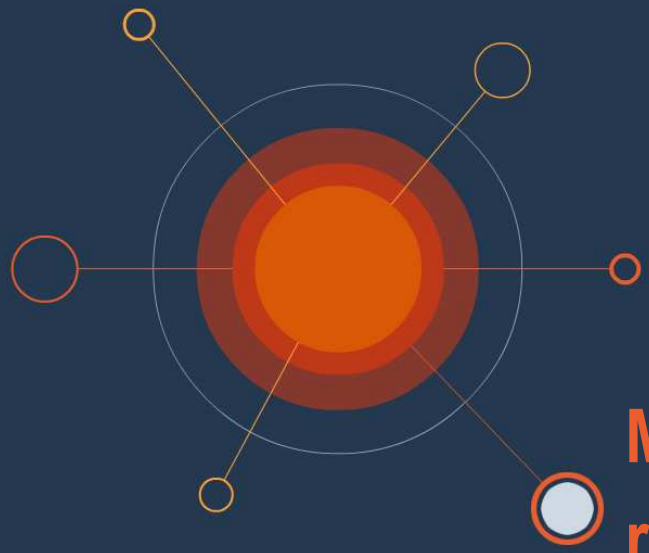
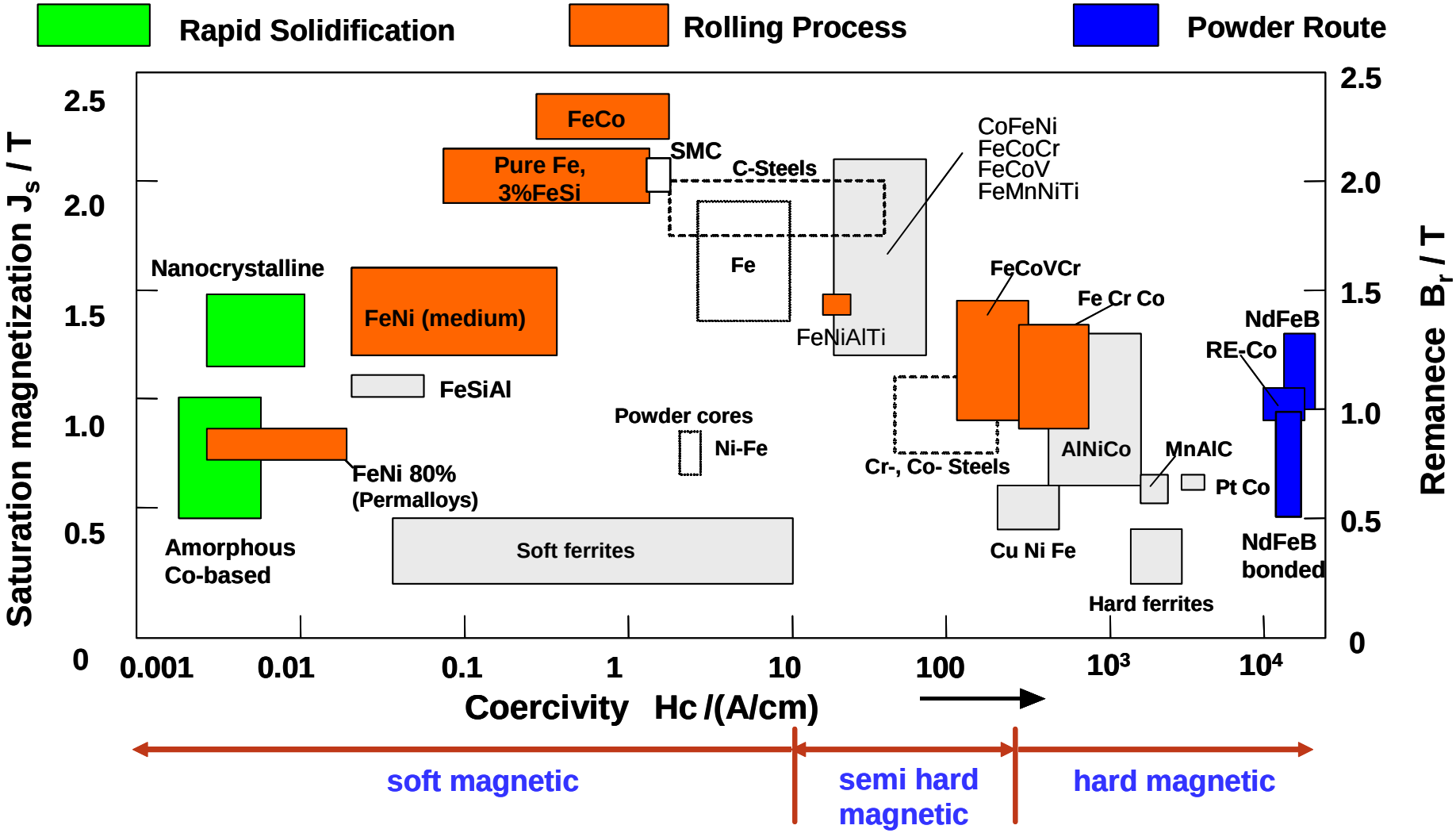


Magnetocaloric properties of reactively sintered $La(Fe,Co,Si)_{13}$

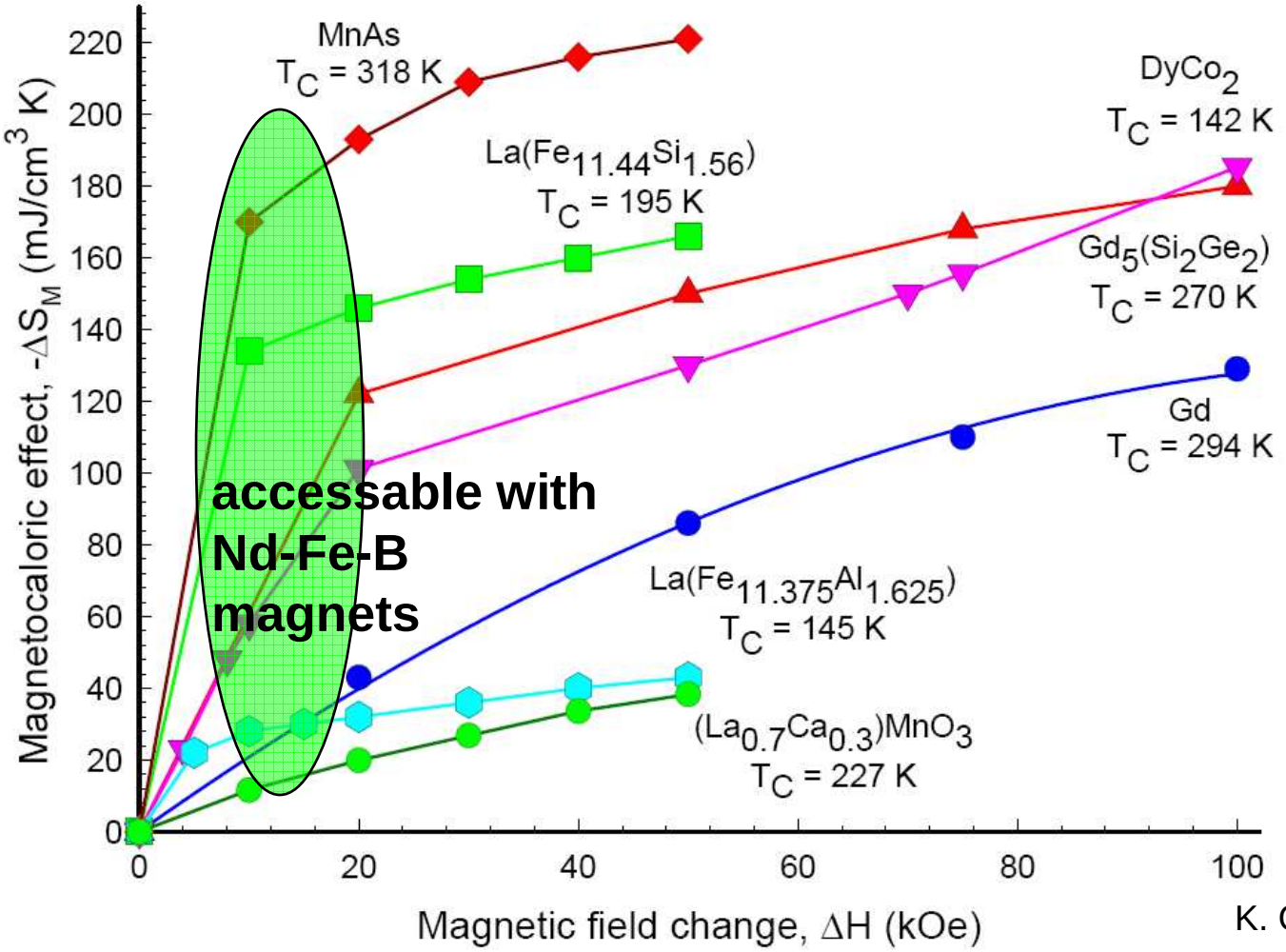
M. Katter, V. Zellmann, G.W. Reppel, K. Uestuener
Vacuumschmelze GmbH & Co. KG
Delft Days on Magnetocalorics

