Study of characteristics of n-p-n type bipolar power transistor in small-sized metalpolymeric package type SOT-89

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Abstract. In this study the input, output and current gain characteristics of silicon n-p-n type medium power bipolar junction transistors KT242A91 made by the "GRUPPA KREMNY EL" in modern small-sized metalpolymeric package type (SOT-89) have been obtained. The SPICE model that allows simulating realistic transistor behaviour of n-p-n type transistor KT242A91 has been proposed. It is shown that established experimental characteristics for KT242A91 transistor correspond to similar transistor's type characteristics.

1. Introduction

Widely known that the bipolar power junction transistors are key component of power semiconductor electronics devices that is primarily used as a switch [1]. It should be noted that at present the modern electronics industry produces a wide range of bipolar transistors of various ratings and in various packages type [2].

Moreover, modern production tends to miniaturize the component base without losing its power characteristics and therefore power electronic industry comes down to use of small type of metalpolymeric package such as SOT (Small Outline Transistor), QFN (Quad Flat No-leads) and others [2]. However, in Russia at this time moment there is no serial production of bipolar junction transistors in small type of metalpolymeric package (SOT-89, SOT-23 etc.). Therefore, recently by electronic company the JSC «GRUPPA KREMNY EL» (Bryansk, Russia) the production of power electronics components (SiC Schottky diodes, bipolar junction transistors etc.) in small type of metalpolymeric packages type began within the framework of import substitution program. For instance, in our previous studies it is established that characteristics of the SiC Schottky type diodes made in small type of metalpolymeric packages [3,4] are comparable with the same similar types.

In presented study the main goal is establish characteristics of silicon n-p-n type medium power bipolar junction transistor in modern small-sized (SOT-89) type of metalpolymeric package made by «GRUPPA KREMNY EL» [5].

2. Materials and methods

In experiments was tested the following silicon medium power n-p-n type bipolar junction transistor KT242A91 (JSC «GRUPPA KREMNY EL», Bryansk, Russia) in small-sized SOT-89 package type [5] which is analogous to a similar transistor BCX56 (Nexperia, Netherlands [6]). The main parameters for KT242A91 n-p-n type bipolar junction transistor were calculated with using of TCAD modelling methods by analogy with SiC Schottky type diodes in small type of metalpolymeric packages that was described in our previous works [7-9]. For measuring the characteristics were used a programmable source AKIP 1144-160-40, Tektronix MDO3102 two-channel oscillograph (bandwidth 1 GHz, refresh rate 5 GS/s) and Fluke 8845A digital multimeter.

3. Results and discussion

Figure 1 displays the photo of n-p-n type bipolar junction transistor in small-sized SOT-89 type of metalpolymeric package KT242A91 that is produced by «GROUP KREMNY EL» [5].

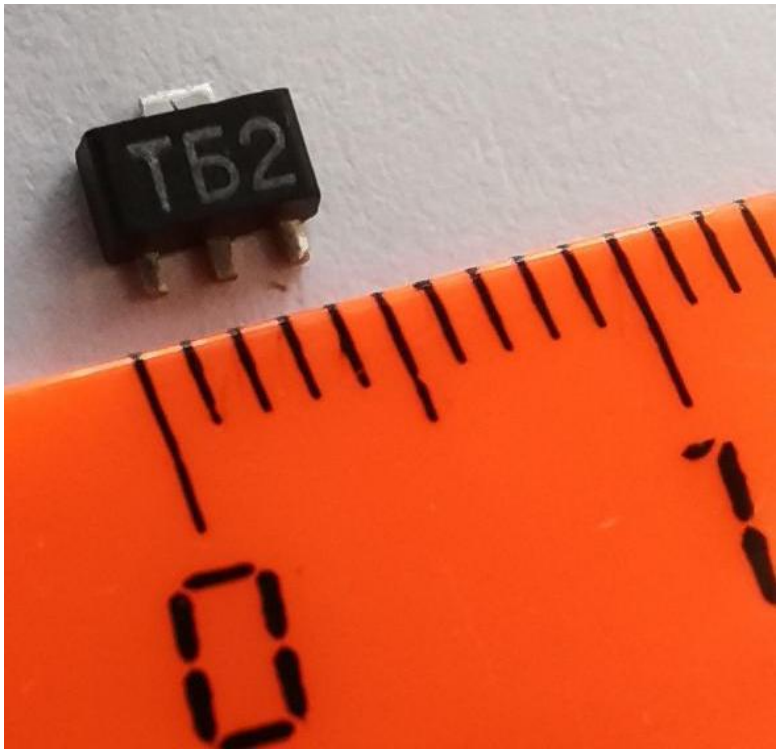

Figure 1. Photo of n-p-n type bipolar junction transistor KT242A91 in small-sized SOT-89 type package [5].

