Effetti da Evento Singolo in MOSFET di potenza

G.Busatto, F.Iannuzzo, A. Porzio, A.Sanseverino, F.Velardi

SOMMARIO

- Introduzione sui MOSFET di potenza
- Set-up Sperimentale
- Analisi Statistica
- Risultati Sperimentali
- Simulazioni 3D
- Conclusioni

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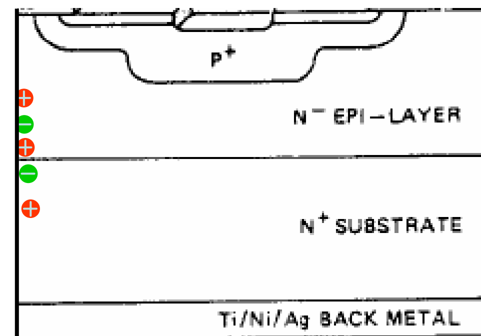
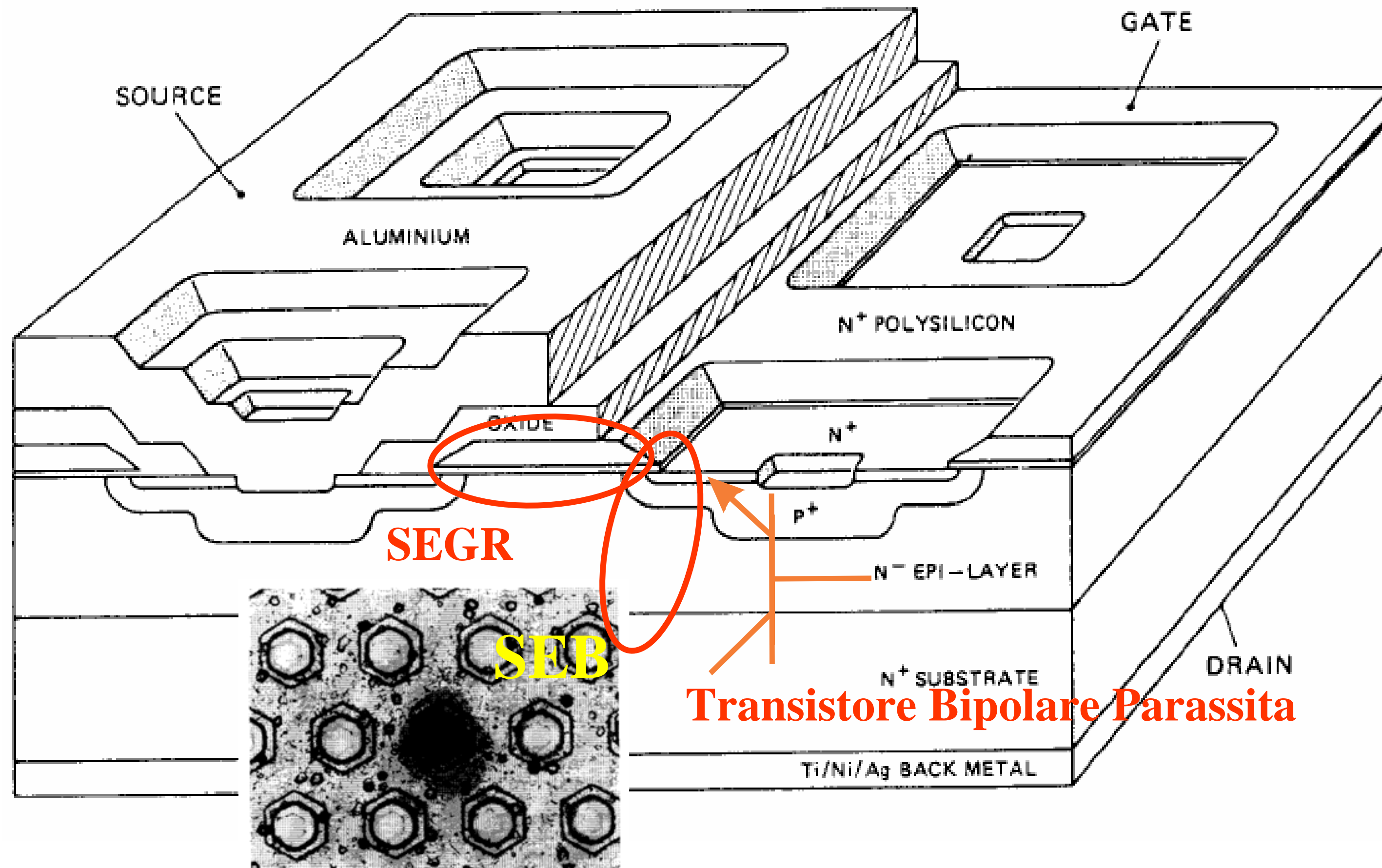
Struttura del MOSFET



Meccanismi di rottura proposti in letteratura



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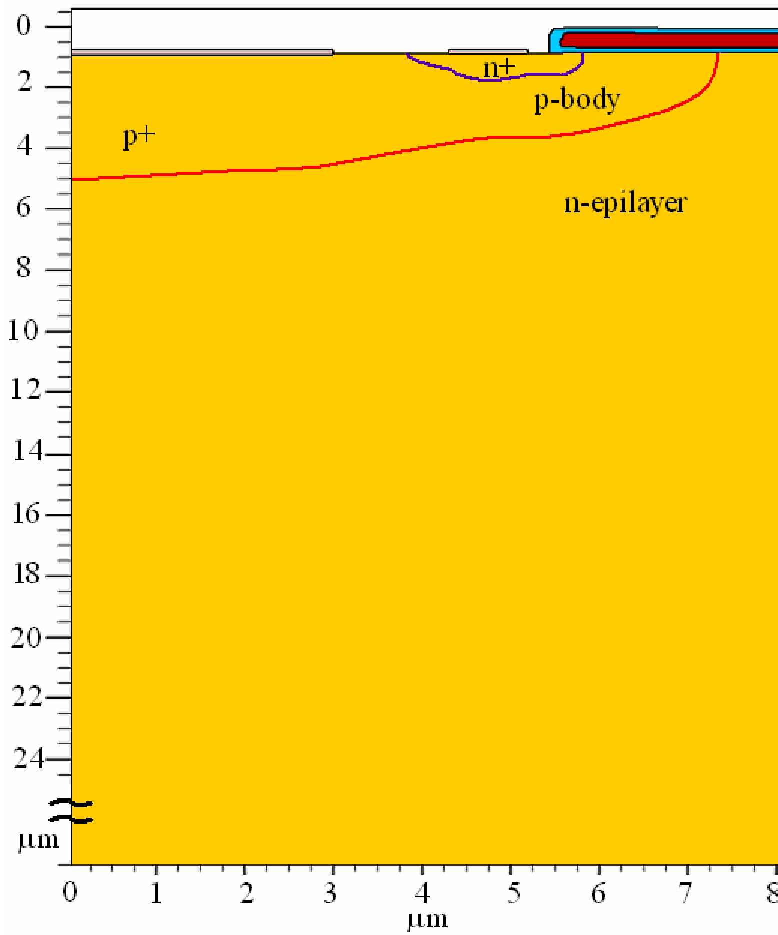
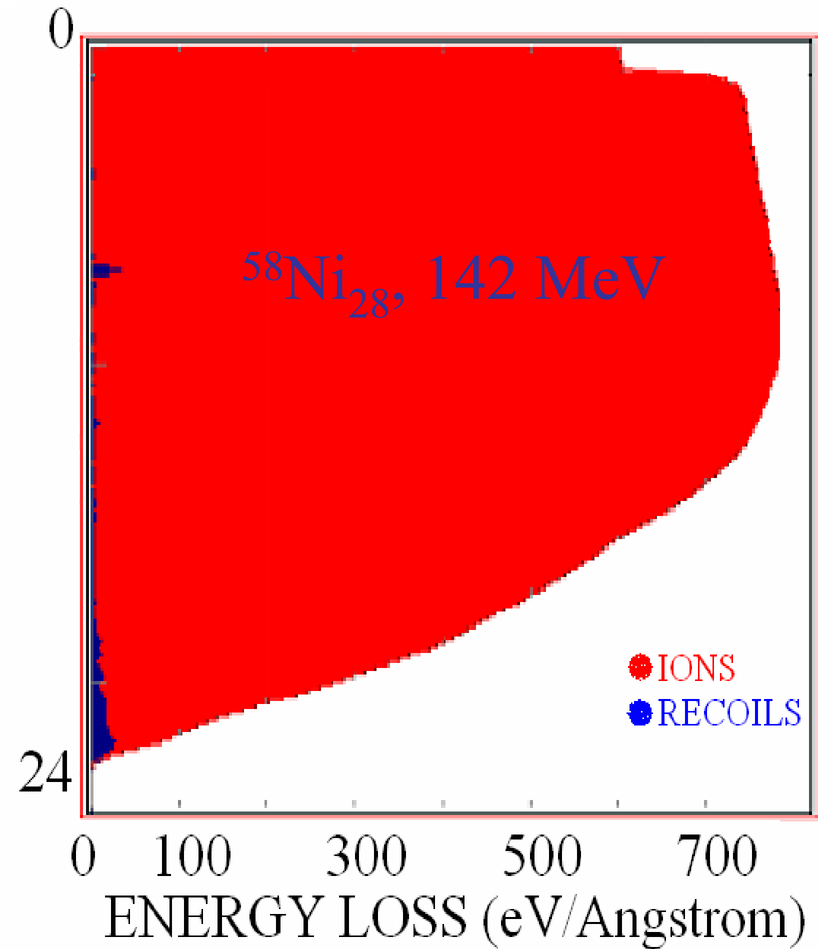
IL SET-UP SPERIMENTALE

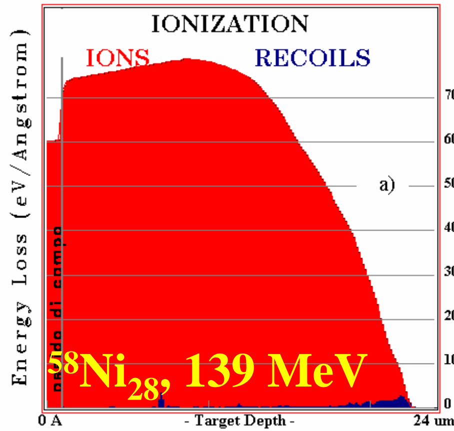
LA SCELTA DELLA PARTICELLA INCIDENTE

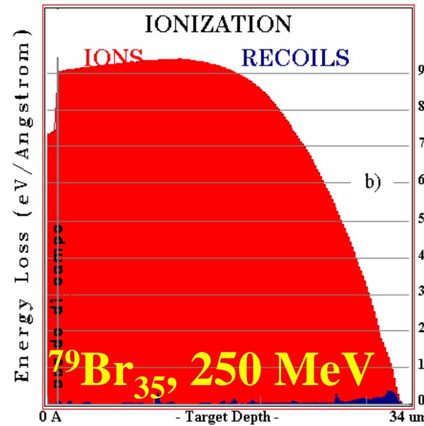


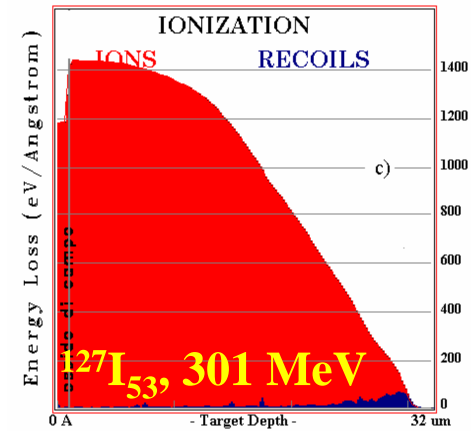


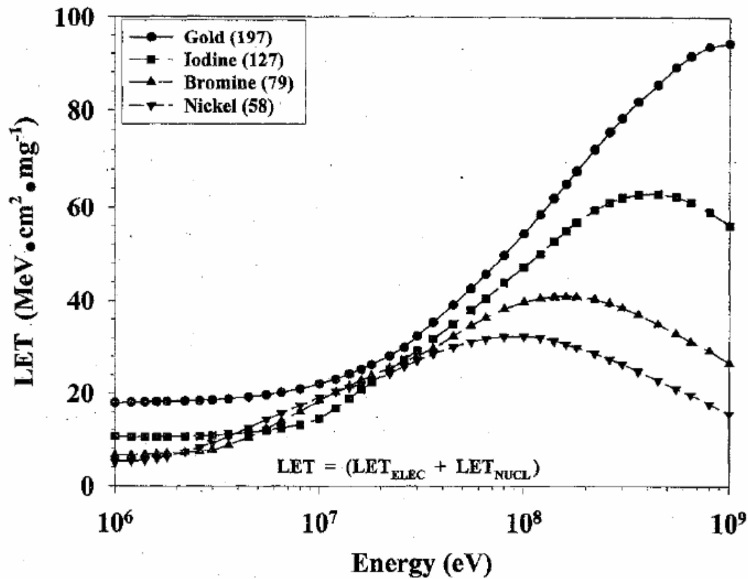
IL SET-UP SPERIMENTALE

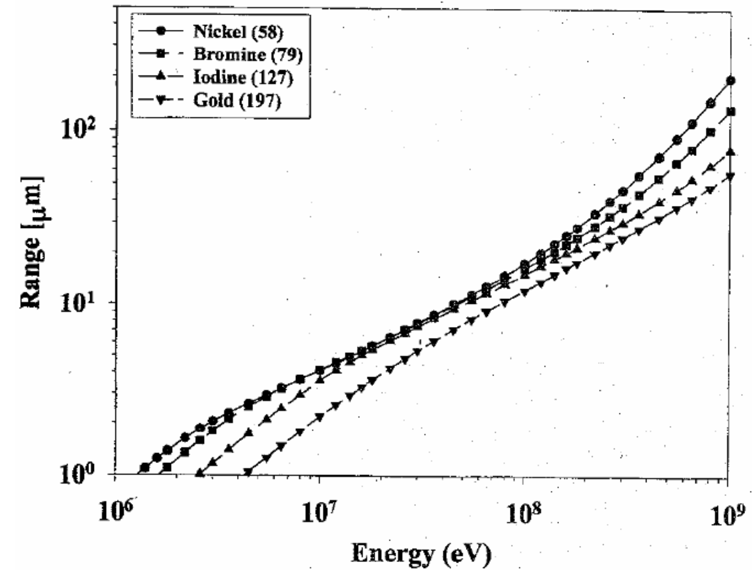
LA SCELTA DELLA PARTICELLA INCIDENTE











Titus et al. – IEEE TNS - 1996

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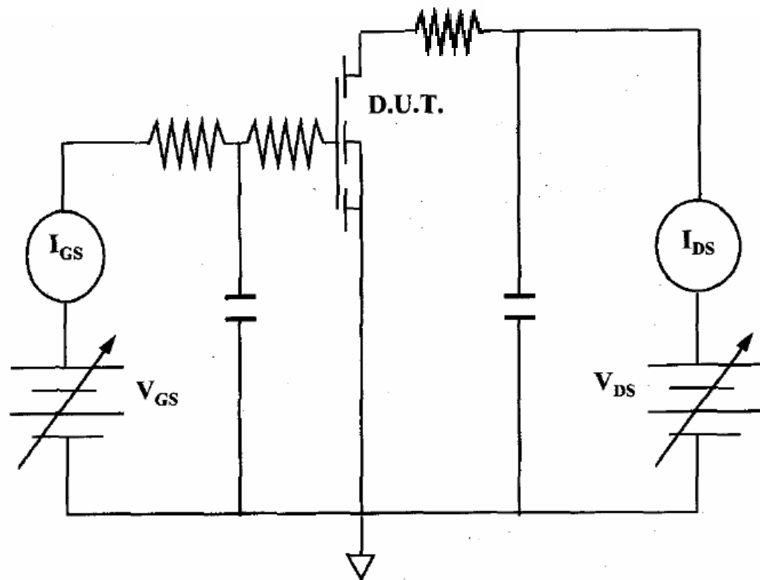
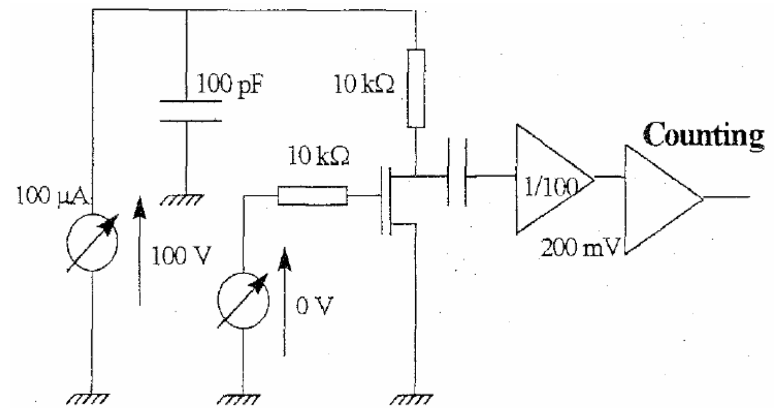
Circuiti di Test proposti in letteratura

Circuito usato per le prove di qualificazione



Circuito STAMTIL (proposto dal CNES)



- Protocollo militare MIL RIF 19500/appendice E sancisce le caratteristiche Rad Hard che il dispositivo deve possedere.

- Standard militare MIL STD 750 stabilisce la metodologia con cui i test devono essere effettuati, in particolare:
  - Metodo 1019 relativo all'affidabilità nei confronti della dose totale ionizzante.
  - Metodo 1080 relativo all'affidabilità nei confronti di effetti da singolo evento.