VACUUMSCHMELZE

overview magnetic materials

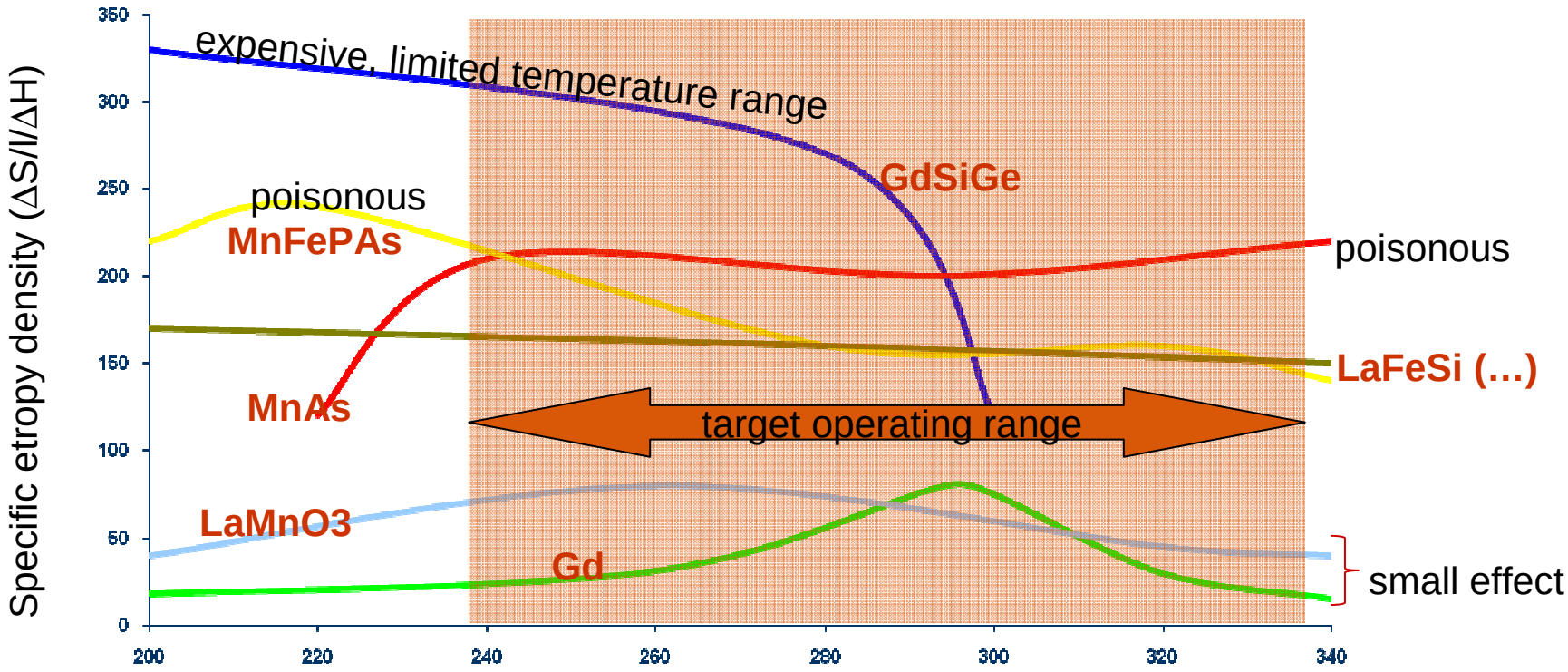


new magnetocaloric materials



K. Gscneidner (2007)

magnetocaloric materials



most promising at the moment: La-Fe-Si

Cooltech Applications (2008)

conventional preparation of $La(Fe,Si)_{13}$

- casting
- anneal, e.g. 1080℃/140 h
- optionally load with hydrogen

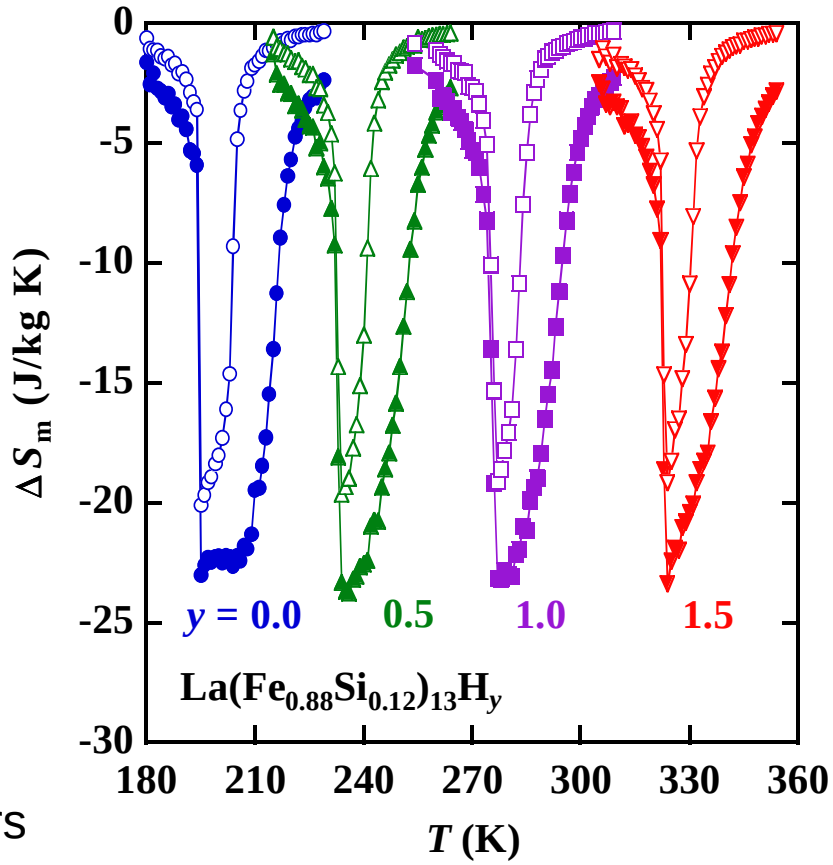
⇒ long annealing times,
⇒ with hydrogen only powder

S. Fujieda et al. 2005
F.X. Hu et al. 2005 (with Co)

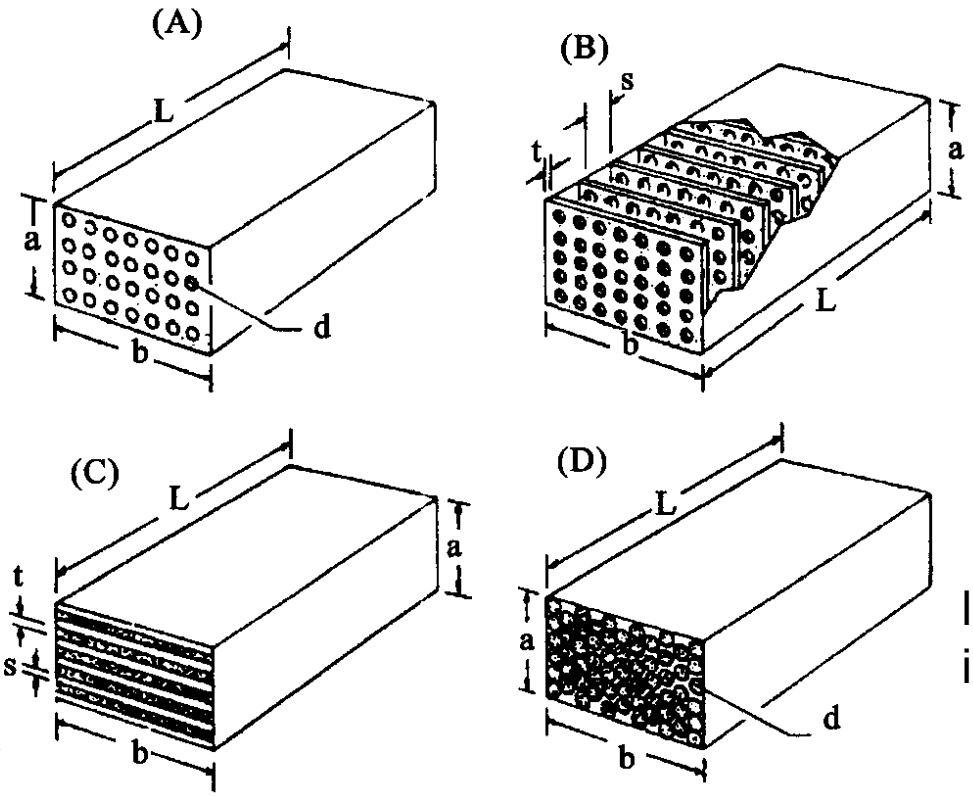
- melt spinning
- short anneal, e.g. 1000℃/2 h

⇒ only flakes or powder,
no shaped parts for heat exchangers

O. Gutfleisch et al. 2005
S. Hirosawa et al. 2006



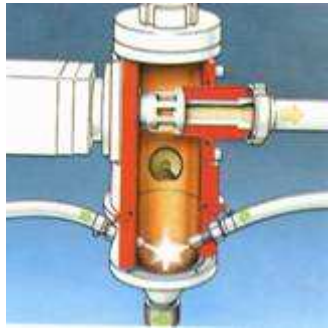
Designs for active magnetic regenerators



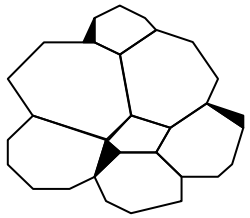
large pressure drops in powder beds?

