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RESISTIVITY OF THE REENTRANT SYSTEMS NiMn AND a-FeZr NEAR THE FERROMAGNETIC PHASE TRANSITION

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Abstract. — We report on the temperature derivative of the resistivity close to the Curie temperature of the reentrant systems NiMn 22 at % and a-FeZr 8 at %. Magnetic susceptibility results for the NiMn system are also presented. Critical exponents could be deduced from the data.

The critical behaviour of systems presenting quenched magnetic disorder is a topic of considerable current interest. In particular, the problem of the existence or not of a spin glass phase transition is still not completely elucidated [1]. Also, the nature of phase transitions in amorphous ferromagnets is not yet well understood [2]. Another interesting case is represented by the so called magnetic reentrant systems, which first undergo a para-ferromagnetic transition followed by a transition to a spin glass-like state at lower temperatures.

In this communication we focus on the critical behaviour at the Curie point of two reentrant-like systems, namely polycrystalline NiMn 22 at % and amorphous FeZr 8 at %. Primarily, we study the temperature derivative of the resistivity, \( \frac{dp}{dT} \), in the vicinity of \( T_c \). It is known that \( \frac{dp}{dT} \) presents the same critical behaviour as the magnetic specific heat [3]. For the NiMn system, we also report on detailed AC susceptibility measurements close to \( T_c \) and on DC magnetization results between 4 K and 300 K.

To obtain the NiMn alloy in the reentrant state, the sample was submitted to an annealing of one hour at 900 °C, followed by 2 hours at 600 °C, then by a rapid quench to room temperature. The FeZr amorphous ribbon was prepared by melt-spinning as described earlier [4]. We perform accurate resistivity measurements for both samples using a standard AC technique. During the measurements, the temperature was allowed to drift very slowly. Around \( T_c \) drift rates were typically of 100 mK/min, either for cooling or heating the samples. By measuring a large number of points, we could numerically determine the temperature derivative of the resistivity using a procedure described in reference [5]. Because of the weakness of the temperature dependence of the resistivity for both systems, the \( \frac{dp}{dT} \) points were obtained within relative uncertainties smaller than 2 % for NiMn and 5 % for FeZr. Close to \( T_c \), the AC susceptibility results are accurate enough for critical behaviour studies [6].

The \( \frac{dp}{dT} \) results for NiMn are shown in figure 1.

The usual power law which describes the divergence of \( \frac{dp}{dT} \) in the critical region is given by [2]:

\[
\frac{dp}{dT} = \frac{A^+}{\alpha} (\varepsilon^{-\alpha} - 1) + B^+ \quad (T > T_c) \tag{1a}
\]

\[
\frac{dp}{dT} = \frac{A^-}{\alpha'} (|\varepsilon|^{-\alpha'} - 1) + B^- \quad (T < T_c) \tag{1b}
\]

where \( A \) and \( B \) are constants, \( \varepsilon = (T - T_c) / T_c \) and the critical exponents \( \alpha, \alpha' \) are expected to be the same as those for the singular part of the specific heat [3]. However, we observe in figure 1 that for \( T < T_c \) a complex feature is apparent in \( \frac{dp}{dT} \), which prevents the analysis of these data with equation (1b). We are thus left with the paramagnetic regime to study the critical behaviour of \( \frac{dp}{dT} \) in NiMn. A non linear least-square-fit of equation (1a) with the points in the interval 0.005 < \( \varepsilon < 0.13 \) gives \( T_c = 228.6 \pm 0.3 \) K and \( \alpha = -0.81 \pm 0.05 \).

In figure 2, we show AC susceptibility results close to \( T_c \) of the same NiMn sample. These results were analysed with \( \chi_0 = \Gamma \varepsilon^{-\gamma} \) (\( \gamma > 0 \)). Noting that this formula, which represents the leading divergence in the suscep-
Fig. 2. - Logarithmic plots of the inverse of the AC susceptibility in arbitrary units as a function of \((T - T_c) / T_c\). The straight line corresponds to \(\gamma = 1.72\). Inset shows DC susceptibility results for \(H = 30 \text{ Oe}\).

Table I. - Critical point exponents for ferromagnetic, reentrant and spin glass systems.

<table>
<thead>
<tr>
<th>system</th>
<th>(\alpha)</th>
<th>(\beta)</th>
<th>(\gamma)</th>
<th>references</th>
</tr>
</thead>
<tbody>
<tr>
<td>model Heisenberg ferromagnet (RG calculation)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>-0.10</td>
<td>0.38</td>
<td>1.34</td>
<td>[2]</td>
</tr>
<tr>
<td>NiMn 22%</td>
<td>-0.81 ± 0.05</td>
<td>0.54(a)</td>
<td>1.72 ± 0.05</td>
<td>[5, 8]</td>
</tr>
<tr>
<td>a-FeZr 8%</td>
<td>-1.1 ± 0.1</td>
<td>0.62</td>
<td>1.92 ± 0.02</td>
<td>[5, 8]</td>
</tr>
<tr>
<td>Ag Mn</td>
<td>-2.2(a)</td>
<td>1 ± 0.1</td>
<td>2.2 ± 0.2</td>
<td>[14]</td>
</tr>
</tbody>
</table>

(a) Estimated from scaling relation (2).

state appear to be strongly disordered and probably dominated by short range correlations. Prior magnetic and neutron scattering results for NiMn [8, 9] and for a-FeZr [4, 10] as well as Mössbauer measurements in this latter system [4] also point out such a description.

To finalize, we should mention that the interesting minimum observed in \(dp / dT\) for NiMn just below \(T_c\) is also seen in \(dp / dT\) results for the Pd2MnSn local moment ferromagnet [11] and, as in that case, seems to be linked with antiferromagnetic correlations which dominate in some regions of an otherwise ferromagnetic matrix (see also discussion by Kouvel et al. [12]).