tor, one would expect a larger number with energies above the gold work function if the tunneling voltage were higher. Also one would expect the higher tunneling voltage to yield a shorter mean free path, since the mean free path should decrease with electron energy.[6] However, the mean free path obtained from the present experiments is a weighted average over the energies from the gold work function up through the tunneling voltage and if a large fraction of the electrons were concentrated at energies near the bottom of the insulator conduction band, the change in apparent mean free path with tunneling voltage would be slight, as observed. If no energy were lost within the insulator, plots similar to those in Fig. 1 would all be expected to have an intercept of unity and slopes which corresponded closely to the true energy mean free path for energy corresponding to the tunneling voltage.

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MEAN FREE PATH OF PHOTOEXCITED ELECTRONS IN Au

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At the present time there is considerable interest in the mean free path of hot electrons in metals.[1] Most of the work on photo-[2] and secondary emission[3] has dealt with electrons whose energy above the Fermi level exceeds the work function of the metal. In the present investigation the mean free path of electrons in Au has been investigated for electron energies between 0.8 and 1.1 ev. Au films of controlled thicknesses were evaporated on freshly cleaved Si surfaces and the spectral dependence of the photoresponse studied.

The samples were bars of 8 ohm cm n-type silicon covered with a 1-micron thick layer of SiO_2. At one end of the bar the oxide was removed and an Ohmic contact was made. The samples were cleaved in vacuum and the cleaved surface immediately covered by an evaporated Au layer. The above procedure is a modification of that employed by Archer and Atalla[4] to study metal-silicon surface barrier rectification. When such diodes are illuminated the silicon acts as a collector for photoexcited electrons in the metal layer. The effect of band-to-band transitions in the silicon is eliminated by restricting the photon energies to $E_{ph} < 1.1$ ev. In order to observe a photocurrent originating from electrons excited in the metal layer, the energy of these electrons must exceed the height of the Schottky barrier at the metal-semiconductor interface. That such a photocurrent can be detected has already been demonstrated for the case of electrochemically deposited metal films on CdS.[5] Figure 1 shows the square root of the response per incident photon as a function of the photon energy for five different thicknesses of Au. The extrapolation of the linear portion of these curves to zero response gives a photoelectric threshold of 0.79 ± 0.01 ev for all the samples. The same value was also obtained from a Fowler plot. This is in excellent agreement with the value 0.79 ev for the energy from the top of the barrier to the Fermi level as obtained from a study of the voltage dependence of the depletion layer capacitance.[4] The photoresponse is not due to scattered light of energy $E_{ph} > 1.1$ ev since the nature of the spectral response was not altered when silicon filters were placed in the spectrometer beam in front of the diode. For a threshold determination the response per absorbed photon rather than per incident photon should be used, but since the energy absorbed in each film was found to be nearly independent of E_{ph} in the region of interest, the data of Fig. 1 yield the correct threshold. The energy absorbed was determined from measurements of the spectral dependence of transmission and reflection of Au films evaporated on glass slides. Since the slides were positioned adjacent to the

