Complex Magneto-volume Effects Induced by Magnetic Field and Pressure in Ni_2MnSn-based Alloys

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MOTIVATION

The Heusler $Ni_2Mn_{1+x}Sn_{1-x}$ alloys in a narrow composition range (0,4 ≤ x ≤ 0,6) exhibit structural martensitic transformation from cubic (austenite - A) into orthorhombic (martensite - M) phase with decreasing temperature at transition temperatures T_{A-M} or T_{M-A}.

.The diffusionless structural transformation is accompanied by significant changes of volume, magnetization and by large anomalies in transport properties that make the alloys interesting for practice.

The mentioned volume changes were a motivation to study effect of high pressure on magnetic properties of the $Ni_{1.92}Mn_{1.56}Sn_{0.52}$ alloy in wide range of pressure, temperature and magnetic field.

MAGNETIC MEASUREMENT under PRESSURE

The high hydrostatic pressure cell was made from non-magnetic CuBe bronze and DAPHNE© oil inside ensures a hydrostatic conditions at room temperature up to 1.2 GPa. Small dimension of the cell allows its use in the MPMS-7T SQUID magnetometer, see Figure 1

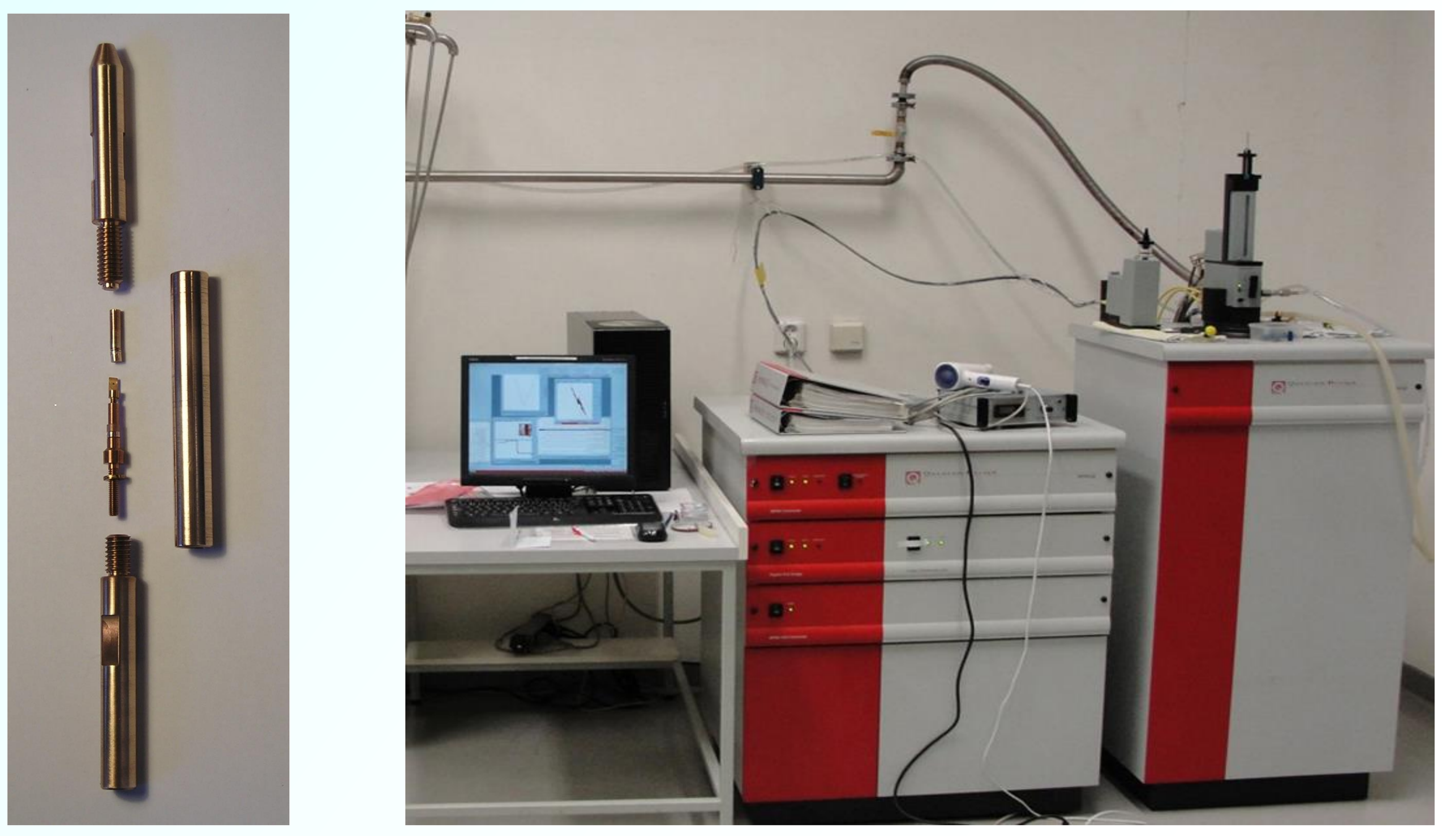

Figure 1: The CuBe pressure cell for magnetic measurements up to 1.2 GPa and the MPMS-7T SQUID magnetometer.

