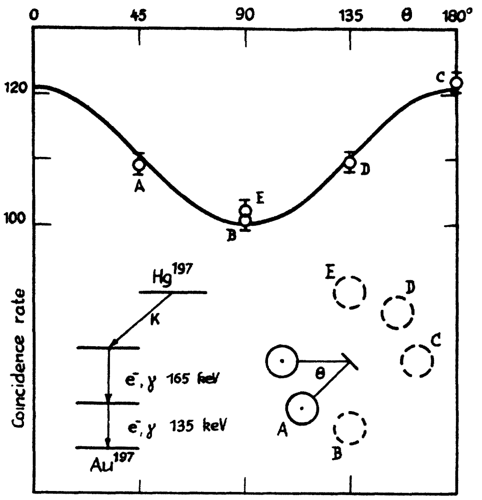

FIG. 1. Angular variation of coincidence rate of successive L-electrons from Au^{197}.

L-electrons were recorded. The contribution from M-electrons is relatively small. To diminish back-scattering the whole apparatus was lined with material of low Z. The points measured in three independent runs are shown in Fig. 1. Assuming a correlation function of the form $(1+A\cos^2\theta)$, with $A=0.24$, and taking into account multiple scattering and the finite solid angles of source and counters we find the solid curve of Fig. 1. The value of A mentioned above gives the best agreement with the measured points, the statistical accuracy being about 0.03.

A rather large contribution from a term of the form $\cos^4\theta$, with the same sign, cannot be excluded because the curve is very insensitive to such terms.

Detailed reports on the measurements and the preparation of the sources will appear in *Helvetica Physica Acta*.

We thank Professor P. Scherrer for his continuous interest and his valuable advice.

Physical Interpretation of Type A Transistor Characteristics

L. P. HUNTER
Westinghouse Research Laboratories, East Pittsburgh, Pennsylvania
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A METHOD of analysis of a transistor characteristic is described which enables one to distinguish between the effects of the efficiency of current carrier injection by the emitter, the effects of the utilization of these carriers at the collector, and the effects of the current carrier mobility ratio. The fundamental assumption involved is that the back conductance of a crystal rectifying barrier is directly proportional to the number of current carriers in the neighborhood of the barrier which are of the type not impeded by the barrier in their passage from the semiconductor to the metal (holes in an N type crystal and electrons in a P type crystal).

The simple expression for hole injection efficiency, γ, in an N type semiconductor as given by Shockley[1] for a filamentary transistor is

$$\gamma=\frac{I_e+I_b}{I_e}\frac{1-G_0/G}{1+b}. \qquad (1)$$

For our case of a Type A transistor we will define: I_e+I_b is the collector current, I_c; I_e is the emitter current, I_e; G_0 is the d.c. conductance of the collector probe held at given negative voltage

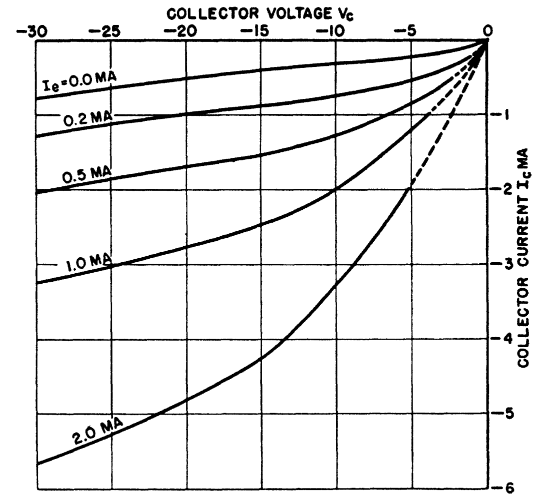

FIG. 1. Typical transistor output characteristics.

with no emitter current; G is the d.c. conductance of the collector probe at the same voltage but with emitter current flowing; b is the ratio of the electron mobility to the hole mobility; and γ is the fraction of the emitter current carried by holes.

From the typical transistor output characteristics of Fig. 1 the above quantities may be obtained, and the value of $\gamma(1+b)$ calculated from (1). A plot of $\gamma(1+b)$ against collector voltage (Fig. 2) produces a set of performance characteristics from which several interesting properties of the transistor may be deduced.