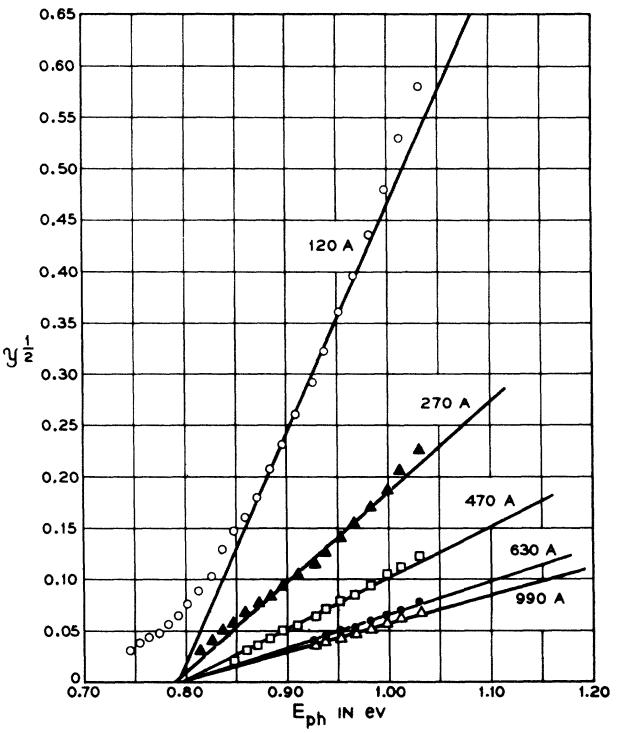

FIG. 1. The square root of the response per incident photon ($y^{1/2}$) vs the incident photon energy (E_{ph}) for five different thicknesses of Au.

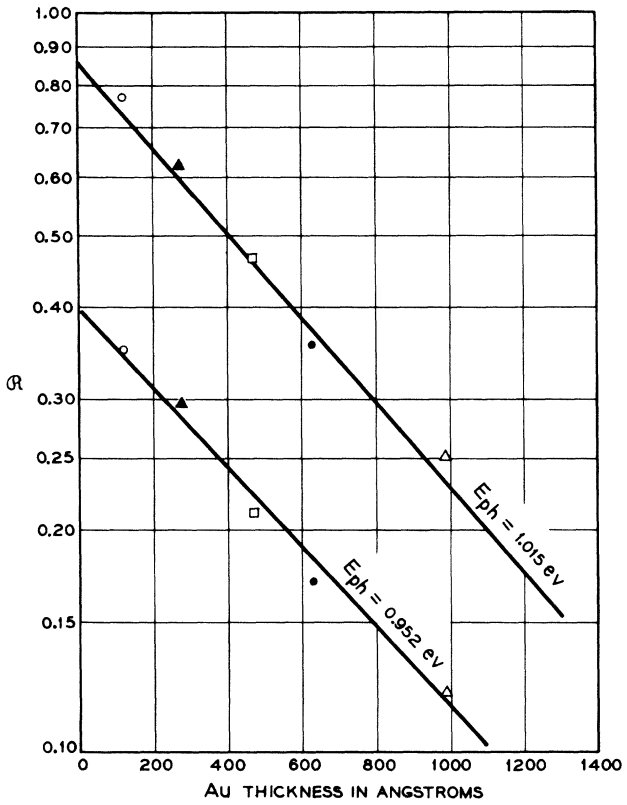

FIG. 2. The points are the response per absorbed photon (R) for the five films of Fig. 1 for photon energies of 1.015 and 0.952 ev.

samples during the evaporation, they also permitted measurements of film thickness. In all cases, except for the thinnest film (120 A), the transmission was sufficiently small that the reflection at the Au-Si interface should be of minor importance. An implicit assumption is that the optical constants of the Au on glass approximate those of the Au on Si.

Figure 2 gives the response per absorbed photon as a function of film thickness for two different values of E_{ph}. For the case where the reflection of light at the Au-Si interface can be neglected, a simple theory based on an exponential attenuation with distance of both the radiation and the collection efficiency predicts

$$R = \frac{\alpha L}{1-\alpha L}\left[\frac{e^{-\alpha t}-e^{-t/L}}{1-e^{-\alpha t}}\right],$$

where R is the response per absorbed photon, α the absorption coefficient, L the electron attenuation length in the metal, and t the film thickness. In the photon energy range of interest values for the radiation penetration depth ($1/\alpha$) range from ~100 to 130 A.[6] Therefore the slope of the lines in Fig. 2 indicates an electron attenuation length of ~740 A. At the present time it is not clear whether this value is characteristic of ballistic or diffusion transport of electrons to the collector. However, in either case, the measured attenuation length is a lower limit of the electron mean free path for collisions after which the electrons are no longer capable of surmounting the collector barrier.

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