SEB Cross-section al variare della LET

IRF150

SEB Cross Section [cm^2]

10^0, 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, 10^{-7}

20 40 60 80 100

LET [MeV•cm^2•mg^{-1}]

Static Mode (V_{DS}=70 V, F= 0 kHz)

Dynamic Mode (V_{DS}=70 V, F=63 kHz)

Titus et al. – IEEE TNS - 1996

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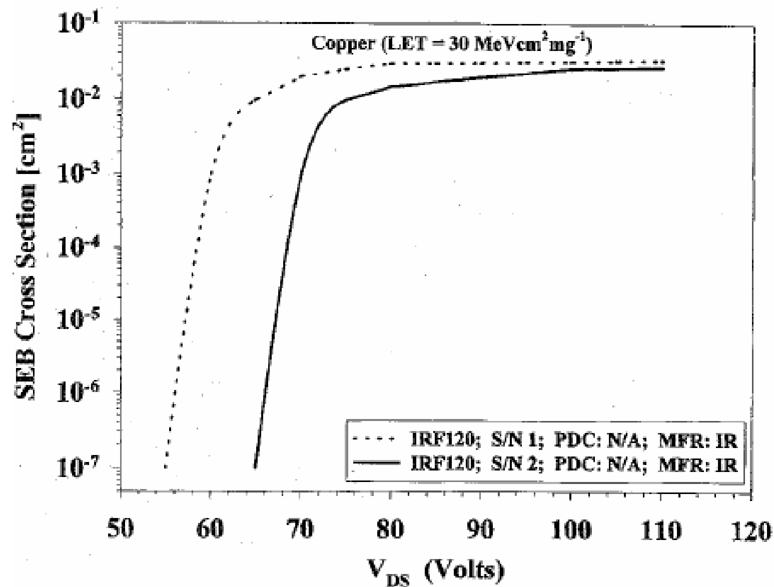
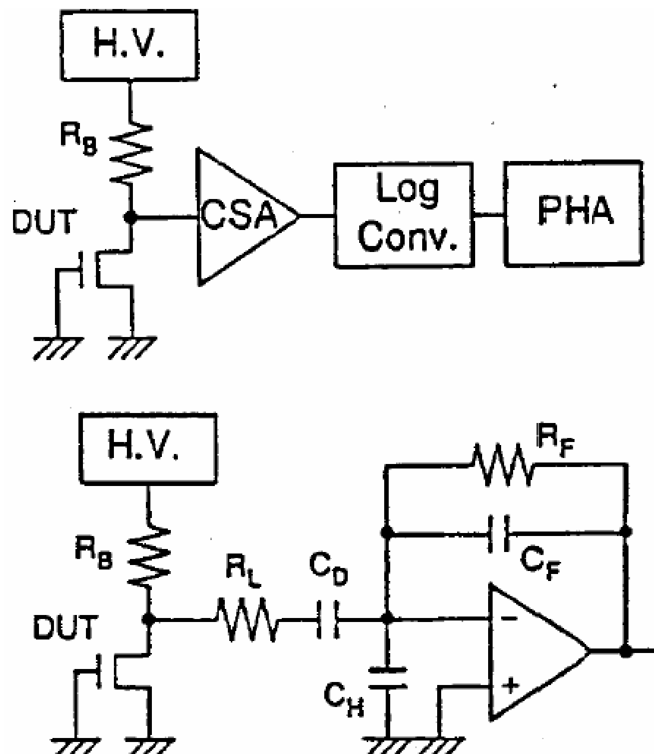
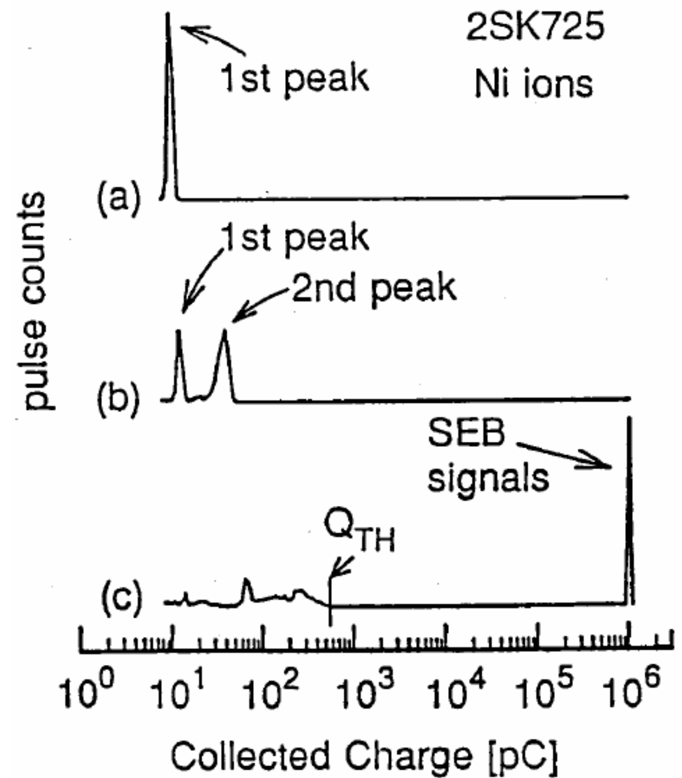
SEB Cross-section al variare della tensione applicata



Titus et al. – IEEE TNS - 1996

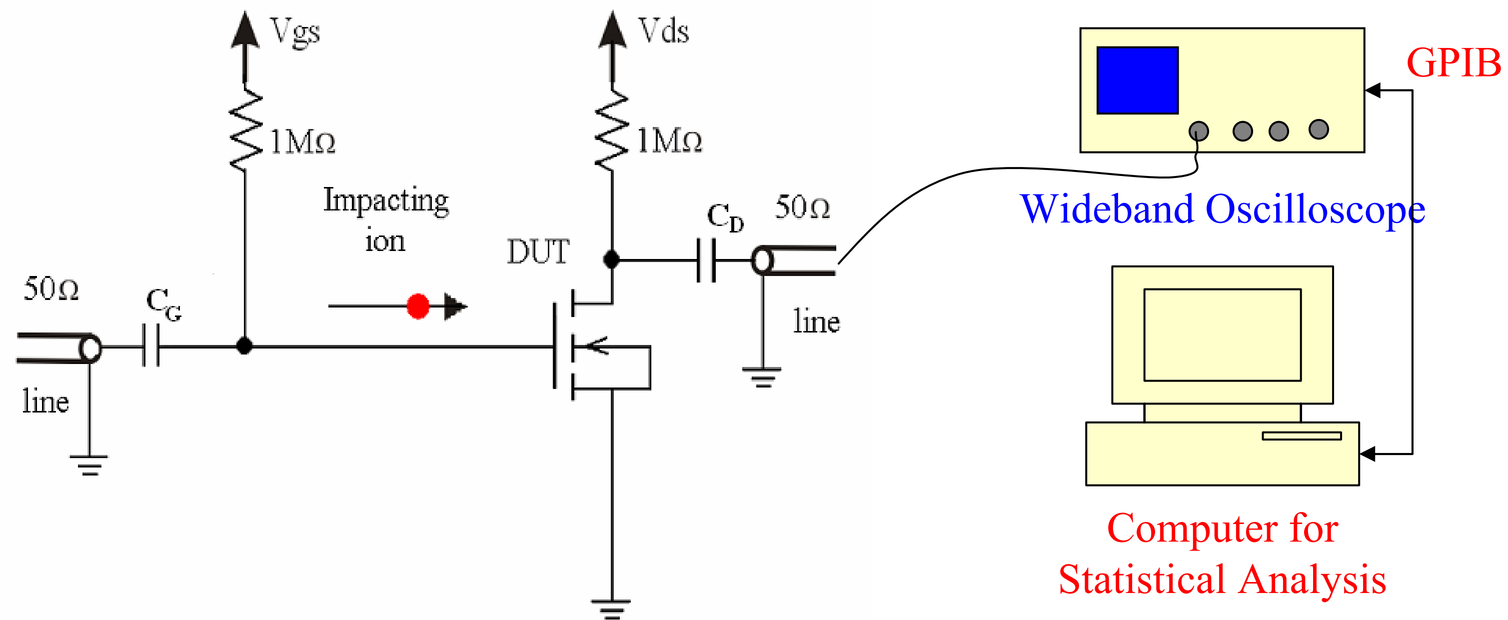
Circuito di Test proposto in letteratura EPIC Spectrum





Kuboyama et al. – IEEE TNS - 1992

IL SET-UP SPERIMENTALE



A large number of events (typically 3000) is acquired and analyzed

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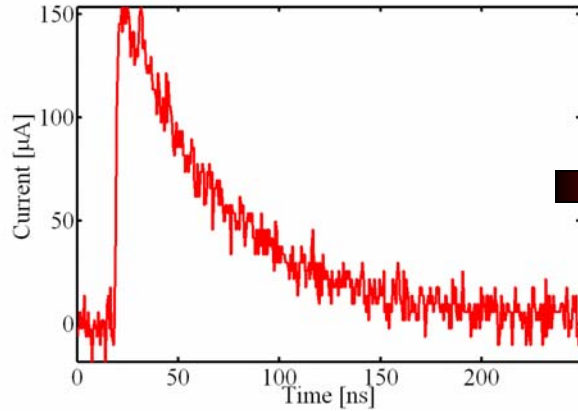
Analisi Statistica

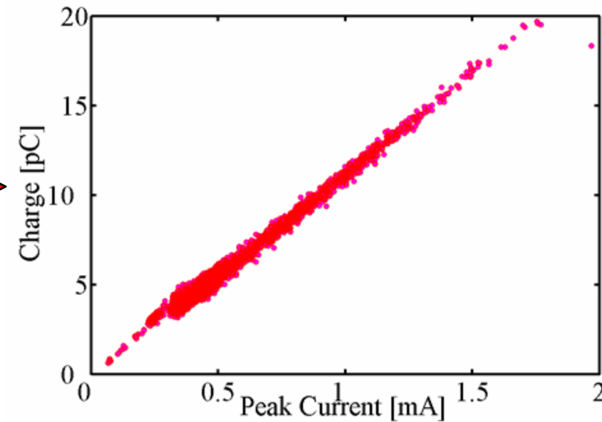
FORME D'ONDA NEL DOMINIO DEL TEMPO



Integrazione

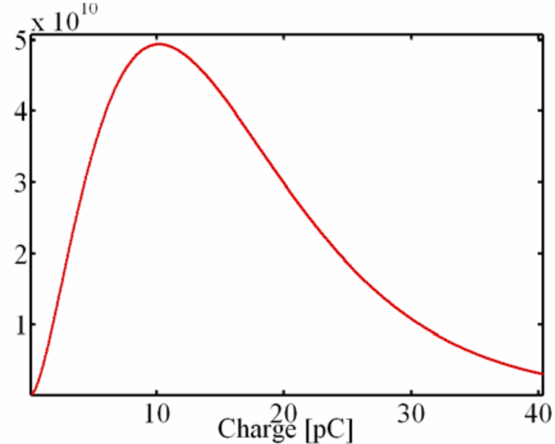
Numerica

SCATTER PLOT

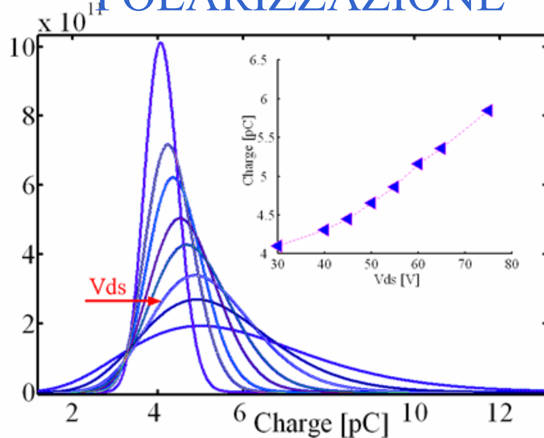


ESTRAZIONE PARAMETRI DISTRIBUZIONE FUNZIONE DI TIPO Γ

FUNZIONE DISTRIBUZIONE



CARICA MEDIA vs TENSIONE DI POLARIZZAZIONE



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Analisi Statistica

Funzione distribuzione di tipo Γ

La carica raccolta per una specie ionica assegnata, ad una fissata energia e polarizzazione è ben descritta da una funzione distribuzione di tipo Γ la cui espressione analitica è:

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

dove i parametri a e b vengono calcolati con una tecnica di stima basata sul criterio della massima verisimiglianza (MLE)

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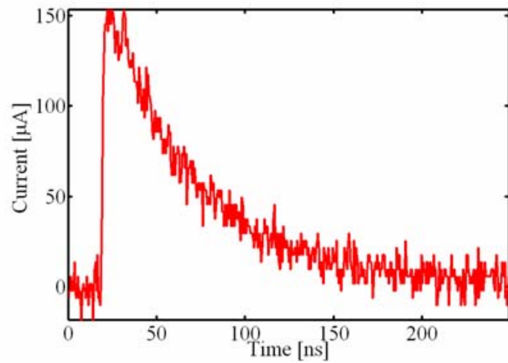
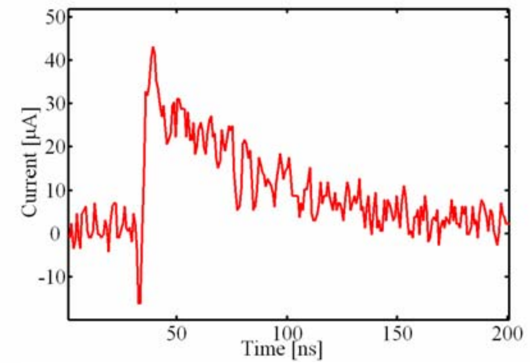
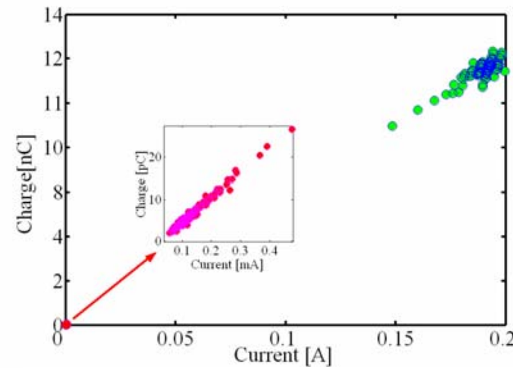
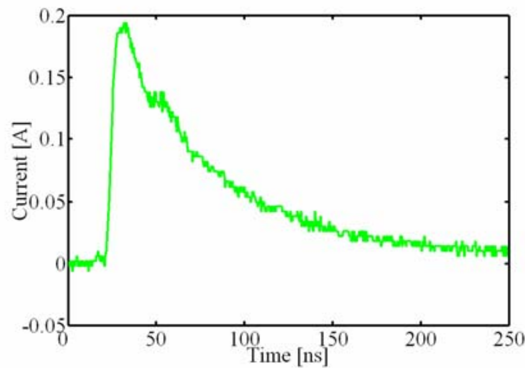
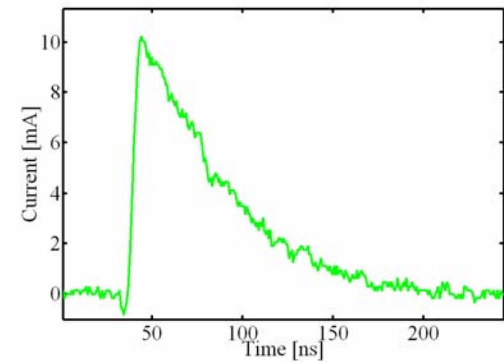
Il comportamento dei MOSFET di bassa tensione (30V)











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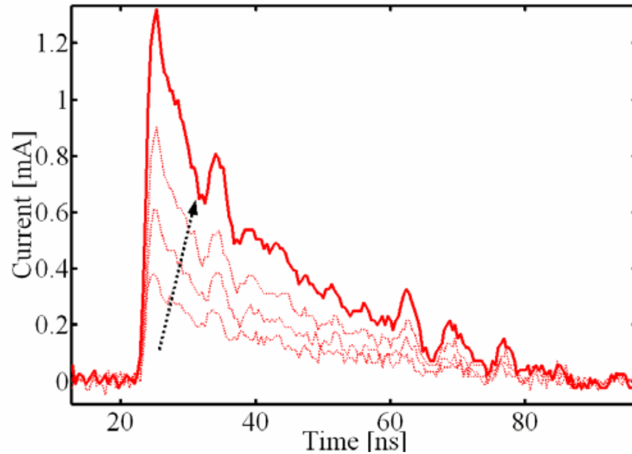
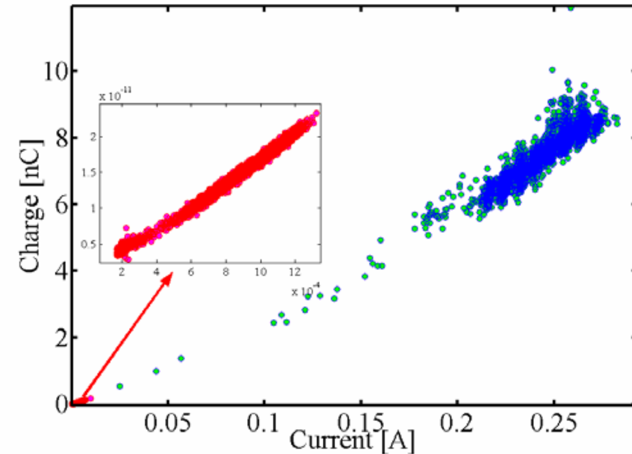
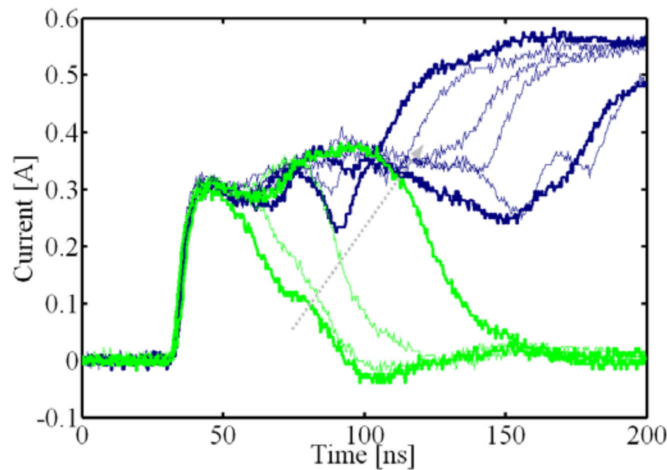
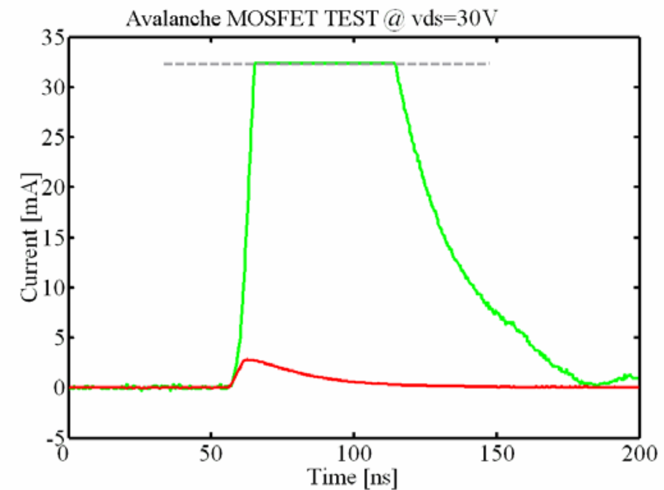
Il comportamento dei MOSFET di bassa tensione (100V)