J.A. Barclay and S. Sarangi 1984 in A.M. Tishin and Y.I. Spichkin 2003

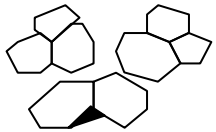
Powder Metallurgical (PM) Processing of La-Fe-Si



Vacuum Induction Alloying and Casting



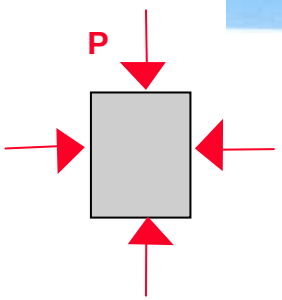
Crushing



Milling

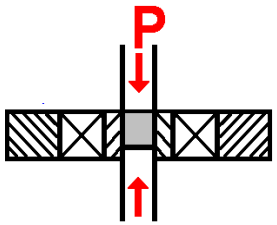
Blending ← elemental powders

Pressing: **CIP - die**

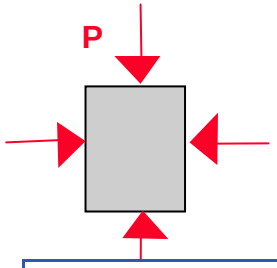


isostatic pressing

die-pressing



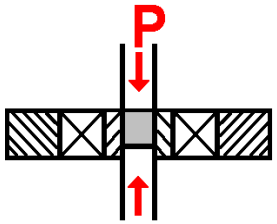
Powder Metallurgical (PM) Processing of La-Fe-Si

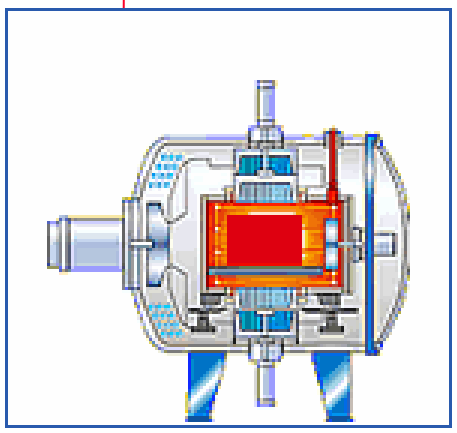


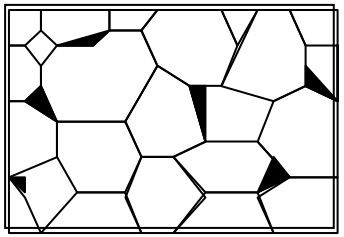
Isostatic pressing

Pressing:
CIP - die

die-pressing

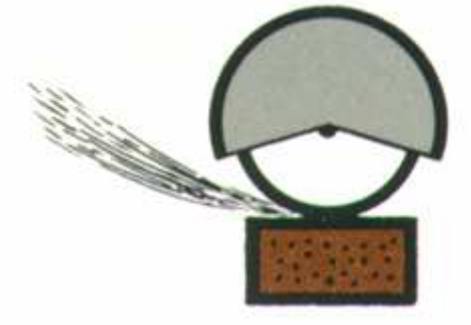


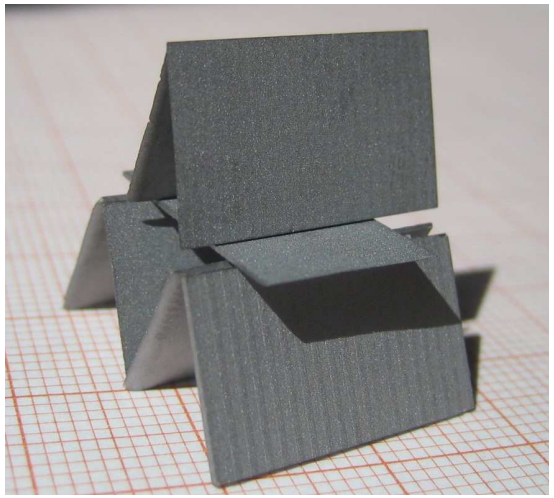




Reactive Sintering

Machining and
Surface Finishing





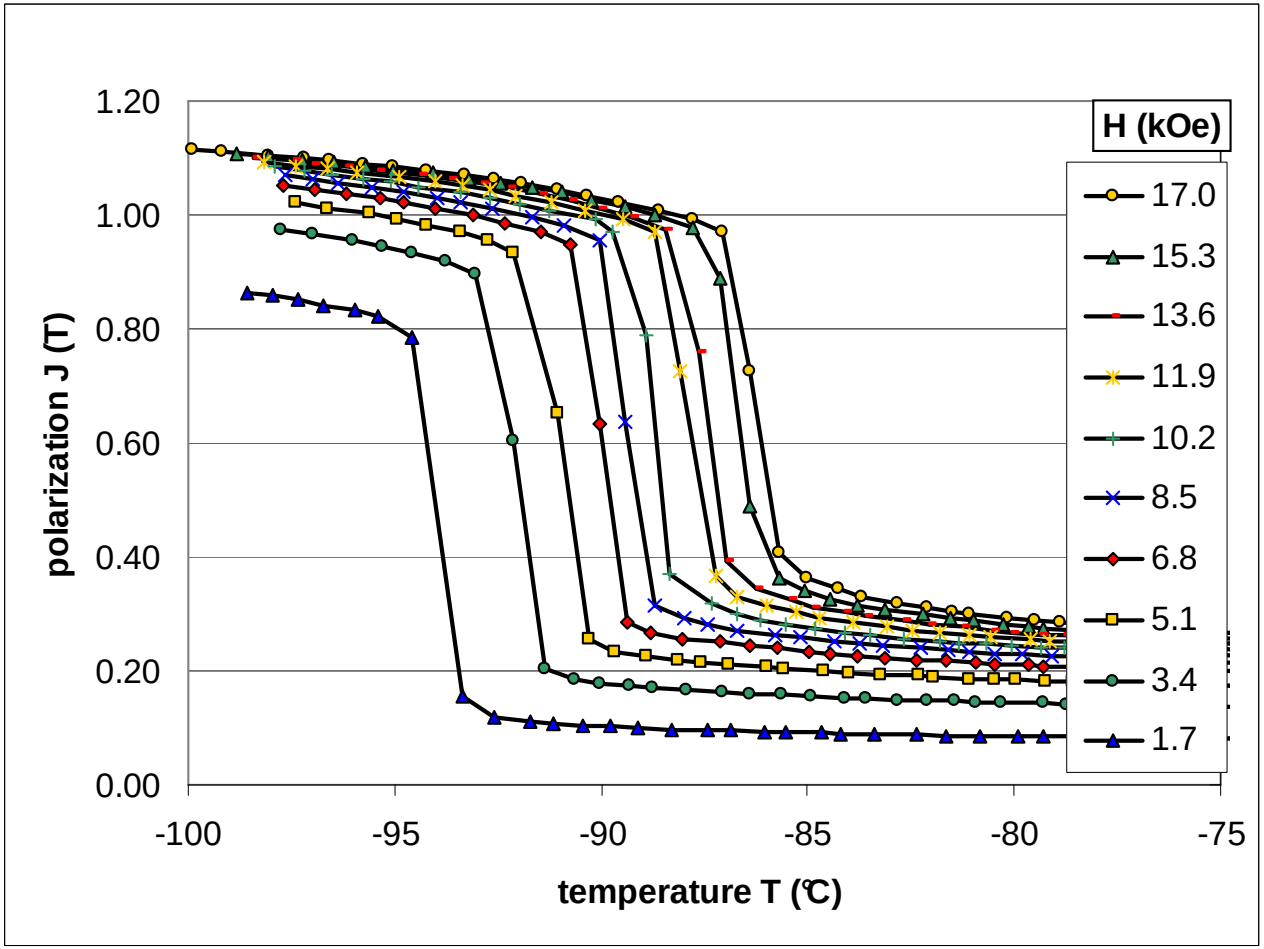
$La(Fe_{0.915}Si_{0.085})_{13}$

powder blend of
Fe, Si and LaH_x
(no melting at all)

