CAP CONGRESS - 2019

Potential mapping in GaN NW p-n junctions via off-axis electron holography

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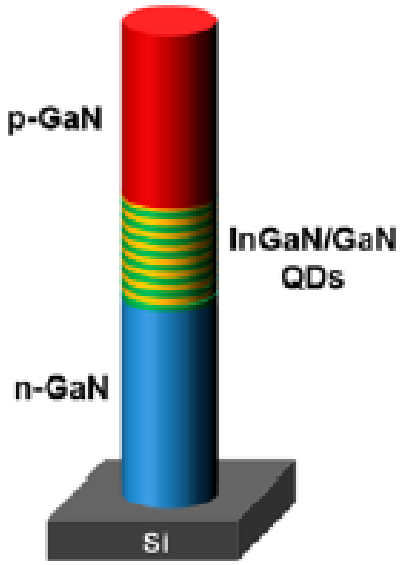
Motivation



GaN NW-LED

Basic element - GaN NW p-n junctions

Understanding dopant incorporation

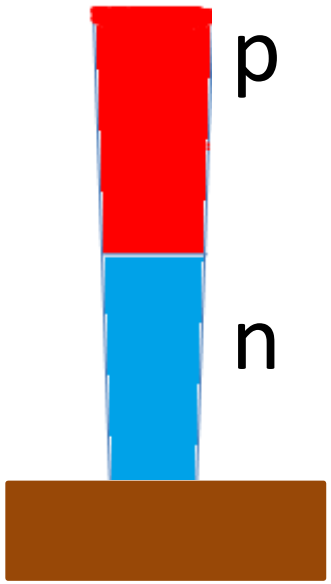
crucial for better-performing devices

Sadaf, S. M., Ra, Y. H., Nguyen, H. P. T., Djavid, M. & Mi, Z. Alternating-Current InGaN/GaN Tunnel Junction Nanowire White-Light Emitting Diodes. *Nano Lett.* **15,** 6696–6701 (2015)

Growth of NWs

Grown by Molecular Beam Epitaxy

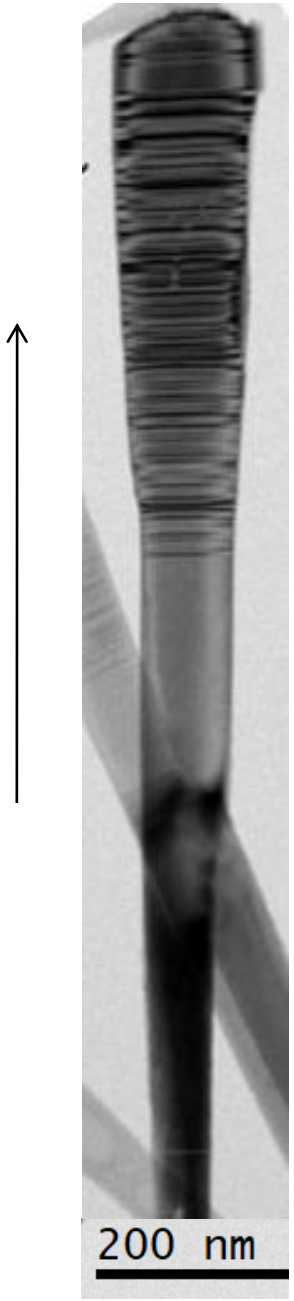
p-type dopant : Mg ($5x10^{17}/cm^3$)
n-type dopant : Si ($10^{19}/cm^3$)



