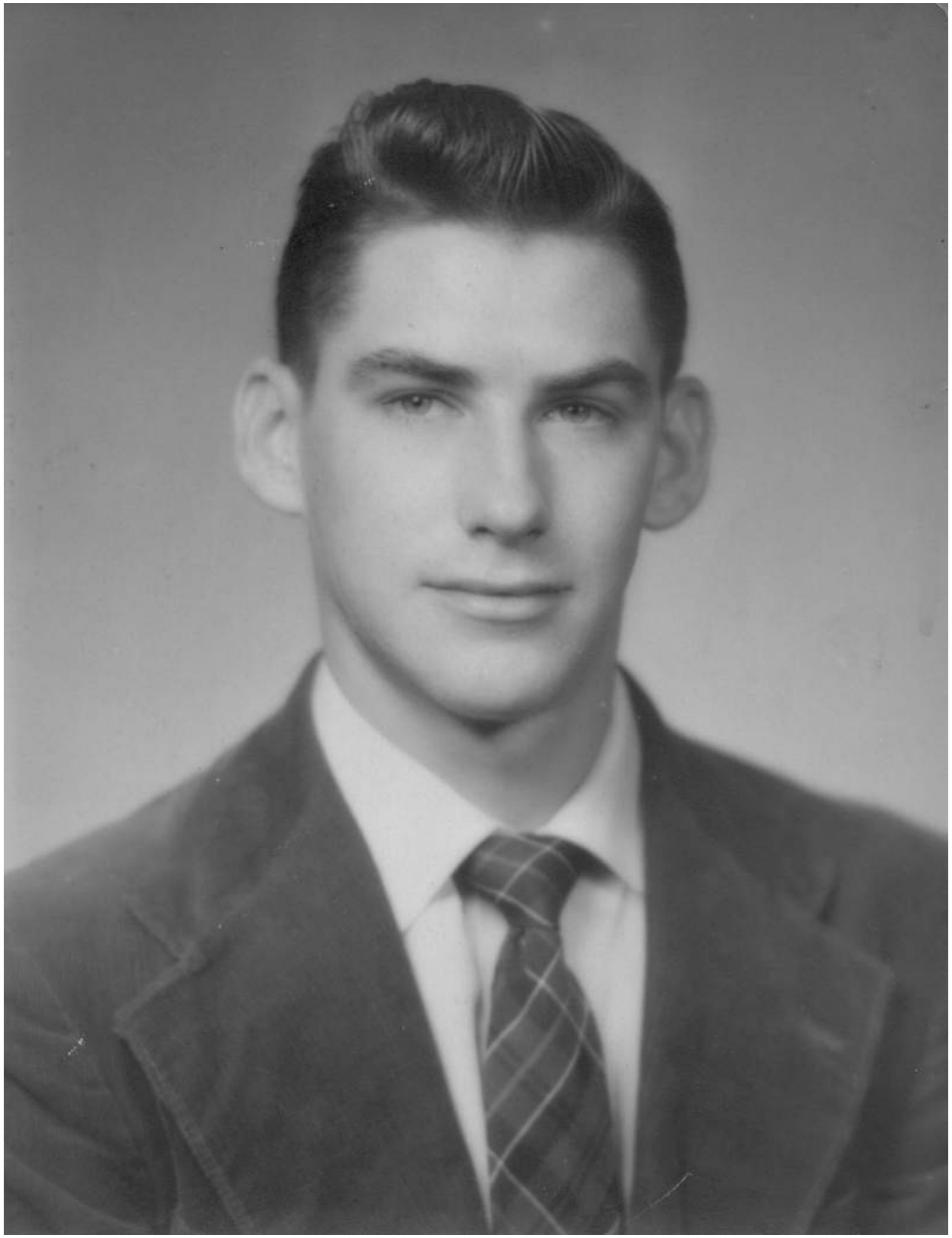

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Reactive Effects in Semiconductor Filaments Due to Conductivity Modulation and an Extension of the Theory of the Double-Base Diode*

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Summary—The effects of conductivity modulation on the terminal characteristics of a semiconductor device are analyzed. Considerable attention is paid to the accompanying reactive effects. The solution for the flow of added carriers is based upon the assumption of quasi-charge neutrality and absence of trapping effects. A double-base diode structure is selected to investigate the transient and ac steady-state effects associated with conductivity modulation, since conductivity modulation by injected carriers proves to be strong in this device. The input characteristics of the double-base diode are considered in this paper. Reactive effects (both inductive and capacitive) in *p-n* junction diodes, previously reported by other researchers, are easily derived as a special case of the more general structure studied here.

