Electrical characterization of the junctions P^+N by C-V technique

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Technique CV exploits measurement in mode of small signals for a relatively high frequency of the capacity of a junction metal-semi driver or a junction P^+NR (or PN^+ polarized in reverse by a tension V_R The experimental analysis of this technique makes it possible to determine some electric properties of the junctions P^+N or Schottky.

We describe here, the method used and we expose then the results obtained by this technique on diodes containing silicon (Si).

Key words: Junction P^+N, Schottky, Capacity-tension

I - INTRODUCTION

In this work we took measurements of capacity according to polarization reverses V_R on samples, which are junctions P^+N containing silicon, with an aim of evaluating the width of the ZCE, the average doping of the active zone as well as the height of barrier of the junctions We **pay** then and discuss the experimental results concerning the parameters quoted above, obtained on junctions containing silicon (Si). [1]

II - THEORETICAL PART

II-1. Capacity of depletion

To introduce the concept of the capacity of depletion we employ the simplified case of uniformly doped material.

The area of depletion of a barrier of Schottky or an abrupt junction asymmetrical P^+N contains a space charge distributed due to the ionized donors.

An increase ΔV in the biasing V involves an increase ΔQ in the load in the area of déplétion.

In this case the capacity C is related to the width of the area of déplétion by [3]:

$$C = S\frac{dQ}{dV_r} = \frac{\varepsilon_0 \varepsilon S}{x_d} \qquad \textbf{(1)}$$

$$x_d = \left(\frac{2\varepsilon_0\varepsilon}{q(N_D - N_A)}(V_b - V_r)\right)^{\frac{1}{2}} \qquad (2)$$

ε is the permittivity of the semiconductor, x_d is the width of the ZCE, $N_D - N_A$ is doping effective, V_b is the tension of diffusion, V_r is opposite polarization, S: the surface of diode.

The expression of the equation of the profile of doping is given by [1]:

$$N(x_d) = -\frac{C^3}{q\varepsilon_0\varepsilon S^2}\left(\frac{\Delta C}{\Delta V_r}\right)^{-1} \qquad (3)$$

What can also be written in the form:

$$N(x_d) = -\frac{2}{q\varepsilon_0\varepsilon S^2}\left(\frac{\Delta C^{-2}}{\Delta V_r}\right)^{-1} \qquad (4)$$

II-2. Case of an abrupt junction

In the model of the abrupt junction, doping is uniform and the N(x) concentration is constant.
The equation (4) is written:

* Junction Pn:

$$C = \left(\frac{S\varepsilon_0\varepsilon\, q}{2(V_r + V_b)}\left(\frac{N_A N_D}{N_A + N_d}\right)\right)^{\frac{1}{2}} \qquad (5)$$

* Junction P^+N $N_A >> N_D$

$$C = \left(\frac{S\varepsilon_0\varepsilon q N_D}{2(V_r + V_b)}\right)^{\frac{1}{2}} \qquad (6)$$

This equation shows that the curve C^{-2}=f(V_R) is a line whose slope gives the concentration of the ionized centers NR and the value of V_B

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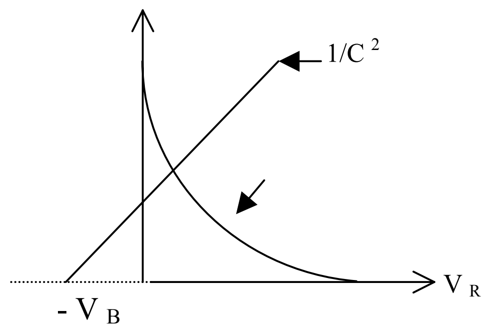


FIG (1): Variation of the capacity in a junction abrupt

II-3. Case of a gradual linear junction

In this junction the profile of doping through the area of depletion is not abrupt any more but gradual and the density of load varies linearly with X through all the area.

