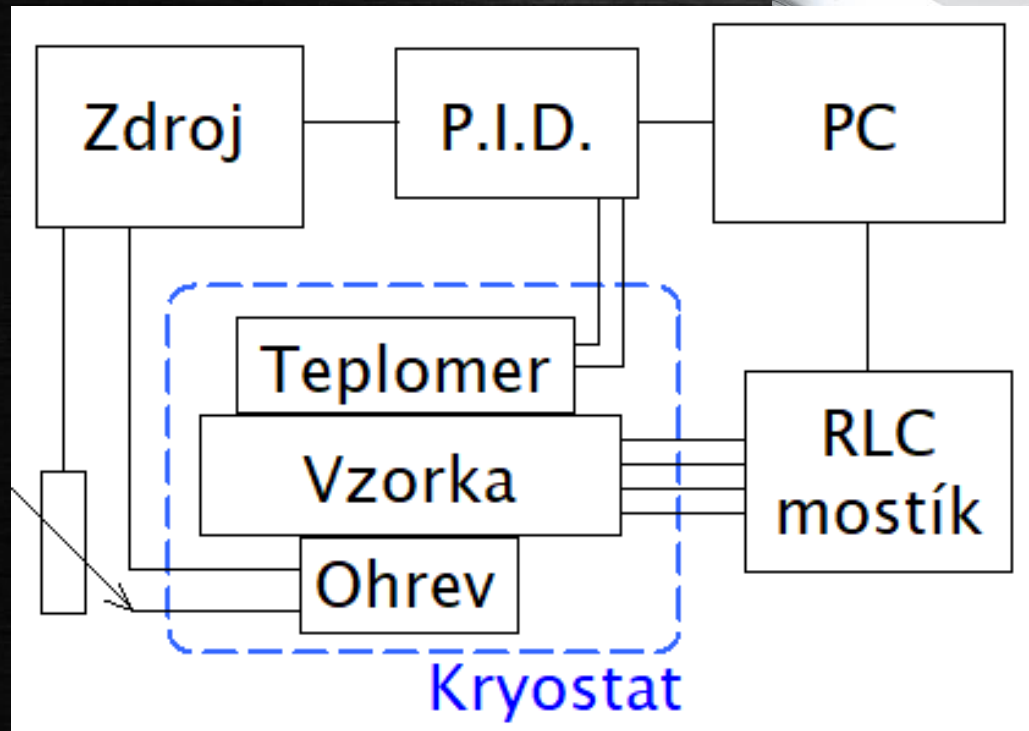


Magnetické merania



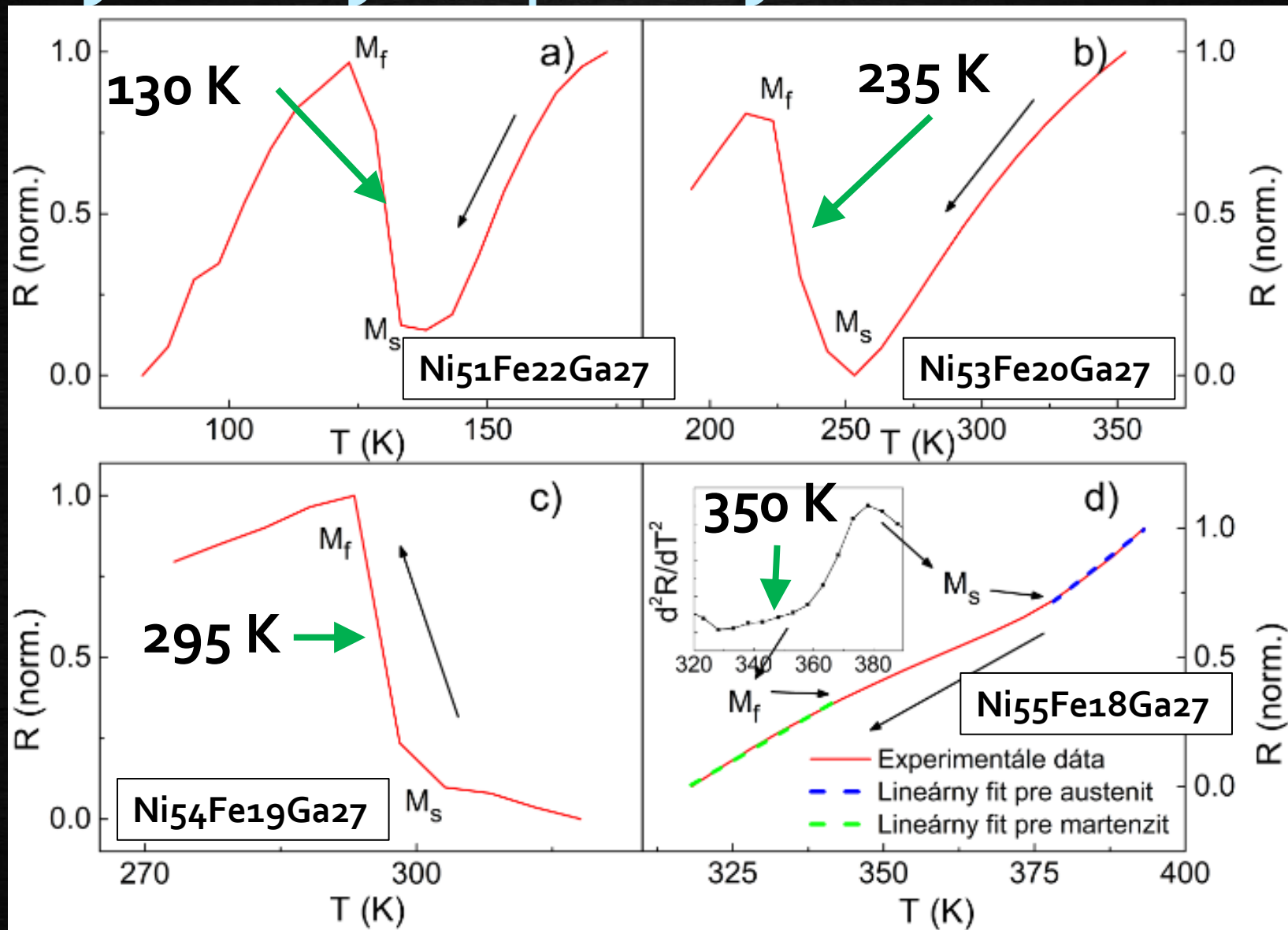
Teplotná závislosť odporu

zmena teplotného
súčiniteľa $\alpha \rightarrow$



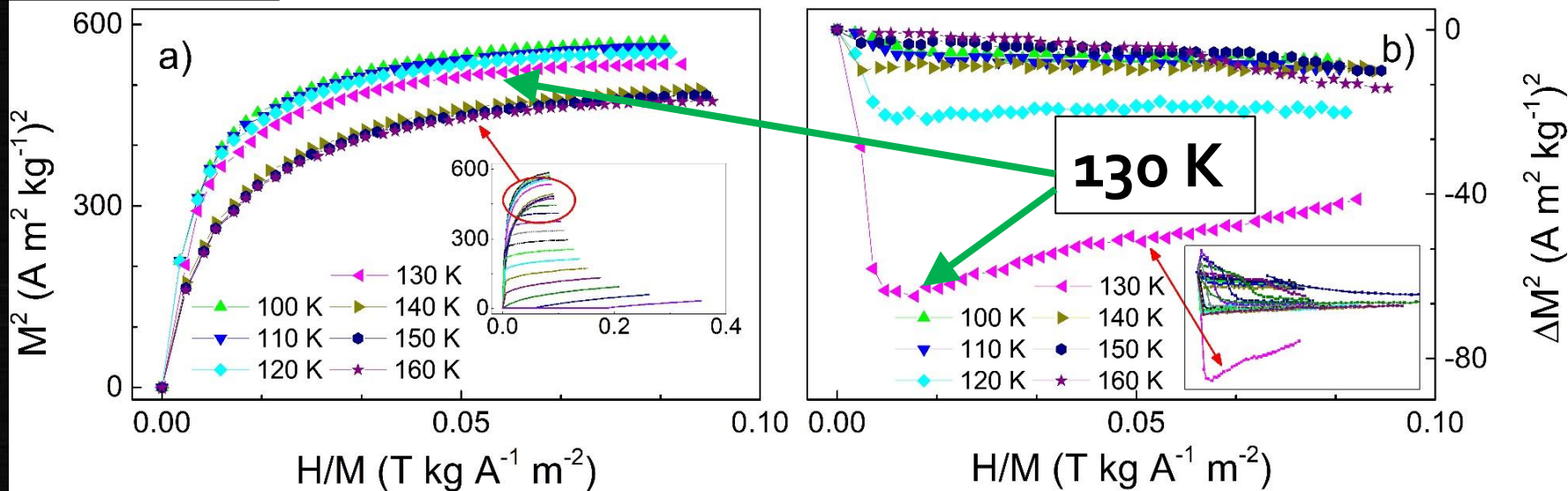
$\rightarrow$ detekcia
štruktúrnych zmien

Výsledky odporových meraní



Arrottove grafy

Ni₅₁Fe₂₂Ga₂₇



