

Work in progress

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Politecnico di Milano - Micron Technology

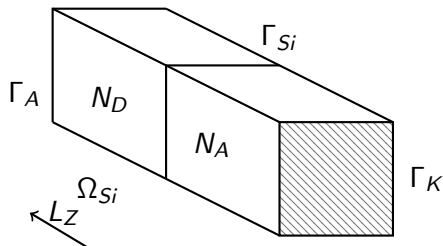
27 settembre 2013



- 1 Silicon
 - PN junction
 - Damping
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- 3 Silicon in oxide
 - N16P16
 - N17P17
 - N19P19
- 4 New results
 - N16P16
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$$\begin{cases} \nabla \cdot (-\epsilon_0 \epsilon_r \nabla \varphi) = q(p - n + D) & \text{in } \Omega_{Si} \\ \nabla \varphi \cdot \mathbf{n} = 0 & \text{su } \Gamma_{Si} \\ \varphi = \varphi_K & \text{su } \Gamma_K \\ \varphi = \varphi_A & \text{su } \Gamma_A \end{cases}$$

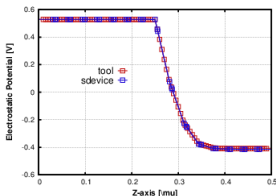


1cmNOTA

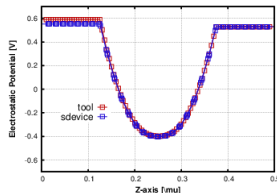
Sono stati fatti anche test sul triodo (NPN)

Confronti con sdevice - Potenziale plot asse Z

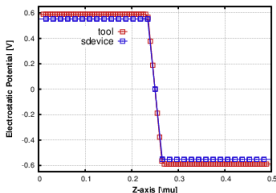
Il diverso built-in per doping maggiori di $10^{19} [cm^{-3}]$ è dovuto al fatto che sdevice setta automaticamente la distribuzione di Fermi.



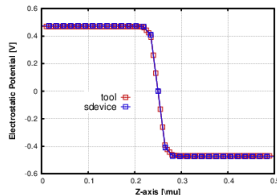
N19P17



N20P17N19



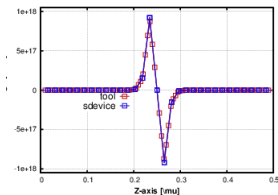
N20P20



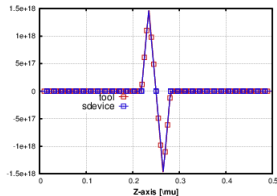
N18P18

Free charge plot asse Z & Newton method (start-end)

L'accordo si mantiene ottimo al variare della mesh (abbiamo prodotto i test lavorando con mesh fra i 450 a 70.000 nodi). Effettuando tagli ortogonali all'asse Z l'accordo si mantiene ottimo.



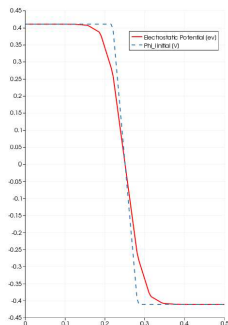
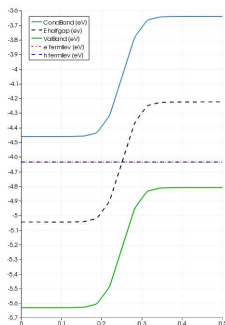
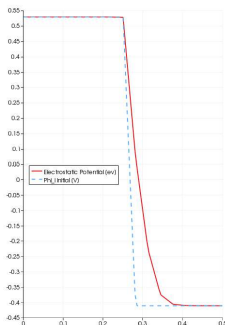
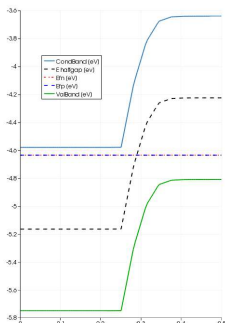
N18P18



N20P20

Newton method (start-end) & Band Diagram

Per la visualizzazione il livello 0 è il vuoto, mentre la risoluzione viene calcolata mettendo a 0 il potenziale di fermi.



