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“Optimization of Carbon Nanotube Field Emission Arrays”

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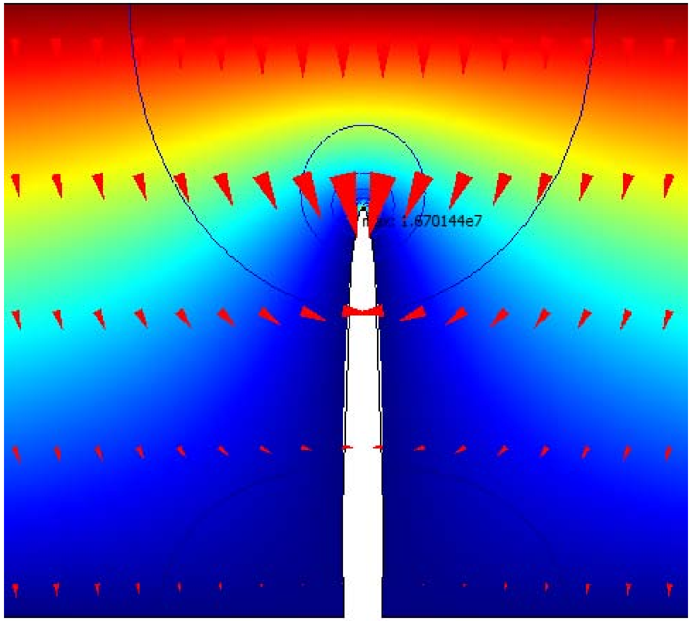
Overview

- Motivation
- CNT Array Models
- Simulation Results
- Conclusions

Motivation

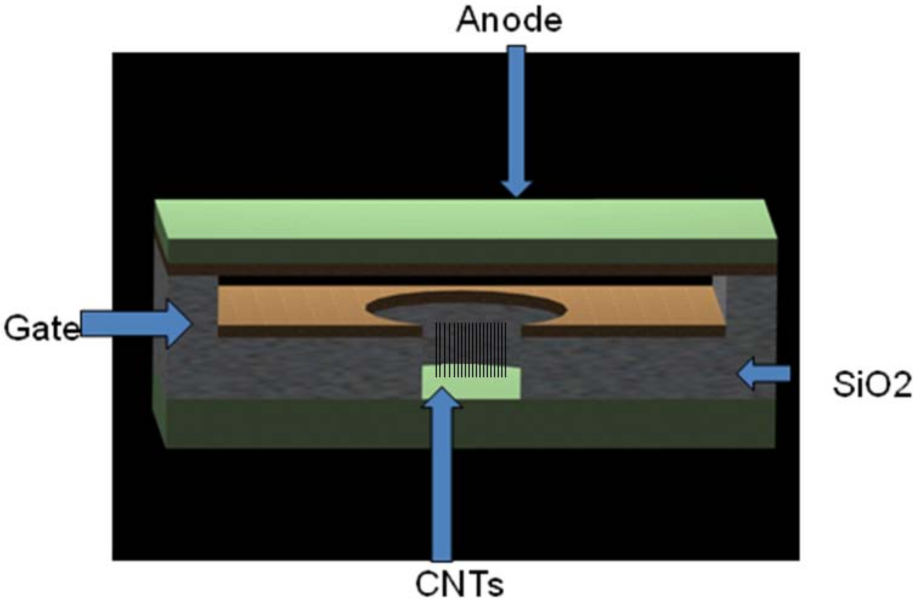
- Carbon nanotubes as emitters
  - Narrow diameters
  - High aspect ratios
  - Good conductivity
  - High temperature stability
  - Structural strength



- CNT emission is due to high localized electric field that forms at small diameter tips.

