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Experimental Determination of the Temperature Dependence of Metallic Work Functions at Low Temperatures

Final Report

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Abstract

Work done since 1973 under the contract which is presently No. DE-AS02-76ERO2314 is described. Much of this work involved the use of a modified Kelvin technique to study the temperature dependence of the work function of both bare metallic surfaces and metallic surfaces with ⁴He gas adsorbed onto them.

The major accomplishments under this contract include the following:

1. the development of a noise thermometry system (COO-2314-1)
2. a theoretical study of a superconducting loop containing a Josephson junction with a temperature gradient across it (COO-2314-3)
3. the measurement of the temperature dependence of the work function of niobium in the neighborhood of the superconducting transition. (COO-2314-9, -11, and -12)
4. the measurement of the temperature dependence of the work function in aluminum between 4K and 12K (COO-2314-11)
5. a search for an indication of a surface screening transition in the temperature dependence of the work function of copper between 2.9K and 17K. (see enclosed reprints)
6. measurements of the effects of adsorbed ^4He gas on the temperature dependence of the work function of copper between 2K and 15K and over a ^4He pressure range of 1 μ torr to 1000 μ torr.

All but items 5 and 6 above have been described in great detail in previously submitted progress and technical reports. Item 5 is covered in the enclosed reprint so only item 6 will be discussed in detail in this final report.

We have made a large set of measurements of the temperature derivative of the work function of copper in the presence of adsorbed ^4He gas covering the temperature range from 2K to 15K and the pressure range from 1 μ torr to 1000 μ torr. Only a

small portion of this data has been analyzed so the results reported here must be considered preliminary.

We have begun our analysis by assuming that the temperature dependence of the work function in the presence of ^4He gas is due to thermal desorption of a monolayer or less from the copper surface. Under this assumption it is found that ^4He adsorbed on the surface of copper decreases the work function. The maximum decrease observed in these experiments is 14.7 ± 1.2 meV at a pressure of 5 torr and a temperature of 2K.

We have constructed adsorption isotherms by assuming a proportionality between the surface coverage and the change in the work function. From this we can estimate the isosteric heat of absorption, Q_{st} , as a function of surface coverage. We find that Q_{st} varies from about -60K at low coverage through a maximum value of -120K at 30% coverage to a value of about -45K at 80% coverage. The extrapolated value of Q_{st} for 100% coverage is consistent with the latent heat of vaporization of bulk ^4He of about 11K.

In summary under this contract we have made significant advances in developing methods to study the temperature dependence of metallic work functions and have applied those methods to the study of both base surfaces and surfaces with adsorbed gas on them. A more complete report of the results of the ^4He adsorption experiments will be submitted when the data are completely analyzed.

A. Journal Articles

1. "A Low Noise Amplifier with Application to Noise Thermometry between 300 and 4K", P.T. Anderson and P.B. Pipes, Rev. Sci. Instrum. 45, 42 (1974).
2. "Thermomagnetic Effect in a Superconducting Ring Containing a Josephson Junction", U.J. Gibson and P.B. Pipes, Phys. Rev. B11, 4219 (1975).
3. "The Effect of the Superconducting Transition on the Electronic Work Function of Niobium", D.H. Darling and P.B. Pipes, Physica 85B, 277 (1977).
4. "Temperature Derivative of the Electronic Work Function of Copper at Low Temperatures", J.U. Free, C.D. Dermer, and P.B. Pipes, Phys. Rev. B 19, 631 (1979).

B. Conference Presentations

1. "Temperature Dependence of Contact Potentials in Nb and Al at Low Temperatures", P.B. Pipes and D.H. Darling, Bull. Am. Phys. Soc. 20, 616 (1975).
2. "Thermomagnetic Flux in a Superconducting Ring Containing a Josephson Junction", P.B. Pipes and U.J. Gibson, Bull. Am. Phys. Soc. 20, 616 (1975).
3. "Temperature Dependence of Contact Potentials in Superconducting Niobium", P.B. Pipes and D.H. Darling (Proceedings of 14th International Conference on Low Temperature Physics, Helsinki, 1975).

4. "Non-isothermal Volta Potentials in Nb, Al, and Cu at Low Temperatures", D.H. Darling and P.B. Pipes, Bull. Am. Phys. Soc. 21, 644 (1976).
5. "Non-isothermal Volta Potential of Copper between 2 and 8K", C.D. Dermer, J.U. Free and P.B. Pipes, Bull. Am. Phys. Soc. 23, 565 (1978).
6. "Effect of Helium Gas on the Contact Potential of Copper between 2 and 20K", J.U. Free, C.D. Dermer and P.B. Pipes, Bull. Am. Phys. Soc. 23, 565 (1978).

C. Theses

1. "The Temperature Dependence of the Work Function of Metals at Low Temperatures", Dale H. Darling, Ph.D. thesis (June, 1977).
2. "Changes in the Work Function of Copper due to Helium Gas Adsorption", Charles D. Dermer, A.M. thesis (January, 1980).