Università degli Studi di Cassino

Experimental Study on the Effect of the Gate Oxide Thickness and the Epitaxial Layer Resistivity on the Reliability of Low Blocking Voltage Power VDMOSFET during Heavy Ion Exposure

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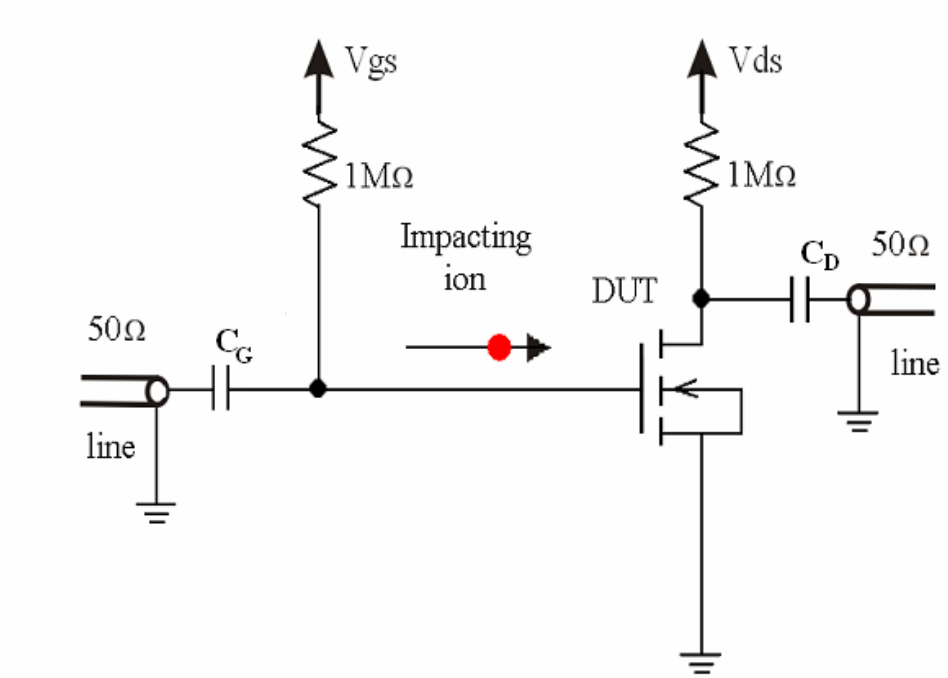
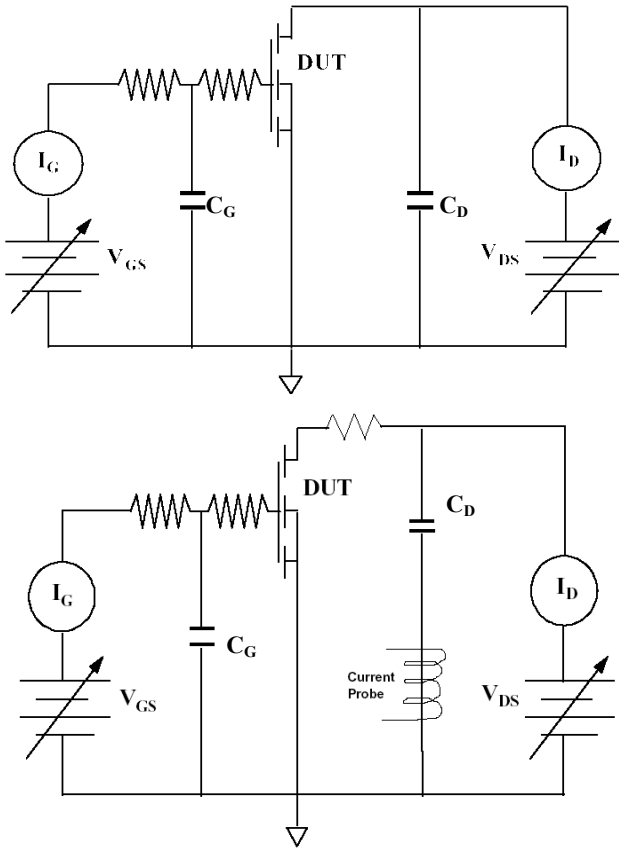
INTRODUCTION

- Power MOSFET's are very important devices for space applications.
- The impact with energetic particles can cause their premature failure. The impact is accompanied by a charge generation that can be experimentally detected.
- The failure mechanisms reported in literature are not completely able to explain the experimental data.
- Further study concerning the correlation between the charge amplification, the oxide/epitaxial layer characteristics and failure mechanism is still necessary.