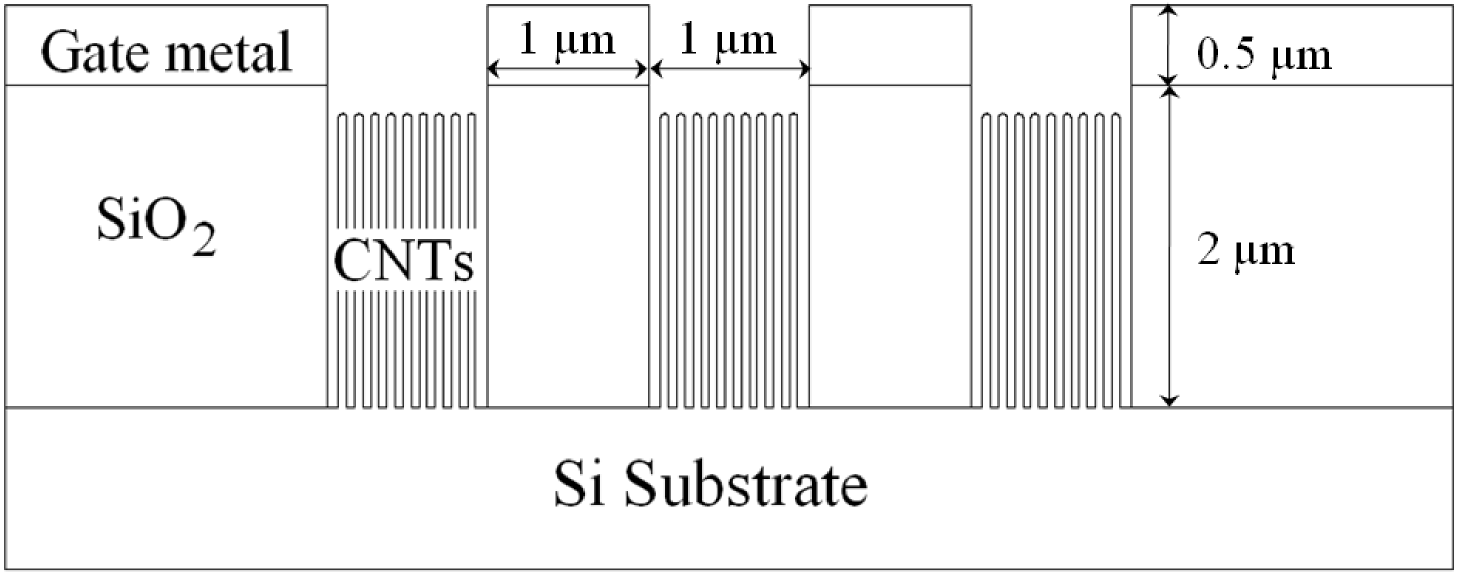
Motivation

- Triode (gated) Devices
  - Lower extraction voltage
  - Simpler control
  - Reduce screening effects



- Maximize field emission by optimizing array geometries within available fabrication processes to maximize the electric field strength at the CNT emitters.

CNT Array Models

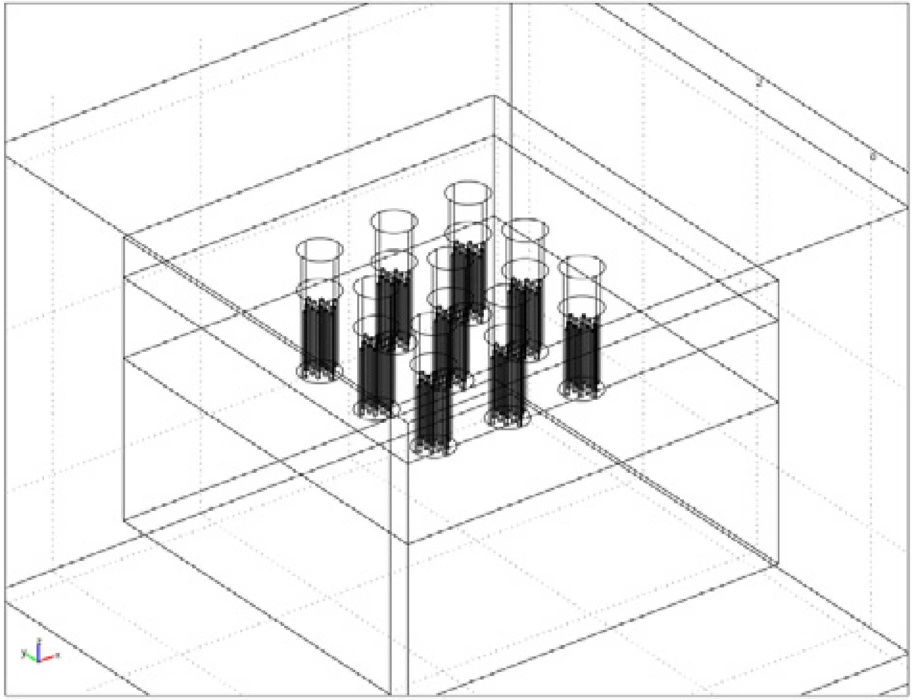


- 2-D model of base CNT array
  - CNTs with 50 nm diameter and 50 nm spacing
  - Array pitch of 1 μm
  - Array elements of 1 μm
  - Element shape (square and round)
  - Dielectric thickness of 2 μm

CNT Array Models

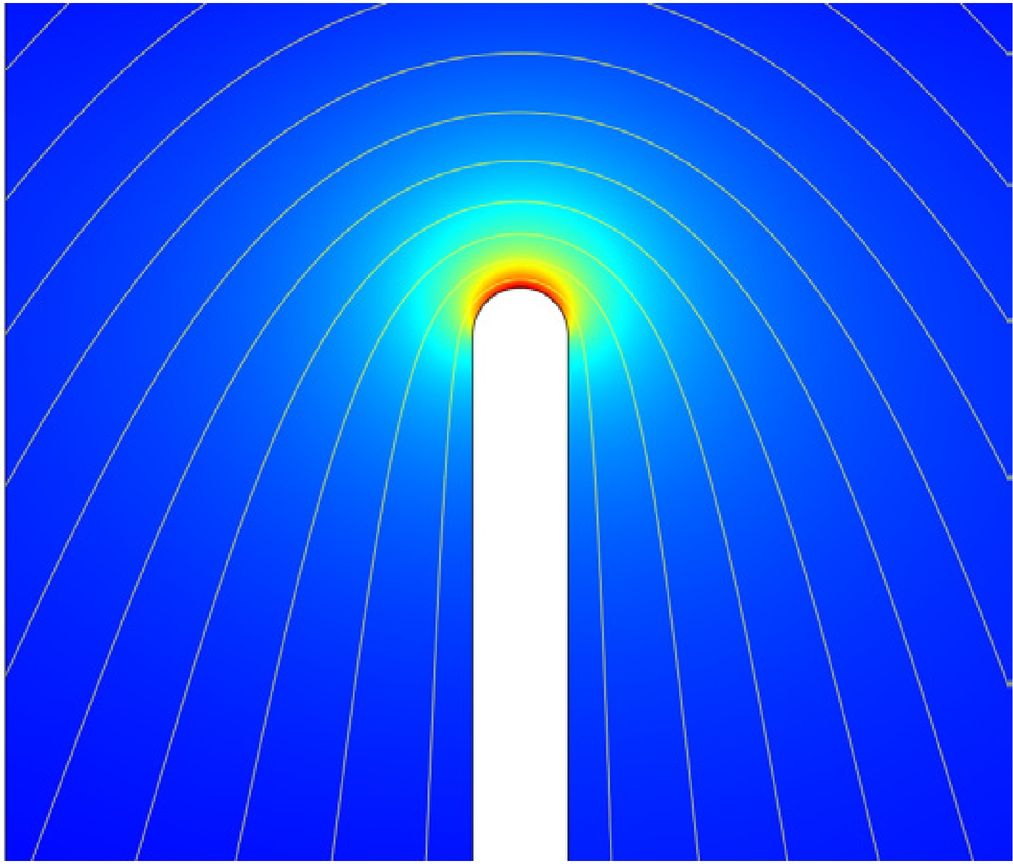
- Optimized electric field strength by varying:
  - CNT spacing
  - Array pitch
  - Array element dimensions
  - Element shape
  - Dielectric thickness

