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To cite this version:

HAL Id: jpa-00228725
https://hal.archives-ouvertes.fr/jpa-00228725
Submitted on 1 Jan 1988

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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, \(\frac{d\rho}{dT}\), in the vicinity of \(T_c\). It is known that \(\frac{d\rho}{dT}\) 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 \(\frac{d\rho}{dT}\) 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 \(\frac{d\rho}{dT}\) results for NiMn are shown in figure 1.

![Figure 1](http://dx.doi.org/10.1051/jphyscol:19888518)

**Fig. 1.** Temperature derivative of the resistivity for NiMn 22 at %. The solid line corresponds to a fit obtained from equation (1a) with \(\alpha = -0.81\) and \(T_c = 228.6\) K.

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

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

\[
\frac{d\rho}{dT} = \frac{A^-}{\alpha^-} (|\varepsilon|^{-\alpha^-} - 1) + B^- \quad (T < T_c) \tag{1b}
\]

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 \(\frac{d\rho}{dT}\), which prevents the analysis of these data with equation (1b). We are thus left with the paramagnetic regime to study the critical behaviour of \(\frac{d\rho}{dT}\) 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 \(\chi_0 = \Gamma \varepsilon^{-\gamma} \quad (\varepsilon > 0)\). Noting that this formula, which represents the leading divergence in the suscep-
Table I. – Critical point exponents for ferromagnetic, reentrant and spin glass systems.

<table>
<thead>
<tr>
<th>System</th>
<th>α</th>
<th>β</th>
<th>γ</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni Heisenberg ferromagnet (RG calculation)</td>
<td>-0.12</td>
<td>0.36</td>
<td>1.39</td>
<td>[13]</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 ± 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 \( \rho / dT \) for NiMn just below \( T_c \) is also seen in \( \rho / dT \) 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]).