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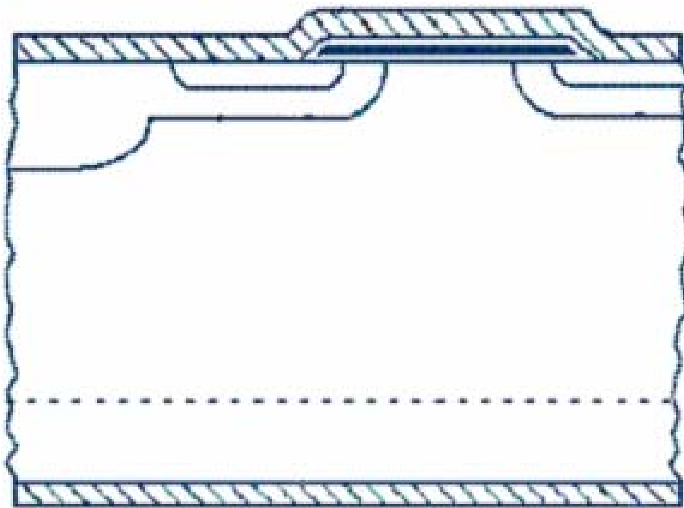
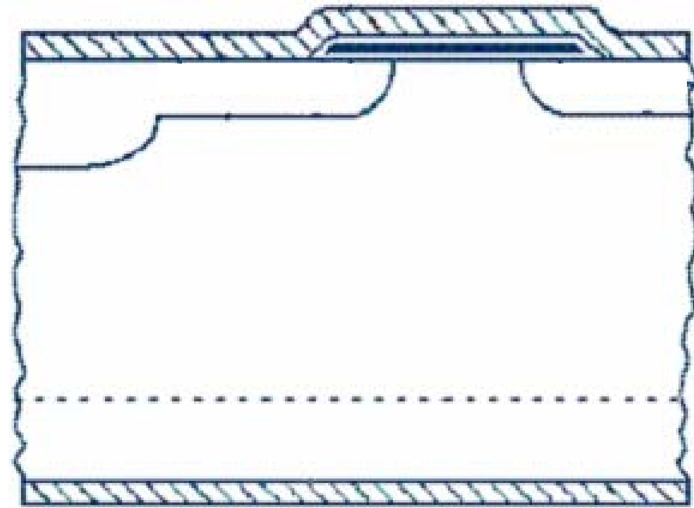
Il comportamento dei MOSFET di media tensione (200V)

Strutture Studiate

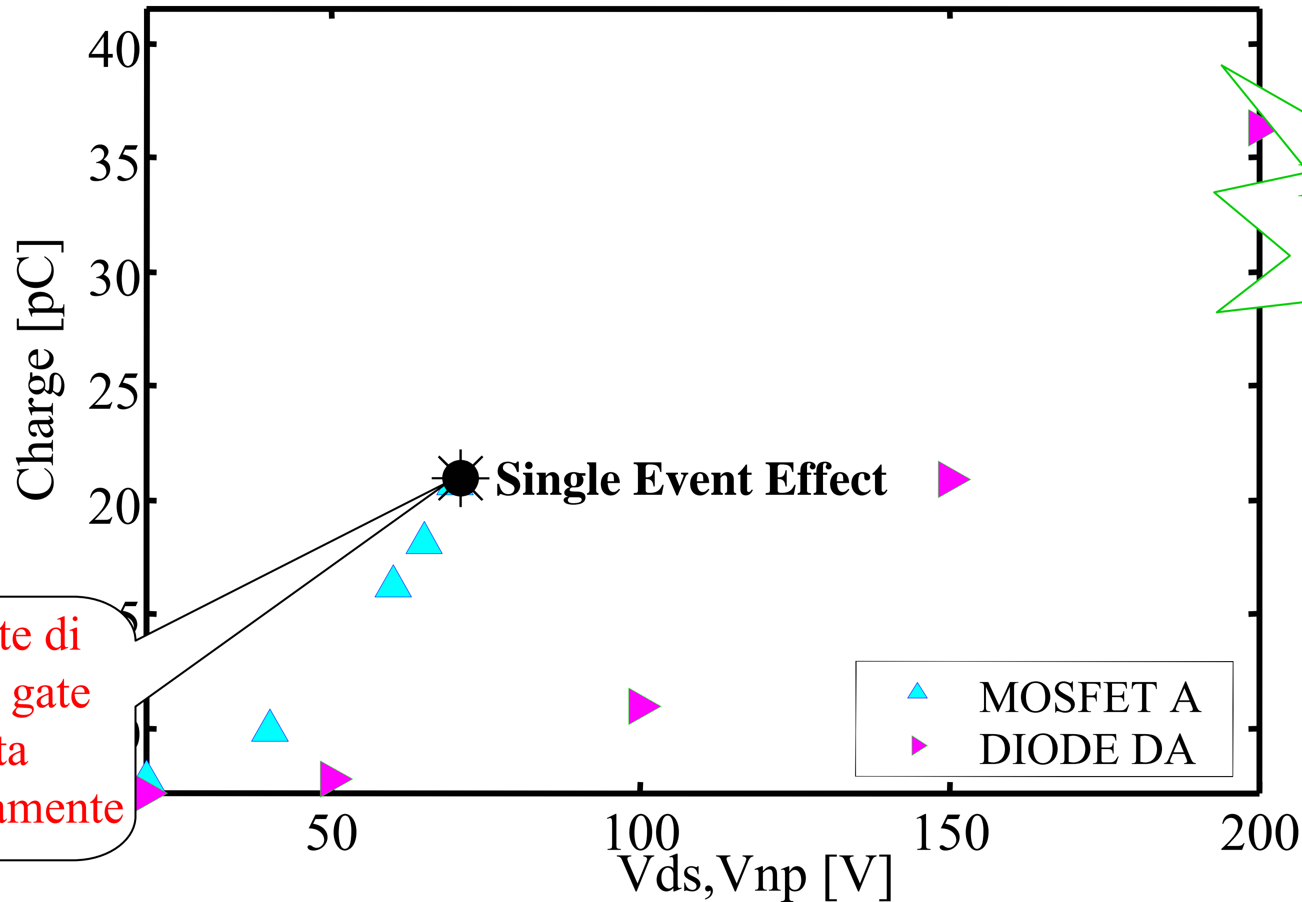
MOSFET



DIODO



Il comportamento dei MOSFET di media tensione (200V)



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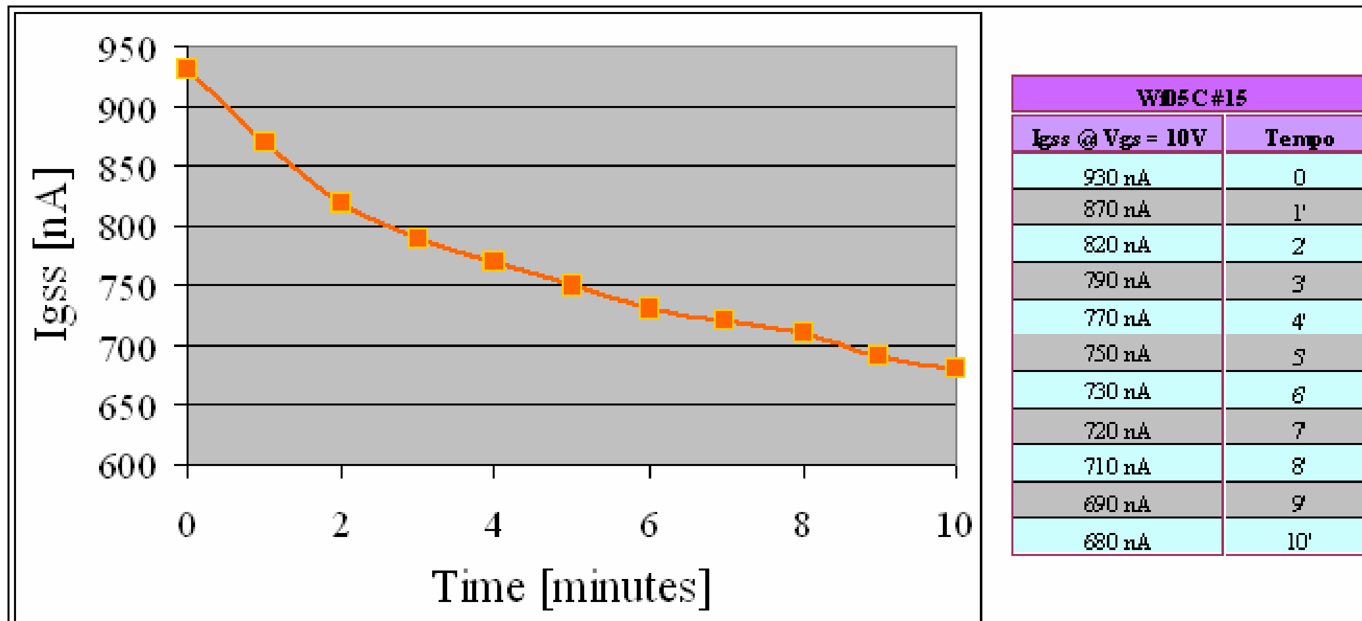
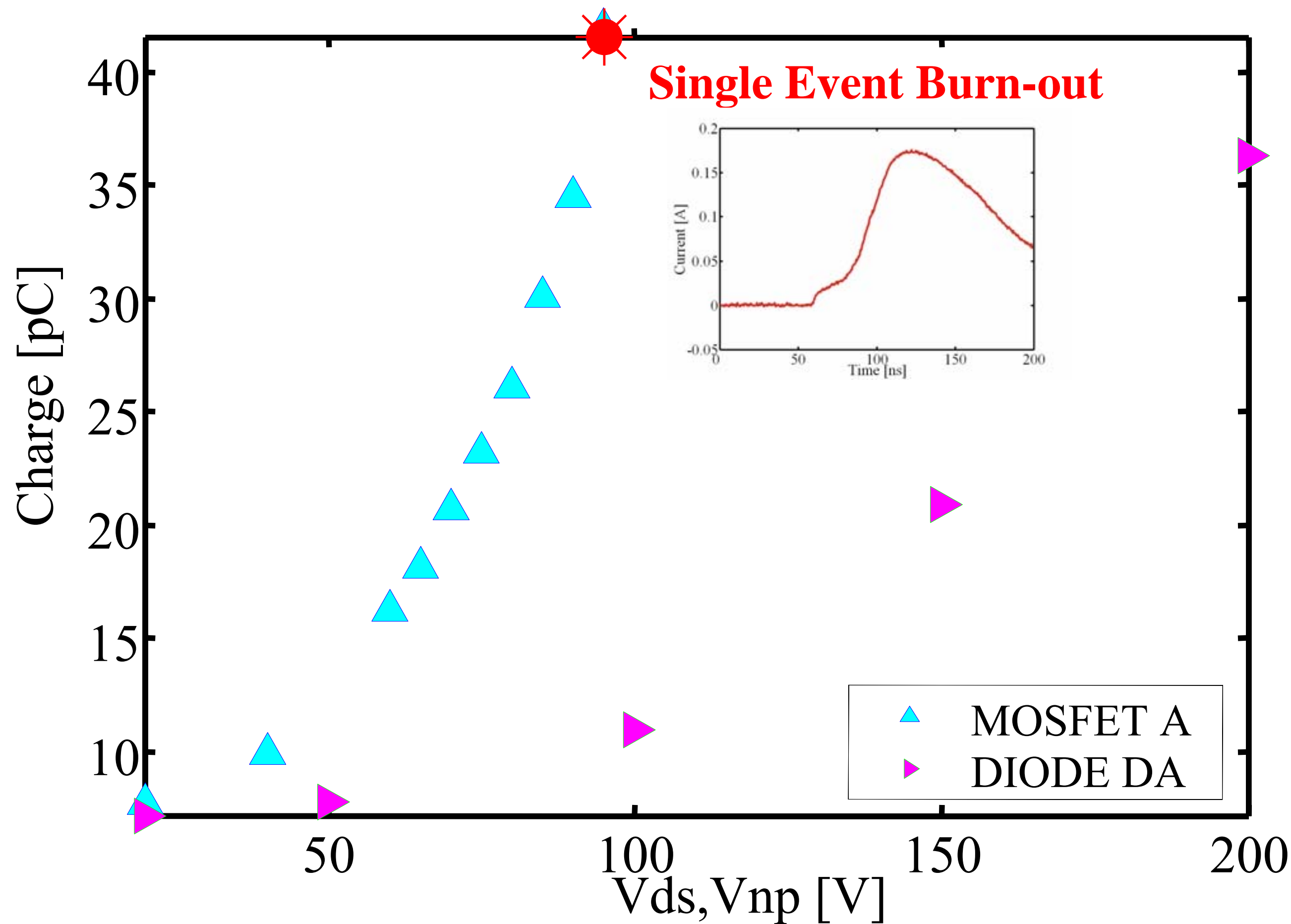
MOSFET da 200V

Decadimento della corrente di leakage di gate dopo l’irraggiamento



W05 C#15	
Igss @ Vgs = 10V	Tempo
930 nA	0
870 nA	1'
820 nA	2'
790 nA	3'
770 nA	4'
750 nA	5'
730 nA	6'
720 nA	7'
710 nA	8'
690 nA	9'
680 nA	10'

Il comportamento dei MOSFET di media tensione (200V)



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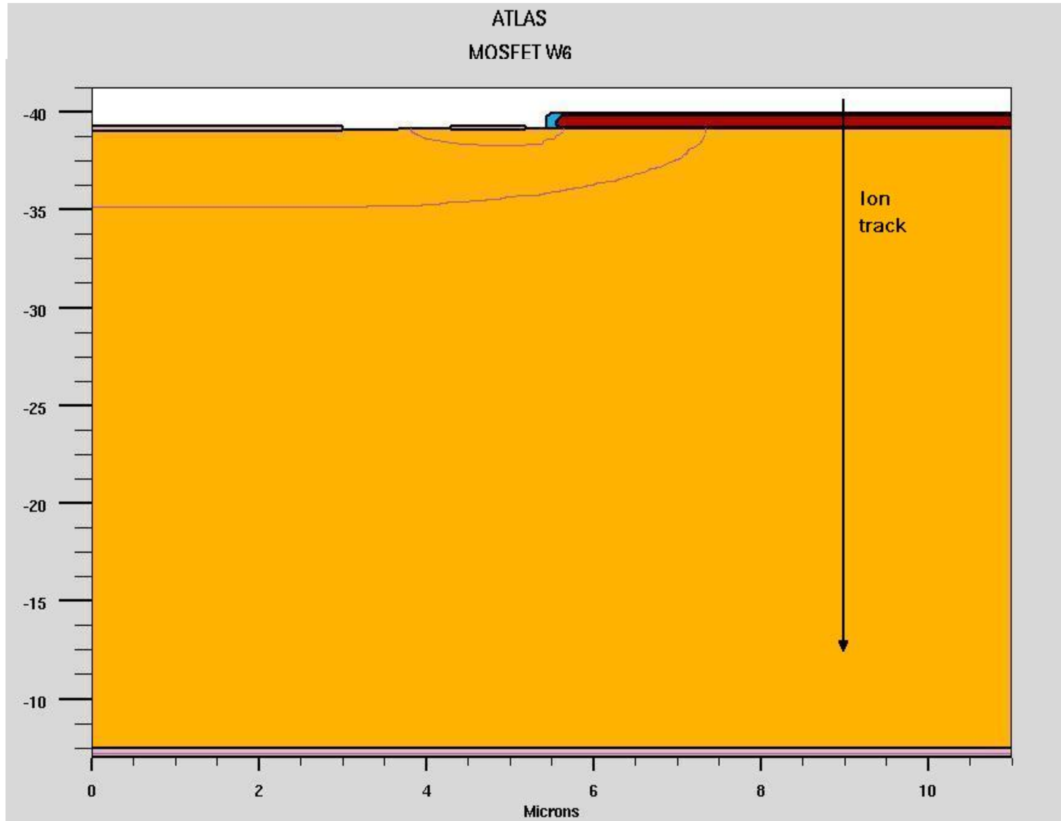
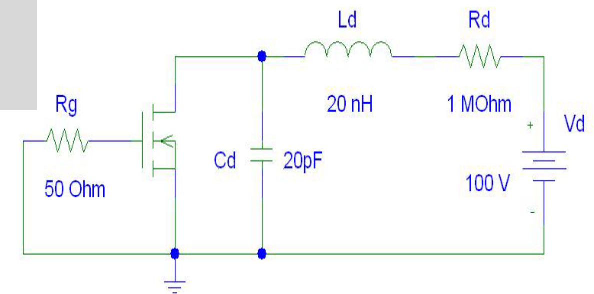
MOSFET da 200V





