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EXPERIMENTAL DETERMINATION OF THE LATERAL SPREADING VELOCITY OF AN ELECTRON-HOLE PLASMA CONFINED IN A $P^+ \nu P^+$ STRUCTURE

J. P. CHANTE and J. J. URGELL

Laboratoire d'Electronique Automatique et Mesures Electriques,
 Ecole Centrale de Lyon, B.P. 163, 69130 Ecully, France

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Résumé. — Nous proposons une méthode utilisant un triac pour mesurer la vitesse d'étalement d'un plasma situé dans la couche ν . Pour une couche ν dont l'épaisseur est de $150\ \mu\text{m}$ cette vitesse est de $100\ \mu\text{m}/\mu\text{s}$.

Abstract. — A method is proposed, using a triac like structure, to measure the spreading velocity of the plasma in the ν layer. For a ν layer width of $150\ \mu\text{m}$ the spreading velocity is found to be equal to $100\ \mu\text{m}/\mu\text{s}$.

Bidimensional current flow in semiconductor devices has received considerable interest during the last few years and a certain number of papers have analysed bidimensional problems associated with transistors [1, 2].

For power devices the conduction area is obviously large and the unidimensional models are a very crude approximation of the actual behaviour. Some papers [3, 4] devoted to the analysis of the turn-on of thyristors have described the spreading of the conduction area during the turn-on.

This note presents a new experimental approach aimed to measure the spreading velocity of an electron-hole plasma appearing in some part of the ν layer of a $P^+ \nu P^+$ sandwich (Fig. 1a).

For this measurement, two N^{++} on P^+ regions have been diffused and the two faces have been covered by an ohmic contact (Fig. 1b). This enables

FIG. 1a. — $P^+ \nu P^+$ structure under test. We see in the ν layer the plasma spreading at $t = t_1$ and $t = t_2$, $t_2 > t_1$.

FIG. 1b. — Triac like device used to test the $P^+ \nu P^+$ structure
 $W = 150\ \mu\text{m}$, $L = 2\ \text{mm}$.

one to realize a triac like structure composed of the thyristors TH_1 and TH_2 .

The general idea of the method is to use the conduction of TH_1 to create a plasma in the ν region under N_1^{++} and the charge-controlled triggering of TH_2 to detect the charge transfer in the ν region from TH_1 to TH_2 .

Let us now describe the experimental steps :

(i) TH_1 is turned on in order to create the plasma under N_1^{++} . As long as TH_1 is conducting, the ohmic contact overlapping N_1^{++} and P_1^+ maintains the plasma under N_1^{++} since the transistor $N_1^{++} P_1^+ \nu$ is saturated and the potential of the ν region is close to the potential of the P_1^+ surface under N_2^{++} .

(ii) The current through TH_1 is driven to zero controlling dI/dt (Fig. 2a) and after a delay time t_d

FIG. 2a. — Recovered charge Q_{RC} at the triggering onset of TH₂ versus dI/dt for several temperatures : 1) $\theta = 100^\circ\text{C}$; 2) $\theta = 80^\circ\text{C}$; 3) $\theta = 60^\circ\text{C}$; 4) $\theta = 40^\circ\text{C}$; 5) $\theta = 20^\circ\text{C}$; 6) $\theta = 0^\circ\text{C}$; 7) $\theta = -20^\circ\text{C}$.

a fast rising reverse voltage is applied to the device. The amplitude of this voltage is small enough to prevent a regular dv/dt switching of TH₂. The delay t_d is adjusted so that the recovery of the corresponding charge Q_R corresponds to the onset of the triggering of TH₂. This delay is called t_{dc} and the corresponding charge Q_{RC} . If $t_d < t_{dc}$ the charge Q_R is greater than Q_{RC} and TH₂ is turned on, if $t_d > t_{dc}$ then $Q_R < Q_{RC}$ and TH₂ remains off.

Figure 2a shows, for several temperatures, this critical recovered charge Q_{RC} as a function of dI/dt .

