Resistive Switching Memory Model using NovaTCAD

-Based on Monte Carlo Simulation of O2 diffusions

NovaTCAD

20 years ANNIVERSARY

CROSSLIGHT

Resistive switching physical processes

- Temperature activated O2 generation and recombination.
- Temperature activated hopping of O2 at interstitial sites.
- Poole-Frenkel de-trapping model for off state leakage current.
- Absorption and release of O2 by electrodes.
- Physical based probabilities with field and temperature dependence.
- O2 site represented by a circuit node in Crosslight MiniSpice model.
- MiniSpice special resistor models: models based on sinh() function and quantum point contact.
- MiniSpice included in NovaTCAD as Mixmode device simulation.

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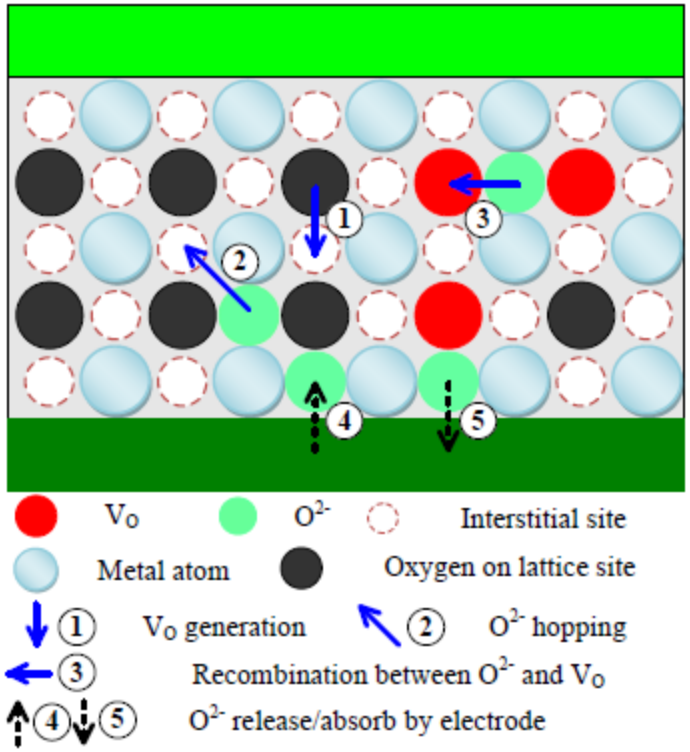
Resistive switching Monte-Carlo approach



Vo generation rate, with Ea as activation energy, delta-phi as barrier lowered by field

$$P_a = f \exp(-\frac{E_a - \Delta\varphi_1}{k_B T_{loc}})$$

Interstitial O2 hopping rate with Eh as activation energy.

$$P_h = f \exp(-\frac{E_h - \Delta\varphi_2}{k_B T_{loc}})$$

[1] Peng Huang, Bin Gao, Bing Chen, Feifei Zhang, Lifeng Liu, Gang Du, Jinfeng Kang, Xiaoyan Liu, "Stochastic Simulation of Forming, SET and RESET Process for Transition Metal Oxide-based Resistive Switching Memory," SISPAD 2012, Sept. 5-7, 2012, Denver, CO, USA

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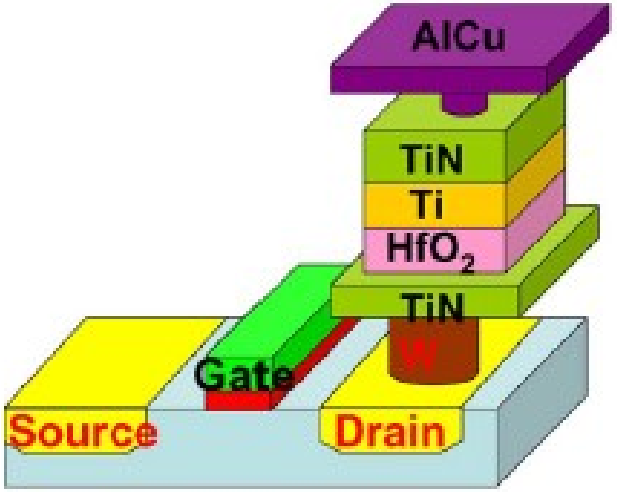
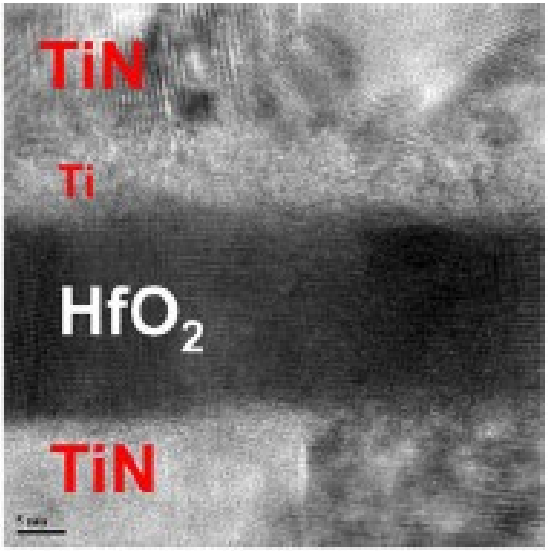
Demo Structure



(a)



(b)

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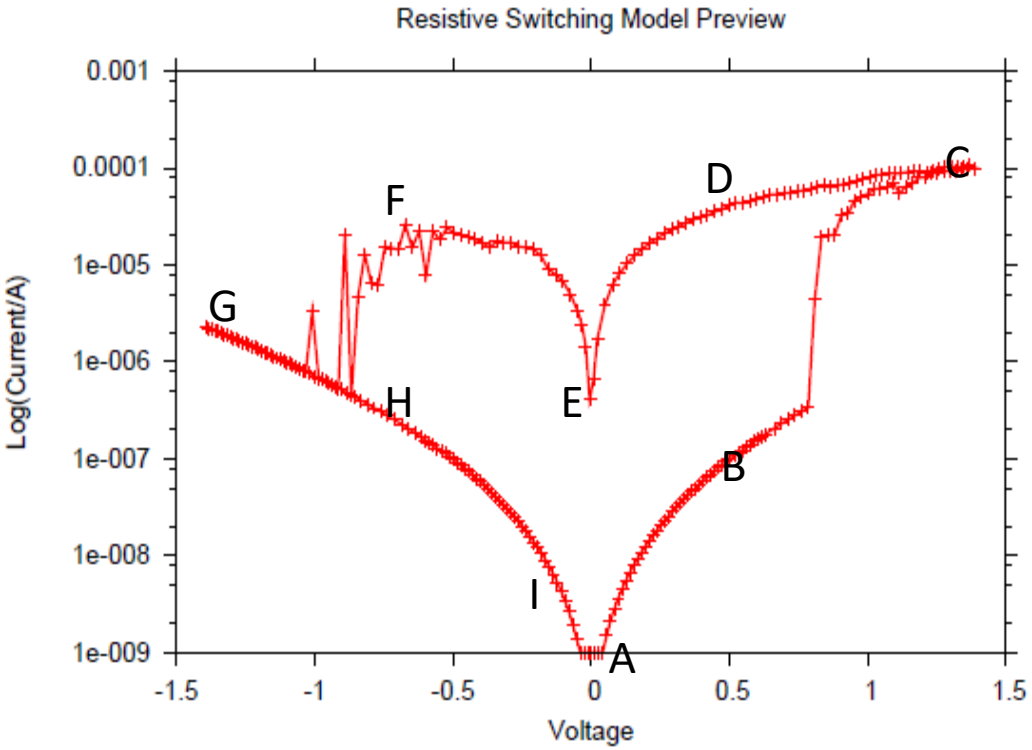

A: Initial
B: set_half_up
C: set_up
D: set_half_down
E: set_down
F: reset_half_up
G: reset_up
H: reset_half_down
I: reset_down