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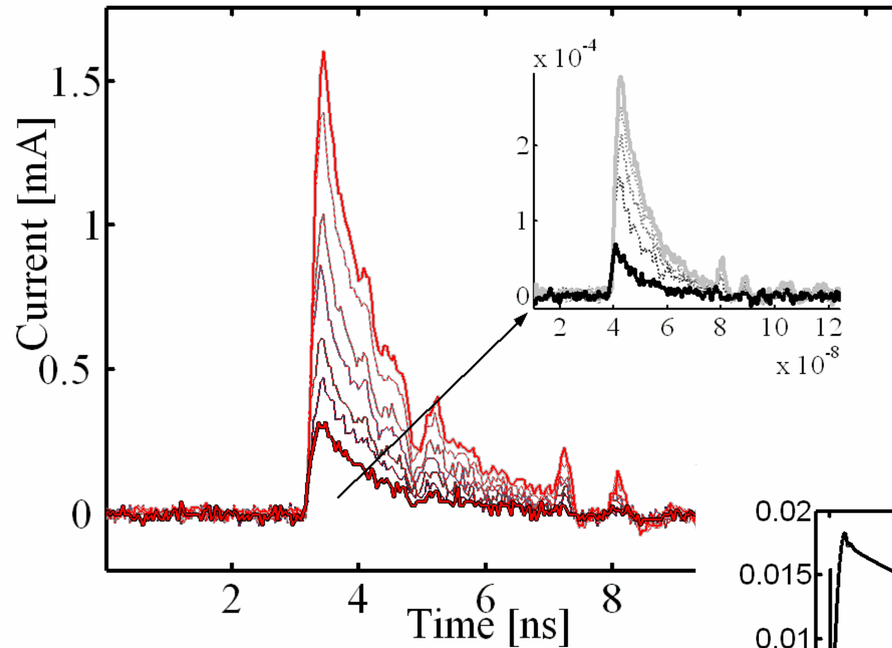
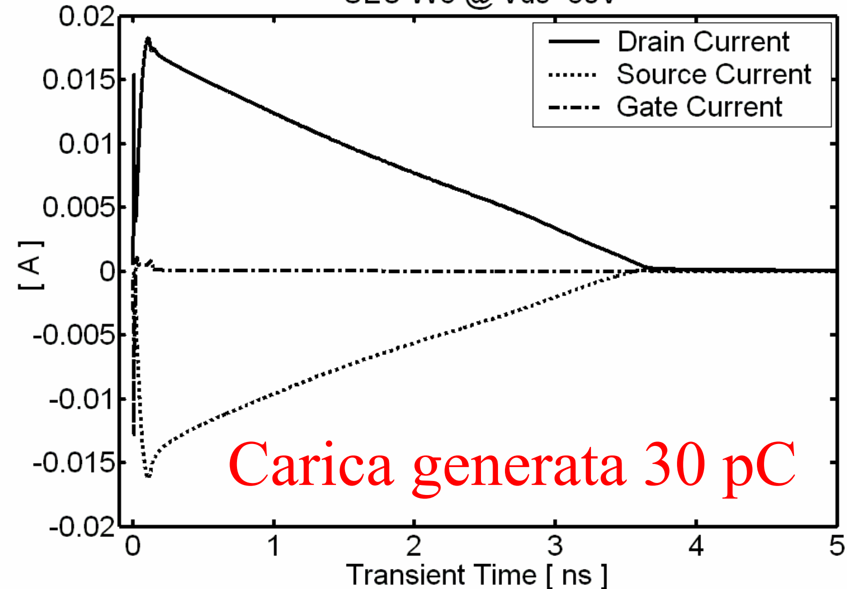
ST

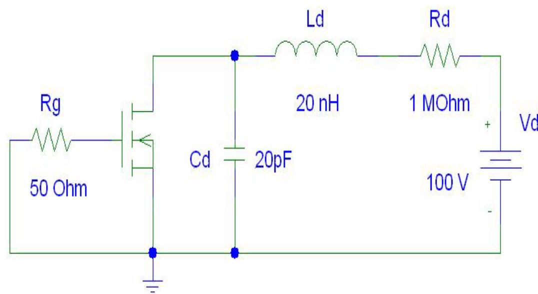
Forme d'onda

Sperimentali



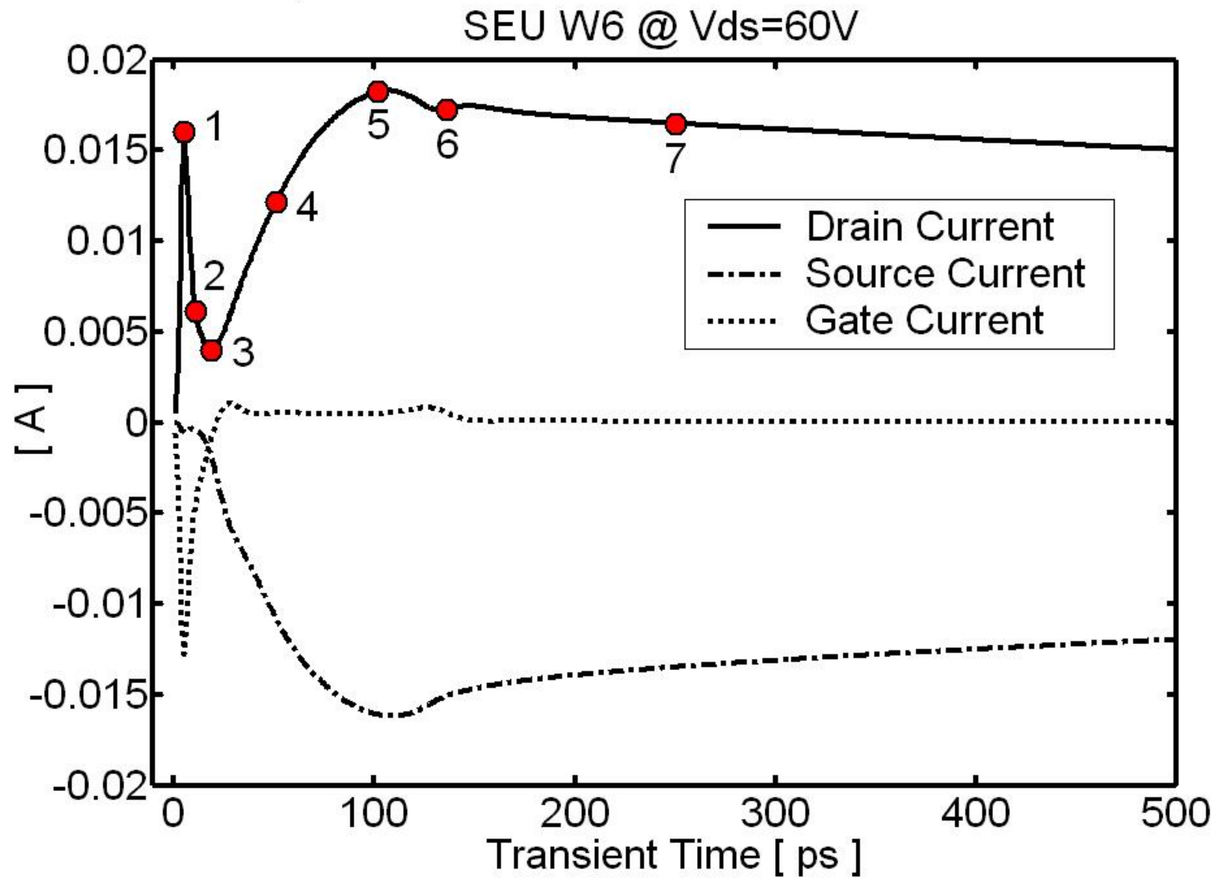
Simulate



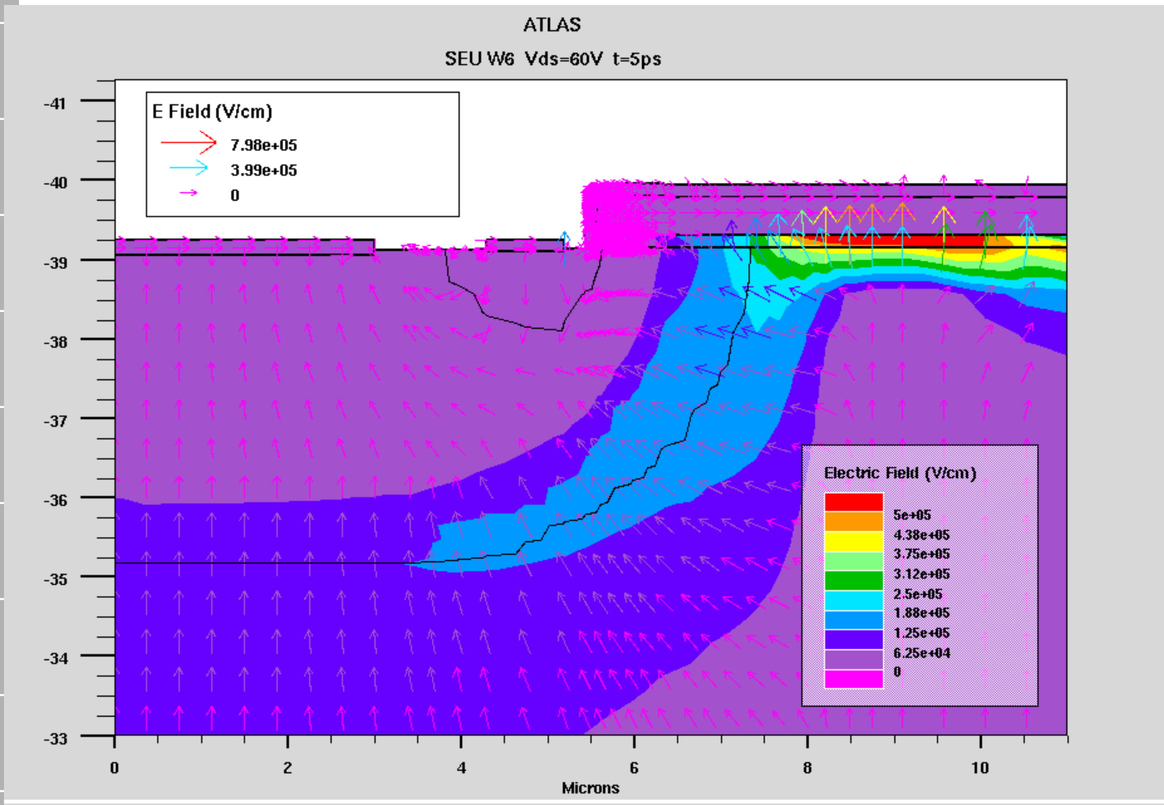


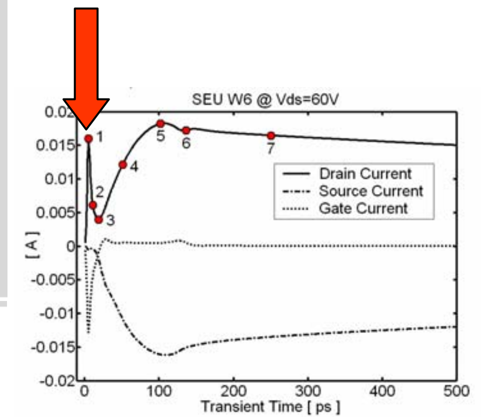
SIMULAZIONE A 60V
Inizio danno di gate

Forme d’onda simulate (Zoom)



Campo elettrico





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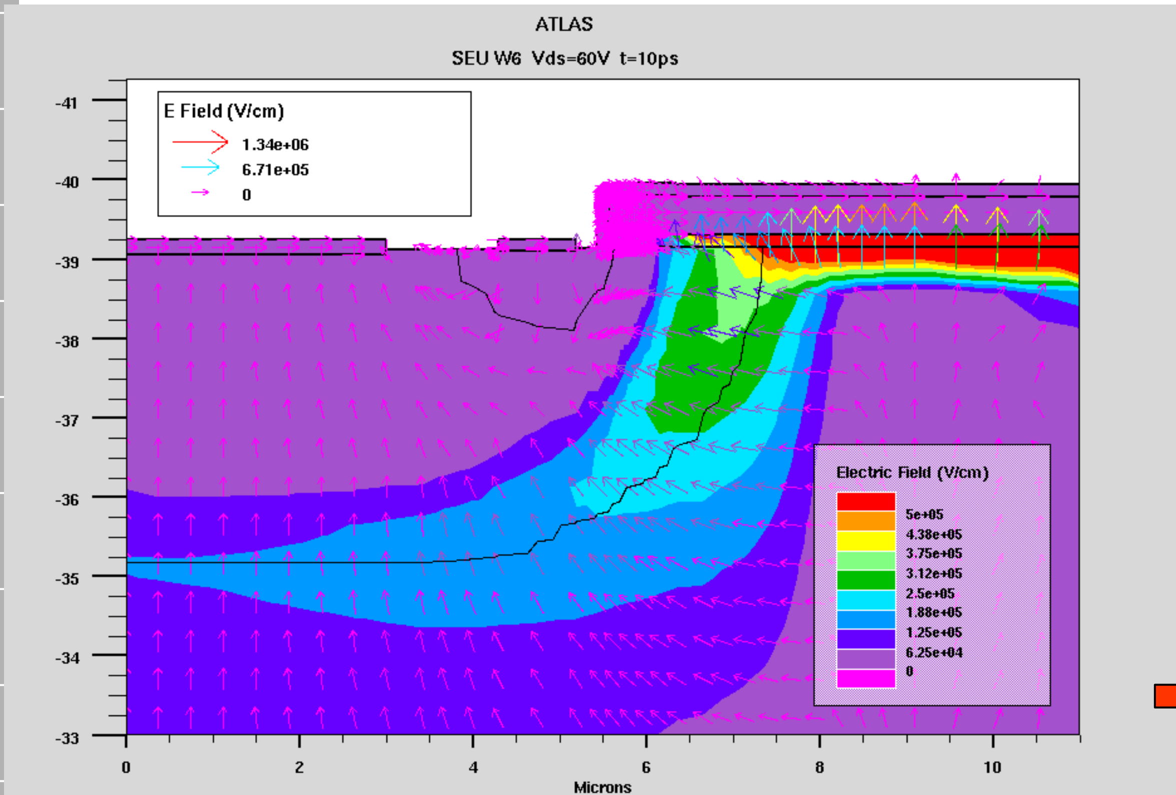

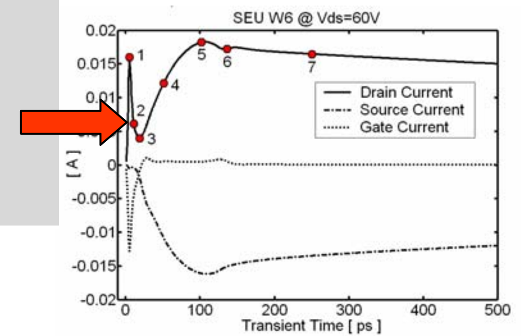

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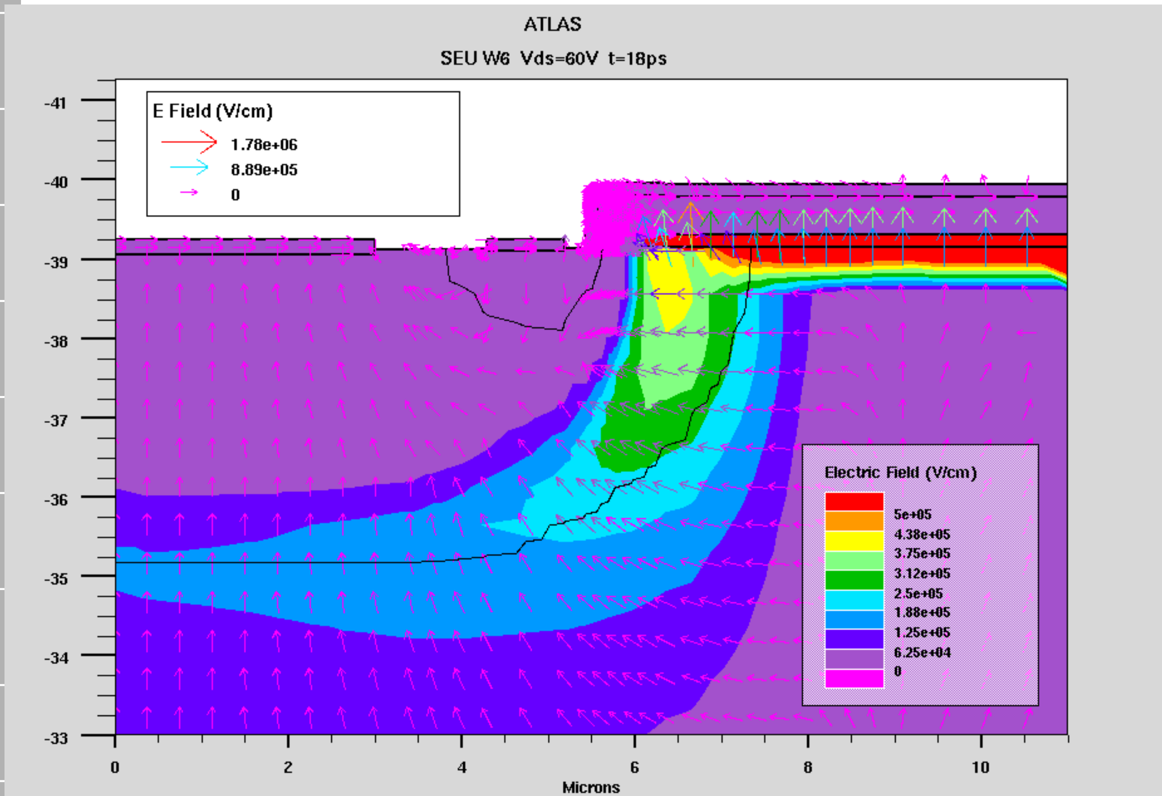