EXPERIMENTAL SET-UP





MIL – STD – 750

METHOD 1080

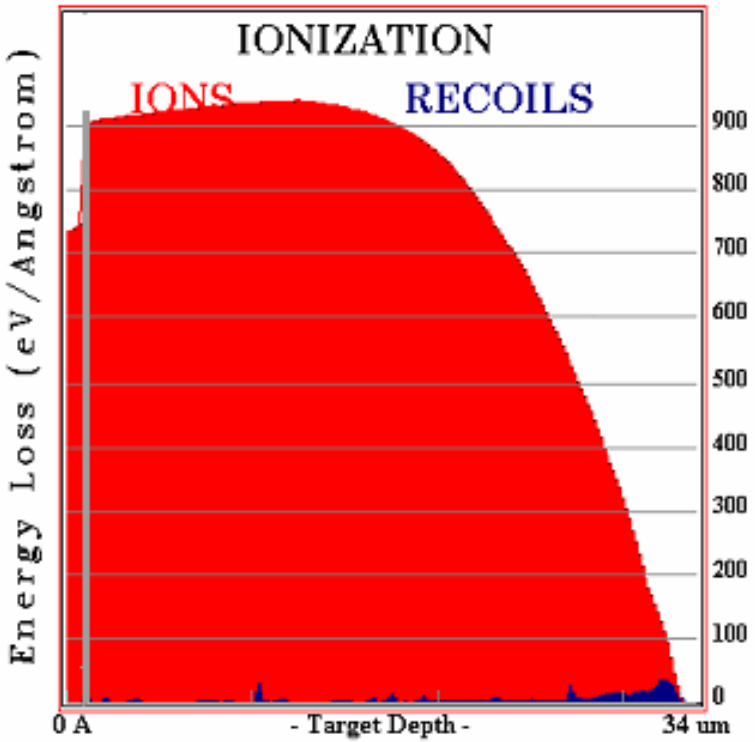
TESTED DEVICES

DUT	Epitaxial Resistivity	Gate Oxide Thickness
A	Same	ToxA
B	Same	ToxB=ToxA*0.9
C	Same	ToxC=ToxA*0.68

DUT	Gate Lay-Out	Epitaxial Resistivity
D	Same	Low
E	Same	High

CHOISE OF THE IMPACT ION

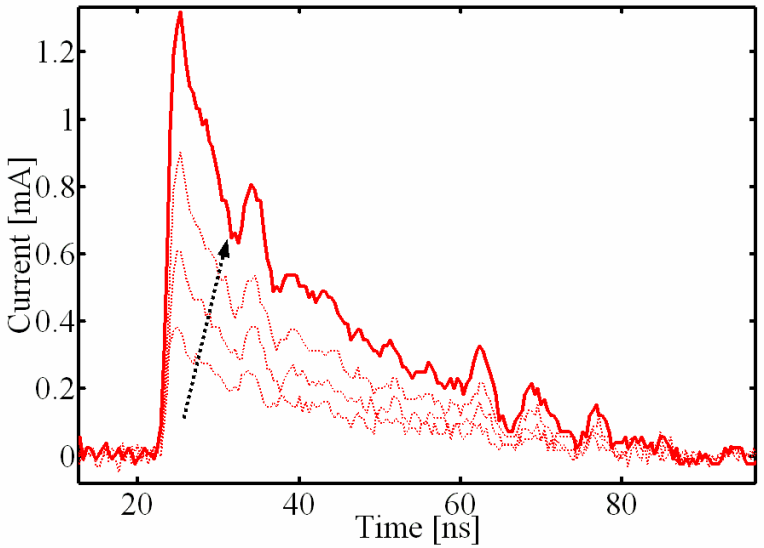
REGION	LOW VOLTAGE POWER MOSFET
Metal	3µm
Silicon Nitride	1µm
Polysilicon	0.5µm
Gate Oxide	0.05µm
Field Oxide	1µm
Base p	1-2µm
Epitaxial n	10-15µm