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Algoritmo implementato

Abbiamo adoperato un'opportuna normalizzazione del termine forzante poiché non usiamo variabili scalate (ordine del drogaggio)

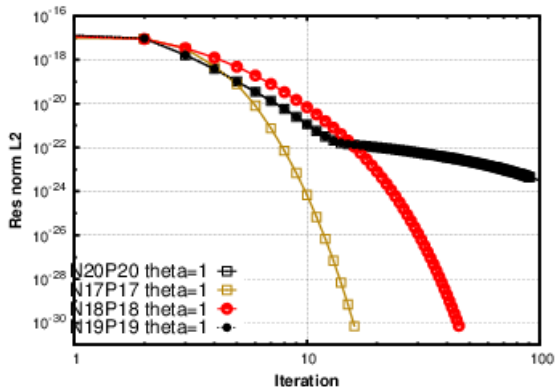
$$\begin{aligned} F_k &= F(\varphi_k) & F_{k+1} &= F(\varphi_k + t_k^{(j)} \delta \varphi_k) \\ t_k^{(j)} &= \frac{1}{1 + K_k^{(j)} \|F_k\|} \quad \longrightarrow \quad \|F_k\| \approx 10^{18} \implies t_k^{(j)} \approx 0 \\ N &\approx 10^{18} & \tilde{t}_k^{(j)} &= \frac{1}{1 + K_k^{(j)} \|F_k\|_\infty N^{-1}} \\ K_k^{(j)} & \text{ t.c. } 1 - \frac{\|F_{k+1}^{(j)}\|_\infty}{\|F_k\|_\infty} < \delta \tilde{t}_k^{(j)} & K_k^{(j)} &= K_{base}^j \end{aligned}$$

1cmProblema

La condizione di uscita non viene mai soddisfatta, si esce dal ciclo solo perchè viene opportunamente settato il maxit su j (altrimenti $t_k^{(j)} \rightarrow 0$ e il sistema non evolve).

Andamento del residuo

Comportamenti differenti del residuo sulla risoluzione di Newton senza damping al variare dei drogaggi.

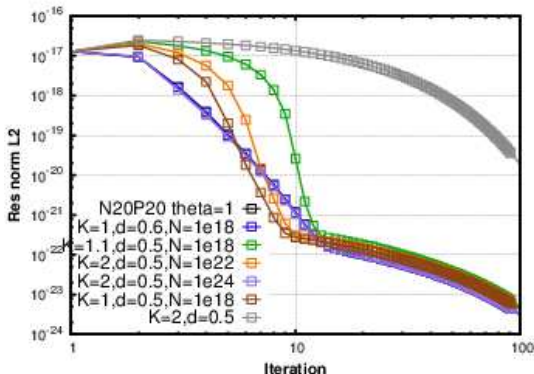


Damping

1cmParametri settati da input file

- K_{base}
- δ
- N (fattore di normalizzazione)

NOTA : abbiamo usato il caso N20P20 più lento a convergere



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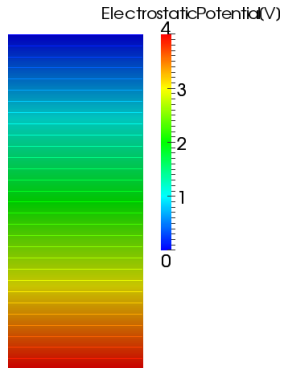
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Esperimento ossido

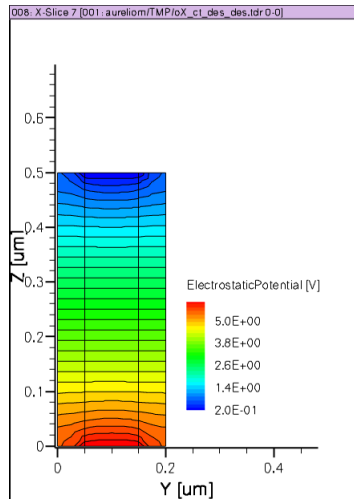
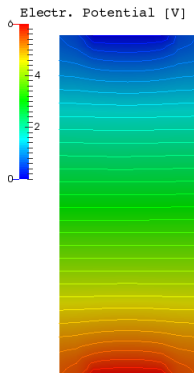
Abbiamo testato il risolutore lineare
in due differenti situazioni,
confrontate entrambe con sdevice.
Per prima vediamo il caso

$$L_{\text{contatto}} = L_{\text{lato}}$$



Esperimento ossido

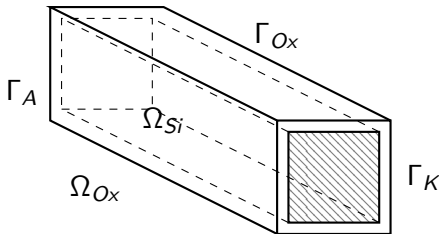
Di seguito il caso $L_{contatto} < L_{lato}$, soluzione non lineare



