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Effect of Pressure on Superconductivity in Transition Metal Alloys*

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Measurements on twelve alloys of the series Zr-Nb-Mo show a close correlation of dT_c/dp with the d-band structure of these alloys and suggest that the d-band is virtually rigid with respect to pressure. The results are not compatible with an empirical observation of McMillan that T_c is governed only by a phonon factor $M\omega^2$.

Introduction

The reaction of superconductivity of transition metals and their alloys to volume changes caused by the application of hydrostatic pressure is complex. Positive and negative signs of dT_c/dp and nonlinearities in $T_c(p)$ have been observed for the various superconductors of this group[1]. Attempts to correlate this behaviour with irregularities in the isotope effect of these metals are made increasingly difficult by a growing body of experimental facts[2]. Also, a correlation of dT_c/dp with the band structure could only be seen for a few selected metals and alloys[3,4].

In contrast, the situation is much simpler in superconducting non transition metals, in which the transition temperatures decrease nearly

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1 For a compilation of relevant data see: Brandt, N. B., Ginzburg, N. I.: Soviet Phys. Usp. **8**, 202 (1965). — More recent work on transition metals: Gardner, W. E., Smith, T. F.: Phys. Rev. **138**, A484 (1965); ibid. **140**, A1620 (1965); ibid. **144**, 233 (1966); ibid. **146**, 291 (1966). — Bucher, E., Müller, J., Olsen, J. L., Palmy, C.: Cryogenics **5**, 283 (1965). — Gey, W., Heyden, G. v.: Z. Physik **193**, 65 (1966). — Köhnlein, D.: Z. Physik **208**, 142 (1968). — Andres, K.: Phys. Rev. **168**, 708 (1968). — Chu, C. W., Smith, T. F., Gardner, W. E.: Phys. Rev. Letters **20**, 198 (1968). — Chu, C. W., Gardner, W. E., Smith, T. F.: Phys. Letters **26**A, 627 (1968).

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linearly with pressure[1,5]. An empirical rule has been established for these metals[6] which more recently has received semiquantitative justification[7,8] by use of a simplification of McMillan's theoretical formula for T_c[9]. Although not yet fully satisfactory, because use of the full expression for T_c makes the agreement worse[8], this approach certainly indicates the direction in which the solution for the simple metals is to be found.

In an attempt to detect similarly a unifying principle for the divergent behaviour of transition metals under pressure, the alloy series Zr-Nb-Mo was chosen on the following grounds:

1. The series is homologous in structure (*bcc*) from $Zr_{80}Nb_{20}$ to molybdenum[10]. 2. Only 4-*d* elements are involved. The rigid-band-model has been shown to be valid[11]. 3. Data on the electronic specific heat coefficient γ and on the Debye characteristic temperature θ exist for almost the whole composition range[12]. 4. Data on dT_c/dp for Zr, Nb, and $Nb_{75}Mo_{25}$ were already available. Those on Nb from different authors were not in complete accord[13,14]. 5. Presumably no effects of electron-magnon interactions obscure the situation[15]. Our main result is that for all alloys the variation of T_c with pressure is governed by the shape of the *d*-band.

Experiment

Pressure

The apparatus used for generation of high pressure has been described earlier[16]. The linear dimensions of the pressure tongs have been increased by a factor of approximately 1.5 which permits the use of a piston-

5 At first sight Tl appears to be an exception since in this case T_c passes through a flat maximum. It seems to be confirmed, however, that this maximum is due to a superposition of two monotonic functions. After subtraction of the one, which stems from a pressure dependent gap anisotropy, Tl also shows a nearly linear decrease of T_c with p. Gey, W.: Phys. Rev. **153**, 422 (1967).

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