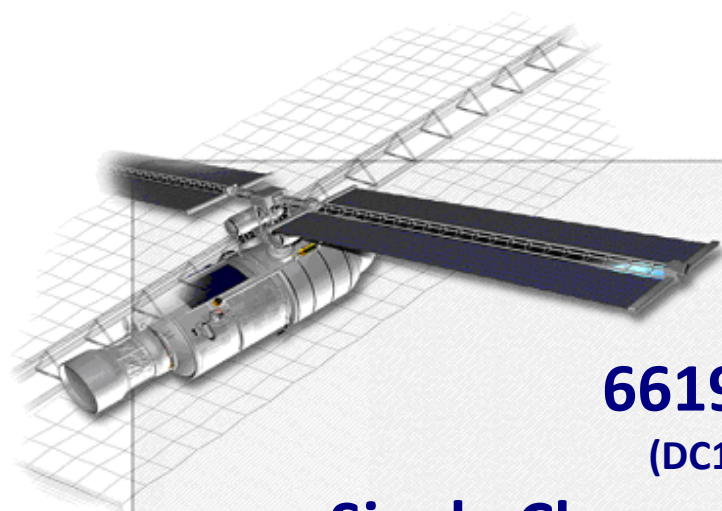


NEUTRONS DISPLACEMENT DAMAGE TEST REPORT



66193-002 (DC1120) Single Channel Optocoupler From MICROPAC



TRAD/TN/66193/XXX1/ESA/YP/1104		Labège, March 8th, 2012	
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Issue : 0			
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TABLE OF CONTENT

1	INTRODUCTION	3
2	DOCUMENTS	3
2.1	Applicable Documents	3
2.2	Reference Documents.....	3
3	DEVICE INFORMATION.....	3
3.1	Device description.....	3
3.2	Procurement information.....	4
3.3	External view.....	4
3.4	Internal view	4
3.5	Serialization.....	4
4	IRRADIATION MEANS AND CONDITIONS	5
4.1	BR1 irradiation facility (Belgium)	5
4.2	Dose measurement.....	5
4.3	Experimental conditions	5
4.4	Exposure set-up	5
5	ELECTRICAL TESTS.....	6
5.1	Test set-up	6
5.2	Electrical parameters	7
6	TEST HISTORY	7
7	SUMMARY RESULTS.....	8
8	CONCLUSION	10
9	DETAILED TESTS RESULTS.....	11

LIST OF FIGURES

Figure 1:	package marking.....	4
Figure 2:	package marking - date code	4
Figure 3:	Internal view	4
Figure 4:	Internal view without potting.....	4
Figure 5:	schematical view of the large cavity and its spherical drivers	5
Figure 6:	view of the sample holder.....	5
Figure 7:	test principle	6

1 INTRODUCTION

This report includes the test results of 66193-002, a Single Channel Optocoupler from MICROPAC to evaluate displacement damage effects under neutron irradiation. On November, week 45, 2011, TRAD characterized this device for neutron sensitivity at the SCK-CEN Facility, Belgium using their BR1 Neutron Irradiator.

The objectives of the test are:

- to detect and measure the degradation of device parameters as a function of neutron fluence,
- to determine if device parameters are within specified limits after exposure to final level of neutron fluence.

2 DOCUMENTS

2.1 Applicable Documents

AD	1.	ESA contract	N°4000102571/10/NL/AF-Radiation Characterization of Laplace RH optocouplers, sensors and detectors
AD	2.	Irradiation Test Plan	ITP_TN_66193_MIC_ESA_1119, Iss.2, 27/06/11

2.2 Reference Documents

RD	1.	Datasheet 66193 by MICROPAC	SINGLE CHANNEL OPTOCOUPERS REPLACEMENT FOR 3C91C
RD	2.	MICROPAC certificate of traceability and conformance dated 25/07/2011	

3 DEVICE INFORMATION

3.1 Device description

The 66193-002 device is a proton radiation tolerant single channel optocoupler (replacement for 3C91C optocoupler). It contains a proton tolerant 660nm GaAlAs LED optically coupled to a silicon planar phototransistor (25 x 25). It is hermetically sealed in a TO46 metallic package. The internal base connection has been eliminated for improved noise immunity.

Type	66193-002
Manufacturer	MICROPAC
Function	Optocoupler
Package	TO46
Date Code	1120
Sample size	4 parts (3 test parts + 1 control sample)

3.2 Procurement information

75 parts reference 66193-002 were procured by TRAD and delivered by MICROPAC through its French distributor ISOTOPE ELECTRONICS.

Their quality level defined by the 002 extension number corresponds to a commercial standard operating in the temperature range of -55° to +100°C and temperature tested (hot & cold temperature) by the manufacturer prior delivery.

One single lot of 75 parts, date-code 1120, was delivered with a Certificate of Conformance [RD2].

3.3 External view



Figure 1: package marking



Figure 2: package marking - date code

3.4 Internal view

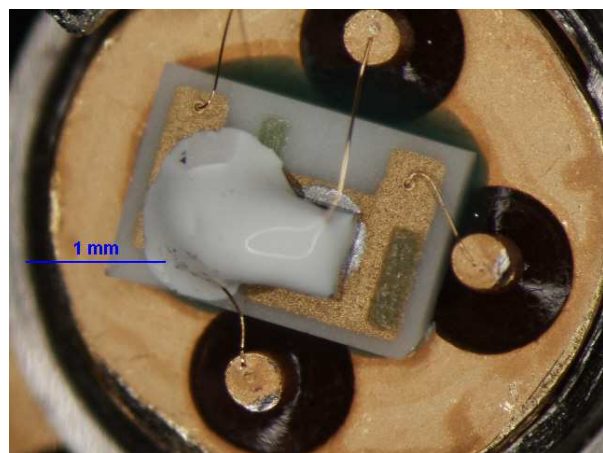


Figure 3: Internal view

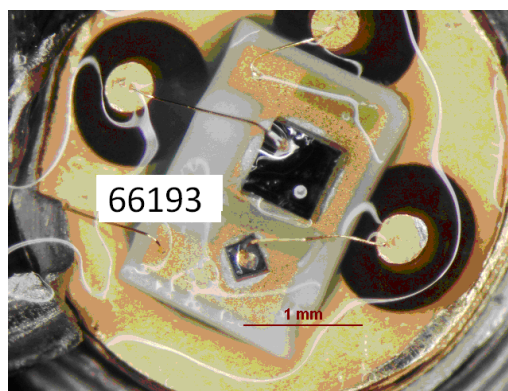


Figure 4: Internal view without potting

3.5 Serialization

Each part is serialized to enable pre and post test identification and comparison.

Serial Number	Control sample	Test samples		
Serialization	1	2	3	4

4 IRRADIATION MEANS AND CONDITIONS

4.1 BR1 irradiation facility (Belgium)

The Reactor BR1 is a versatile neutron / gamma irradiation tool. The large cavity is used for this test. To obtain the required neutron flux, a 6cm Uranium shell is used. This spherical converter provides a 1 MeV equivalent neutron flux of $2.86E+08n/cm^2.s$, with a low ionizing dose rate of 2,5Gy/h.

All exposures are made at $20^{\circ}C \pm 10^{\circ}C$.

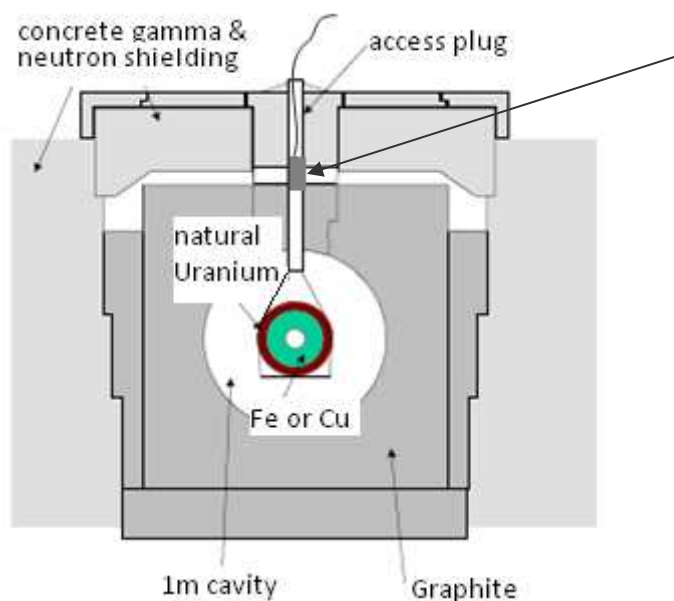
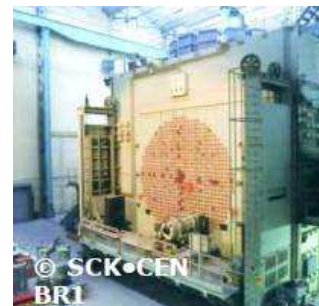


Figure 5: schematical view of the large cavity and its spherical drivers

The sample holder is a cylinder, dimensions of which are 3.5 cm diameter and 5.5 cm length made of high-density polyethylene.



Figure 6: view of the sample holder

4.2 Dose measurement

The SCK•CEN reactor dosimetry service is accredited by BELAC (Ministry of Economic Affairs from Belgium) under the accreditation number 015-TEST. The accreditation towards norms NBN EN ISO/IEC 17025 for the Standard Practice for Determining Neutron Fluence Rate, Fluence, and Spectra by Radioactivation Techniques (ASTM261 & ASTM262) is in progress.

4.3 Experimental conditions

An Equivalent total fluence of $1E12 \# /cm^2$ of 10 MeV protons is required [AD2] for this TNID (Total Non Ionizing Dose) evaluation test. Considering NIEL (Non Ionizing Energy Loss) value for 1 MeV neutron ($1.14E-03 \text{ MeV cm}^2 \text{ g}^{-1}$), it corresponds to a total fluence of $6.89E+12 \# /cm^2$ for 1 MeV neutron.

Five steps are defined to determine the component degradation under 1 MeV neutron irradiation.

The test devices have been exposed to the following neutron fluence levels:

	Step1	Step2	Step3	Step4	Step5
Fluence n/cm^2	5,00E+10	1,00E+11	5,00E+11	1,00E+12	7,00E+12
Flux $n/cm^2.s$	2,86E+08	2,86E+08	2,86E+08	2,86E+08	2,86E+08

4.4 Exposure set-up

The samples were exposed to neutron irradiation in an un-biased state and had all their terminal leads open.

5 ELECTRICAL TESTS

Electrical parameters to be measured in pre and post exposure tests are described in the following table. Electrical tests are performed on each part using the test set-up hereunder. All required data are recorded for each device. Test conditions and limits are given in the applicable irradiation test plan [AD2] and shown hereafter.