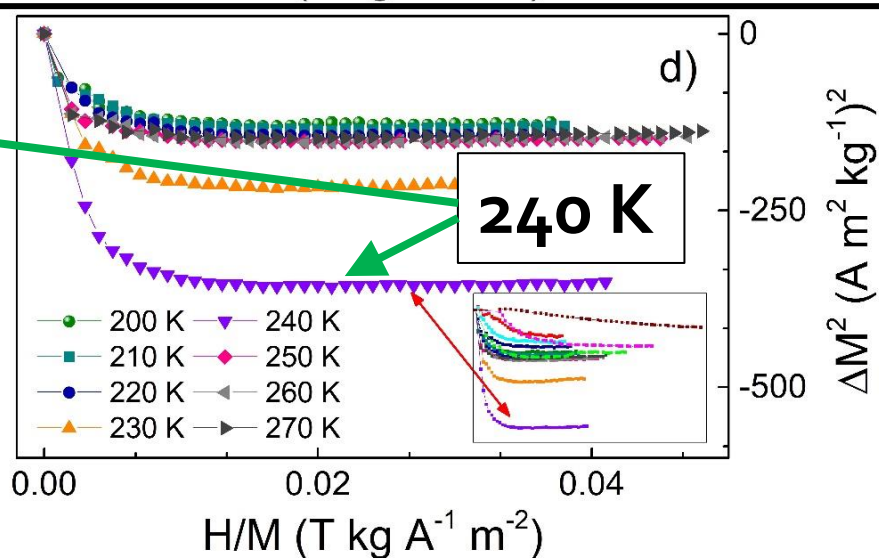
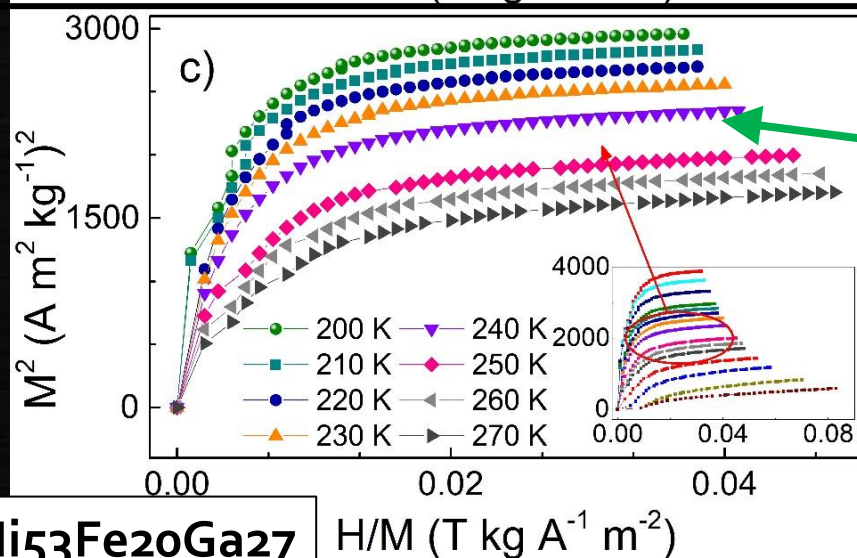
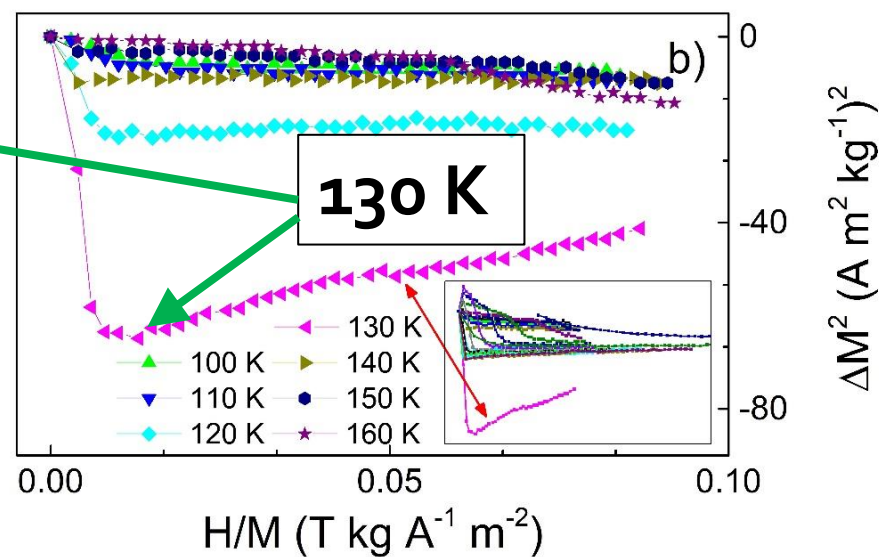
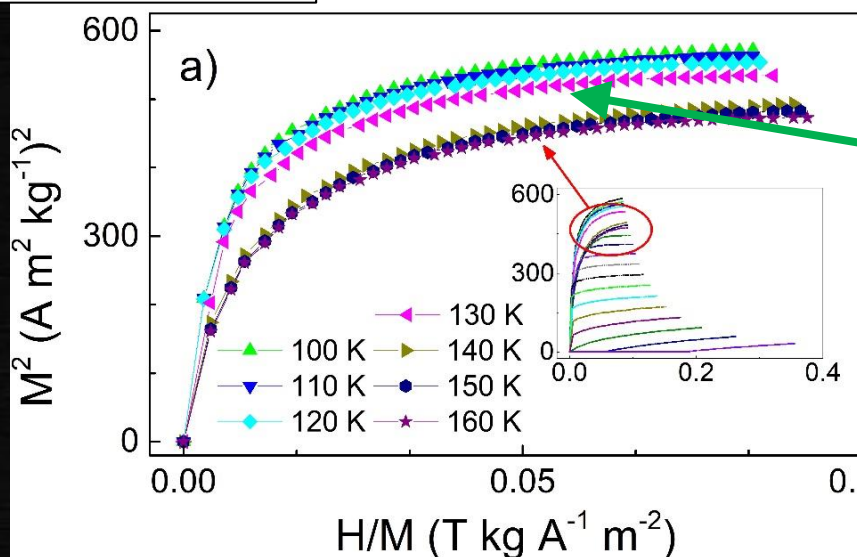
$$M^2 = \frac{1}{4b} \frac{H}{M} - \frac{a}{2b} \varepsilon$$

$$\Delta M^2 = \left(\frac{1}{4b_2} - \frac{1}{4b_1} \right) \frac{H}{M} - \left(\frac{a_2}{2b_2} - \frac{a_1}{2b_1} \right) \varepsilon$$