The output characteristic for silicon n-p-n type medium power bipolar junction transistor KT242A91 in small-sized (SOT-89) type package obtained at temperature of 20°C is shown in Figure 2.

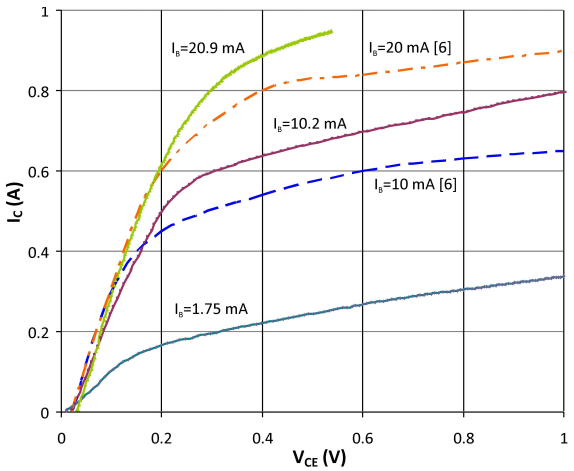

Figure 2. Output characteristics of n-p-n type bipolar junction transistor KT242A91 in small-sized SOT-89 type package.

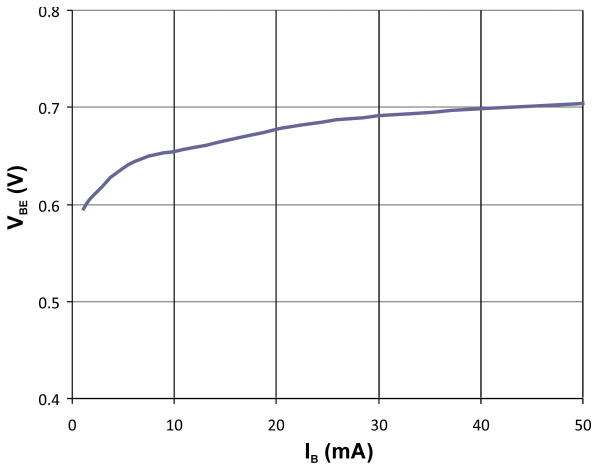

Figure 3. Input characteristics of n-p-n type bipolar junction transistor KT242A91 in small-sized SOT-89 type package (V_{CE}=0 V).

As can be seen from Figure 2 the produced transistor KT242A91 operates with collector current up to 1 A that corresponds to a such type similar transistor BCX56 (1 A [6]). In Figure 2 for comparison also presented data for original medium power n-p-n type bipolar junction transistor BCX56 (Nexperia [6]) for analogous base currents (I_B=10 mA and I_B=20 mA). In Figure 3 presents the experimental input characteristic of n-p-n type bipolar junction transistor KT242A91.

Table 1. The main SPICE model parameters for a modeling of the behavior of the of n-p-n type bipolar junction transistor KT242A91 in small-sized SOT-89 packages type.

Parameters	Description	Value	Units
IS	Transport saturation current	6.2×10^{-14}	A
RC	Collector ohmic resistance	285.417×10^{-3}	Ohm
EG	Bandgap voltage (barrier height)	1.11	eV
VAF	Forward Early voltage	230.45	V
BF	Ideal maximum forward beta	315	–
BR	Ideal maximum reverse beta	20	–
CJC	Base-collector zero-bias p-n capacitance	15.9×10^{-12}	F
FC	Forward-bias depletion capacitor coefficient	495×10^{6}	–
IKF	Corner for forward-beta high-current roll-off	0.9	A
IKR	Corner for reverse-beta high-current roll-off	0.5	A
ISC	Base-collector leakage saturation current	1.2×10^{-13}	A
ISE	Base-emitter leakage saturation current	1×10^{-14}	A
MJC	Base-collector p-n grading factor	0.4	–
MJE	Base-emitter p-n grading factor	0.35	–
NC	Base-collector leakage emission coefficient	1.2	–
NE	Base-emitter leakage emission coefficient	1.2	–
NF	Forward current emission coefficient	0.99	–
NK	High-current roll-off coefficient	0.7	–
NR	Reverse current emission coefficient	0.98	–
RB	Zero-bias (maximum) base resistance	0.2	Ohm
RE	Emitter ohmic resistance	0.08	Ohm
TF	Ideal forward transit time	0.8×10^{-9}	s
TR	Ideal reverse transit time	53×10^{-9}	s
VAR	Reverse early voltage	25	V
VJC	Base-collector built-in potential	0.53	V
VJE	Base-emitter built-in potential	0.67	V
VJS	Collector-substrate built-in potential	729×10^{6}	V
XTB	Forward and reverse beta temperature coefficient	1.3	–