- Simulations used both 2D and 3D models



Simulation Results

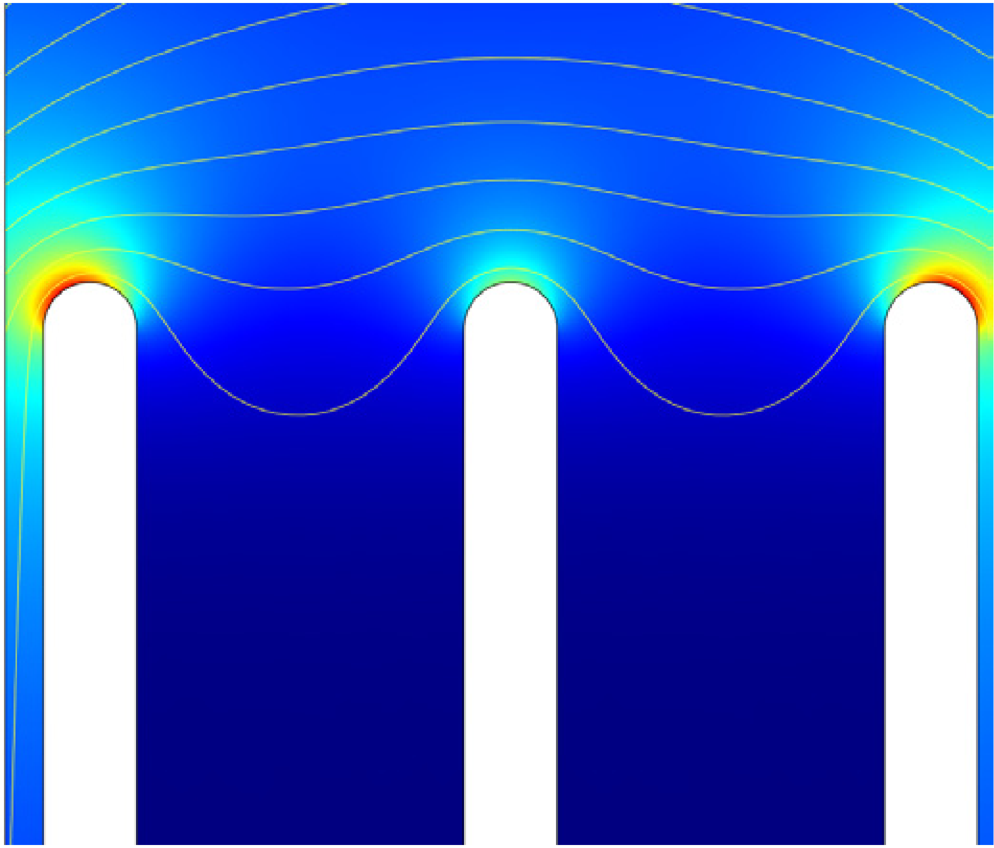
- CNT spacing within array element
  - Single CNT
  - 200 nm
  - 50 nm