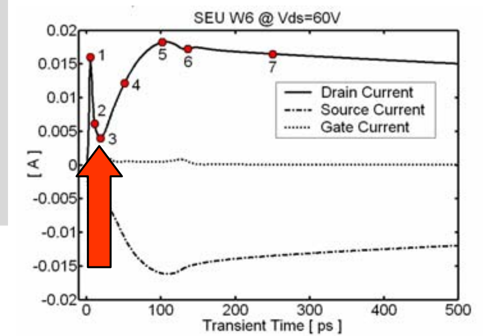

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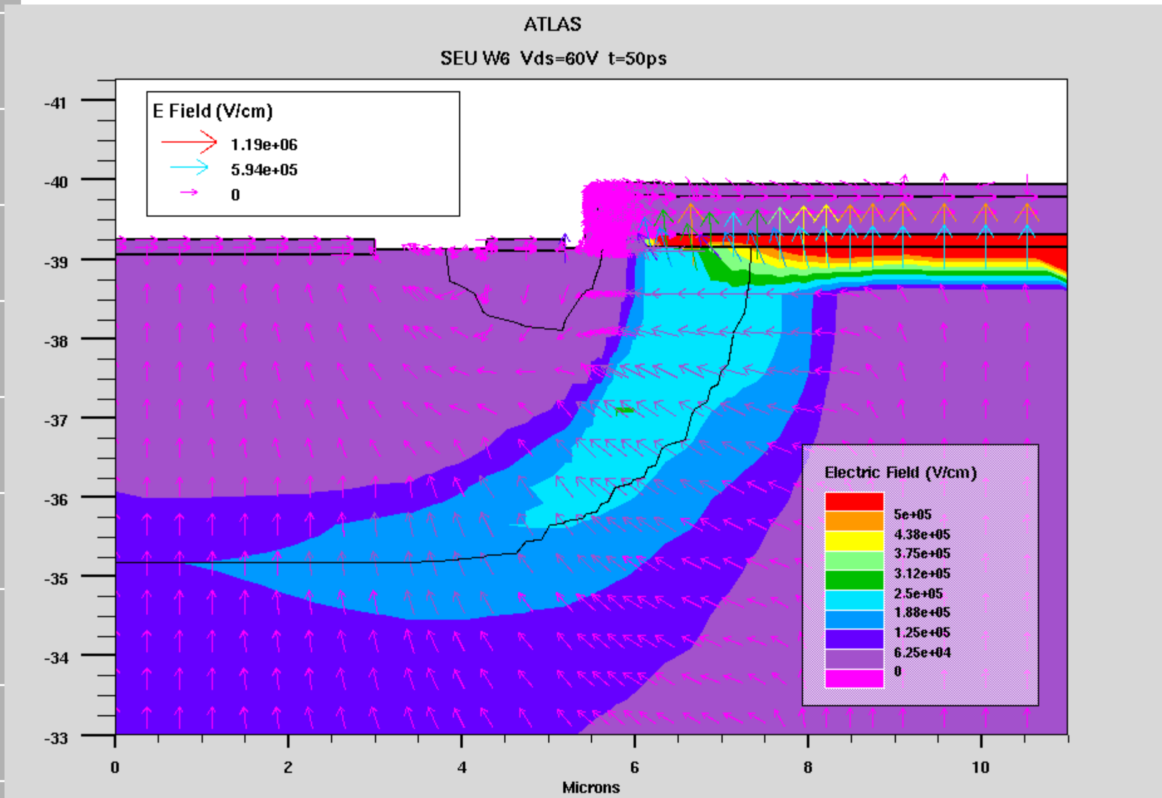

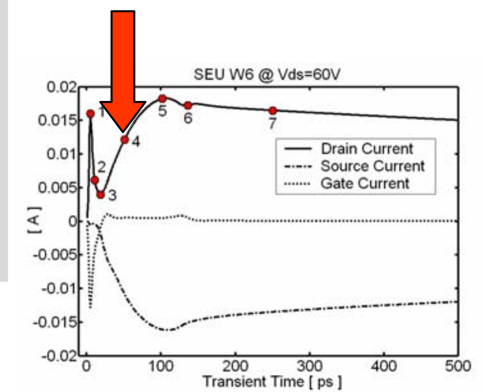

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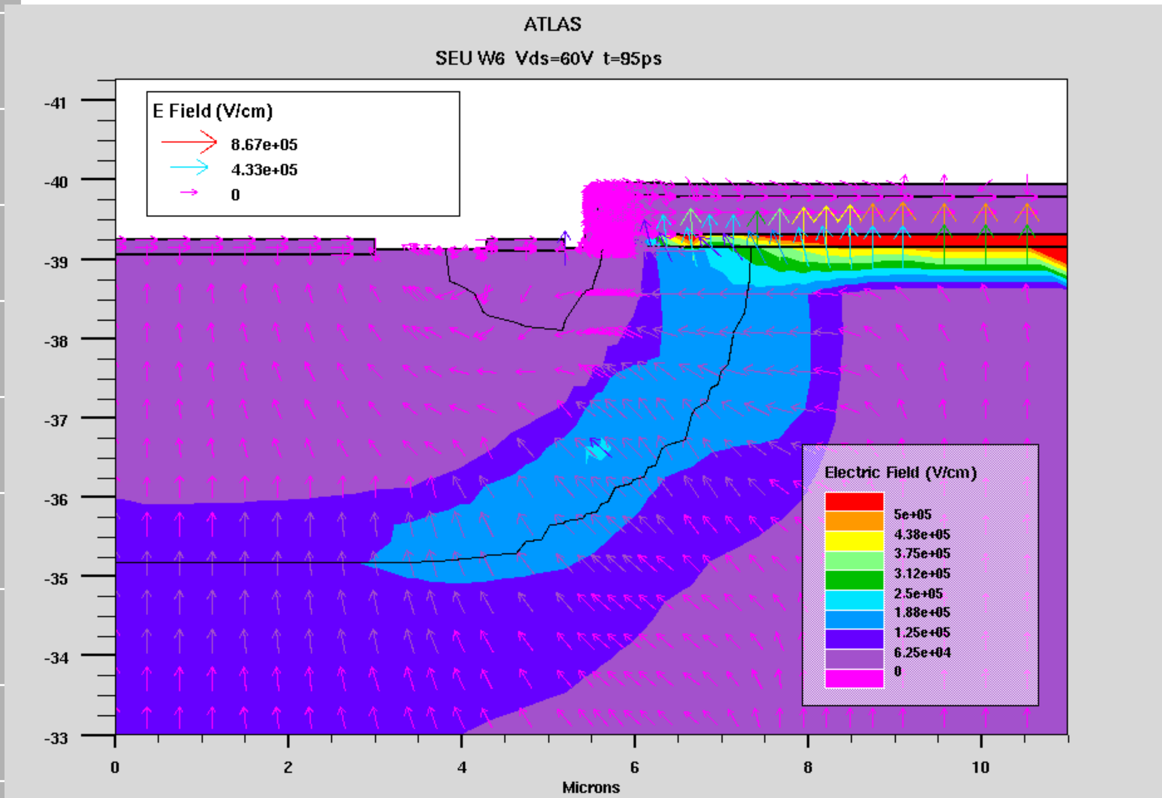

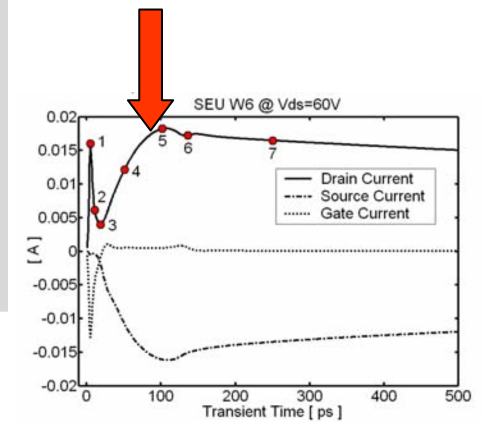

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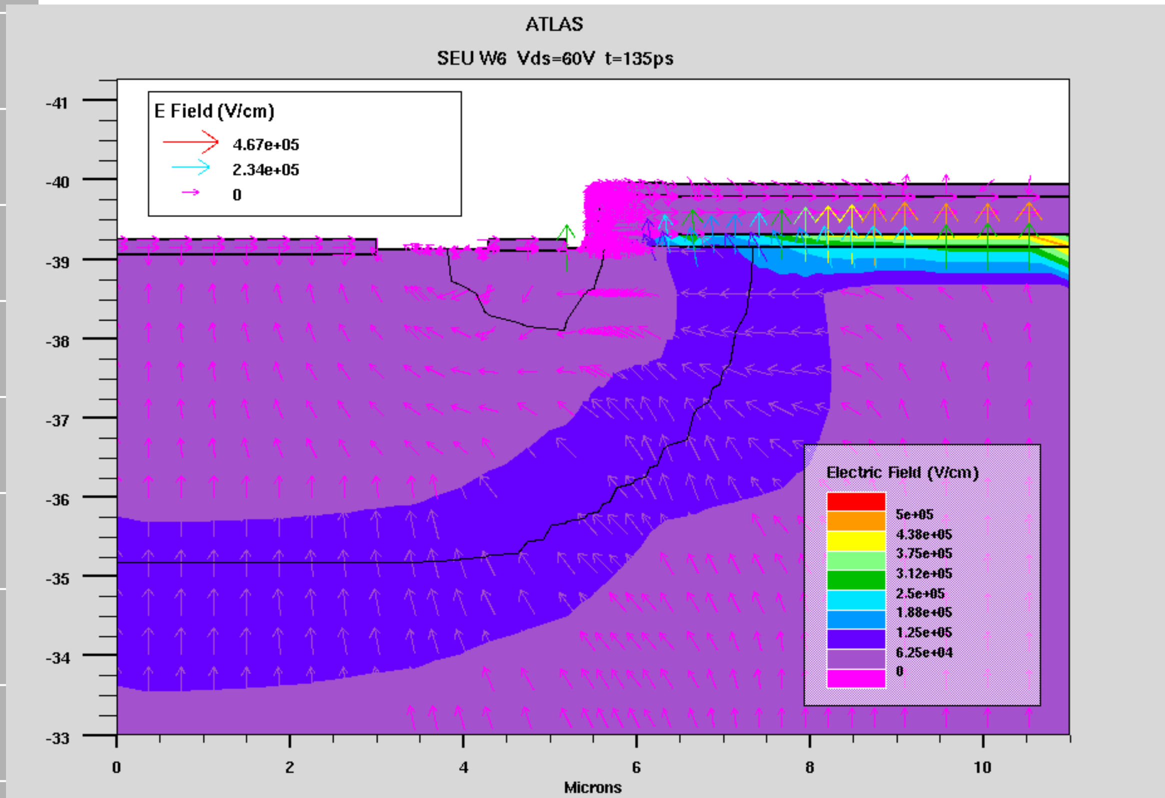
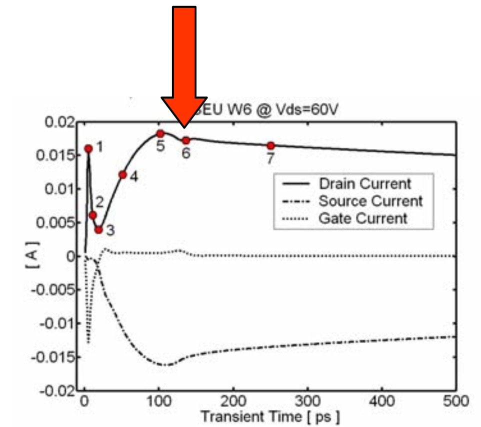
Campo elettrico





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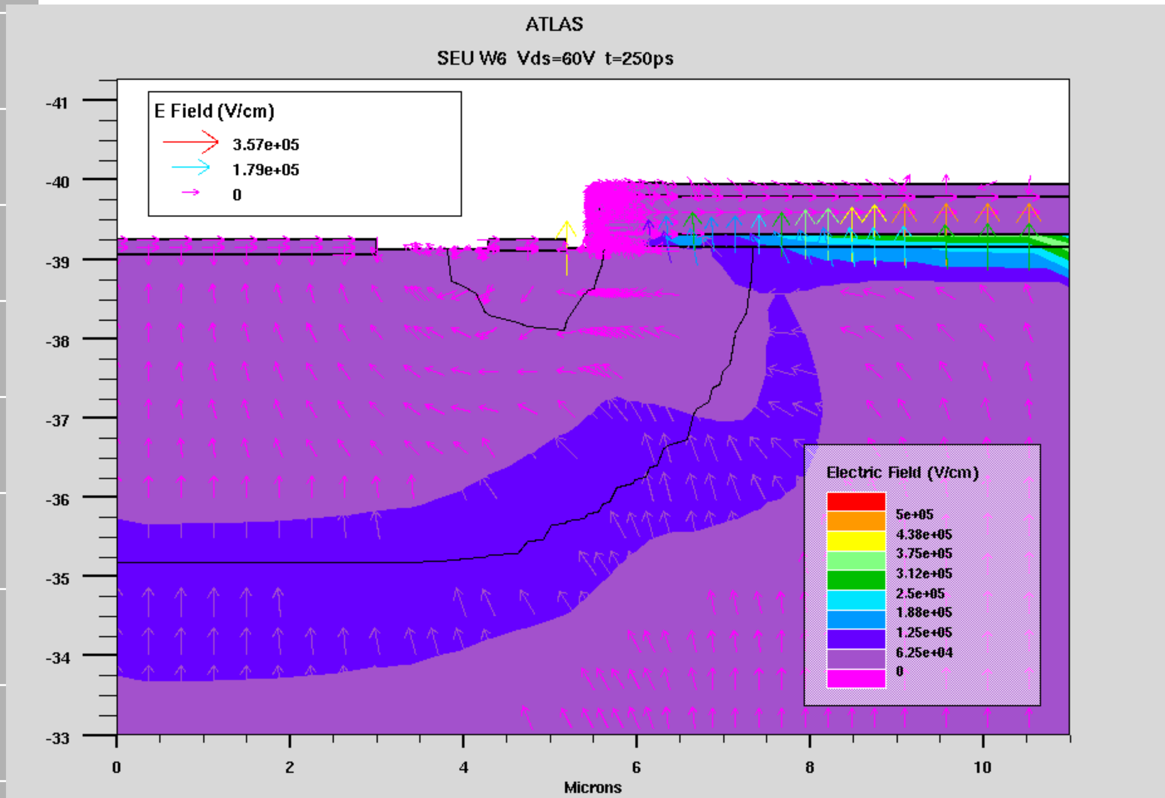
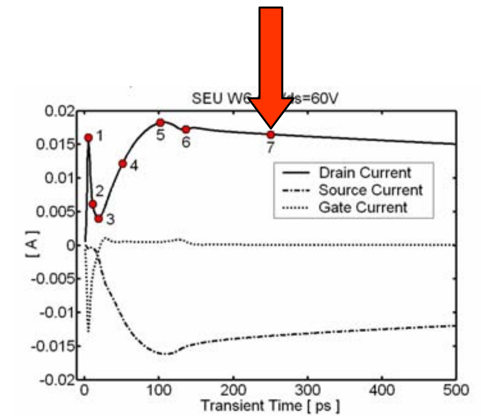
Campo elettrico





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SIMULAZIONE A 100V
SEB del MOSFET