5.1 Test set-up

TEST BOARD	TRAD/CT1/N/OPTO/ZIP14/BR/1109
TEST PROGRAM	66193_TN_XXX1_B1_V10.Ilb

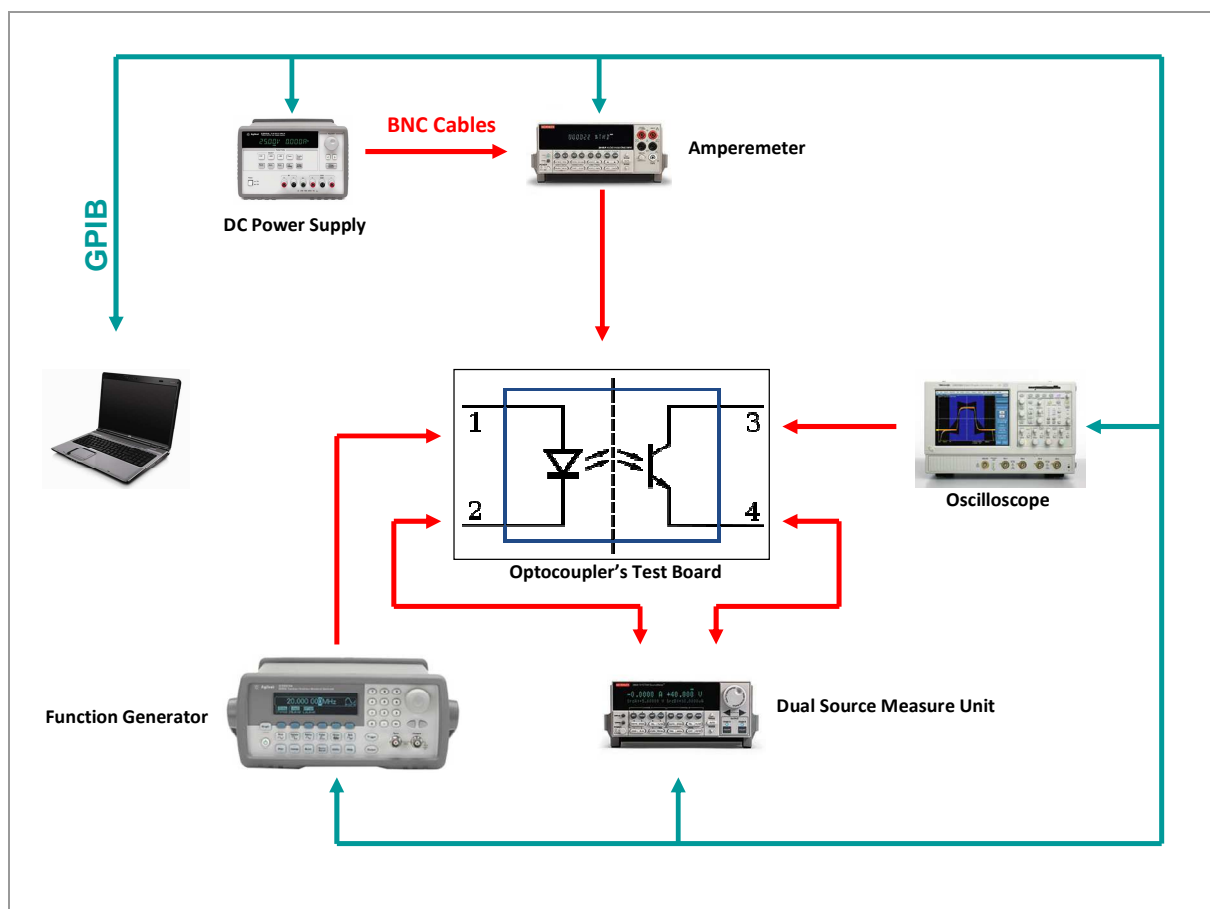


Figure 7: test principle

5.2 Electrical parameters

PARAMETER	SYMBOL	TEST CONDITION	MIN	MAX	UNIT
Input Diode Static Reverse Current	I_R	$V_R = 3V$		1	μA
Input Diode Static Forward Voltage	V_{F1}	$I_F = 10mA$		2	V
	V_{F2}	$I_F = 20mA$		2,2	V
Reverse Breakdown Voltage	B_{VR}	$I_R = 100\mu A$	7		V
Collector-Emitter Breakdown Voltage	$V_{(BR)CEO}$	$I_C = 1mA, I_b = 0, I_F = 0$	50		
Emitter-Collector Breakdown Voltage	$V_{(BR)ECO}$	$I_C = 10\mu A$	7		
Collector-Emitter Dark Current	I_{CEO1}	$V_{CE} = 50V, I_F = 0mA$		100	nA
	I_{CEO2}	$V_{CE} = 5V, I_F = 0mA$		10	nA
On State Collector Current	$I_{C(ON)1}$	$V_{CE} = 5V, I_F = 10mA$	4		mA
	$I_{C(ON)2}$	$V_{CE} = 0.4V, I_F = 10mA$	3		mA
Collector-Emitter Saturation Voltage	$V_{CE(SAT)}$	$I_F = 50mA, I_C = 10mA$		0,4	V
Rise Time	tr	$V_{CE} = 5V, I_F = 2mA, R_L = 100\Omega$		5	μs
Fall Time	tf	$V_{CE} = 5V, I_F = 2mA, R_L = 100\Omega$		5	μs
Current Transfer Ratio	CTR1	$V_{CE} = 5V, I_F = 1mA$			%
	CTR2	$V_{CE} = 5V, I_F = 2mA$			%
	CTR3	$V_{CE} = 5V, I_F = 10mA$	40		%
	CTR4	$V_{CE} = 5V, I_F = 20mA$			%
	CTR5	$V_{CE} = 30V, I_F = 10mA$			%

Min/ Max values are those specified in the reference data-sheet [RD1].

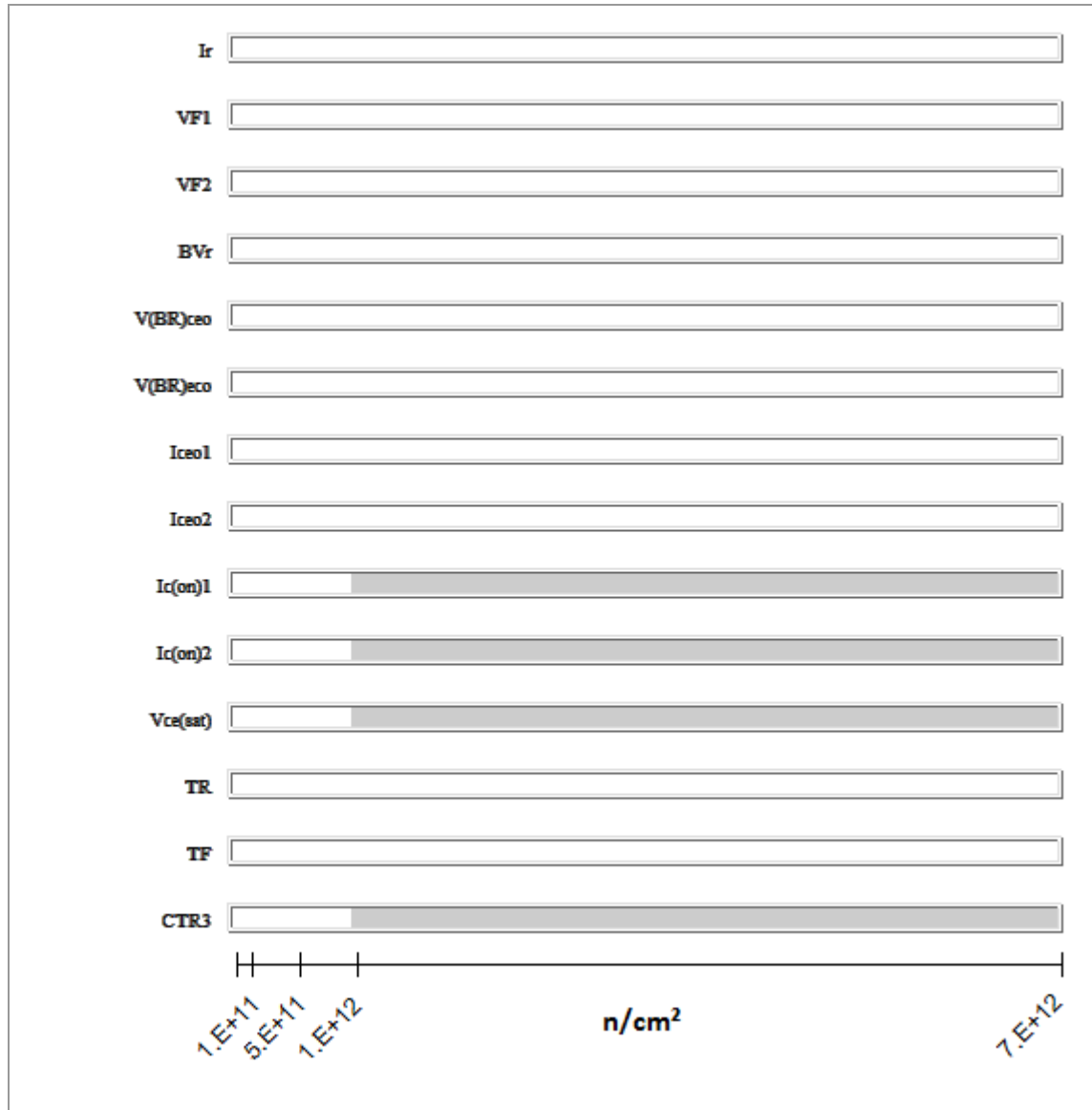
Test measurements are performed at $20^\circ C \pm 10^\circ C$.

6 TEST HISTORY

Test sequence and all required conditions were executed as described in the test plan.
No incident during the test was noticed.

7 SUMMARY RESULTS

Only parameters with applicable test limits are shown hereunder.



- Within specification
- Transition
- Out of specification or parameter not measurable

- The parameter Vce(sat) is out of specification at step 1.78E+12.n/cm² by interpolation.
- The parameter Ic(on)2 is out of specification at step 5.20E+12.n/cm² by interpolation.
- The parameter Ic(on)1 is out of specification at step 6.67E+12.n/cm² by interpolation.
- The parameter CTR3 is out of specification at step 6.67E+12.n/cm² by interpolation.

Due to the important gap between the $1E12n/cm^2$ and the $7E12n/cm^2$ step, interpolations are given as indicative information.

Next table show parameters results on the three components tested which are out of specification at step $7E12n/cm^2$.

	Device N°2	Device N°3	Device N°4	Data-sheet Min/Max values
Ic(on)1 at step $7E12n/cm^2$	2.813 mA	1.275 mA	2.649 mA	MIN : 4 mA
Ic(on)2 at step $7E12n/cm^2$	1.469 mA	0.835 mA	1.424 mA	MIN : 3 mA
Vce(sat) at step $7E12n/cm^2$	1.577 V	1.939 V	1.600 V	MAX: 0.4 V
CTR3 at step $7E12n/cm^2$	28.4 %	13.85 %	28.354 %	MIN: 40%

8 CONCLUSION

Total fluence steady-state irradiation test using neutrons has been applied on three 66193-002, a Single Channel Optocoupler from MICROPAC up to $7E+12$ neutrons/cm², with an energy of 1 MeV.

Final test results are:

- For the three components tested, $I_{c(on)1}$, $I_{c(on)2}$, $V_{ce(sat)}$ and $CTR3$ are out of specification at step $7E12$ n/cm².

PARAMETERS	SYMBOLS	TEST CONDITIONS	Applicable specification			Worst Measurement at step $7E12$ n/cm ²
			Min	Max	Unit	
On State Collector Current	IC(ON)1	VCE = 5V, IF = 10mA	4		mA	1.275 mA
	IC(ON)2	VCE = 0.4V, IF = 10mA	3		mA	0.835 mA
Collector-Emitter Saturation Voltage	VCE(SAT)	IF = 50mA, IC = 10mA		0.4	V	1.939 V
Current Transfer Ratio	CTR3	VCE = 5V, IF = 10mA	40		%	13.85 %

Nevertheless, all devices are functional up to $1 E+12$ neutrons/cm² total fluence level.

- Average drift current transfer ratio are described in next table function of the irradiation step and CTR configuration

PARAMETERS	SYMBOL	UNIT	STEP IRRADIATION					
			0 n/cm ²	5E10 n/cm ²	1E11 n/cm ²	5E11 n/cm ²	1E12 n/cm ²	7E12 n/cm ²
Average drift Current Transfer Ratio	$\overline{\Delta CTR1}$	%	0.00E+00	6.63E-05	1.68E-04	1.71E-03	4.44E-03	3.07E-01
	$\overline{\Delta CTR2}$	%	0.00E+00	6.75E-05	1.37E-04	1.07E-03	2.74E-03	1.64E-01
	$\overline{\Delta CTR3}$	%	0.00E+00	7.12E-05	8.77E-05	3.11E-04	7.10E-04	4.39E-02
	$\overline{\Delta CTR4}$	%	0.00E+00	1.05E-04	1.35E-04	4.86E-04	1.11E-03	2.55E-02
	$\overline{\Delta CTR5}$	%	0.00E+00	8.43E-06	2.23E-05	1.25E-04	3.51E-04	2.69E-02

- The least sensitive configuration up to a fluence of $1E12$ n/cm² is the CTR5 configuration ($V_{ce}=30V$; $I_f=10mA$). At $7E12$ n/cm², it is the CTR4 configuration ($V_{ce}=5V$; $I_f=20mA$) which exhibits the smallest average.
- CRT1 configuration ($V_{ce}=5V$; $I_f=1mA$) exhibits the greatest parameter degradation at all steps.
- CTR3 configuration is the only specified CTR [RD1]. CTR3 configuration is out of limit at the final step $7 E12.n/cm^2$.

9 DETAILED TESTS RESULTS

The pre and post radiation test results are shown graphically in the following pages (9-2 to 9-19). The data is displayed in the following tables and graphs.

These graphs show parameter's shifts observed during the neutron testing sequence. The Control sample results are shown on each graph (black curve).

When available in the device data-sheet/specification, the maximum/minimum/typical values are also shown (red dotted line).

