N72 30742

NASA TECHNICAL MEMORANDUM

NASA TM X-68109

NASA TM X-68109

CASE FILE COPY

MAGNETIC FIELD EFFECTS ON SUPERCONDUCTIVITY IN ALKALI METAL INTERCALATES OF MoS_2

by John A. Woollam, Dennis J. Flood, and David E. Wagoner
Lewis Research Center
Cleveland, Ohio

and

Robert Somoano and Alan Rembaum
Jet Propulsion Laboratory
Pasadena, California

TECHNICAL PAPER proposed for presentation at
The Physics and Chemistry of Layered Compounds Conference
sponsored by the Office of Naval Research
Monterey, California, August 17-18, 1972

MAGNETIC FIELD EFFECTS ON SUPERCONDUCTIVITY IN ALKALI METAL INTERCALATES OF MoS_2

John A. Woollam, Dennis J. Flood, and David E. Wagoner
NASA Lewis Research Center
Cleveland, Ohio

and

Robert Somoano and Alan Rembaum
Jet Propulsion Laboratory
Pasadena, California

E-7075

We have studied the effects of a magnetic field on the superconducting transition in MoS_2 intercalated with potassium and sodium.

In most applications of superconducting materials, the properties of the materials in magnetic fields are involved. The most desirable superconductors have high transition temperatures and are not easily driven into the normal state by the application of a magnetic field. Most materials in commercial use today have cubic crystal structures. In the search for high temperature, high critical field superconductors a new series of compounds have been discovered which have layered structures, and have been shown to have the steepest critical field versus critical temperature boundary of any material yet found.

Research on layered superconducting materials began in 1965 when Hannay and his coworkers intercalated graphite with alkali metals.[1] More recently, transition metal-dichalcogenide compounds have been intercalated with organic molecules, such as pyridine, to produce important new superconducting properties.[2] Zero field results on alkali metal intercalates of MoS_2 were reported earlier and our present samples were prepared and analyzed as described at that time.[3,4] In zero magnetic field, the transition to superconductivity begins near 6.5 K for potassium compounds, and near 4 K for sodium compounds. We have used applied magnetic fields between zero and 3.5 tesla (1T = 10 kG) and have extended the temperature range down to 1.10 K, to study the superconducting critical boundaries.

Samples were sealed in a glass tube with helium exchange gas at a pressure of 740 mm of mercury trapped inside. To detect the superconducting transition, the self-inductance technique of Schawlow and Devlin,[5] with a few modifications, was used as indicated in figure 1. A 500 turn self-inductance coil was wound on the glass enclosing the sample, using number 44 copper wire. In order to detect superconductivity in the layer planes, the samples were always oriented with the layer planes perpendicular to the axis of the coil. The frequency of the oscillator circuit was plotted continuously as a function of thermometer resistance for a series of fixed magnetic fields. Frequency changes were caused by a change in penetration depth of the superconductor as it passed into the diamagnetic superconductive state. Temperatures were accurately controlled and measured using calibrated carbon resistors. Exchange gas and samples were contained in a temperature controlled double dewar system, as illustrated in figure 2, insuring thermal equilibrium.

Transitions in sodium MoS_2 are shown in figure 3 where frequency is plotted against temperature for fields of 0, 0.25, 0.5, 1.0, 1.5, 2.0, and 2.5 tesla applied parallel to the layer planes. The vertical scale on the right hand side of figure 1 is expanded five times over that on the left side, for the high field data, in order to more clearly show the paramagnetic minimum just before the full diamagnetic transition. It has been suggested that this minimum is evidence for a Type I superconductor.[4,6] Since this minimum is observed in fields above 2.5 tesla, and since known Type I superconductors have very small critical fields, the presence of a paramagnetic minimum as a criterion for distinguishing between Type I and Type II superconductivity is questionable.

In figure 4, the temperature at the lowest frequency (in the paramagnetic dip) for each curve of figure 3 is plotted versus field. Similarly, straight line extensions from the steepest part of the curve of figure 3 to the temperature axis are plotted against the corresponding magnetic fields. The depression of critical temperature by applied field is more severe by about a factor of 10 in sodium MoS_2 (~1.5 T/K) than found[7] in pyridine intercalated TaS_2 (15 T/K).