The charge Q_{RC} is recovered maintaining a voltage between the two electrodes. As a consequence :

(i) the recovery conditions correspond to the presence of an electric field in the v region as described by H. Benda and E. Spenke [5];

(ii) the recovery time is short enough to prevent, during the recovery, the action of the transistors $N_2^+ P_2 v$ and $P_1^+ v P_2^+$ on the measured value of Q_{RC} .

For high values of dI/dt a large concentration of plasma exists under TH₁ when the current goes to zero, t_{dc} has to be increased and Q_{RC} tends towards a constant value (on the right part of figure 2a). This constant value of Q_{RC} is noted $2 Q_C$. Indeed when t_{dc} is large enough, the concentration of the plasma is uniform along the v region, and half of the total area being occupied by TH₁ or TH₂, Q_{RC} corresponds to twice the minimum triggering charge of TH₂ which is Q_C .

As dI/dt is decreased, t_d decreases and Q_{RC} increases, this can be explained considering that the charge Q_C has to be present under N_2^+ to trigger TH₂ and t_{dc} is too small to have a complete spreading of the charge along the v layer.

FIG. 2b. — $R = \frac{Q_{RC} - 2 Q_C}{2 Q_C}$ versus the delay time t_{dc} .

The ratio :

$$R(t_{dc}) = \frac{Q_{RC} - 2 Q_C}{2 Q_C}$$

can be computed from the graphs of figure 2a for several temperatures. This ratio is drawn on figure 2b as a function of t_{dc} .

Now, if Q_1 is the stored charge under TH₁ and Q_2 the stored charge under TH₂, it is easy, from $R(t_{dc})$, to derive the ratio Q_1/Q_2 of the charges under TH₁ and TH₂. We have :

$$\frac{Q_1}{Q_2} = 1 + 2 R.$$

When t_{dc} is very long $Q_{RC} = 2 Q_C$ and $R(t_{dc}) = 0$. This means the plasma is uniform along the v layer and $Q_1 = Q_2$. If t_{dc} is short, R is large and Q_1 is larger than Q_2 , this means that we have not a complete spreading of the charge in the v layer. The ratio Q_1/Q_2 therefore gives the position of the plasma under the electrodes : for instance : $t_{dc} = 7 \mu\text{s}$; $R = 0.2$; $Q_1/Q_2 = 1.4$ and the plasma covers 70 % of the area of TH₂, that is a length $x = 700 \mu\text{m}$ in the TH₂ thyristor. The deduced lateral spreading velocity of $100 \mu\text{m}/\mu\text{s}$ is typical of the sandwich $P^+ v P^+$ tested :

- width of the v layer : $150 \mu\text{m}$,
- resistivity : $30 \Omega \cdot \text{cm}$.

This measured velocity is in agreement with other experimental data [3, 4]. We believe that this velocity is not due only to diffusion because :

(i) the diffusion velocity is lower than the measured velocity,

(ii) the diffusion length is about $200\text{ }\mu\text{m}$ in the ν layer and in that case the diffusion mechanism alone cannot explain the presence of a significant amount of charge at a distance $x = 700\text{ }\mu\text{m}$.

We suppose that the diffusion of carriers biases

the $\text{P}^+ \nu$ junctions in the forward direction and the regular diffusion mechanism is accelerated by this injection process.

We are currently working on other $\text{P}^+ \nu \text{P}^+$ sandwiches varying the width of the ν layer in order to give a theoretical representation of the spreading velocity.

References

- [1] HAUSER, J. R., *IEEE Trans. Electron Devices*, **ED. 11** (1964) 238.
 - [2] REY, G. et LETURCQ, P., *Etude approfondie du transistor bipolaire* (Masson) 1972.
 - [3] RUHL, H. J., *IEEE Trans. Electron Devices*, **ED. 17** (1970) 672.
 - [4] GREKHOV, I. V., LEVINSKTEIN, M. E. and SERGEEV, V. G., *Soviet Physics-Semicond.* **4** (1971) 1844.
 - [5] BENDA, H. and SPENKE, E., *Proc. IEEE*, **55** (1967) 1331.
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