Pressure-induced structural phase transition in MnSb

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In recent years, a great deal of interest has been focused on metallic systems close to a magnetic instability, particularly at low temperatures in the vicinity of a quantum critical point (QCP). By varying a control parameter such as external pressure, the system can be tuned through its QCP; i.e. where magnetic order disappears. In this regime, quantum fluctuations strongly affect the physical properties of the system and result in a deviation of the Fermi-liquid behaviour and the formation of new ground states (e.g. partial order in MnSi [1]) and unconventional superconductivity (e.g. Fe metal [2]). Motivated by these new aspects, we investigate the magnetic quantum phase transition of the ferromagnetic metal MnSb induced by external pressure.

The ferromagnetic metal ($T_C = 588$ K) MnSb crystallizes in the hexagonal NiAs type structure (space group $P6_3/mmc$) and exhibits spin reorientation around 520 K. The saturation moment amounts to 3.5 μ_B [3]. The ferromagnetic state is found to be unstable under high pressure: Both T_C and μ_{Mn} decrease with increasing pressure. It has been shown that T_C is strongly suppressed to 339 K with increasing pressure up to 6 GPa (initial rate of -32 K/GPa) [4]. Also measurements of the magnetization (M_S) under pressure up to 0.9 GPa indicate that M_S decreases with applied pressure at a rate of about -0.3 μ_B/GPa [5]. These observations strongly suggest the collapse of the magnetic state under very high pressure.

In order to investigate whether a pressure-induced instability of the ferromagnetic state is reflected in a structural instability, we performed energy dispersive x-ray powder diffraction at beamline F3, HASYLAB, using a diamond anvil cell (DAC) setup with liquid nitrogen as pressure-transmitting medium. The beam collimated to a size of about 100×100 μm^2 hit the sample in a cylindrical sample chamber of about 200 μm in diameter and 50 μm in height. The detector collecting the diffracted photons was situated at an angle of $3.6°$ with respect to the direction of the incoming beam. Typical acquisition time for one spectrum was about 30 min.

Fig. 1 shows the results obtained at room temperature and pressures up to 31.1 GPa. Spectra for selected pressures are displayed in Fig. 1a). At low pressures ($p \leq 10.1$ GPa), all reflections can be indexed using the NiAs type structure. By further increasing the pressure, diffraction patterns change dramatically and can be indexed using the orthorhombic MnP type structure. Such a pressure-induced phase transition from a hexagonal into an orthorhombic phase has been also observed in isostructural MnTe and other related materials with NiAs type structure [6]. Fig. 1b) shows the pressure dependence of the volume which has been divided by the number of atoms in the corresponding unit cell (4 and 8 for NiAs and MnP type, respectively). At the phase transition a reduction of the volume of about 7 % can be seen. A fit to the data using Birch′s equation of state [7] gives a Bulk modulus of $B_0 = 39(6)$ GPa and its derivative $B_0' = 5(2)$ for the low pressure NiAs phase.

In summary, we have investigated the effect of pressure on the structural properties MnSb using the high pressure x-ray diffraction setup located at beamline F3, HASYLAB. The data reveal a pressure-induced structural phase transition in an orthorhombic phase at room temperature and a critical pressure p_c around 11 GPa. We believe that this structural instability is connected to a magnetic to nonmagnetic phase transition at this pressure and temperature.

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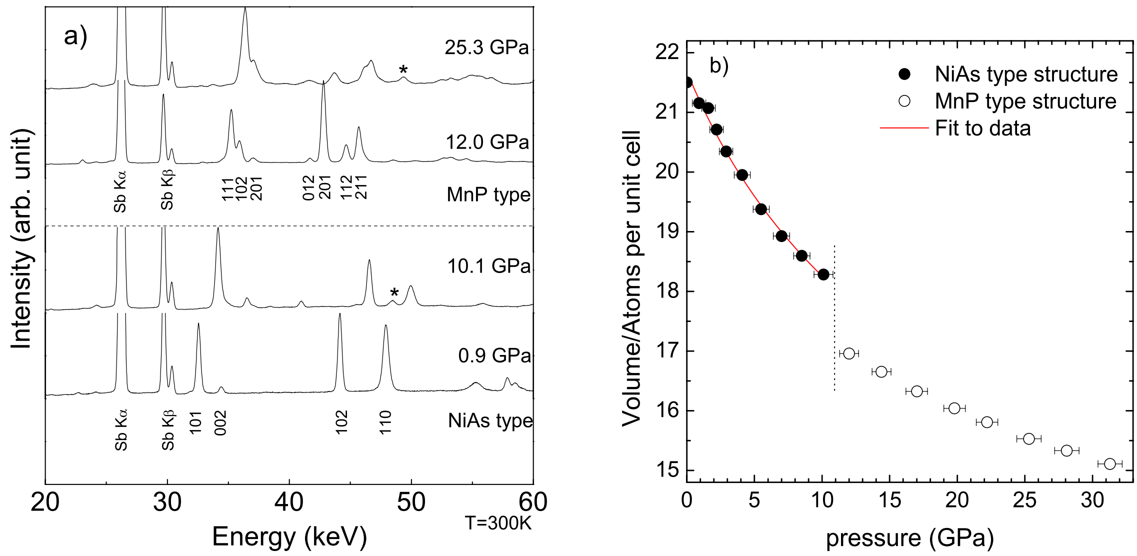

Figure 1: a) x-ray diffraction pattern for some selected pressures. For $p \leq 10.1$ GPa, reflections can be indexed with the NiAs type structure. By further increase of pressure, spectra change dramatically and can be indexed using a MnP type structure. Asteriks mark reflections from the gasket material. b) Pressure dependence of the volume in the NiAs type (•) and MnP type (○) phase. The volume of the unit cell is divided by the number of atoms in the unit cell for a better comparison.

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