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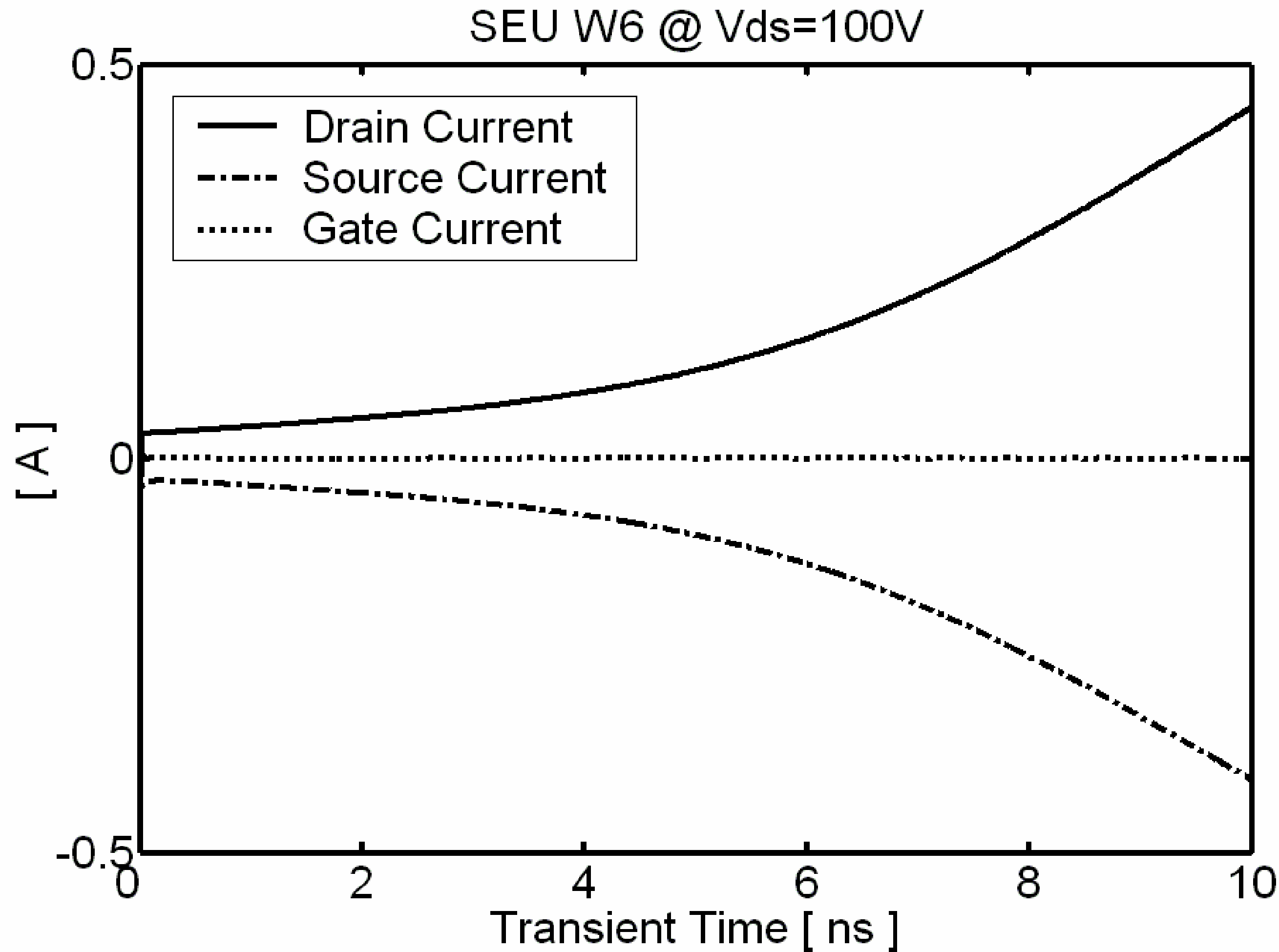
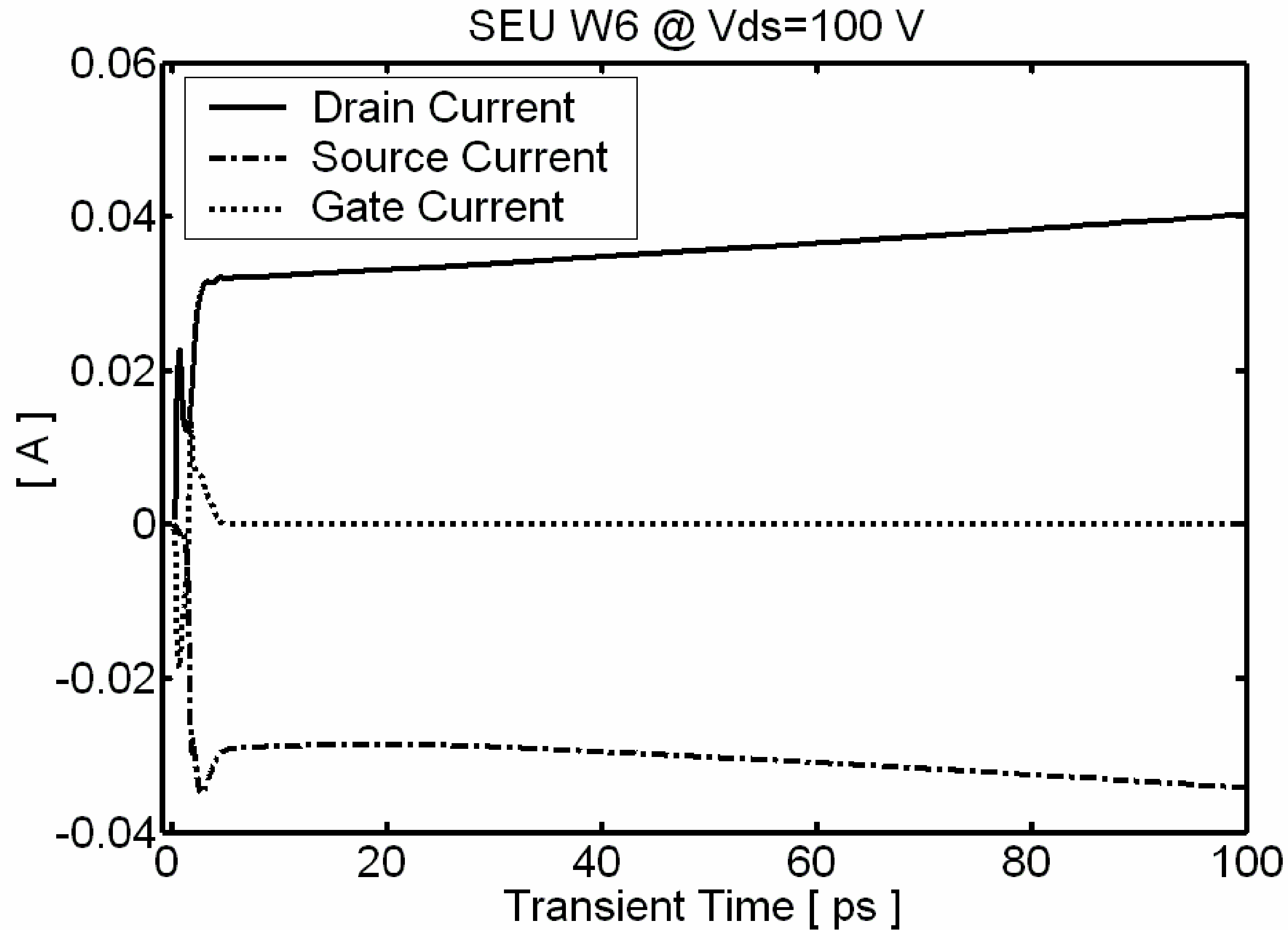
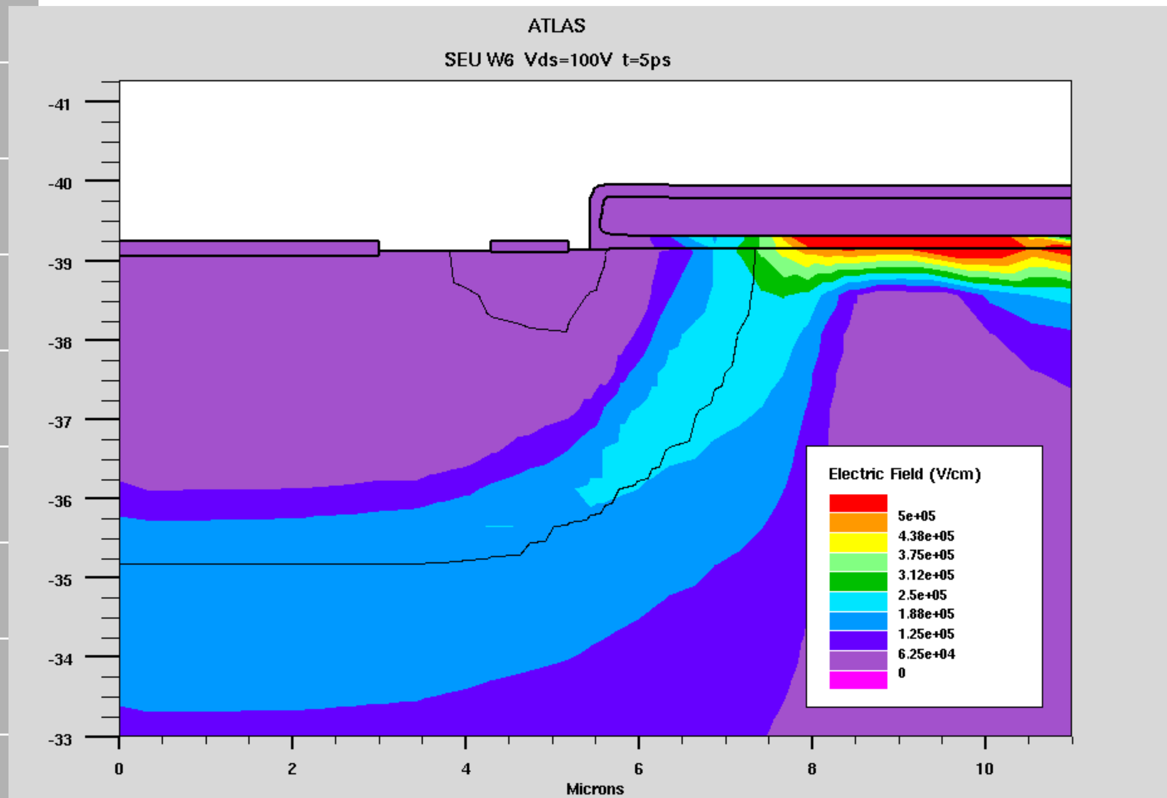
Forme d'onda simulate 100V

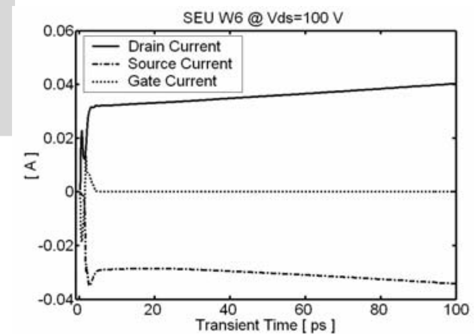


Forme d'onda simulate 100V (Zoom)



Campo elettrico (5ps)





Campo elettrico (35ps)

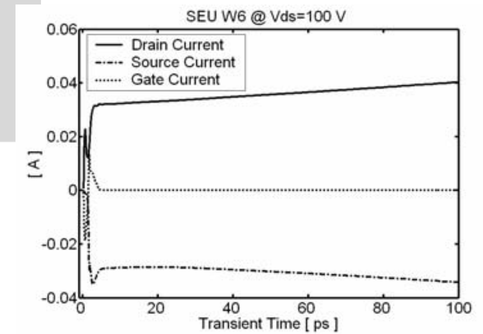
ATLAS

Electric Field

Electric Field (V/cm)

3e+05
2.62e+05
2.25e+05
1.88e+05
1.5e+05
1.12e+05
7.5e+04
3.75e+04
0

Microns



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SIMULAZIONE DIODO A 100V

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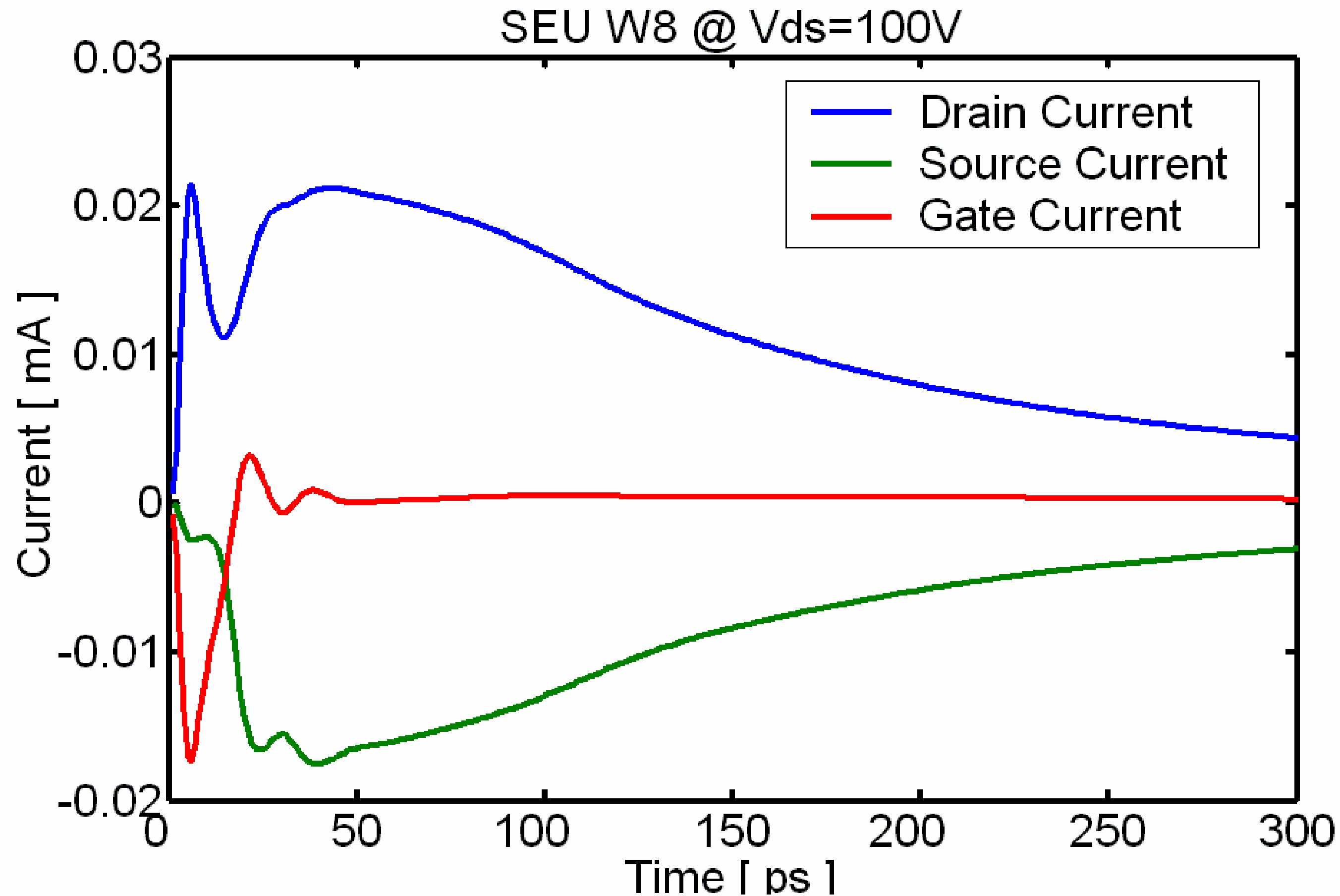
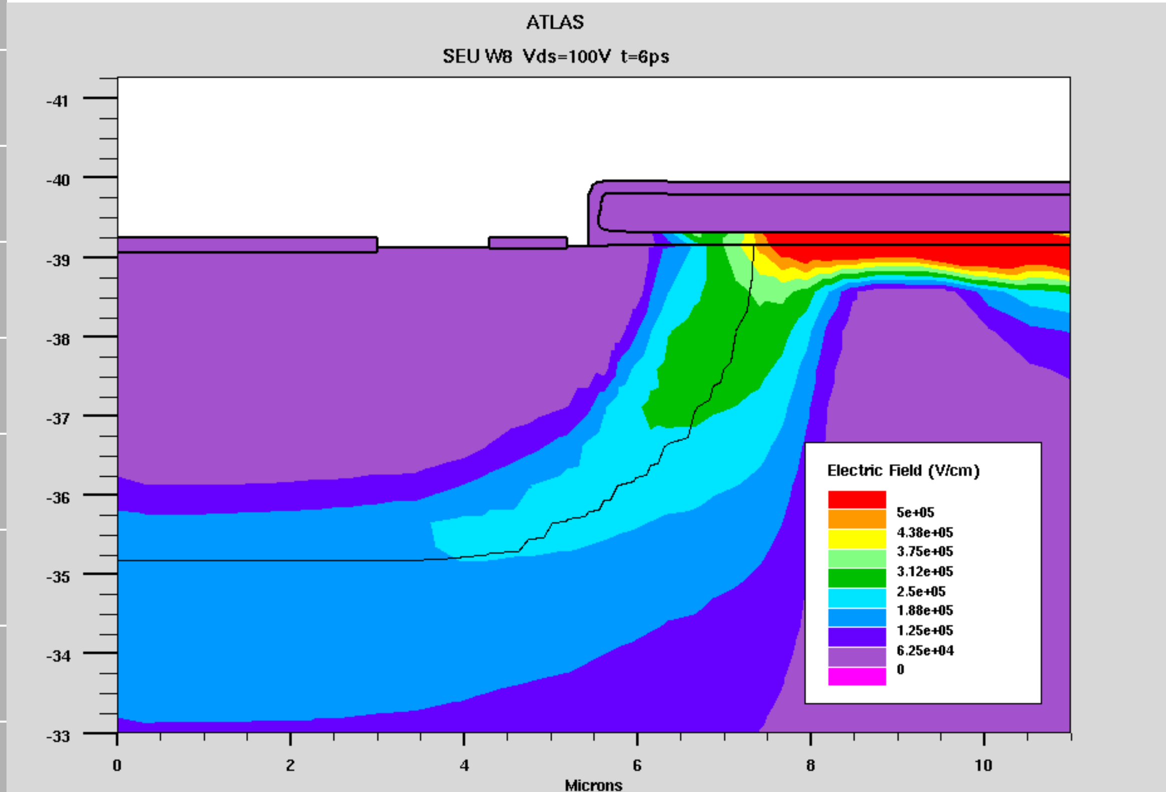
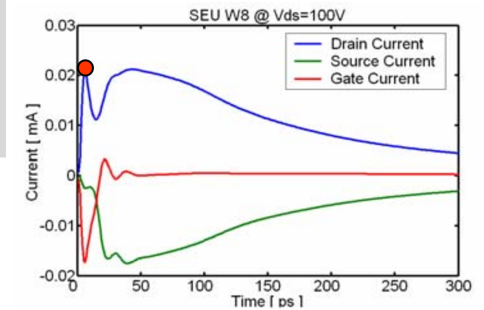
Forme d'onda simulate (Struttura diodica)



Campo elettrico





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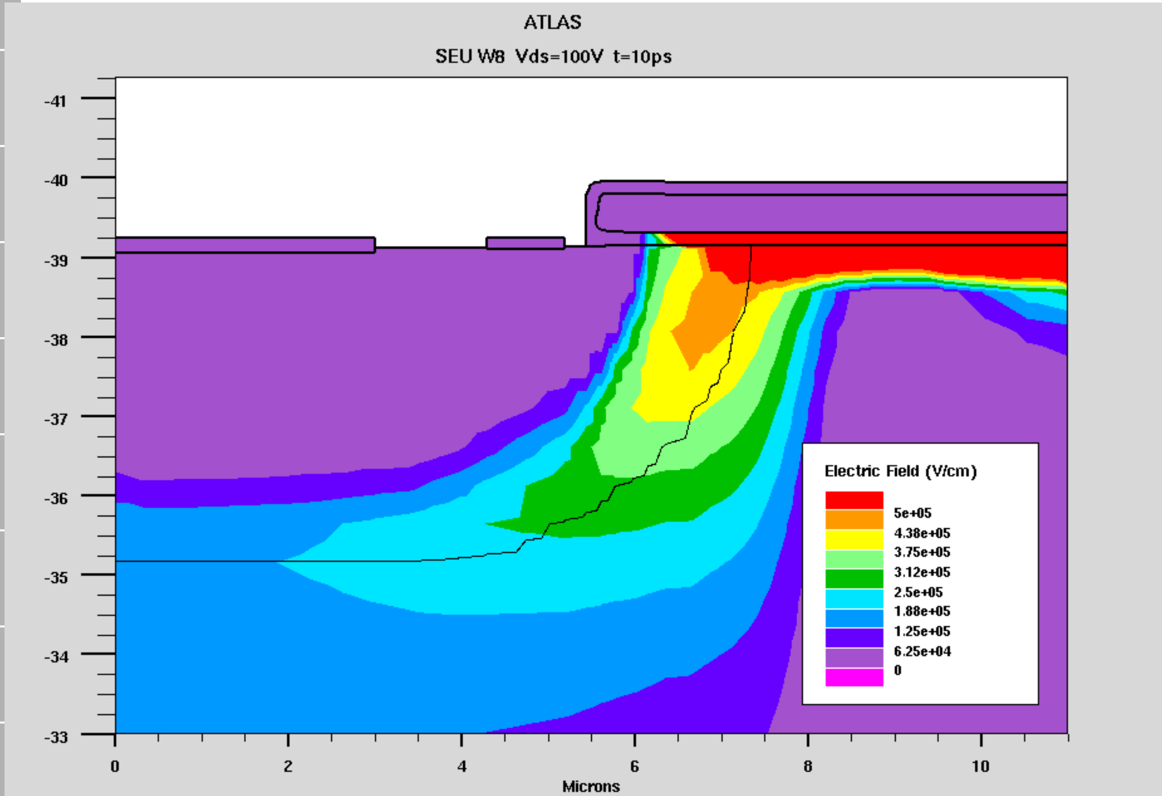
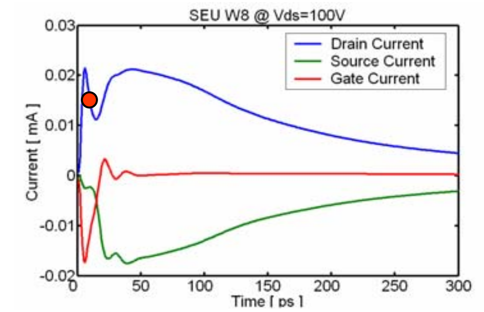
Campo elettrico





