Extraction Of The Series-Resistance Of Au-Oxide-n-InP Structures

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Abstract - **This paper reports on the electrical properties of Au-oxide-n-InP structures obtained by oxygen plasma oxidation and those oxidised by air. A discussion on the evolution of the series resistance according to the temperature is presented. The values of the electrical parameters are obtained with a modified current-voltage-temperature model. The results obtained establish the relationship between the series resistance and the temperature for the Au - oxide - n-InP structures obtained by oxygen plasma oxidation and those oxidised by air. The values of this parameter in the Au-oxide-n-InP structures are in good agreement with those published in the literature.**

I. INTRODUCTION

A lot of research has been done on metal-insulator (oxide) - Indium Phosphide structures [1-7]. In the past decades, several methods have been developed to estimate the parameters of metal-oxide-semiconductor. They all differ from each other in the method used to determine the series resistance values. Norde [8] suggested an empirical relationship for diode analysis, provided that the ideality factor (n) equals unity. In some work, Norde's equation (where n>1) was modified so as to get a better evaluation of the diode parameters from the direct current-voltage characteristics. Chung and Chung [9] developed an alternative approach to evaluate these parameters, but with a great error interval. Werner [10] implemented a technique based on the calculation of the conductance, allowing the estimation of the diode parameters with a relatively good accuracy. Nevertheless, this technique cannot be applied to samples treated with oxygen plasma. Chattopadhyay and Raychaudhuri [11] devised a modified conductance technique for the determination of the series resistance. In order to fix the Richardson constant, they represented diodes made of interfacial layers by a realistic but simplified model. They used this model to compute all the physical parameters of these diodes.

In this work, we have developed an approach for the determination of the electrical parameters. Samples were studied in this paper are obtained, at oxygen pressure of 10^{-3} mbar, plasma power varies from 50 W to 140 W and treatment duration ranges times at ranges of 1.3 min to 25 min.

II. EXPERIMENTAL PROCEEDING

<100> oriented undoped n-InP substrates, with a free carrier concentration of 10^{16} cm^{-3} (provided by the company " Métaux Spéciaux "), were investigated at the laboratory of plasma. The unpolished surface (backside) is treated with HCL (1:2) for two minutes. Thereafter, it is rinsed in deionized water and then in ethanol. Finally, the surface is blown dry in a nitrogen flow. The ohmic contact is then made with Au-Ge eutectic alloy and Au is deposited on the backside, under vacuum 10^{-4} mbar. The polished surface is prepared in the same way as the backside, but with a lower HCL concentration of only 1:4. The substrate is then mounted on a holder and introduced into a plasma reactor. After oxygen plasma treatment, six Metal-Insulator-Semiconductor (MIS) structures are formed on each sample by evaporation of the Au contacts.

The thickness of each Au contact is equal to 2µm and its area equals to 0.78mm^2. The sample is then annealed at 200°C for 15 minutes at nitrogen pressure of 200mbar. In order to improve the quality of the oxide and the interfacial layer, annealing is performed at the surface of the Au contact.

III. EXTRACTION OF PARAMETERS

The current transport in the structures under study results from thermionic emission, the expression for the current through the junction of the Au – oxide interfacial – n-InP samples is modified [12].

$$I = I_o \exp(\frac{q\Phi'}{nkT}) \exp(\frac{q(V - R_s I)}{nkT}) \qquad (1)$$

with $V > 3\ \frac{kT}{q}$, $I_0 = S.A^*.T^2$ and $\Phi' = n\ \Phi_b$

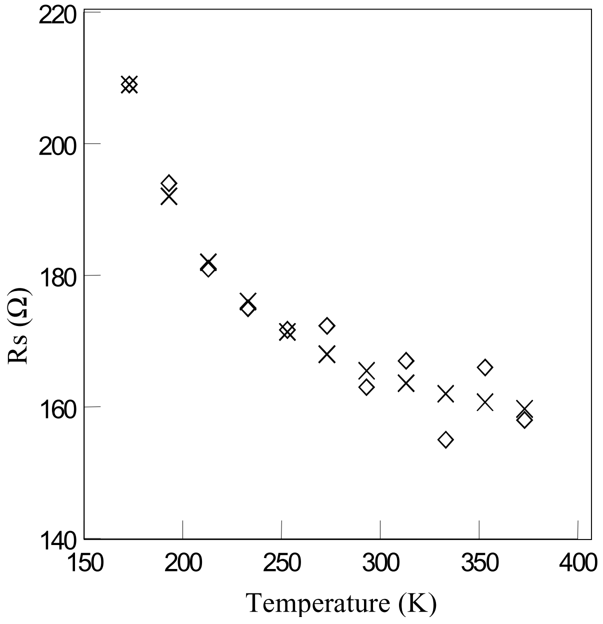

Fig.1: Temperature variation of series resistance R_S for Au-n-InP diodes treated with oxygen plasma: (◊) experimental (x) simulated

A^* and S are the effective Richardson constant and the diode area, respectively. The other symbols bear their usual meanings.

In this equation, the parameters to be found are I_0, Φ', n and R_S[12]. Table I presents the diode parameters computed for different values of the oxide thickness at ambient temperature. The oxide thickness of these structures lies between 65 Å and 635 Å.