- Single CNT
  - Strongest E-field
  - Complete electrostatic field penetration

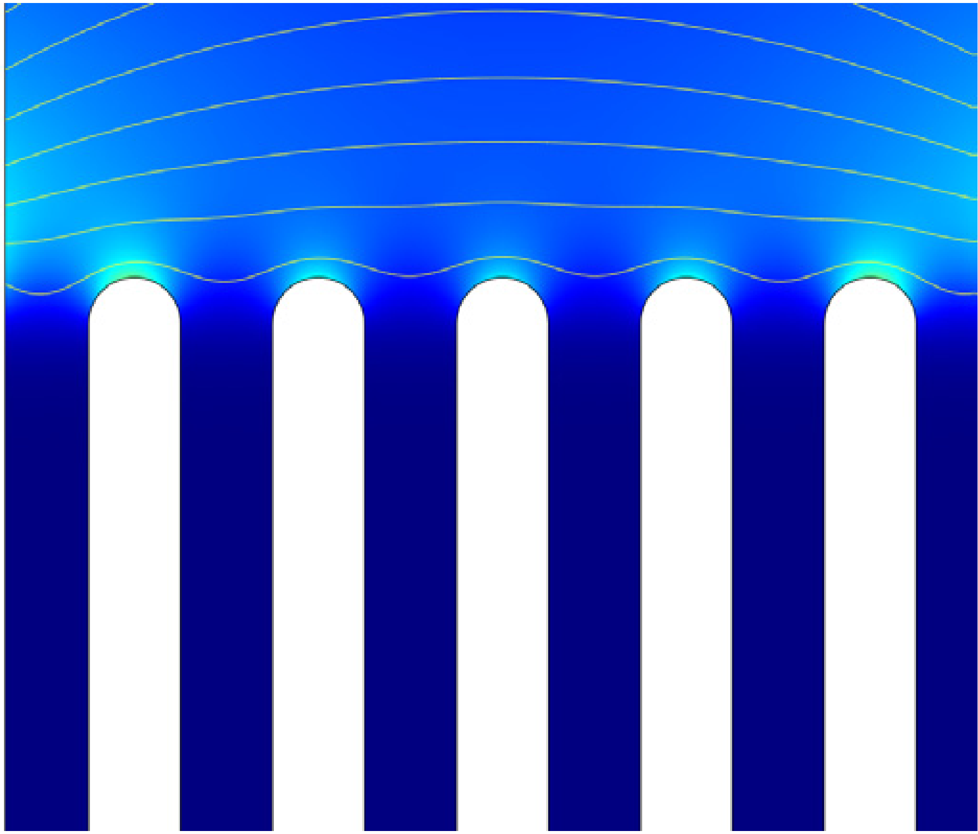
Simulation Results

- 200 nm CNT separation
  - 3 CNTs
  - Significantly reduced penetration
  - 42% Reduction in center CNT E-field



Simulation Results

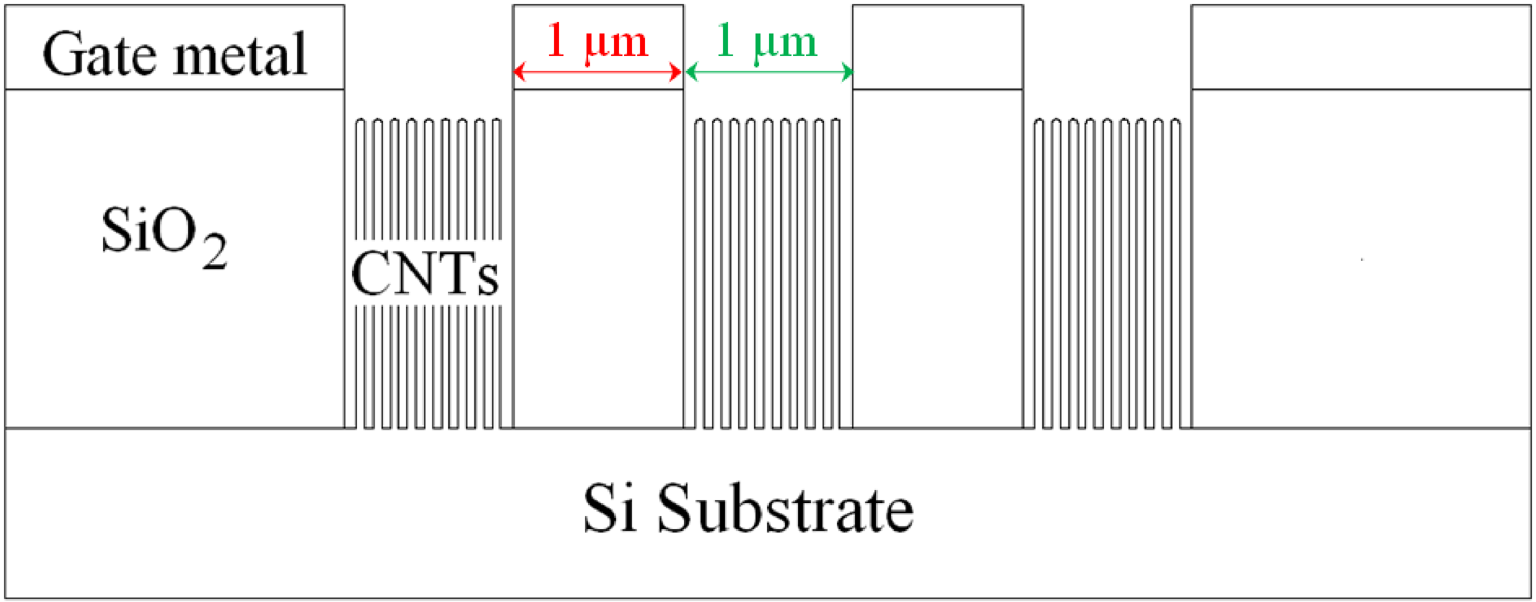
- 50 nm CNT separation
  - 9 CNTs (center 5 shown)
  - Significantly reduced penetration
  - 60% Reduction in center CNT E-field