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Formulazione problema

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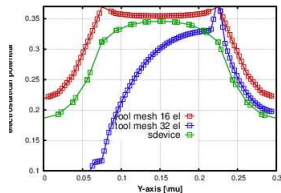
$$\left\{ \begin{array}{ll} -\nabla \cdot (\epsilon_{Si} \nabla \delta\varphi) + \sigma \delta\varphi = \nabla \cdot (\epsilon_{Si} \nabla \varphi) + q(p - n + D) & \text{in } \Omega_{Si} \\ -\nabla \cdot (\epsilon_{Ox} \nabla \delta\varphi) = \nabla \cdot (\epsilon_{Ox} \nabla \varphi) & \text{in } \Omega_{Ox} \\ \nabla \delta\varphi \cdot \mathbf{n} = 0 & \text{su } \Gamma_{Ox} \\ \delta\varphi = 0 & \text{su } \Gamma_K \\ \delta\varphi = 0 & \text{su } \Gamma_A \end{array} \right.$$

1cmDomanda:

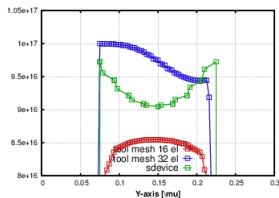
Cosa bisogna imporre, come valore di forzante e coefficiente di reazione, sui nodi di frontiera fra il bulk di silicio e l'ossido?

Sezioni fissate le coordinate X e Z

Valori al bordo pari al silicio

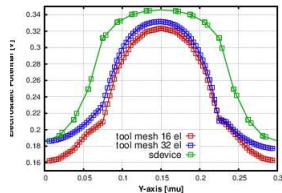


Potenziale

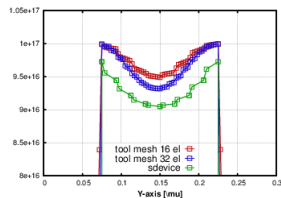


Carica

Valori al bordo pari all'ossido



Potenziale



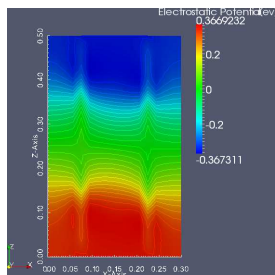
1. Le soluzioni non coincidono più con sdevice
2. La scelta di imporre i valori relativi all'ossido sembra portare la soluzione più vicina ad sdevice

Nei test successivi adottiamo la scelta di valori pari all'ossido sull'interfaccia.

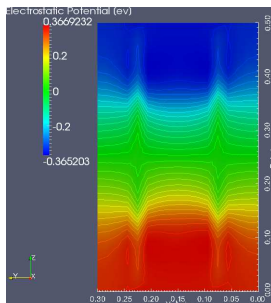
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Asimmetria-Potenziale N16P16

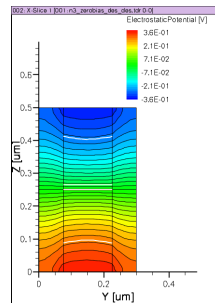
Evidente asimmetria fra le differenti sezioni e problema allineamento valore di interfaccia sulla frontiera ossido silicio.