Arrottove grafy 1/2

$$M^2 = \frac{1}{4b} \frac{H}{M} - \frac{a}{2b} \epsilon$$

Ni₅₁Fe₂₂Ga₂₇

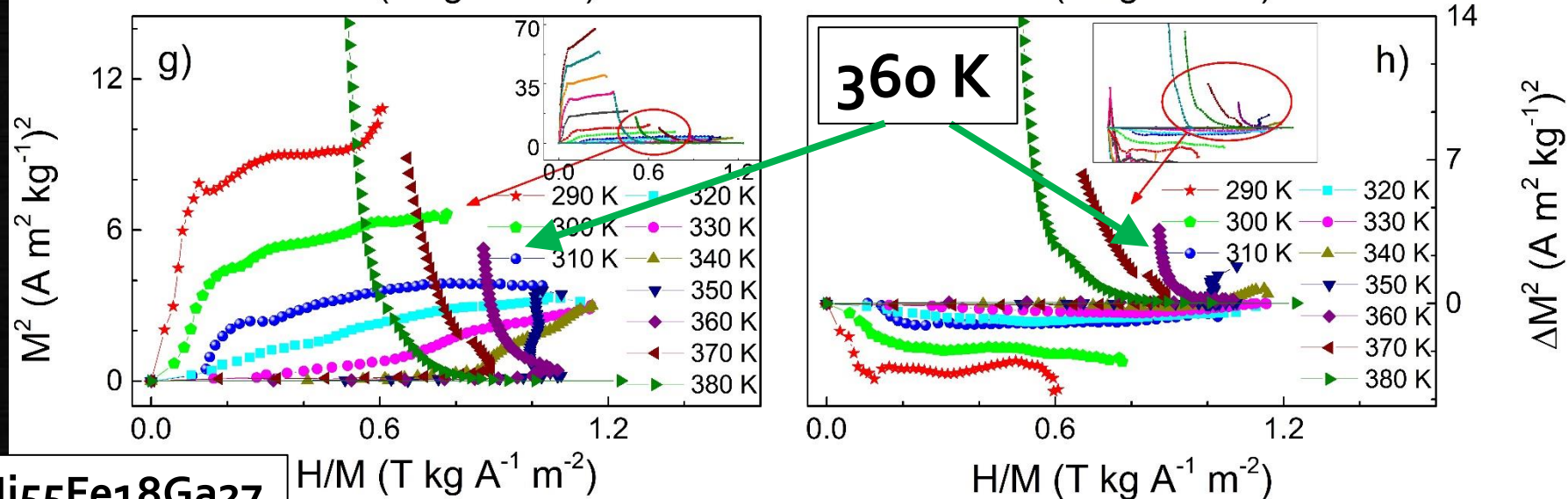
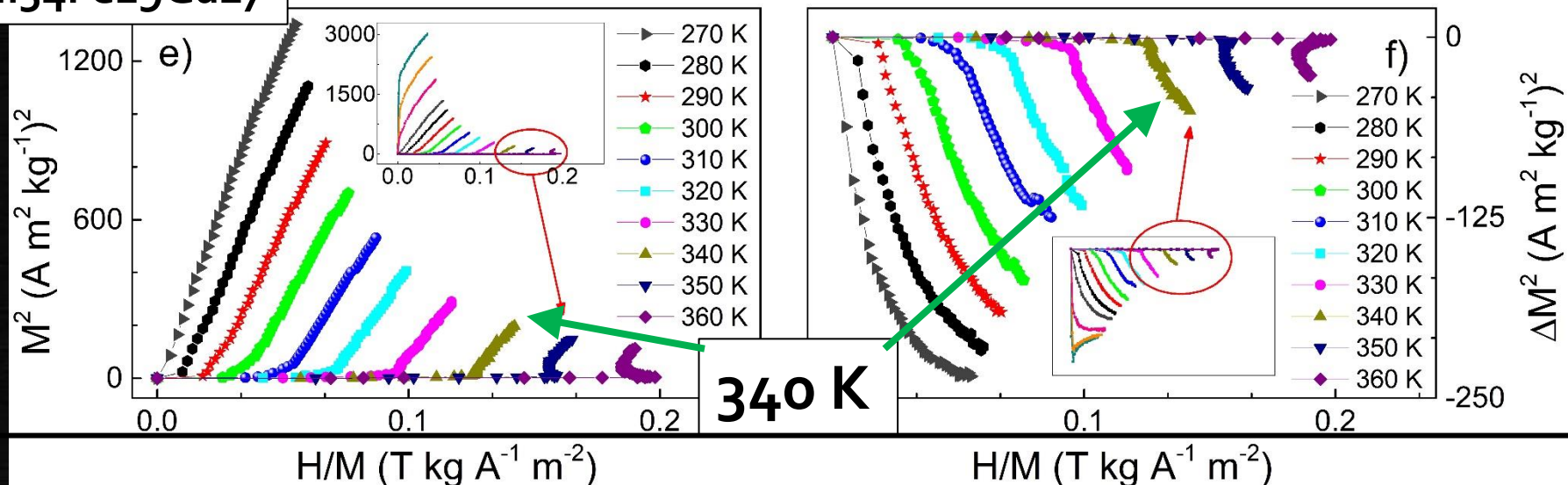