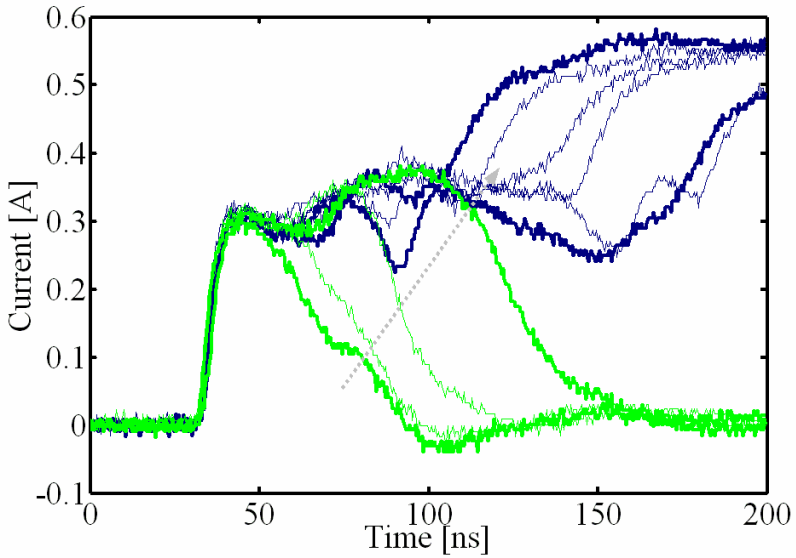


$^{79}Br_{35}$, 250 MeV

EXPERIMENTAL RESULTS

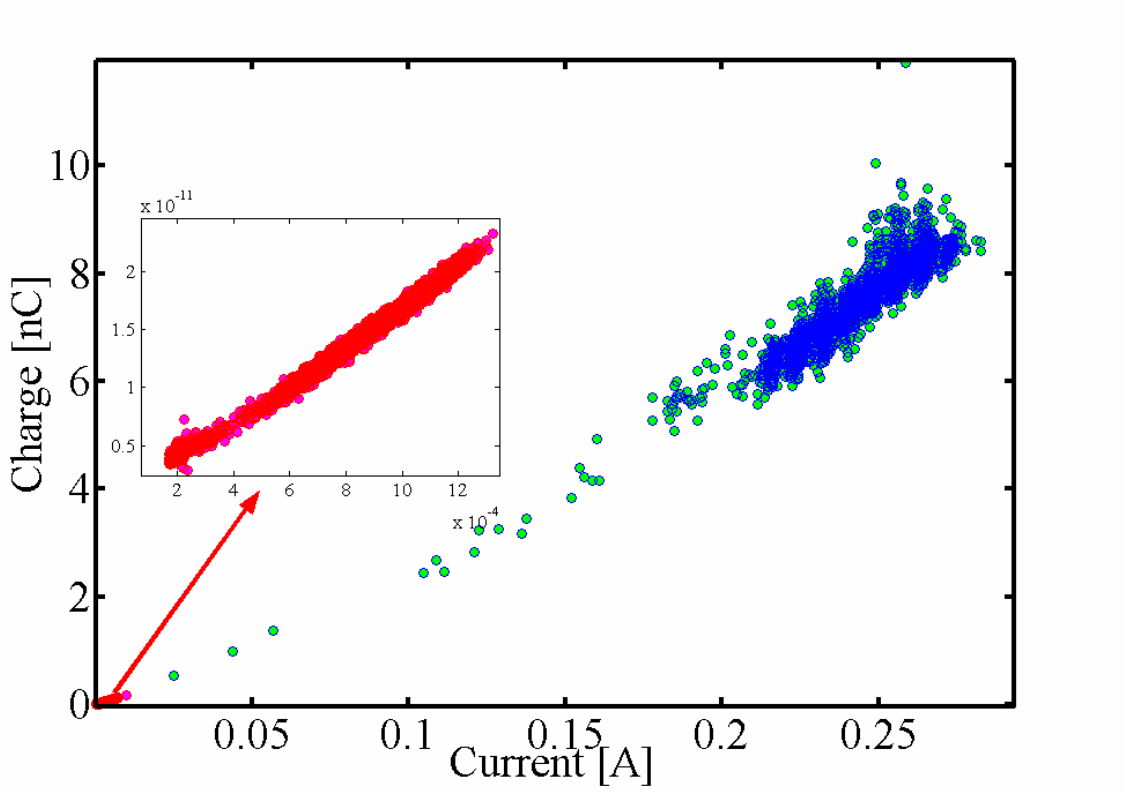
Typical Drain Current Waveforms





EXPERIMENTAL RESULTS

Two-dimensional Scatter Plot



STATISTICAL ANALISYS

Γ-like Distribution Function

The collected charge at fixed ion species, energy and