Sezione XZ



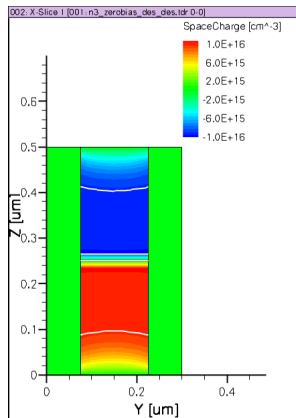
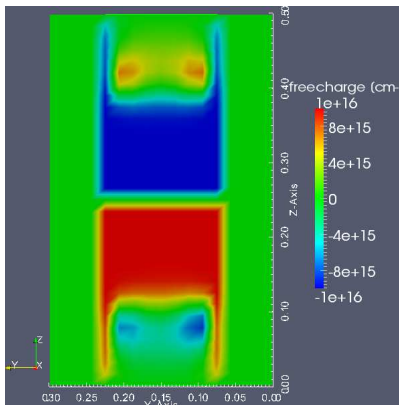
Sezione YZ



Sdevice

Picchi inaspettati - Free Charge N16P16

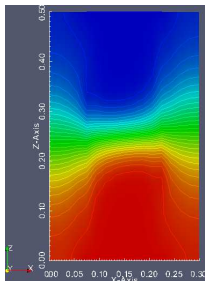
Valori numerici nella prima parte di zona svuotata soddisfacenti.
Cambiamento di tendenza avvicinandosi ai contatti. Instabilità? Condizioni di bordo applicate male?



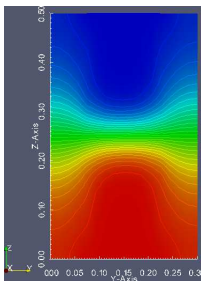
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Asimmetria - Potenziale N17P17

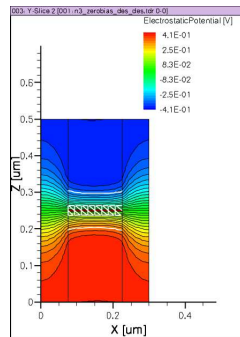
Asimmetria accentuata (o forse prima era mascherata dai problemi di interfaccia?). Sovraddiffusione del potenziale all'interno dell'ossido.



Sezione XZ



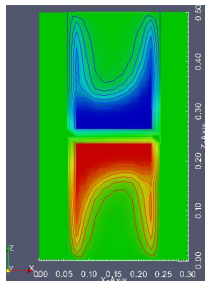
Sezione YZ



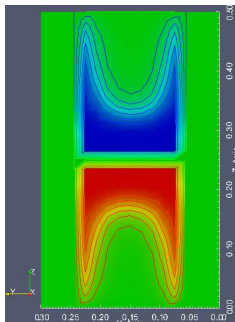
Sdevice

Asimmetria - Free Charge N17P17

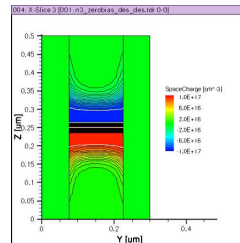
Ripercussioni della asimmetria evidenti sulla carica. Migliore grafico ottenuto per valori e distribuzione (l'apporto sovradiffusivo si fa notare allungando maggiormente le code di zona svuotata)



Sezione XZ



Sezione YZ

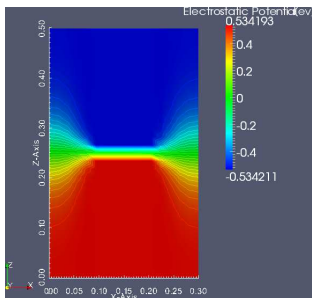


Sdevice

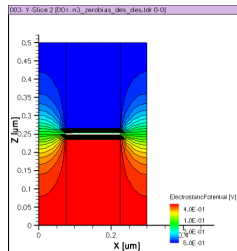
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Asimmetria scomparsa - Potenziale N19P19

Smorzamento dell'asimmetria dei risultati, probabilmente dovuto al drogaggio alto (che rendendo più fine la zona svuotata non permette di valutare un'eventuale asimmetria). Fenomeno di sovraddiffusione contenuto (o assente?) probabilmente per la medesima motivazione.



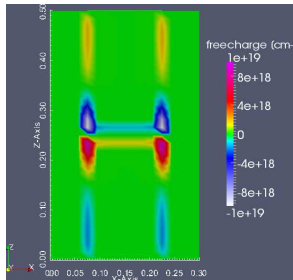
Sezione XZ



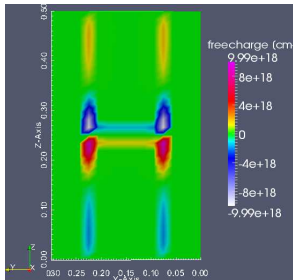
Sdevice

Carica interfacciale - Free Charge N19P19

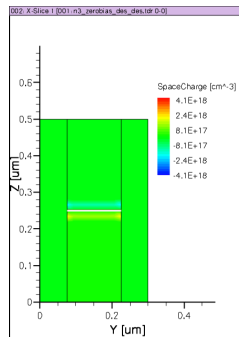
Problemi evidenti di carica interfacciale nonostante la soluzione del potenziale sembra essere quella che si avvicini di più alla soluzione sdevice.