Ni₅₃Fe₂₀Ga₂₇

Arrottove grafy 2/2

$$M^2 = \frac{1}{4b} \frac{H}{M} - \frac{a}{2b} \varepsilon$$

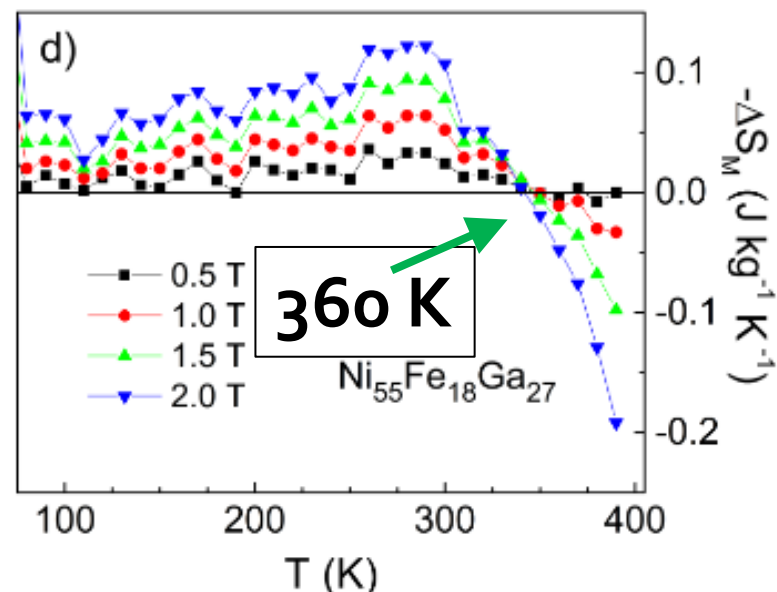
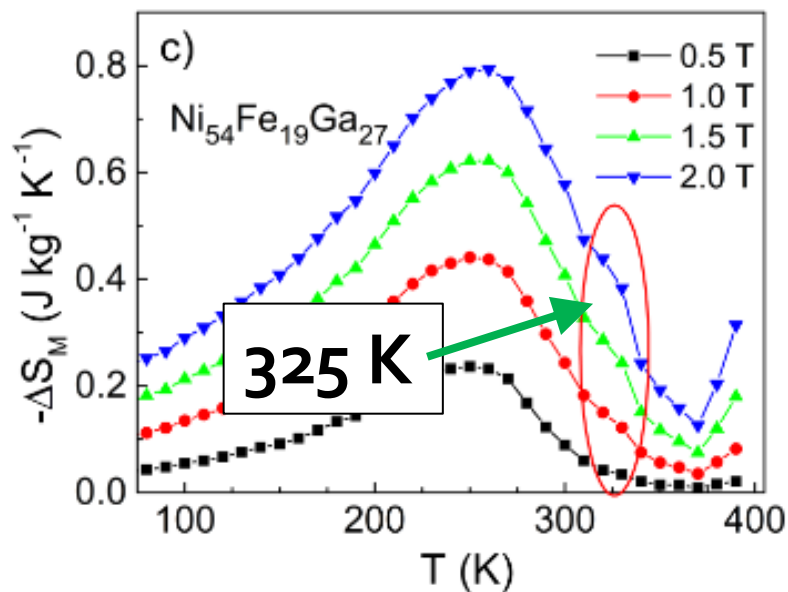
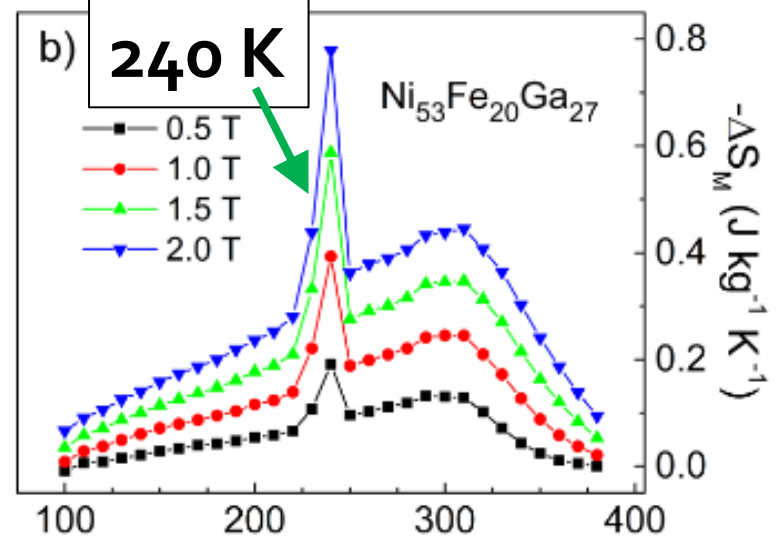
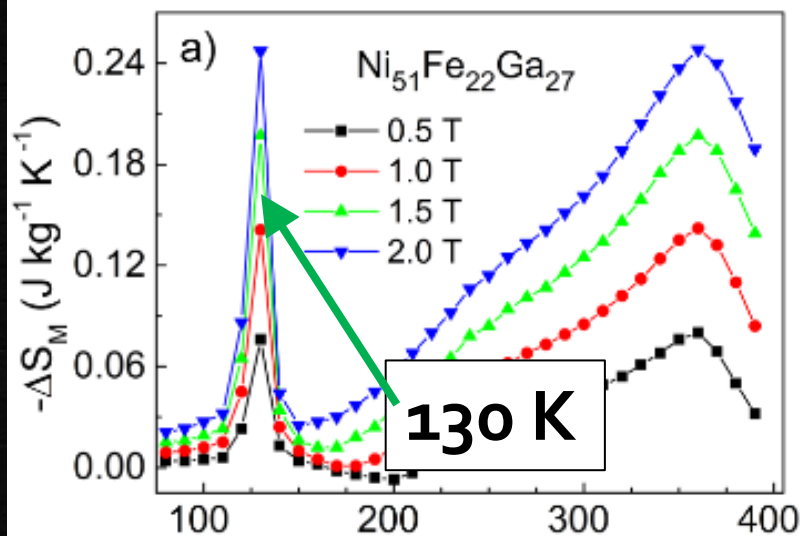
Ni₅₄Fe₁₉Ga₂₇



Ni₅₅Fe₁₈Ga₂₇

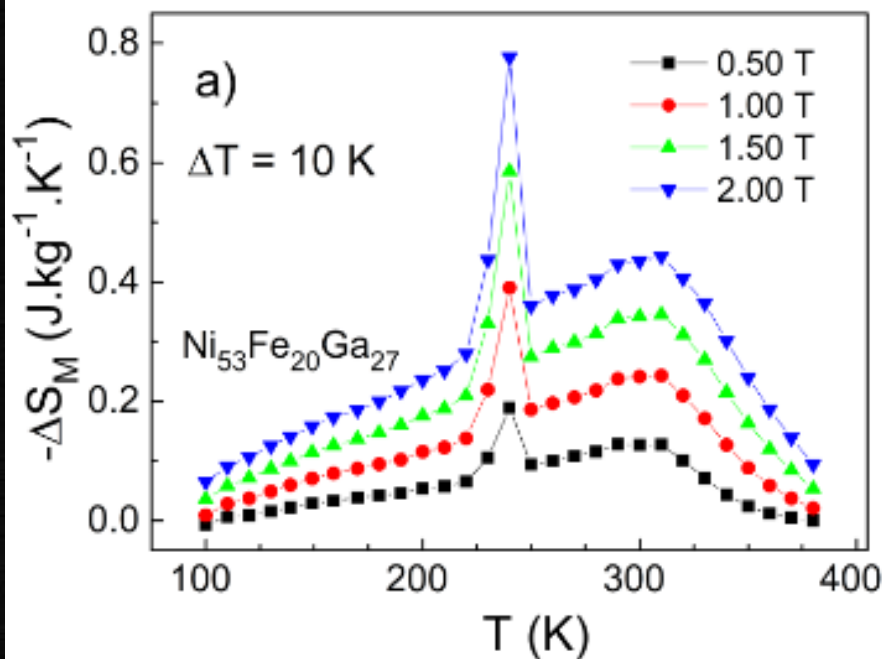
Zmena mag. entropie

$$\Delta S_M = \int_{H_0}^{H_{max}} \left(\frac{\partial M}{\partial T} \right)_H dH$$

