Magnetostriction - a way to detect lattice contributions to the magnetocaloric effect in CoMnSi based materials

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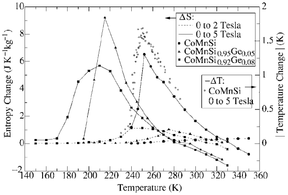
Why do we study CoMnSi based alloys?

CoMnSi based compounds are:

- relatively cheap metals
- not (very) toxic alloys
- magnetic properties can be tailored by substituting elements



- maximal entropy changes of $\sim 10\ J/kgK$ in magnetic field changes from 0 T to 5 T around room temperature
- What are the individual contributions to the total entropy change?

Total entropy change

To a first order approach the total entropy change can be split up into individual parts:

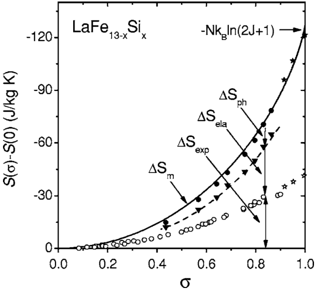
$$\Delta S_{total}(T,H,V) = \Delta S_{lat}(T,H,V) + \Delta S_{el}(T,V) + \Delta S_{mag}(T,H,V)$$

- $\Delta S_{lat} = \Delta S_{ph} + \Delta S_{ela}$
- $\Delta S_{el} = \gamma T$
- $\Delta S_{mag}^{max} = -Nk_B ln(2J+1)$

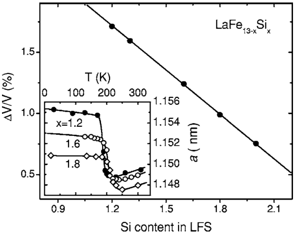
Total entropy change

The individual parts have only been studied in a very small number of compounds:

- LaFeSi: magnetic entropy change dominates but is reduced by a large opposed lattice entropy



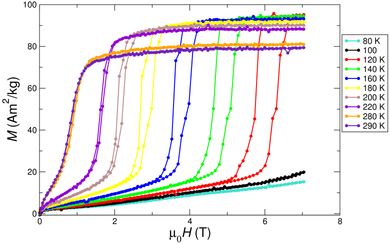
Jia et al., J. Appl. Phys. **100** 123904 (2006)

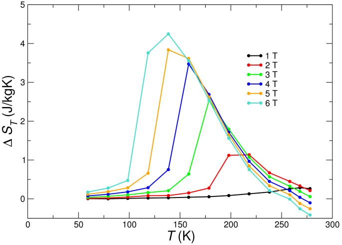


Isothermal magnetisation

$Co_{0.95}Ni_{0.05}MnSi$:

- Isothermal entropy change ΔS_T was calculated from magnetisation data via the Maxwell equation.
- maximal entropy change of ~ 6 J/kgK



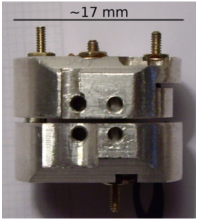


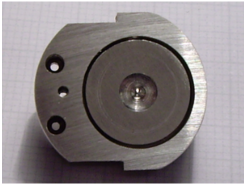
- What are the individual contributions to the total entropy change?

Thermal expansion and magnetostriction

Capacitance dilatometry is a macroscopic method:

- measuring length change of a macroscopic sample under various conditions
- with very high sensitivity $\frac{\Delta l}{l} \sim 10^{-9}$
- having a simple design
- useable in a wide range of temperatures (0.01 K - 1000 K) and magnetic fields (50 T)