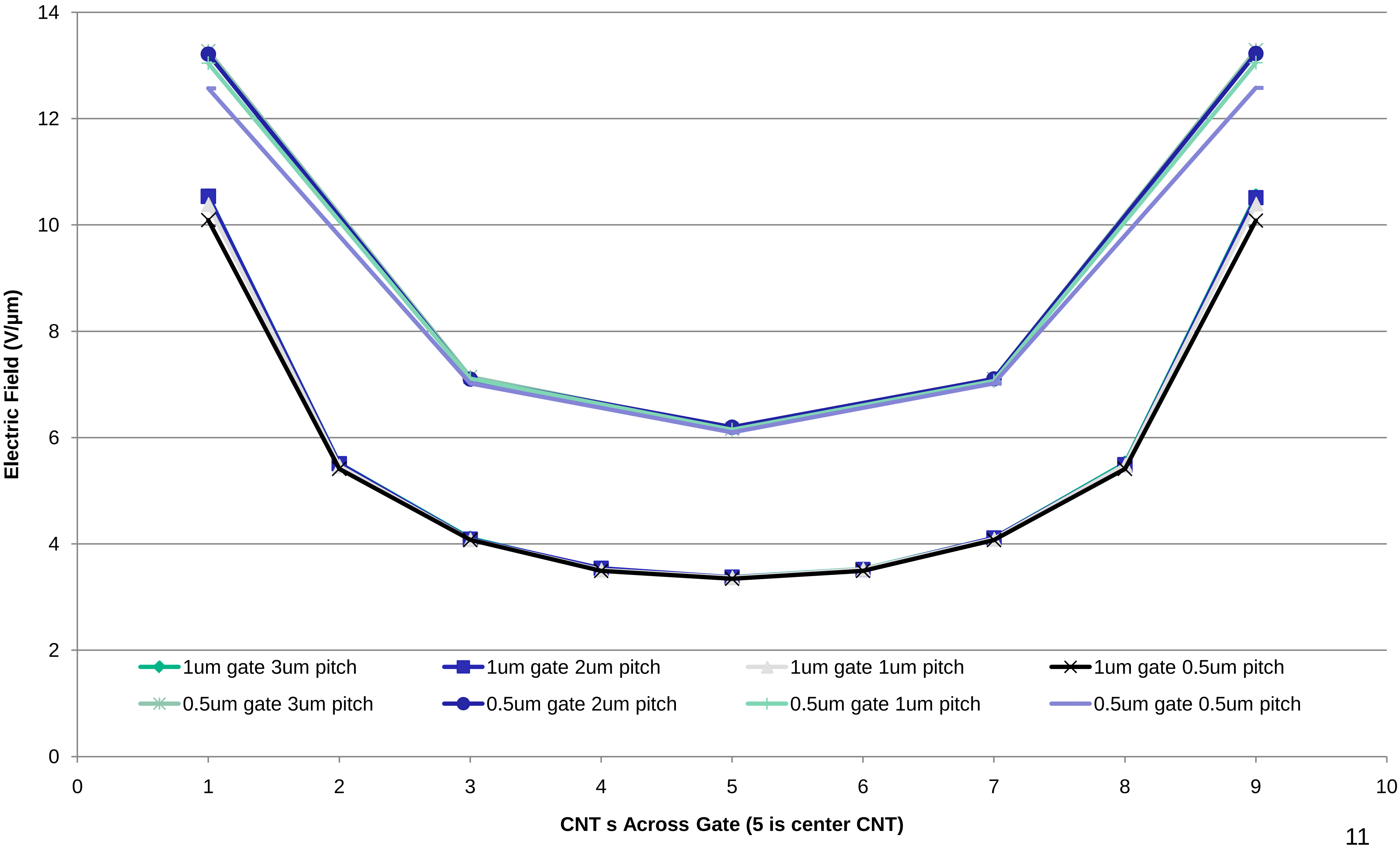
- Screening effects are significant within array elements

Simulation Results

- Element pitch and dimension
  - Potential increase in field emission current density through increase in total number of elements with stronger E-fields
  - Element dimensions (green) of 1 µm and 0.5 µm simulated with pitches (red) of 3 µm, 2 µm, 1 µm, and 0.5 µm