The tables include drift calculation between each measurement step and the "0" neutrons/cm² step.

For CTR values, the formula used is:

$$\text{Drift} = \frac{1}{\text{measurement (X neutrons /cm}^2)} - \frac{1}{\text{measurement (0 neutrons /cm}^2)}$$

For the other measurements the formula used is:

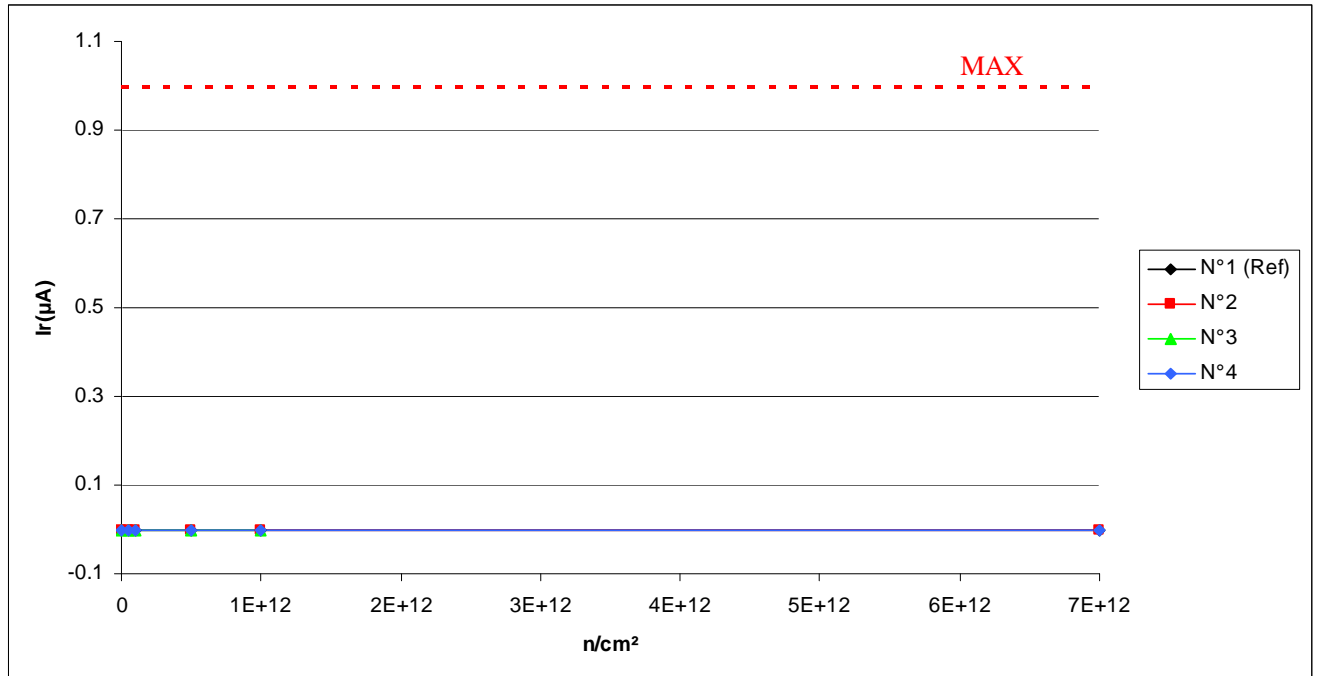
$$\text{Drift value} = \text{measurement (X neutrons/cm}^2) - \text{measurement (0 neutrons/cm}^2)$$

CONTENTS

1. IR	2
2. VF1	3
3. VF2	4
4. BVR	5
5. V(BR)CEO	6
6. V(BR)ECO	7
7. ICEO1	8
8. ICEO2	9
9. IC(ON)1	10
10. IC(ON)2	11
11. VCE(SAT)	12
12. TR	13
13. TF	14
14. CTR1	15
15. CTR2	16
16. CTR3	17
17. CTR4	18
18. CTR5	19

1. Ir

Ta=25°C; Vr=3V



Ir . (µA)

Max = 1.0

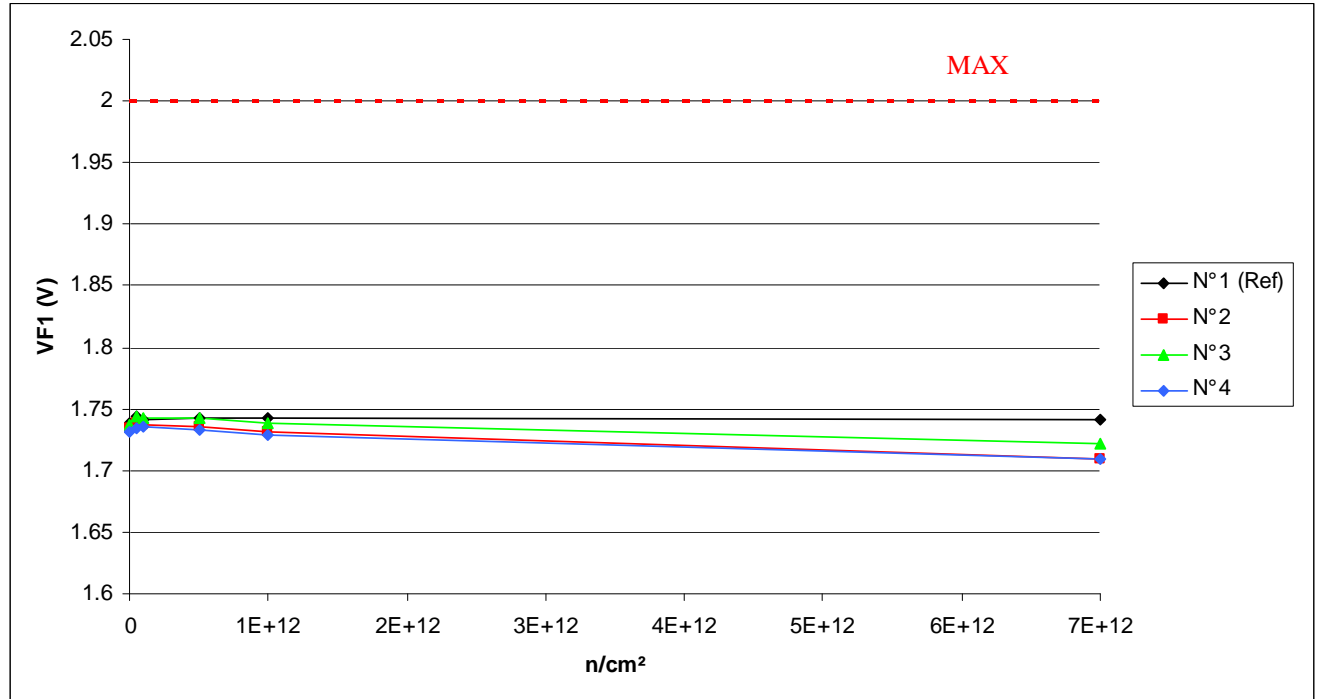
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	2.512E-5	4.177E-6	7.569E-6	7.193E-6	5.014E-6	2.801E-5
N° 2	2.436E-5	1.502E-5	5.767E-6	8.984E-6	1.037E-5	2.600E-5
N° 3	1.686E-5	1.184E-5	8.785E-6	4.794E-6	1.586E-5	2.692E-5
N° 4	3.417E-5	1.385E-5	3.881E-6	7.811E-6	1.439E-5	2.176E-5

Delta [Ir]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	-2.094E-5	-1.755E-5	-1.792E-5	-2.010E-5	2.894E-6
N° 2	---	-9.337E-6	-1.859E-5	-1.538E-5	-1.399E-5	1.637E-6
N° 3	---	-5.021E-6	-8.075E-6	-1.207E-5	-1.003E-6	1.006E-5
N° 4	---	-2.032E-5	-3.029E-5	-2.636E-5	-1.978E-5	-1.240E-5
Average	---	-1.156E-5	-1.899E-5	-1.793E-5	-1.159E-5	-2.353E-7
σ	---	7.887E-6	1.111E-5	7.481E-6	9.615E-6	1.135E-5
Average+3σ	---	1.210E-5	1.435E-5	4.508E-6	1.725E-5	3.381E-5
Average-3σ	---	-3.522E-5	-5.232E-5	-4.038E-5	-4.044E-5	-3.428E-5

2. VF1

Ta=25°C; If=10mA



VF1 . (V)

Max = 2.0

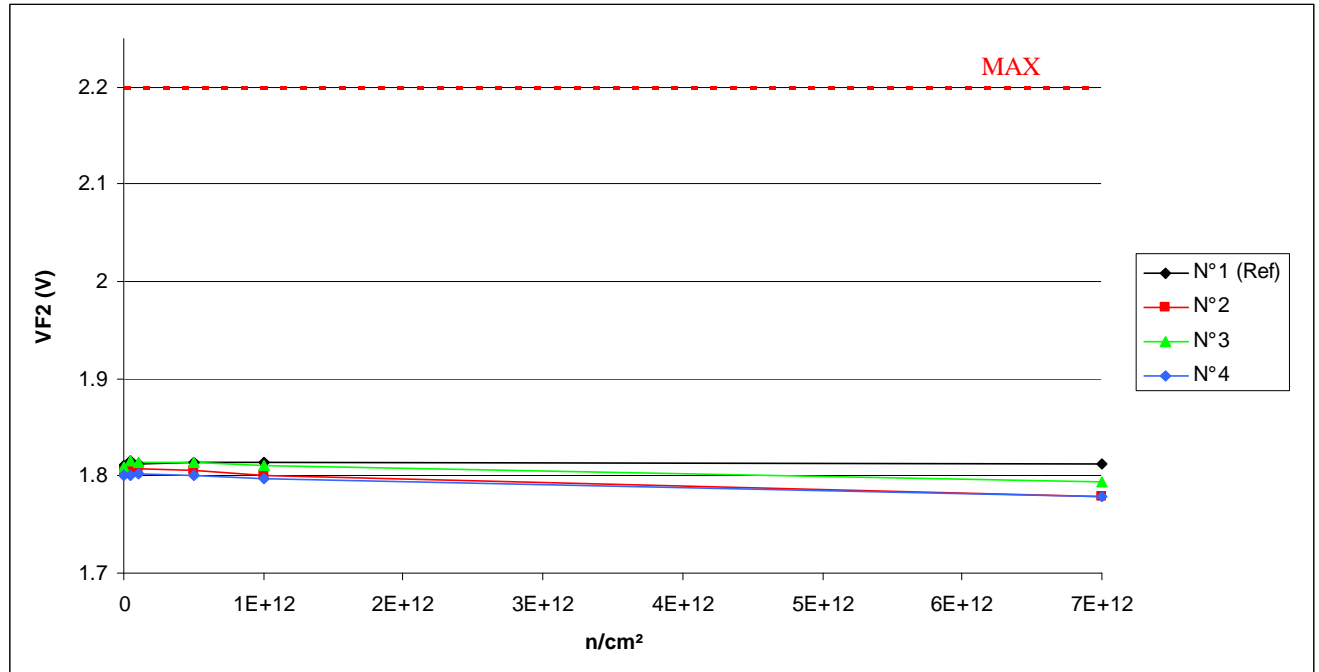
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	1.739	1.744	1.741	1.743	1.743	1.741
N° 2	1.734	1.738	1.737	1.735	1.731	1.710
N° 3	1.737	1.744	1.743	1.742	1.739	1.722
N° 4	1.732	1.734	1.735	1.733	1.729	1.710

Delta [VF1]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	4.766E-3	2.257E-3	3.827E-3	4.188E-3	1.774E-3
N° 2	---	3.803E-3	3.251E-3	8.820E-4	-2.755E-3	-2.406E-2
N° 3	---	6.874E-3	6.054E-3	5.091E-3	2.667E-3	-1.483E-2
N° 4	---	1.438E-3	2.416E-3	1.003E-3	-3.700E-3	-2.260E-2
Average	---	4.038E-3	3.907E-3	2.325E-3	-1.263E-3	-2.049E-2
σ	---	2.726E-3	1.906E-3	2.396E-3	3.436E-3	4.961E-3
Average+3σ	---	1.222E-2	9.624E-3	9.513E-3	9.045E-3	-5.611E-3
Average-3σ	---	-4.139E-3	-1.810E-3	-4.862E-3	-1.157E-2	-3.538E-2

3. VF2

Ta=25°C; If=20mA



VF2 . (V)