Sezione XZ



Sezione YZ



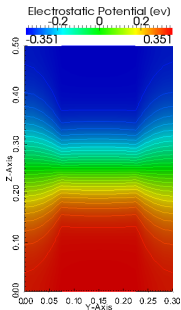
Sdevice

Conclusioni

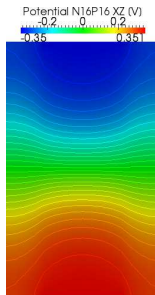
1. Il solutore non lineare di Poisson sul silicio è allineato con i risultati di sdevice.
2. Il solutore lineare di Poisson su ossido è allineato con i risultati di sdevice
3. Il solutore non lineare di Poisson applicato alla situazione silicio-ossido non dà soluzioni corrette: viste le conclusioni precedenti il problema è legato al trattamento dell'interfaccia silicio-ossido.

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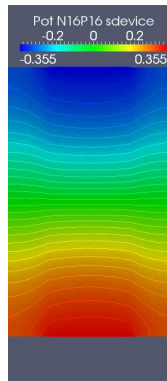
Potenziale N16P16



Coeff Si

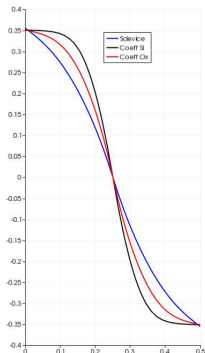


Coeff Ox

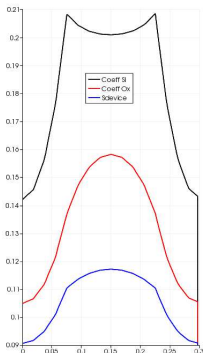


Sdevice

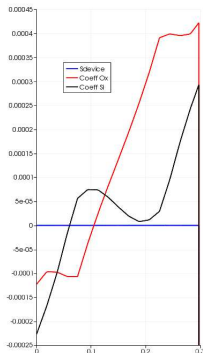
Potenziale tagli N16P16



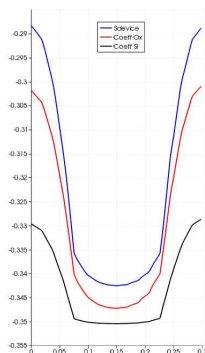
X=Y=0.15



X=0.15 Z=0.2

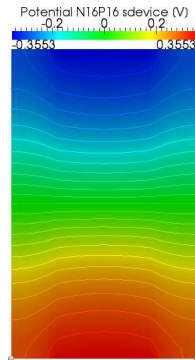
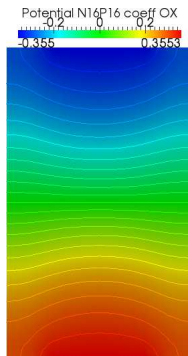
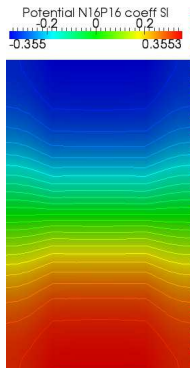


