SEARCH FOR SUPERCONDUCTIVITY IN RUBIDIUM AT HIGH PRESSURE

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Résumé.- La résistance électrique de Rb a été mesurée jusqu'à 140 kbar à l'aide de la technique des 4 pointes. On ne détecte pas de supraconductivité en descendant jusqu'à la très basse température de 0.045 K. Ce résultat appuie l'hypothèse qu'à haute pression Cs est un métal de bande 4f.

Abstract.- The electrical resistance of Rb has been measured up to 140 kbar by a four probe technique. No superconductivity was detected down to a lowest temperature of 0.045 K. The result lends some support to the hypothesis that Cs is a 4f-band metal at high pressure.

Cesium is the only alkali metal which has been found to become superconducting. Thus far superconductivity has been observed in a high pressure phase (Cs V) above ≃ 100 kbar. T_c is approximately 1.5 K /1/. It is hence an interesting question, whether the other alkali metals (Rb,...) will also become superconducting at high pressure. An unprecedented increase of the electrical resistance with pressure has been reported for Rb and K by Stager and Drickamer /2/. The room temperature resistance of Rb increases by a factor of ≃ 30 between normal pressure and ≃ 150 kbar; see also our data in figure 1. This may hint at a strong increase of the electron-phonon coupling with pressure. We present preliminary data of a study of Rb up TO 140 kbar. Our search for superconductivity was extended down to a lowest temperature of 0.045 K.

Liquid Rb was filled into thin-walled glas capillaries under an argon atmosphere. The capillaries were cut to the proper length under molten paraffin. The paraffin-sealed samples were mounted between polyethylene disks in a high pressure cell described previously /3/. Upon application of pressure the capillaries shatter and electrical shatter and electrical contact is established between the overlyring electrodes and the Rb sample. The pressure is generated by a mechanical press which subsequently can be cooled in a $^3He/^4He$ dilution refregerator /4/. The pressure was determined from the T_c of a Pb manometer sample.

Figure 1 shows the room-temperature resistance as a function of pressure for one particular cell. Our data confirm Stager and Drickamer's finding /2/ that the resistance of Rb increases dramatically with pressure toward the RbII/III phase transformation.

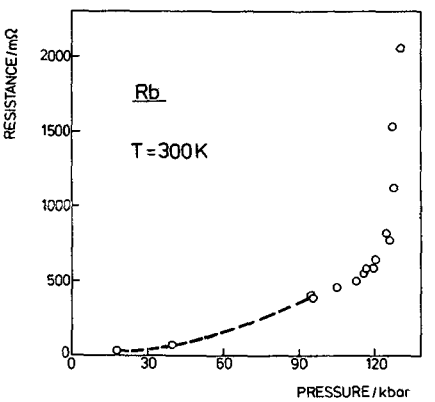

Fig. 1 : Room-temperature resistance of Rb vs. pressure.

A discountinuous rise of the resistance by a factor of ≃ 3 occurs at the RbII→III phase change. Figure 2 shows R-T data for pure RbIII and also two other runs in which the sample re-transformed to RbII upon cooling. It is seen that the hysteretic RbII→III transformation shifts to lower temperatures with decreasing pressure. Figure 3 is a P-T diagram containing all of our data for the RbII/III phase boundary. We have investigated RbIII for superconductivity at 130 and 140 kbar, the sample remaining normal down to a temperature of 0.045 K. The same result was obtained for RbII at ≃ 100 kbar, i.e. in the pretransitional range (figure 1) of the RbII III phase change. Our samples

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revealed a residual resistance ratio of about 60.

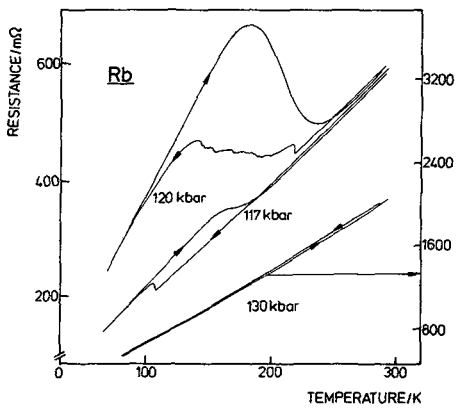

Fig. 2 : Resistance vs. temperature for Rb at indicated pressure.

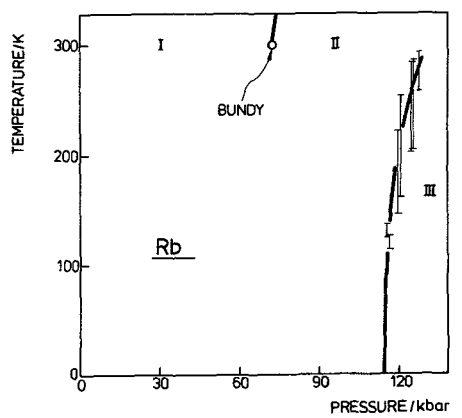

Fig. 3 : Rudimentary P-T diagram for Rb. The data point near 70 kbar indicates the RbI/II phase change first observed by Bundy. At 300 K the RbII→III transformation ran simultaneously with the PbI→II transformation (130 kbar).

We think it is a remarkable result that Rb is not a superconductor down to 0.045 K whereas Cs possesses a T_c of the order of 1 K in the same pressure range. It has been suggested by several authors /5-7/ that the heavy alkali metals (K, Rb and Cs) are turned into d-transition metals at high pressure. The superconductivity of Cs has thus been attributed to a considerable 5d character of the Bloch waves. /5-7/ In line with this picture it has been speculated that Rb and K will also become superconducting because of increasing d admixture. /5,7/ One of the present authors however has suggested that the "good" superconductivity of Cs and other anomalies may be intimately linked to the appearance of 4f character in the conduction electron wave functions /8/. Clearly, such 4f character cannot appear in Rb or K. Hence the absence of superconductivity in Rb up to 140 kbar lends some support to the hypothesis /8/ that Cs has not-negligible 4f character at the Fermi surface at high pressure. In pursuing this concept the experiments will be extended to higher pressure, lower temperatures and purer samples.

References

/1/ Wittig, J., Phys. Rev. Lett. 24 (1970) 812.

/2/ Stager, R.A. and Drickamer, H.G., Phys. Rev. 132 (1963) 124.

/3/ Eichler, A. and Wittig, J., Z. Angew. Phys. 25 (1968) 319.

/4/ Wittig, J. and Probst, C., Proceedings of the Int. Conf. on High Pressure and Low Temp. Physics Cleveland 1977.

/5/ Stocks, G.M., Gaspari, D.G. and Gyorffy, B.L., J. Phys. F : Metal Phys. 2 (1972) L 123.

/6/ Louie, S.G. and Cohen, M.L., Phys. Rev. B10 (1974) 3237 and references therein.

/7/ Gandel'man, G.M. and Itskovich, O. Yu., High Temp.-High Press. 7 (1975) 682 and references therein.

/8/ Wittig, J., in Festkörperprobleme XIII (H.J. Queisser, ed., Vieweg, Braunschweig, 1973) p. 375.