Max = 2.2

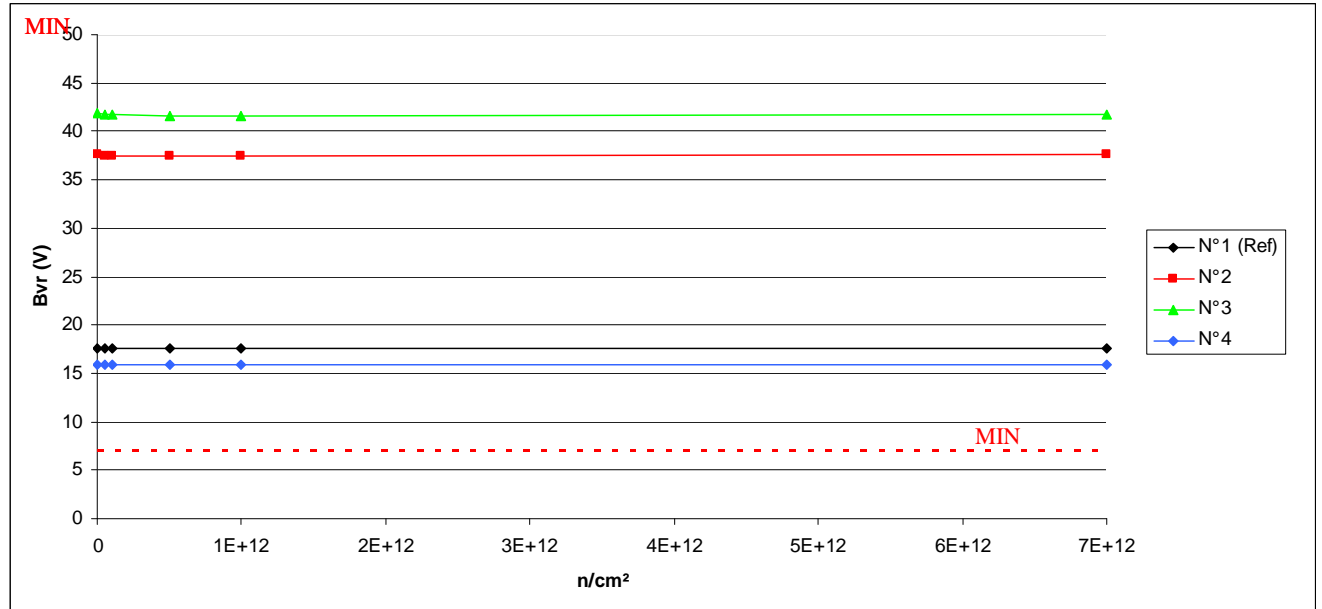
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	1.811	1.815	1.812	1.814	1.814	1.812
N° 2	1.804	1.807	1.807	1.805	1.801	1.779
N° 3	1.809	1.815	1.814	1.814	1.811	1.794
N° 4	1.801	1.801	1.803	1.801	1.797	1.778

Delta [VF2]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	3.843E-3	1.563E-3	2.877E-3	3.287E-3	9.110E-4
N° 2	---	2.857E-3	2.447E-3	4.340E-4	-3.039E-3	-2.492E-2
N° 3	---	5.789E-3	5.004E-3	4.152E-3	1.763E-3	-1.564E-2
N° 4	---	5.490E-4	1.610E-3	4.720E-4	-3.983E-3	-2.333E-2
Average	---	3.065E-3	3.020E-3	1.686E-3	-1.753E-3	-2.130E-2
σ	---	2.626E-3	1.768E-3	2.136E-3	3.081E-3	4.964E-3
Average+3σ	---	1.094E-2	8.325E-3	8.093E-3	7.491E-3	-6.406E-3
Average-3σ	---	-4.814E-3	-2.284E-3	-4.721E-3	-1.100E-2	-3.619E-2

4. BvR

Ta=25°C; Ir=100µA



BvR . (V) Min = 7.0

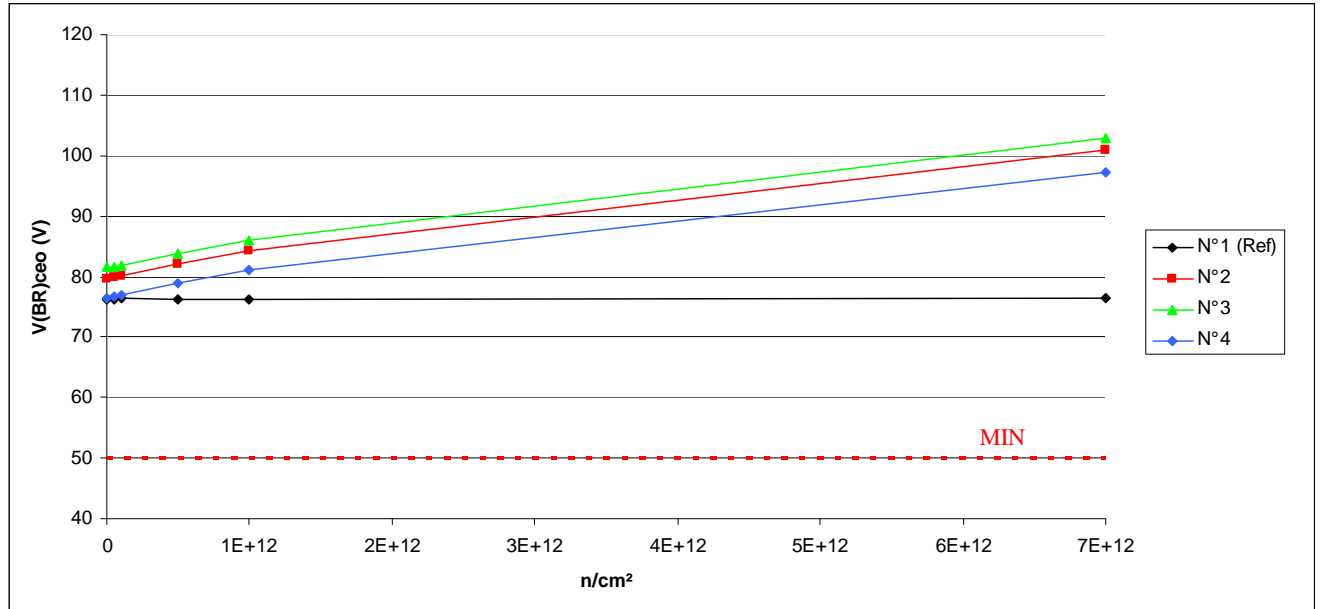
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	17.56	17.54	17.55	17.54	17.54	17.55
N° 2	37.58	37.48	37.49	37.46	37.47	37.57
N° 3	41.86	41.71	41.71	41.66	41.65	41.74
N° 4	15.94	15.92	15.91	15.90	15.91	15.91

Delta [BvR]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	-2.059E-2	-8.610E-3	-1.541E-2	-1.653E-2	-9.540E-3
N° 2	---	-9.547E-2	-8.697E-2	-1.191E-1	-1.108E-1	-1.215E-2
N° 3	---	-1.483E-1	-1.561E-1	-2.064E-1	-2.136E-1	-1.193E-1
N° 4	---	-2.154E-2	-3.040E-2	-4.583E-2	-3.906E-2	-3.719E-2
Average	---	-8.844E-2	-9.115E-2	-1.238E-1	-1.212E-1	-5.620E-2
σ	---	6.368E-2	6.294E-2	8.039E-2	8.775E-2	5.603E-2
Average+3σ	---	1.026E-1	9.768E-2	1.174E-1	1.421E-1	1.119E-1
Average-3σ	---	-2.795E-1	-2.800E-1	-3.649E-1	-3.844E-1	-2.243E-1

5. V(BR)ceo

Ta=25°C; Ic=1mA; Ib=0; If=0



V(BR)ceo . (V)

Min = 50.0

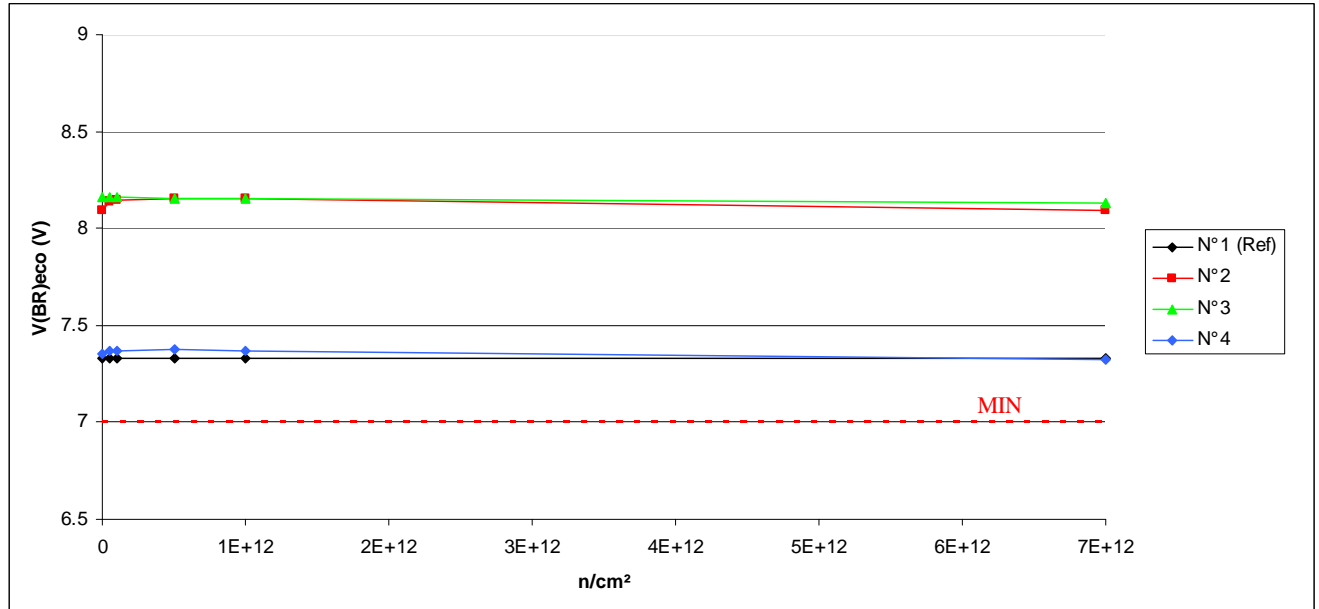
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	76.3	76.3	76.4	76.3	76.3	76.4
N° 2	79.7	80.0	80.2	82.2	84.4	101.0
N° 3	81.5	81.7	81.8	83.9	86.0	102.9
N° 4	76.5	76.8	77.0	78.9	81.0	97.3

Delta [V(BR)ceo]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	-3.421E-2	1.811E-2	-1.707E-2	-1.921E-2	1.587E-2
N° 2	---	2.478E-1	4.557E-1	2.448E+0	4.622E+0	2.123E+1
N° 3	---	2.129E-1	3.553E-1	2.432E+0	4.470E+0	2.139E+1
N° 4	---	2.801E-1	5.105E-1	2.338E+0	4.503E+0	2.078E+1
Average	---	2.469E-1	4.405E-1	2.406E+0	4.532E+0	2.113E+1
σ	---	3.363E-2	7.870E-2	5.914E-2	8.027E-2	3.199E-1
Average+3σ	---	3.478E-1	6.766E-1	2.583E+0	4.772E+0	2.209E+1
Average-3σ	---	1.460E-1	2.044E-1	2.229E+0	4.291E+0	2.017E+1

6. V(BR)eco

Ta=25°C; Ic=10μA



V(BR)eco . (V)