Objectives

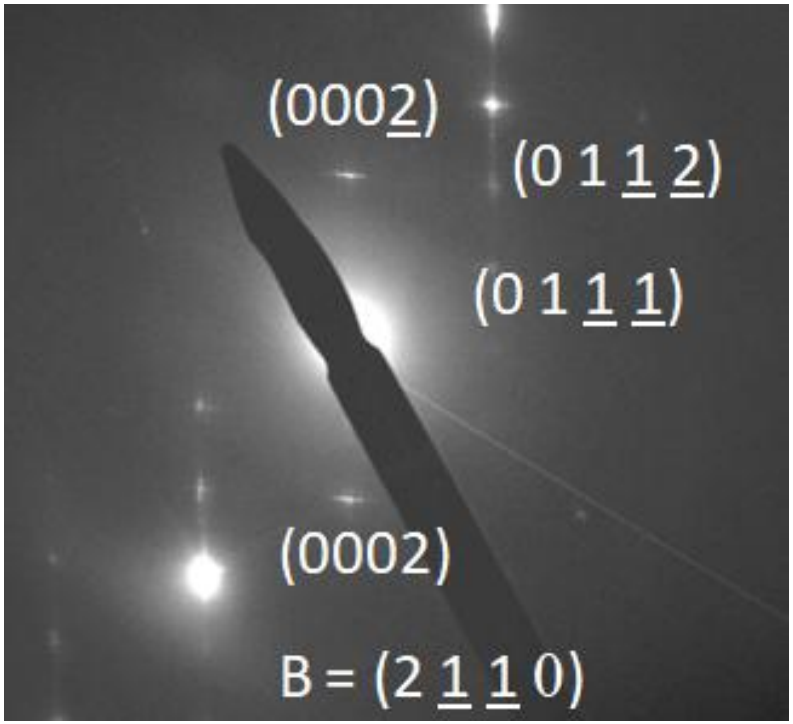
- To confirm the presence of p-n junction in GaN NW
- To understand the dopant incorporation in the NW.