Potassium intercalated MoS_2 has been found to have considerably better properties in a magnetic field than the sodium compounds. In zero magnetic field the transition to superconductivity begins near 6.4 K as illustrated by the frequency versus temperature plot shown in figure 5. The two curves in figure 6 correspond to the temperatures at minimum frequency from figure 5 and to an extension of the steepest slope in figure 5 to a horizontal axis at the normal state frequency. As marked in figure 6, the slope of the critical field versus critical temperature is 4.2 tesla/K which is only a factor of $\sim 3\frac{1}{2}$ smaller than the highest yet found. It should be pointed out that the potassium intercalated MoS_2 has a considerably higher transition temperature (6.4 K) than the pyridine intercalated TaS_2 (3.5 K).

The unusual curvature shown in figures 4 and 6 for fields below 1 tesla is not presently understood. Extensions of the present investigations to 10 tesla and similar studies of rubidium and cesium compounds is underway. The zero field critical temperatures of rubidium and cesium compounds are each above 6 K so their properties in high magnetic fields should prove interesting.

1. N. B. Hannay, T. H. Geballe, B. T. Matthias, K. Andres, and D. MacNair, Phys. Rev. Letters 14, 225 (1965).

2. F. R. Gamble, J. H. Osiecki, M. Cais, R. Pisharody, F. J. DiSalvo, and T. H. Geballe, Science 174, 493 (1971.

3. R. B. Somoano, and A. Rembaum, Phys. Rev. Letters 27, 402 (1971).

4. R. Somoano, V. Hadek, and A. Rembaum, in Proc. AIP Conferences No. 4, Superconductivity in d- and f- Band Metals (1972), p. 243.

5. A. L. Schawlow and G. E. Devlin, Phys. Rev. 113, 120 (1959).

6. D. Schoenberg, Proc. Cambridge Phil. Soc. 33, 559 (1937).

7. S. Foner, private communication.

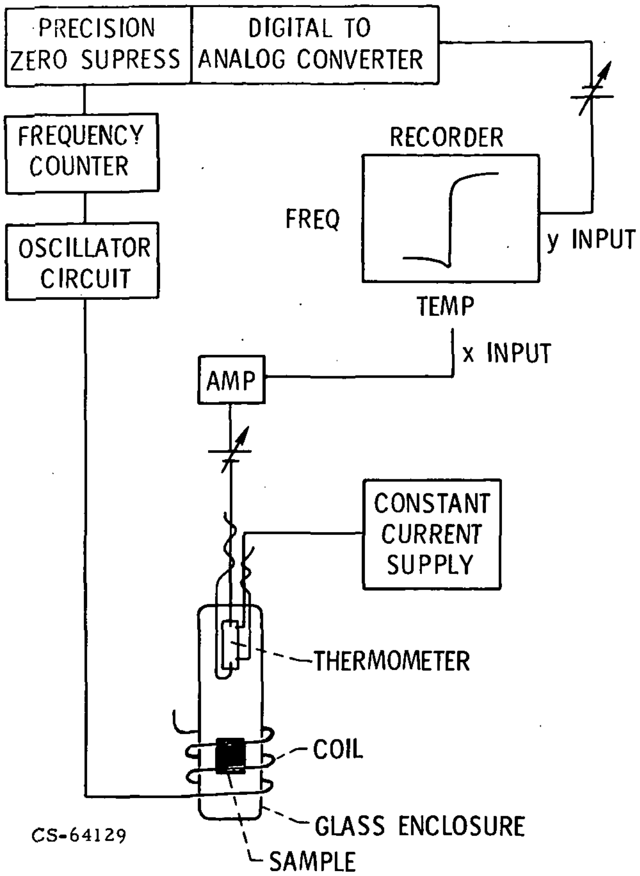

Figure 1. - Basic circuitry for superconducting transition studies.