Min = 7.0

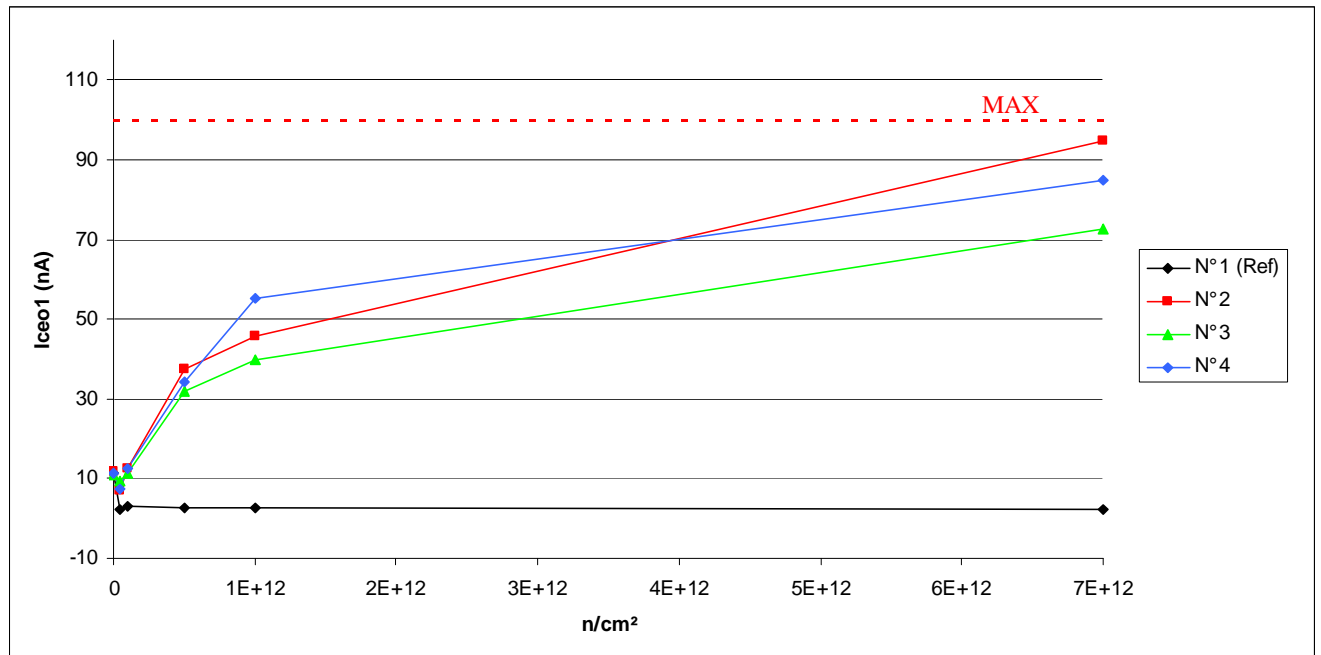
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	7.327	7.332	7.329	7.332	7.332	7.328
N° 2	8.090	8.140	8.147	8.155	8.152	8.094
N° 3	8.159	8.161	8.161	8.157	8.152	8.131
N° 4	7.352	7.368	7.372	7.374	7.370	7.322

Delta [V(BR)eco]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	5.088E-3	1.810E-3	4.533E-3	4.792E-3	1.084E-3
N° 2	---	4.960E-2	5.692E-2	6.445E-2	6.139E-2	3.731E-3
N° 3	---	1.963E-3	2.216E-3	-1.574E-3	-6.633E-3	-2.815E-2
N° 4	---	1.623E-2	2.047E-2	2.231E-2	1.816E-2	-3.046E-2
Average	---	2.260E-2	2.654E-2	2.840E-2	2.431E-2	-1.829E-2
σ	---	2.445E-2	2.785E-2	3.343E-2	3.443E-2	1.911E-2
Average+3σ	---	9.595E-2	1.101E-1	1.287E-1	1.276E-1	3.903E-2
Average-3σ	---	-5.075E-2	-5.702E-2	-7.190E-2	-7.898E-2	-7.561E-2

7. Iceo1

Ta=25°C; Vce=50V; If=0



Iceo1 . (nA)

Max = 100.0

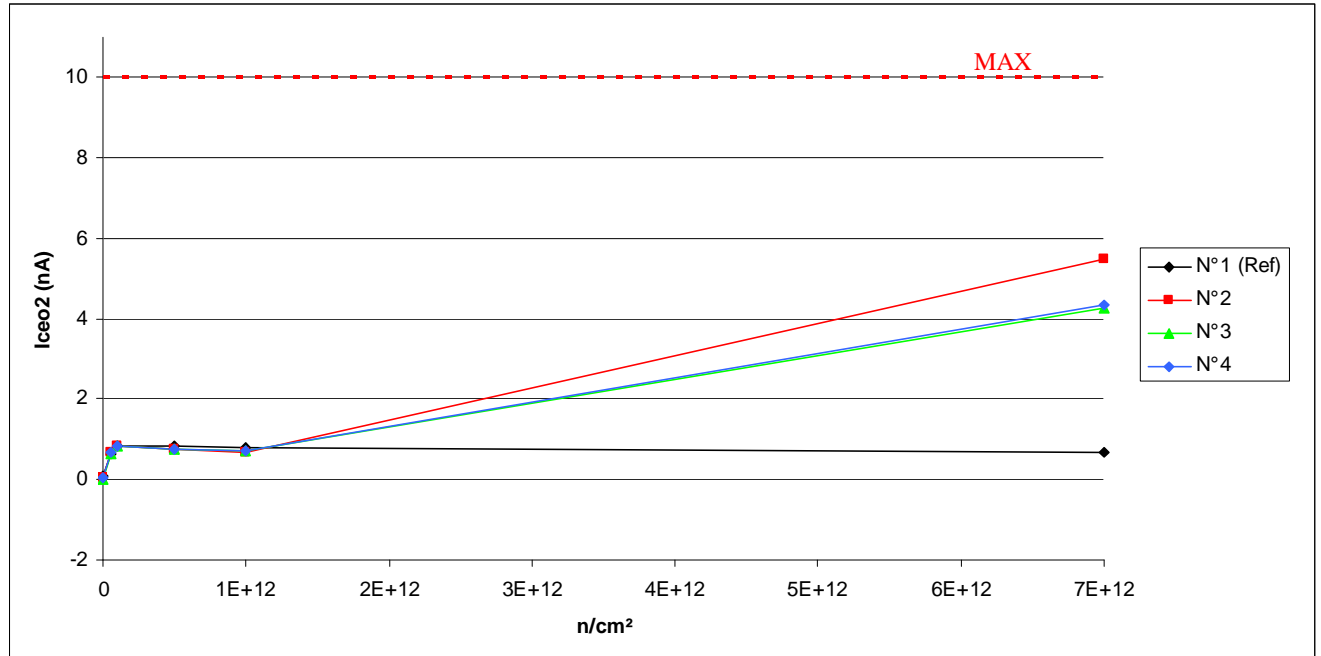
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	11.492	2.180	2.977	2.694	2.555	2.340
N° 2	11.669	7.162	12.641	37.367	45.765	94.678
N° 3	11.128	9.219	11.352	32.069	39.597	72.396
N° 4	11.202	7.239	12.505	34.257	55.394	84.671

Delta [Iceo1]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	-9.312E+0	-8.515E+0	-8.798E+0	-8.936E+0	-9.152E+0
N° 2	---	-4.508E+0	9.714E-1	2.570E+1	3.410E+1	8.301E+1
N° 3	---	-1.909E+0	2.236E-1	2.094E+1	2.847E+1	6.127E+1
N° 4	---	-3.963E+0	1.303E+0	2.306E+1	4.419E+1	7.347E+1
Average	---	-3.460E+0	8.327E-1	2.323E+1	3.559E+1	7.258E+1
σ	---	1.371E+0	5.530E-1	2.383E+0	7.967E+0	1.090E+1
Average+3σ	---	6.516E-1	2.492E+0	3.038E+1	5.949E+1	1.053E+2
Average-3σ	---	-7.572E+0	-8.263E-1	1.608E+1	1.169E+1	3.989E+1

8. Iceo2

Ta=25°C; Vce=5V; If=0



Iceo2 . (nA)

Max = 10.0

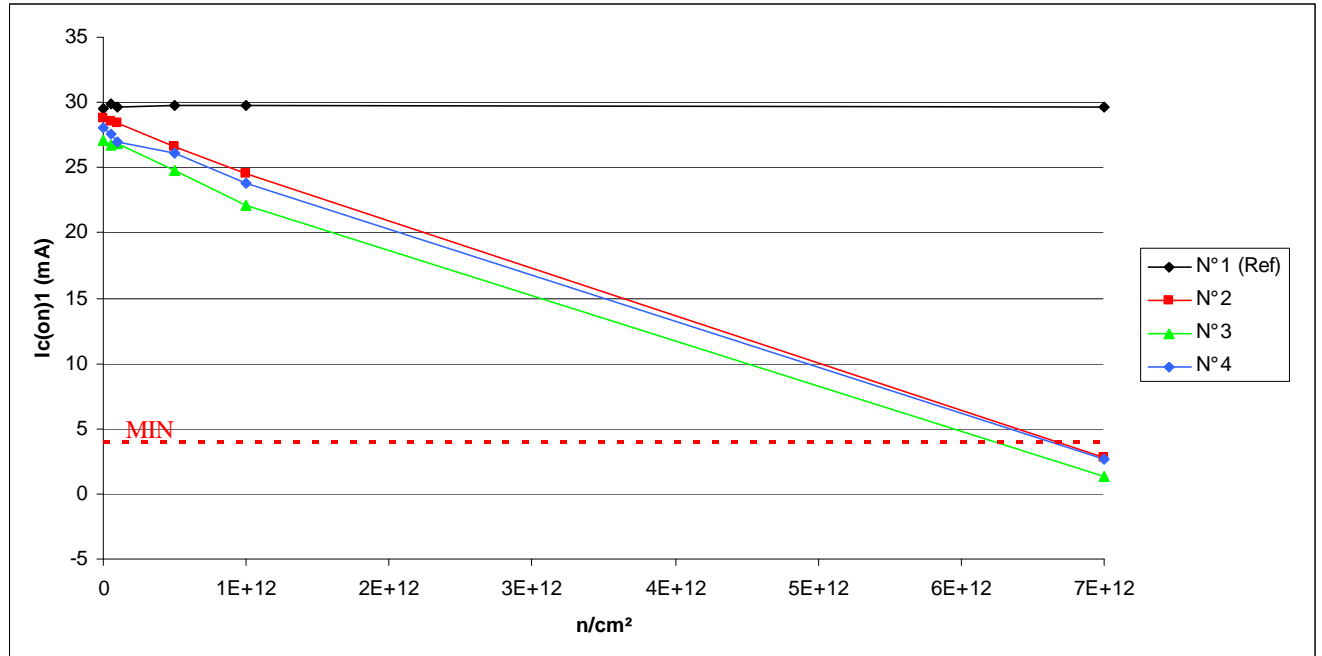
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	0.101	0.628	0.837	0.821	0.803	0.684
N° 2	0.041	0.682	0.826	0.750	0.691	5.479
N° 3	0.021	0.652	0.854	0.747	0.700	4.247
N° 4	0.029	0.695	0.835	0.770	0.716	4.351

Delta [Iceo2]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	5.272E-1	7.366E-1	7.205E-1	7.024E-1	5.832E-1
N° 2	---	6.413E-1	7.856E-1	7.093E-1	6.509E-1	5.439E+0
N° 3	---	6.311E-1	8.333E-1	7.264E-1	6.788E-1	4.226E+0
N° 4	---	6.664E-1	8.066E-1	7.411E-1	6.871E-1	4.323E+0
Average	---	6.463E-1	8.085E-1	7.256E-1	6.723E-1	4.662E+0
σ	---	1.816E-2	2.388E-2	1.591E-2	1.898E-2	6.738E-1
Average+3σ	---	7.007E-1	8.801E-1	7.733E-1	7.292E-1	6.684E+0
Average-3σ	---	5.918E-1	7.369E-1	6.779E-1	6.153E-1	2.641E+0

9. Ic(on)1

Ta=25°C; Vce=5V; If=10mA



Ic(on)1 . (mA)