Bright field image and SAD pattern

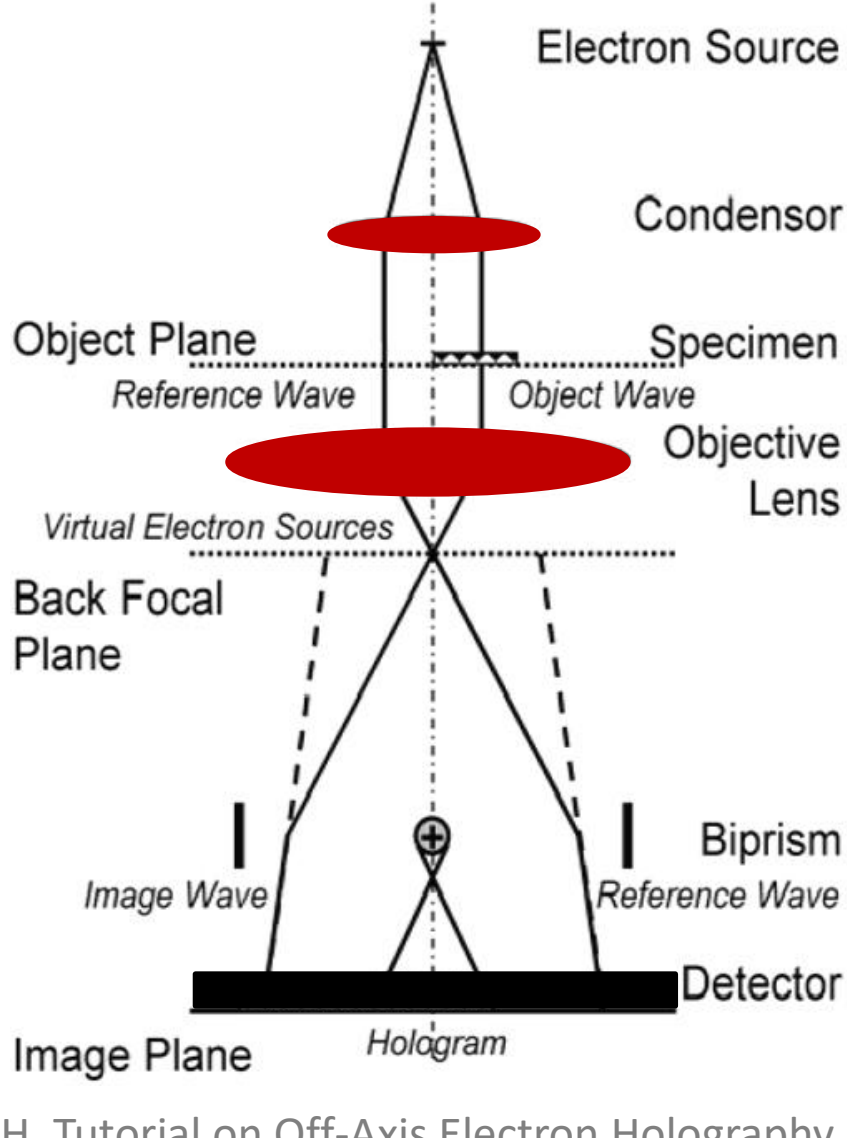


p

n

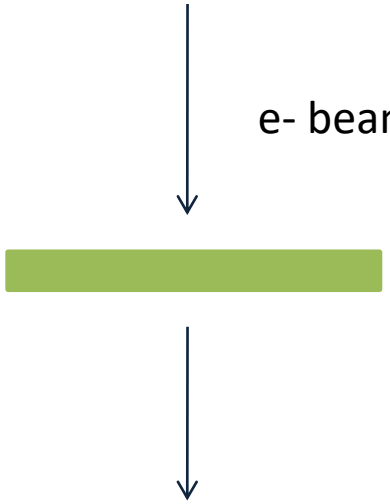


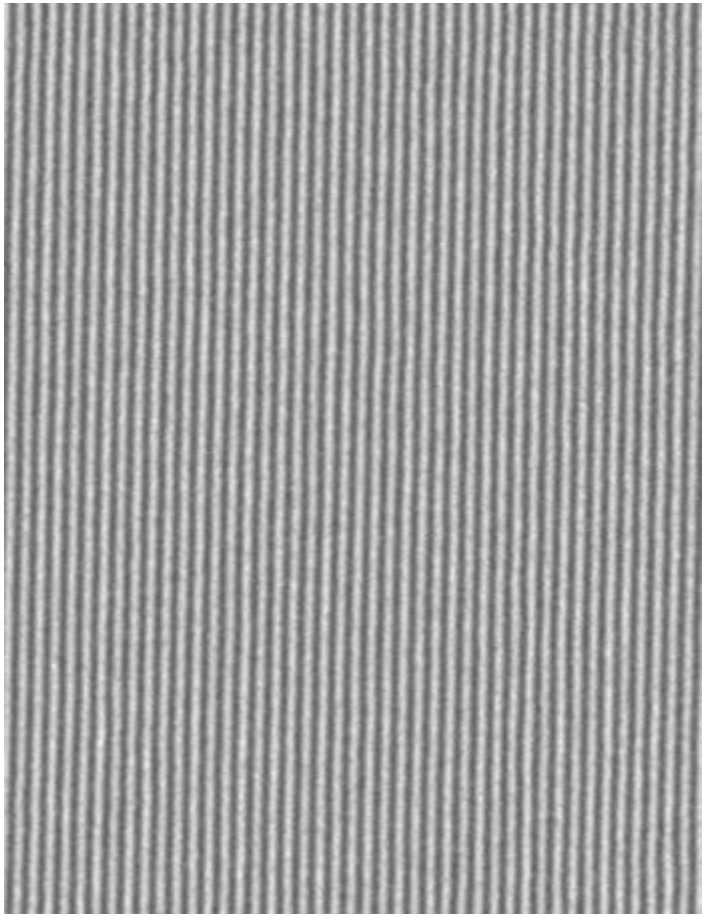
Electron Holography



Lehmann, M. & Lichte, H. Tutorial on Off-Axis Electron Holography, Microscopy and Microanalysis, 8,447–466. (2002).