Then, with practical point of view in case when electronic circuits consist from thousands components (diodes, transistors etc.) as a rule for discrete components it makes sense to use of their models created in SPICE (simulation program with integrated circuit emphasis) circuit program that simulates electronic circuits [10].

With this aim the obtained experimental data then were analyzed in Micro-Cap 12 model editor SPICE circuit program [11] that gives us to obtain a SPICE model of the KT242A91 transistor. The main SPICE model parameters for a modeling of the behavior of the of n-p-n type bipolar junction transistor KT242A91 in small-sized SOT-89 package are summarized in the Table 1.

Further, on the base of SPICE model parameters from Table 1 then were calculated in LTspice simulator [12,13] the output and input characteristics for silicon n-p-n type medium power bipolar junction transistor KT242A91 in small-sized (SOT-89) type package (20^{o}C). The output and input characteristics for transistor KT242A91 are shown in Figure 4 and Figure 5. As can be seen, obtained SPICE model for KT242A91 transistor well describes the output and input characteristics with sufficient accuracy.

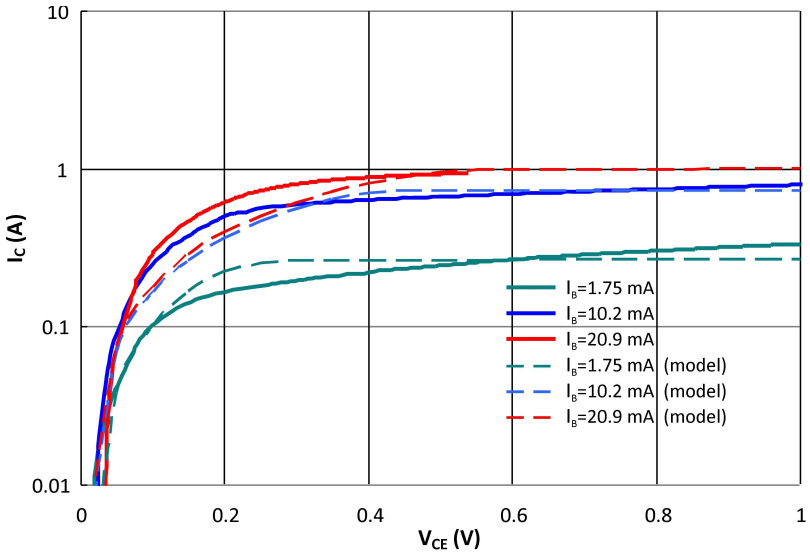

Figure 4. Output characteristics of n-p-n type bipolar junction transistor KT242A91 in small-sized SOT-89 type package calculated in LTspice (dashed line) by model and experimental data (solid line).

