these T_{sphere}^*-T corrections cannot apply.

We have found that measurements of the critical-field curve for superconducting tungsten are consistent with the weak-coupling BCS theory and give the calorimetric value of γ (as determined for high-purity samples) if we use the simple relation $T = T^*$ for $T^* \gtrsim 3$ mdeg K, where T^* is determined for a powdered CMN thermometer having our particular geometry. Adding to T^* a positive or negative Δ not exceeding a few tenths of a millidegree does not qualitatively change this result. On the other hand, if we take $T_{\text{sphere}}^* = T^* + \Delta$ with Δ as large as 1.7 mdeg K, as suggested by Abraham and Eckstein, we find (whether or not we use the T_{sphere}^*-T relation of Hudson and Kaeser, a correction which requires a large Δ) that the W critical-field measurements deviate strongly from the BCS theory for weak-coupling superconductors and that the value obtained for γ is much too small.

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GIANT TEMPERATURE DEPENDENCE OF THE WORK FUNCTION OF CESIUM-COVERED GaAs

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The cesiated (110) surface of n-type GaAs shows an unusually large temperature dependence of its work function. The reduction of the work function by 0.55 eV upon cooling from room temperature to 80°K is caused entirely by a change in band bending; the electron affinity remains constant.

In the few instances where the temperature dependence of the work function of clean semiconductor surfaces is known, it is of the same order of magnitude as that of metals. So far, measurements were mostly performed on silicon; thermionic emission,[1,2] field emission,[3] photoelectric emission,[4] and electron reflection[5] measurements all indicated a variation not exceeding 0.1 eV in the range extending from 77°K to the melting point. Between 77 and 550°K, $d\Phi/dT$ is negative, and the temperature dependence seems to be more pronounced below room temperature than above.[3] A variation in work function of a semiconductor (with temperature, adsorption, or other agent) is the sum of the variation of the electron affinity χ and of the position of the Fermi level with respect to the band edge at the surface. These two components are easily separated through measurement of the energy distribution of photoelectrically emitted electrons.[4] A change $\Delta\Phi$ in work function is observed as a shift ΔS of the low-energy cutoff of the energy distribution of emitted electrons, $\Delta\Phi = \Delta S$ (see Fig. 1). A change in band bending, i.e., a variation in the position of the top of the valence band with respect to the Fermi level, is measured as a shift in the high-energy limit (H in Fig. 1) of the distributions.

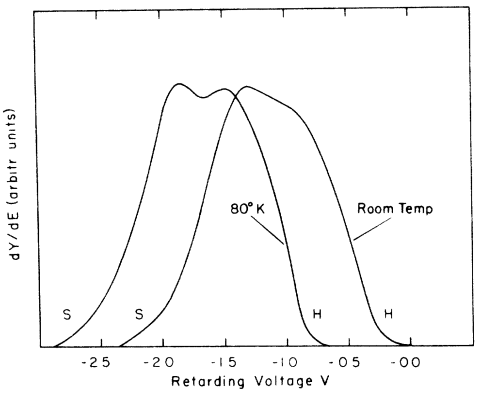

FIG. 1. Energy distributions of photoelectrically emitted electrons from a cleaved and annealed (110) surface of GaAs covered with 6×10^{14} cm^{-2} cesium. Measured for $h\nu=4.49$ eV at room temperature and 82 ±5°K. The retarding potential is the voltage applied between collector and emitter; it represents the energy of the electrons minus the work function of the collector.

In the course of an investigation of photoelectric emission from GaAs we observed a large temperature dependence of the work function. This is shown below to be entirely due to a change in band bending. The material was a single crystal of n-type GaAs with $N_D-N_A=10^{16}$ cm^{-3}. With such a doping, the Fermi level lies 0.05 eV below the bottom of the conduction band at room temperature. A clean (110) surface was exposed by cleavage in vacuo ($p<10^{-9}$ Torr). The crystal was then heated to 600°C for approximately 5 sec, after which a cesium coverage of 6×10^{14} cm^{-2} was applied. Energy distributions of photoelectrically emitted electrons were measured with the crystal at room temperature, then at 80°K, and again at room temperature. The results for a photon energy $h\nu=4.49$ eV are shown in Fig. 1 and were reproducible. We observe that $\Delta H=0.55\pm0.02$ eV and $\Delta S=0.55\pm0.1$ eV, indicating a reduction of the work function upon cooling. The relatively large uncertainty in ΔS results from the poorly defined low-energy cutoffs, a consequence of fringe fields and inhomogeneous cesium coverage. Contact potential measurements by the Kelvin method also showed a decrease in work function by 0.5 ± 0.1 eV upon cooling.

The fact that $\Delta\Phi\approx\Delta H$ shows that the large change in work function upon cooling is due to a change in band bending near the surface (the bands in the bulk shift by no more than 0.05 eV). The electron affinity remains constant within the limits of precision of the experiment. Since the bulk is n-type, the change in band bending shows that the bands are bent upwards towards the surface, the Fermi level lying at least 0.55 eV below the bottom of the conduction band. At 80°K the bands are nearly flat. This explains the differences in shapes visible in Fig. 1: The structure is well developed at 80°K but smeared by the band bending at room temperature.[6] Similar energy distributions were measured at ten other wavelengths of the light with identical results.