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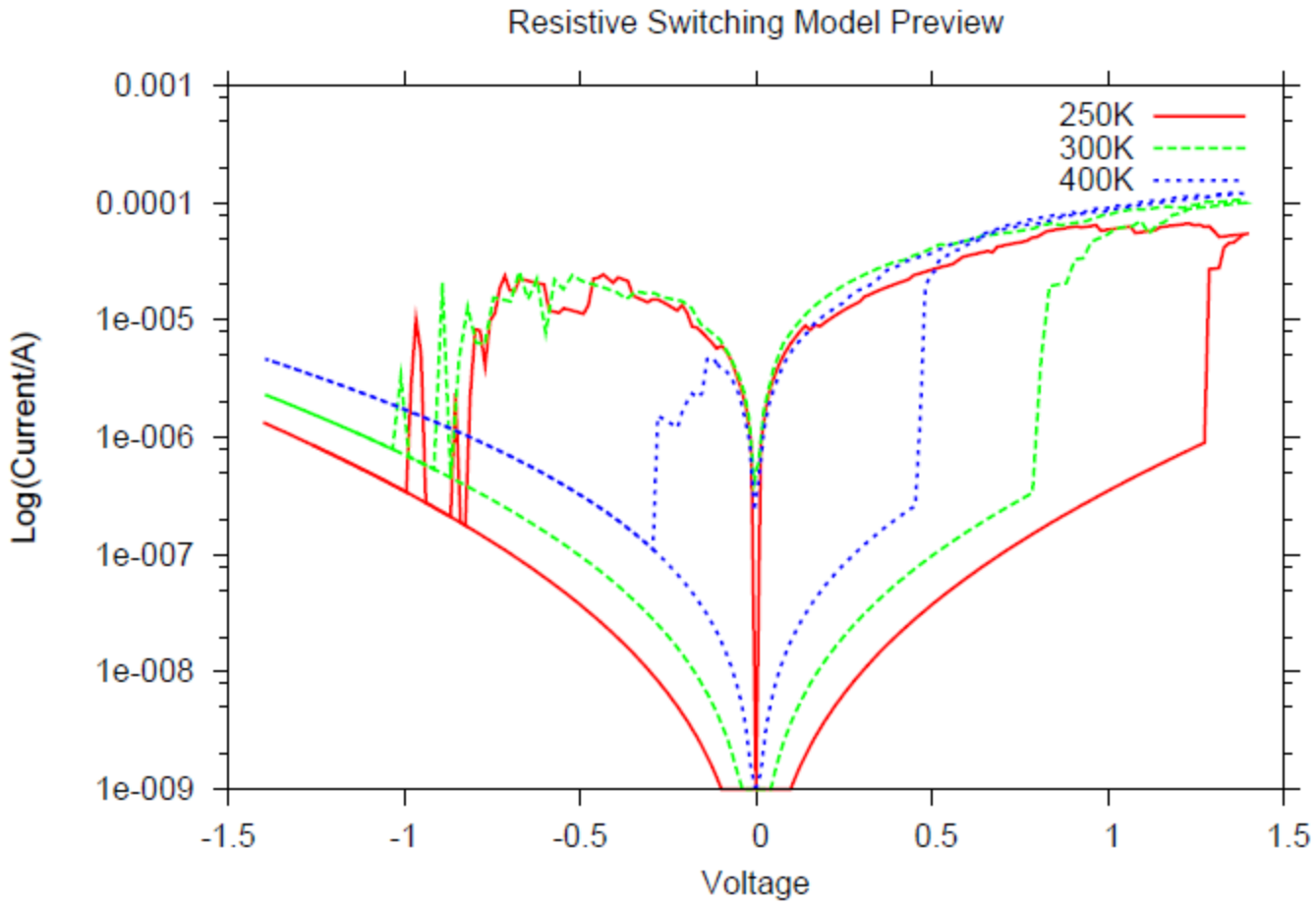
Resistive Switching Model Preview
0.001
0.0001
1e-005
1e-006
1e-007
1e-008
1e-009
Log(Current/A)
250K
300K
400K
-1.5
-1
-0.5
0
0.5
1
1.5
Voltage

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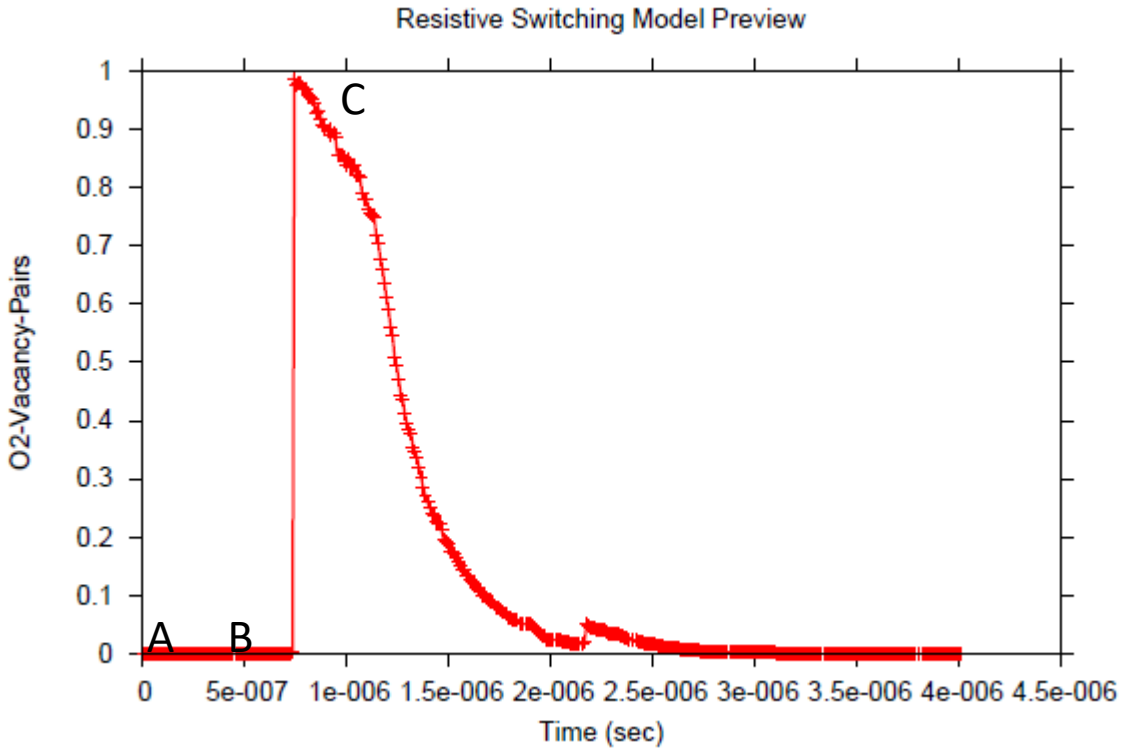
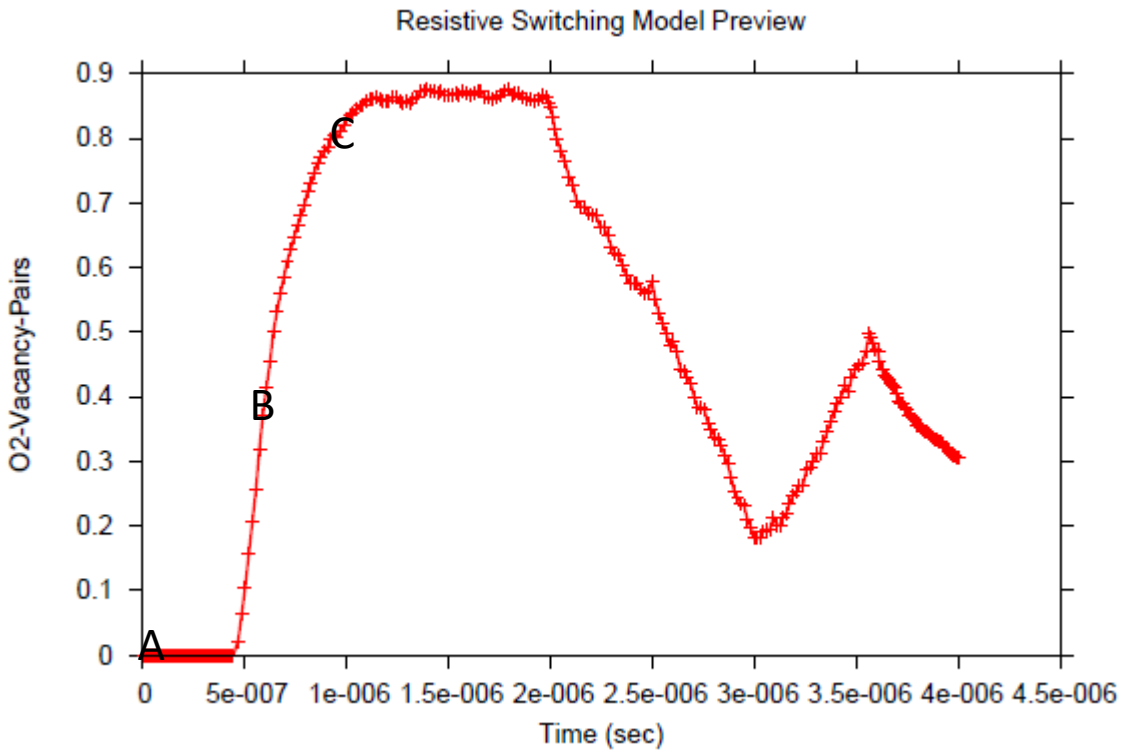

Resistive Switching Model Preview
O2-Vacancy-Pairs
Time (sec)
A
B
C
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
5e-007
1e-006
1.5e-006
2e-006
2.5e-006
3e-006
3.5e-006
4e-006
4.5e-006

NovaTCAD


Resistive Switching Model Preview
O2-Vacancy-Pairs
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
A
B
C
0
5e-007
1e-006
1.5e-006
2e-006
2.5e-006
3e-006
3.5e-006
4e-006
4.5e-006
Time (sec)

