SWITCHING TRANSIENT OF MISS DIODES INFLUENCED BY ILLUMINATION

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1. Introduction

The MISS diode, of metal-tunneling oxide-n layer-p^+ layer structure, was discovered by Yamamoto and Morimoto [1], and was also investigated by others [2—4]. Simmons and Habib established the first quantitative model, followed by some more exact models [5—8]. A somewhat different theory was given by Buxo and Sarrabayrouse [9, 10]. The switching transient of the device was measured by Kroger [2], Yamamoto [4] and Buxo [9]. Some charge-storage phenomena were also reported [11, 12]. The physical process during switching was outlined in [13] and an approximate calculation was given to determine the switching times. The effect of illumination on the MISS was measured by Yamamoto [4], Nassibian [14], Machalov [15] and Sarrabayrouse [10], unanimously giving a decrease of the threshold voltage with increasing light intensity.

2. Operation of the device and physical picture of the transient process

The device has a high and a low impedance state. In the high impedance state a wide depletion layer stretches from the insulator- (n-type) semiconductor interface toward the p—n junction. The thermally generated holes may traverse the thin insulator, and there is a high voltage across the device. In the low impedance state the surface is inverted, there is a high (hole) inversion charge, the depletion layer is collapsed, the p—n junction is forward biased and a high electric field exists in the insulator. As a result, electrons are injected from the metal into the conduction band of the n-layer, these electrons force the junction into forward direction. The junction injects holes to the insulator-semiconductor interface thus maintaining the inversion charge in spite of hole losses across the thin insulator.

Connecting the device to a pulse generator across a resistor, a three-phase switch-in process can be observed [13]. First the depletion layer starts to extend toward the p—n junction, and the voltage across the device increases. (First phase).

Near to or at the threshold voltage the p—n junction starts to inject holes, and the build-up of the inversion charge begins. The voltage across the device is nearly constant (second phase). After reaching a critical charge, the metal starts to inject electrons into the n-layer, the depletion layer collapses and the device turns on (third phase). Increasing the pulse voltage, the first phase decreases slowly, the second phase decreases drastically, and the third phase hardly changes.

3. Results and discussion

Epitaxial n/p^+ slice was used to prepare the device. The n-type epitaxial layer had about $1.5 \cdot 10^{15}/\text{cm}^3$ doping concentration and 7 μm thickness. The thin oxide layer was grown in dry oxigen for 10 min at 800 °C. This resulted in an oxide thickness of about 3.5 nm (35 Å). A platinum layer was formed atop of this oxide by cathode sputtering. The thin oxide layer had a circular shape with a diameter of about 0.4 mm. The device was driven by a voltage pulse with a resistor in series. When the device was illuminated by white light, the length of the second phase was greatly reduced, the first and the third phases were very little influenced. This is in accordance with the physical model outlined above. The first phase, basically the result of a capacitive effect, cannot be influenced effectively by light.

In the third phase where both the electron injection from the metal and the hole injection from the p—n junction are high, the photo current cannot influence significantly the switching process. However, in the second phase the photo current can greatly aid the formation of the inversion layer at the insulator-semiconductor interface. This is partly accomplished by the photogenerated holes, drifting to the interface, but to a greater extent by an amplified photo current: the generated electrons bias the p—n junction into the forward direction, thus holes are injected to the interface, like in a phototransistor. The duration of the second phase was measured with different pulse amplitudes (V_g) and illumination intensities (Fig. 1). The second phase decreased by increasing the voltage or the illumination. [13] gives the formula for calculating the second phase:

$$t_d = \frac{R_S \cdot \text{const}}{V_g - V_{th}} = \frac{K}{V_g - V_{th}} \tag{1}$$

where t_d is the duration of the second phase, V_g is the pulse amplitude, V_{th} is the threshold voltage (where the device turns to the low impedance state), R_S is the series resistance, K is a constant, which, however, depends on the structural parameters of the MISS, and slightly on V_{th}. Using Eq. (1), taking a value of $4 \cdot 10^{-7}$ s V for K, and choosing the value of V_{th} so that the calculated and the

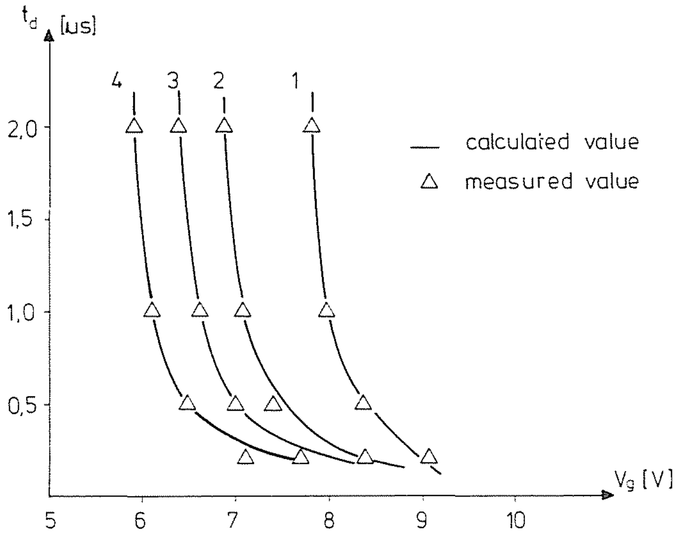

Fig. 1. Second phase vs. generator voltage and illumination intensity. Intensities: 1: 0 lux, 2: 7000 lux, 3: 14000 lux, 4: 21000 lux

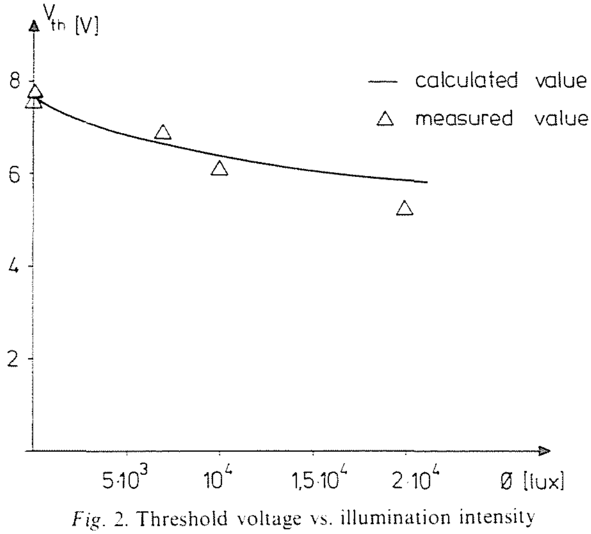

Fig. 2. Threshold voltage vs. illumination intensity

measured results are equal at $t_d = 1$ μs, leads to the curves in smooth line in Fig. 1. The measured values fit quite well this curve. There are greater deviations only for higher pulse amplitudes and lower t_d values. In this region, however, t_d cannot be measured correctly, because there are no sharp boundaries between the first and the second as well as between the second and third phases.

The decrease of the threshold voltage with illumination was also measured under static circumstances, as shown in Fig. 2. The calculated curve fits rather well the measured values, there is a greater deviation only for higher light intensities.

Summary

The voltage transient of the MISS diode is discussed, when the device is driven by a voltage pulse across a series resistor and is illuminated. The second phase of the switching transient decreases with increasing light bias or pulse amplitude. An approximate calculation is given, which fits quite well the measured data.

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