Specific Contact Resistance Extraction of Metal-Semiconductor Contact for Power Integrated Circuits

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Abstract

This work comes in the context of realization of what is termed a power integrated circuit (PIC), following the functional integration or ASD^{TM} [1](Application Specific Discrete), by placing a parametric test for the 10µm process devices within the STMicroelectronics company.

In the manufacture of power devices, the need of monitoring the process technology requires to place a parametric test like the one used in the VLSI technology. So, to evaluate the quality of a contact between metal and semiconductor after the metallization process step, the specific contact resistance ρ_c is extracted by using specific test structures. Contact resistance test structures are usually fabricated with other conventional test devices on the same die or wafer to monitor a particular process.

Our goal in this study is to validate one test pattern among the others permitting the characterization of the metal-semiconductor contacts of the ASD2^{TM} process. This test pattern will be inserted in a test vehicle dedicated to monitor this process.

In this study, we have chosen the most commonly used contact test structures to measure contact resistance R_C and extract ρ_c of the metal-semiconductor contact in the planar devices [2]. These test structures are, Transfer Length Method (TLM), Cross Bridge Kelvin Resistor (CBKR), and Contact End Resistance (CER). Generally, CBKR is the most test structure used to characterize metal-semiconductor contact of VLSI technology [3][4], because the specific contact resistance is easily extracted from measuring the contact resistance and adapted well it self within a parametric test. Moreover, CBKR is recommended in the extraction of ρ_C for the ULSI technology [5]. However, in our knowledge, there is no specific study concerning test structures for power device technologies when the dimensions of structures are bigger than the VLSI structures.

The test structures used in this study were fabricated with the ASD2^{TM} standard flow. Contacts are formed by Al-Si metallization, equally distributed across a 5-inch wafer, of 210 µm thickness, n-type substrate of resistivities of 40-60 Ω.cm, <111> oriented, and floating zone pulled. On each wafer a total of 27 dices were measured to provide statistical information. The validation of our results will be done by comparing the experimental results of each test structure with the abacus giving specific contact resistance versus surface concentration for both n- and p- type. The surface concentration of the diffused layer located under the contact is measured by spreading resistance technique.

From the experimental results shown in Table 1(a), the specific contact resistances extracted from the different test structures are in agreement with those extracted from the spreading resistance, for the n-type diffused layer. for the p-type diffused layer, the table 1(b) shows clearly that the experimental results of ρ_C values extracted from CBKR and CER test structures are very higher than those extracted from the spreading resistance. However, the TLM test structure gives ρ_C values in the range of the manufacturer specifications. Thus, TLM allows us to extract correct values of ρ_C.

On the other hand, CBKR and CER test patterns permit to measure very low contact resistance but they are valid as long as the spacing (δ) between the contact window and the diffused layer stands inferior to 5 µm [6][7]. However, our test structures have a minimum δ of 20 µm. Moreover, CBKR [8] and CER test patterns are very sensitive to the lateral crowding current around the contact when contact window is smaller than the diffusion tap. A lateral current flow around the contact accounts for additional resistance that induces a voltage drop at the contact's periphery. For high quality contacts with $\rho_C < 10^{-6}$ Ω.cm², and for higher sheet resistances, like for the p-type diffused layer, the additional resistance becomes important. In Table 1, we can see the influence of the p-type diffused layer for the CBKR and CER test structures on the specific contact resistance values.

In conclusion, TLM test structure is more adapted to qualify the contact resistance of the metal-semiconductor contact for the power technologies and gives values of ρ_C in agreement with those extracted from the spreading resistance method. Moreover, TLM method is described like a one good method to follow the uniformity and the reproducibility of the contact resistance in a process technology [9].

	ρ_C (x10^{-6} Ω.cm²)			
	Spreading resistance	TLM	CBKR	CER
Min	0.4	0.32	2.75	1.50
Max	5	1.04	4.60	5

(a)

	ρ_C (x10^{-6} Ω.cm²)			
	Spreading resistance	TLM	CBKR	CER
Min	1	0.17	110	50
Max	3	2.5	160	160

(b)

Table 1: Summary of extraction results from different test pattern structures of specific contact resistance value for (a) n- and (b) p- type.

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