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THE RELATION BETWEEN NORMAL STATE PROPERTIES AND T_c FOR SOME Zr_2X COMPOUNDS

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We find that a certain feature of the normal state resistivity correlates with T_c in a closely related group of superconductors.

THE INTERMETALLIC compounds, Zr_2Rh (T_c = 11°K), Zr_2Ir (T_c = 7°K), Zr_2Co (T_c = 5°K) and Zr_2Ni (T_c = 1.5°K), all crystallize in the tetragonal C16 structure. The first three compounds form an isoelectronic series, which is especially interesting because Zr_2Rh has one of the highest T_c's of all the non-cubic inter-transition metal compounds.[1] The investigation reported here was motivated by a desire to understand how a certain feature in the electrical resistivity correlates with T_c.

The resistance data are shown in Fig. 1. All the curves have a similar shape and we are interested particularly in the region of pronounced negative curvature. The negative curvature can be characterized by the inflection point which we shown in Table 1. For the isoelectronic compounds we note that as this region of negative curvature moves to high temperatures the T_c decreases.

A least-squares fit has been made to the resistance data using the model of Cohen *et al.*[2] In this model, developed to explain the resistivity and other normal state properties of A-15 compounds, one assumes an almost empty or full *d*-band overlying a low density of states *s*-band. The ratio of *s*-density of states to the total density of states at the Fermi level is called α; T_0 is the effective Fermi temperature of

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Table 1. Inflection point of resistivity curves and best fit parameters to resistivity model of reference 2

Compound	$T_{infl.}$	θ_R	T_0	α	r.m.s Deviation of fit (%)
Zr_2Rh	39	160	120	0.11	1.3
Zr_2Ir	50	205	90	0.11	1.2
Zr_2Co	69	305	95	0.11	1.4
Zr_2Ni	65	272	95	0.3	1.3

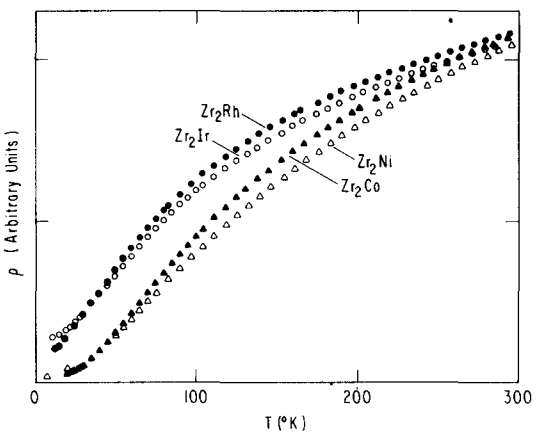

FIG. 1. Temperature dependence of the electrical resistivity of Zr_2X compounds. All curves were scaled to make the room temperature values equal.

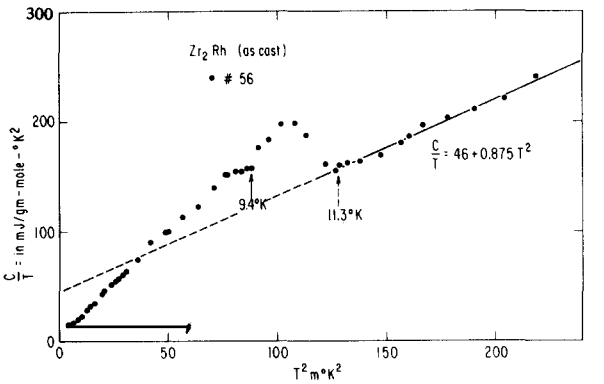

FIG. 2. Low temperature heat capacity of Zr_2Rh.

the d-band (electrons or holes for the almost empty or full cases, respectively); and θ_R denotes the Debye temperature. One simply assumes that the total density of states is dominated by the d-band and thus s to d-state scattering dominates the electrical resistivity. These parameters, as determined by the least-squares fit, are given in Table 1. We notice that the fits, which are very good, show little variation in T_0 and α for the sequence Zr_2Co–Zr_2Rh–Zr_2Ir, but that θ_R varies significantly. The fit for Zr_2Ni, with $\alpha = 0.3$, indicates that the model is not as appropriate for this compound, since the d-density of states is not dominant.

Low temperature heat capacity measurements have been made on the same specimens by an a.c. calorimetry technique.[3,4] The electronic heat capacity coefficient γ and Debye temperature θ_D of Zr_2Ir and Zr_2Co have been determined by equating the entropy of normal and superconducting states below their respective T_c's. The T_c for Zr_2Ni was below the present temperature range of measurement and Zr_2Rh exhibited two distinct transitions (Fig. 2), most of the bulk T_c being at the higher temperature 11.3 K. In these two cases γ and θ_D values were deduced by simple extrapolation procedure of the C/T vs T^2 plots from above T_c. The data are given in Table 2. It is interesting to note that θ_D varied only slightly from compound to compound whereas γ changes considerably; but neither parameter seems to correlate with T_c. Similar anticorrelation has been pointed out in susceptibility measurements on these compounds earlier.[1] The origin of the second heat capacity anomaly in Zr_2Rh is *not* clear at present.

What interests us here is that θ_R does not seem to depend sensitively on θ_D. This suggests, therefore, that there are groups of special phonons especially connected with both the resistance and the superconductivity. It is, of course, possible that the Cohen model, which provides an accurate and convenient parametrization, may not be particularly appropriate.

Table 2. Experimental low temperature specific heat parameters and magnetic susceptibility from reference 1

Compound	T_c (°K)	θ_D (°K)	γ(mJ/mol °K)^2	$\chi_{R.T.}$(× 10^4 emu/mol)[1]
Zr_2Rh	11.3	188	46	3.7
Zr_2Ir	7.5	200	17	3.0
Zr_2Co	5.5	180	28	5.2
Zr_2Ni	1.6	221	18	3.2

Both experimental and theoretical work for *d*-band superconductors, however, indicate that peculiarities in phonon spectra are particularly important for T_c,[5] a result consistent with our analysis.

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REFERENCES

1. McCARTHY S.L., *J. Low Temp. Phys.* **4**, 489 (1971).
2. COEHN R.W., CODY G.D. and HALLORAN J.J., *Phys. Rev. Lett.* **19**, 840 (1967).
3. VISWANATHAN R., *Proc. 3rd Symp. on Analytical Calorimetry, Los Angeles, California*, March 31–April 5, (1974), Plenum Press (in press).
4. SULLIVAN P.F. and SEIDE G., *Phys. Rev.* **174**, 679 (1968).
5. SMITH H.G., in *Superconductivity in d- and f-band Metals*, p. 321 (edited by DOUGLASS D.H.) New York (1972).