Enhanced field emission from ZnO nanopencils by using pyramidal Si(100) substrates

Applied Surface Science, Jing Xiao, Yue Wu, Wei Zhang, Xin Bai, Ligang Yu, Shiqi Li, Gengmin Zhang, Peking University

OUTLINE

- Introduction
- Experiment
- Result
  - SEM
  - XRD
  - TEM
- Conclusion

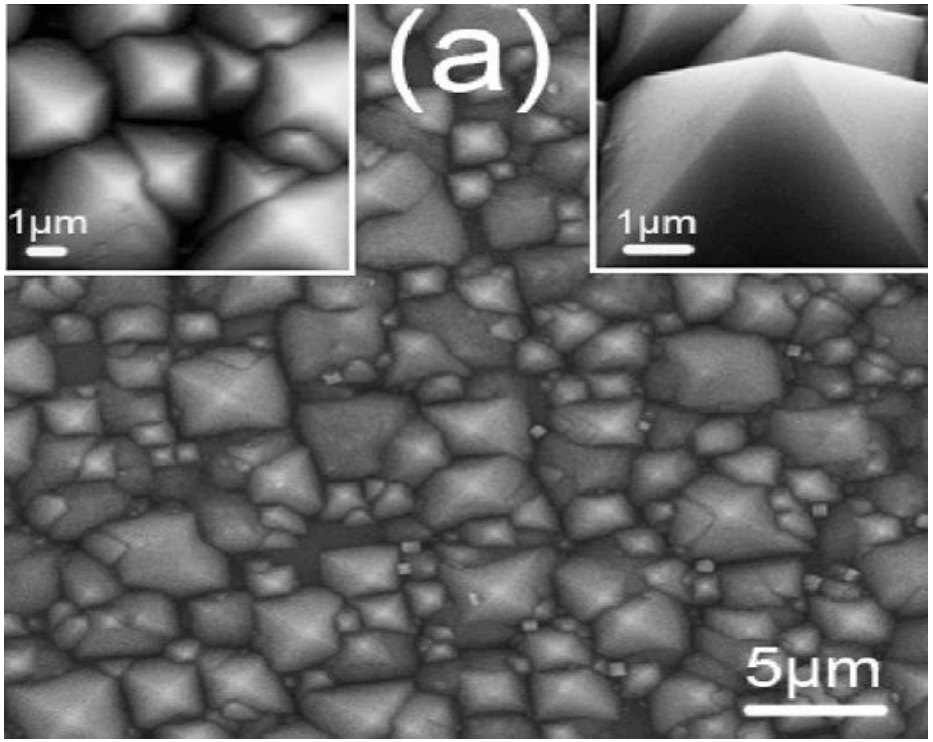
Introduction

- Comparing to similar nanostructures grown on smooth silicon wafers, the pyramidal Si-based nanostructures had lower turn-on electric field and larger enhancement factor.

Experiment-etching

- Substrate: P-type Si Wafer (100)
- KOH(100g), Alcohol(62.5cc), DI-Water(1000cc)
- Temperature:75^{o}C
- Etching time:45min