X=0.15 Z=0.25

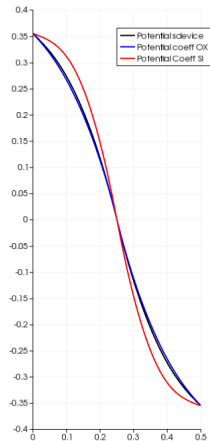


X=0.15 Z=0.48

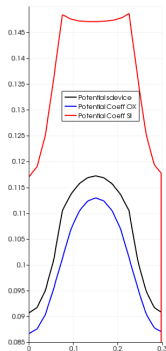
Potenziale N16P16



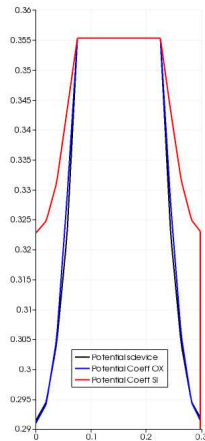
Potenziale tagli N16P16



$X=Y=0.15$



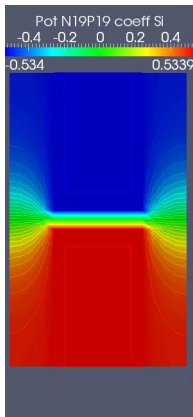
$X=0.15$
 $Z=0.25$



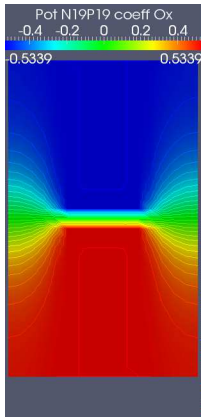
$X=0.15$ $Z=0.0$

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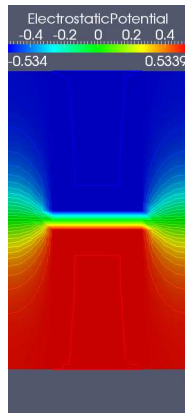
Potenziale N19P19



Coeff Si

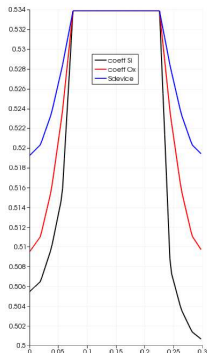


Coeff Ox

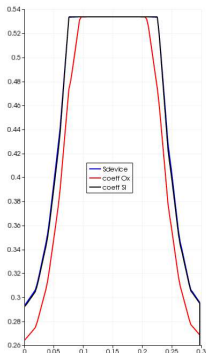


Sdevice

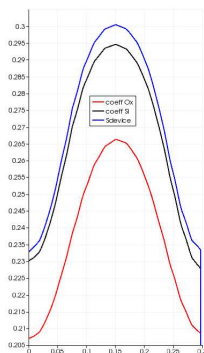
Potenziale tagli N19P19



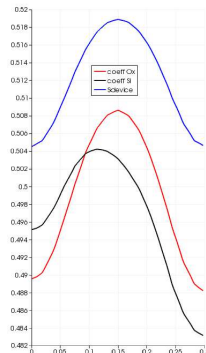
$Z=0$ $Y=0.15$



$Y=0.15$ $Z=0.2$

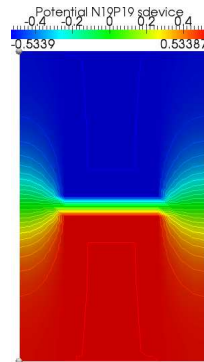
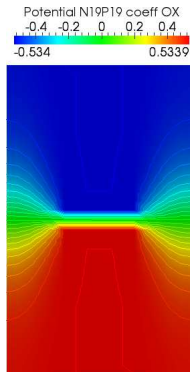
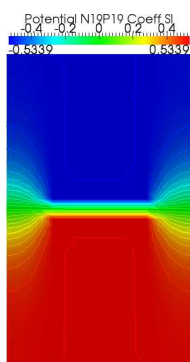


$X=0.01$ $Z=0.2$

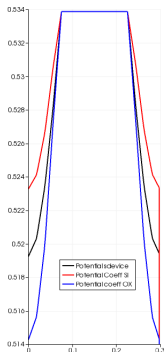


$X=0.01$ $Z=0.02$

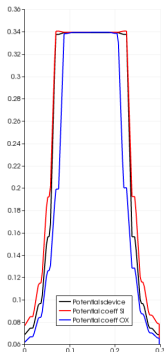
Potenziale N19P19



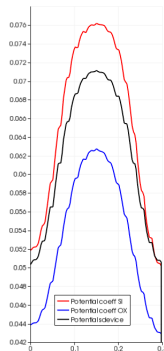
Potenziale tagli N19P19



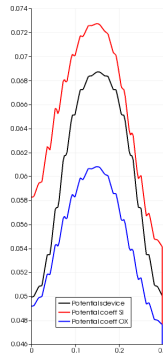
$X=Y=0.15$



$X=0.15$ $Z=0.2$



$X=0.005$
 $Z=0.024$



$X=0.0295$
 $Z=0.024$