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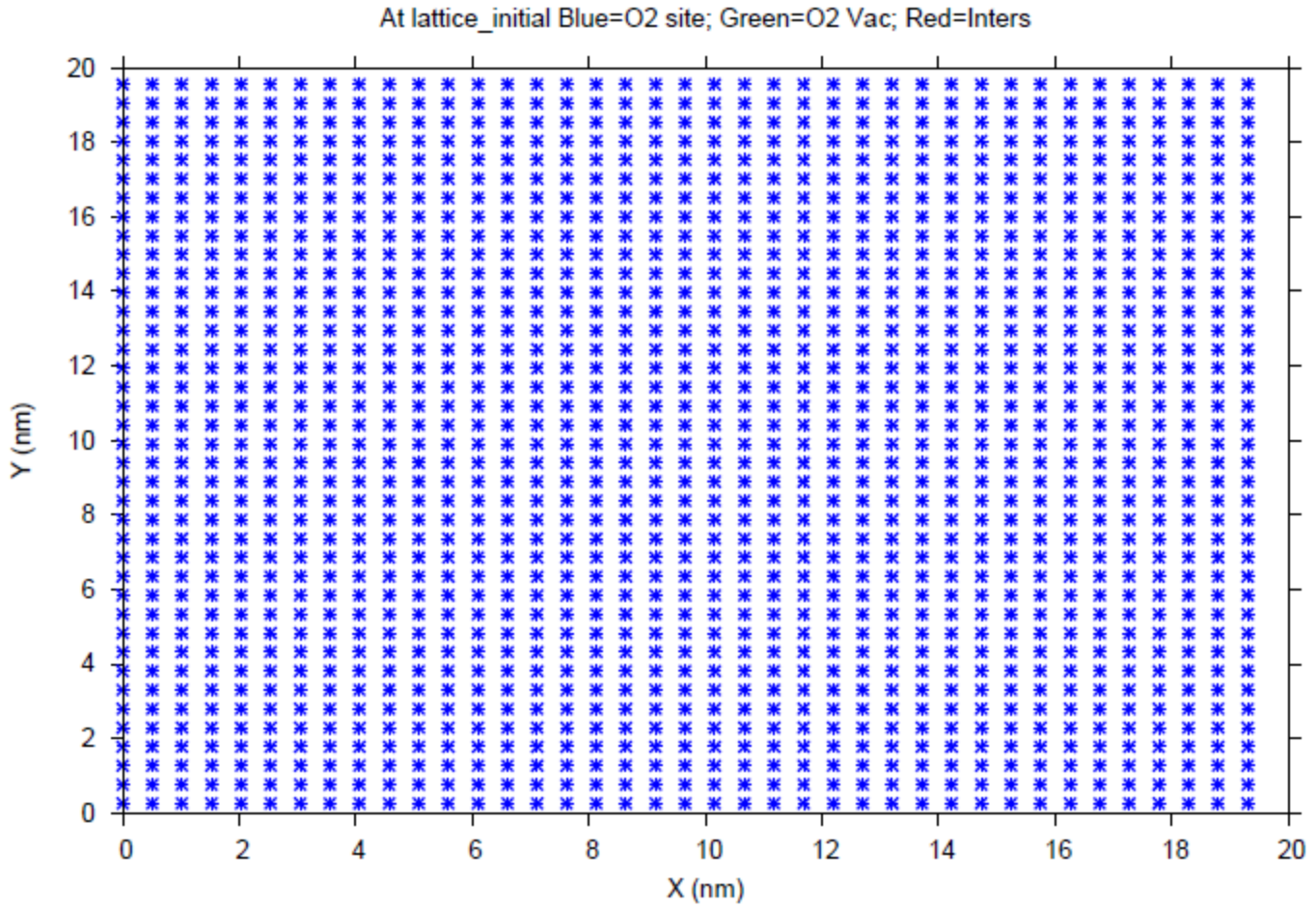
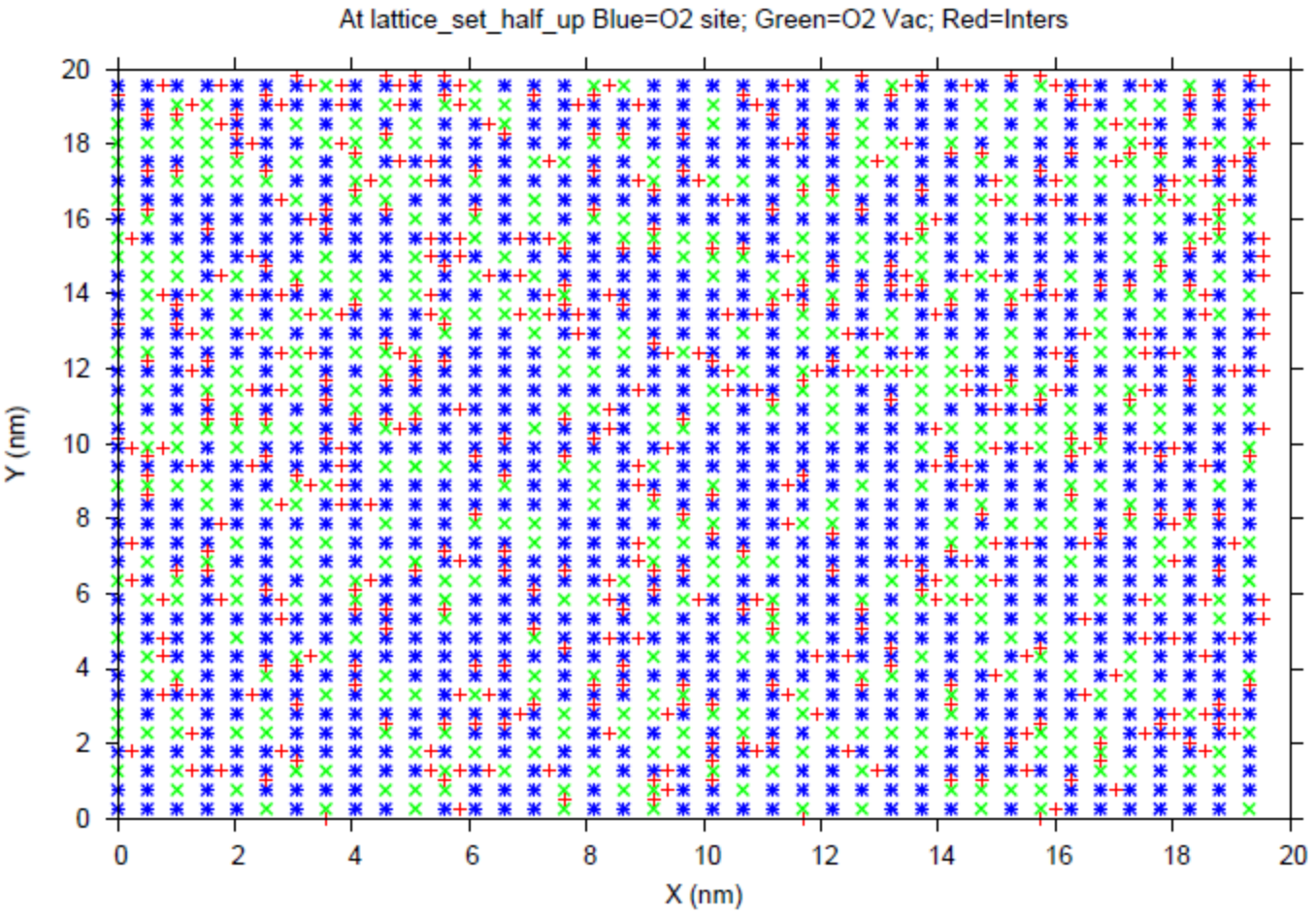
A


At lattice_initial Blue=O2 site; Green=O2 Vac; Red=Inters
Y (nm)
X (nm)
0
2
4
6
8
10
12
14
16
18
20

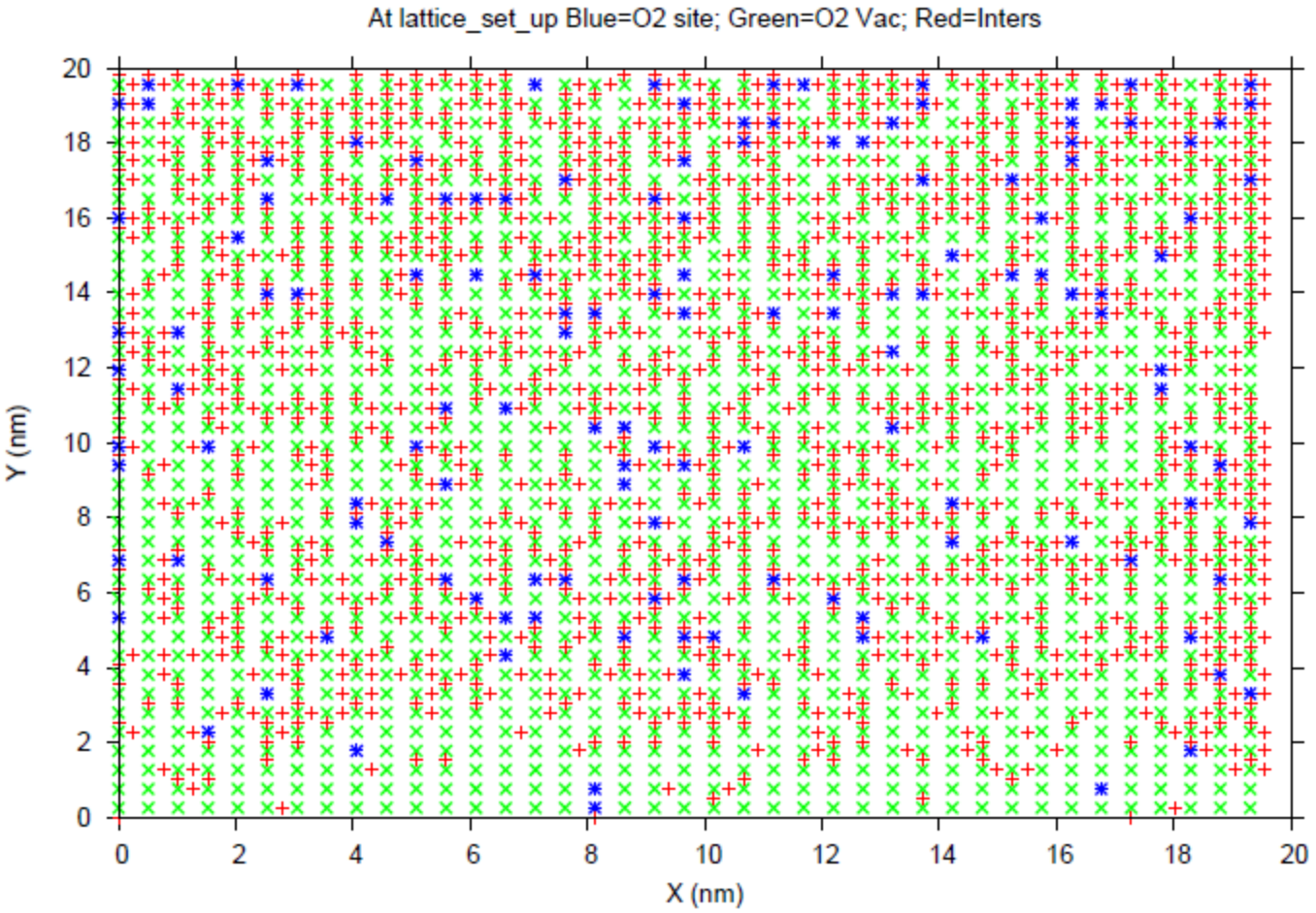
NovaTCAD

B:


At lattice_set_half_up Blue=O2 site; Green=O2 Vac; Red=Inters
Y (nm)
X (nm)
0
2
4
6
8
10
12
14
16
18
20

NovaTCAD

C:


At lattice_set_up Blue=O2 site; Green=O2 Vac; Red=Inters
Y (nm)
X (nm)
0
2
4
6
8
10
12
14
16
18
20

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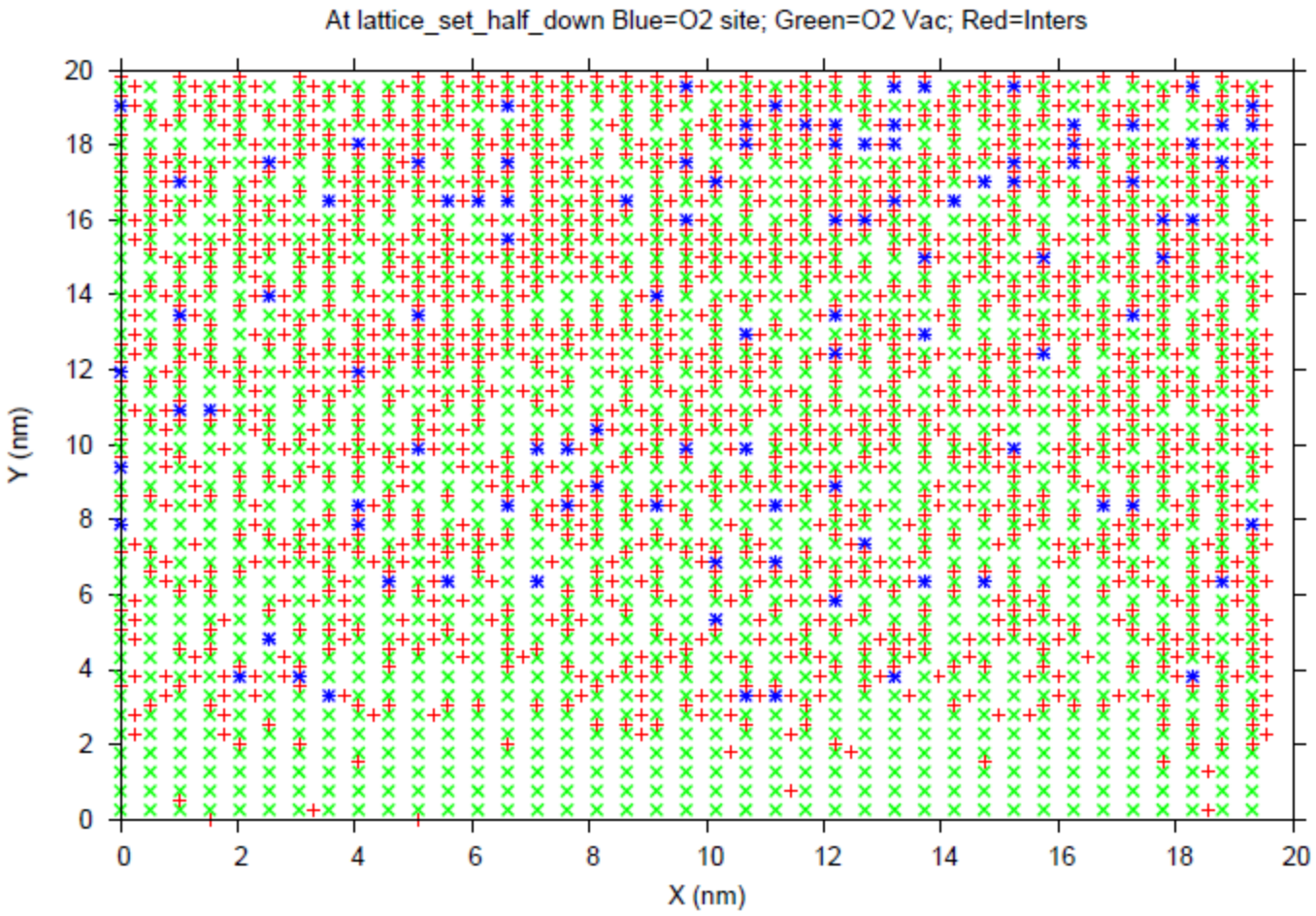
D:


At lattice_set_half_down Blue=O2 site; Green=O2 Vac; Red=Inters
Y (nm)
X (nm)
0
2
4
6
8
10
12
14
16
18
20

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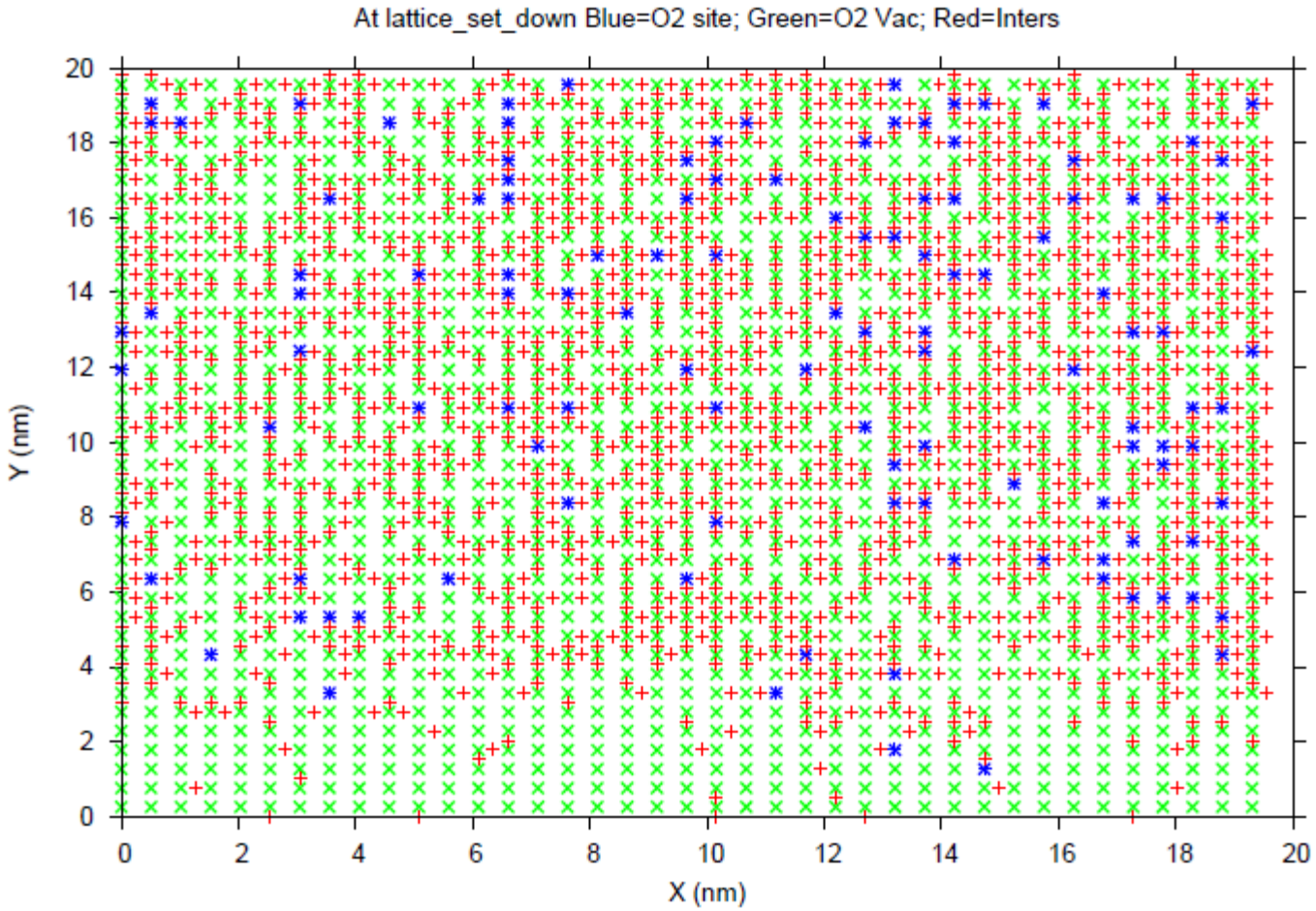
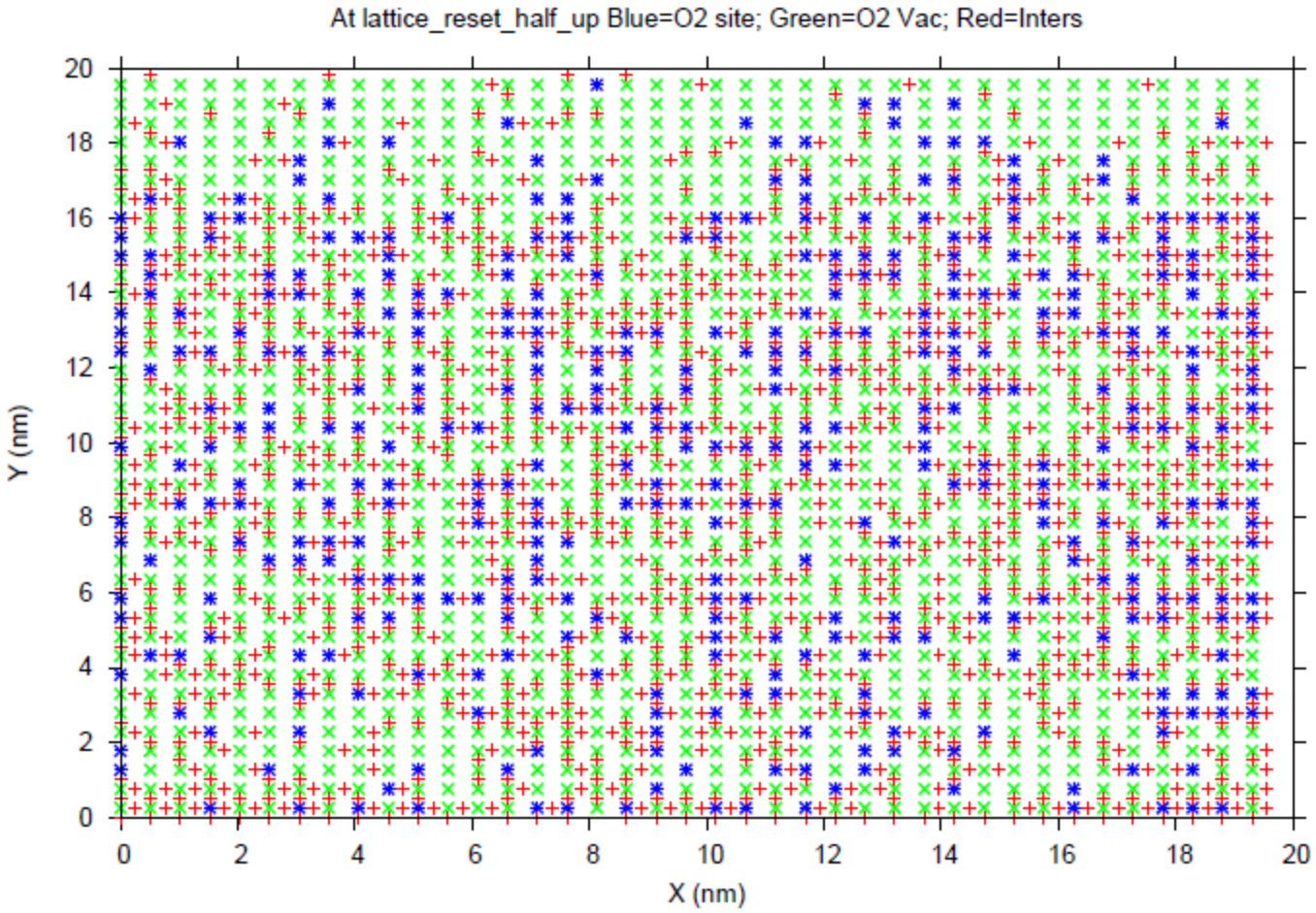
E:


At lattice_set_down Blue=O2 site; Green=O2 Vac; Red=Inters
Y (nm)
X (nm)
0
2
4
6
8
10
12
14
16
18
20

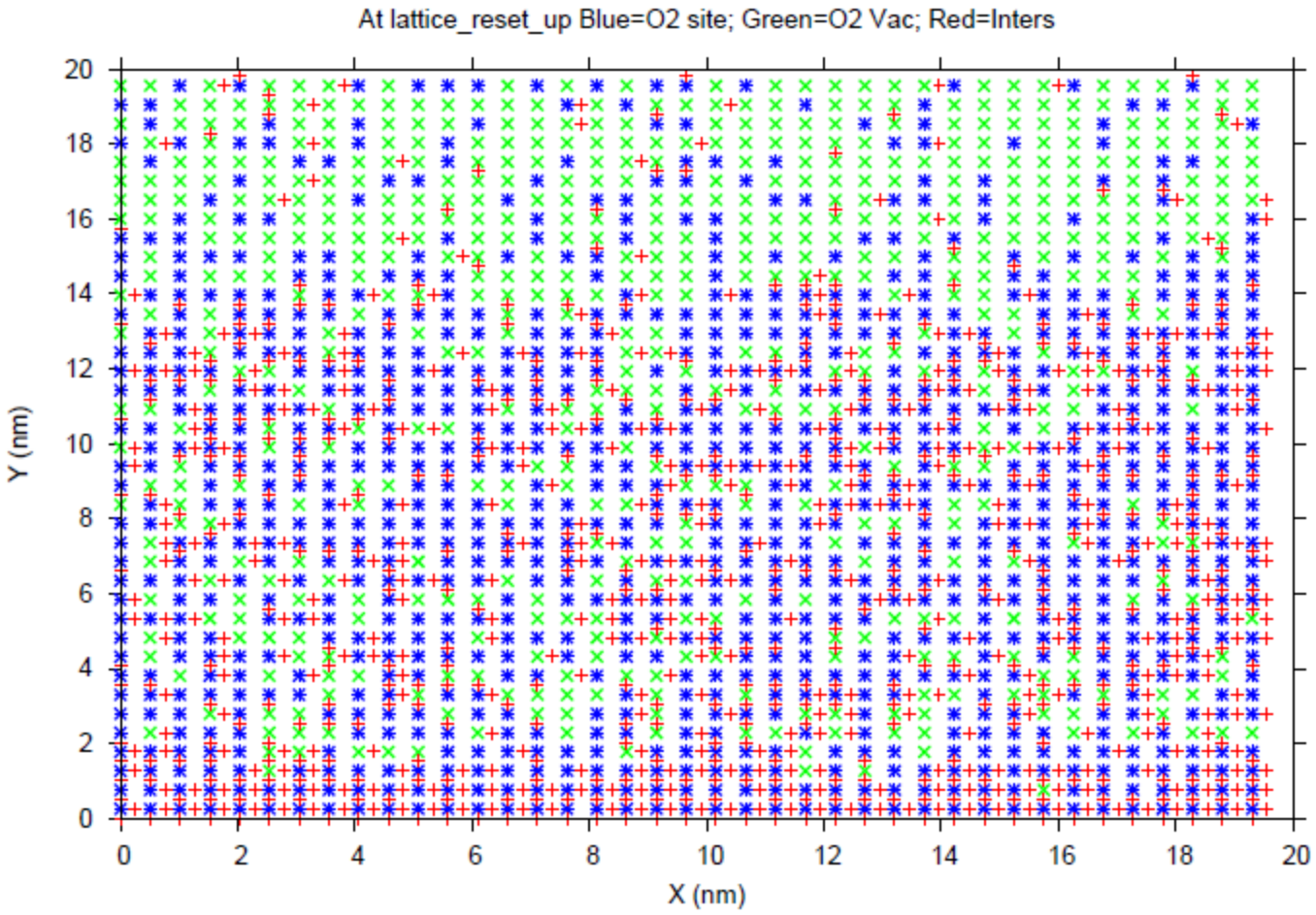
NovaTCAD

F:


At lattice_reset_half_up Blue=O2 site; Green=O2 Vac; Red=Inters
Y (nm)
X (nm)
0
2
4
6
8
10
12
14
16
18
20