The current transport in the structures under study results from thermionic emission, tunneling across the interfacial layer and the effect of barrier lowering due to the image force [12]. The expression for the current through the junction of the Au – oxide interfacial – n-InP samples is then modified so as to get the Richardson constant independent of the temperature. Let A^*_c be the correct value of Richardson constant. For the samples treated by plasma, the current is written as:

$$I = SA_c^* T^2 \exp(-a\delta\chi^{1/2}) \exp(\frac{-q(\Phi_b(0K)-\Delta\Phi_{oi})}{nkT}) \exp(\frac{q(V-R_sI)}{nkT}) \tag{2}$$

The effective barrier height Φ_b, Richardson constant A* depend on the temperature, as following:

$$\Phi_b = \alpha \frac{kT}{q} + \beta \tag{3}$$

$$ln\, A^* = \eta \frac{q}{kT} + \gamma \tag{4}$$

Where $A^* = \frac{Io}{ST^2}$, and α, β, γ, η are the simulated coefficients, which are independent of temperature. Physical parameters can be determined by the following expressions:

$$A^*_c = \exp(\gamma) \tag{5}$$

$$a\delta\chi^{1/2} = \alpha \tag{6}$$

$$\Phi_b(0K) = \beta \tag{7}$$

$$\Delta\Phi_{oi} = \eta \tag{8}$$

IV. THE MODEL OF THE SERIES RESISTANCE

At ambient temperature, series resistance varies from structure to another for the same group and it is independent of the thickness of the oxide layer.

For the Au-oxide-n-InP structures treated by oxygen plasma and those oxidized by air, the curves of series resistance are plotted versus temperature in Fig. 1 and 2, respectively. From these curves, it is then deduced that the series resistance decreases when the temperature increases from 173 K to 373 K, and it is then deduced that the series resistance can be described by the equation 2. The series resistance of the structures treated by plasma oxygen is more important than that treated by air.

Generally, resistance series decreases when the temperature increases and tends towards constant value. We note that these variations close to the theory are established by Rhoderick [13] for the Au – Si and Au – GaAs Schottky diode.

oxide thickness (Å)	n	Rs (Ω)	Φ_b (eV)
65	1.39	166	0.70
140	1.68	114	0.67
240	1.56	482	0.67
635	1.36	79	0.67

Table I. Numerical parameters of Au-n-InP structures oxidised by oxygen plasma at room temperature.

The model established for the studied samples is given by the following equation:

$$Rs = Rc + \left[\frac{A}{T}\right] \exp\left[\frac{B}{T}\right] \tag{9}$$

Where Rc represents the resistance of contact, A and B are constants. For the samples untreated by plasma with a oxide layer order of 45 Å, series resistance is given by following expression:

$$Rs = 2.114 + \left[\frac{1.622}{T}\right]\exp\left[\frac{1034}{T}\right] \quad (\Omega) \qquad (10)$$

The same model makes it possible to characterise the structures treated by plasma.

The sample with 260 Å thickness, the series resistance is given by the following expression:

$$Rs = 161 + \left[\frac{1218}{T}\right]\exp\left[\frac{365}{T}\right] \quad (\Omega) \qquad (11)$$

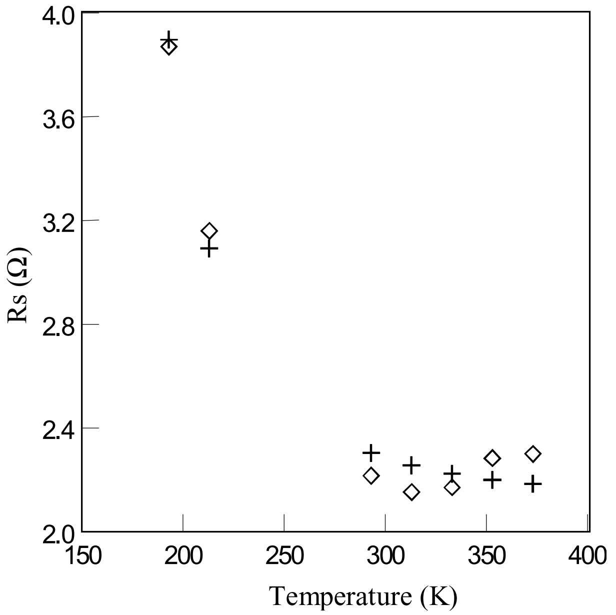

Fig.2: Temperature variation of series resistance R_S for Au-n-InP diodes oxidised by air : (◊) experimental (+) simulated

From the analysis of the chemical composition of the oxide by ESCA, it is observed that the oxide Ta_2O_5 is formed at the interfacial Au / n-InP [14]. This oxide layer is obtained with a plasma power of 100W and a duration of 13 min . Therefore, the oxidation conditions by oxygen plasma directly influence the interfacial layer properties and they can also change the electrical properties of the structures.

V. CONCLUSION

The approach presented above, enables us to determine the series resistance of Au-oxide-n-InP structures from the I-V-T characteristics in the range running from 173 K to 373 K. The contact resistance is determined for Au-n-InP diodes treated with oxygen plasma and those oxidised by air. The series resistance of Au-oxide-n-InP structures treated by plasma is independent of the oxide thickness and treatment conditions (duration and power). For the structures oxidised by air, the value of resistance is very low compared to that treated by plasma. The values of this parameter in the Au-oxide-n-InP structures are in good agreement with those published in the literature.

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