ISSN 0735-2727, Radioelectronics and Communications Systems, 2009, Vol. 52, No. 9, pp. 460–465. © Allerton Press, Inc., 2009.
Original Russian Text © A.N. Frolov, K.A. Frolov, Ye.A. Baganov, 2009, published in Izv. Vyssh. Uchebn. Zaved., Radioelektron., 2009, Vol. 52, No. 9, pp. 10–17.

Parameters Calculation of Drift *n-p-n* Transistors Using Their Output Characteristics

A. N. Frolov, K. A. Frolov, and Ye. A. Baganov
Kherson National Technical University, Kherson, Ukraine

Received in final form August 4, 2008

Abstract—A methodology of estimating physical parameters of transistor's structure in order to obtain the necessary set of its main electrical parameters is described. The suggested methodology is based on applying semi-empiric formulas, obtained by means of statistical processing of a large number of experimental data, and allows determining parameters of transistor's structure with the best optimal combination of current gain, breakdown voltage and cutoff frequency. The methodology is proven by numerous experimental results.

DOI: 10.3103/S0735272709090027

Known and approved methodologies of designing discrete *n-p-n* transistors, bipolar integrated circuits allow calculating physical parameters of transistor's structure, which determine its output electrical characteristics, from technological formation modes. During design of new devices it is often needed to determine physical parameters of transistor's structure using its output parameters: frequency characteristics, gains, junction breakdown voltages, etc. In the present paper we present the basic concepts of methodology used to determine parameters of drift *n-p-n* transistor's structure using specified values of its electrical characteristics.

At the first stage, admixture concentrations at emitter–base N_{EB} and collector–base N_{CB} *p-n* junctions are determined. As practice shows, the avalanche breakdown voltage of the emitter–base junction V_{EB0} used for calculations should be greater by 2–4 times than the required one. In this case, the concentration N_{EB} and the surface concentration of basic admixture decrease. Decrease of N_{EB} causes smaller acceleration field and increased base thickness under the constant base breakdown voltage. However this does not lead to a decrease in cutoff frequency and gain, since lifetime and mobility of the charge carriers at the emitter–base junction increase. It deals with the fact that gain is inversely proportional to the Gummel number [1, 2], i.e. the admixture doze in the active region of base. In this case the capacity of emitter–base *p-n* junction decreases, which causes smaller emitter switching time.

Admixture concentration at the emitter–base *p-n* junction (in cm^{-3}) is determined using avalanche breakdown voltage V_{EB0} (in volts) in accordance with expression [3]:

$$N_{EB} = \left(\frac{2.7 \times 10^{12}}{V_{EB0} - 10/(V_{EB0})^{0.72}} \right)^{3/2}. \tag{1}$$

The best optimal combination of electrical parameters of transistors is obtained, when concentration N_{EB} coincides with maximal admixture concentration in the diffusion region of base $N_{\max}$, i.e. when $N_{\max} = N_{EB}$. It is well known that during formation of planar transistor's base a region with maximal admixture concentration is achieved at some distance from surface. When doping with boron the depth of point with maximal concentration (in um) is determined by expression [4]:

$$x_{j\max} = 0.787(Q_{\text{B}})^{0.104}(Dt)_{\text{B}}^{0.45}, \tag{2}$$

where Q_{B} is boron doze ($\mu\text{C/cm}^2$), $(Dt)_{\text{B}}$ is product of diffusion coefficient of boron D (in cm^2/sec) by time t necessary for the base region to form (in seconds).