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(*C–V*) and *y*-parameters determination of JFETs under different environmental conditions

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ABSTRACT

The *C–V* characteristics of n-channel JFET have been measured under different environmental conditions of temperature up to 140 °C and γ-rays up to 100 kGy. For low bias voltage and frequency, the input capacitance, C_{iss}, is shown to be a direct function of temperature. On the other hand, its value was shown to decrease from 11.68 down to 8.17 nF due to γ-exposure up to 100 kGy. The *y*-parameters of common source amplifier were calculated under the influence of temperature and γ-rays. The results show that the susceptance component of the admittance increases due to increase in temperature, while decreasing after γ-exposure. Considering the cutoff frequency f_{T0}, it is clear that as the temperature increases from 30 up to 140 °C, f_{T0} dropped from 47 MHz down to 5 MHz, measured at 0.8 V. On the other hand its value was shown to increase from 43 MHz up to 102 MHz, measured at the same bias voltage, due to γ-exposure up to 100 kGy.

1. Introduction

Capacitance–voltage (*C–V*) measurements provide an excellent means of monitoring the formation of channels on junction field effect transistors [1–3]. On the other hand, admittance or *y*-parameters are widely used to describe the characteristics of electronic devices, where the values of the *y*-parameters for junction field effect transistor (JFET) are affected by the internal capacitance values [4]. The physical structure of the JFET produces inter-terminal capacitances; these are the gate–drain capacitance C_{gd}, the gate–source capacitance C_{gs}, and the drain–source capacitance C_{ds}.

In data sheet these are represented by C_{iss} (input), C_{oss} (output), and C_{rss} (reverse transfer) capacitances, where [5]

$$C_{iss} = C_{gs} + C_{gd} \quad (1)$$

$$C_{oss} = C_{ds} \quad (2)$$

$$C_{rss} = C_{gd} \quad (3)$$

In determining the switching performance of a JFET device C_{iss} is the most important factor. When an input voltage pulse is applied to a device, the input capacitance must be charged and discharged, before V_{GS} rise, or fall to its final value. The common source FET amplifier is affected by the inter-electrode capacitance that affects its high-frequency performance. On the other hand, the mutual conductance of a FET will fall at high frequencies. The intrinsic cutoff frequency f_{T0} of JFET is the frequency at which transconductance g_{m0} has fallen to 0.7 times its value at 1 kHz. Also, f_{T0} depends on C_{gs} and C_{gd} [6–8]. Therefore, the present paper is concerned with studying the inter-terminal capacitances of N-channel JFET, *y*-parameters, and intrinsic cutoff frequency, wherever the devices are operated under different environmental conditions of temperature and γ-radiation.

2. Experimental procedure

The temperature dependence of *C–V* relationship and common source *y*-parameters of N-channel junction field effect transistors (JFET) of type 245B amplifier (Fig. 1) are investigated in different environmental conditions of temperature (from 10 up to 140 °C) and γ-radiation (up to 100 kGy). The γ-source used is a Cobalt-60, and irradiation process was carried out at the National Center for Radiation Research and Technology, Atomic Energy Authority of Egypt. A programmable automatic RCL meter, model PM 6306, manufactured by Fluke was used for precise measurements of *C–V* and *C–F* characteristics of the proposed devices. Finally, from the obtained results, the gate-to-source capacitance, C_{gs}; drain-to-source capacitance, C_{gd}; quality factor, *Q*-factor; dissipation factor, *D*-factor; phase angle, φ; and impedance, *R* are investigated.

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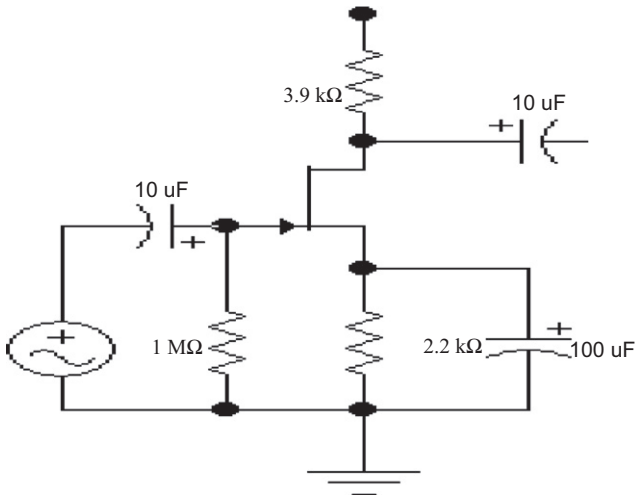

Fig. 1. JFET amplifier circuit.

3. Results and discussion

3.1. C–V characteristics

For studying the reverse gate–source and gate–drain junctions, the *C–V* relationships were plotted at a reverse bias voltage ranging from 0.0 up to 5 V at a step of 0.1 V, at different frequency levels in the range from 100 Hz up to 1 MHz.

Fig. 2a and b shows the *C–V* and *C–F* curves of the input capacitance plotted at two temperature levels of 10 and 140 °C, from which it is clear that the input capacitance value is a direct function of both voltage and frequency. Also, it is clear that the input capacitance is a function of temperature when measured at small bias voltage and low frequency bands. Concerning the input capacitance (Fig. 2c), its value is shown to increase with temperature in the range from 10 up to 140 °C, measured at 100 Hz and 1 MHz.

