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FINAL REPORT

"Stabilization of High T_c Superconductivity in Cadmium Sulfide"

DOE Grant No. DE-FG02-88ER-45362

by

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Introduction

The experimental program which led to insight into the critical factors likely to yield the desired goal "Stabilization of High T_c Superconductivity in Cadmium Sulfide" was difficult, that is, time consuming. The details of the initial efforts will be found in our February 1990 progress report. These efforts, and, in particular, the equipment we were able to acquire with the help of the DOE grant, have allowed us to continue the project, first to the termination date of the contract, June 30, 1990, and at a drastically reduced rate, up to the present time. While we have still not succeeded in realizing the goal of the original proposal, that is, to lay down an unequivocal procedure which will yield the highly anomalous diamagnetism in chlorine doped CdS which anyone can follow, all of our efforts, as well as further discoveries in high T_c superconductivity outside of our own work, reinforce our belief that high T_c superconductivity in Cl-treated CdS can be stabilized.

The progress has been in two areas, materials preparation and theory.

Materials Preparation

As matters stood in February 1990 the existence of the anomalous diamagnetism in the doped CdS was again verified by measurements on the old material prepared for us at NIST, but no such definite results could be confirmed with material of our own preparation. The stumbling block is the very narrow window in the wt % Cl as a function of the temperatures of preparation about the critical doping concentration of 0.7 wt. % (see Fig. 9 of the Feb. '90 progress report). The method employed was the standard method of precipitating CdS from CdCl_2 solution. Since then we actively pursued the alternate preparation method of precipitation from H_2S solution. This has led to two discoveries:

- a) The window can be bridged
- b) X-ray diffraction patterns from mixtures in the window begin to reproduce those obtained from the active NBS (NIST) doped material. The diffraction patterns indicate that the material does have what we believe to be the critical ingredient, the correct mixture of wurtzite and zinc-blende structures.

Unfortunately, the latter developments have been slowly obtained, given the lack of funding, by volunteer undergraduates being our only source of help, over a very long period of time.

Given the difficulty of sensitive diamagnetic measurements, again with our extreme limitations of operating measuring equipment, we have to date not succeeded in again setting up the functioning procedure of systematic preparation, characterization, and diamagnetic measurement needed to complete the project. In conclusion, we are very grateful to DOE for having given us the opportunity for investigating the CdS magnetic phenomenon, but, in hindsight believe that the withdrawal of funding after two years was a rather hasty decision by the agency, and, hereby express the hope that DOE, having already made a sizable investment, will in the spirit of patient research eventually provide the possibility of our completing this very significant project.

Theory

The challenge of the theory component of the project lay in the joint occurrence of anomalous paramagnetism on the one hand, and anomalous diamagnetism on the other; the paramagnetism occurs at Cl doping levels somewhere in the immediate neighborhood of the level critical for diamagnetism. The first and easier task, then, was to understand the paramagnetism. It is this theory which is outlined in our first comprehensive paper of both the theoretical and experimental effort (Bilodeau, Nettel, and MacCrone¹).

A generally accepted theory of high temperature superconductivity has eluded six years of effort by the international physics community. The situation in cadmium sulphide, as we have come to understand, it points unequivocally to lattice softening as an essential component. We have published a second paper in Physical Review (Nettel and MacCrone²) giving a comprehensive theory of how lattice softening does, in fact, lead to superconductivity. While this paper draws on the more complete structural changes with onset of superconductivity available with La-Ba-Cu-O, the structural changes that we have learned accompany the transition to anomalous diamagnetism in doped cadmium sulphide leave little doubt that the theory has application there as well. Indeed, as already indicated, the cadmium sulphide work was instrumental in our taking the soft mode path towards theoretical understanding. A third paper no longer under the auspices of DOE has now been submitted showing how recent results with laser pump probe experiments on films of 1-2-3 compounds directly reveal the role of lattice deformations in the superconductivity process.

References

1. S.Bilodeau, D.Campbell, R.K.MacCrone, and S.J.Nettel, "Structure, soft modes, and superconductivity in Cl-doped cadmium sulfide", Phys. Rev. B 37, 3275 (1988).
2. S.J.Nettel and R.K.MacCrone, "Possible Effect on T_c of lattice deformation in La-Ba-Cu-O", Phys. Rev. B 47, ? (1993).

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