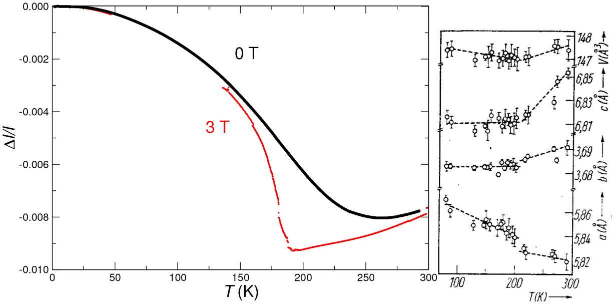




$$\textit{dilation} \sim \frac{\textit{area}}{\textit{capacitance}}$$

Thermal expansion of $Co_{0.95}Ni_{0.05}MnSi$

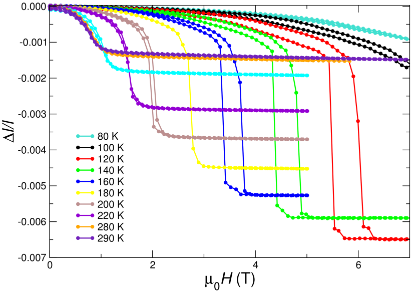
- negative thermal expansion from 2 K to metamagnetic transition temperature
- broad transition in zero magnetic field around 250 K
- magnetic field shifts transition to lower temperatures
- samples break during magnetic field sweeps!



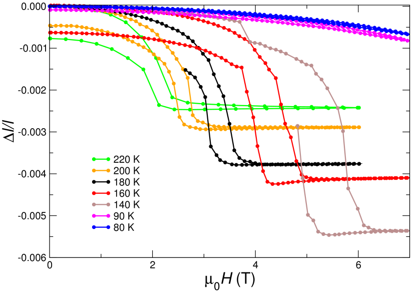
S. Niziol et al., Phys. Stat. Sol. (a) 45 591 (1978)

Magnetostriction of $Co_{0.95}Ni_{0.05}MnSi$

- very large magnetostriction values up to 0.5 % in 6 T
- volume changes during the magnetic field induced phase transition
- transition becomes more first order at lower temperatures

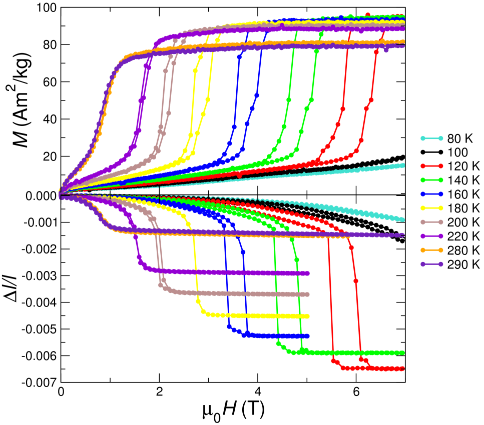


temperature dependent transversal magnetostriction of $Co_{0.95}Ni_{0.05}MnSi$



longitudinal magnetostriction

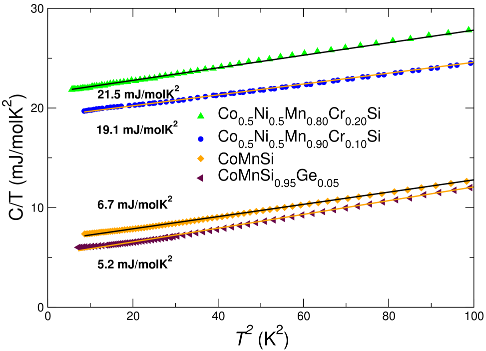
Magnetostriction versus magnetisation



- critical fields match very well!
- coefficient of magnetostriction increases with decreasing temperature
- lattice contraction has a contribution to the total entropy

Heat capacity

- large difference in electronic heat capacity between antiferro- and ferromagnetic materials
- expected to have similar order of magnitude in **one** material
- electronic part of entropy during the antiferro- to ferromagnetic transition is expected to be $\Delta S_{el} \sim 30$ J/kgK for $T_t = 280$ K



Conclusions:

- we performed macroscopic thermal expansion, magnetostriction, and heat capacity measurements
- results suggest large electronic and lattice contributions
- magnetic contributions for the order-order transition are expected to be smaller

Acknowledgements:
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