Temperature and field dependence of magnetization was measured in the SQUID magnetometer from 2 K to 400 K at field up to 7 T.

Magnetostriction was measured by a strain-gage-bridge up to field 14 T in Physical Property Measuring System (PPMS-14T).

DISCUSSION & CONCLUSIONS

In hierarchy – structural transformation – magneto-volume effect – changes of magnetic structure:

* the observed sharp change of $\Delta L/L_0$ at around T_{M-A} and T_{A-M} well agrees with rtg-data on $\Delta V/V_0$ within structural *M-A* or *A-M* changes, where external magnetic field supports ferromagnetism of austenite

* in martensite, a coincidence of forced-volume-magnetostriction with pressure parameter, $1/M_0 * dM_S(H,P,5K)/dP$, points to effect of pressure on magnetic moments

* no changes of $\Delta L/L_0$ were observed in magnetostriction measurements within temperature-field domain of exchange-spring and exchange-bias effects based on an arrangement of magnetic entities

RESULTS

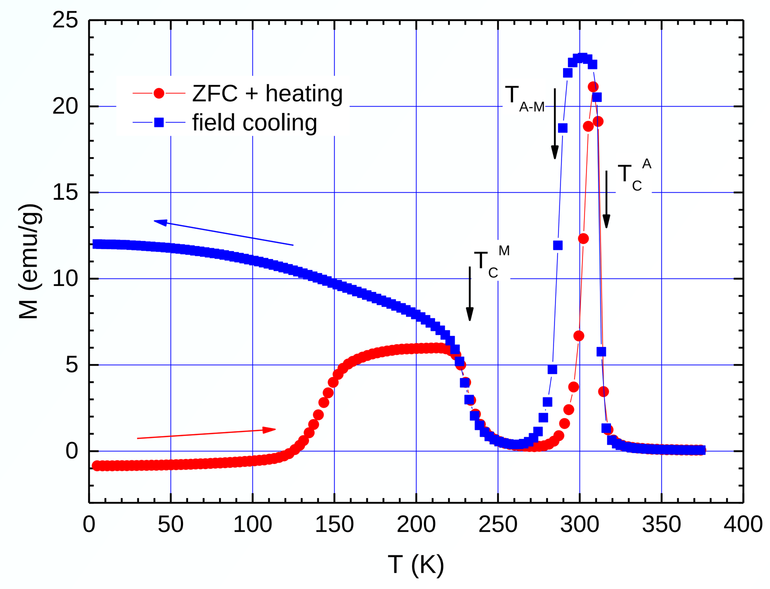

Figure 2: Temperature dependence of magnetization at field 200 Oe

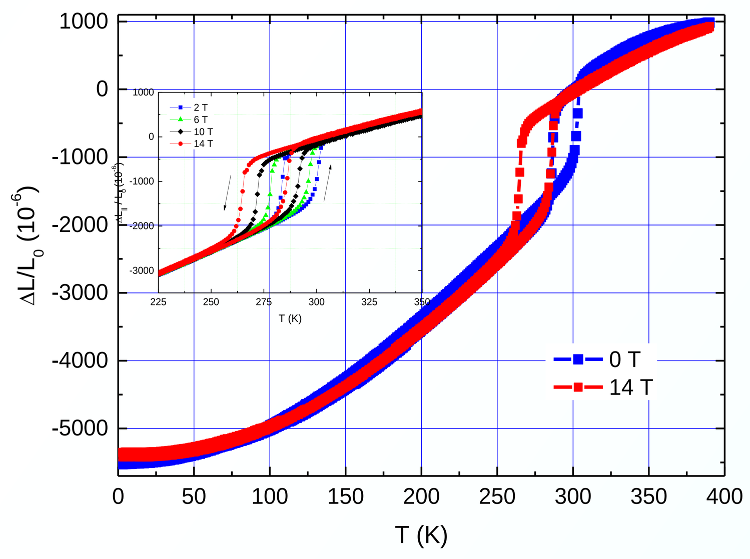

Figure 3: Thermal expansion at zero and high magnetic fields

The $Ni_{1.92}Mn_{1.56}Sn_{0.52}$ alloy exhibits zero magnetization at range between T_C^M and T_{A-M} and a complex cluster-glass magnetic structure at low temperatures.