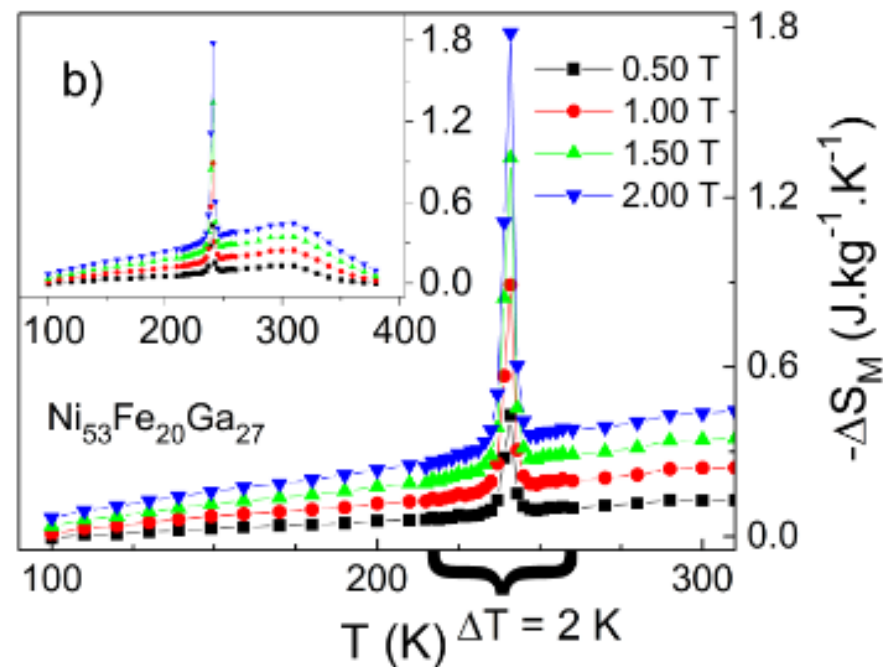


Detailné meranie izoteriem

Ni₅₃Fe₂₀Ga₂₇



Ni₅₃Fe₂₀Ga₂₇

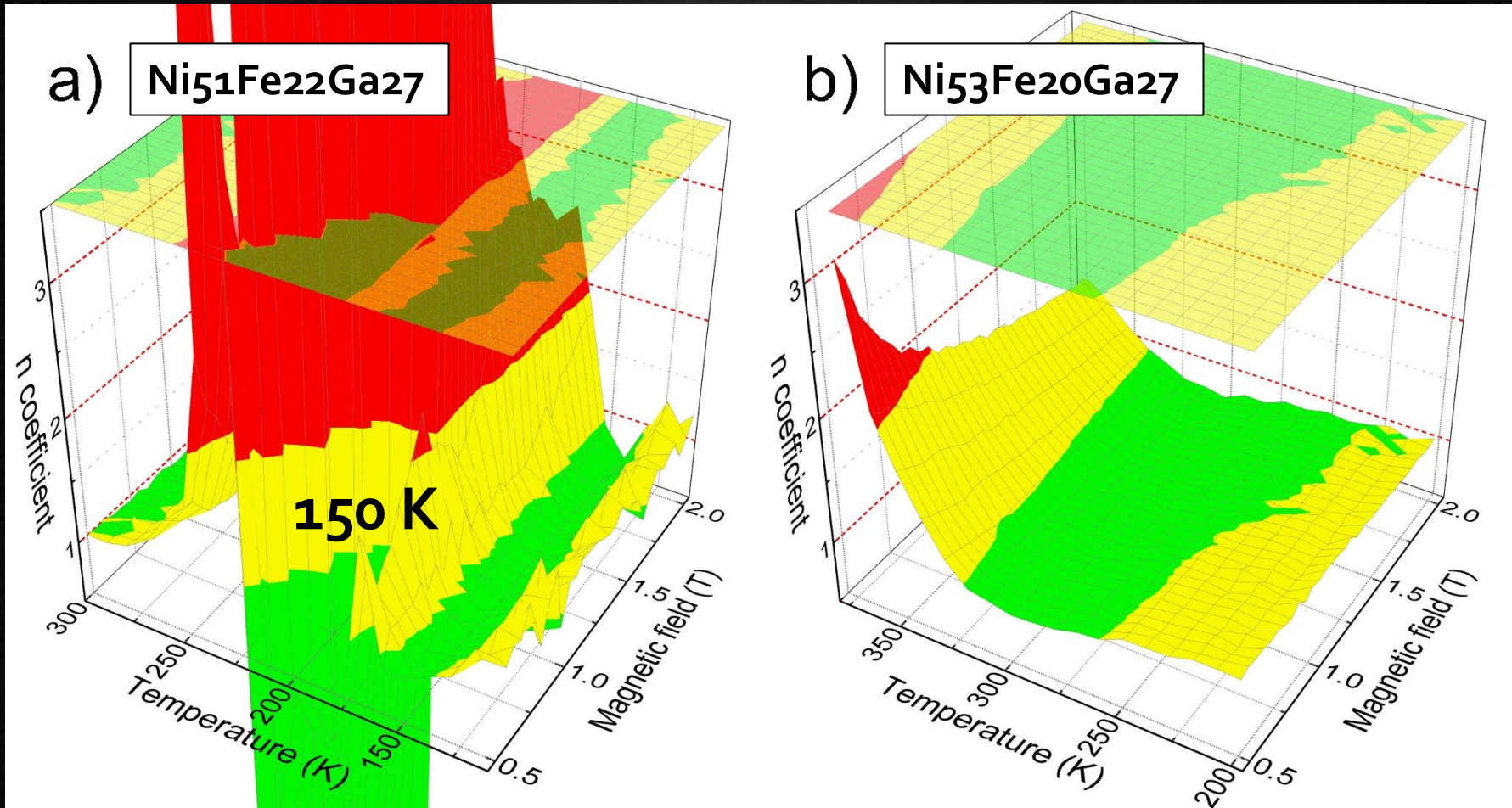


Menší krok merania → presnejšie určená teplota
→ vyššia zmena ΔS_M

n – koeficient 1/2

Franco, V. et al. *Nat Commun* 9, 2680 (2018).

$$n(T, H) = \frac{d(\ln|\Delta S_M|)}{d(\ln H)}$$



$$\Delta S_M \propto H^n$$

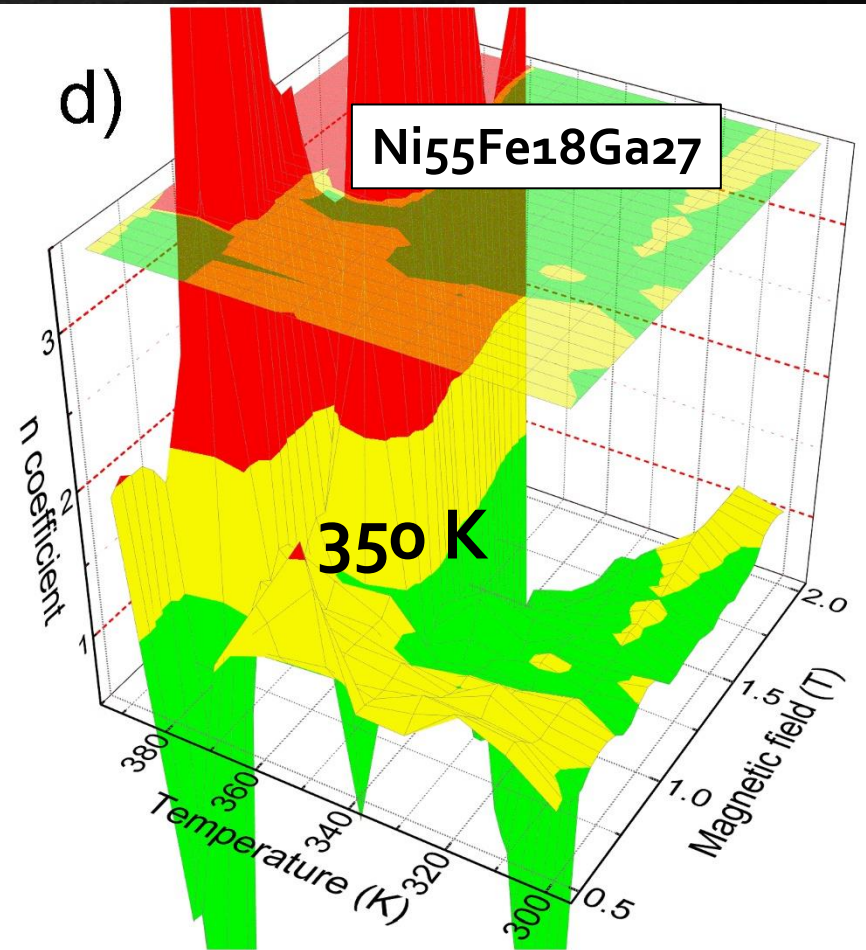
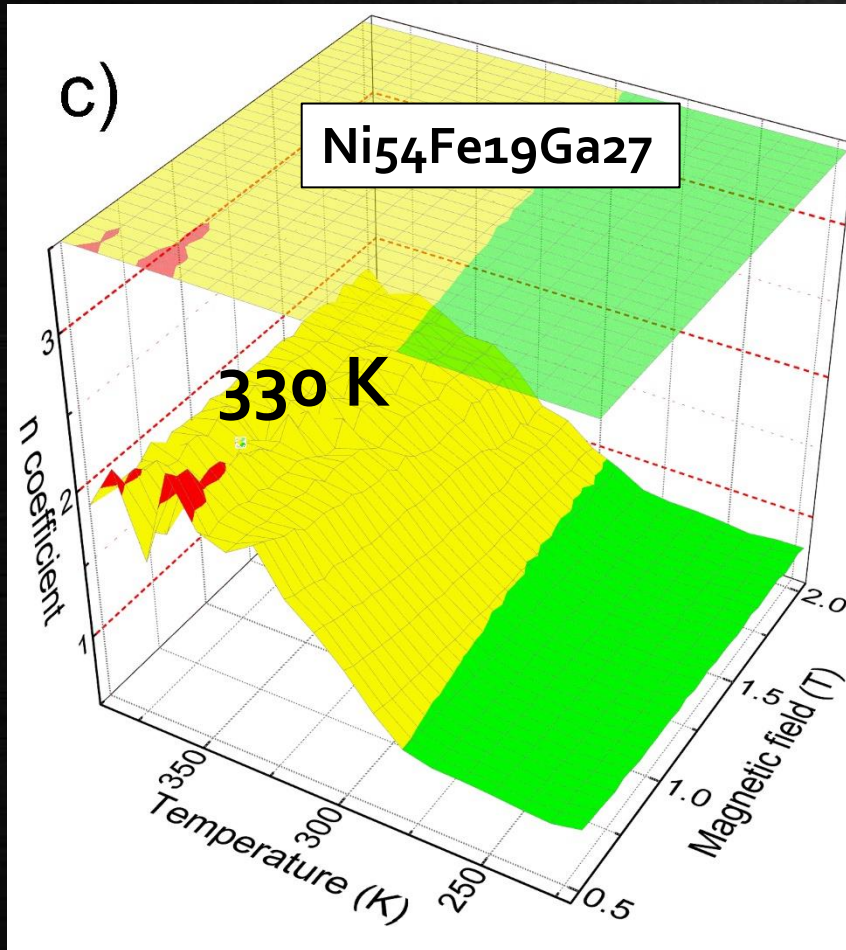
$$n \geq 2$$