Simulation Results

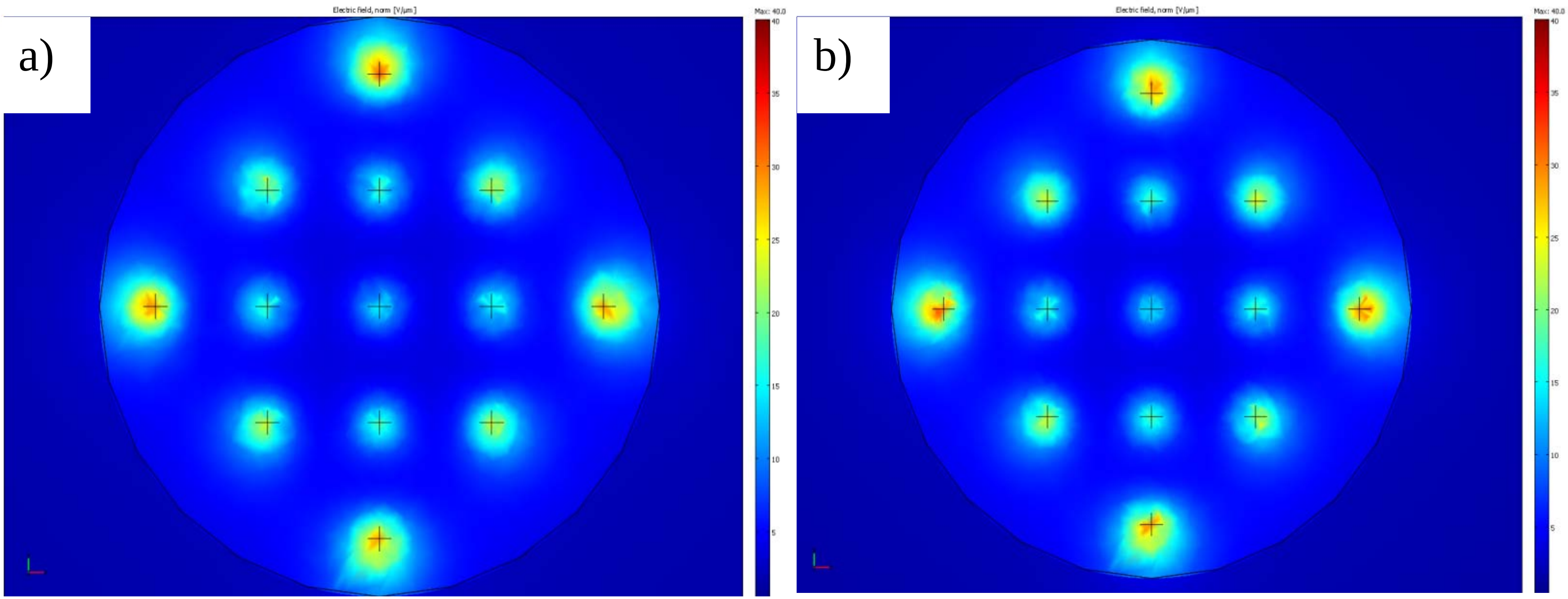


Simulation Results

- Decreasing element dimensions increases E-field
  - Reduction from 1 µm to 0.5 µm increased E-field at center from 3.3 V/µm to 6.1 V/µm
- Pitch has little effect on E-field strength
  - Decreasing pitch from 3 µm to 0.5 µm had no effect on the E-field at the center of the element
  - ~4% drop at edge CNTs
  - Screening effects dominate center of elements

Simulation Results

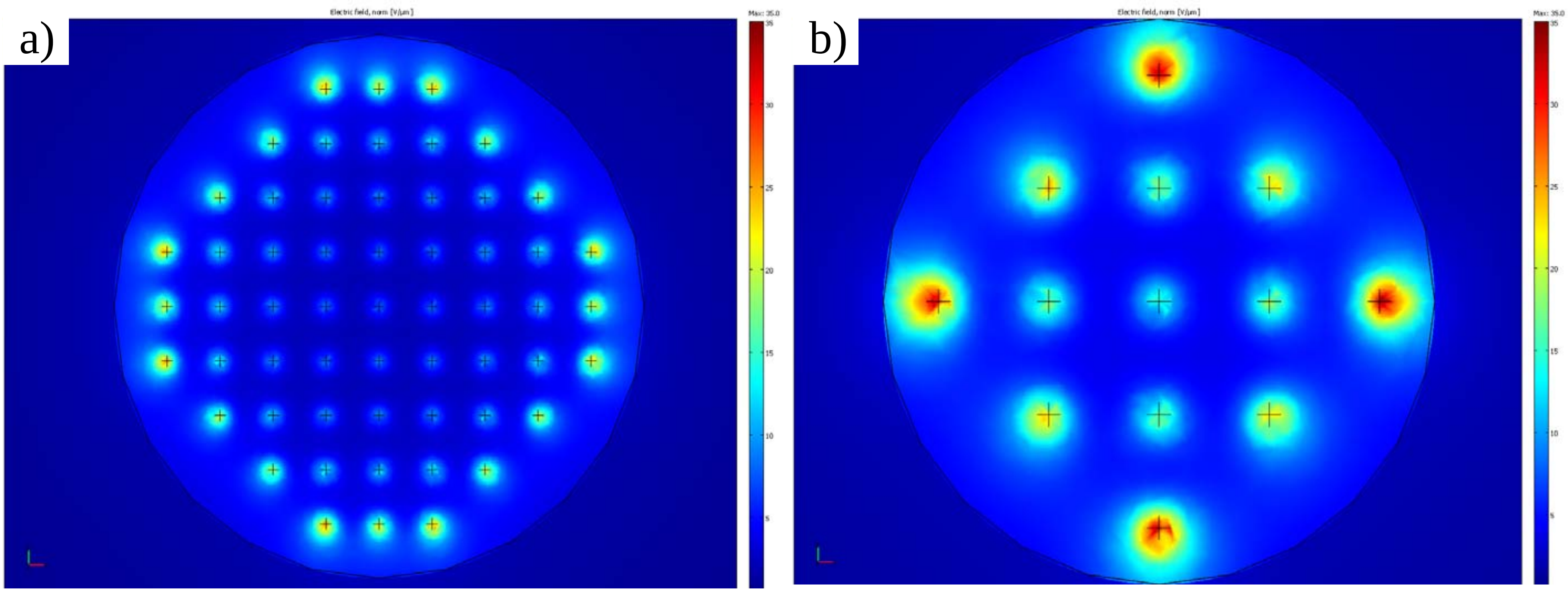
- 3D simulations also showed no difference between
  - a) 0.5 µm pitch
  - b) 1 µm pitch