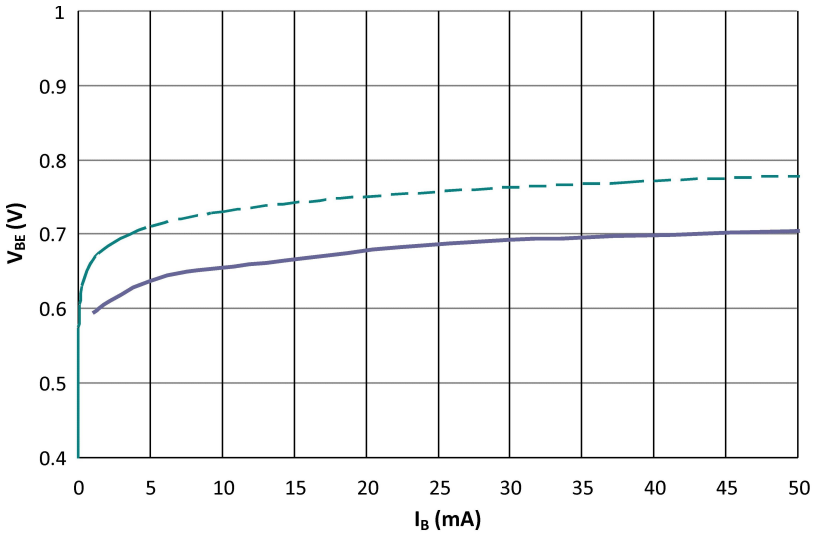

Figure 5. Calculated in LTspice (dashed line) by model and experimental data (solid line) the input characteristics of n-p-n type bipolar junction transistor KT242A91 in small-sized SOT-89 type package (V_{CE}=0 V).

The another important parameter is DC current gain for transistor [14,15] and therefore for KT242A91 transistor this characteristic was obtained experimentally (see Figure 6). Because of this,

on the basis of SPICE model for KT242A91 transistor such characteristic was calculated in LTspice simulator that also presented in Figure 6. As follows from Figure 6 the obtained experimental and simulation data of the current gain dependences for KT242A91 transistor (V_{CE}=1 V) are very close and varying in interval of 91-202 that corresponds to a similar BCX56 transistor type, where current gain values equal of 40-250 [6].

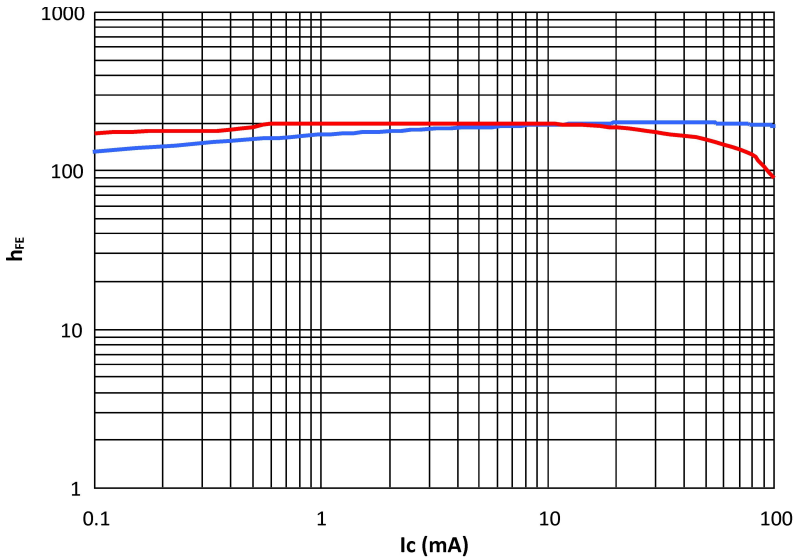

Figure 6. DC current gain dependence on collector current for n-p-n bipolar transistor KT242A91 (small-sized SOT-89 type package) calculated in LTspice (blue line) by model and experimental data (red line) (V_{CE}=1 V).

Thus, analysis of experimental results for silicon medium power n-p-n type bipolar junction transistor KT242A91 made by «GRUPPA KREMNY EL» in small-sized SOT-89 type package shows that obtained characteristics corresponds to data for similar BCX56 [8] transistor type.

4. Conclusions

Finally, the input, output and current gain characteristics of silicon medium power n-p-n type bipolar junction transistor KT242A91 made by «GRUPPA KREMNY EL» in small-sized (SOT-89) type package within the framework of import substitution program have been obtained. In addition, for silicon medium power n-p-n type bipolar junction transistor KT242A91 has been obtained SPICE model that allows simulating realistic transistor behaviour.

It has been established that the studied characteristics for KT242A91 transistor correspond to similar transistor's type and therefore modern small-sized package of this type for transistors can be used in Russian electronic industry within the framework of import substitution program.

Acknowledgements

This work was carried out with financial support of the Russian Ministry of Science and High Education within the framework of complex project by creation of highly technological industry «Creation of highly technological industry of silicon and silicon carbide microelectronic technics products in small-sized metal-polymeric packages of the SOT, SO and QFN types» (agreement of 29 November No. 075-11-2019-035) at the organization of the leading performer of RDDTE (Research and Development Design and Technological Engineering) the Bryansk State Technical University.

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