Two models are employed in the analysis. One model is used to study double-base diodes made of extrinsic filaments. Here, due to the externally applied electric field, injected carriers are transported essentially by the drift mechanism. The second model describes devices constructed of high resistivity material such that excess carriers are transported primarily by diffusion, as in an intrinsic structure. However in both models drift currents are responsible for inductive and negative resistive effects. The input static characteristics, transient effects and impedance predicted from theory are in good agreement with those observed experimentally.

I. Introduction

THE SUBJECT of this paper is the transport of injected carriers in a semiconductor filament when conductivity modulation is important. More specifically, the effects of conductivity modulation on the terminal characteristics of a particular semiconductor device are analyzed. Considerable attention is paid to the inductive-type transient, which seems to be an inseparable part of conductivity modulation phenomena.

Inductive-type transients and inductive reactances in forward-biased *p-n* junctions and in semiconductor devices incorporating them have attracted much attention in the literature.[1] For a good account of the origin of inductive effects in *p-n* junctions and an extensive bibliography the reader is referred to an earlier paper by Spenke.[2]

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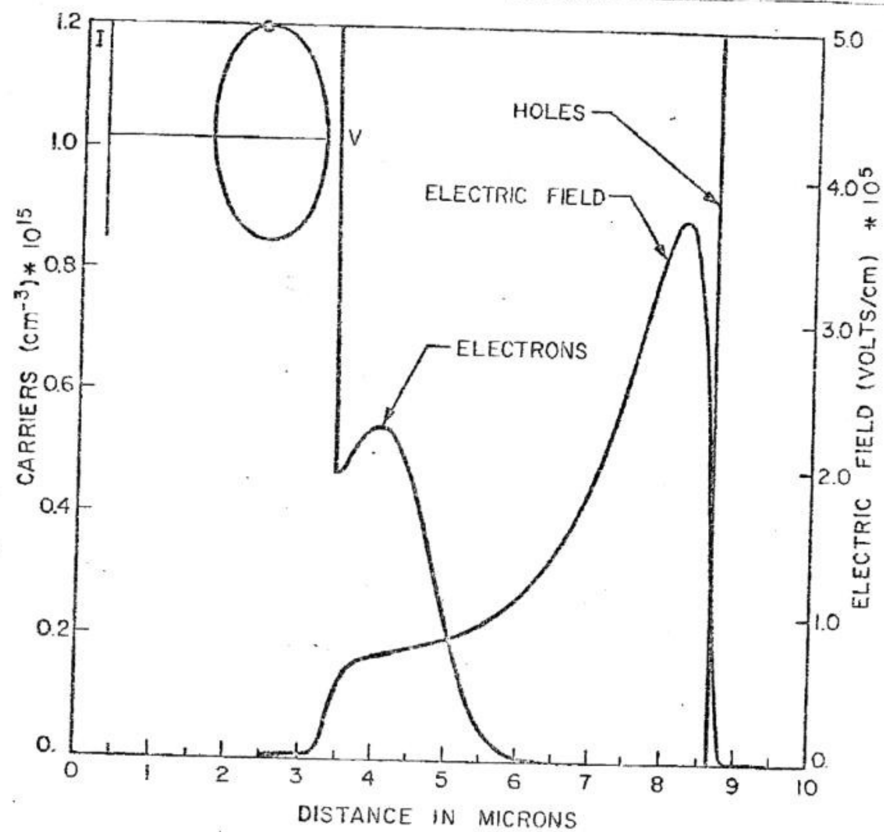
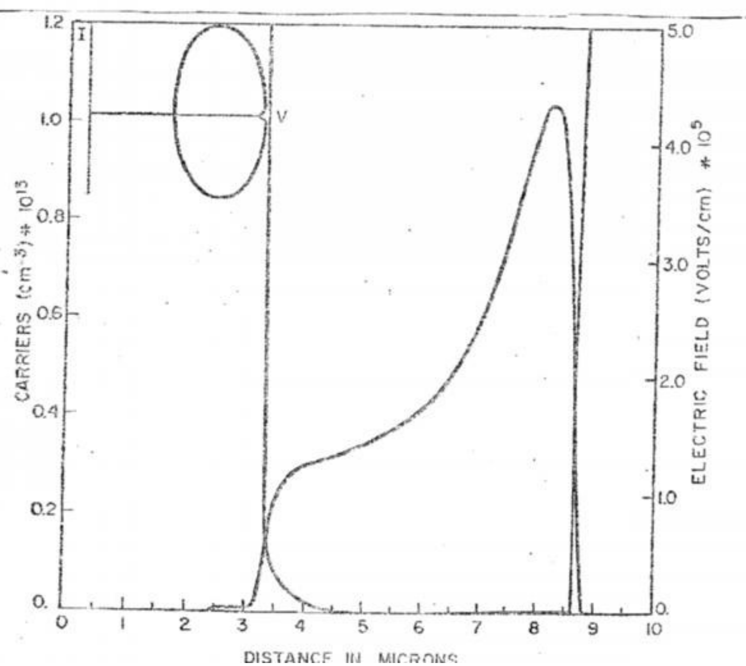
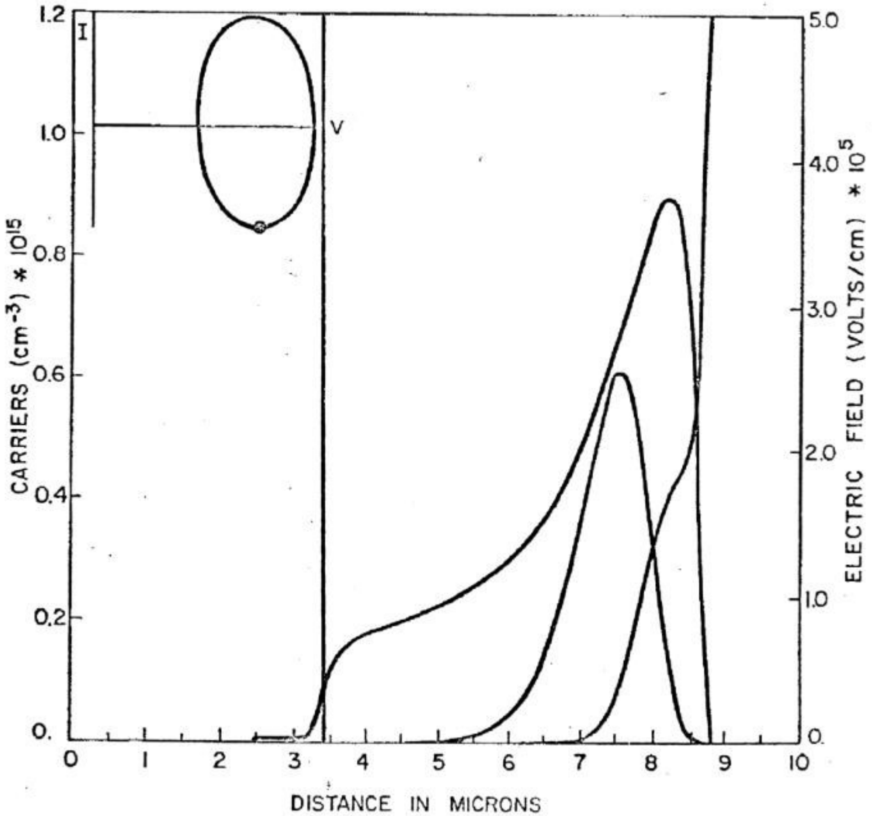
$$
\begin{aligned}
J_p(M) = E(M) \Bigg[& \frac{p(N)\mu_p(M)}{(1.0 - \exp\left(-E(M)\Delta x\right))} \\
& + \frac{p(N+1)\mu_p(M)}{(1.0 - \exp\left(E(M)\Delta x\right))} \Bigg] \\
J_n(M) = E(M) & \frac{n(N+1)\mu_n(M)}{(1.0 - \exp\left(-E(M)\Delta x\right))} \\
& + \frac{n(N)\mu_n(M)}{(1.0 - \exp\left(E(M)\Delta x\right))} .
\end{aligned}
$$