E-field strength at CNT tips across center element of a 3x3 array

Simulation Results

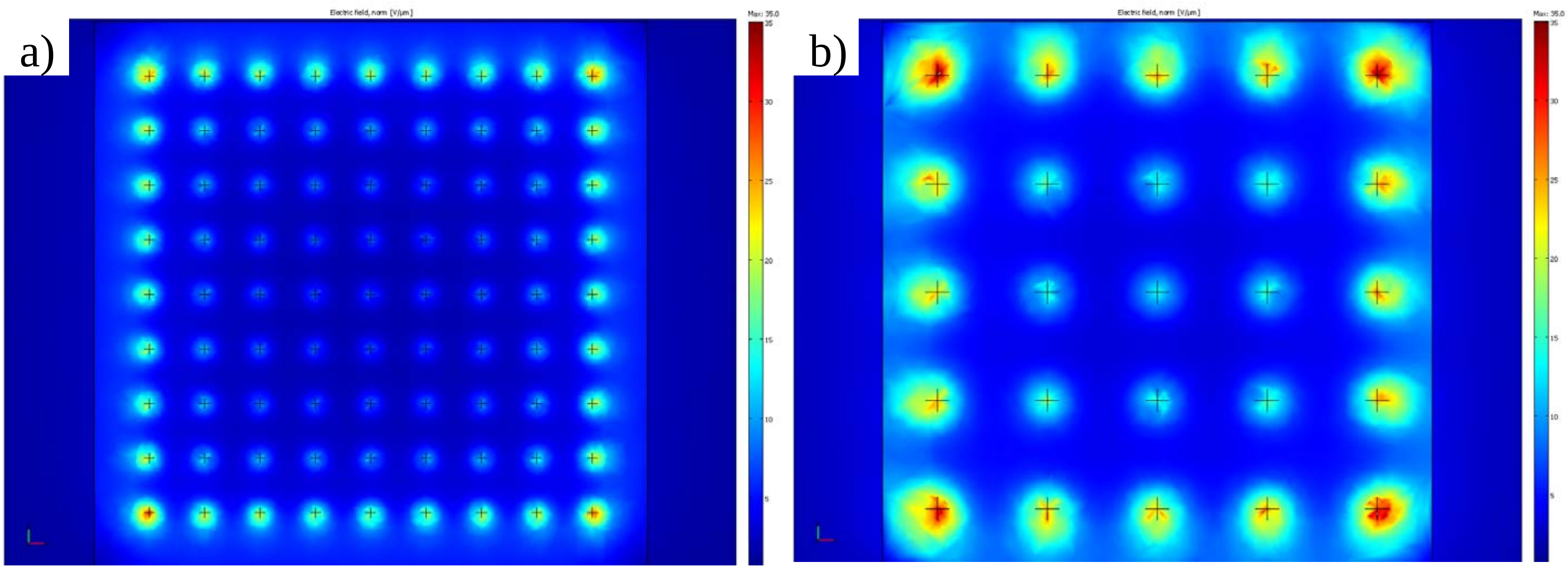
- 3D simulations resulted in a greater increase in E-field with a reduction in element dimension
  - a) 1 µm element diameter: E-field at center 5.3 V/µm
  - b) 0.5 µm element diameter: E-field at center 14.7 V/µm



E-field strength at CNT tips across center element of a 3x3 array

Simulation Results

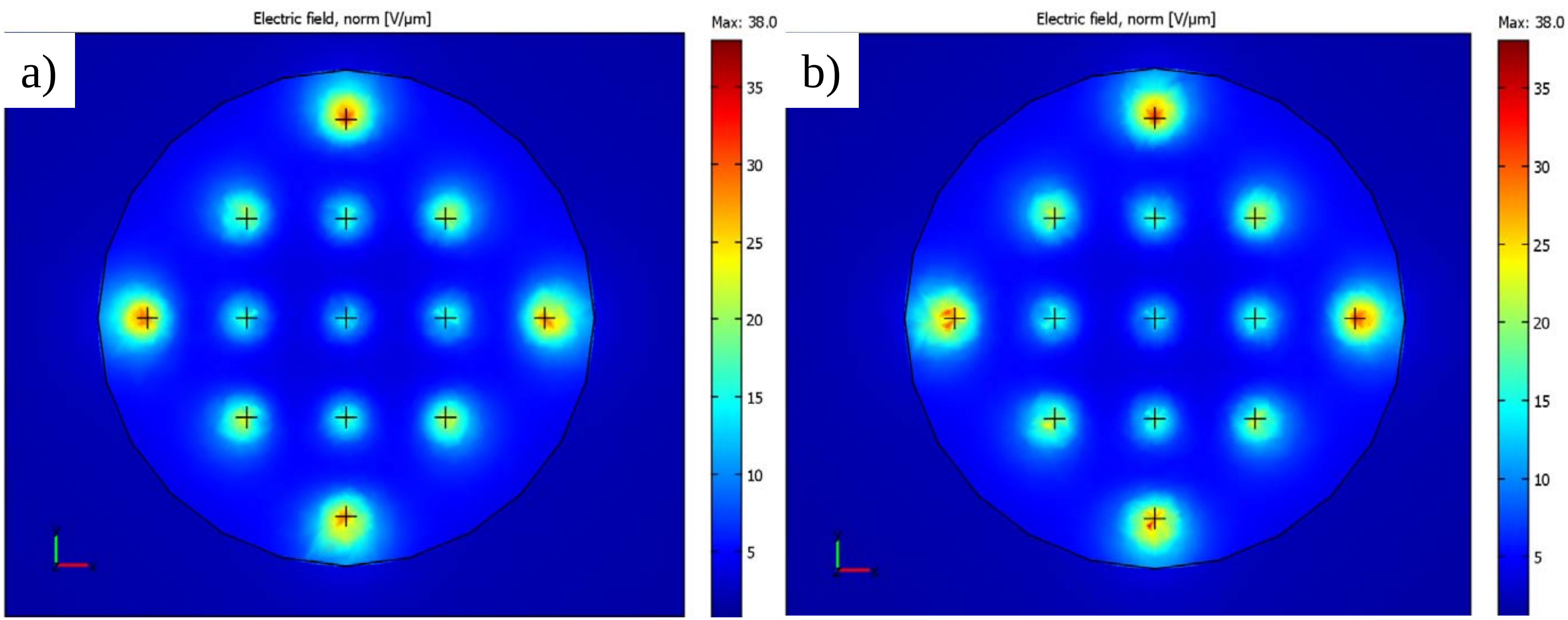
- Square elements also showed greater increase in E-field
  - a) 1 µm element: E-field at center 7.8 V/µm
  - b) 0.5 µm element: E-field at center 17.7 V/µm
- Square elements had stronger E-field at element center