bias voltages results well described by a Γ-pdf whose formula is:

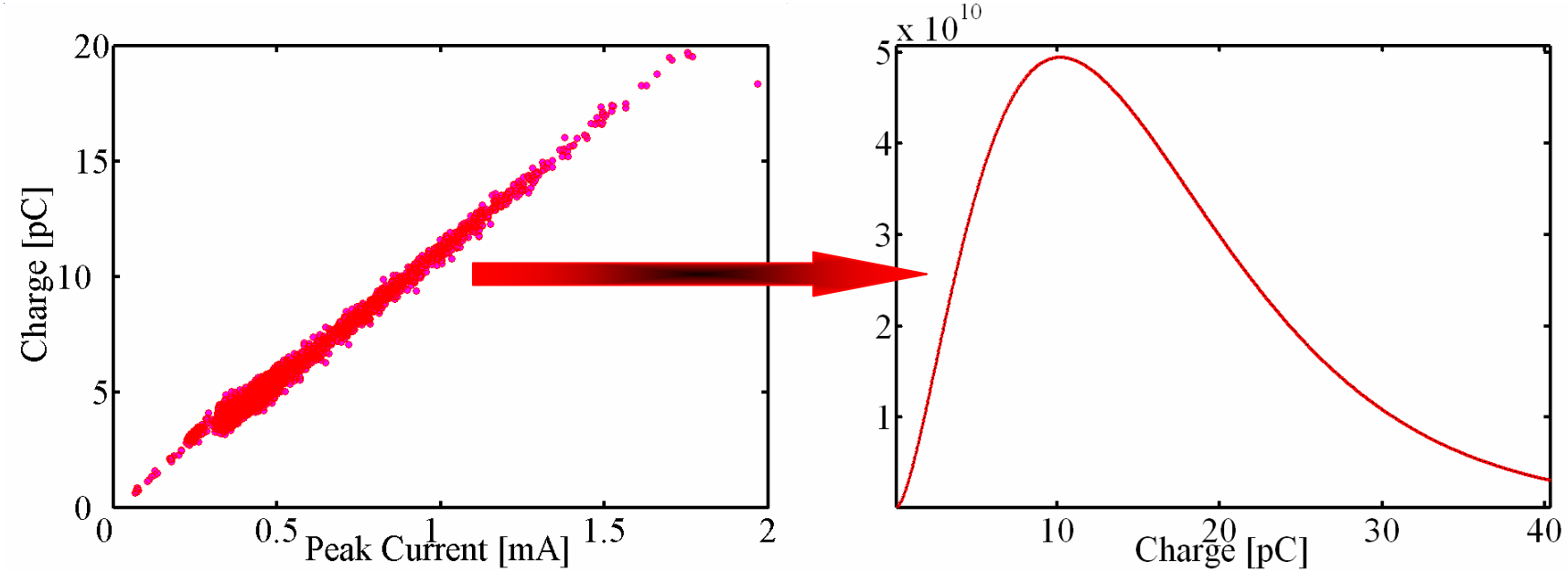
$$f(x|(a,b)) = \begin{cases} \dfrac{x^{a-1}\, e^{x/b}}{b^{a}\, \Gamma(a)}, & x > 0 \\ 0, & x \le 0 \end{cases}$$

where the parameters a and b have been calculated with the Maximum Likelyhood Estimation Technique (MLE)