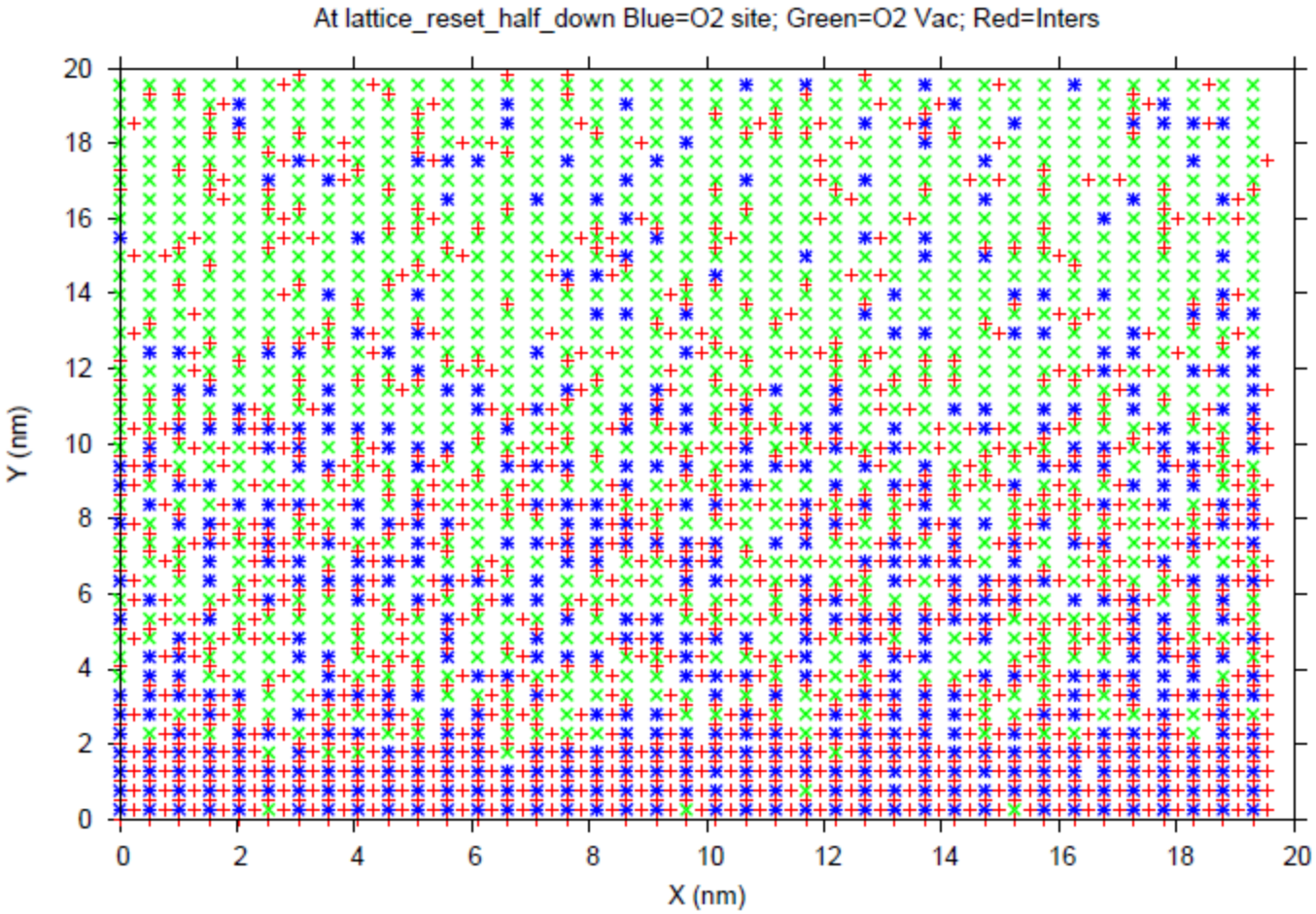
NovaTCAD

G:


At lattice_reset_up Blue=O2 site; Green=O2 Vac; Red=Inters
Y (nm)
X (nm)
0
2
4
6
8
10
12
14
16
18
20

NovaTCAD

H:


At lattice_reset_half_down Blue=O2 site; Green=O2 Vac; Red=Inters
Y (nm)
X (nm)
0
2
4
6
8
10
12
14
16
18
20

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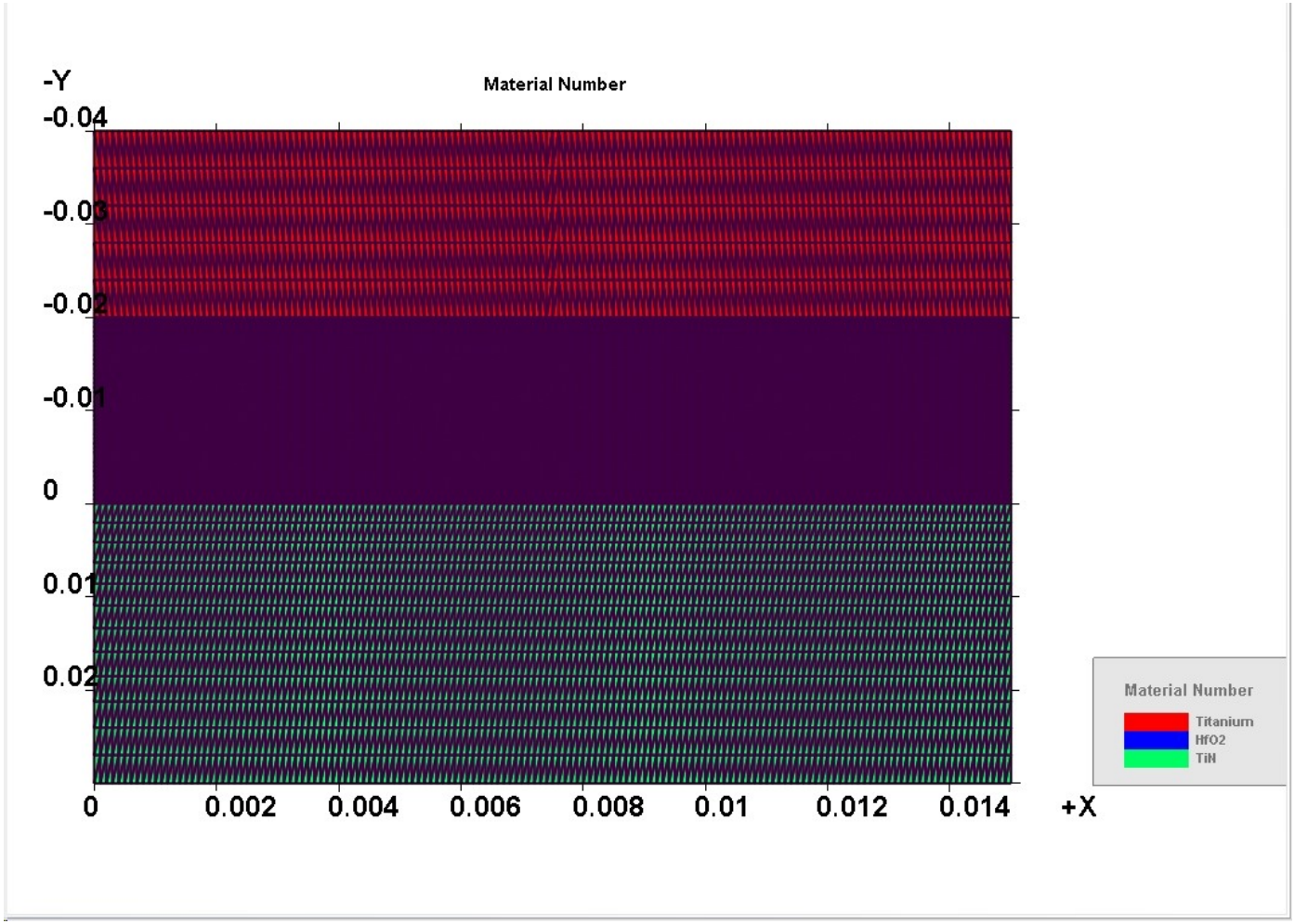
Use of CSUPREM for TCAD mesh



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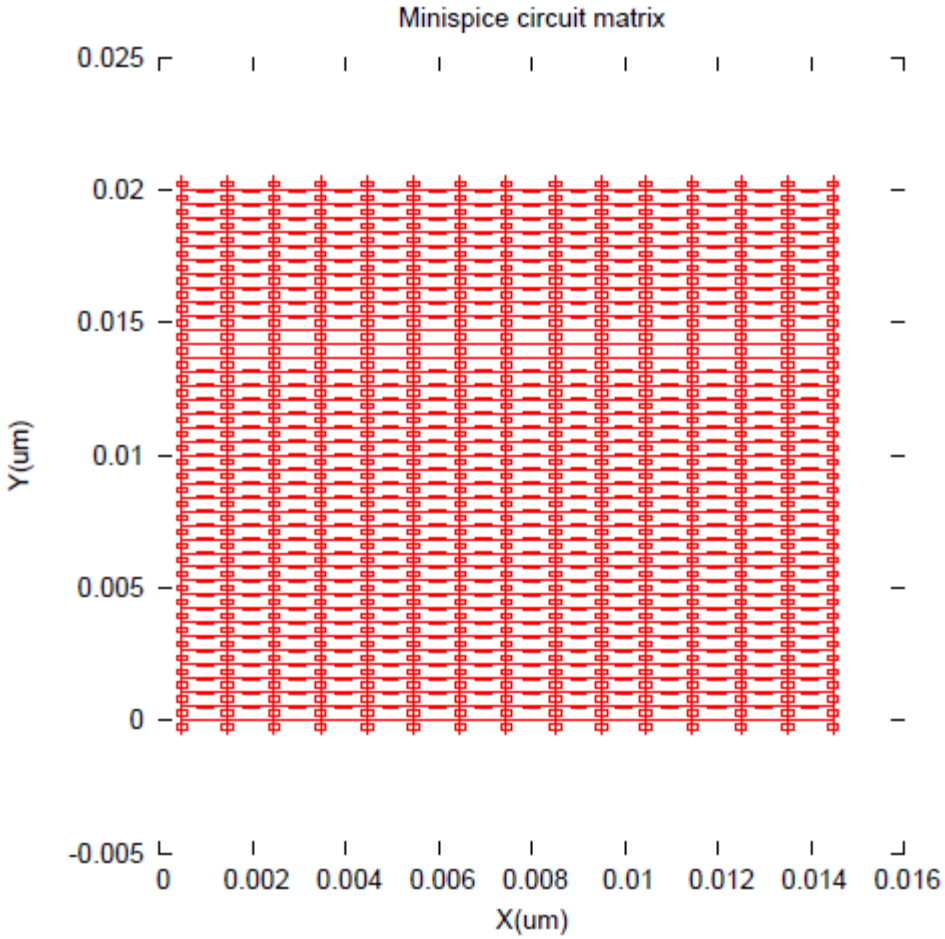
Minispice circuit matrix
0.025
0.02
0.015
0.01
0.005
0
-0.005
Y(um)
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
X(um)