Result of SEM

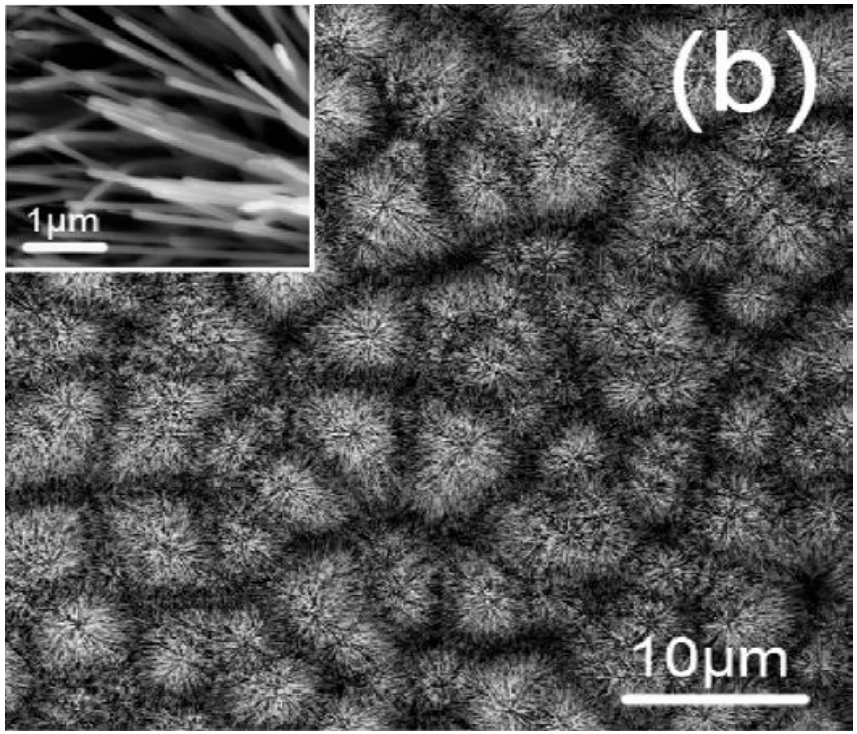


Pyramidal Si substrate, left inset: an enlarged view, right inset: side view of single pyramid

Experiment-Thermal Evaporation

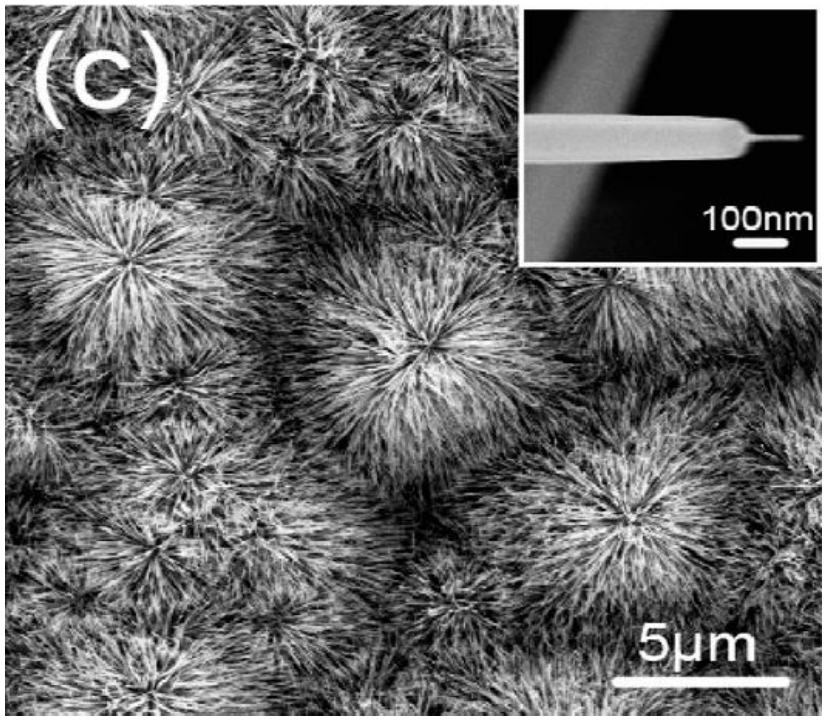
- Zn powder purity:99.99%
- Temperature:550^{o}C
- Temperature rate:50^{o}C/min
- Working pressure:1x10^{2}Pa
- Mixing gas: Argon/Oxygen=54/3(sccm)