Phase shift from Potential





Hologram

$$\Delta\varphi(x,y) = C_E \int_0^t V(x,y,z)dz$$

z = incident beam direction

(x,y) = the sample plane

V= Potential source

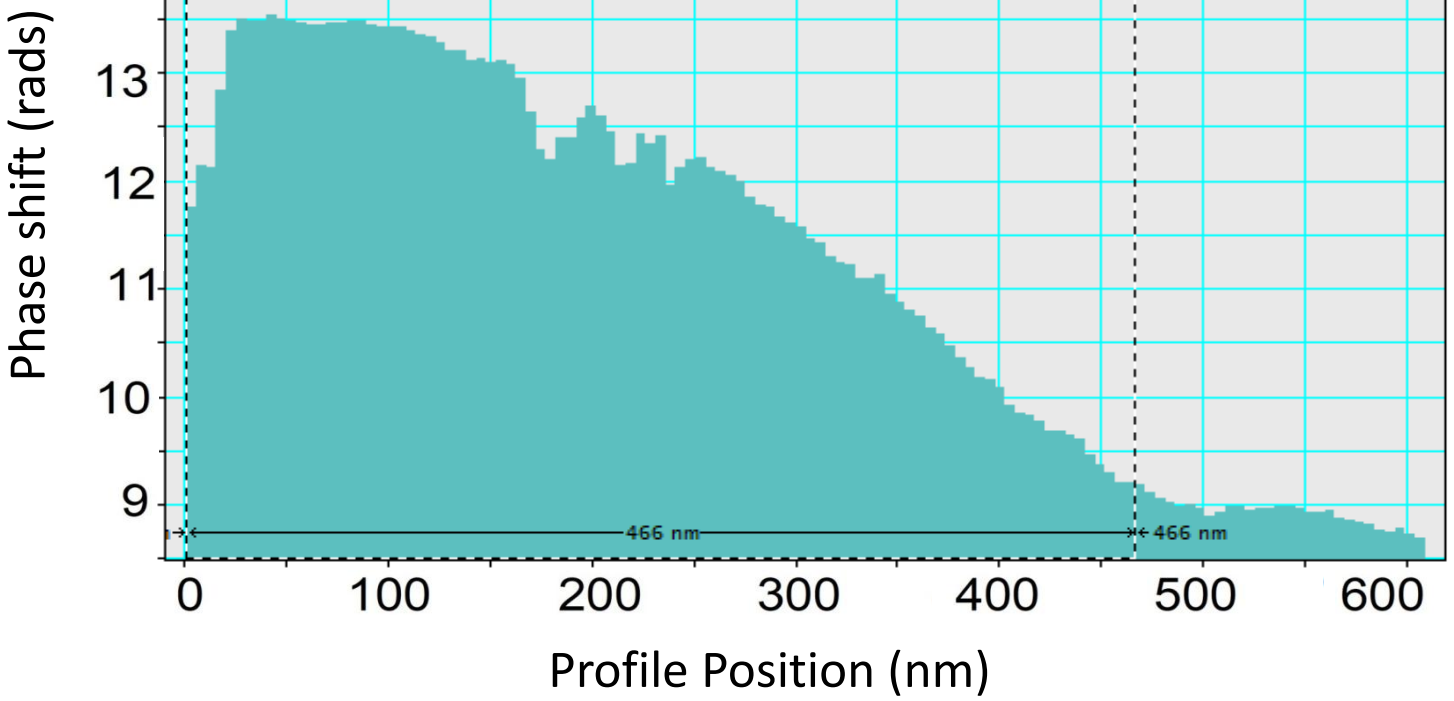
C_E = constant that depends on the incident beam energy