From Fig. 2 it can be seen that none of the performance characteristics exceed the value 2.5 for $\gamma(1+b)$. From a study of a number of good transistors it was found that the saturation value of the performance characteristics never exceeded 2.5. It seems reasonable to assume that this value of $\gamma(1+b)$ then represents a hole injection efficiency of 100 percent, or a γ of 1.0. The mobility ratio, b, for these samples of germanium is then seen to be about 1.5. This value of b is in good agreement with other measurements.[2]

Many poor transistors show saturation values of performance characteristics much lower than 2.5. In these cases the mobility ratio is probably still about 1.5 but the hole injection efficiency of the emitter is low and may be computed from the saturation value of $\gamma(1+b)$ by dividing by 2.5. These considerations would

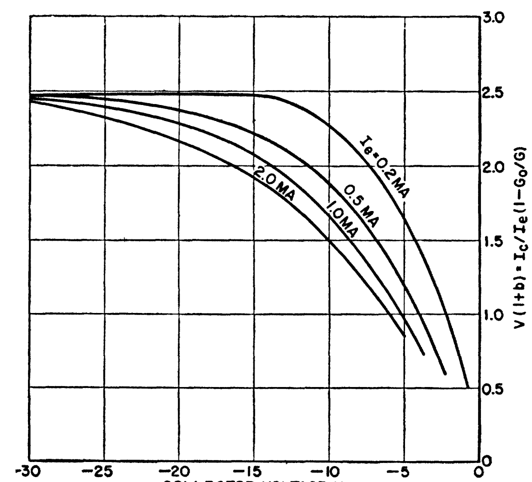

FIG. 2. Typical transistor performance characteristics.

lead one to believe that the maximum value of the small signal current gain, $\alpha = (\partial I_c/\partial I_e)V_c$, for a Type *A* transistor is 2.5 as it is for a filamentary transistor.[1]

The region of a performance characteristic below saturation represents a combination of effects. Here the emitter may still be carrying a sufficiently large proportion of the total current that it must remove some electrons from the crystal as well as inject holes into it. Here also, the field set up in the crystal by the voltage on the collector may not be strong enough to bring all injected holes into the neighborhood of the collector before some of them disappear. This effect should only be noticed for collector voltages less than one or two volts however, since one would expect that the transit time of holes at higher collector voltages should be negligible in comparison with their average lifetime under these conditions. The performance characteristics are terminated on the low voltage end at the point where the collector and emitter currents are equal. (Only the solid portions of the output characteristics of Fig. 1 are used in plotting the performance characteristics.) At this point there is no current in the base lead of the transistor and the emitter efficiencies given by these points may approximate the hole injection efficiency of the emitter probe when it is carrying the total current.

In making measurements at power levels over 100 milliwatts it was found necessary to correct for the change in *G* due to heating. If the semiconductor temperature rises sufficiently in the neighborhood of the barrier to reach the range of intrinsic conductivity the number of holes present even in the absence of hole injection will rapidly increase and raise the value of *G*. This effect shows up in the performance characteristic as a failure to saturate at a constant $\gamma(1+b)$ value for high collector voltages.

[1] Shockley, Pearson, and Haynes, Bell Sys. Tech. J. **28**, 352 (1949).
[2] G. L. Pearson, Phys. Rev. **76**, 179 (1949).

Forbidden Lines in the Spectra of Impure Hg^{198}

K. G. KESSLER
National Bureau of Standards, Washington, D. C.
January 9, 1950

MROZOWSKI[1] has shown that the observed structures of Hg 2967.5A ($6p\,^3P_0-6d\,^1D_2$) are explained as due to one line from Hg^{199} and three from Hg^{291}, the separations and intensities of all components being in complete agreement with the predicted pattern. Deloume and Holmes[2] have studied the lines 3320A ($5p\,^3P_0-5s\,^1S_0$) and 3141A ($5p\,^3P_2-5s\,^1S_0$) in natural and enriched Cd^{111} and found that the intensities of these forbidden lines increased in proportion to the increase in abundance of the odd isotope.