milled to
F.S.S.S. < 5 µm

isostatically
pressed

sintered
at 1120℃/4h

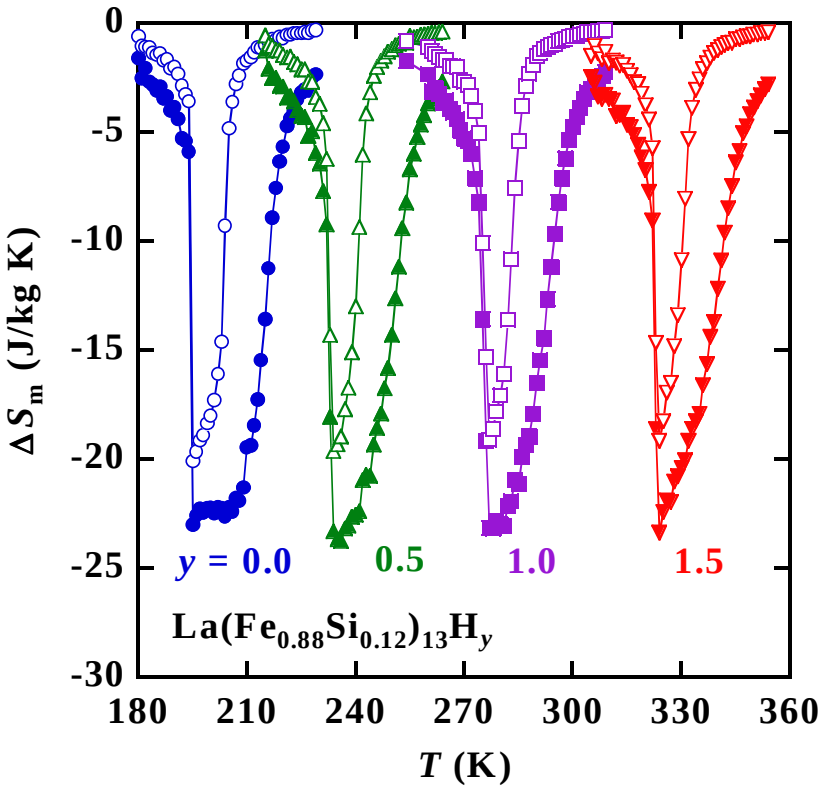


density = 6.6 g/cm³

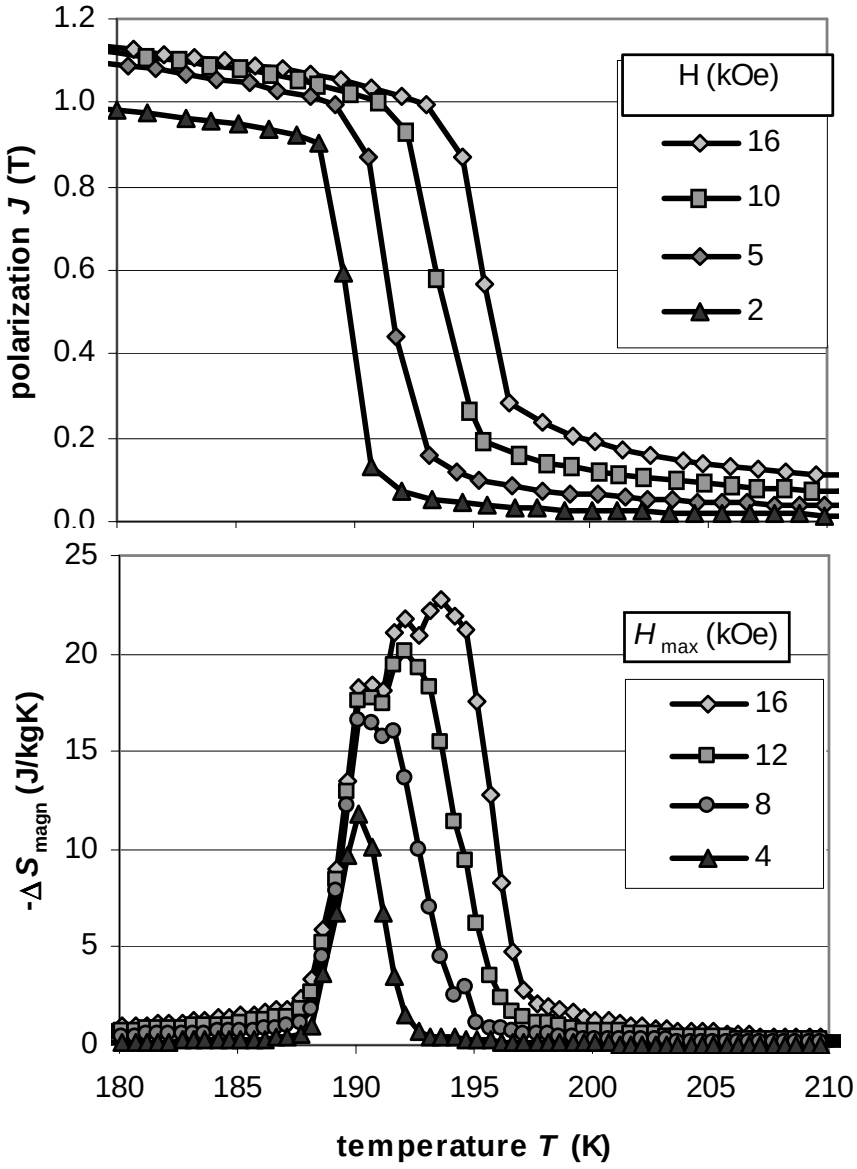
sample: 4,2 x 2 x 1,2 mm

$La(Fe_{0.893}Si_{0.107})_{13}$, sintered

$$\Delta S_T = \int_0^H \left(\frac{\partial M(T,H)}{\partial T} \right)_{P,H} dH$$