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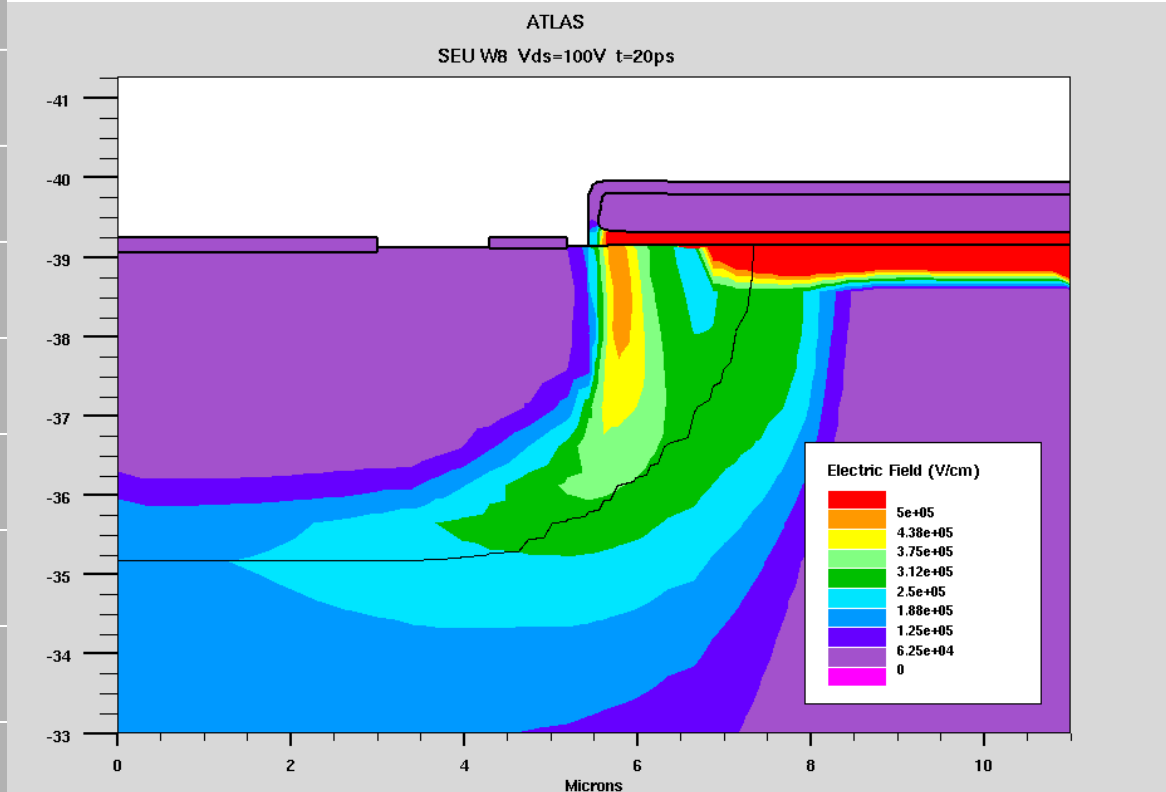

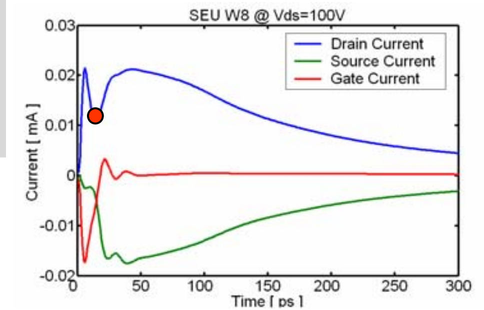

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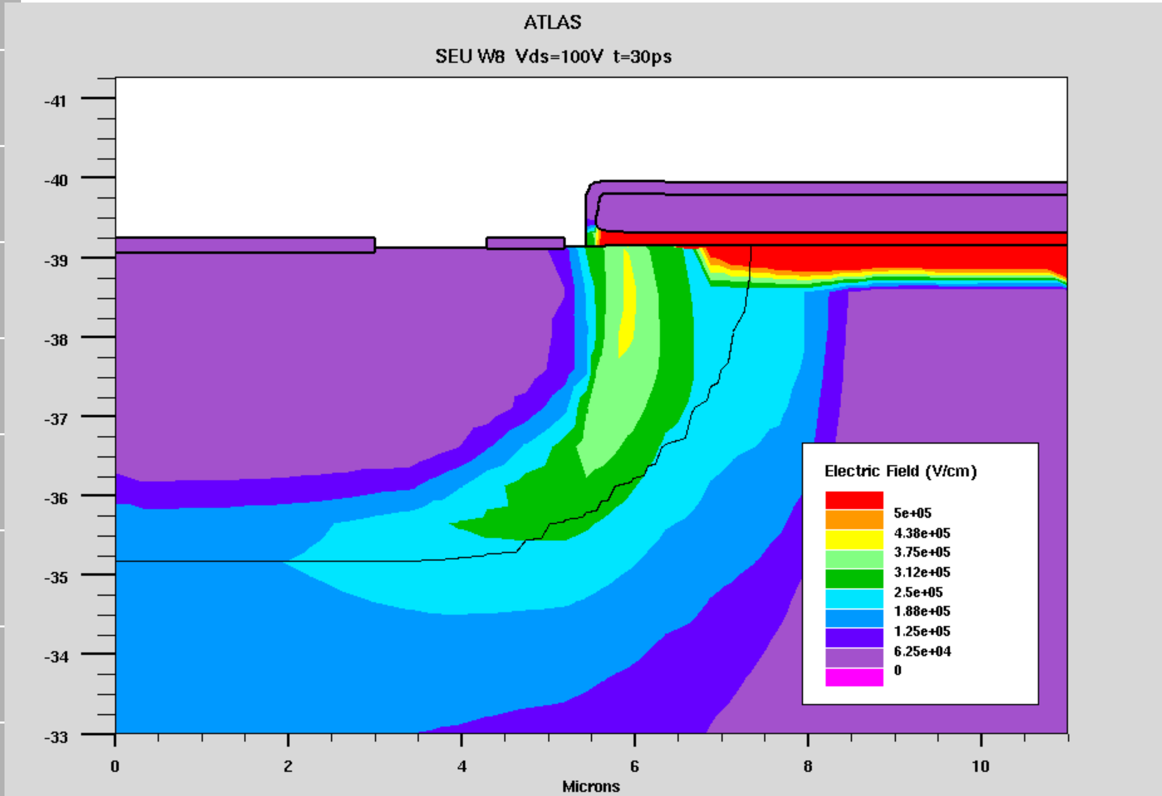

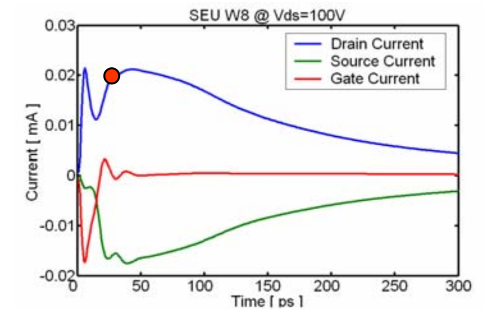

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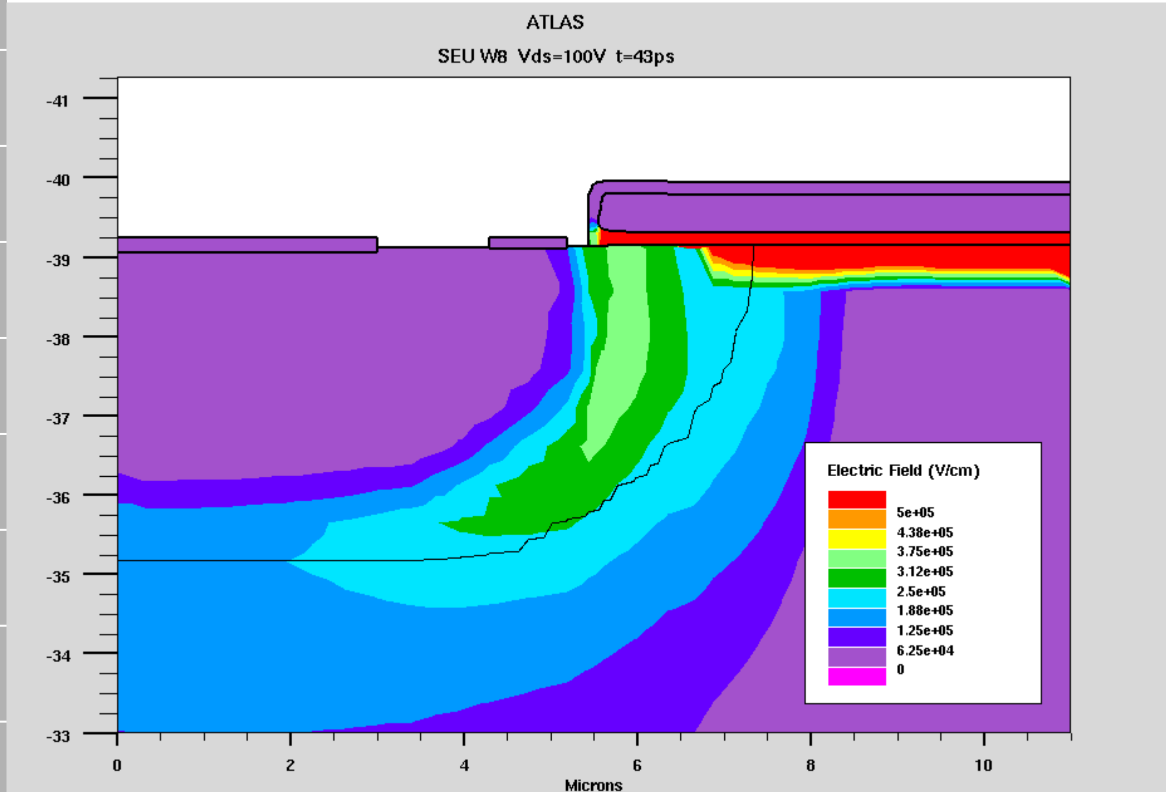
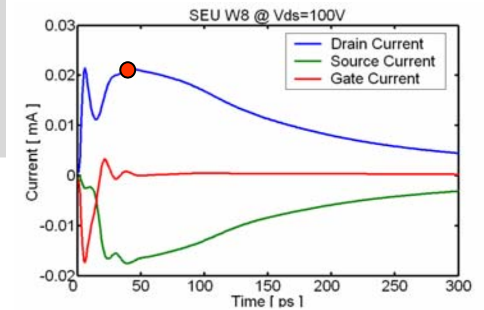
Campo elettrico





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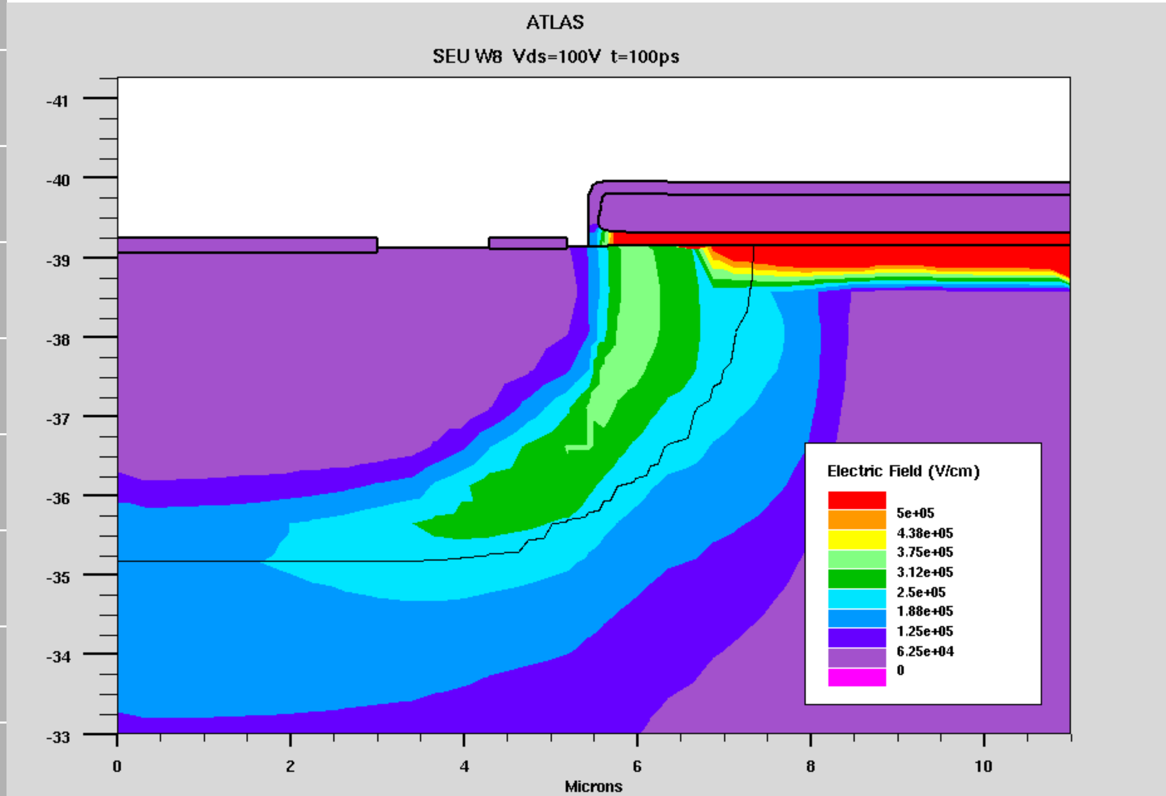

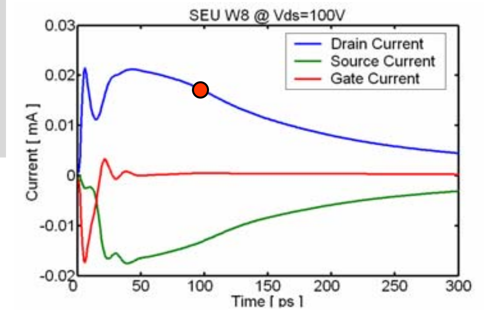

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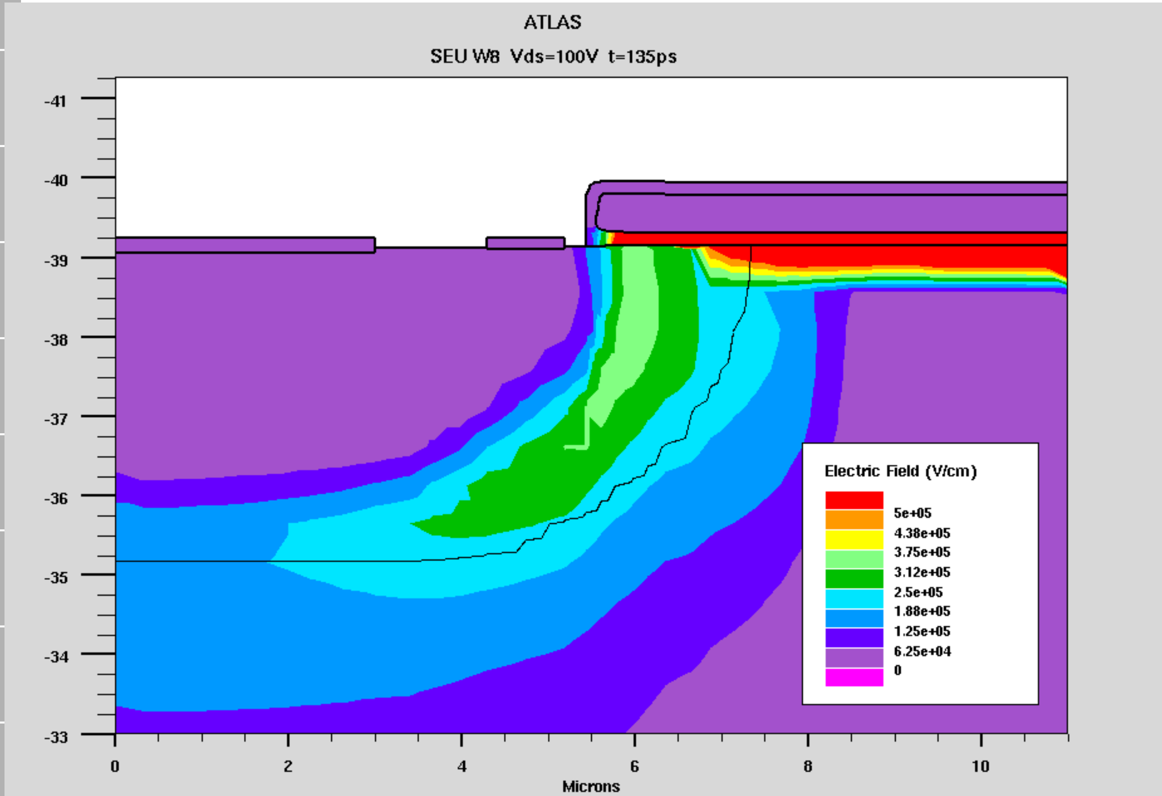