STATISTICAL ANALISYS

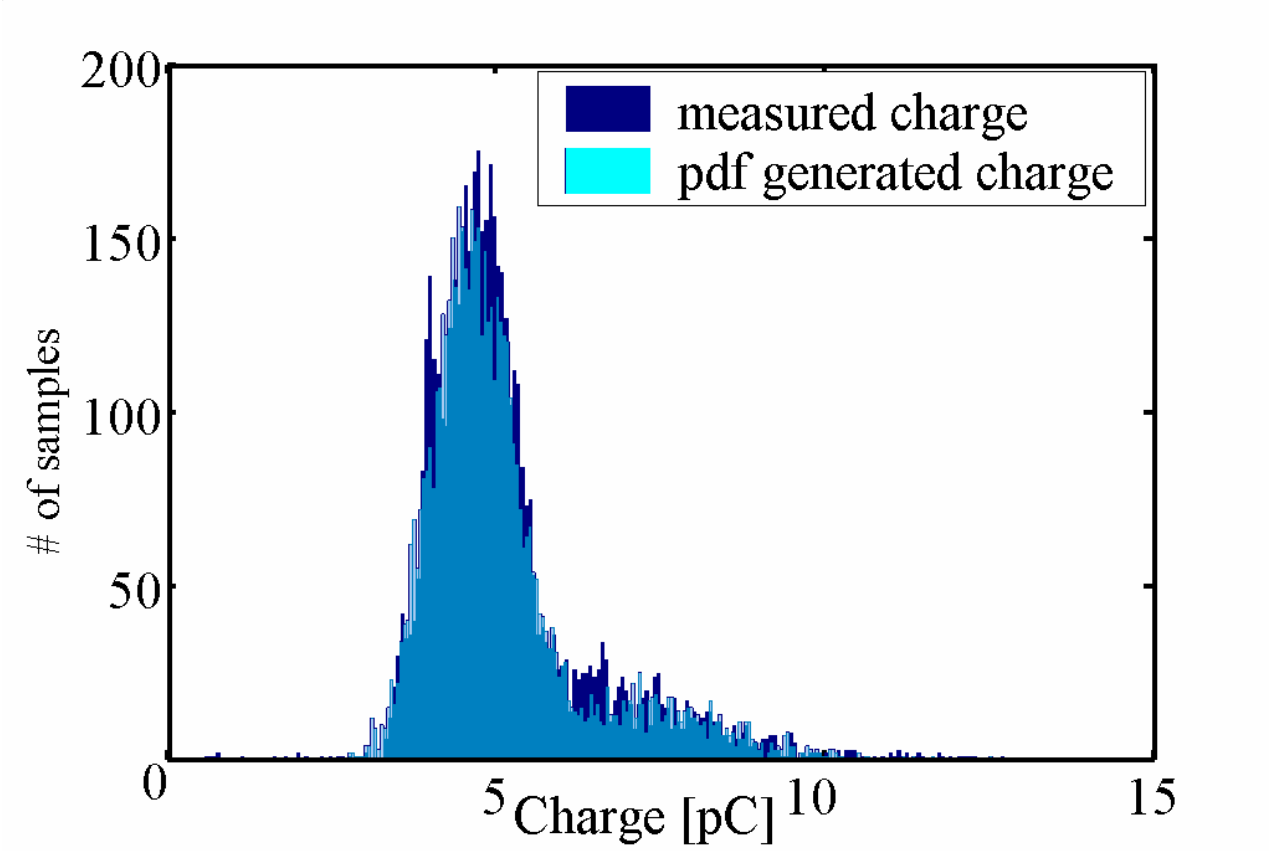
Γ-like Distribution Function

250 MeV $^{79}Br_{35}$



STATISTICAL ANALISYS

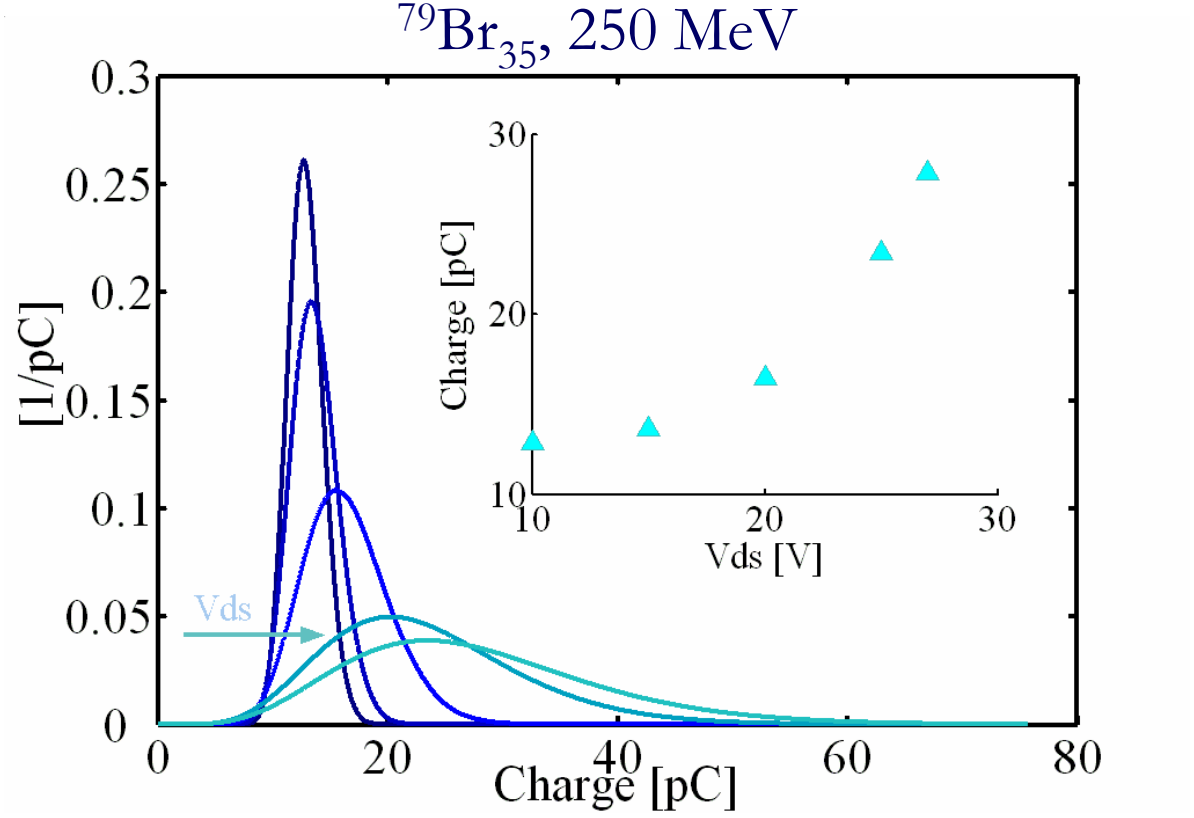
Γ-like Distribution Function



STATISTICAL ANALISYS