t = thickness

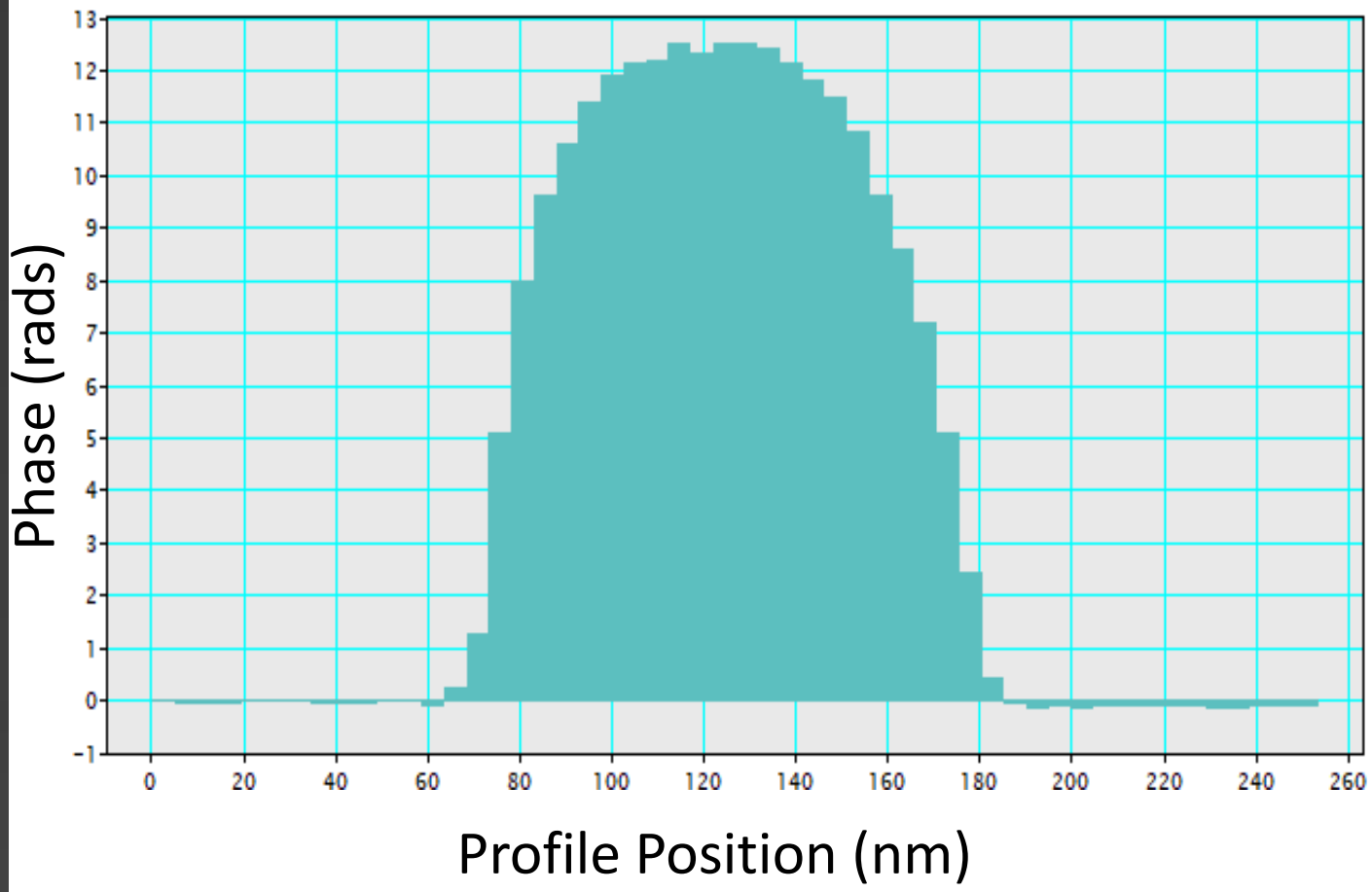
Corresponding BF and phase images

a)

b)



