# Work Function of Gold

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The work functions of sixteen gold surfaces have been determined by measurement of their contact differences of potential with respect to barium reference surfaces of known work function. The gold surfaces were prepared by subjecting spectroscopic standard gold to repetitive fusion-solidification outgassing followed by fractional distillation and condensation on tantalum; the barium surfaces by a similar technique which yields surfaces reproducible and constant to 0.01 ev. Measurement was by the Kelvin method with a time interval of 15 seconds between deposition and measurement of a fresh surface.

The contact difference of potential Au-Ba is found to be 2.31±0.02 volts and the work function of gold 4.83±0.02 ev, referred to a barium work function of 2.52 ev.

THE work function of gold is of more than ordinary interest at present because of the need which now exists for a metallic reference material suitable for surface potential studies on semiconductors. Gold is one of the more likely possibilities for this role, in particular for studies involving exposure of the semiconductor surfaces to gases at low pressures. A second requirement for the profitable investigation of semiconductor surface potentials, and for metallic surfaces in gaseous atmospheres, is a measuring method which introduces no disturbance of the surface, by heating, irradiation, or electron bombardment. The Kelvin method of contact and surface potential measurement is unique in that it meets these conditions unequivocally. The objective of the present work was a determination of the work function of clean gold by Kelvin measurement of its contact difference of potential with respect to barium, our standard reference material for work function studies on clean metal surfaces.

Previous determinations of $\phi_{Au}$ by the thermionic method[1] have yielded values ranging from 4.0 to 4.58 ev. The careful photoelectric measurements of Morris[2] lead to the value 4.90 ev when analyzed by the Fowler method[3] and to 4.81 ev when subjected to analysis by DuBridge's monochromatic method.[4] A determination of $\phi_{Au}$ by the contact potential method,[5] carried out with questionable techniques, gave a value of 4.46 ev.

## EXPERIMENTAL METHODS; PROCEDURES

The experimental methods were similar and the preparative procedures of tube outgassing identical to those employed in our earlier Kelvin measurements on vapor-deposited silver and barium.[6] The tube, Fig. 1, was so designed as to satisfy the conditions essential for satisfactory Kelvin measurements in glass systems[6] and,

through use of a swinging-plate arrangement, to reduce the time interval between deposition and measurement of a fresh film to approximately 15 seconds. Since this interval is small relative to the minimal deposition time for a monolayer of gas at the pressures obtaining in a barium-gettered tube,[7] and since fresh barium surfaces show no short-period drift in work function, determination of the contact potential as a function of time provided a means for detecting any progressive contamination of the gold surfaces which might have followed their deposition.

The barium surfaces were prepared from the material and by the technique described previously.[6] The gold was Johnson-Matthey spectroscopic standard material in the form of 40-mil wire, about 0.8 g per vaporizer. Each of the metal charges was outgassed by repetitive fusion and solidification before sealing the tube from the pumps. Since gold vaporizes very slowly at temperatures slightly above the melting point, it is easily outgassed by this method. After seal-off, the barium was subjected to six more fusions, each accompanied by heavy vaporization to the walls of the tube. The measured surfaces were laid down after adjusting the
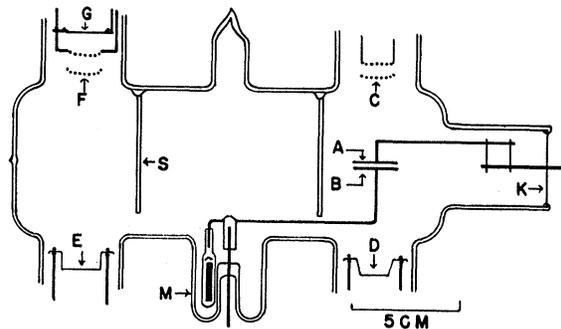


FIG. 1. The tube. Vaporizers $C$ (20-mil W wire helix) and $D$ (1-mil×5-mm W foil boat) deposit gold on 5-mil Ta disk $A$. Vaporizers $E$ (1-mil×10-mm Ta boat) and $F$ (20-mil W wire) and re-vaporizer $G$ (1-mil×18-mm Ta foil) deposit barium on Ta plate $B$, swung by armature $M$. $A$ is rocked through 10-mil flexible Kovar diaphragm $K$. $S$ is cylindrical glass shield beaded to envelope.

