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## High pressure study of ferromagnetic US (\*)

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**Résumé.** — Nous avons étudié la variation avec la pression hydrostatique de la susceptibilité magnétique d'un échantillon polycristallin du sulfide d'uranium (US) ferromagnétique. Sa température de Curie décroît linéairement de 180,0 K, à la pression atmosphérique, jusqu'à 175,9 K à 18 kbar.

**Abstract.** — We have investigated the variation of the ac magnetic susceptibility of a polycrystalline ferromagnet US as a function of hydrostatic pressure. The Curie temperature decreases linearly from 180.0 K at atmospheric pressure to 175.9 K at 18 kbar.

**1. Introduction.** — In the actinide series the greater extent of the 5f atomic wavefunctions implies that the crystal field interactions are greater than those in the lanthanide series. This large crystal-field potential leads to a break-down of Russell-Saunders coupling. The difficulties in understanding the magnetism of the actinides are further enhanced by the absence of any spontaneous magnetism of the early elements (U, Np, and Pu) in the series. Nonetheless, compounds of these elements, especially those with elements of group VIA (S, Se, Te) show ferromagnetic ordering [1, 2]. All these monochalcogenides crystallize with the NaCl crystal structure. They are fairly good metallic conductors.

Guided by the unusual pressure dependence of the superconducting transition temperature of uranium metal [3], Huber *et al.* [4] investigated the pressure effects on ferromagnetic UPt. They found that the saturation magnetic moment was reduced by more than 90 % at 20 kbar and that the Curie temperature was pressure independent.

Our investigation on the pressure effect on ferromagnetic US was stimulated by these interesting properties of uranium compounds.

**2. Experimental results.** — The uranium monosulphide used in this experiment was prepared by the direct reaction of uranium metal with elemental sulphur. Uranium turnings with sufficient amount of sulphur to produce a slightly hyperstoichiometric monosulphide and a small amount of iodine to boost the reaction are placed in a magnesium oxide crucible which in turn are placed in a sealed stainless steel reaction vessel. The crucible portion of the reaction vessel is placed in a pot furnace and slowly heated until the reaction starts (500-600 °C). The charge is then cooled to room temperature. The reaction product can then be melted in an argon arc furnace. This

second melting consolidates the reaction product and, at the same time, removes any excess sulphur in the product.

A high pressure cell with the piston-cylinder arrangement designed by C. W. Chu was employed in this study. High pressure was generated at room temperature using a one-to-one mixture of isoamyl alcohol and n-pentane to transmit the pressure. The pressure was determined by a superconducting Pb manometer. The isobaric runs were made by locking the pressure at room temperature using a Be-Cu clamp before varying the temperature of the sample and the clamp.

Figure 1 shows the measured Curie temperatures,  $T_c$ , which we defined to be the temperatures of the maxima of the ac susceptibility. In contrast to UPt,  $T_c$  for US decreases linearly from 180.0 K at atmospheric pressure to 175.9 K at 18 kbar. We have also analysed our susceptibility data using [5]  $\chi = \text{constant} + C/(T - \theta)$ , where  $C$  is the Curie constant and  $\theta$  the paramagnetic Curie temperature. Our data revealed that  $\theta$  decreased with pressure. The magnetic moment at 17.6 kbar decreased ~ 30 % from its value at the atmospheric pressure.

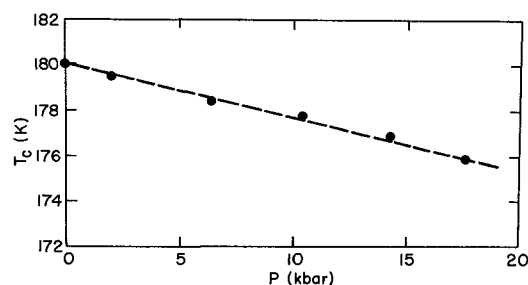


Fig. 1. — Curie temperature,  $T_c$ , versus pressure  $P$  of US.

**3. Discussions.** — First, the simplest theory for describing the actinide NaCl-structure compounds is one in which an integral number of f electrons on the

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actinide is assumed. Accordingly, Grunzweig-Genossar *et al.* [6] took uranium in uranium chalcogenides to be  $U^{4+}$  with a  $5f^2$  configuration and with the total angular momentum of  $J = 4$  in the ground state as a good quantum number. Contrastingly, because the spatial extent of  $5f$  electrons is considerably greater than that of the  $4f$  electrons in lanthanides and the band approach is more appropriate than the localized magnetic moment approximation, Davis [7] has made band calculations and his results are consistent with the photoemission work on US by Eastman and Kuznietz [8] who concluded that the Fermi surface is located in a broad f-d band which is almost indistinguishable from the conduction band. Following Goodenough's idea [9] of a critical interatomic distance beyond which electrons are localized and under which they are itinerant, Hill [10] combined the localized and band approach

by proposing a critical value for the actinide-actinide spacing beyond which magnetic ordering results.

From the discussions above, it is clear that our data support the band picture — i.e. under high pressure, the U-U spacing in US decreases, resulting in a broadening of the f band and an increase in the f electron participation in the bonding of the metal. This *delocalization* of the f electrons gives rise to a reduction in the magnetic moment at high pressure.

Extrapolation of our  $T_c$  data indicates that  $T_c \sim 0$  K at  $\sim 1$  megabar pressure. It is interesting to speculate whether the system might become superconducting at this point similar to Ce [11].

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#### References

- [1] LAM, D. J. and ALDRED, A. T., in *Actinides : Electronic Structure and Related Properties*, eds. J. B. Darby and A. J. Freeman (Academic Press, New York) 1974, vol. 1, p. 109, and references therein.
- [2] SUSKI, W., in *Plutonium and Other Actinides*, eds. H. Blank and R. Lindner (North-Holland Publishing Company, Amsterdam) 1976, p. 621.
- [3] MAPLE, M. B. and WOLLEBEN, D., *Phys. Lett.* **38A** (1972) 351.
- [4] HUBER, J. G., MAPLE, M. B. and WOLLEBEN, D., *J. Mag. Mater.* **1** (1975) 58.
- [5] ALLBUTT, M., JUNKISON, A. R. and DELL, R. M. in *Compounds of Interest in Nuclear Reactor Technology*, eds. J. T. Waber, P. Chiotti and W. N. Miner, *Met. Soc. AIME* (New York) 1964, p. 65.
- [6] GRUNZWEIG-GENOSSAR, J., KUZNIETZ, M. and FRIEDMAN, F., *Phys. Rev.* **173** (1968) 562; KUZNIETZ, M. and GRUNZWEIG-GENOSSAR, J., *J. Appl. Phys.* **41** (1970) 906.
- [7] DAVIS, H. L., in *Actinides : Electronic Structure and Related Properties*, eds. A. J. Freeman and J. B. Darby (Academic Press, New York) 1974, vol. 2, p. 1.
- [8] EASTMAN, D. E. and KUNNETZ, M., *Phys. Rev. Lett.* **26** (1971) 846.
- [9] GOODENOUGH, J. B., *Magnetism and the Chemical Bond* (Wiley, New York) 1963.
- [10] HILL, H. H., in *Plutonium and Other Actinides 1970*, ed. W. N. Miner, *Metal Soc. AIME*, 1971, vol. 1, p. 2.
- [11] WITTIG, J., *Phys. Rev. Lett.* **21** (1968) 1250.