Phase image and corresponding radial profile



$$\Delta\varphi(x,y) = C_E \int_0^t V(x,y,z)dz$$

z = incident beam direction

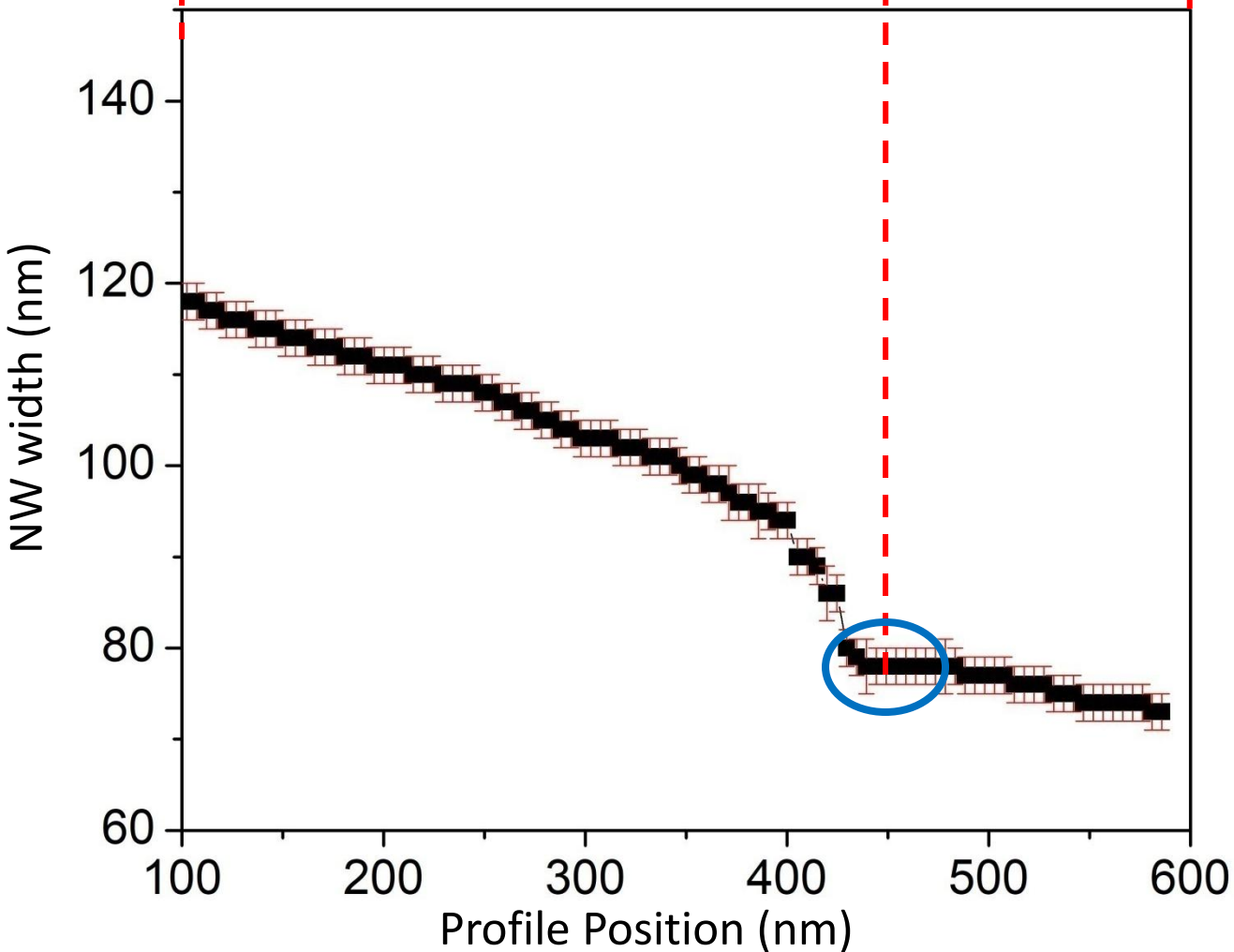
(x,y) = the sample plane

V= Potential source