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vaporizer currents to deposit a visible film of each metal in approximately 2 minutes. The measurements were carried out in sequences of the type $A_1B_1$, $A_1B_2$, $A_2B_2$, where $A_1A_2\cdots$ and $B_1B_2\cdots$ represent, respectively, successively deposited films of gold and barium. This scheme of single-surface renewal provided information concerning the aging characteristics of the individual films of gold and barium; it was varied occasionally by renewing both surfaces simultaneously.

## RESULTS

Sixteen pairs of gold-barium surfaces were measured. The barium films showed their usual high reproducibility and long-term constancy throughout the measurements. In the first four depositions of gold, the initial contact potential values were erratic and marked drifts in contact potential occurred on aging for periods of one to two days. With deposition of the fifth gold film, the variation in the initial readings and the drift with aging disappeared simultaneously. All measurements on the last 12 gold surfaces, including those taken immediately after deposition and after aging periods extending to 48 hours, gave contact potential values within the extreme limits 2.29–2.32 volts. For this group, all measurements on freshly deposited gold surfaces fell within the limits 2.31–2.32 volts. Aging of the gold films for 24–48 hour periods generally, though not invariably, lowered the observed contact potential by 0.01 to 0.03 volt. The variability of gold films 1–4 was probably due to incomplete coverage of the tantalum substrate resulting from agglomeration and piling up of the gold about crystallization nuclei.

Taking 2.31 volts as the contact potential value best representing these measurements and 2.52 ev as the work function of barium,[8] we obtain $4.83\pm0.02$ ev as our value for the work function of gold vapor-deposited on smooth tantalum. This value is in excellent agreement with the Morris-DuBridge photoelectric determination of Au.[4]

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# Polarization Processes in Partially Illuminated Photoconducting Insulators

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A quantitative analysis of polarization phenomena in photoconducting insulators is presented for the case in which a strip of the sample is illuminated far from the electrodes. It is shown that if the drift length of the photo-excited carriers is small compared with the dimensions of the dark and illuminated regions, the photocurrent decays exponentially during both the buildup and release of polarization. The decay constant is essentially independent of the characteristics of the contacts and the applied voltage, and can be expressed in terms of geometrical factors and the photoconductance of the illuminated strip. The conclusions of the analysis are checked in colored single crystals of NaCl. The experimental results are found to be in satisfactory agreement with the theory presented.

## INTRODUCTION

IT is well known that photocurrents in insulators frequently exhibit polarization effects.[1] Following a relatively rapid initial rise, the photocurrent decays slowly with time of illumination as the polarization builds up, until a fairly constant "saturation" value is reached. Further, on the removal of the external field, a short-circuit photocurrent appears which subsequently decays to zero as the polarization is released. The buildup of polarization is associated with the accumulation of space charge in the sample as a result of the drift under field of the photo-excited carriers. Such an accumulation can materialize only when the discharge of current carriers between the space-charge regions and the electrodes is insufficient to neutralize the space charge formed. This may arise from contact effects and/or nonuniform illumination. In either case, to maintain the given voltage across the sample, the constant-voltage source must supply additional charge to the electrodes at a rate determined by that of the space-charge accumulation in the sample. The measured photocurrent is given by the rate at which the charge is induced at the electrodes, superimposed on any discharge current between the electrodes and the space-charge regions that may be present. The initial photocurrent and its subsequent decay are associated with the self-limiting rate of space-charge formation. The saturation value of the photocurrent represents the discharge current which, under steady-state conditions,

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