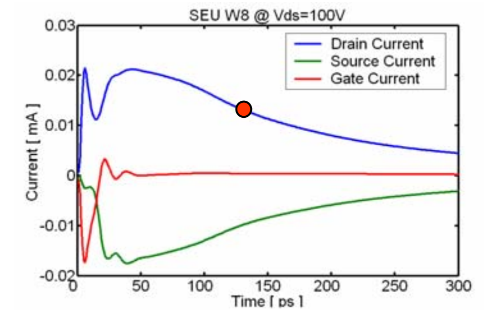

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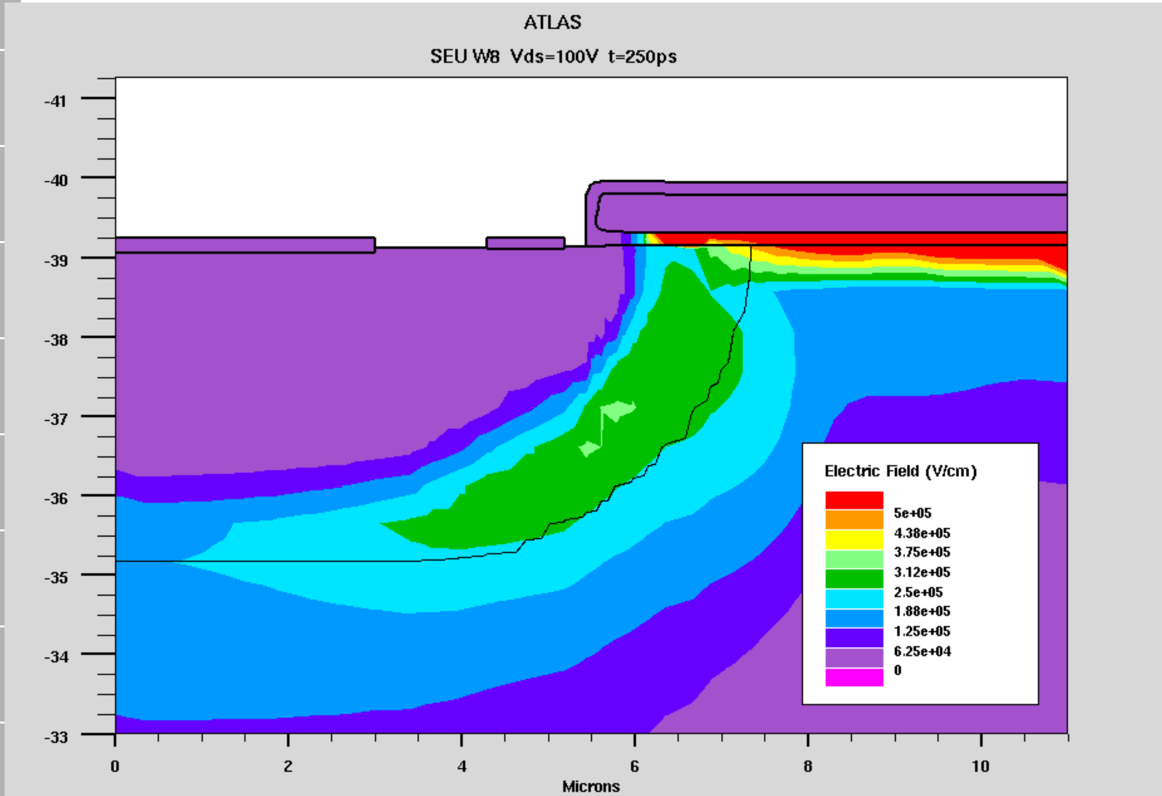

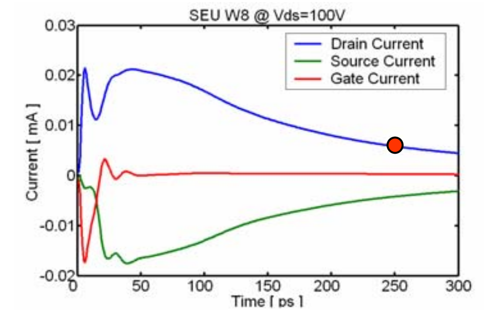

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Effetti della ionizzazione da impatto

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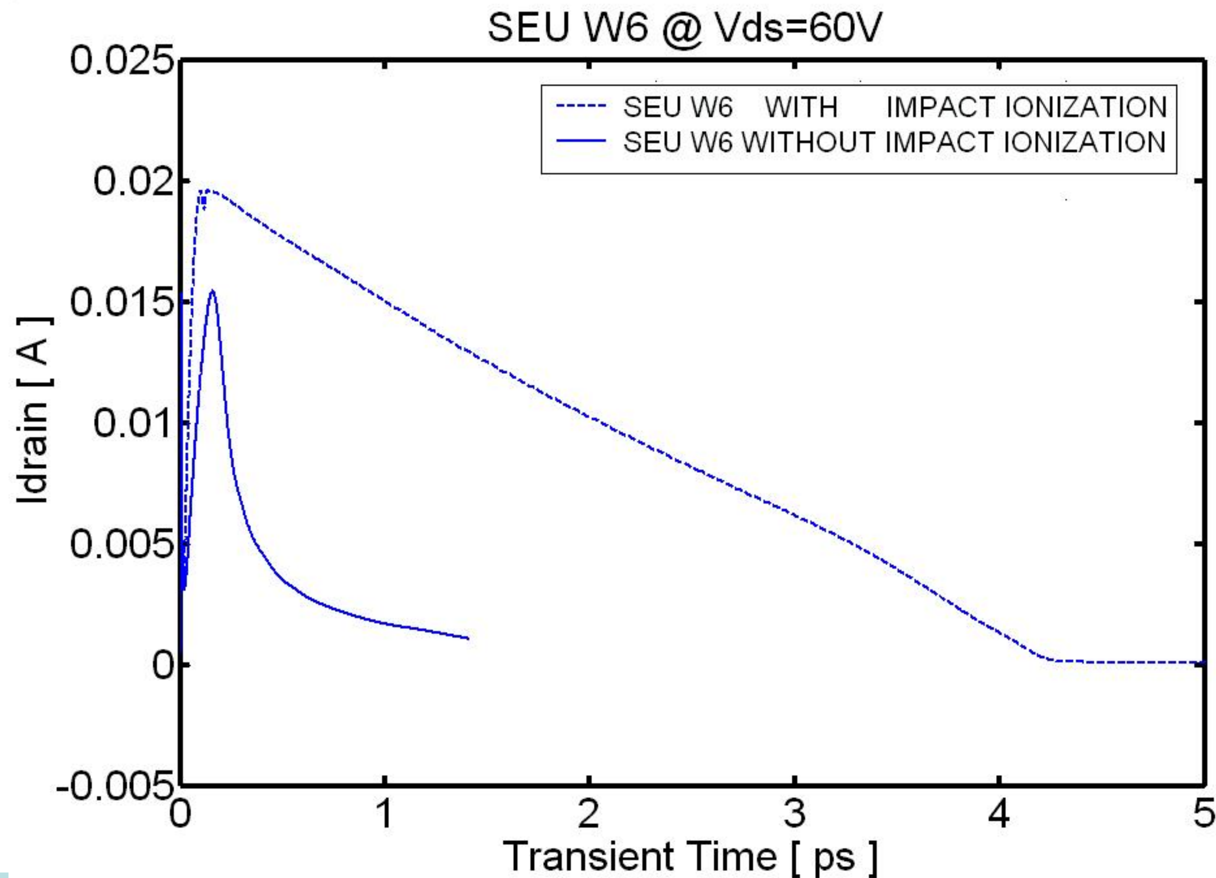
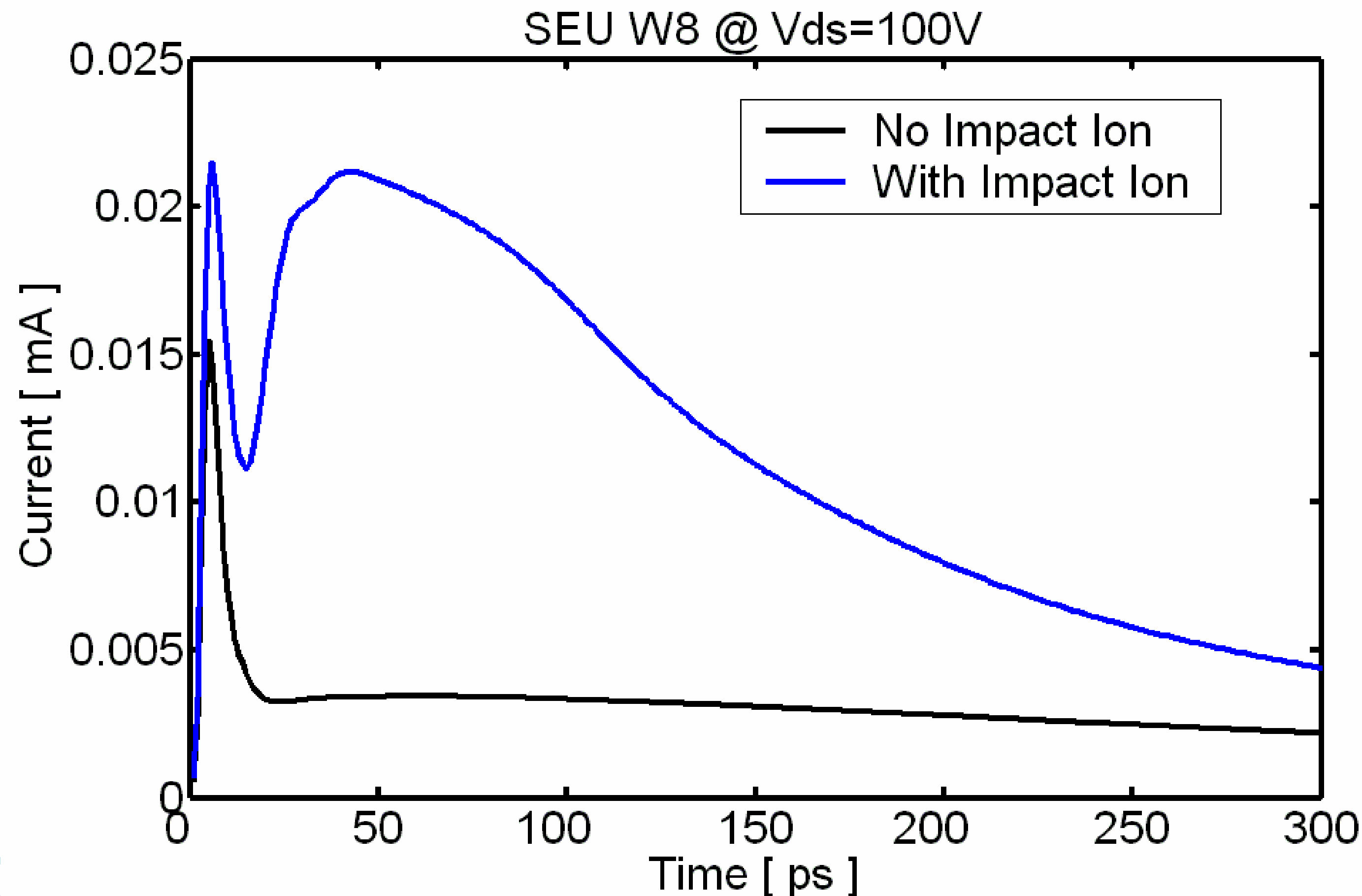
Forme d'onda simulate (Ionizzazione da impatto)



Forme d’onda simulate
(Struttura diodica – Ionizzazione)



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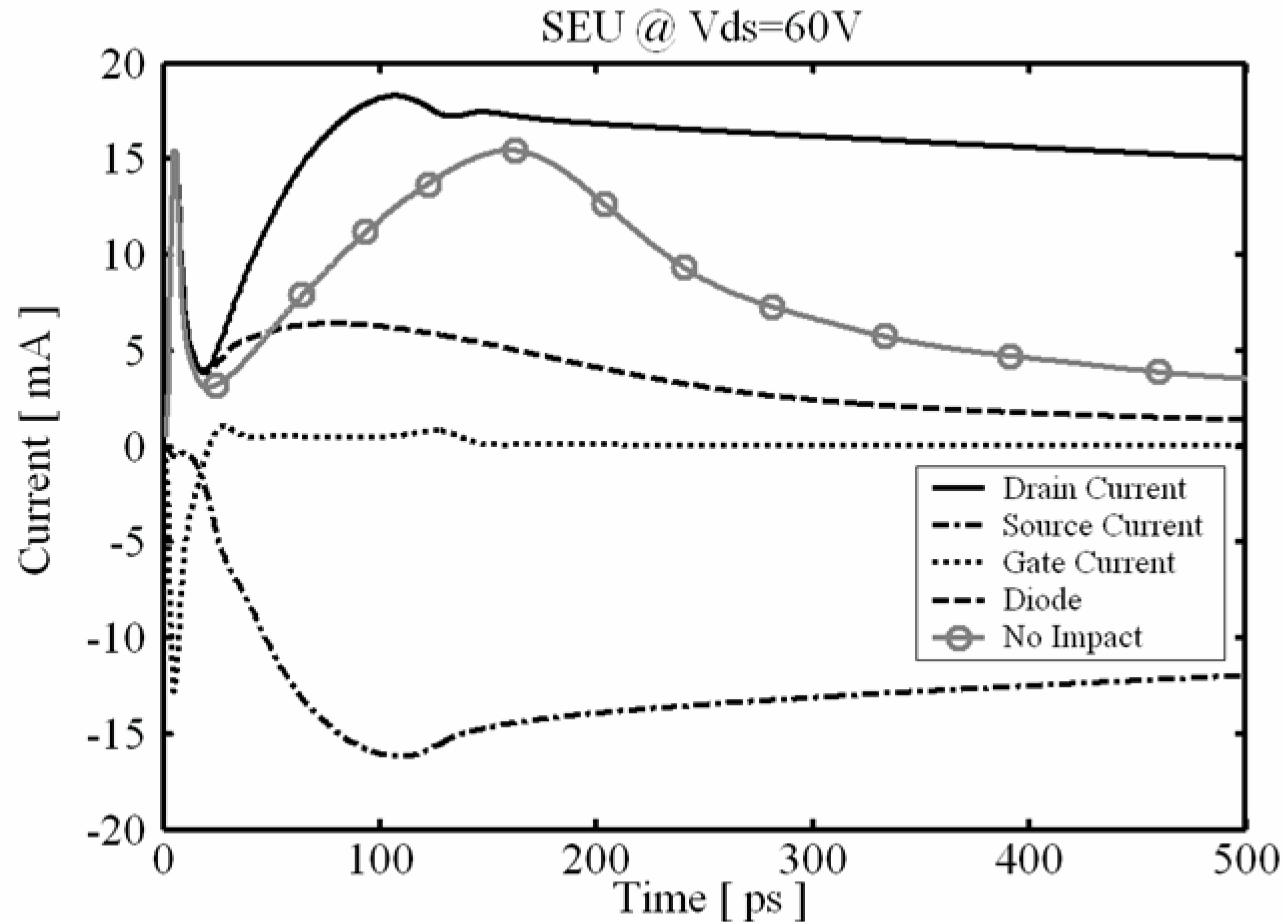
IL SET-UP SPERIMENTALE



Effetti dello spessore dell’epitassia

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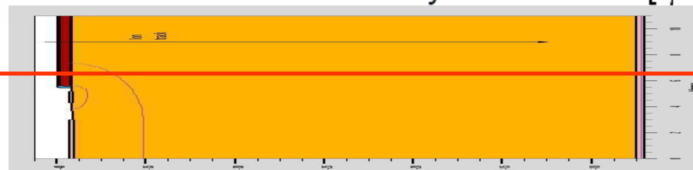
Campo elettrico

SEU @ Vds=60V t=100ps x=6.5μm

W6 with W_{epi}=22μm
W6 with W_{epi}=24μm
W24C

Electric Field [V/cm] ($\times 10^5$)

y coordinate [μm]



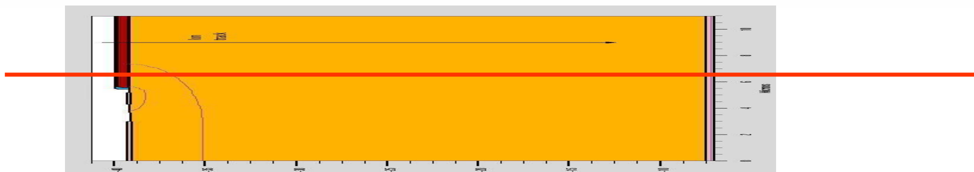
Generazione da impatto

SEU @ Vds=60V t=100ps x=6.5μm

W6 with W_{epi}=22μm
W6 with W_{epi}=24μm
W24C

Impact Gen Rate [$s^{-1}cm^{-3}$]

y coordinate [μm]



Conclusioni

- Il SEB dei MOSFET di potenza non è stato ancora totalmente spiegato.
- E' confermato che dipende dall'attivazione del BJT parassita.
- Nel meccanismo di rottura gioca un ruolo fondamentale la ionizzazione da impatto legata alla formazione di un campo molto elevato durante il moto delle particelle sotto l'ossido.
- Per prevenire la rottura dei dispositivi è necessario realizzare spessori epitassiali molto maggiori di quelli usati nei MOSFET commerciali.

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