C_E = constant that depends on the incident beam energy

t = thickness

NW Width vs. Position



Thickness Estimation

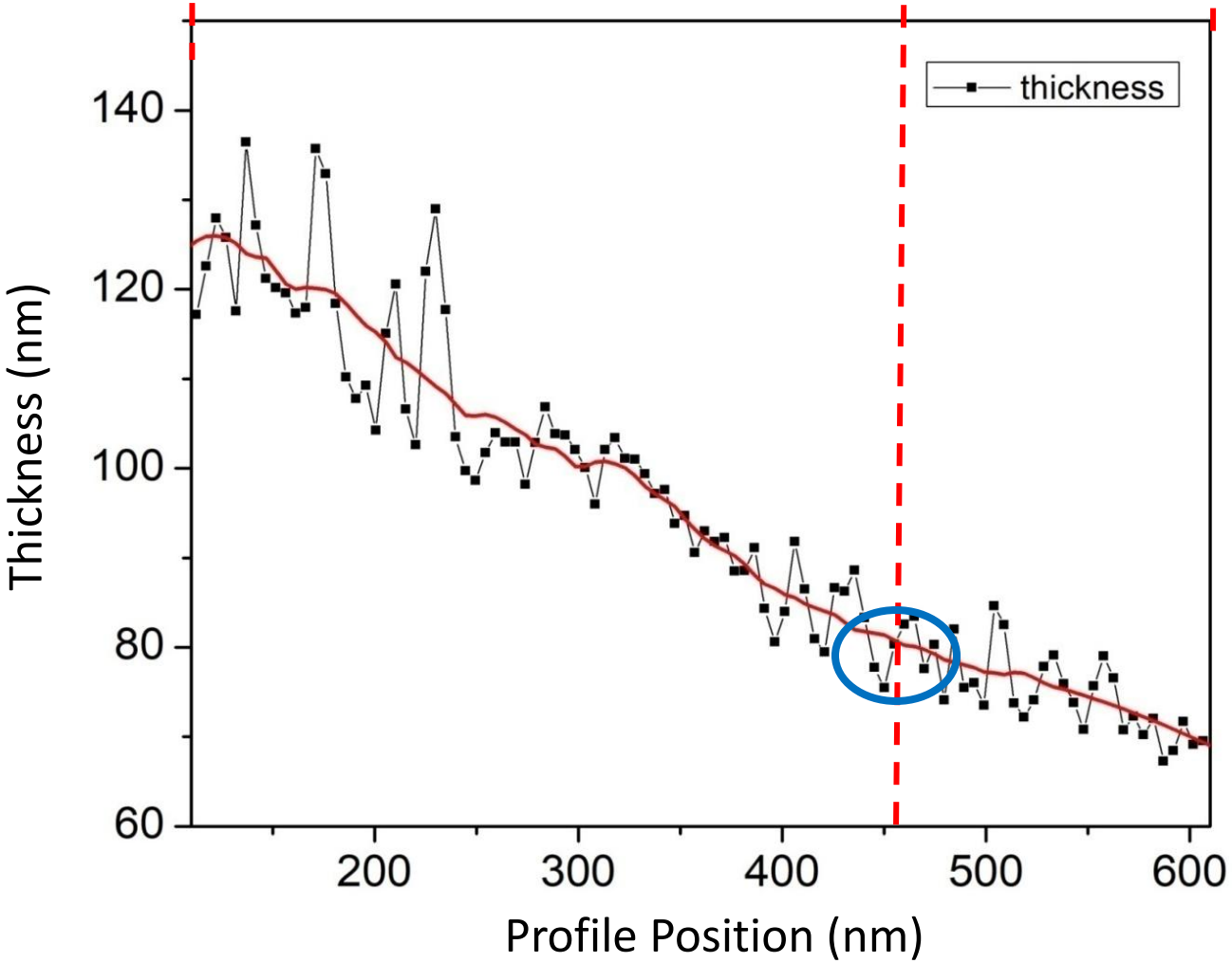
$$A(x,y) = \exp\left(-\frac{t(x,y)}{2\lambda}\right),$$