Γpdf of the Drain Charge

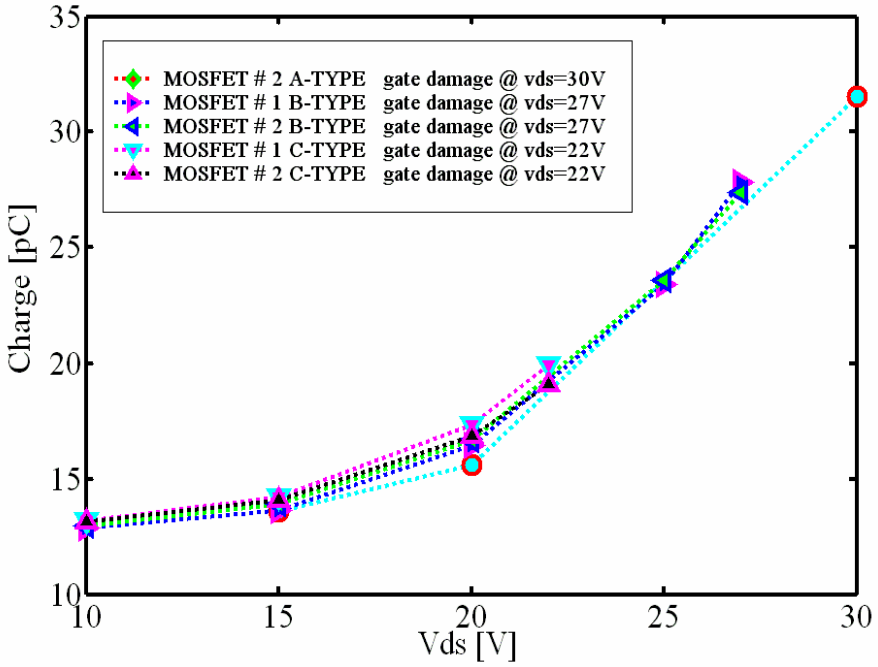
$^{79}Br_{35}$, 250 MeV



STATISTICAL ANALISYS

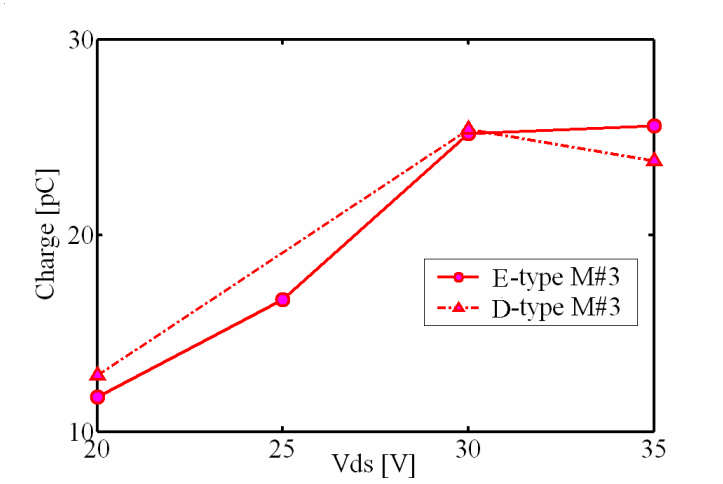
Mean Drain Generated Charge Versus Vds

DUT	GATE OXIDE THICKNESS	V_{DS}* @ V_{GS}=0V
Mosfet #1 A-TYPE	$T_{OX}A$	30V
Mosfet #2 A-TYPE	$T_{OX}A$	30V
Mosfet #1 B-TYPE	$T_{OX}B = T_{OX}A * 0.9$	27V
Mosfet #2 B-TYPE	$T_{OX}B = T_{OX}A * 0.9$	27V
Mosfet #1 C-TYPE	$T_{OX}C = T_{OX}A * 0.68$	22V
Mosfet #2 C-TYPE	$T_{OX}C = T_{OX}A * 0.68$	22V

