COMMENTS AND ADDENDA

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Isotope Effect in Superconducting γ-Uranium Alloys*

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(Received 16 October 1972)

A new determination of the isotope effect in γ-stabilized uranium-molybdenum alloys has been made. We find $T_c \propto M^{-0.40}$, rather than the previously reported $T_c \propto M^{-0.53}$.

Subsequent to the report[1] by Hill *et al.* on the isotope effect in superconducting γ-uranium alloys, we obtained some more pure ^{238}U and ^{235}U, and also some ^{236}U and ^{233}U. The ^{236}U metal was purified by successive ether extractions of its nitrate. The ^{233}U was not further purified.

The stabilized γ-uranium phase was made by arc melting each uranium sample together with molybdenum to form the 18-at.%-Mo alloy.[1,2] Alloys prepared from five batches each of ^{235}U and ^{238}U, and two batches of ^{236}U, were annealed for 16 h at 900 °C, *in vacuo,* then quenched into liquid argon, wherein they were stored until placed in a cryostat for measurement. The superconducting transition temperatures of these samples were determined in a resonant-bridge detector[3] at 30 kHz, and were taken as at the "onset" of superconductivity. The transitions were all 0.002–0.003 K in width. A ln-ln plot of the T_c values vs the corresponding values of M (Fig. 1), with a straight line fitted to the 12 points by the method of least squares, showed that $T_c \propto M^{-0.40 \pm 0.01}$.

Transition-temperature measurements similarly made on some samples of the γ-phase alloy, which were prepared from some of the old less-pure ^{235}U and ^{238}U and then subjected to the new heat treatment, now showed $T_c \propto M^{-0.43}$, in reasonably close agreement with the above results.

The difference between the results obtained in this work and those of the earlier work is, perhaps, due to the uniform heat treatment given to the samples, as well as to their greater purity. The linearity of the ln-ln plot of data for the three isotopes supports the validity of the result.

A point is shown in Fig. 1 for ^{233}U. This isotope emits α particles of average energy 4.808 MeV, with a relatively short half-life (compared to the half-lives of ^{235}U, ^{236}U, and ^{238}U) of 1.62×10^5 years. Because of probable apparatus contamination by this relatively great radioactivity, the ^{233}U-Mo alloys were not heat treated, but their transition temperatures were measured on the as-arc-melted samples. Furthermore, the self-heating due to the radioactivity causes a temperature difference between sample and thermometer. We determined the magnitude of this temperature difference by *in situ* heating of a ^{238}U-Mo alloy and measurement of the resultant apparent lowering of T_c. This was done by doping the ^{238}U-Mo alloy with 0.04 wt% of ^{232}U (which emits α particles of average energy 5.299 MeV, with a half-life of 73.6 years), enough to duplicate the self-heating in ^{233}U, but too little to cause an appreciable isotopic shift in T_c. In two such ^{232}U-doped ^{238}U-Mo alloys an average apparent lowering in T_c of 0.055 K was found. This value, when applied as a positive correction to the observed transition temperatures of four ^{233}U-Mo alloys made from two batches of ^{233}U, gave an average value for T_c of 2.134 K. Since the two ^{233}U metal batches were considerably different from each other in purity, since both batches were less pure than the other isotopes, and since the samples were not heat treated, their transitions were 0.008–0.028-K wide, with the transition temperatures deviating from their mean value to a considerable extent. These temperatures plus the

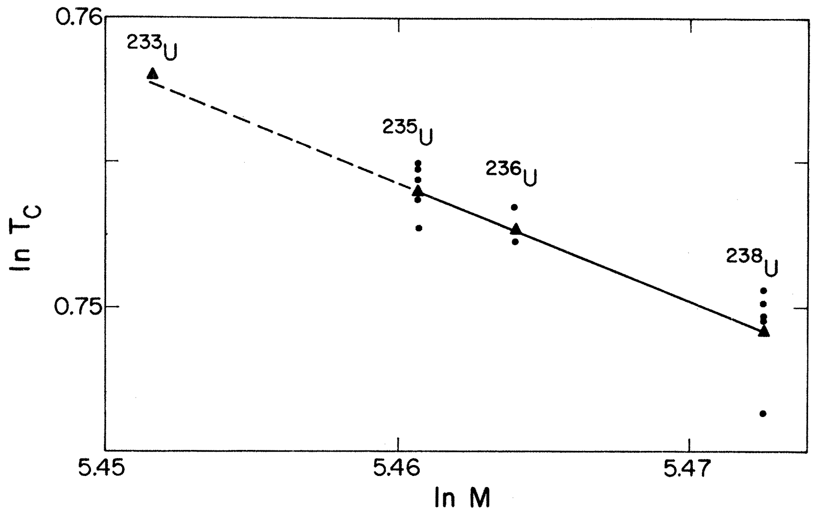

FIG. 1. γ-U isotope effect. (Small solid circles are data points, large triangles are averages of ln for each isotope.)

correction were therefore not included in the least-squares calculation previously mentioned. However, we believe that since the value 2.134 K lies very nearly on the extrapolation of the straight line derived from the other isotopic values of T_c it provides an additional confirmation of the results.

It may be remarked that the theory of Morel and Anderson[4] predicts an isotope effect of $T_c \propto M^{-0.42}$ for γ-U if the Debye temperature used by Goodman *et al.*[5] is used in the calculation.

The authors are very grateful to Dr. James E. Rounsville, Jr. of the Oak Ridge National Laboratory for providing us with the ^{232}U, and for making the solid solutions of it and ^{238}U. They also wish to express their appreciation to Dr. Richard Bard, Group Leader of CMB-8 of the Los Alamos Scientific Laboratory, for putting uranium purification and metal producing facilities of his group at our disposal.

*Work performed under the auspices of the U. S. Atomic Energy Commission.

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PHYSICAL REVIEW B VOLUME 7, NUMBER 9 1 MAY 1973

Photon-Induced Electron Pairing

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(Received 2 October 1972)

The earlier work on the possibility of interband electron pairing in the presence of a strong radiation field has been further extended. Some additional terms, neglected earlier, have been taken into account and generalized to a situation where the electron-phonon coupling coefficients for the two conduction bands (valleys) are different. It is found that the pairing interaction is attractive and the strength depends on the photon density.

I. INTRODUCTION

In a recent paper[1] (hereafter referred to as KS), interband pairing of electrons belonging to two different conduction bands (valleys) of a solid in the presence of a strong radiation field was suggested. The mechanism invoked the exchange of both phonons and photons between the interacting electrons. It was assumed, for simplicity, that the electron-