COMPUTER AND EXPERIMENTAL INVESTIGATION OF INTERACTION BETWEEN EM FIELD AND PIN-DIODE.

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INTRODUCTION. In spite of semiconductor PIN-diodes successfully used in microwave control devices many aspects of their behavior are not clear yet. For instance, only few experimental facts are known in precedent literature concerning bistability in PIN-diodes at radiofrequencies and microwave. An impedance jumps accompanied by input RF or microwave power changes and producing corresponding jumps in output and reflected signals are the external display of this effect.

Different explanations of this effect were suggested: the influence of impact ionization, thermal mechanism and etc. [1...3]. But all of them didn't give neither quantitative nor qualitative model. There is more accurate model of this effect in [4,5]. It based on the PIN-diode model [4] and takes into consideration an internal DC and RF current and RF voltage feedback between two spatial structure regions in the i-layer: PN junction depletion (space-charge) region providing the detector action and the undepleted region. At high-power level this feedback leads to a rapid change of RF field distribution between the i-layer regions and to a jump of the diode RF impedance. This model allowes to get the physics model for bistability effect analysis and to compare the computer simulation results with experimental data. Previous physics-based models and numerically-based simulation using the one-dimensional isothermal drift-diffussion model of a semiconductor structure [6,7] didn't allow to simulate this effect.

COMPUTER SIMULATION RESULTS. The computer simulation of the PIN-diode bistability effect was developed. The equivalent circuit under test comprised the PIN-diode (it's impedance was calculated according [4] taking account of the internal feedback) connected in shunt to a transmission line with the characteristic impedance Z_c terminated by a matched load Z_L. External DC circuit of the PIN-diode was short. Two points of the input power P_1 and P_2 at the amplitude characteristic (Fig.1) determined the bistability area. In case there were no such area $P_1=P_2$.

The computer analysis allowed the relationship between bistability effect and device dimensions, material characteristics and circuit parameters to be determined. The numerical results are shown in Figs. 2...4. Figure 2 shows the relation between the operating frequency and two borders of the bistability area. The bistability effect is presented at frequency area from 10 MHz to 10 GHz. The appearance of the hysteresis area depends on the internal DC and RF current and RF voltage feedback between two spatial structure regions in the i-layer. The dissapearance of this effect with operating frequency rising is determined by the two reasons. The first is the insertion loss rising. From the other hand the influence of diode lead inductance began to increase too and the isolation is decrease. Due to this facts the falling down of the PIN-diode impedance caused by high level microwave power begin to be negligible. Therefore the bistability area is dissappeared.

Figures 3 and 4 illustrate the relation between the bistability effect borders and the diode characteristics. They are the i-layer thickness W_i and the i-layer doping level N_i. This parameters determined a distribution of the DC and RF current and RF voltage between two spatial structure regions in the i-layer. Note that the increase of the characteristic impedance Z_c leads to the decrease of the bistability area. The presence of the bistability effect is determined by the internal feedback in PIN-diode and by the circuit parameters.

EXPERIMENTAL RESULTS. The validity of the computer simulation results has been experimentally verified by investigating PIN structures in the different frequency bands. The experimental installation in simplified form includes a RF or microwave high-power source connected to a waveguide with the PIN-diode under test and a matched load. The measurements were carried out in the following frequency ranges: 1-20 MHz, 2-8 GHz with power levels up to 20 W. Figure 5 shows, for example, the relation between the borders of the bistability area (the borders in this case are expressed in volts) and operating frequency for the commercial available Si PIN-diode KA507ü. Computer simulation results and experimental data are in a satisfactory agreement.

CONCLUSION. The hysteresis effect is an important physical property of the PIN-diodes. Modeling and experimental results having in this work helped to explain the PIN-diode bistability effect.

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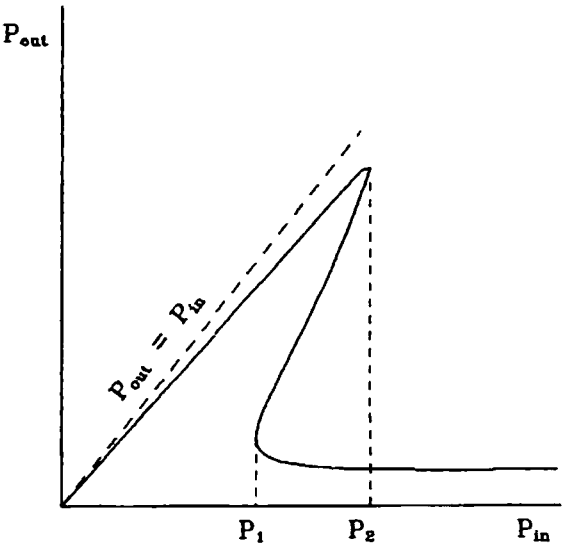
P_{out}
$P_{out} = P_{in}$
P_1
P_2
P_{in}