The doping of this junction is given by the expression:

$$N = a.x \quad (7)$$

has being the gradient of doping.
Of this expression we can write:

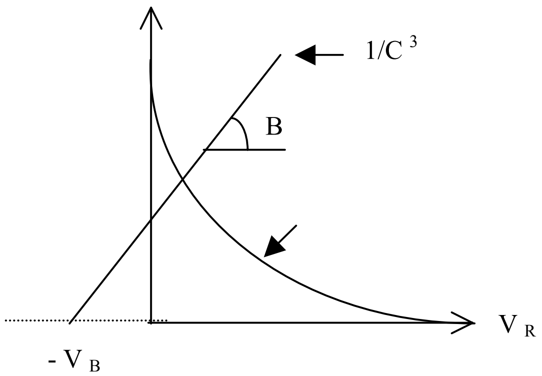
$$N = \frac{a\varepsilon_0\varepsilon\, S}{C} \quad (8)$$

If we replace the equation (8) in the equation (4), we obtain after integration:

$$C = \left(\frac{aq(\varepsilon_0\varepsilon)^2 S^3}{3(V_r + V_b)}\right)^{\frac{1}{3}} \quad (9)$$

the curve C^{-3} according to V_R is a line whose slope B gives the value of gradient a:

$$b = \frac{3}{aq(\varepsilon_0\varepsilon)^2 S^3}$$



FIG(2): Variation of the capacity in a gradual linear junction

III - EXPERIMENTAL PART

We took measurements C-V at ambient temperature at the Laboratory of materials and renewable energies of the University of Tlemcen on diodes containing silicon, by using the impedance measures (Keithley 590).
The sweeping of tension is carried out of 0 to 2v with the step of 0,02V. The frequencies of measurement are 1MHz and 100 KHz.
The results obtained are presented in the two following tables:

frequencies	Samples	V_B (v)	Doping (cm^{-3}/S^2)
F = 1 MHz	D2	1	$1,19.10^{8}$
F=100 KHz		0,86	$1,14.\ 10^{8}$
F = 1 MHz	D3	1,08	$5,9.\ 10^{7}$
F=100 KHz		0,9	$5,56.\ 10^{7}$
F = 1 MHz	D4	0,69	$3,78.\ 10^{7}$
F=100 KHz		0,56	$4,07.\ 10^{7}$
F=1 MHz	D5	2,9	$7,85\ 10^{8}$
F=100 KHz		1,18	$7,64\ 10^{8}$

frequencies	Sample	V_B (v)	Doping (cm^{-3}/S^2)
F = 1 MHz	D6	1,62	$2,25.\ 10^{8}$
F=100 KHz		0,88	$2,46.\ 10^{8}$
F = 1 MHz	D8	1,09	$5,10.10^{7}$
F=100 KHz		0,98	$5,04.10^{7}$
F = 1 MHz	D11	0,41	$8,03.10^{11}$ (cm^{-3}/S^3)
F=100 KHz		0,34	$8.47.10^{11}$ (cm^{-3}/S^3)

The following figures represent the variations of the capacity-tension of the various diodes.

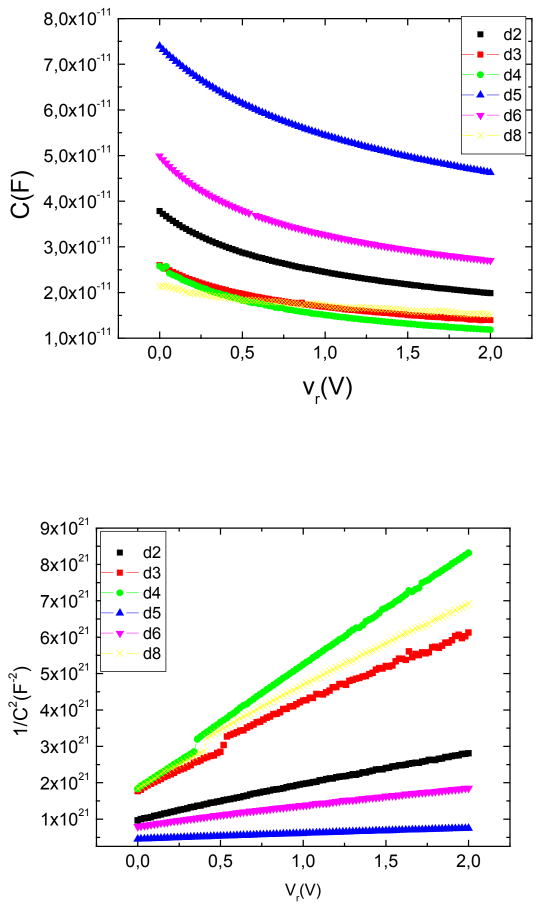


FIG (3) Characteristic $C = f(V_R)$ and $1/C^2 = f(V_R)$ Diodes (Si) at F=1MHz.