$$1 \leq n < 2$$

$$n < 1$$

n – koeficient 2/2

$$n(T, H) = \frac{d(\ln|\Delta S_M|)}{d(\ln H)}$$



$$\Delta S_M \propto H^n$$

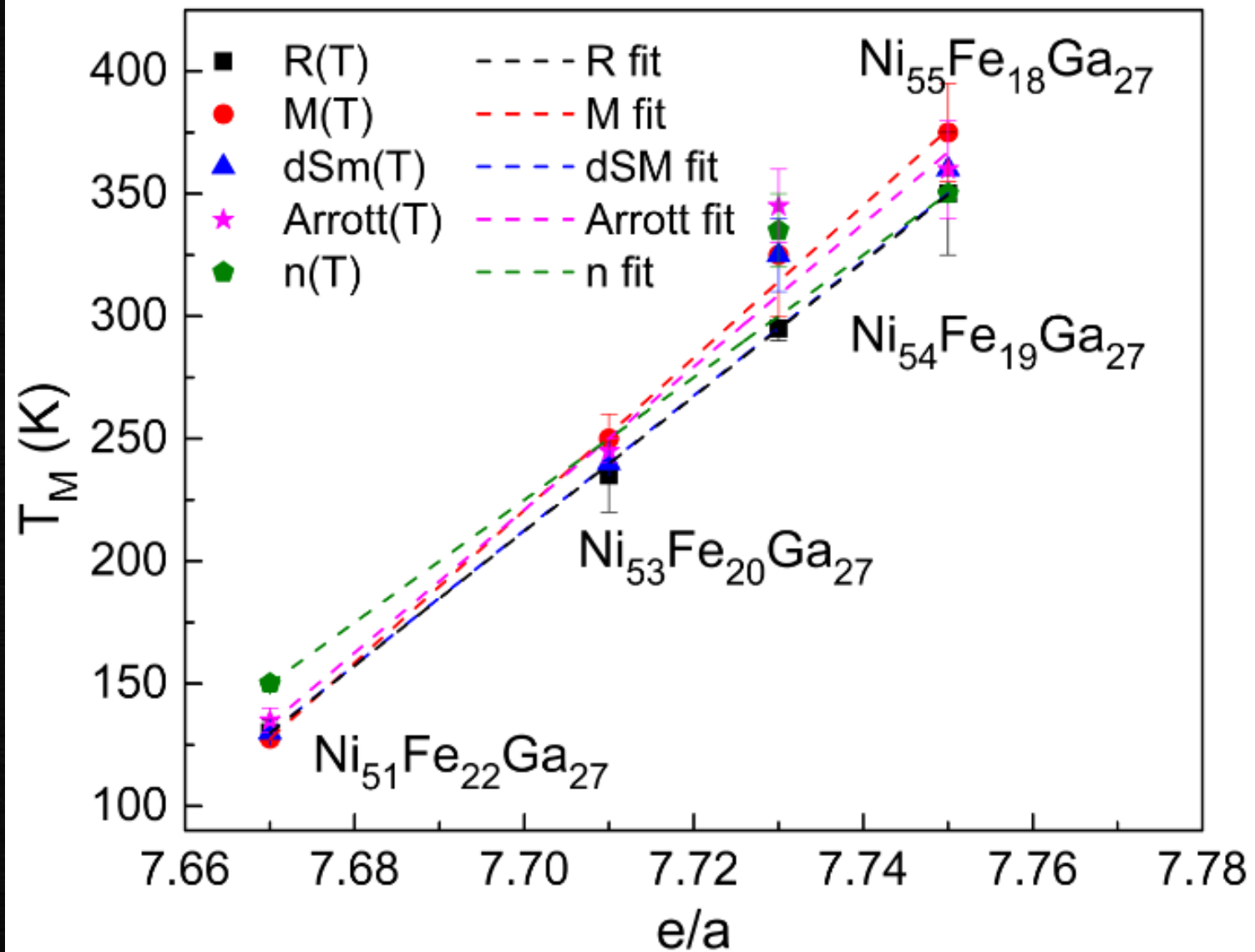
$$n \geq 2$$

$$1 \leq n < 2$$

$$n < 1$$

Výsledky

$$T_M = 3000 \cdot e/a - 22800$$

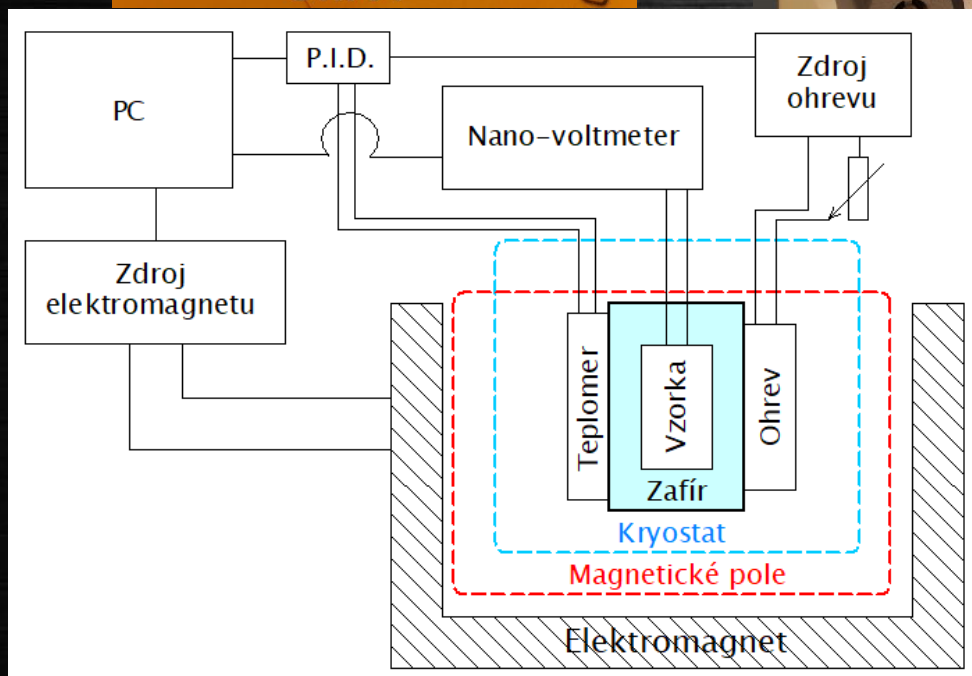
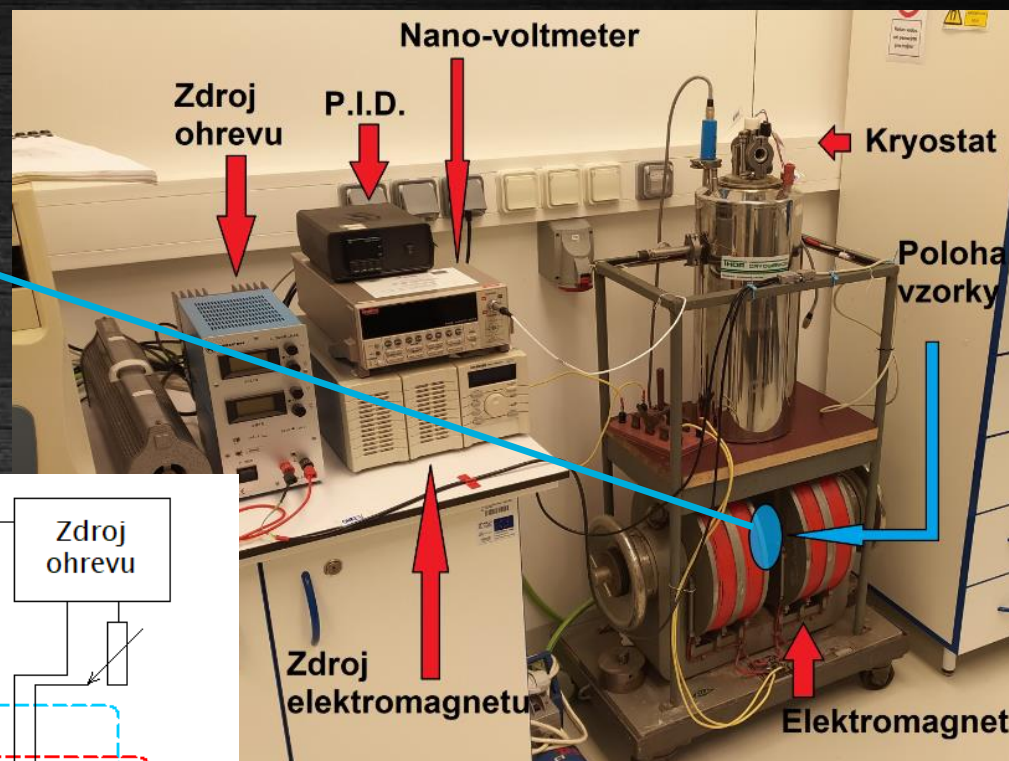
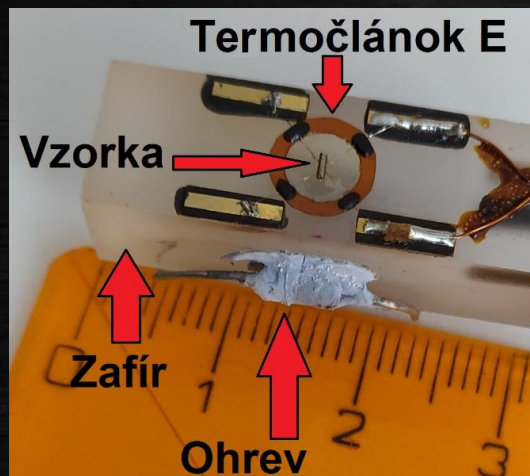


Záver

- Potvrdený model – vzťah medzi e/a a T_M
 - Magnetické merania
 - Meranie teplotnej závislosti odporu