To corroborate Mrozowski's conclusion, three electrodeless discharge tubes were prepared, containing respectively natural Hg (17 percent Hg^{199}, 13 percent Hg^{201}, and remainder even-mass isotopes), Hg^{198} with a 3.6 percent contamination of Hg^{199}, and Hg^{198} with 0.3 percent Hg^{199} contamination. The last two were made by neutron bombardment of gold. Spectrograms were made with a large quartz spectrograph possessing at 2967A dispersive power of 1.7A/mm and practical resolving power exceeding 100,000. The forbidden lines from natural mercury could be photographed with exposures of two minutes duration. The resultant spectra show, in the case of natural Hg, clearly resolved components due to Hg^{199} and Hg^{201}. The component due to Hg^{201} is further resolved into three components corresponding to $\Delta F = -1, 0, +1$. In the spectrum of the 3.6 percent contaminated sample, the Hg^{201} components are almost absent and the Hg^{199} component has been greatly reduced in intensity. The 0.3 percent contaminated sample shows only a faint trace of the forbidden line ascribed to Hg^{199}. Spectrograms obtained with exposure times inversely proportional to the abundance of Hg^{199} show that the intensities of the forbidden lines are indeed proportional to the abundance of the odd isotopes, thus verifying the nuclear perturbational nature of the forbidden transitions.

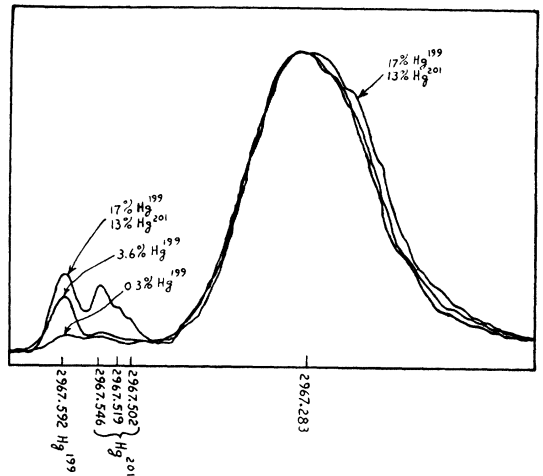

FIG. 1. Microphotometer traces of the 2967.5A forbidden lines and the allowed line 2967.3A for samples containing different concentrations of odd isotopes.

Microphotometer traces of the permitted line, 2967A ($6p\,^3P_0-6d\,^3D_1$) and for forbidden lines from three samples of impure Hg108 are reproduced in Fig. 1.

[1] S. Mrozowski, Phys. Rev. **67**, 161 (1945); Rev. Mod. Phys. **16**, 153 (1944).
[2] F. F. Deloume and J. R. Holmes, Phys. Rev. **76**, 174 (1949).

Temperature Effects in the Spurious Discharge Mechanism of Parallel Plate Counters*

FRANK L. HEREFORD
Rouss Physical Laboratory, University of Virginia, Charlottesville, Virginia
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AN outstanding limitation of the parallel plate spark counter is the large spurious counting rate which thus far has been suppressed only through operation at inconveniently long recovery times (>0.05 sec.). Investigations of this phenomena[1,2] have been limited to the observation that the spurious rate is appreciably influenced by the cathode material and its preparation. It also was pointed out that the clearance time for positive ions should be at the most 10^{-4} sec., and hence that the necessity for longer recovery times must be due to some mechanism associated with the cathode surface rather than the state of the gas. Such a mechanism giving rise to delayed electron emission from a surface (described by Malter[3] and Paetow[4]) was cited as a possible process in this connection.

During the preparation and testing of a number of such counters for use in investigation of short time delay phenomena, a marked dependence of counting rate upon temperature has been observed. The counters used consisted of copper plates, 9 cm^2 in area, spaced at 0.2 cm separation, and mounted in glass envelopes. After washing with acid solution and rinsing with distilled water, the counters were baked in vacuum at 425°C for two hours and allowed to cool slowly with one-half atmosphere of hydrogen admitted during this period. After complete cooling a premixed filling of 85 percent argon and 15 percent ethyl ether was admitted, the total filling pressure being 70 cm Hg.

In obtaining the data reported here a conventional Neher-Harper quench circuit was employed (Fig. 1). The counters were operated at approximately 200 volts over-voltage and held at various temperatures in an oven. Figure 1 shows the variation of counting rate with recovery time, t_r, at various temperatures.