We are unable at this time to propose a satisfactory explanation for this behavior. It is probably linked to a temperature dependence of the spectrum of surface states which could be brought about by a temperature-dependent arrangement of the adsorbed cesium atoms, possibly an ordering of the adsorbed layer at low temperatures. Such an ordering could be observed by low-energy electron diffraction; experiments to this effect are being initiated at Yale University.

The observed temperature dependence of the band bending has a few interesting implications:

(1) The band bending at room temperature, which is a direct conclusion from our measurements, implies a negative net surface charge despite a cesium coverage of 6×10^{14} cm^{-2}. This is an apparent contradiction to the usual model for the reduction of work functions of semiconductors by cesium.[7] In fact, the assumption[8] that adsorption of cesium produces a degenerate n-type surface has been disproved for several materials,[9] including silicon,[10] GaP,[11] and InP.[12]

(2) We do not believe that this large temperature dependence of the band bending with a tendency of producing degenerate n-type surfaces at low temperatures is characteristic of annealed surfaces, since it has been observed previously with cleaved and cesiated silicon,[4] but is representative of surfaces covered with a foreign substance, such as cesium. Clean semiconductor surfaces have not shown this effect.

(3) It appears that in those cases where an n-type surface is desirable, such as the study of band structure including the edge of the conduction band,[13] or the achievement of large photoelectric yields at long wavelengths,[14] cooling of the surface might be very useful.

The observations reported here are obviously preliminary results; a more detailed investigation of the temperature dependence of surface properties of semiconductors is being carried out at Yale University

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DECAY OF Ca^{50} †

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The decay of Ca^{50} has been reinvestigated. The serious discrepancy between various theoretical calculations of Sc^{50} and earlier experimental results has been resolved by the observation of an allowed Ca^{50} β decay to the 1848-keV level in Sc^{50}. The $J^{\pi}=1^{+}$ assignment for this state and its γ-ray branching ratio are in good agreement with the recent theoretical treatment of Sc^{50} by Hughes and Soga.

Calcium-50 was first observed by Shida et al.,[1] who reported that the dominant decay mode was an allowed β transition to the level in Sc^{50} at 329 keV, to which they made a 1^{+} spin and parity assignment. As pointed out by these authors, the rather low excitation energy of the 1^{+} level was surprising since the lowest shell-model configuration, $(f_{\frac{7}{2}})_p(p_{\frac{3}{2}})_n$, allows only states with spins and parities of 5^{+}, 4^{+}, 3^{+}, and 2^{+}. Such a 1^{+} state, arising from more complex configurations, would be expected to lie several MeV above the $(f_{\frac{7}{2}})_p(p_{\frac{3}{2}})_n$ quartet of levels.

At the time of the work of Shida et al., the positions of only three states in Sc^{50} were known, namely, the ground state and the levels at 257 and 329 keV. Since then, levels have been observed in Sc^{50} up to an energy of 3289 keV by Ohnuma et al.[2] Using the reaction $Ca^{48}(He^3,p)Sc^{50}$, they found levels at 259, 331, 761, and 1857 keV, and five more at about 2 MeV. The grouping of four rather low-lying levels followed by a gap of more than 1 MeV strongly suggests that the low levels do indeed arise from the $(f_{\frac{7}{2}})_p(p_{\frac{3}{2}})n$ configuration, which then contradicts the assignment of the 329-keV Sc^{50} level indicated by the work of Shida et al. Moreover, quantitative theoretical work on the positions of the levels in Sc^{50} has been done[3-6] which also indicates that the 329-keV level should not be a 1^{+} state. This Letter is a preliminary report on some new experimental results on the decay of Ca^{50} which are directly applicable to the solution of this dilemma.

Calcium-50 was produced in the reaction $Ca^{48}(t,p)Ca^{50}$ using 3.0-MeV tritons from the Lockheed 3.5-MeV Van de Graaff accelerator. Calcium, enriched in Ca^{48} to 85%, was obtained in the form of $Ca^{48}CO_3$, but was transformed into $Ca^{48}I_2$ to eliminate oxygen from the target. The oxygen produces prolific amounts of 511-keV γ rays from the decay of F^{18} formed in the reaction $O^{16}(t,n)F^{18}$, and the excessive counting rate from these γ rays was not tolerable in this experiment. With the chemical procedure[7] used to make CaI_2 and subsequent careful handling of the target to minimize water absorption from the surroundings, a reduction in the 511-keV γ-ray counting rate by two orders of magnitude, relative to that from a $CaCO_3$ target, was obtained.

Gamma rays from the decay of Ca^{50} and its daughter Sc^{50} were detected in a 20-cm^3 Ge(Li) counter which had a resolution of less than 3 keV for Co^{60} γ rays. The Ge(Li) counter was located about 5 cm from the target. The irradiate-count data acquisition procedure was controlled by an on-line computer system described elsewhere.[8] The γ-ray pulse-height distributions were re-