Result of SEM

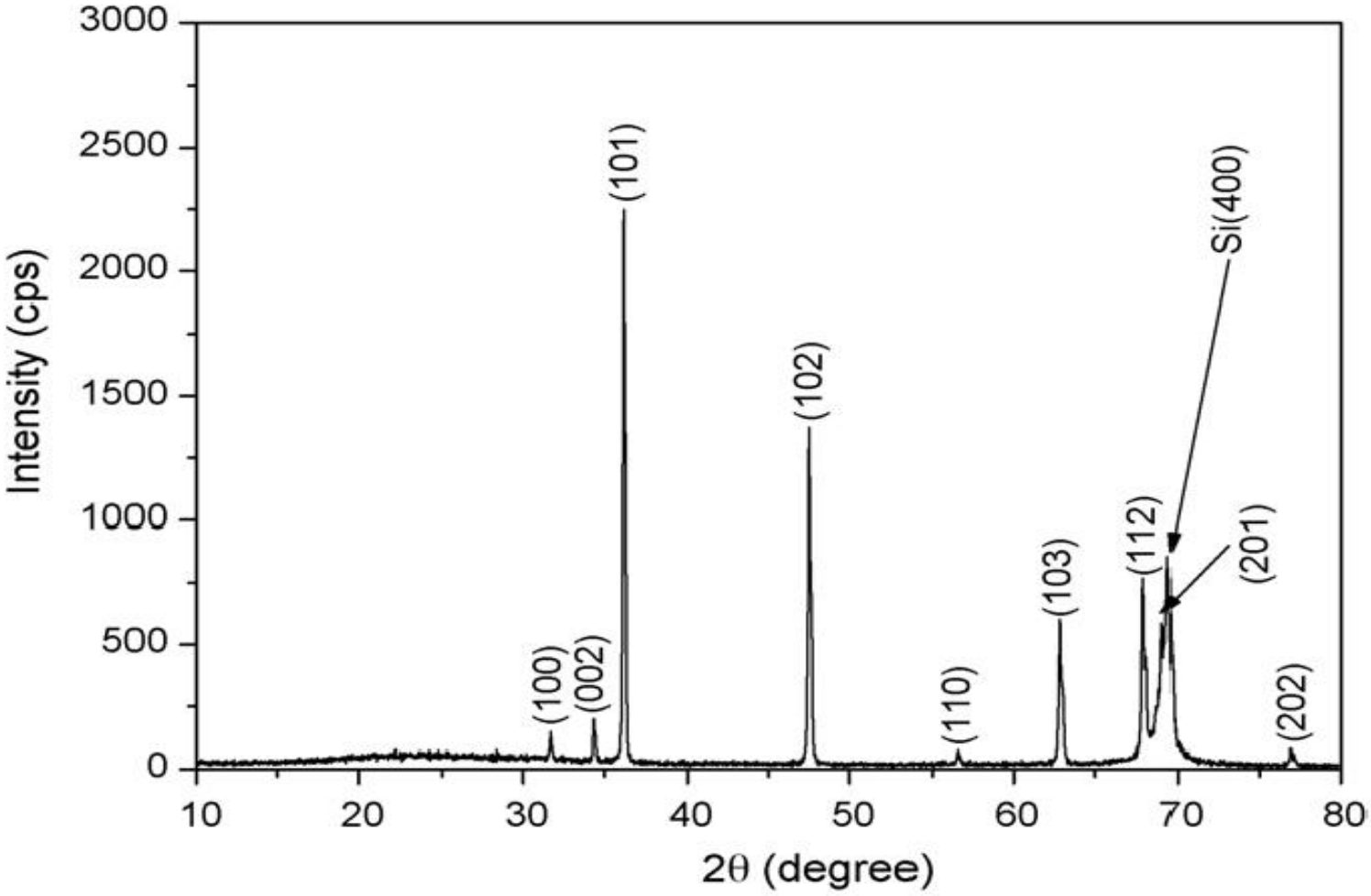


Low-magnification image of ZnO nanopencils on pyramids, inset: an enlarged view of some nanopencils

