INVESTIGATING THE DYNAMIC PROPERTIES OF AN MOS-TRANSISTOR STRUCTURE

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The literature provides practically no information on the operation of MOS-transistor switches in the low-temperature range.

The purpose of the present work was to study the dynamic parameters in the temperature range from 77 to 400 K. The investigations were carried out on horizontal high-voltage MOS structures having a drift region and a polysilicon gate, which had been fabricated on KDB80 plates.

Transistor structures at room temperature are characterized by a breakdown voltage of about 400 V, a threshold voltage of about 1.5 V, and a resistance in the unblocked state ≤ 1000 ohm.

The load resistance of the investigated switch amounted to $R_L = R_{L1} + R_{L2}$, where R_{L1} was constant, while R_{L2} was chosen in accordance with the experimental conditions. The input resistance at the point where the oscilloscope was connected was determined mainly by R_{L1} ($R_{L1} \ll R_{L2}$) and was matched to the wave impedance of the connecting cable and the input impedance of the S1-75 oscilloscope. The duration of the transients in the measurement circuit proper amounted to $1 \cdot 10^{-8}$ sec which is much shorter than the time corresponding to the transients in the investigated devices. The time required for the transistor to make the transition from the blocked state to the unblocked state includes three stages (see [1]); delay, switching-on, and establishment of steady-state conduction.

The times required for switching the device on and off were determined as the times during which the voltage across the sink varied from 0.1 to 0.9 V. The values determined for τ_{on} and τ_{off} correspond to the stages in the transition of the switch to the active mode. The dynamic parameters of the switch were investigated in the temperature interval from 77 to 400 K for various values of load resistance (2 to 25 kohm).

Figure 1 displays the temperature dependence of the time required to switch the device on (curves 1, 2), and of the time required to switch the device off (curves 3, 4): curves 1, 3 correspond to a load resistance of 2 kohm, while curves 2, 4 correspond to a load resistance of 25 kohm.

The switching-on time τ_{on} manifests a complex dependence on temperature and, as is evident from Fig. 1 (curves 1, 2), it decreases fairly abruptly at first with increasing temperature, reaches a minimum at 100-120 K, and then increases again. Thus, at a temperature of 400 K, τ_{on} increases by approximately a factor of 5 in comparison with the switching-on time determined at a temperature of 110 K.

At high temperatures, the switching-on time depends substantially on the load resistance. Whereas at liquid-nitrogen temperature a decrease of the load resistance from 25 kohm to 2 kohm leads to an increase of approximately 18% in the switching-on time, at T = 300 K a similar change in load resistance increases the switching-on time by almost a factor of two. The minimum τ_{on} amounted to 55 nsec for a load of 25 kohm and a temperature of 110 K.

The switching-off time τ_{off} increases linearly with increasing temperature (Fig. 1, curves 3, 4). At liquid-nitrogen temperature, τ_{off} amounts to 20 nsec for a load of 2 kohm and reaches 230-240 nsec for R_L = 25 kohm. The higher the load resistance, the smaller the relative change in the switching-off time. Thus, for R_L = 2 kohm a change in temperature from 77 K to 400 K leads to a change in τ_{off} by a factor of two (curve 3), while for R_L = 25 kohm the change is merely 13% (curve 4).

From the results obtained it follows that for a low load resistance the principal parameter determining the inertia of an MOS-transistor switch throughout the entire temperature interval is the switching-on time whose minimum value lies in the temperature range from 100-120 K. The switching-off time in the same temperature range amounts to 25% of τ_{on} for R_L = 2 kohm. If R_L = 25 kohm, it follows that in the indicated temperature range (100-120 K) the effect of the switching-on time may be neglected. With an increase or decrease in temperature

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