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Surface States and Barrier Height at Metal-GaAs Interface

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Schottky Barrier contacts have been fabricated by vacuum evaporation of thin films of six different metals (Mg, In, Al, Au, Bi and Sb.) onto chemically cleaned n-type GaAs substrates. Barrier height measurements for Bi and Sb contacts on GaAs have been presented for the first time and have not been reported earlier.

The GaAs slices were lapped and polished in bromine-methanol solution and ohmic contacts were made to the surface containing Ga atoms by evaporating In-Au alloy and heating the same in inert ambient. The barrier metals were evaporated at a typical pressure of 10^{-6} Torr using either a tungsten filament or a molybdenum boat onto the surface opposite to that having the ohmic contact.

Most of the fabricated diodes exhibit near ideal I-V characteristics with the value of ideality factor n ranging from 1.06 to 1.1. The barrier height on each contact was determined from the usual C-V and I-V measurements. In the C-V method the intercept V_o of $1/C^2$ versus applied voltage plot was determined and the barrier height φ_B was obtained from the relation:

$$\varphi_B = q\ (V_o + V_n) + kT \tag{1}$$

Where qV_n represents the depth of the Fermi-level below the conduction band edge. In the I-V method the saturation current density J_s of the contact was determined from the measurement of the forward I-V characteristics and then φ_B was calculated from J_s.

$$J_s = A^* T^2 \exp\left[- \frac{\varphi_B}{nkT} \right] \tag{2}$$

The value of the Richardsons constant A^* has been estimated from the activation energy plot of I_s/T_2^2 versus $1/T$ shown in Fig. 1. From this plot $A^* = 131$ Amp/cm^2 $^\circ$K^2, which is significantly different from that reported earlier.

One of our significant observations has been that the values of φ_B obtained from equation (2) could be brought into agreement with those obtained from the C-V method only when the non ideal nature of the diodes was taken into consideration and the measured value of n was substituted into equation (2). When this was not done and n was put equal to unity, as has been done by the previous workers, the values of φ_B obtained from equation (2) were about 10 to 12%

less than those obtained from equation (1).

In an effort to correlate the barrier height values with the metal work function and the surface properties of GaAs the average φ_B values are plotted against the metal work function φ_M in Fig. 2. In chosing the φ_M values we have put reliance on the most recently determined values. From the analysis of this plot the following results are obtained

(a) If we disregard the point represented by Al, then the equation of the plotted data can be represented by the straight line

$$\varphi_B = 0.12\ \varphi_M + 0.37 \qquad (3)$$

With the known values of the electron affinity, thickness and permittivity measured on the chemically etched surfaces of GaAs this equation leads to a density of 3.4×10^{14} states/cm^2 ev at GaAs surface and the pinning of the Fermi-level at 0.32 E_g above the valence band edge. These results alongwith equation (3) are significantly different from the earlier results.

(b) From Fig. 2 one notes that φ_B value for Al is smaller than those for In and Sb although Al is reported to have the largest work function among the three metals. It is thus clear that the more recently determined value of φ_M=4.13 ev for Al is too large to predict the correct value of φ_B on GaAs and the older value of 3.75 ev is more consistent with our experiment results.

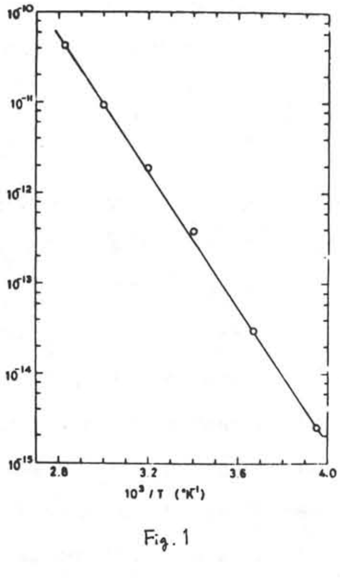

Fig. 1

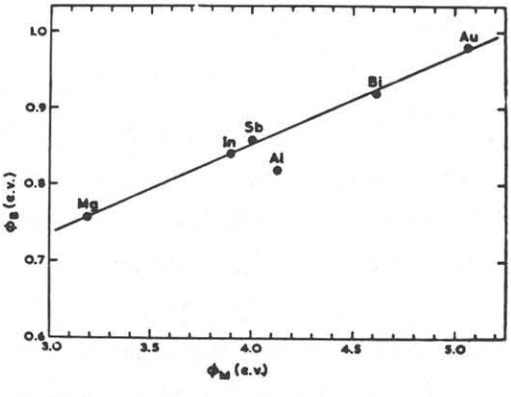

Fig. 2