Reversion of Base Currents in the Dipping Grown Diffused Transistors

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The dipping-grown-diffused pnp Ge-transistors¹⁾ sometimes have a current amplification factor α , which becomes greater than unity with increasing current, and then the reversion of base current occurs with increasing emitter current for the grounded base connection. For the grounded emitter connection, a large increase of current occurs and the voltage across the unit drops to a very low value as shown in the characteristics curves of Fig. 1.

The important parameter determining the transition to the high conductivity state is the collector current and the transition value of this current is called the break over current.

Fig. 1 Negative resistances of a transistor with a collector contact made by soldering with an alloy of lead and tin.
parameter=base current (μ A)

Fig. 2 Characteristics and the reversion of base currents for the grounded connection by a direct current method.
parameter=emitter current (mA)

Fig. 2 shows an experimental plot of V vs. I_c , obtained by the direct current measurements for the grounded-base connection in a dipping-grown-diffused transistor.

The reversion points of the base currents are indicated by the crosses. In the region between points C and D, the direct current amplification factor exceeds 1.0 with increasing junction temperature by the collector dissipation, and the reversion of the base currents occurs. It will be shown that the region between points B and C is predicted from the electron injection at a contact, which was found by C.W Mueller²⁾ in the study of Thyristor, and that these phenomena are prevented by the use of the collector contacts, which have highly doped p layers or layers with a very short life time between the collector contact and the collector region.

The break over current I_{CEN} for the grounded emitter-connection is the collector current at which the a.c. amplification factor b is equal to unity, and the break over current I_{CBN} for the grounded base connection is the collector current at which the d.c. amplification factor is equal to unity.

$$b = B + I_E \frac{dB}{dI_E} \dots\dots\dots (1)$$

Thus I_{CEN} is a little smaller than I_{CBN} .

The region between points A and B is predicted from the same electron injection at the collector contact as the region between points B and C, and the break over current in this region is a function of a

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collector voltage since the current amplification factor varies as the collector voltage.

In order to prove that the reversion of base currents for the grounded-base connection, and the negative resistances for the grounded-emitter in the dipping-grown-diffusion transistors occur from the electron injections on the collector contacts, a special collector contact C_1 was attached on the normal transistor as sketched in Fig. 3.

Fig. 3 A dipping-grown-diffused transistor with a special collector C_1 made by alloying indium.

Fig. 5 Base currents for grounded base connections by pulse measurement.
A; collector contact C_1
B; " " C_2

Fig. 4 Measuring circuits by the pulse method.

Fig. 6 Collector currents vs a.c. current amplification factors (α)

The contact C_2 is made by soldering, at a temperature of 300°C to 400°C, a nickel wire with an alloy of lead and tin, and the contact C_1 is made by alloying at a temperature of 500°C to 550°C with indium.

The characteristic curves of the dipping-grown-diffused transistor are shown in Fig. 1 in the case of a collector contact C_2 , and in Fig. 9 in the case of a collector contact C_1 .

In order to get rid of a thermal effect, pulse technic is used in all measurements and the duration time of a pulse is 100 μ sec. and the repetition rate is 500 c/s. The measuring circuit is shown in Fig. 4. The results are shown in Fig. 5 where the line A (indicated with circles) shows base currents vs emitter currents in the case of the contact C_1 , and B (indicated with crosses) is in the case of the

contact C_2 . The former is normal, but the latter is abnormal and the reversion of the base current occurs at about 10 mA of the collector current. In Fig. 6 are shown the a.c. current amplification factors calculated from Fig. 5.

Fig. 7 shows the efficiency calculated theoretically, which is the ratio of a electron current collected at the collector junction to the electron current injected into collector region on the collector contact.

From Fig. 5 and 7, we can calculate the injection efficiency on the collector contact C_2 . The result is shown in Fig. 8.

Fig. 7 Collector currents vs transit efficiency μ .

As shown in Fig. 6, 8, and 9, it is obvious that the contact C_2 injects electrons, and the efficiency increases with the increasing collector currents.

The a.c. current amplification factor exceeds unity at about 7 mA of the collector current in the case of contact C_2 as shown in Fig. 6. It coincides well with the break over current, obtained from Fig. 1.

The contacts made by soldering at a temperature of 300°C to 400°C with an alloy of lead, tin and indium or with pure indium have the same characteristics as that of the contact C_2 .

In the case of the collector contacts made by soldering with an alloy of lead and tin to the lapped surface of the collector region, the break over current is much larger than that to the etched surface. This is predicted from the recombination of electrons in the abrasion layer.

The authors have shown that, in the dipping-grown-diffused transistor,

(1) the reversion of the base current for the grounded-base connection and the negative resistance for the grounded-emitter occur from the electron injection on the collector contact.

(2) This phenomenon is prevented by the use of collector contacts made by alloying indium. In other words, it is necessary that there is a highly doped layer between a collector contact and a collector region.

REFERENCE

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Fig. 8 Injection efficiency vs collector currents.

Fig. 9 Characteristic curves of a transistor with a collector contact made by alloying with indium.
parameter=base current (μ A)

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