A sharp change of $\Delta L/L_0$ is observed in thermal expansion of the alloy at T_{M-A} and T_{A-M} that are shifted significantly to lower temperatures by field (Fig.3).

No visible change of $\Delta L/L_0$ was detected at around T_C^M and T_C^M itself is insensitive to external pressure.

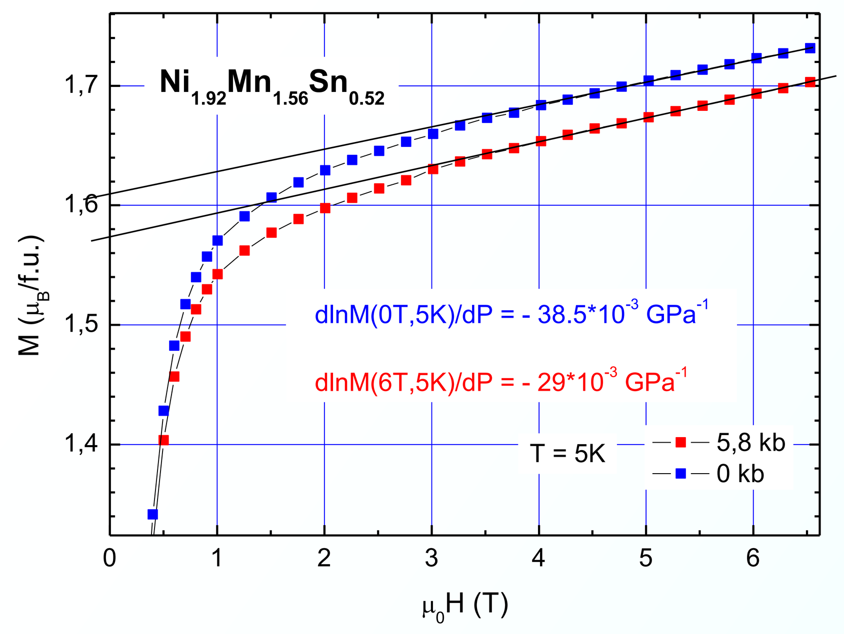

Figure 4: Pressure dependence of magnetization *M(5K,H,P)* of the alloy.

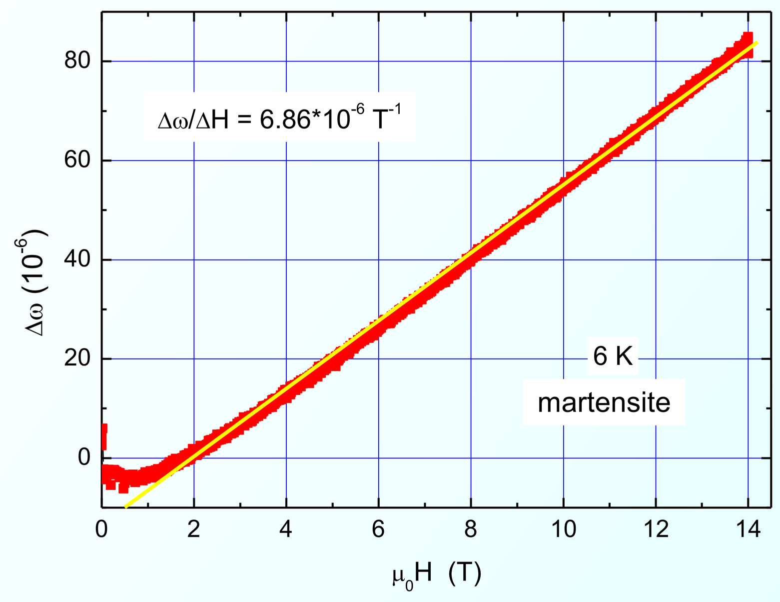

Figure 5: Forced volume magnetostriction of the alloy at temperature 6 K.

