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Critical behaviour of transport coefficients at a structural-ferromagnetic transition (*)

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Résumé. — On rapporte des mesures précises de la résistivité électrique, du pouvoir thermoélectrique, et de la conductivité thermique de TbZn. La dérivée des coefficients par rapport à la température est examinée. Le comportement critique est expliqué par la diffusion électronique sur les fluctuations de spin corrélées et par la présence de domaines magnétiques et structuraux.

Abstract. — Accurate measurements of the electrical resistivity, the thermoelectric power and the thermal conductivity of TbZn are reported at the ferromagnetic-structural transition. The temperature derivative of the coefficients is examined. The critical behaviours are understood in terms of conduction electron scattering on spin correlated fluctuations and the presence of structural and magnetic domains.

A detailed characterization of the static properties of the equiatomic Cs-Cl compounds of the rare earth metals with Zn is available [1]. Here we extend our knowledge of such systems to the case of transport properties, using a monocrystalline sample of TbZn. It has a ferro-paramagnetic transition at $T_c = 200$ K, with an apparently simultaneous cubic to tetragonal transition; the easy magnetic direction occurs along a quaternary axis. At $T_R = 63$ K, the lattice distortion practically disappears and the easy magnetic direction rotates to a binary axis [1].

Figure 1 shows the general behaviour of the electrical resistivity (ρ) and its temperature derivative $d\rho/dT$ along a quaternary axis. The data have been normalized by a factor $\rho_c = \rho(T_c)$. The phase transitions in TbZn are clearly revealed in the $d\rho/dT$ curve, which is remarkably similar to that of the specific heat (C) (inset of figure 1; from [1]). The ferro-paramagnetic transition induces a peak in $d\rho/dT$, followed by an extended tail in the paramagnetic phase due to short range order. The transition at T_R is accompanied by a latent heat and marked by a very high and narrow peak, in a manner characteristic of 1st-order transitions [2]. The resistivity is practically discontinuous at T_R ($\Delta\rho/\rho \simeq 5\%$), whereas $d\rho/dT$ changes by 20%. A qualitatively similar mismatch occurs also in C at T_R (see inset).

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Fig. 1. — Normalized c-axis resistivity and temperature derivative of single crystal TbZn; inset: specific heat from [1].

The thermoelectric power (S) has been measured from 90 to 300 K. The temperature gradient was along a quaternary axis. Figure 2 shows that S is negative. The critical temperature T_c , as derived from $d\rho/dT$ measurements is indicated. The pronounced increase in S below T_c is indicative of a H_{sd} conduc-

Fig. 2. — *c*-axis thermoelectric power of single crystal TbZn.

Fig. 3. — *c*-axis temperature derivative of thermoelectric power and normalized thermal conductivity of TbZn.

tion electron-localized spin interaction [3]. This behaviour is similar to that observed in pure Tb along a basal axis [4]. The data for S above T_c practically extrapolate through the origin, whereas its slope is rather small and negative. This indicates a hole-dominated thermopower, in contrast to pure Tb, where the slope above T_c is positive. Figure 3 shows the derivative dS/dT for TbZn. It is remarkable that dS/dT presents a characteristic λ -shape anomaly, with a sharp peak at T_c , reminiscent of that found in $d\rho/dT$ near T_c . Important differences are apparent at lower temperatures. Whereas dS/dT decreases smoothly and monotonically with T , $d\rho/dT$ exhibits anomalously high values and a complex behaviour. Any reasonable theory must explain why such effects are so exuberantly present in $d\rho/dT$ and not in dS/dT [5].

We have also measured the thermal conductivity (K), using a novel experimental approach described

elsewhere [6]. This enables the small changes of K near T_c to be accurately measured (figure 3). For convenience, a linear background has been previously extracted, so as to reveal more clearly the changes in K near T_c . The main features are a localized depression in K near T_c and a pronounced increase in the slope dK/dT when the sample enters the paramagnetic state. The depression in K is consistent with the expected reduction in the mean free path of the long wavelength phonons caused by the critical fluctuations [7]. The increase in dK/dT can be qualitatively understood in terms of the electronic contribution to K [8].

Finally the existence of time-dependent effects below T_c is most probably due to magnetic and structural domains. The influence of such domains on transport properties is being worked out theoretically [5]. Technical assistance of J. Bessa is gratefully acknowledged.

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