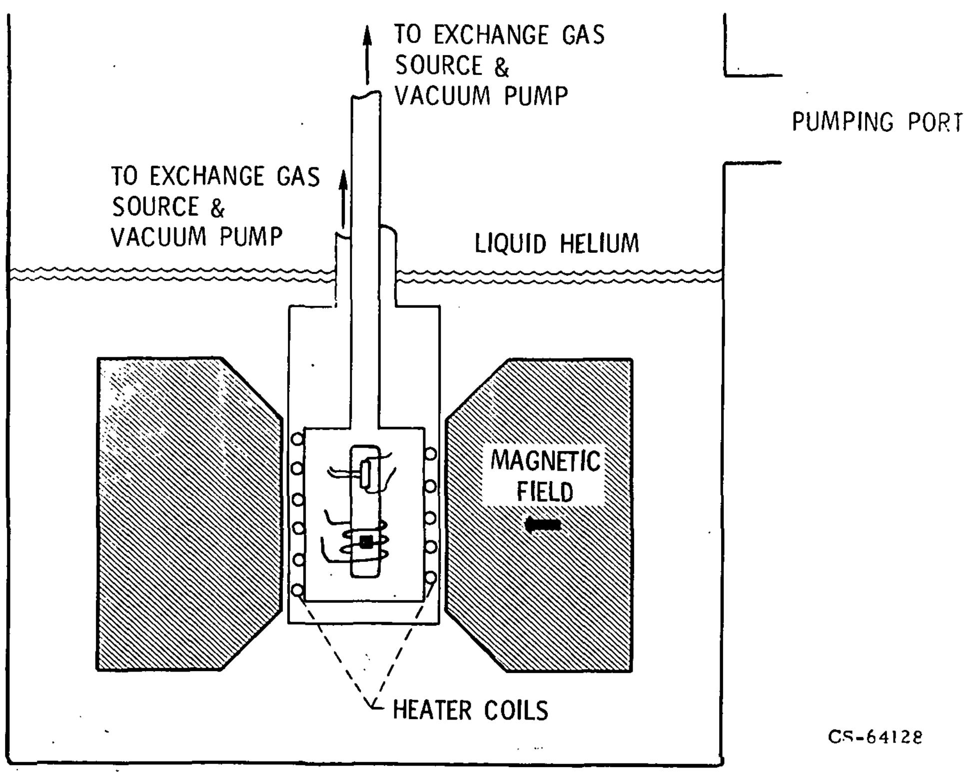

Figure 2. - Cryostat and double vacuum/exchange gas system.

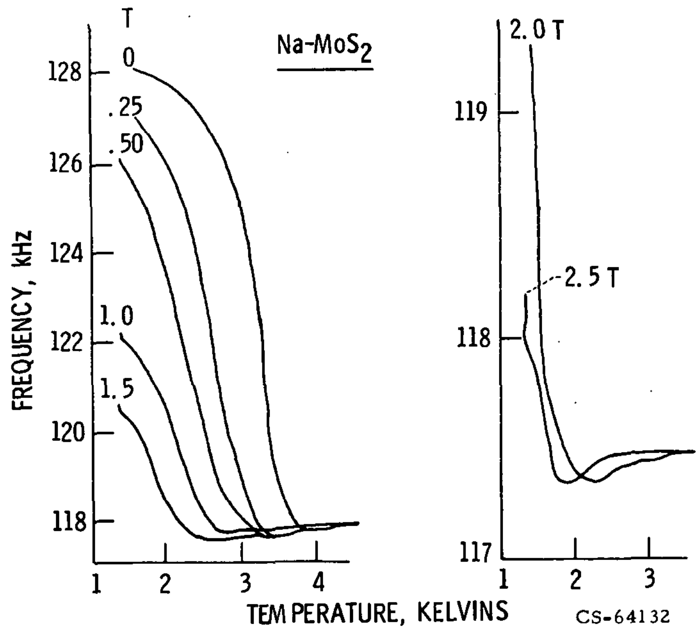

Figure 3. - Oscillator frequency versus temperature for magnetic fields of 0, 0.25, 0.50, 1.0, 1.5, 2.0, and 2.5 tesla (1T = 10 kg), in sodium intercalated MoS_2.