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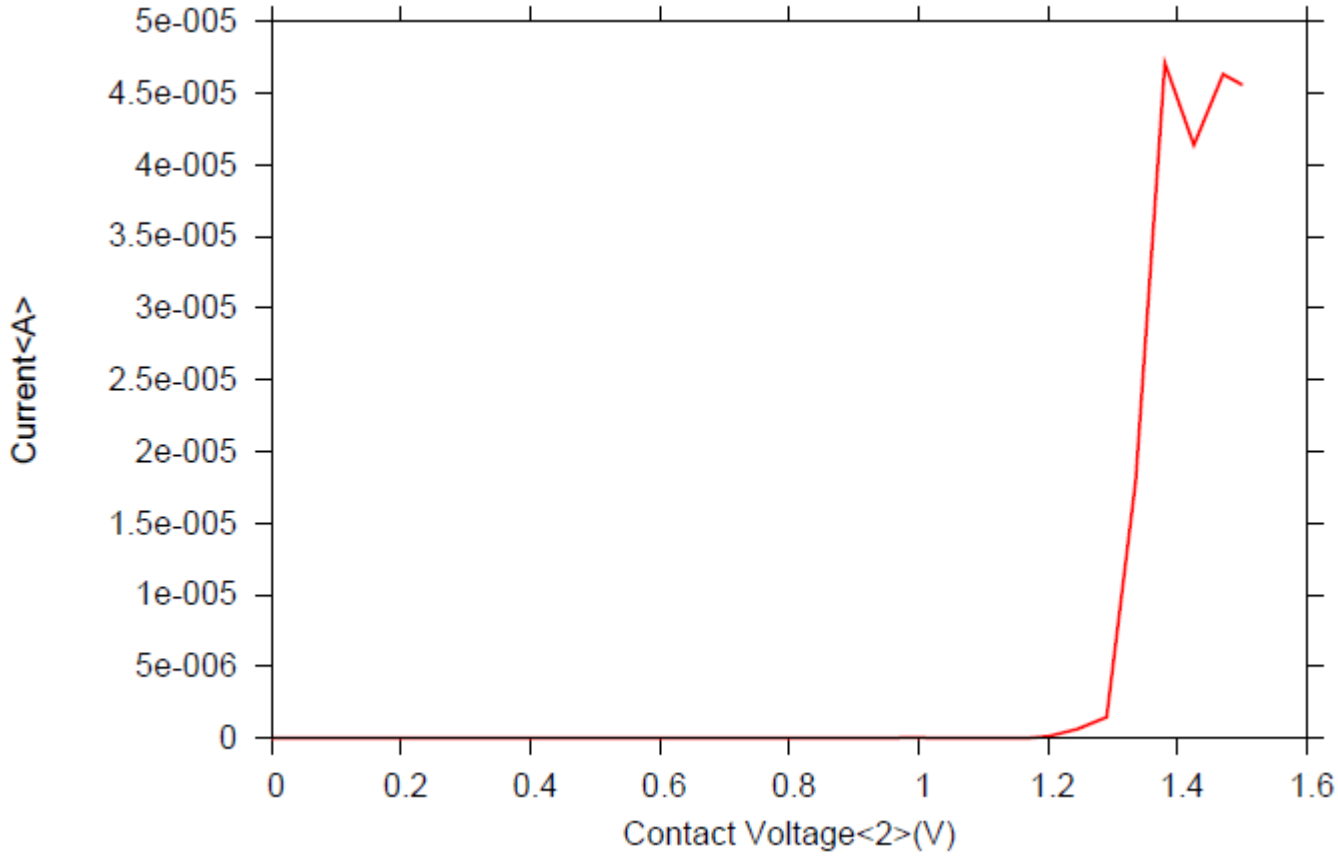
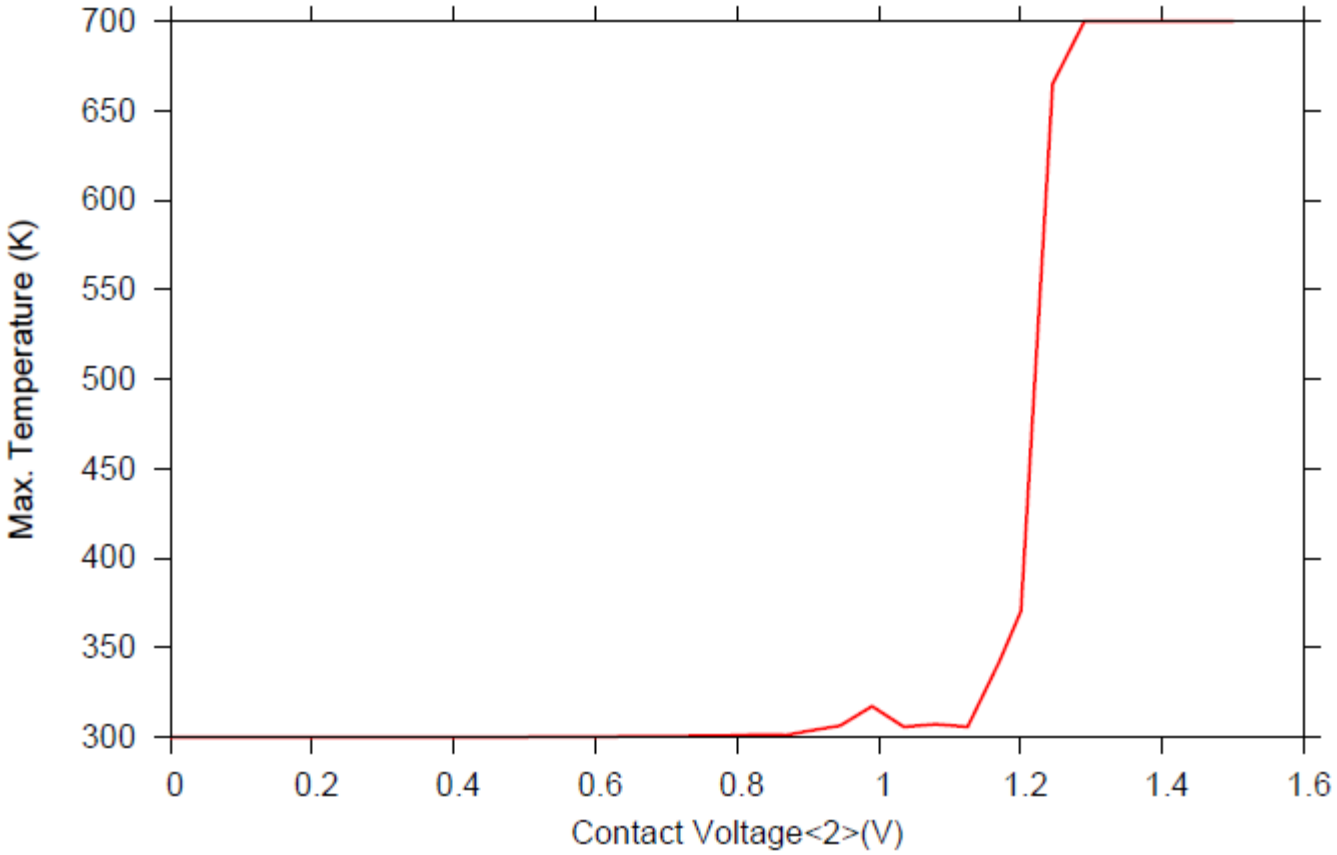
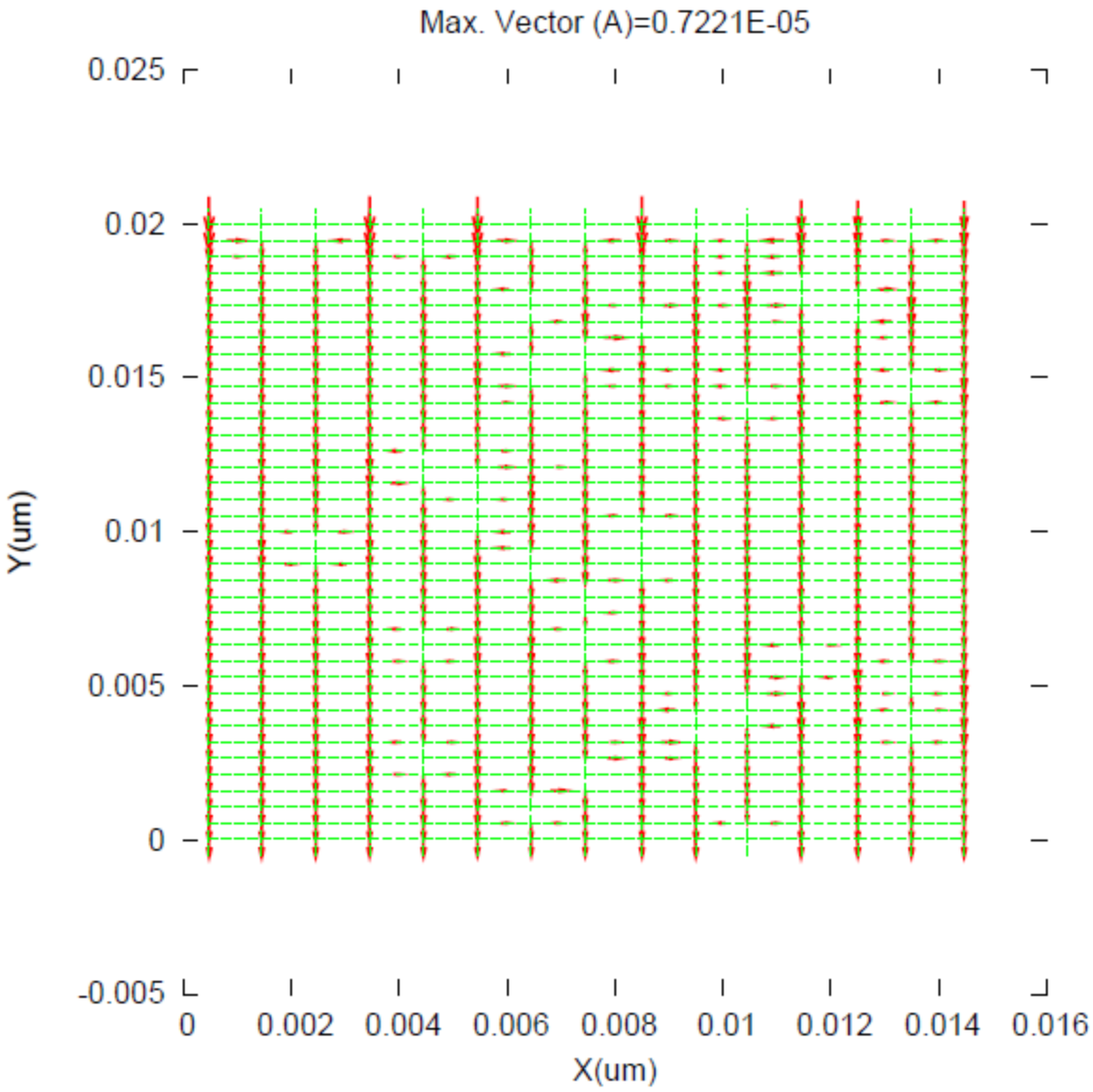