Min = 4.0

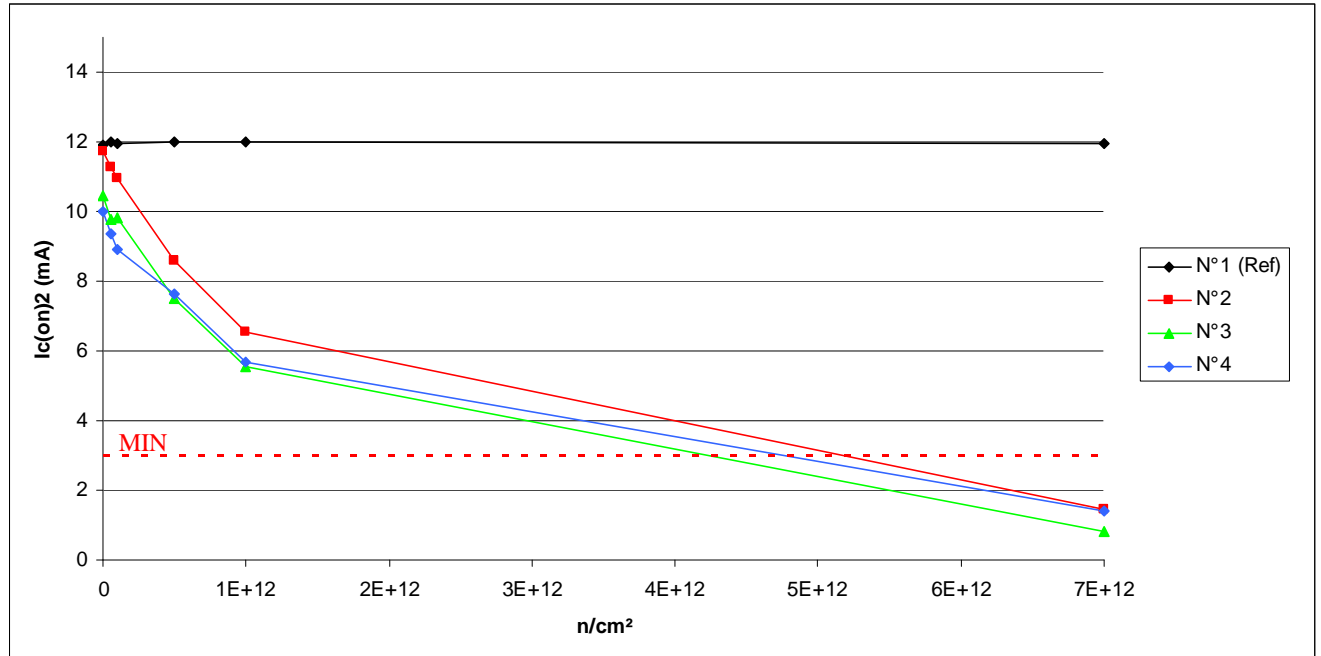
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	29.485	29.873	29.664	29.791	29.782	29.661
N° 2	28.747	28.593	28.379	26.566	24.493	2.813
N° 3	27.107	26.681	26.869	24.784	22.166	1.275
N° 4	28.046	27.553	26.974	26.166	23.846	2.649

Delta [Ic(on)1]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	3.884E-1	1.792E-1	3.058E-1	2.975E-1	1.759E-1
N° 2	---	-1.541E-1	-3.675E-1	-2.181E+0	-4.254E+0	-2.593E+1
N° 3	---	-4.265E-1	-2.388E-1	-2.323E+0	-4.942E+0	-2.583E+1
N° 4	---	-4.935E-1	-1.072E+0	-1.880E+0	-4.200E+0	-2.540E+1
Average	---	-3.580E-1	-5.595E-1	-2.128E+0	-4.465E+0	-2.572E+1
σ	---	1.797E-1	4.487E-1	2.262E-1	4.135E-1	2.852E-1
Average+3σ	---	1.812E-1	7.866E-1	-1.449E+0	-3.225E+0	-2.487E+1
Average-3σ	---	-8.973E-1	-1.906E+0	-2.806E+0	-5.706E+0	-2.658E+1

10.Ic(on)2

Ta=25°C; Vce=0.4V; If=10mA



Ic(on)2 . (mA)

Min = 3.0

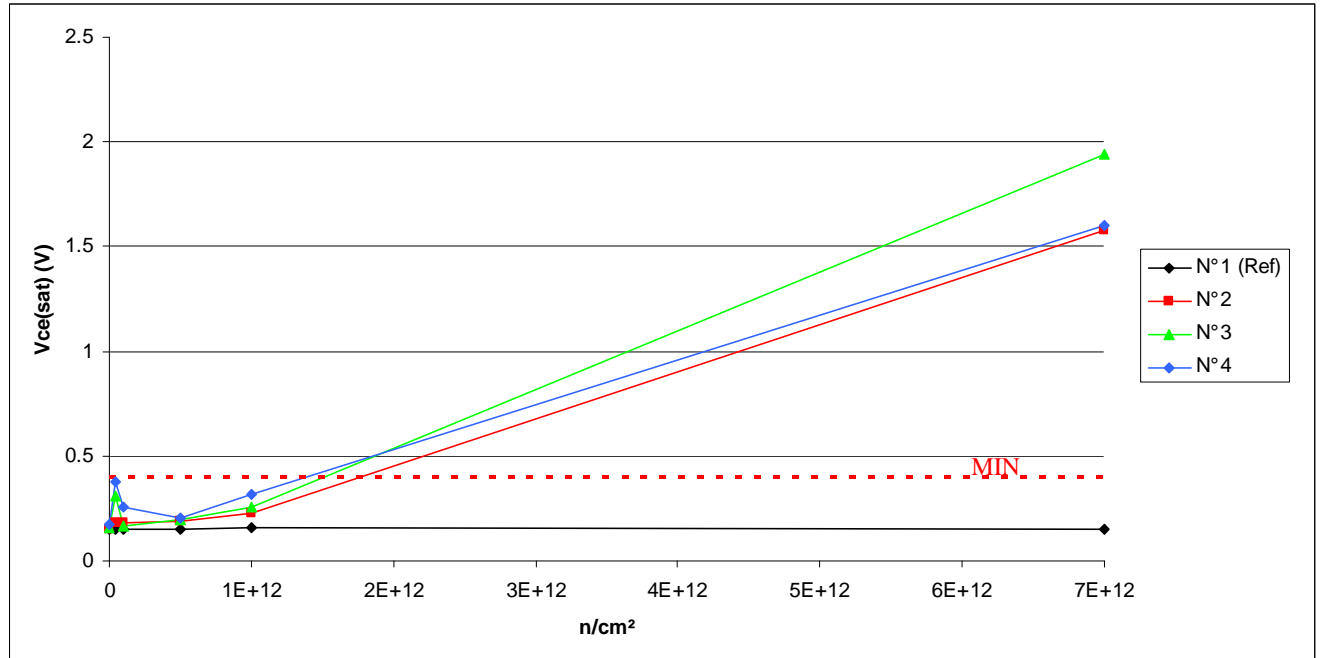
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	11.903	12.008	11.957	11.993	11.978	11.949
N° 2	11.731	11.255	10.969	8.601	6.566	1.469
N° 3	10.442	9.782	9.805	7.506	5.547	0.835
N° 4	10.011	9.372	8.892	7.616	5.699	1.424

Delta [Ic(on)2]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	1.048E-1	5.331E-2	9.002E-2	7.446E-2	4.591E-2
N° 2	---	-4.760E-1	-7.622E-1	-3.130E+0	-5.165E+0	-1.026E+1
N° 3	---	-6.602E-1	-6.378E-1	-2.936E+0	-4.895E+0	-9.608E+0
N° 4	---	-6.391E-1	-1.120E+0	-2.395E+0	-4.312E+0	-8.588E+0
Average	---	-5.918E-1	-8.399E-1	-2.820E+0	-4.791E+0	-9.486E+0
σ	---	1.008E-1	2.501E-1	3.810E-1	4.360E-1	8.440E-1
Average+3σ	---	-2.893E-1	-8.952E-2	-1.677E+0	-3.483E+0	-6.954E+0
Average-3σ	---	-8.943E-1	-1.590E+0	-3.964E+0	-6.099E+0	-1.202E+1

11.Vce(sat)

Ta=25°C; If=50mA; Ic=10mA



Vce(sat) . (V)

Max = 0.4

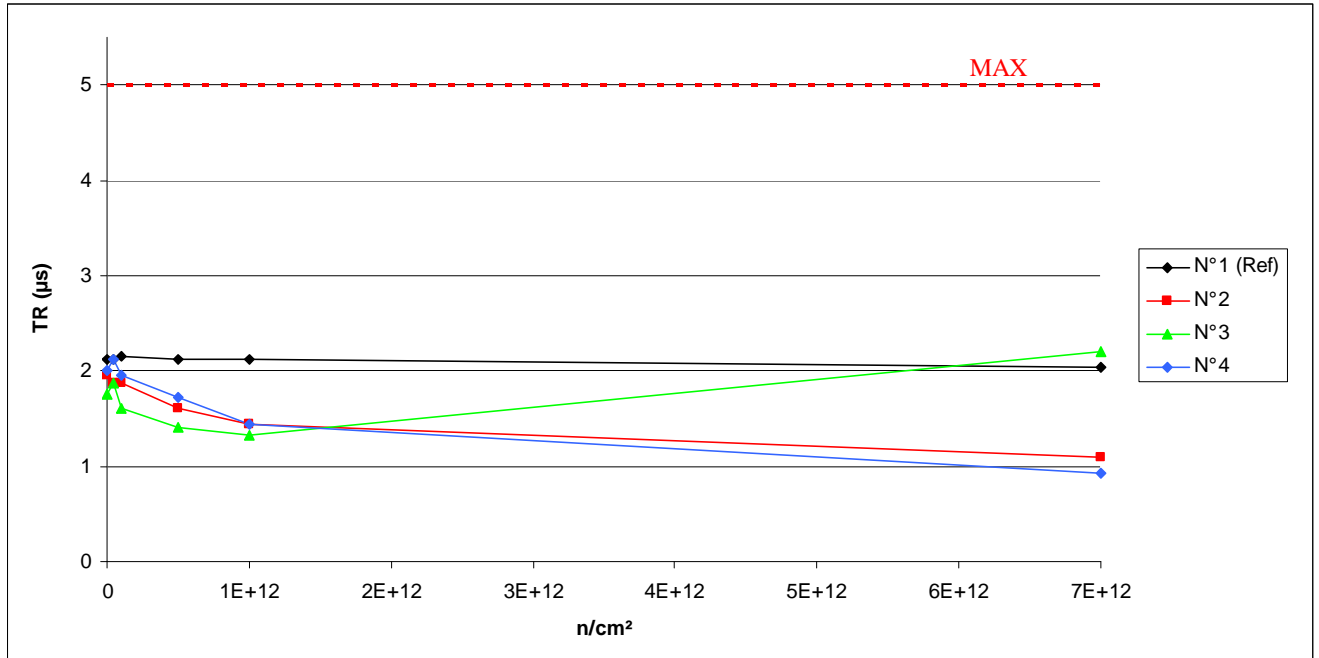
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	0.154	0.154	0.153	0.153	0.155	0.152
N° 2	0.152	0.178	0.178	0.189	0.223	1.577
N° 3	0.160	0.310	0.169	0.198	0.255	1.939
N° 4	0.174	0.374	0.258	0.206	0.315	1.600

Delta [Vce(sat)]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	-3.811E-4	-9.936E-4	-1.406E-3	1.001E-3	-1.699E-3
N° 2	---	2.583E-2	2.566E-2	3.693E-2	7.059E-2	1.425E+0
N° 3	---	1.499E-1	8.854E-3	3.745E-2	9.455E-2	1.779E+0
N° 4	---	1.997E-1	8.401E-2	3.234E-2	1.408E-1	1.426E+0
Average	---	1.251E-1	3.951E-2	3.557E-2	1.020E-1	1.543E+0
σ	---	8.954E-2	3.944E-2	2.815E-3	3.568E-2	2.040E-1
Average+3σ	---	3.938E-1	1.578E-1	4.402E-2	2.090E-1	2.155E+0
Average-3σ	---	-1.435E-1	-7.882E-2	2.713E-2	-5.055E-3	9.312E-1

12.TR

Ta=25°C; Vce=5V; If=2mA; RL=100 Ohms



TR . (µs)