Result of SEM

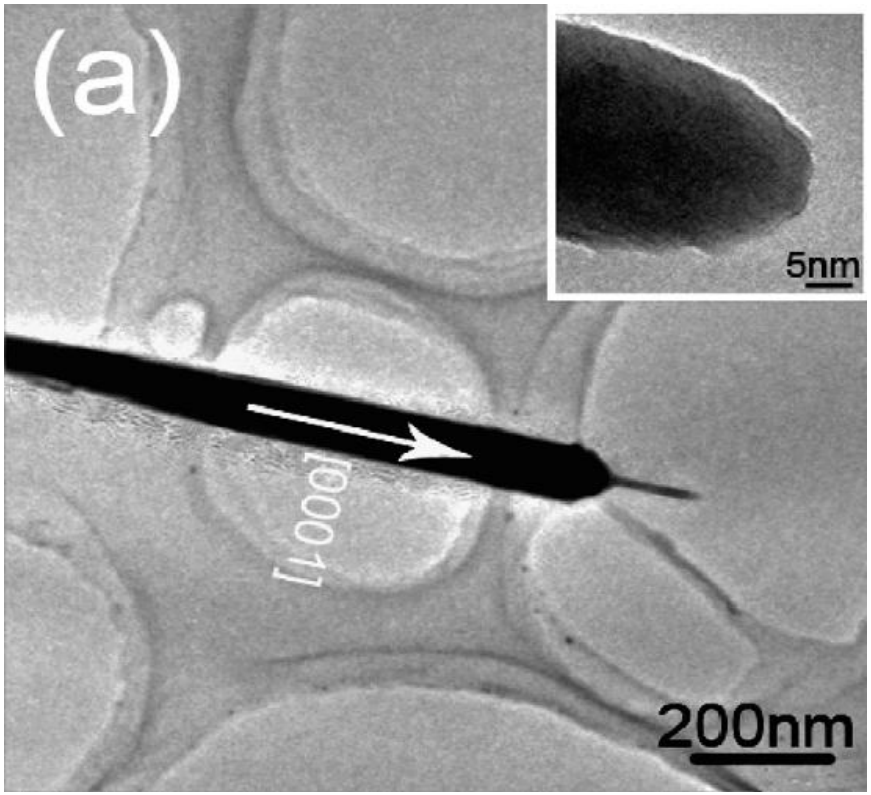


Medium magnification image of ZnO nanopencils on pyramids, inset: details of a single nanopencil



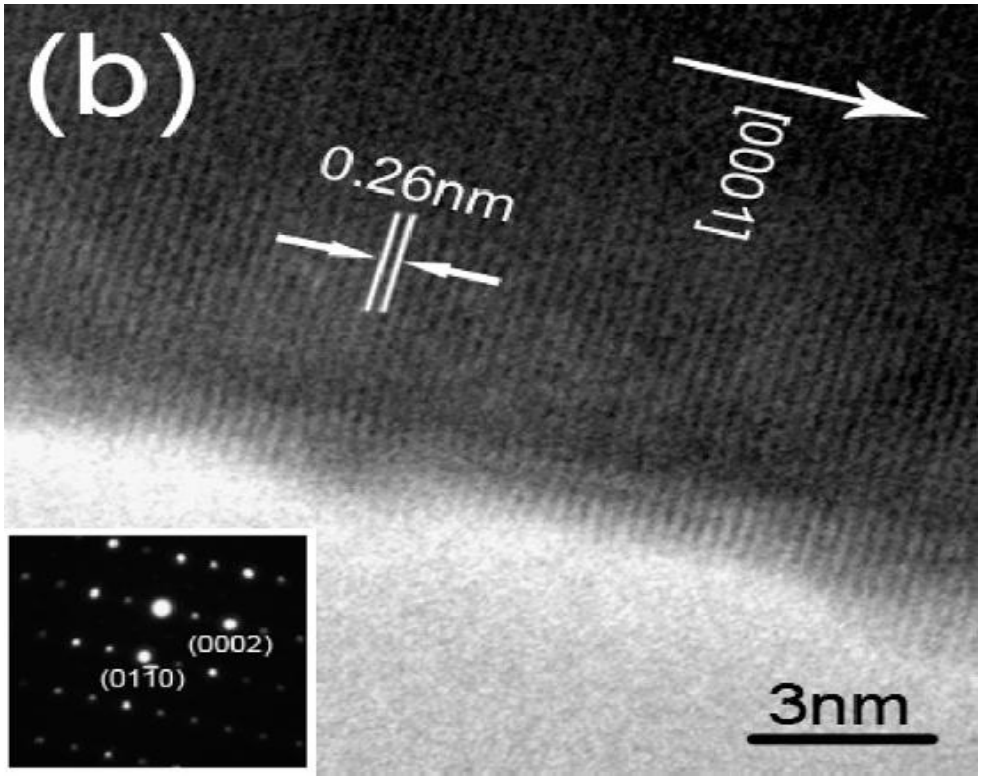
XRD pattem of the ZnO nanopencils on the pyramidal Si