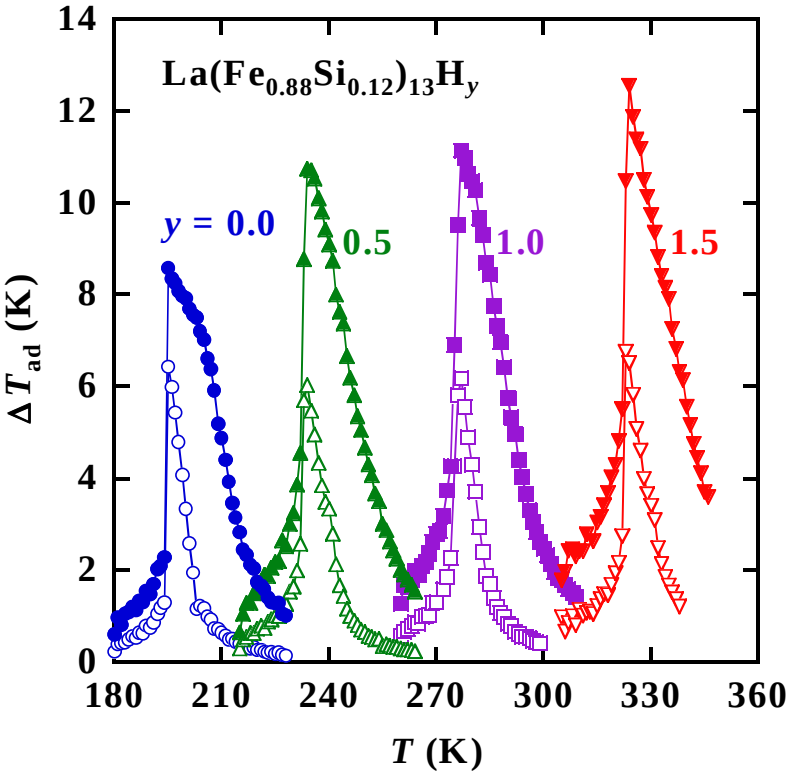


S. Fujieda et al. 2005, 0 - 2 bzw. 0 - 5 T

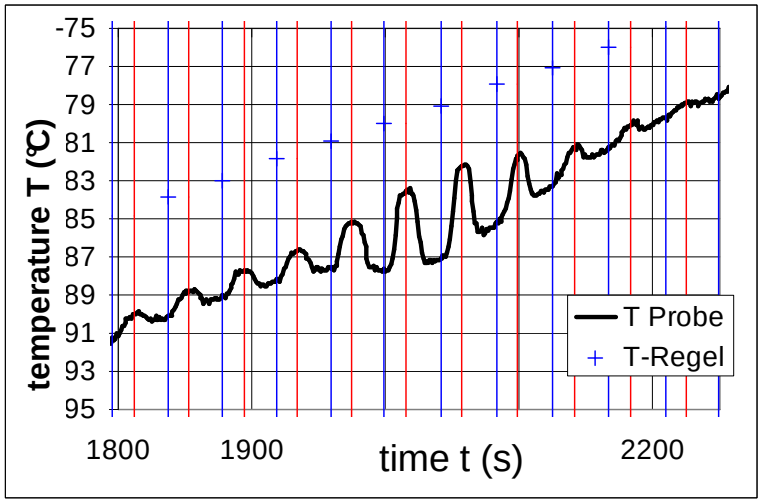


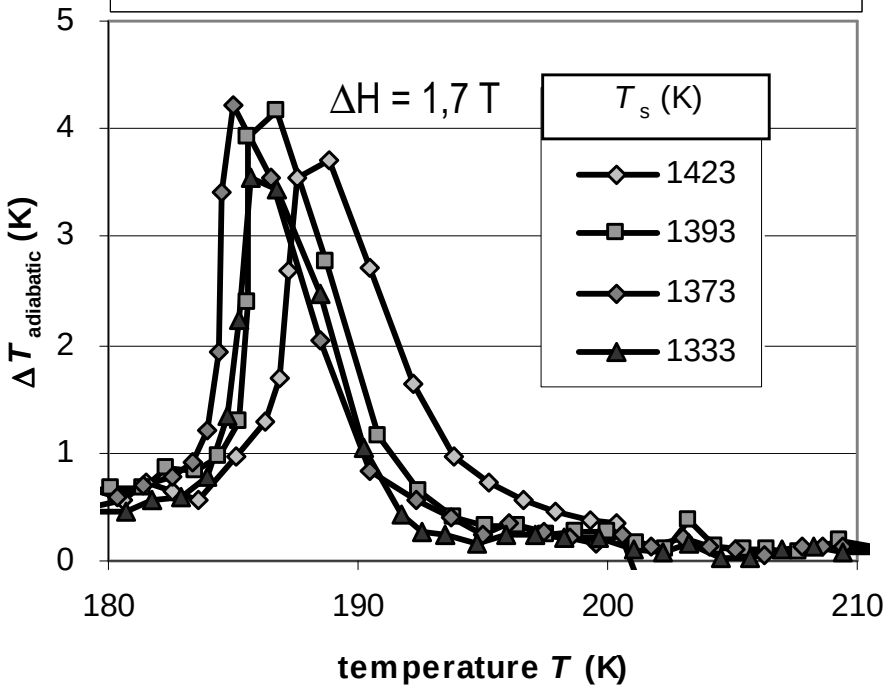
$La(Fe_{0.915}Si_{0.085})_{13}$, sintered

adiabatic temperature change



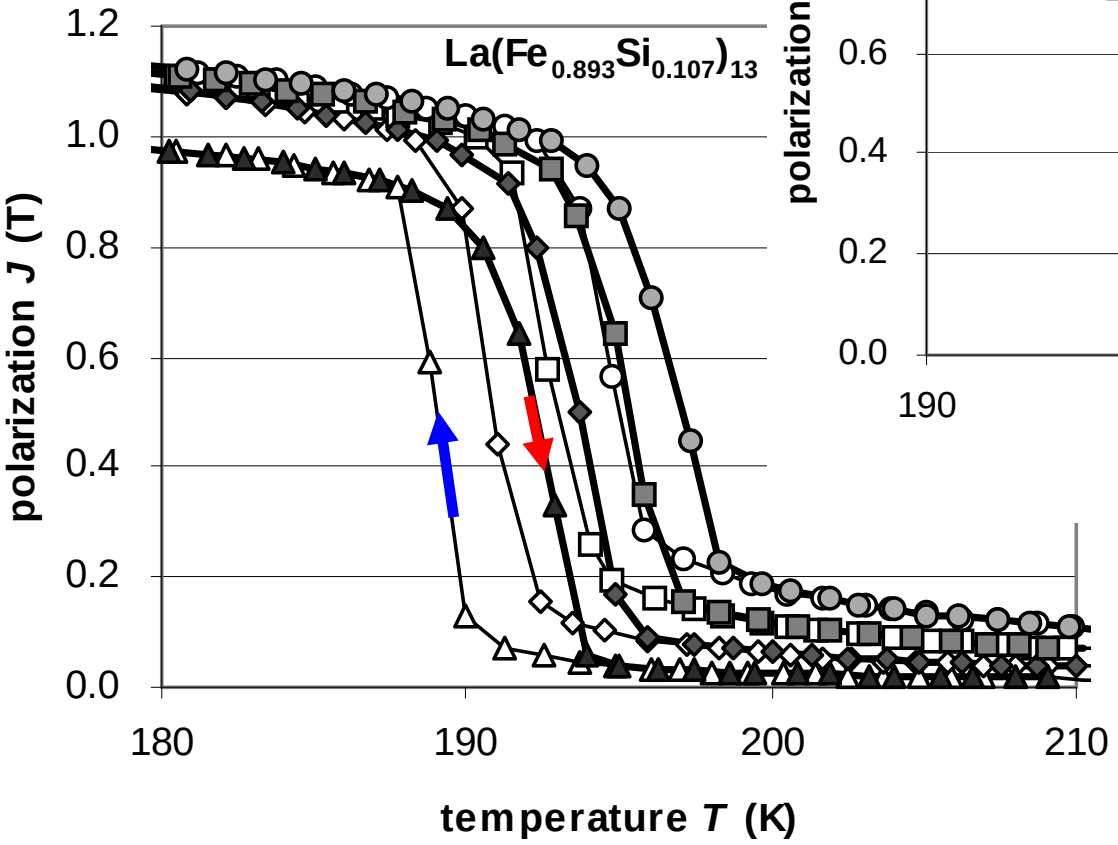
S. Fujieda et al. 2005, 0 - 2 bzw. 0 - 5 T