5e-005
4.5e-005
4e-005
3.5e-005
3e-005
2.5e-005
2e-005
1.5e-005
1e-005
5e-006
0
Current<A>
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Contact Voltage<2>(V)

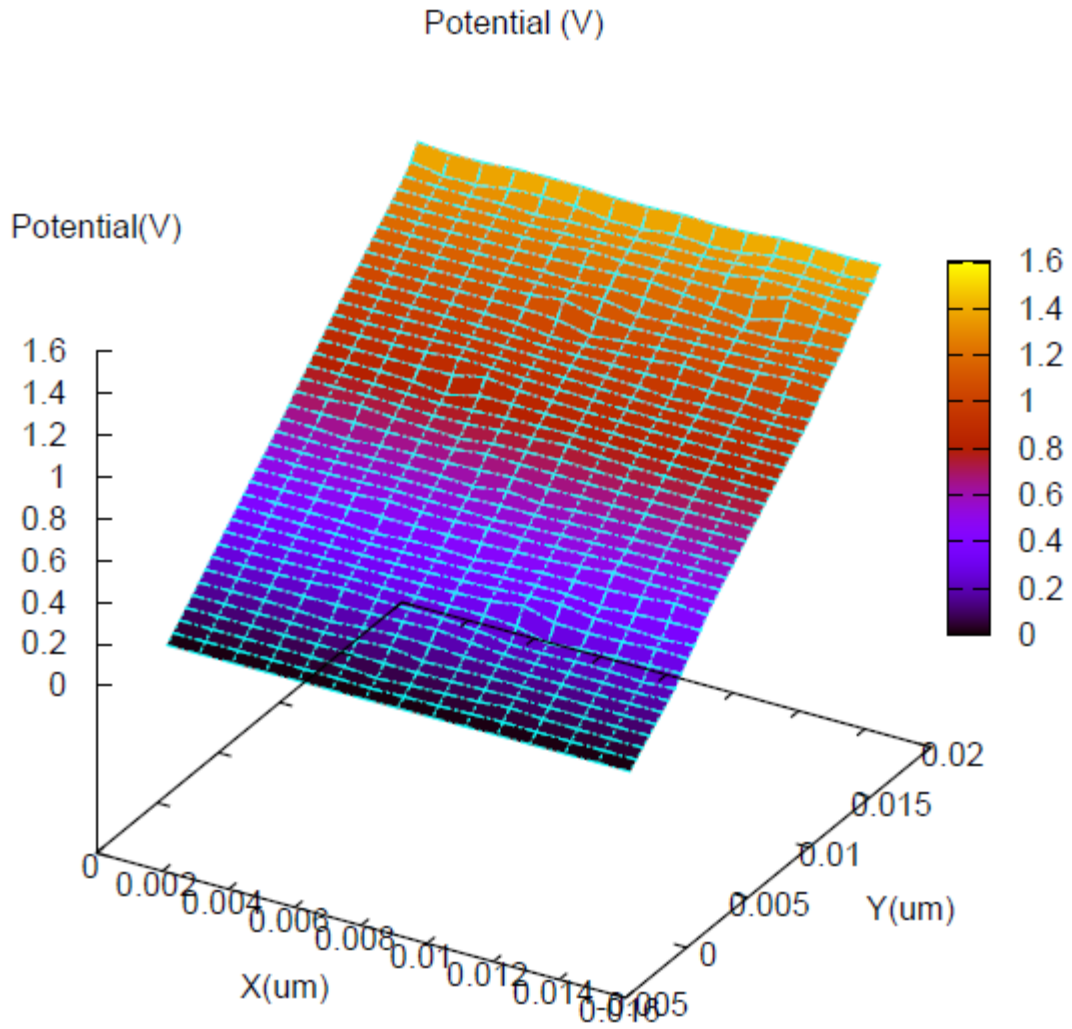
NovaTCAD


Max. Temperature (K)
700
650
600
550
500
450
400
350
300
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Contact Voltage<2>(V)

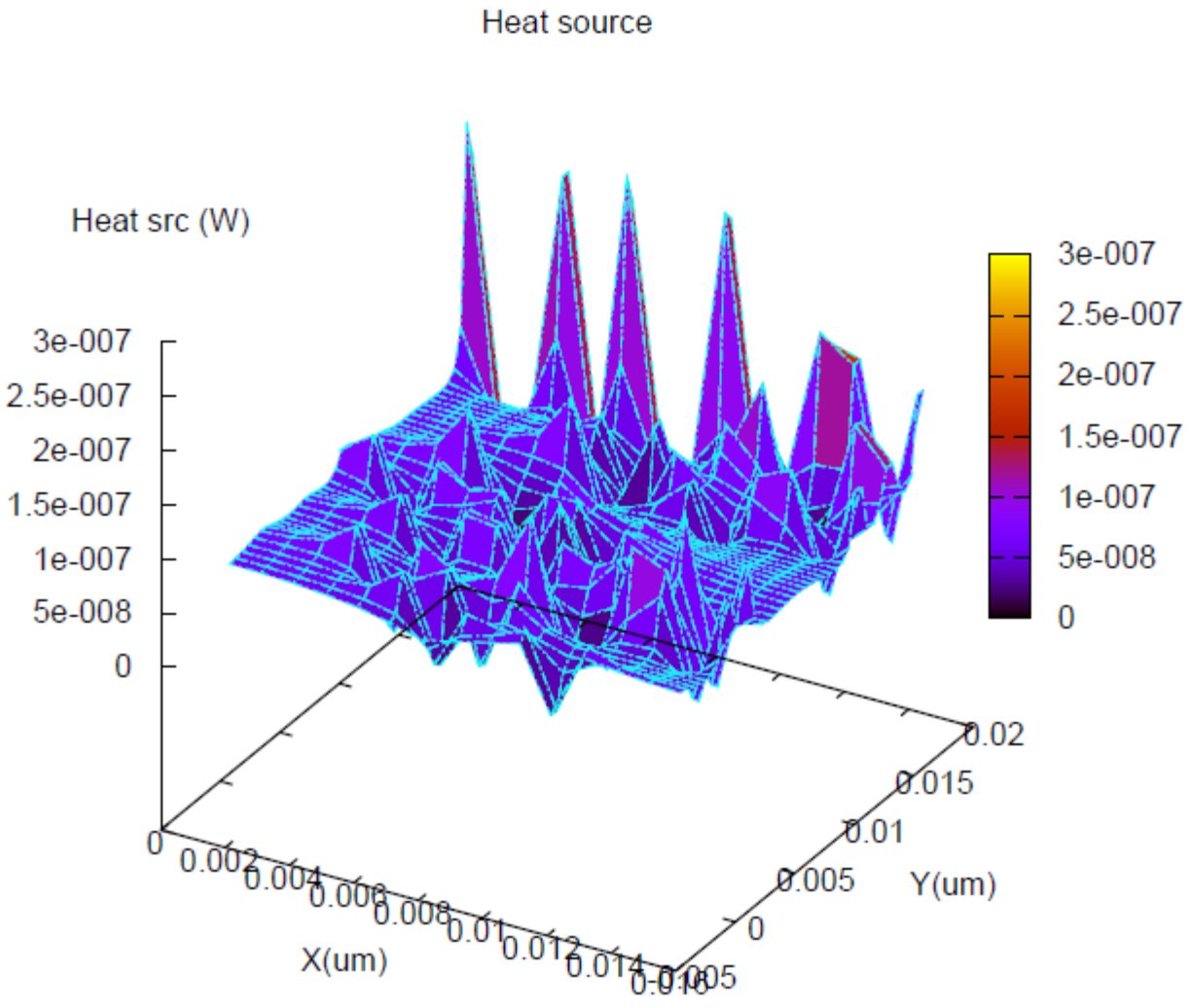
NovaTCAD


Max. Vector (A)=0.7221E-05
0.025
0.02
0.015
0.01
0.005
0
-0.005
Y(um)
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
X(um)

NovaTCAD


Potential (V)
Potential(V)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
X(um)
0.02
0.015
0.01
0.005
0
0.005
Y(um)

NovaTCAD


Heat source
Heat src (W)
3e-007
2.5e-007
2e-007
1.5e-007
1e-007
5e-008
0
0
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
X(um)
0.02
0.015
0.01
0.005
0
-0.005
Y(um)
3e-007
2.5e-007
2e-007
1.5e-007
1e-007
5e-008
0

NovaTCAD

Summary

- Monte Carlo method integrated with NovaTCAD mixmode.
- Basic set and reset characteristics demonstrated.
- Suitable for TCAD design as well as for research.

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