Result of TEM



Low-magnification TEM image, inset:an enlarged view of the apex of the penpoint

Result of TEM

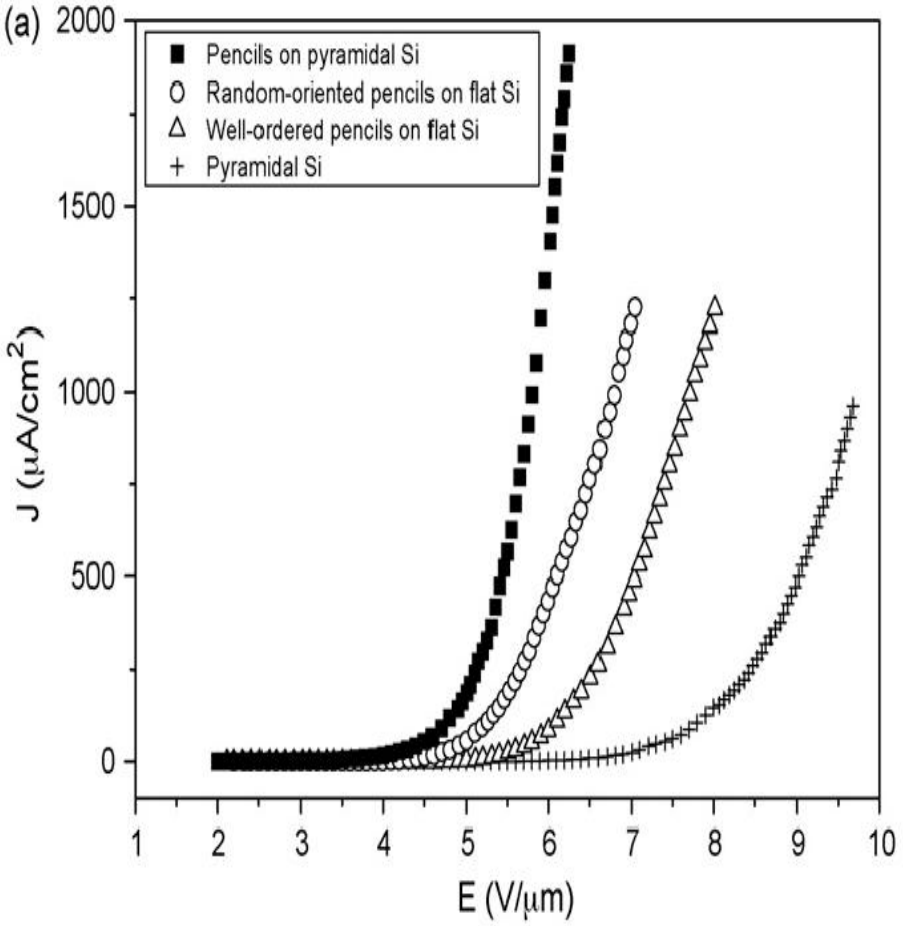


High-resolution TEM image, inset: corresponding electron diffraction pattern

Result of J-E Plot 1

$$J = \frac{1.56 \times \beta^2 E^2}{\Phi} \exp\left(-\frac{6.83 \times 10^3 \Phi^{3/2}}{\beta E}\right)$$