Magnetization of martensite of the $Ni_{1.92}Mn_{1.56}Sn_{0.52}$ alloy decreases significantly with increasing pressure (Fig.4).

Taking into account Maxwell's relation $d\omega/dH = -\rho dM/dP$, the observed value of *dlnM/dP* well agrees with measured value of the forced volume magnetostriction presented in Fig.5.

Surprisingly, pronounced exchange-spring and exchange-bias effects were observed in the alloy at temperatures below 100 K, where the cluster-glass structure is considered (Fig.6). Both these effects are insensitive to an application of external pressure up to 1 GPa.

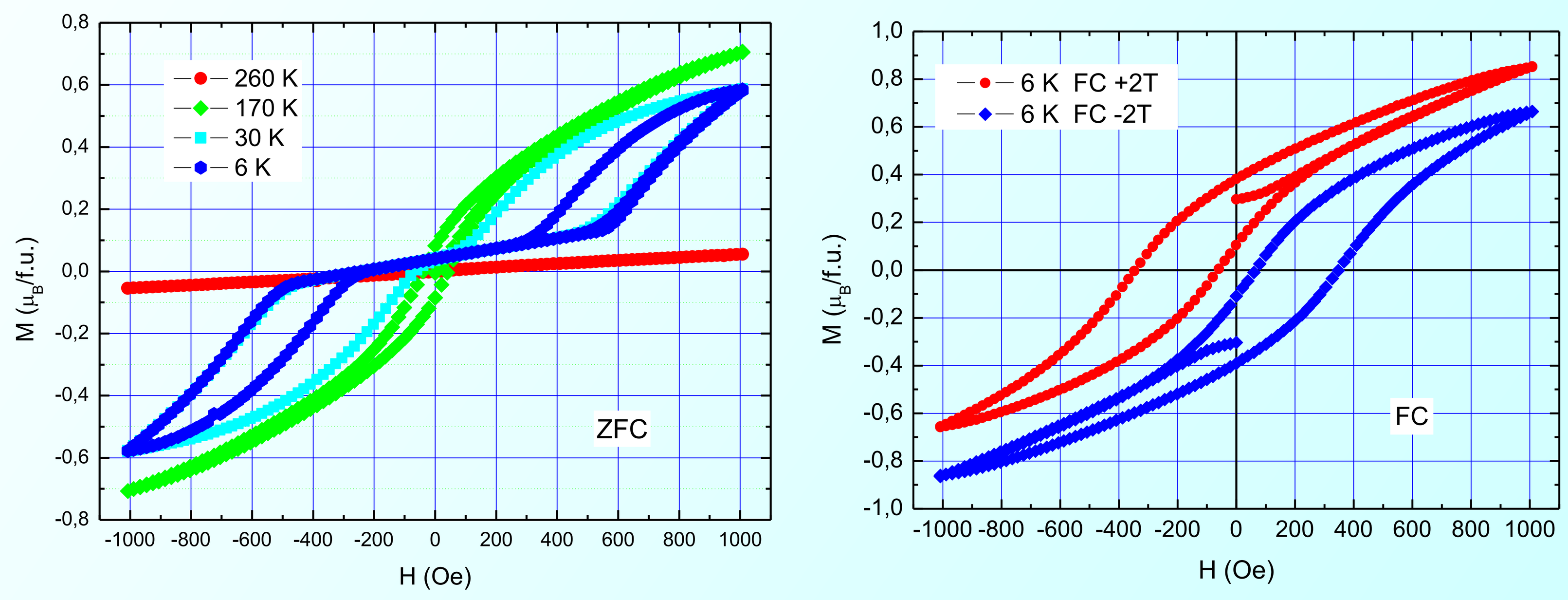

Figure 6: The exchange-spring effect in the alloy cooled in zero-field (ZFC) observed below 100 K and the exchange-bias effect at 6 K in the alloy cooled in field +2T and -2T..

References: J. Kaštil, J. Kamarád, M. Míšek, J. Hejtmánek, Z. Arnold, J. Magn. Magn. Mats. 466 (2018) 260–266; J. Kaštil, J. Kamarád, O. Isnard, Y. Skourski, M. Míšek and Z. Arnold,, J. Alloys and Comp. **650** (2015) 248-255; J. Kamarád, J. Kaštil, Y. Skourski, F. Albertini, S. Fabbrici and Z. Arnold,, Mater. Res. Express **1** (2014) 016109

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