On the other hand C_{iss} was plotted as a function of bias voltage (Fig. 3a) and frequency (Fig. 3b) before and after γ-exposure dose of 50 and 100 kGy. An initial value of C_{iss}, measured at no bias voltage and frequency of 100 Hz, was found to be 11 600 pF (Fig. 3a). This value was shown to decrease down to 8100 pF due to γ-exposure up to 100 kGy. But at higher bias voltage values, the change in capacitance value due to γ-exposure is shown to be less sensitive. Also, at higher frequency values the change in C_{iss} due to γ-exposure is negligible.

The obtained decrease in the capacitance value may be attributed to a widening occurring at the edges of the space charge region for the same applied voltage. In other words, due to the formation of a very narrow intrinsic region in the neighborhood of the metallurgical PN-junction, i.e., compensation of chemical doping by radiation induced deep traps will tend to produce a region [9–11].

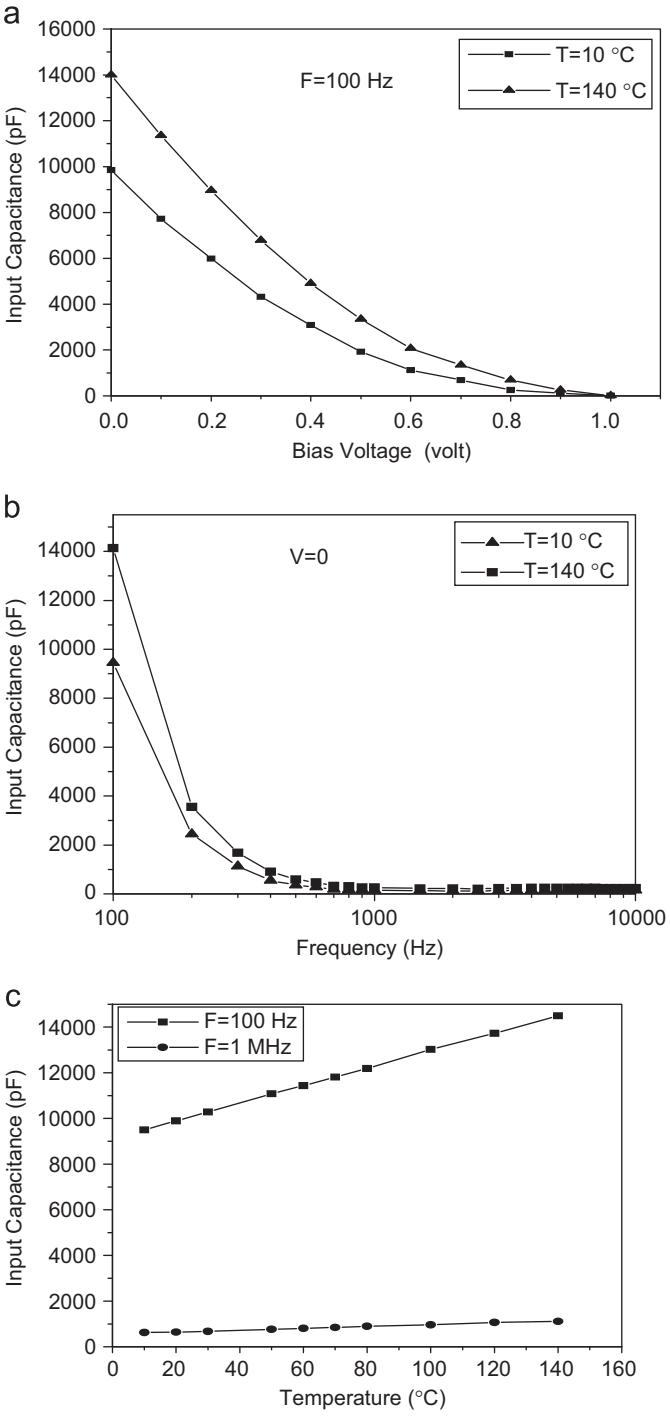

Fig. 2. (a) (C_{iss}–bias voltage) relationship measured at two temperature levels; (b) (C_{iss}–F) relationship measured at two temperature levels and (c) temperature dependence of input capacitance of JFETs measured at different frequency levels.

3.2. Temperature effect on physical parameters of gate–source junction

By definition, the quality factor of a junction (Q) can be expressed as the ratio of the inductive reactance of the junction to its resistance. On the other hand, the dissipation factor (D) is governed by

$$D = 1/2\pi \ \text{FCR} \tag{4}$$

The temperature effect on both *Q*- and *D*-factors was investigated in the range from 20 up to 140 °C. It is clear from Fig. 4 that at reverse gate–source mode, the temperature increase leads to a pronounced increase in quality factor and as a result dissipation factor decreases pronouncedly.

Considering the junction impedance, it is clearly shown (Fig. 5) that the gate–source junction impedance is greatly affected by temperature variations. The junction impedance was shown to decrease from an initial value of 430 Ω, measured at 20 °C, down to 200 Ω, measured at 120 °C. Also, it is clear from the same figure that the phase angle decreases with temperature increase, where its value decreased from −37, measured at 20 °C down to −42, measured at 140 °C.