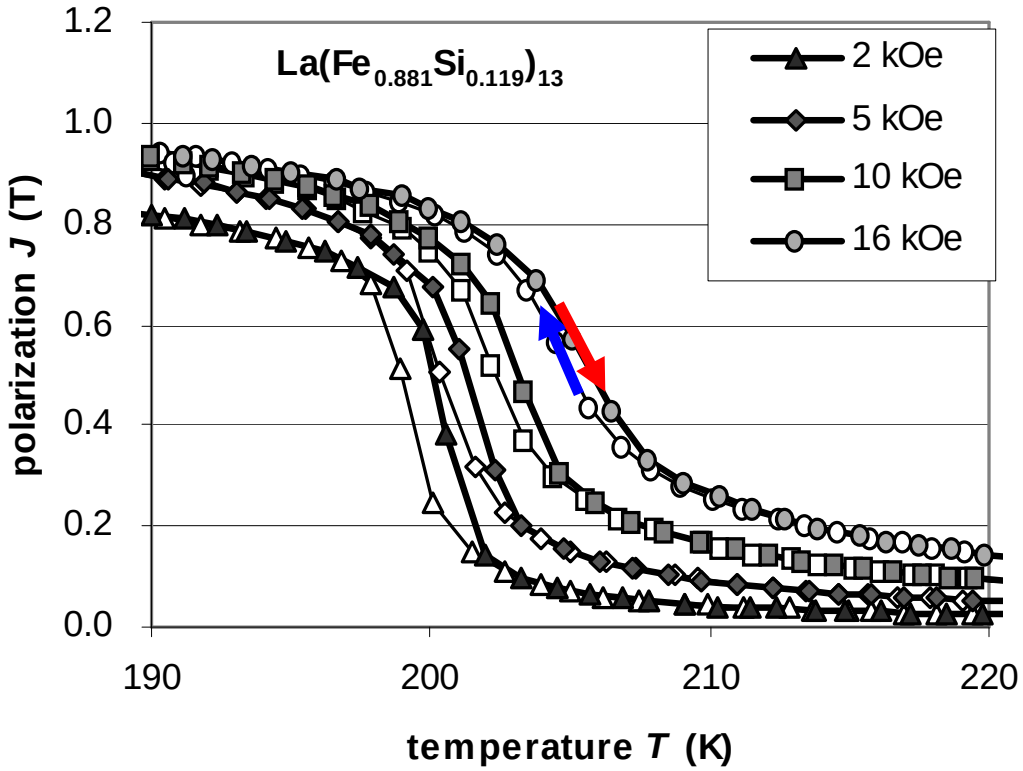




thermal hysteresis

temperature
change rate: 8 K/min

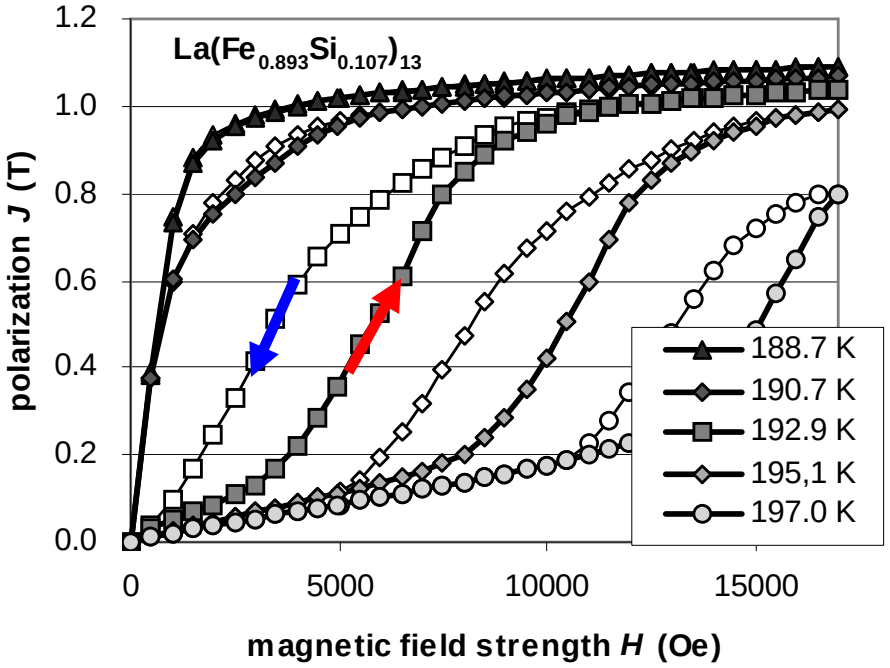


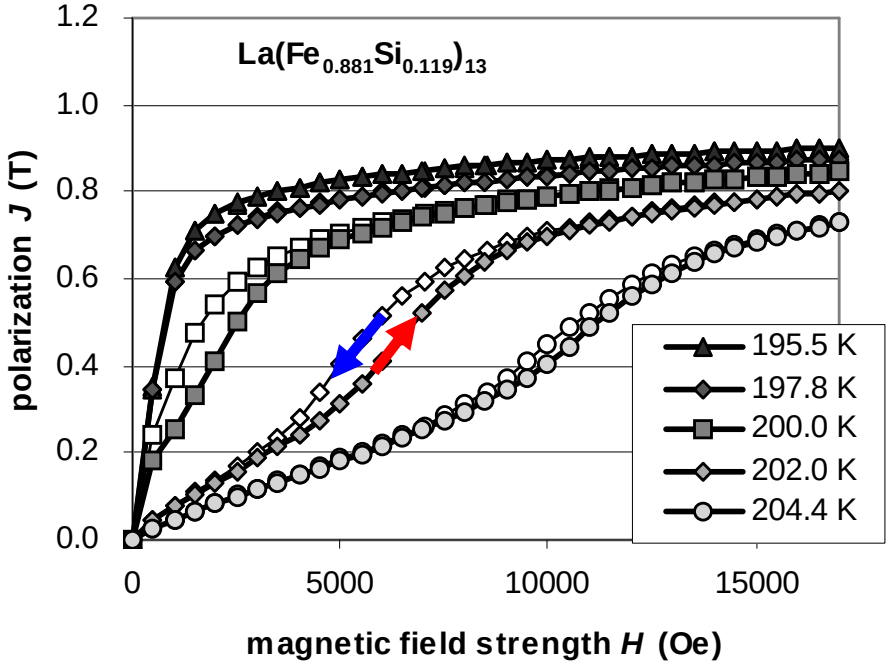


hysteresis decreases with increasing Si content and field strength

field hysteresis

field sweep rate: 4.3 kOe/min

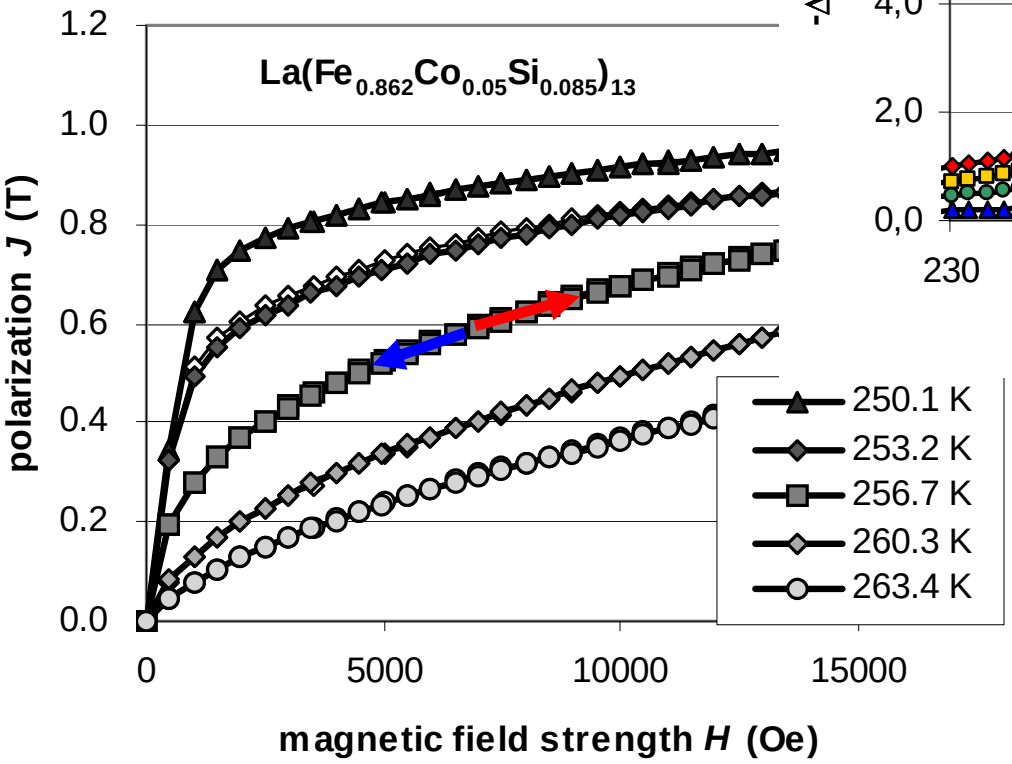


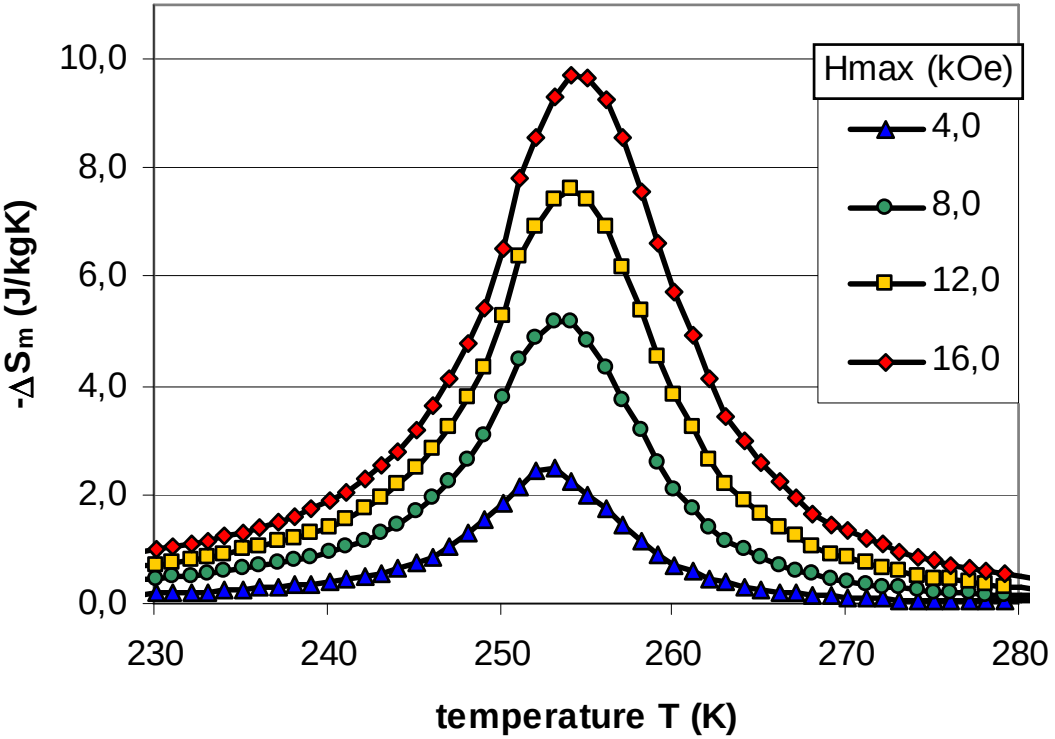


composition	temperature decreasing at –8 K/min			temperature increasing at +8 K/min			temperature hysteresis	field hysteresis
	$-\Delta S_{magn}$ (J/kgK)	T_{peak} (K)	ΔT_{WHH} (K)	$-\Delta S_{magn}$ (J/kgK)	T_{peak} (K)	ΔT_{WHH} (K)	ΔT_{peak} (K)	ΔH (kOe)
$La(Fe_{0.893}Si_{0.107})_{13}$	21.9	192.7	6.6	22.0	195.2	6.6	2.5	2.2
$La(Fe_{0.887}Si_{0.113})_{13}$	18.7	196.5	7.0	18.9	198.9	7.0	2.4	1.6
$La(Fe_{0.881}Si_{0.119})_{13}$	16.9	202.2	6.7	16.2	202.9	7.2	0.7	0.9