Max = 5.0

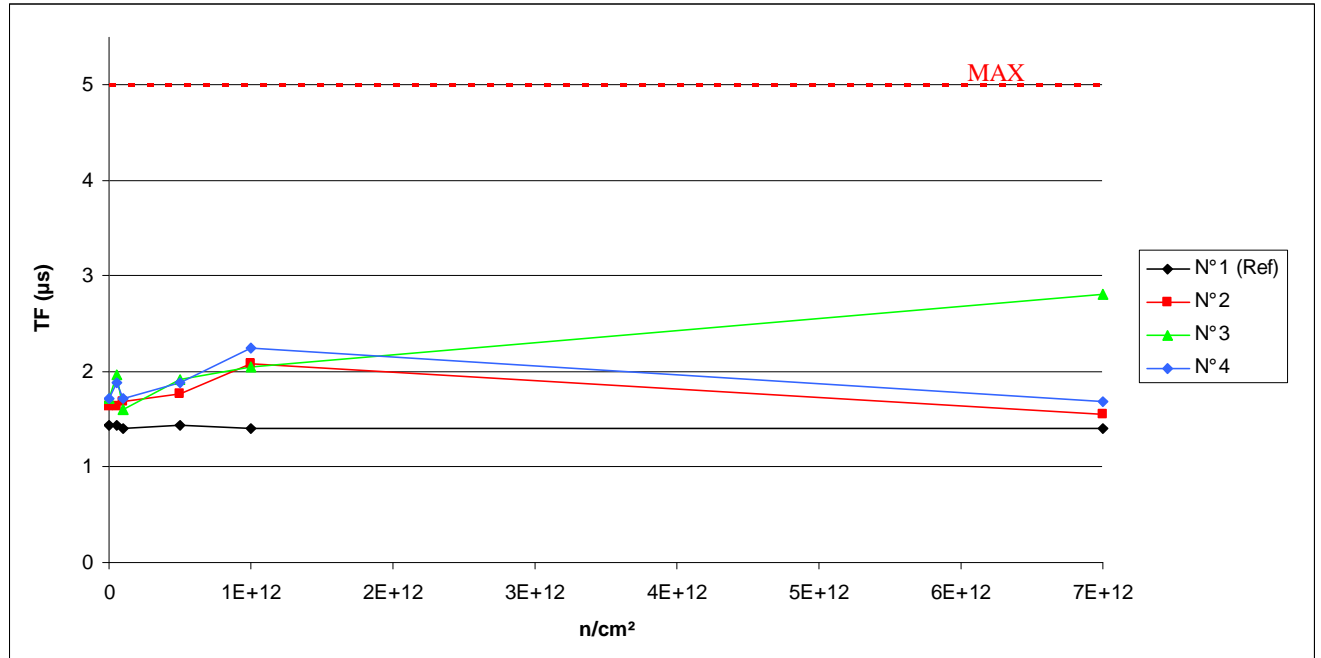
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	2.12	2.12	2.16	2.12	2.12	2.04
N° 2	1.96	1.88	1.88	1.60	1.44	1.10
N° 3	1.76	1.88	1.60	1.40	1.32	2.20
N° 4	2.00	2.12	1.96	1.72	1.44	0.92

Delta [TR]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	0.000E+0	4.000E-2	0.000E+0	0.000E+0	-8.000E-2
N° 2	---	-8.000E-2	-8.000E-2	-3.600E-1	-5.200E-1	-8.600E-1
N° 3	---	1.200E-1	-1.600E-1	-3.600E-1	-4.400E-1	4.400E-1
N° 4	---	1.200E-1	-4.000E-2	-2.800E-1	-5.600E-1	-1.080E+0
Average	---	5.333E-2	-9.333E-2	-3.333E-1	-5.067E-1	-5.000E-1
σ	---	1.155E-1	6.110E-2	4.619E-2	6.110E-2	8.215E-1
Average+3σ	---	3.997E-1	8.997E-2	-1.948E-1	-3.234E-1	1.964E+0
Average-3σ	---	-2.931E-1	-2.766E-1	-4.719E-1	-6.900E-1	-2.964E+0

13.TF

Ta=25°C; Vce=5V; If=2mA; RL=100 Ohms



TF . (µs)

Max = 5.0

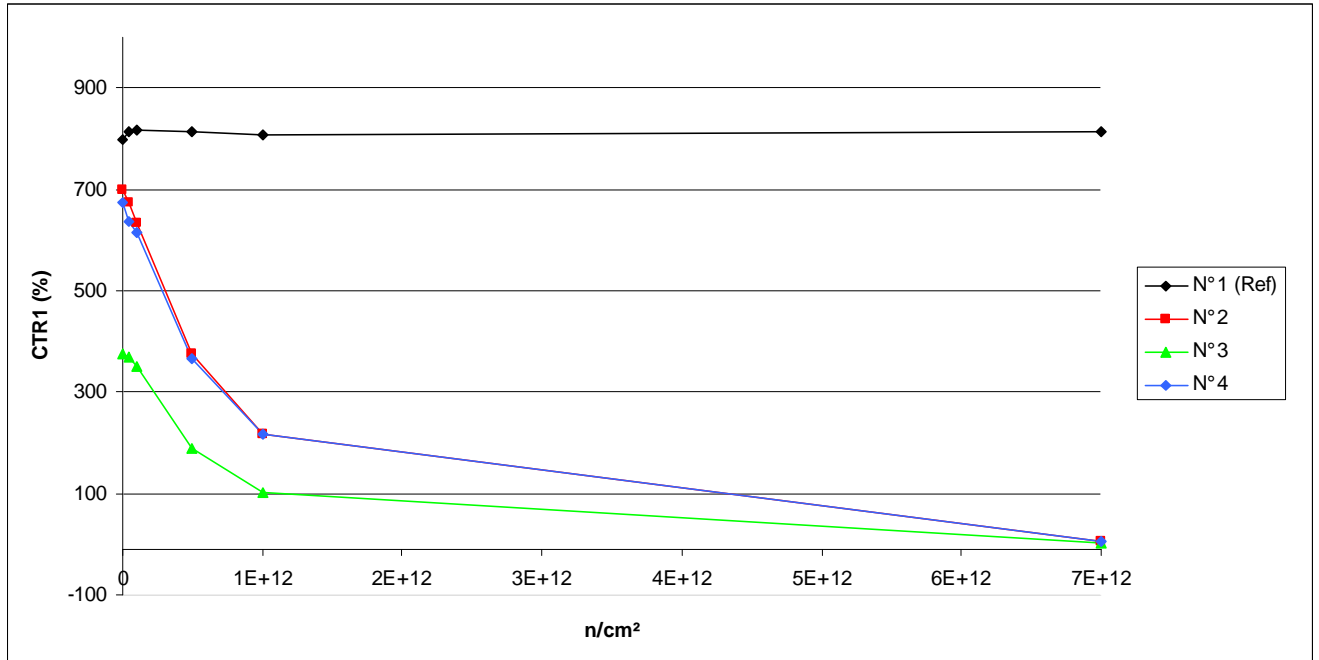
	0.n/cm ²	5E10.n/cm ²	1E11.n/cm ²	5E11.n/cm ²	1E12.n/cm ²	7E12.n/cm ²
N° 1 (Ref)	1.44	1.44	1.40	1.44	1.40	1.40
N° 2	1.64	1.64	1.68	1.76	2.08	1.56
N° 3	1.72	1.96	1.60	1.92	2.04	2.80
N° 4	1.72	1.88	1.72	1.88	2.24	1.68

Delta [TF]

	0.n/cm ²	5E10.n/cm ²	1E11.n/cm ²	5E11.n/cm ²	1E12.n/cm ²	7E12.n/cm ²
N° 1 (Ref)	---	0.000E+0	-4.000E-2	0.000E+0	-4.000E-2	-4.000E-2
N° 2	---	0.000E+0	4.000E-2	1.200E-1	4.400E-1	-8.000E-2
N° 3	---	2.400E-1	-1.200E-1	2.000E-1	3.200E-1	1.080E+0
N° 4	---	1.600E-1	0.000E+0	1.600E-1	5.200E-1	-4.000E-2
Average	---	1.333E-1	-2.667E-2	1.600E-1	4.267E-1	3.200E-1
σ	---	1.222E-1	8.327E-2	4.000E-2	1.007E-1	6.585E-1
Average+3σ	---	4.999E-1	2.231E-1	2.800E-1	7.287E-1	2.295E+0
Average-3σ	---	-2.333E-1	-2.765E-1	4.000E-2	1.247E-1	-1.655E+0

14.CTR1

Ta=25°C; Vce=5V; If=1mA



CTR1 . (%)

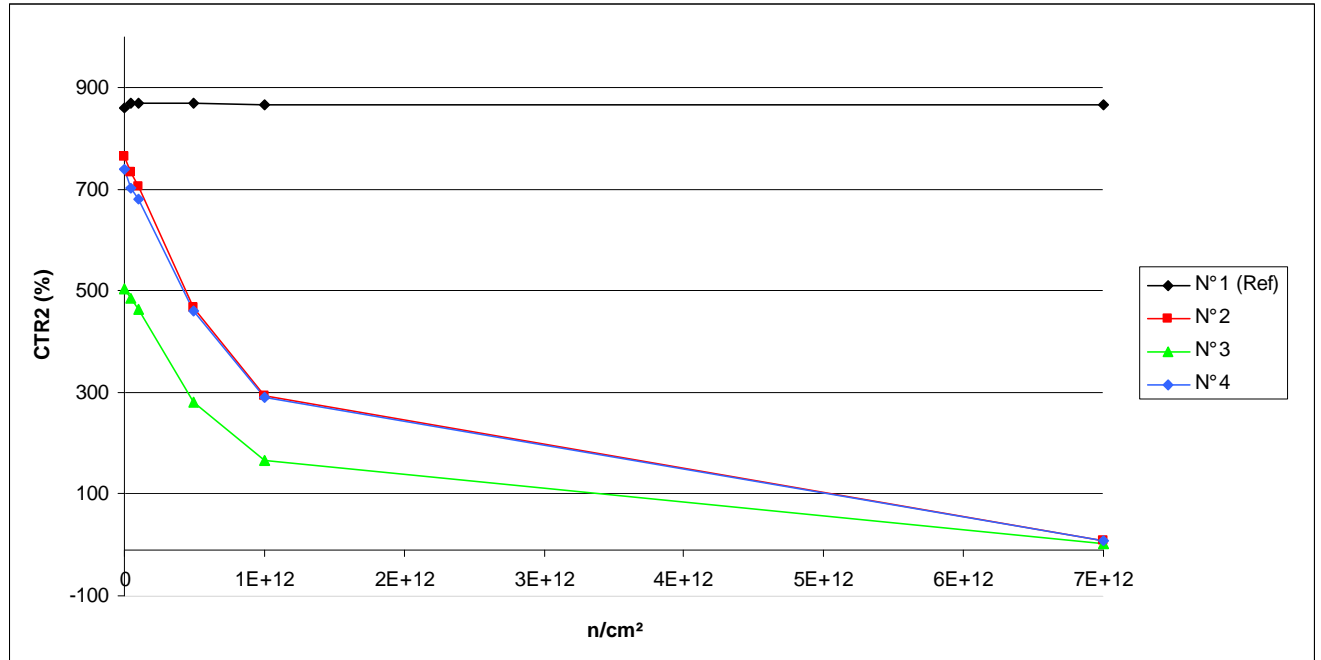
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	799.237	814.156	815.126	815.021	806.623	814.884
N° 2	699.236	672.500	632.439	373.930	217.559	5.516
N° 3	375.998	368.214	349.267	188.535	103.409	1.765
N° 4	674.328	637.477	613.189	367.549	215.805	5.646

1/Delta [CTR1]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	-2.293E-5	-2.439E-5	-2.423E-5	-1.146E-5	-2.402E-5
N° 2	---	5.686E-5	1.510E-4	1.244E-3	3.166E-3	1.799E-1
N° 3	---	5.622E-5	2.035E-4	2.644E-3	7.011E-3	5.639E-1
N° 4	---	8.573E-5	1.479E-4	1.238E-3	3.151E-3	1.756E-1
Average	---	6.627E-5	1.675E-4	1.709E-3	4.443E-3	3.065E-1
σ	---	1.685E-5	3.127E-5	8.103E-4	2.224E-3	2.230E-1
Average+3σ	---	1.168E-4	2.613E-4	4.140E-3	1.111E-2	9.753E-1
Average-3σ	---	1.571E-5	7.367E-5	-7.221E-4	-2.230E-3	-3.624E-1

15.CTR2

Ta=25°C; Vce=5V; If=2mA



CTR2 . (%)