Hole and Electron concentrations, electric field and terminal current and voltage (point in cycle indicated by o) at four points in time. Note the slight tilt of phase plot, indicating microwave negative resistance. Frequency 12.4 Ghz and efficiency of 12%.



Point of maximum voltage has minimal particle current

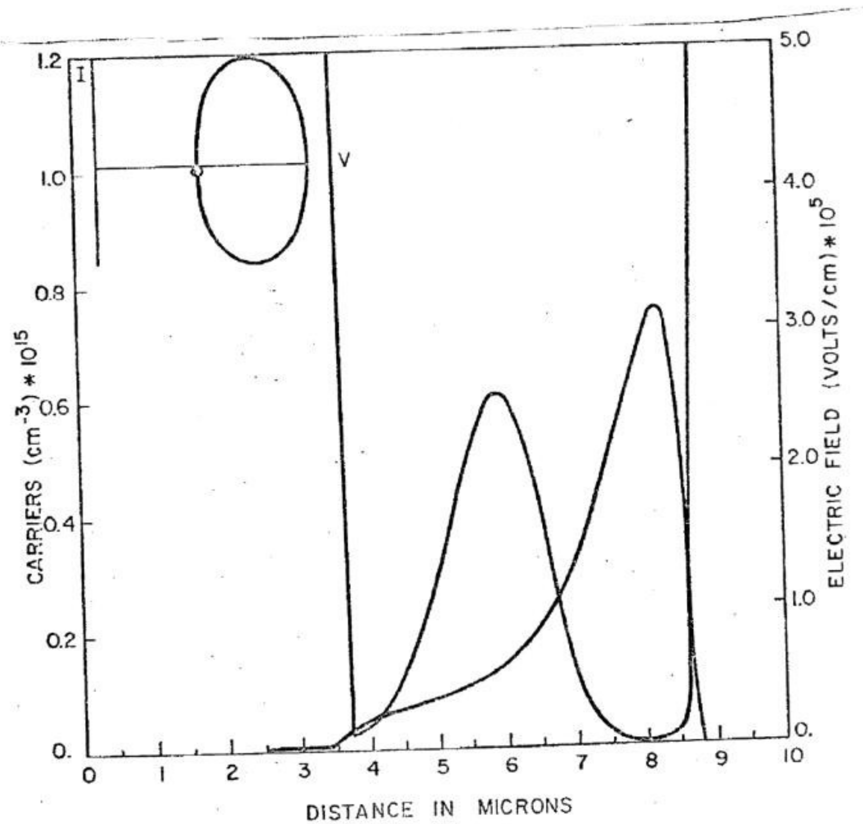




1.2
1.0
0.8
0.6
0.4
0.2
0.
CARRIERS (cm^-3) * 10^15
I
V
0 1 2 3 4 5 6 7 8 9 10
DISTANCE IN MICRONS
5.0
4.0
3.0
2.0
1.0
0.
ELECTRIC FIELD (VOLTS/cm) * 10^5

Fig. 1b

Point of minimum voltage has maximum particle current



Hole and Electron concentrations, electric field and terminal current and voltage (point in cycle indicated by o) at four points in time. Note the slight tilt of phase plot, indicating microwave negative resistance. Frequency 12.4 Ghz and efficiency of 12%.