$La(Fe_{0.862}Co_{0.05}Si_{0.085})_{13}$ sintered

allmost no hysteresis at all





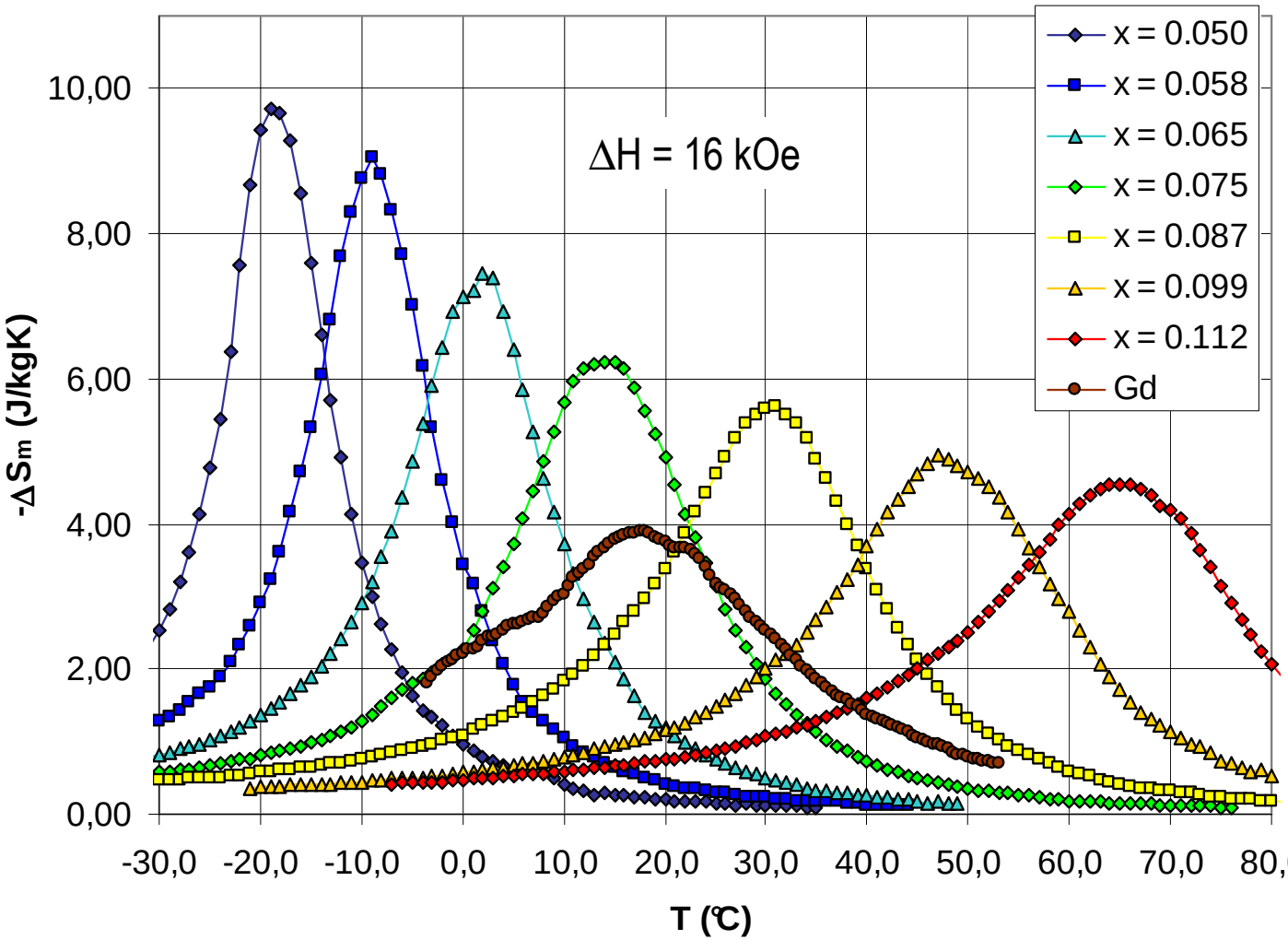
ρ = 7.24 g/cm³

$-\Delta S_{m\ @16\ kOe}$ = 67 kJ/m³K

T_{peak} = -19 ℃

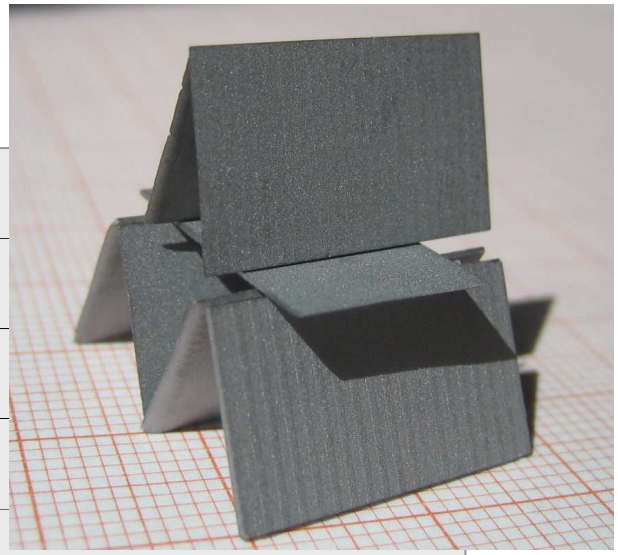
ΔT_{WHH} = 14 K

sintered $La(Fe_{0.915}Co_xSi_{0.085})_{13}$

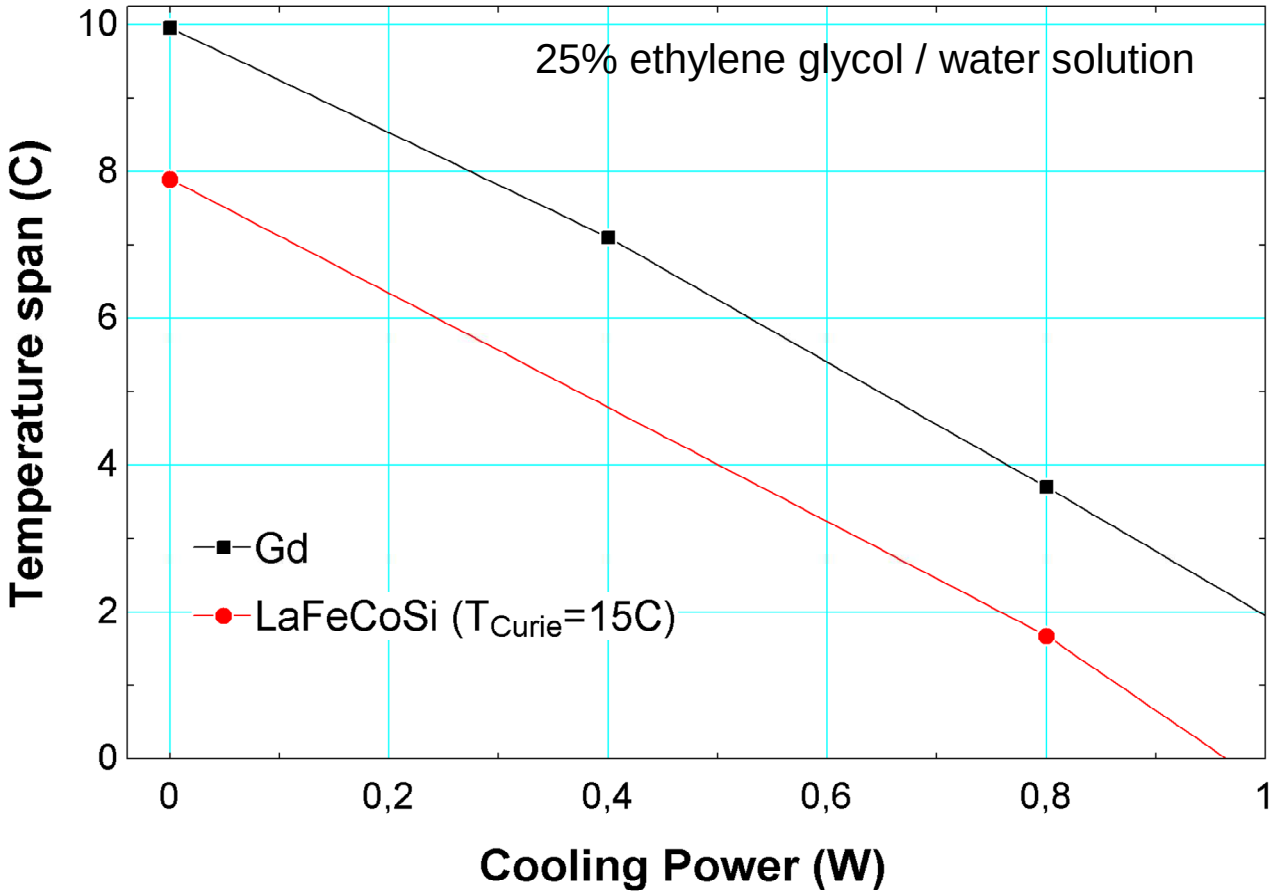


several kg blocks 23x19x12 mm produced on labscale for prototyping

thermal expansion of sintered La-Fe-Co-Si



performance in a magnetic refrigeration prototype at Risø National Laboratory for Sustainable Energy