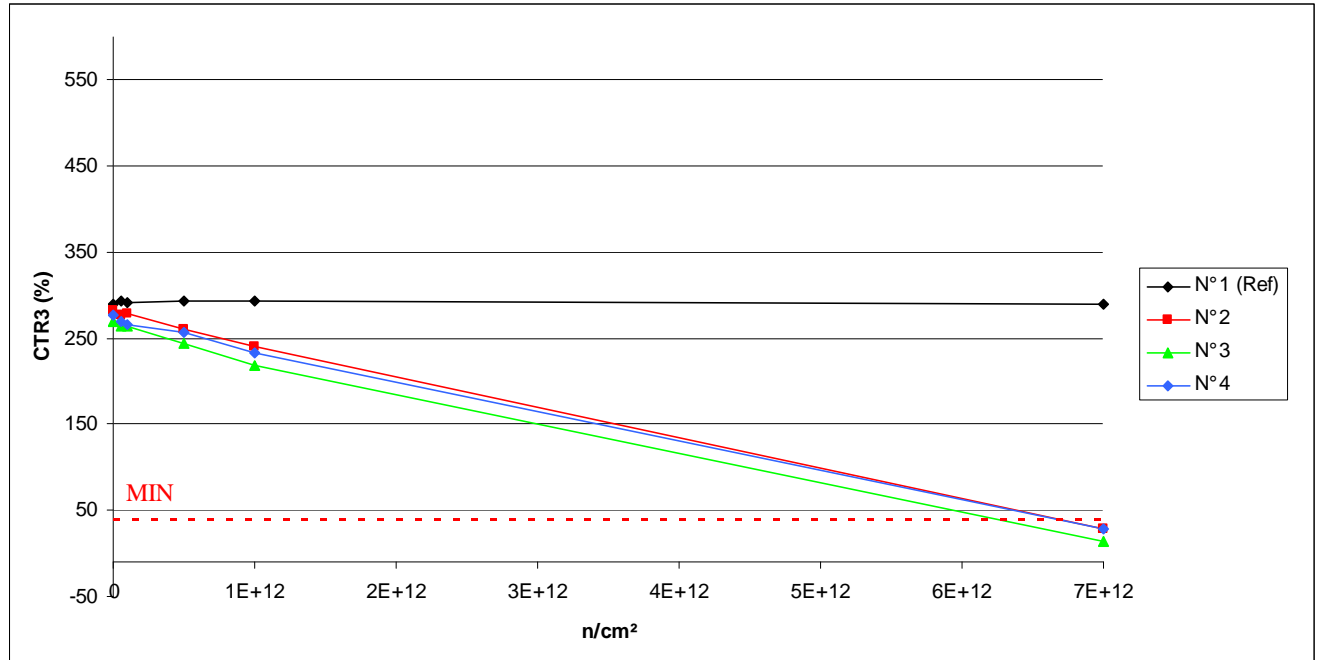
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	861.489	869.540	868.346	869.402	866.861	866.106
N° 2	765.261	734.466	704.561	468.065	294.999	9.374
N° 3	504.549	485.055	462.767	282.125	165.610	3.514
N° 4	739.461	704.082	679.616	461.291	291.601	9.528

1/Delta [CTR2]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	-1.075E-5	-9.168E-6	-1.057E-5	-7.194E-6	-6.189E-6
N° 2	---	5.479E-5	1.126E-4	8.297E-4	2.083E-3	1.054E-1
N° 3	---	7.965E-5	1.789E-4	1.563E-3	4.056E-3	2.826E-1
N° 4	---	6.795E-5	1.191E-4	8.155E-4	2.077E-3	1.036E-1
Average	---	6.747E-5	1.369E-4	1.069E-3	2.739E-3	1.639E-1
σ	---	1.244E-5	3.658E-5	4.273E-4	1.141E-3	1.028E-1
Average+3σ	---	1.048E-4	2.466E-4	2.351E-3	6.162E-3	4.724E-1
Average-3σ	---	3.015E-5	2.712E-5	-2.126E-4	-6.842E-4	-1.447E-1

16.CTR3

Ta=25°C; Vce=5V; If=10mA



CTR3 . (%)

Min = 40.0

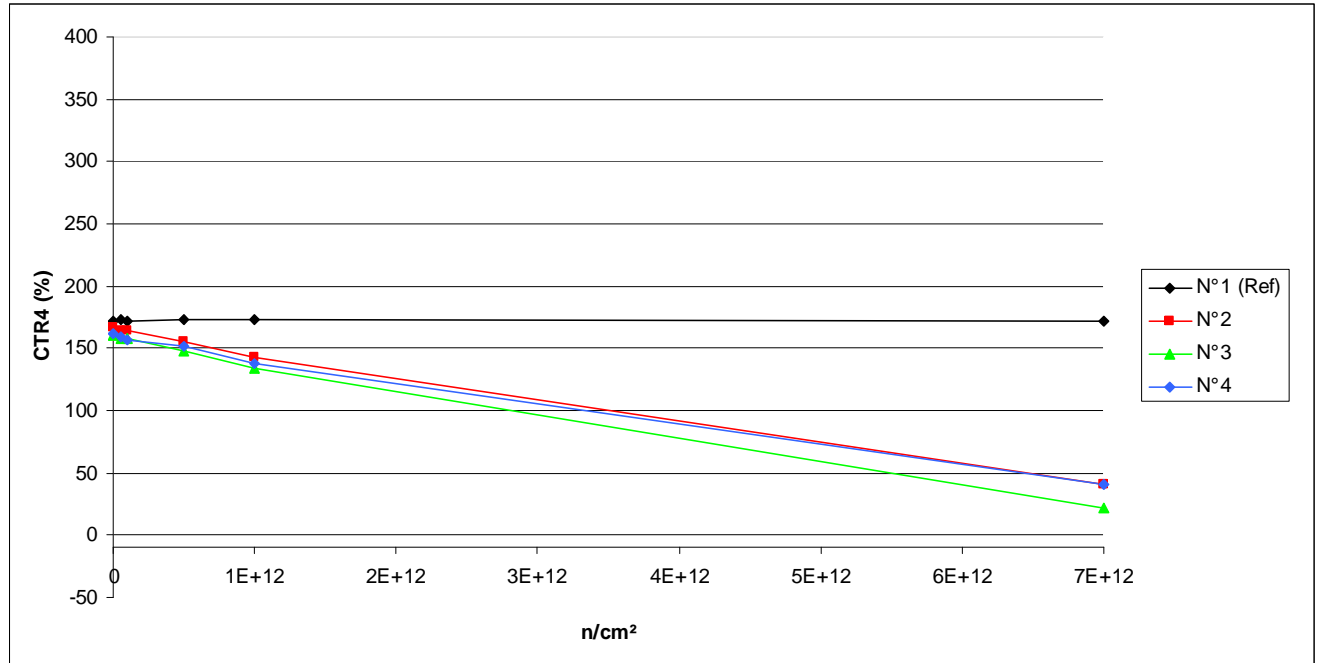
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	290.045	292.451	290.686	292.378	293.205	289.829
N° 2	282.512	277.734	277.813	260.552	241.048	28.413
N° 3	268.951	263.515	263.783	244.637	219.153	13.850
N° 4	276.092	270.409	266.489	257.283	232.634	28.354

1/Delta [CTR3]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	-2.837E-5	-7.604E-6	-2.751E-5	-3.716E-5	2.565E-6
N° 2	---	6.090E-5	5.987E-5	2.983E-4	6.089E-4	3.166E-2
N° 3	---	7.669E-5	7.284E-5	3.695E-4	8.449E-4	6.848E-2
N° 4	---	7.612E-5	1.305E-4	2.648E-4	6.766E-4	3.165E-2
Average	---	7.124E-5	8.774E-5	3.109E-4	7.101E-4	4.393E-2
σ	---	8.959E-6	3.761E-5	5.349E-5	1.215E-4	2.126E-2
Average+3σ	---	9.811E-5	2.006E-4	4.714E-4	1.075E-3	1.077E-1
Average-3σ	---	4.436E-5	-2.509E-5	1.504E-4	3.456E-4	-1.987E-2

17.CTR4

Ta=25°C; Vce=5V; If=20mA



CTR4 . (%)

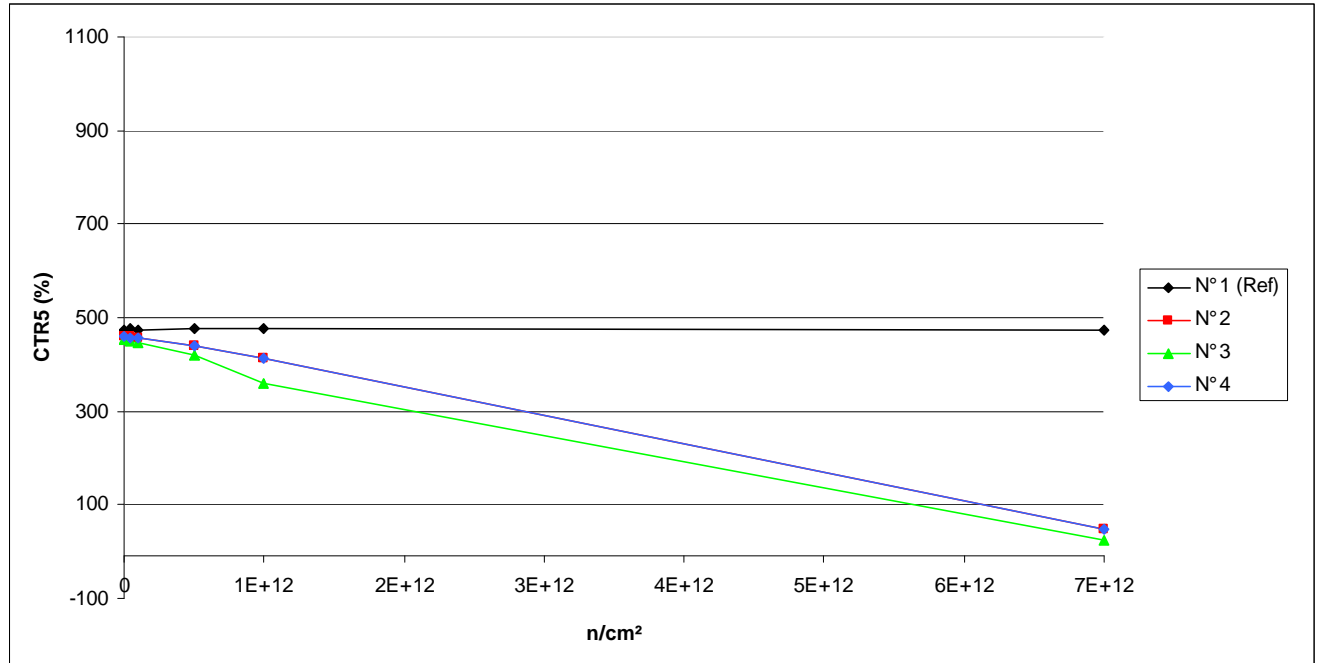
	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	172.050	173.327	172.366	173.254	173.683	171.900
N° 2	167.406	164.878	164.452	155.398	143.392	40.621
N° 3	160.550	157.720	158.462	147.302	134.593	21.995
N° 4	162.017	159.161	156.533	151.336	137.215	40.141

1/Delta [CTR4]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	-4.282E-5	-1.066E-5	-4.041E-5	-5.467E-5	5.072E-6
N° 2	---	9.161E-5	1.073E-4	4.616E-4	1.000E-3	1.864E-2
N° 3	---	1.118E-4	8.207E-5	5.602E-4	1.201E-3	3.924E-2
N° 4	---	1.108E-4	2.163E-4	4.356E-4	1.116E-3	1.874E-2
Average	---	1.047E-4	1.352E-4	4.858E-4	1.106E-3	2.554E-2
σ	---	1.135E-5	7.131E-5	6.571E-5	1.008E-4	1.186E-2
Average+3σ	---	1.388E-4	3.491E-4	6.829E-4	1.408E-3	6.113E-2
Average-3σ	---	7.065E-5	-7.870E-5	2.887E-4	8.035E-4	-1.004E-2

18.CTR5

Ta=25°C; Vce=30V; If=10mA



CTR5 . (%)

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	473.639	476.344	473.768	475.375	475.777	472.482
N° 2	460.830	459.284	457.584	439.705	414.396	45.981
N° 3	452.284	450.628	446.448	419.257	359.995	22.470
N° 4	459.661	457.590	454.940	440.409	413.702	47.648

1/Delta [CTR5]

	0.n/cm²	5E10.n/cm²	1E11.n/cm²	5E11.n/cm²	1E12.n/cm²	7E12.n/cm²
N° 1 (Ref)	---	-1.199E-5	-5.767E-7	-7.709E-6	-9.491E-6	5.168E-6
N° 2	---	7.306E-6	1.540E-5	1.043E-4	2.432E-4	1.958E-2
N° 3	---	8.126E-6	2.891E-5	1.742E-4	5.668E-4	4.229E-2
N° 4	---	9.845E-6	2.258E-5	9.510E-5	2.417E-4	1.881E-2
Average	---	8.426E-6	2.229E-5	1.245E-4	3.506E-4	2.689E-2
σ	---	1.296E-6	6.760E-6	4.325E-5	1.873E-4	1.334E-2
Average+3σ	---	1.231E-5	4.257E-5	2.543E-4	9.124E-4	6.692E-2
Average-3σ	---	4.538E-6	2.015E-6	-5.246E-6	-2.113E-4	-1.313E-2