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SIMULATION OF TEMPERATURE CHARACTERISTICS OF SILICON SENSORS OPERATING AT LOW INJECTION LEVELS

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The thermal sensitivity of silicon bipolar structures is investigated as dependence of the nonequilibrium contact voltage of *p–n*-junction on temperature. A model equation is derived to describe temperature characteristics of silicon sensors with *p–n*-junctions. Experimental dependencies of the voltage across the *p–n*-junction on temperature are compared with similar dependencies obtained in the model suggested.

The temperature properties of silicon diode structures have long been in use in semiconductor measuring transducers. Particularly, the almost linear temperature dependence of the voltage across a forward-biased *p–n*-junction, and the open-circuit e.m.f. of a *p–n*-junction exposed to light, are used as the basis for a whole number of the measuring transducers [1, 2]. The attractiveness of these techniques for temperature measurements is that the thermal sensitivity coefficient of such pickups is invariant to *p–n*-junction area, and is defined by functional properties of the semiconductor (the energy gap width, concentration and lifetime of charge carriers, etc.). All this permits to create high-sensitive instrumental transducers of temperature with the use of integrated microelectronic technology.

Analysis of temperature properties of a *p–n*-junction in the nonequilibrium state is usually performed based on the known Shockley formula for the thin (ideal) *p–n*-junction: $I = I_s(e^{qV/kT} - 1)$. The mode of *p–n*-junction connection and properties of the semiconductors material dictate the corrections, to be introduced as components of the saturation current I_s, in the form of the recombination current $I_{\rm rec}$ and generation current $I_{\rm gen}$, in the space charge regions (SCR) and the adjacent semiconductor layers. In the photogalvanic mode of operation, the Shockley formula is supplemented with another component — the photocurrent $I_{\rm ph}$, which gives $I = I_s(e^{qV/kT} - 1) - I_{\rm ph}$.

The *p–n*-junction voltage V_{pn}, apart from the explicit temperature dependence, exhibits also a latent dependence via the current ratios I/I_s or $I_{\rm ph}/I_s$. Each of these components is a many-factored function of temperature, and the fully explicit representation $V(T)$ becomes awkward enough [3]. Introduction of some restrictions, admissible at analysis of processes in the *p–n*-junction in the nonequilibrium state, permits to set up a simple model of temperature-sensitive diode structure able to describe appropriately the output characteristics of actual sensors. To do this, the voltage $V(T)$ across the *p–n*-junction is considered as a temperature-dependent function of the nonequilibrium contact voltage (CV).

The typical output temperature dependence of a forward-biased silicon *p–n*-junction, as well as the temperature dependence of photovoltage in open-circuit conditions, are well described by the following linear function

$$V_{pn}(T) = V_{pn}^0 - a(T - T^0) \quad (1)$$

where V_{pn}^0 is the voltage (photovoltage) across the *p–n*-junction at the temperature T^0, and a is the temperature coefficient.

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