Fig.1

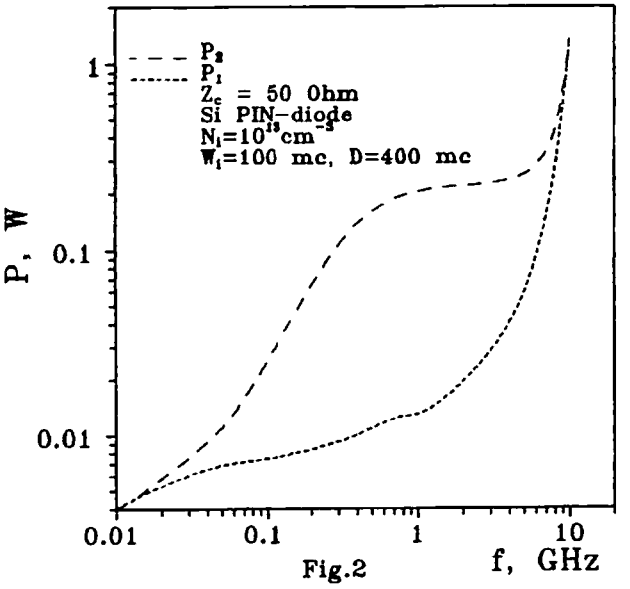
P_2
P_1
Z_c = 50 Ohm
Si PIN-diode
$N_i=10^{13}cm^{-3}$
W_i=100 mc, D=400 mc
P, W
1
0.1
0.01
0.01
0.1
1
10
f, GHz

Fig.2

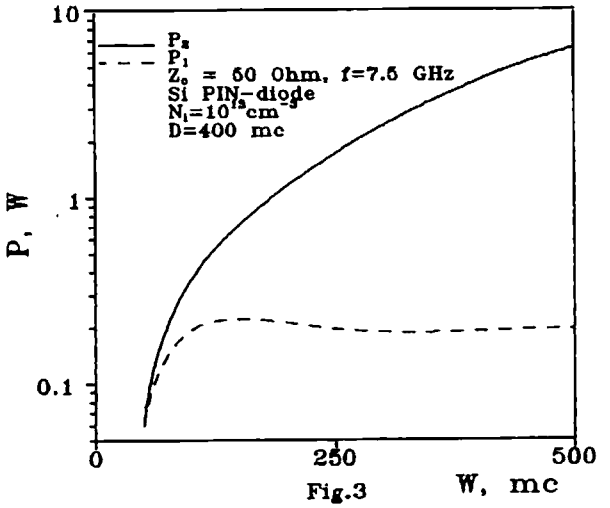

Fig.3

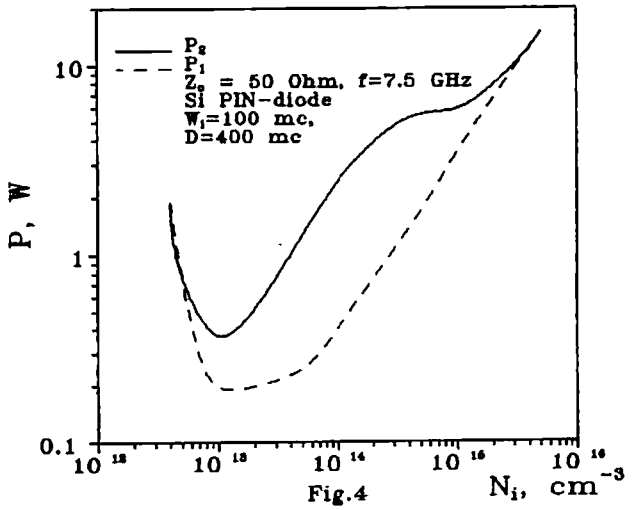

Fig.4

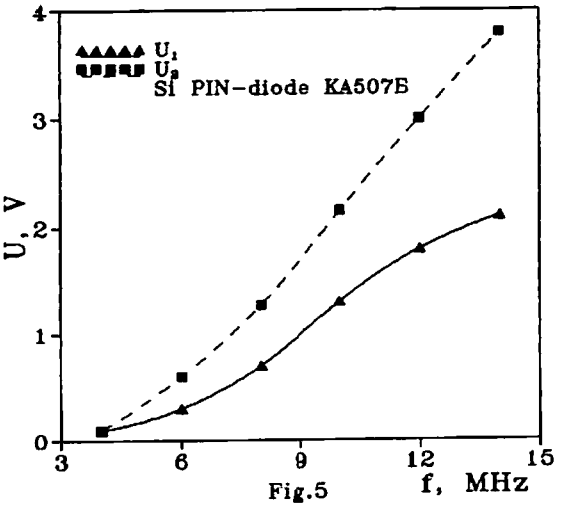

Fig.5