E-field strength at CNT tips across center element of a 3x3 array

Simulation Results

- Reduction in dielectric layer had little effect on the E-field
  - a) 1 µm dielectric layer: E-field at center 14.7 V/µm
  - b) 2 µm dielectric layer: E-field at center 15.2 V/µm
- 0.5 µm layer resulted in a 10% reduction of center E-field



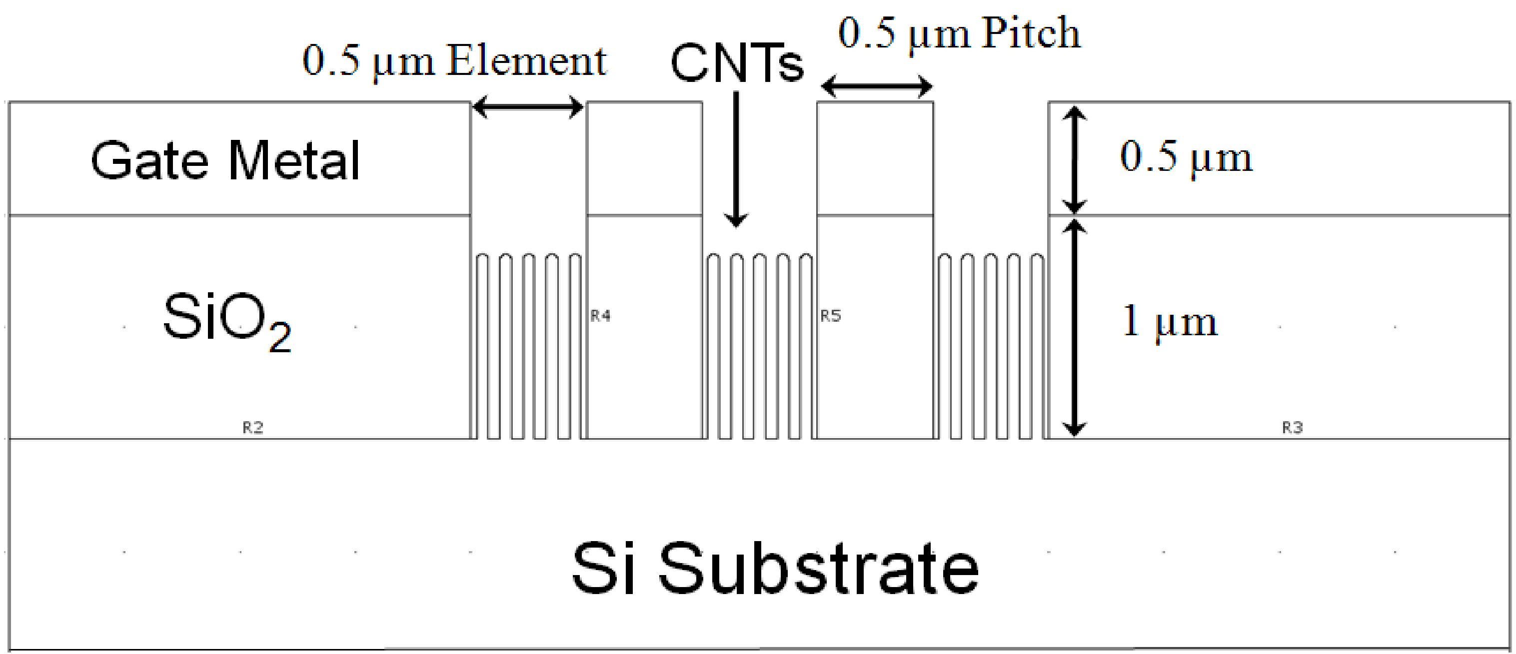
E-field strength at CNT tips across center element of a 3x3 array

Conclusions

- Electrostatic screening between CNTs dominates the E-field strength within an element
- Pitch can be reduced to increase array current densities
- Smaller element dimensions significantly increases the E-field magnitude across an element
  - Also increases the total number of elements in the array
- Square elements had stronger E-field at the center of the element
- Large reductions in dielectric thickness resulted in only small decreases in E-field magnitude

Conclusions

- Optimized CNT field emission array design based on available fabrication capabilities
  - Circular elements with 0.5 µm diameter
  - 0.5 µm pitch
  - 1 µm thick dielectric layer



Questions

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