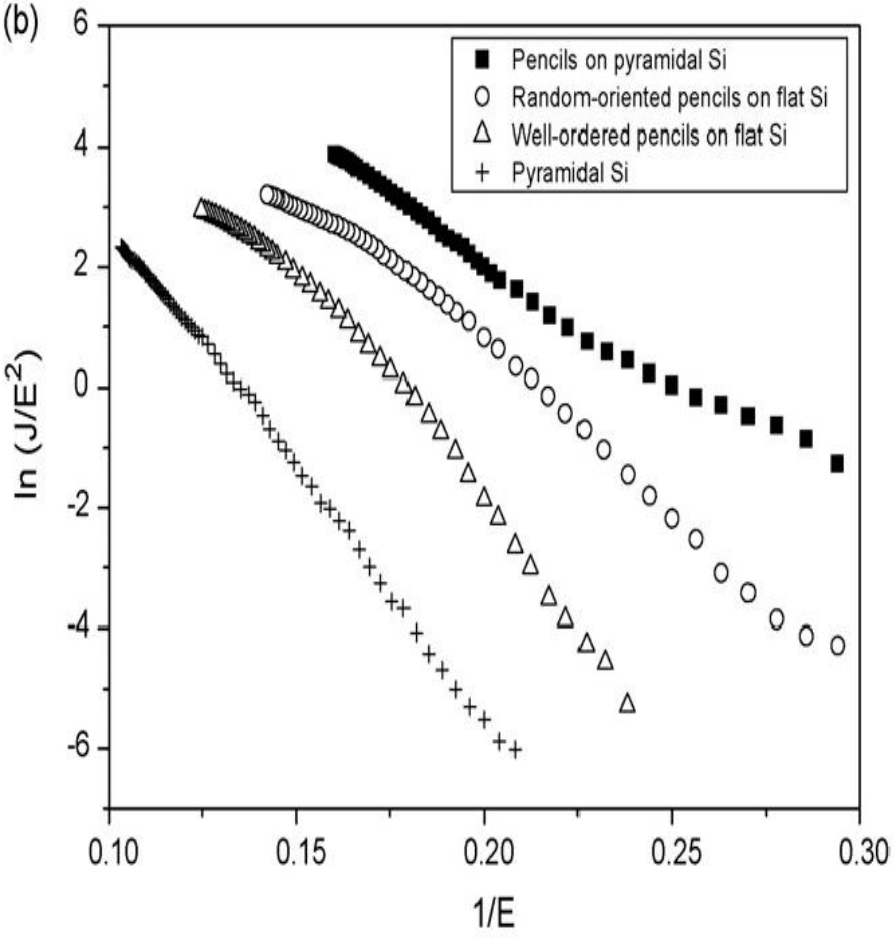
$$\ln \frac{J}{E^2} = -\frac{6.83 \times 10^3 \Phi^{3/2}}{\beta} \times \frac{1}{E} + \ln\left(\frac{1.56 \times \beta^2}{\Phi}\right)$$