 - Analýza ΔS_M
 - Arrottové grafy
 - n – koeficient
- } Vlastný program
v *Python-e*



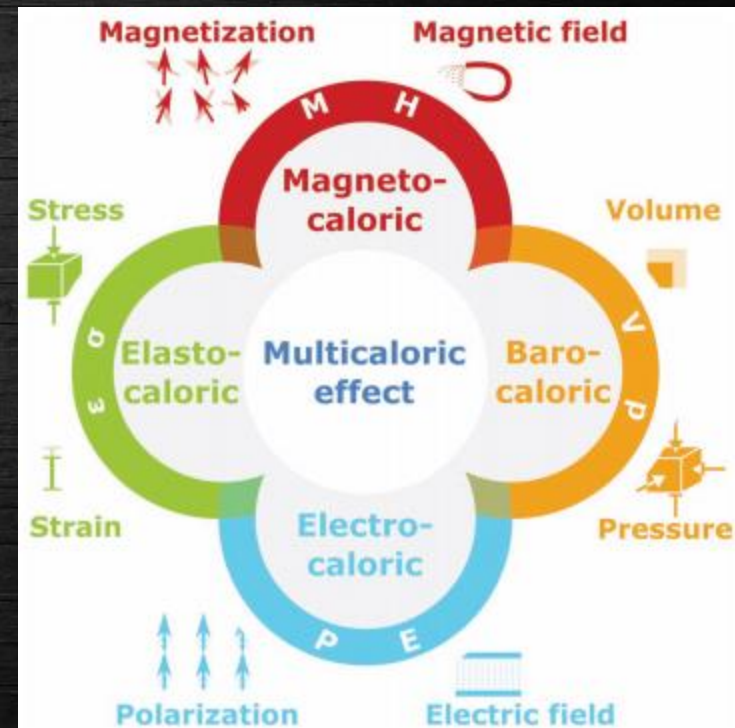
Priame meranie MCE



$$\Delta T_{\text{ad}} \approx 35 \text{ mK}$$

Ciele ďalšieho výskumu

- Mechanicky kvalitné jadro – meranie elastokalorického javu + magnetokalorický jav = multikalorický jav
- Analýza T_M pri zachovaní e/a
 B, Al, In
- 1D Isingov model
- Hľadanie technických riešení pre aplikácie v mikrochladení



Ďakujem Vám za pozornosť!