K.K. Nielsen
J.B. Jensen
K. Engelbrecht
Ch. Bahl

2008

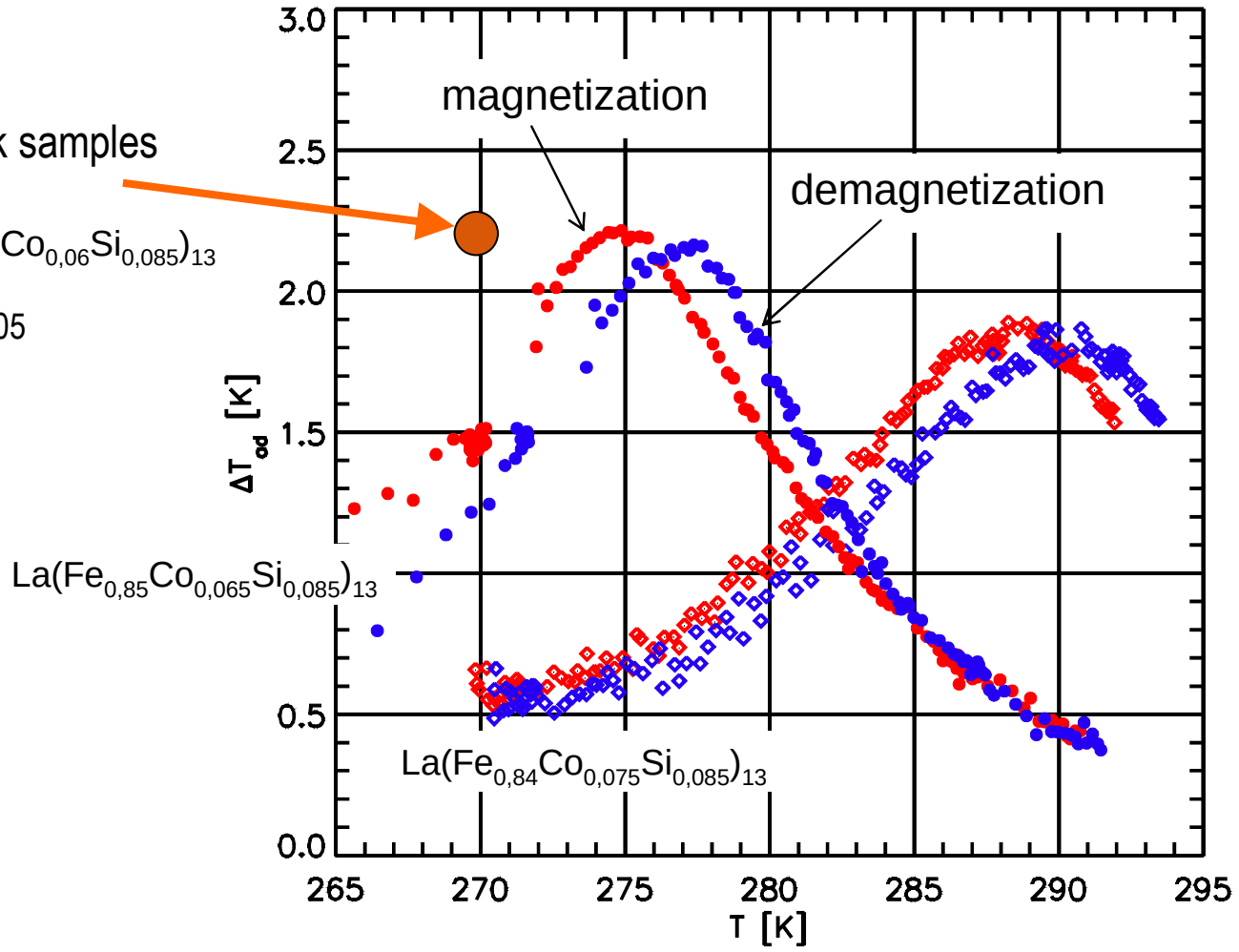
Adiabatic temperature change measured at Risø

$\Delta H = 1.1$ T

Cast bulk samples

$La(Fe_{0,855}Co_{0,06}Si_{0,085})_{13}$

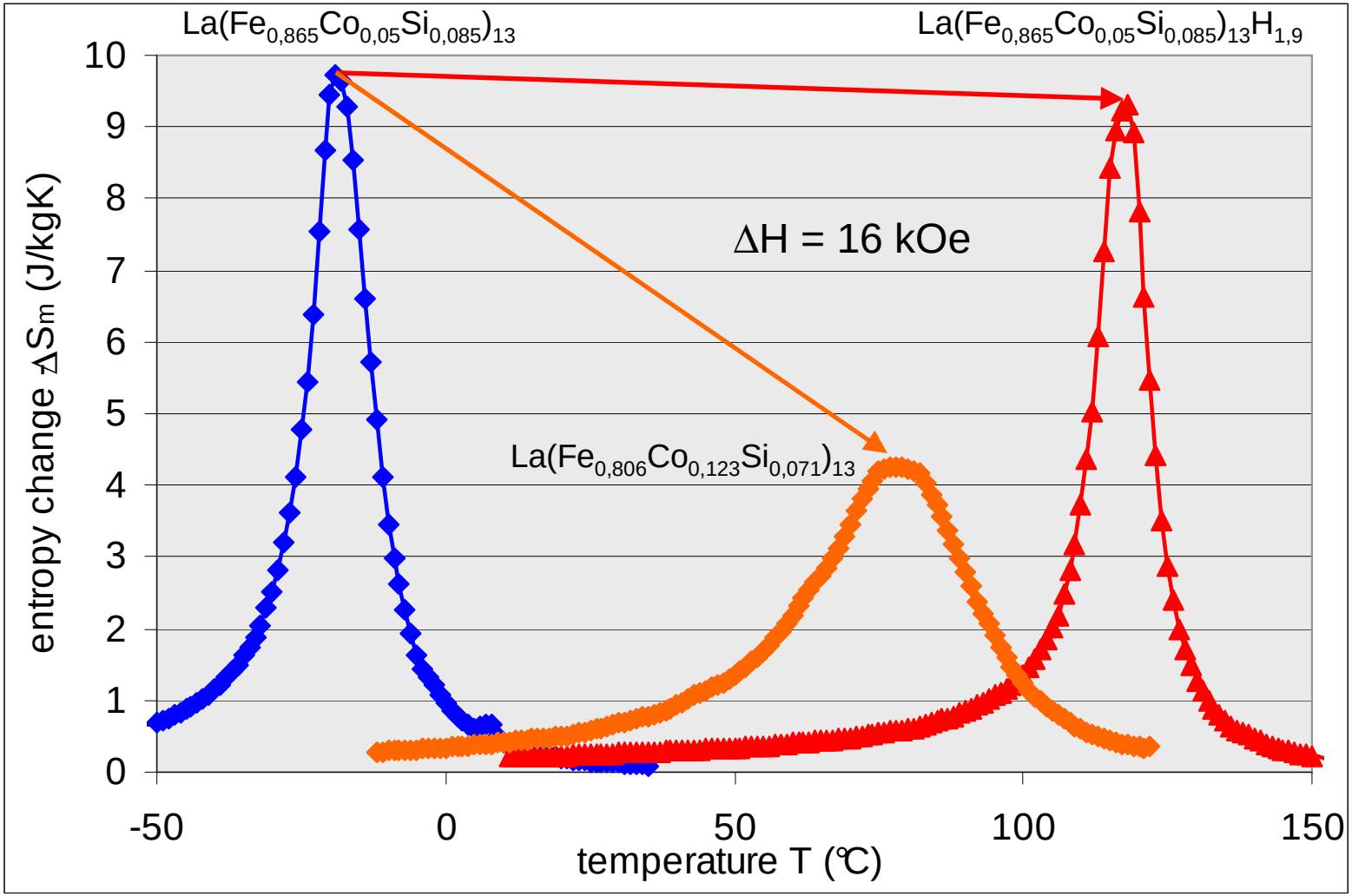
F.X. Hu 2005



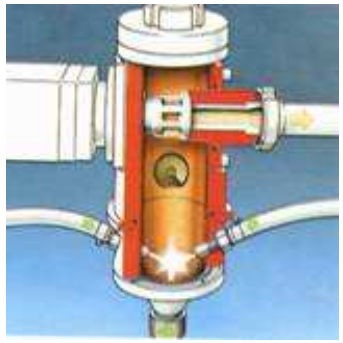
K.K. Nielsen
J.B. Jensen
K. Engelbrecht
Ch. Bahl

2008

Hydrogenation of sintered La-Fe-Co-Si



Conclusion



- $La(Fe,Si)_{13}$ sucessfully prepared by powder metallurgy
- bulk material available after reactive sintering for a few hours
- hysteresis decreases with increasing Si and Co content
- Curie temperature controllable by Co or H substitution
- entropy change similar or better compared to Gd
- several kg with various Curie temperatures produced
- process upscalable on an industrial basis
- temperature span comparable to Gd