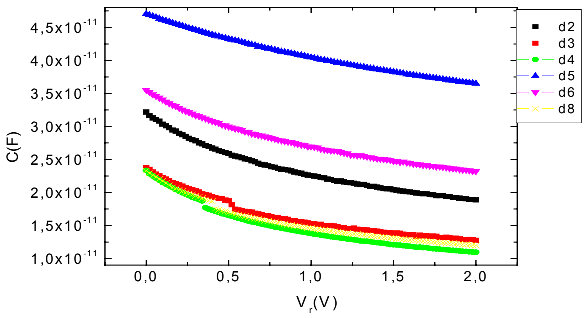


FIG (4-a): Characteristic C=f(V $_R$) Diodes (Si) at f=100 KHz

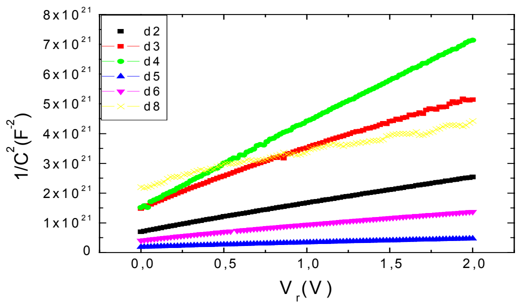
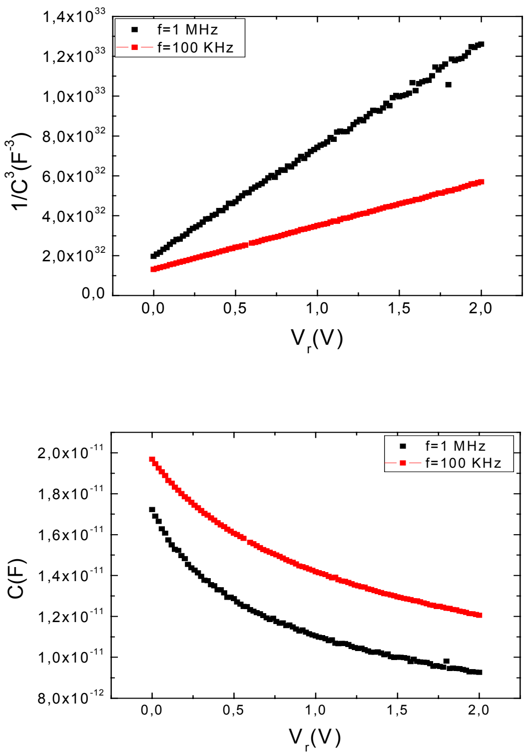


FIG (4-b): Characteristic 1/C ^{2} = f(V$_R$) Diodes (Si) at f=100 KHz



FIG(5): Characteristic C=f(V $_R$ and 1/C ^{3} = f(V$_R$) diode N°11

We noted (for the two frequencies) that:

- characteristic 1/C ^{2} according to reverse polarization is linear for the diodes N 2;3,;4;5;6;8. consequently, these diodes are abrupt.
- the diode N°11 has a gradual junction because characteristic 1/C ^{3} is linear.

CONCLUSION

The characteristics capacity-tension of the diodes which we studied, have permisde to deduce us:

- the height of barrier and concentration of the impurities ionized in the zone of déplétion.
- profile of this concentration if the material is not uniformly doped and if this concentration does not vary in a too abrupt way.
- the nature of the junction: abrupt if curve
- 1/C ^{2} = f(V$_R$)is a line, gradual if curve

1/C ^{3} = f(V $_R$ is linear.

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