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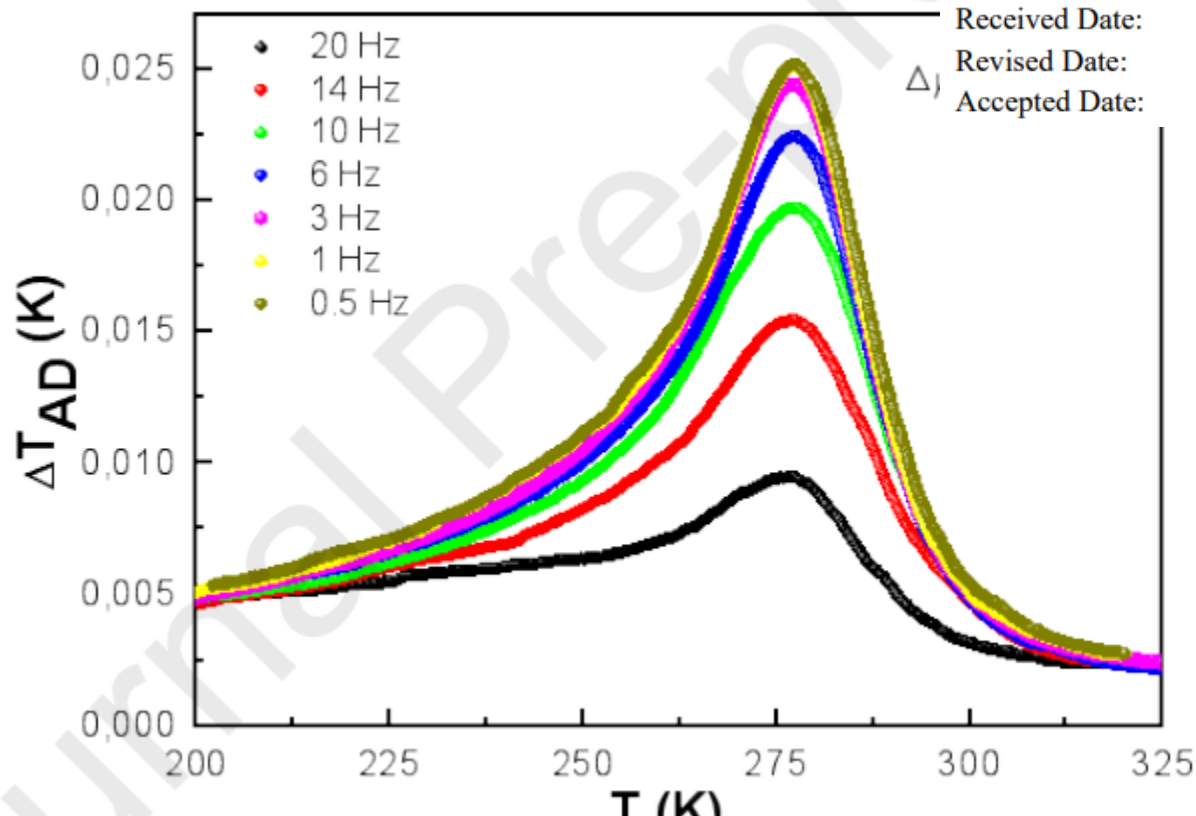


Magnetic properties and magnetocaloric effect in Heusler-type glass-coated NiMnGa microwires



A. Zhukov^{a,b,*}, V. Rodionova^{a,c,d}, M. Ilyn^e, A.M. Aliev^f, R. Varga^g, S. Michalik^g, A. Aronin^h,
G. Abrosimova^h, A. Kiselev^h, M. Ipatov^a, V. Zhukova^a

$\alpha^2 = 3 \times 10^{-7} \text{ m}^2/\text{s}$, $\Delta T = 1 \text{ K}$. After 100 ms 95% of initial heat was
dissipated through the glass shell. This rate of heat exchange al-
lows the frequency of the magnetic refrigerators of 10 Hz. Despite



Thermal Conductivity and Diffusivity Measurements of Glass-Coated Magnetic Microwires Using Lock-in Thermography

R. Fuente, S. Rodríguez, A. Mendioroz, A. Salazar ✉, A. Zhukov & V. Zhukova

International Journal of Thermophysics 36, 1137–1141(2015) | Cite this article

233 Accesses | 1 Citations | Metrics

Table 1 Summary of the thermal-diffusivity data of both glass-coated and bare-magnetic microwires

Material	Diameter of micewire (μm)	Diameter of metallic core (μm)	Glass-coated wire		Bare wire	
			<i>D</i> amorphous (mm ² · s ^{−1})	<i>D</i> crystalline (mm ² · s ^{−1})	<i>D</i> amorphous (mm ² · s ^{−1})	<i>D</i> crystalline (mm ² · s ^{−1})
Fe ₇₄ B ₁₃ S ₁₁ C ₂	26.6	19.4	1.35	2.18	1.72	3.10
Co _{77.5} B ₁₅ Si _{7.5}	22.8	17.8	1.60	2.55	1.94	3.35
Ni _{77.5} B ₁₅ Si _{7.5}	29.8	16.3	1.67	2.20	3.53	4.67

The uncertainty is 5 %

Table 2 Summary of the thermal-conductivity values of amorphous and crystalline magnetic microwires obtained from Eq. 2

Material	<i>v</i> _{wire}	<i>K</i> amorphous (W · m ^{−1} · K ^{−1})	<i>K</i> crystalline (W · m ^{−1} · K ^{−1})
Fe ₇₄ B ₁₃ S ₁₁ C ₂	0.53	4.97	7.88
Co _{77.5} B ₁₅ Si _{7.5}	0.61	5.97	8.76
Ni _{77.5} B ₁₅ Si _{7.5}	0.30	7.80	11.7

The uncertainty is 10 %

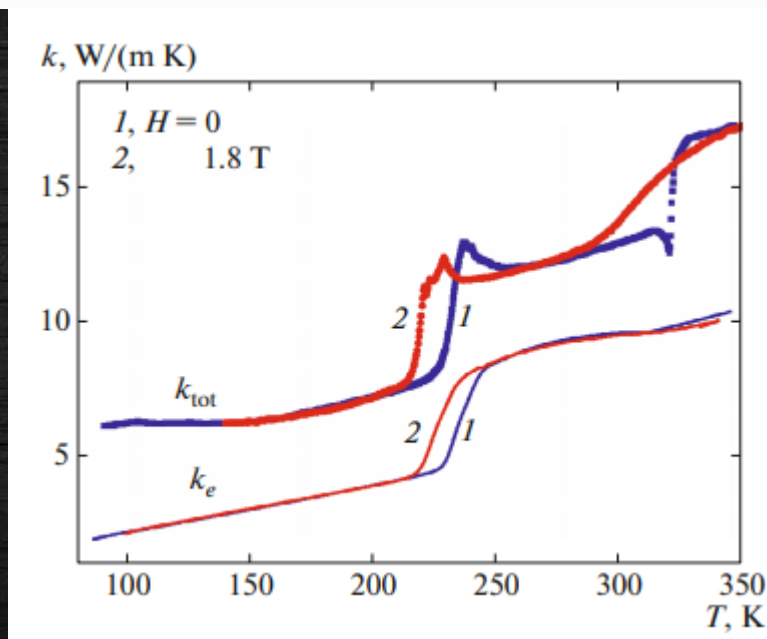
A napr. také gadolínium má vodivosť tiež len 10 W/(mK)! Železo 80 W/(mK).

Magnetic, thermal, and electrical properties of an $\text{Ni}_{45.37}\text{Mn}_{40.91}\text{In}_{13.72}$ Heusler alloy

[A. B. Batdalov](#), [A. M. Aliev](#) , [L. N. Khanov](#), [V. D. Buchel'nikov](#), [V. V. Sokolovskii](#), [V. V. Koledov](#), [V. G. Shavrov](#), [A. V. Mashirov](#) & [E. T. Dil'mieva](#)

[Journal of Experimental and Theoretical Physics](#) **122**, 874–882(2016) | [Cite this article](#)

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A napr. také gadolínium má vodivosť tiež len 10 W/(mK)! Železo 80 W/(mK).