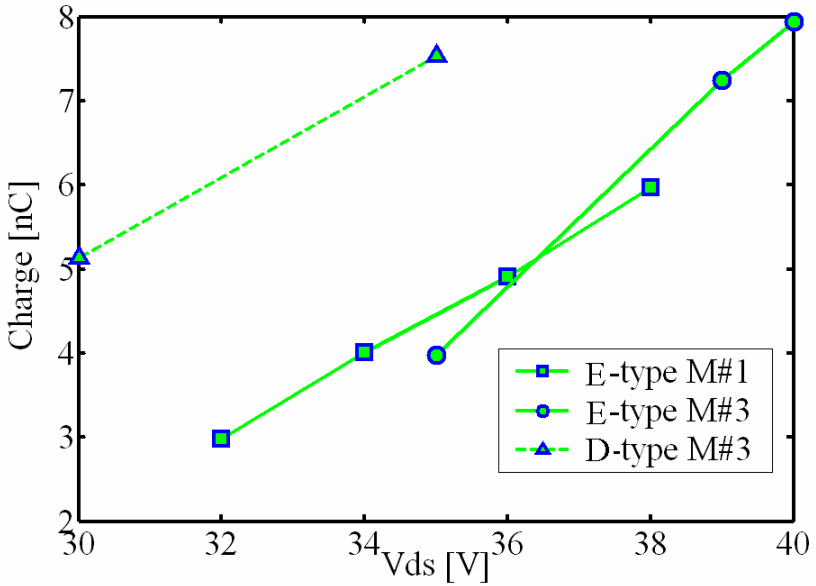


STATISTICAL ANALISYS

Mean Drain Generated Charge Versus Vds

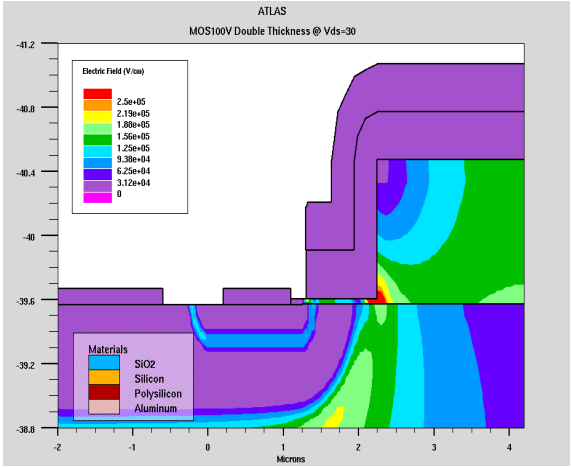


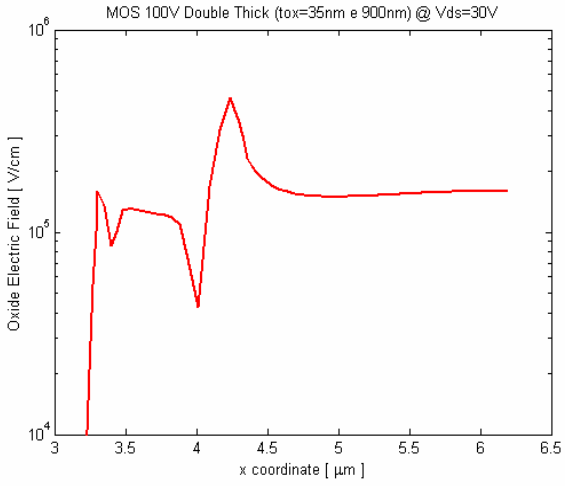
DUT	Gate Lay-Out	Epitaxial Resistivity
D	Same	Low
E	Same	High



GATE DAMAGE

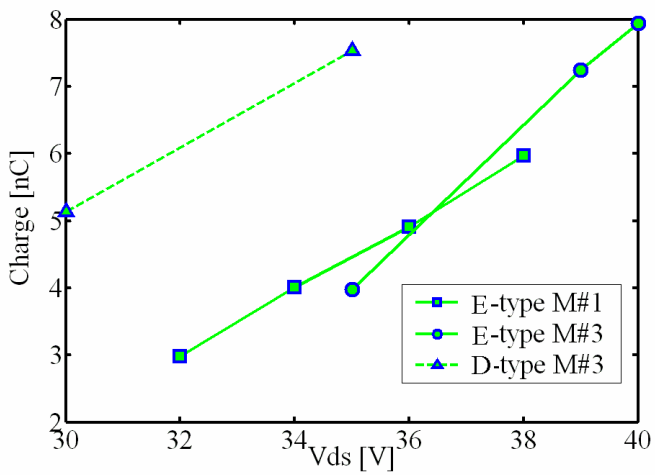
DUT	GATE OXIDE THICKNESS	V_{DS}* @ V_{GS}=0V
Mosfet #1 A-TYPE	$T_{OX}A$	30V
Mosfet #2 A-TYPE	$T_{OX}A$	30V
Mosfet #1 B-TYPE	$T_{OX}B = T_{OX}A * 0.9$	27V
Mosfet #2 B-TYPE	$T_{OX}B = T_{OX}A * 0.9$	27V
Mosfet #1 C-TYPE	$T_{OX}C = T_{OX}A * 0.68$	22V
Mosfet #2 C-TYPE	$T_{OX}C = T_{OX}A * 0.68$	22V





CHARGE GENERATION INSIGHTS

DUT	Gate Lay-Out	Epitaxial Resistivity
D	Same	Low
E	Same	High



$$J_0 = \frac{q\mu_{epi} N_{epi} (V_{CB} + \psi)}{W_{epi}}$$

$$\frac{J_D}{J_E} = \frac{W_{epi,E} N_D}{W_{epi,D} N_E}$$

$$\frac{J_D}{J_E} = \frac{N_D}{N_E}$$

CONCLUSIONS

- An experimental investigation on the charge generation and the single event damage of medium voltage power MOSFET as a function of the gate oxide and the epi-layer characteristics has been presented.
- The failure voltage is sensitive to the gate oxide thickness.
- The charge generation is sensitive to the gain of the parasitic BJT.
- In conclusion the experimental data show that the failure mechanisms of the tested devices involves both the gate structure and the drain structure for which an important role is played by the activation of the parasitic bipolar transistor.