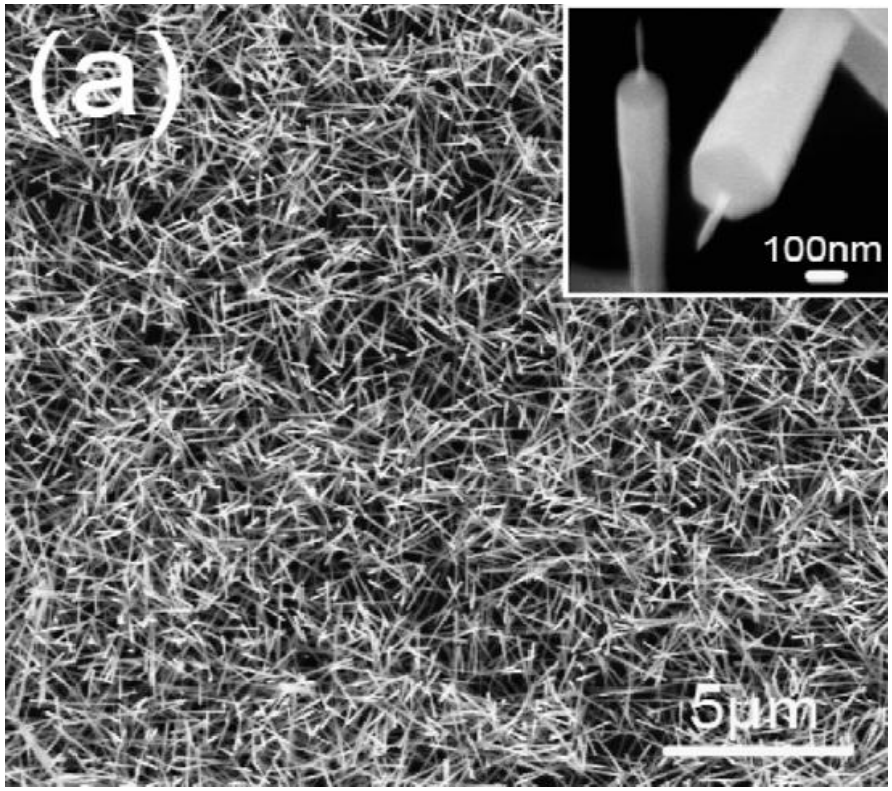
Result of J-E Plot 2

$$J = \frac{1.56 \times \beta^2 E^2}{\Phi} \exp\left(-\frac{6.83 \times 10^3 \Phi^{3/2}}{\beta E}\right)$$

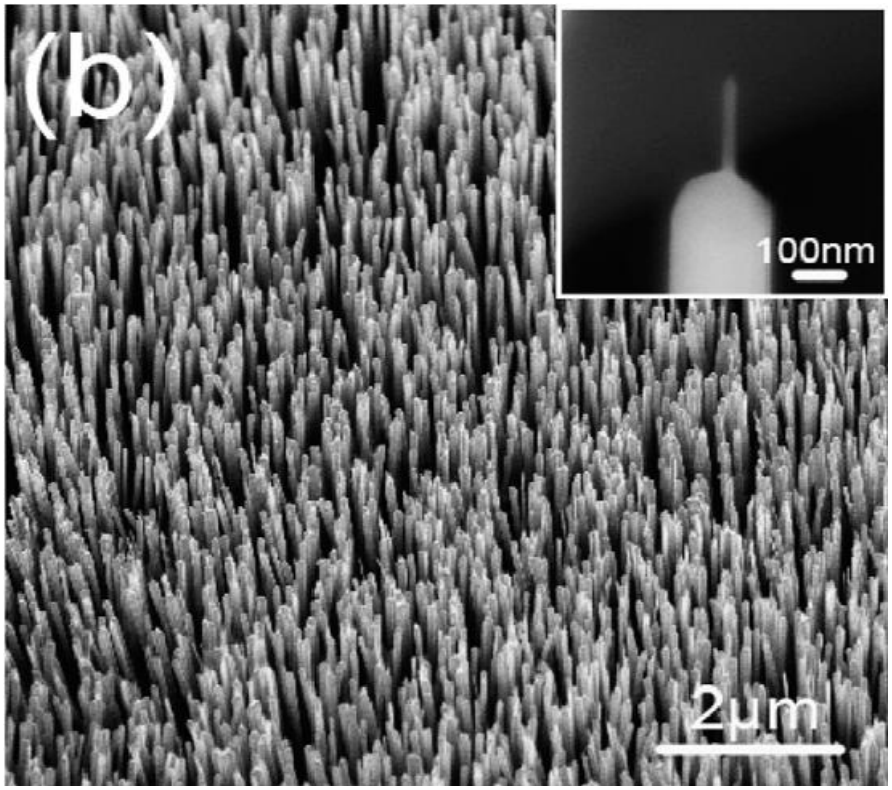
$$\ln \frac{J}{E^2} = -\frac{6.83 \times 10^3 \Phi^{3/2}}{\beta} \times \frac{1}{E} + \ln\left(\frac{1.56 \times \beta^2}{\Phi}\right)$$



Result of SEM



Result of SEM



Table

Sample	Turn-on field (V/μm)	Threshold field (V/μm)	Field enhancement factor (β)
Pyramidal Si	6.6	–	569
Well-ordered pencils on flat Si	5.2	7.7	1165
Random-oriented pencils on flat Si	4.4	6.8	2404
Pencils on pyramidal Si	3.8	5.8	2776

Conclusion

- In this study, the turn-on electric field was about 3.8V/10^{-6}m and the threshold electric field was about 5.8V/10^{-6}m.
- The pyramidal Si substrates could not only suppress the field screening effect but also improve the field enhancement effect during the field emission process.