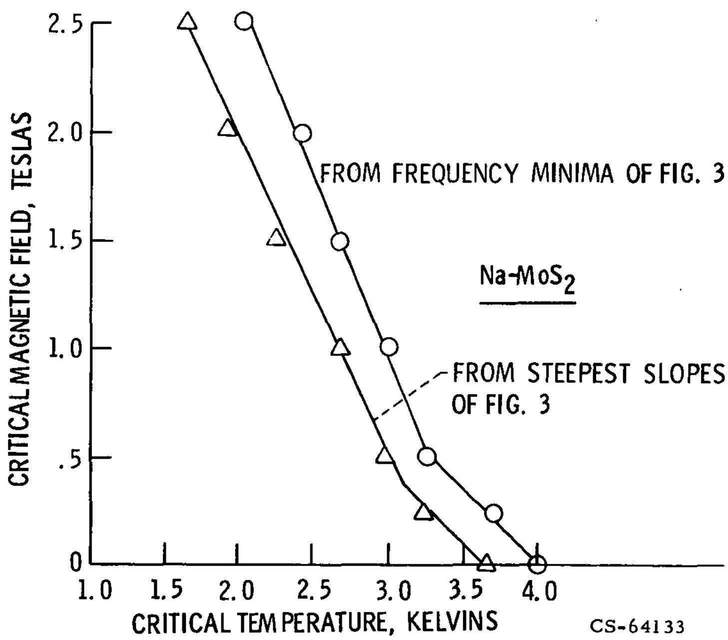

Figure 4. - Critical magnetic field versus critical temperature from data of figure 3, for sodium intercalated MoS_2.

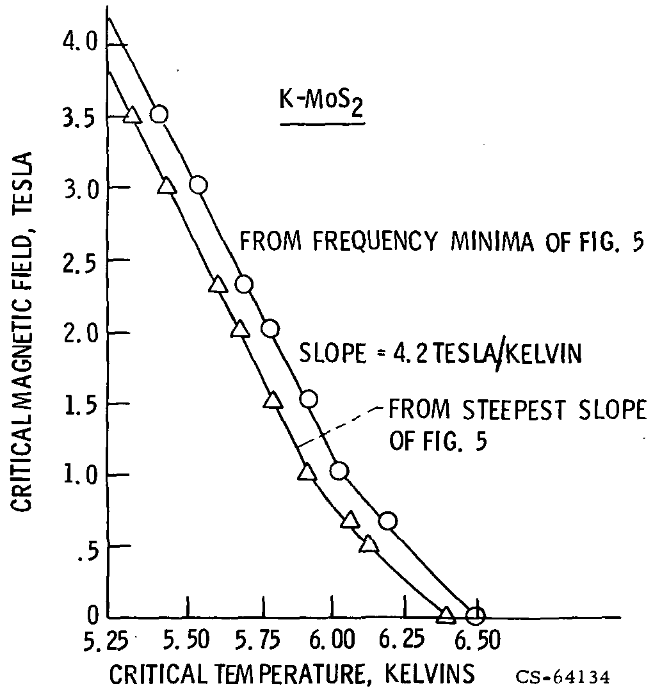

Figure 6. - Critical magnetic field versus critical temperature, from data of figure 5, for potassium intercalated MoS_2.

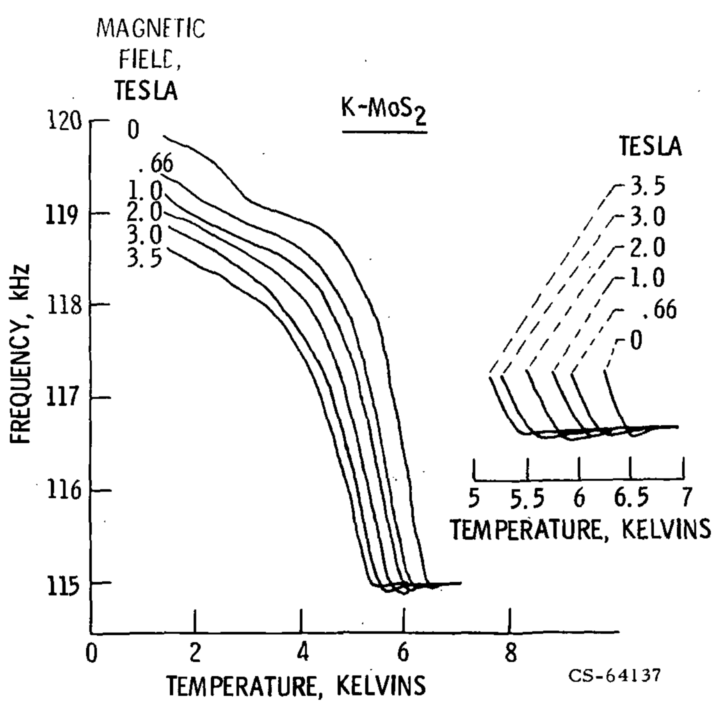

Figure 5. - Oscillator frequency versus temperature for magnetic fields of 0, 0.66, 1.0, 2.0, 3.0, and 3.5 tesla, in potassium intercalated MoS_2.