$t(x,y)$ = thickness

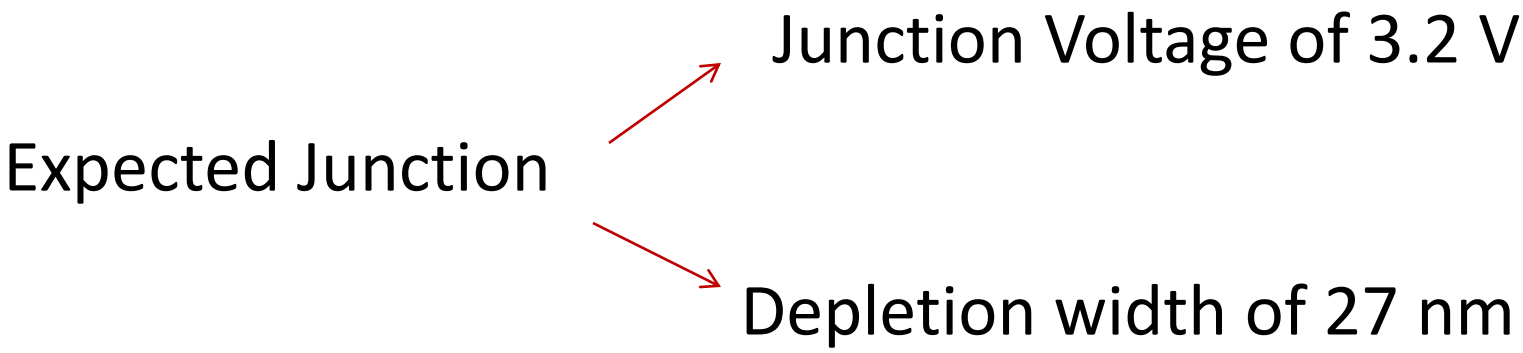
$A(x,y)$ = amplitude

λ = mean free path

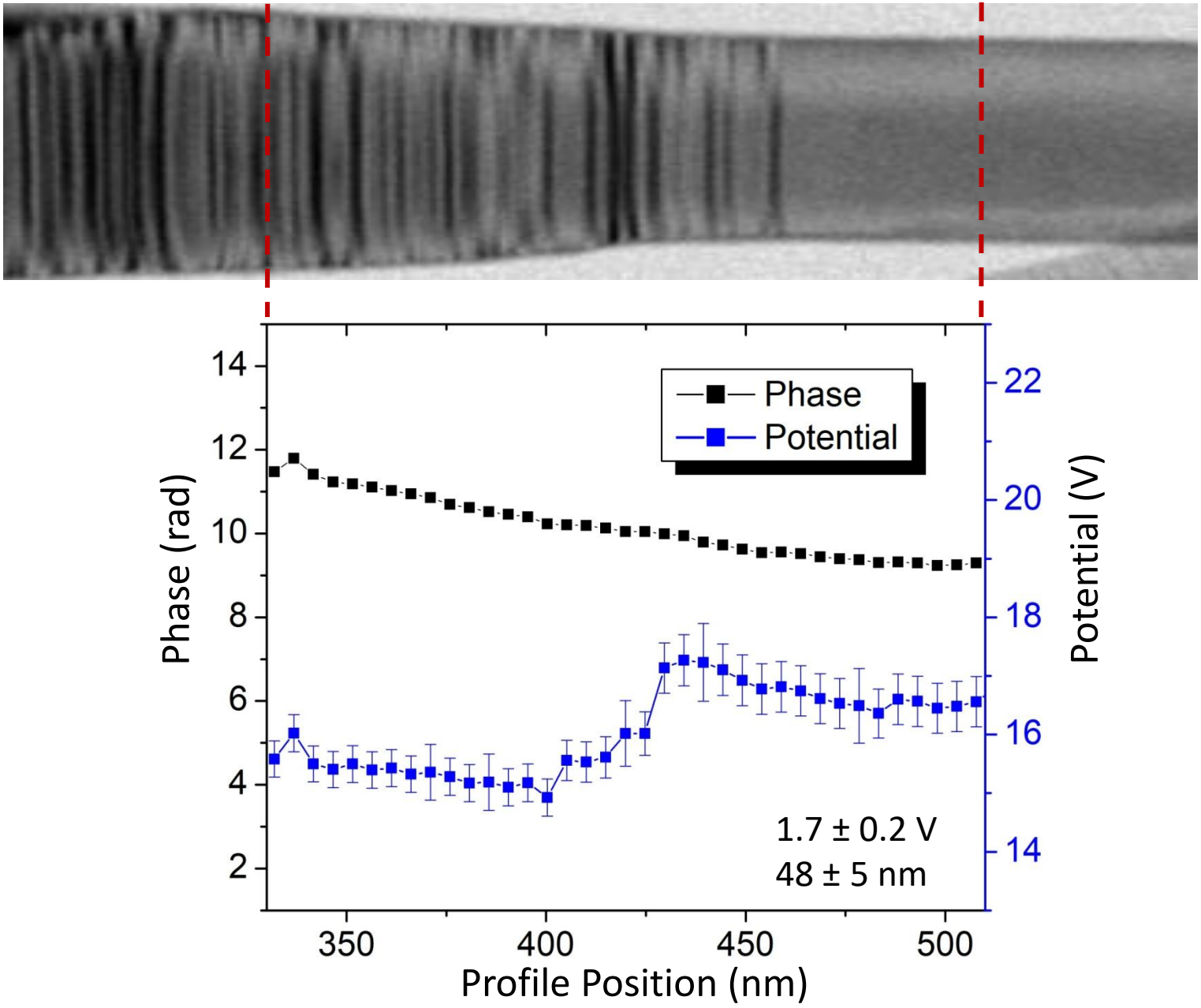
Thickness Profile of the NW

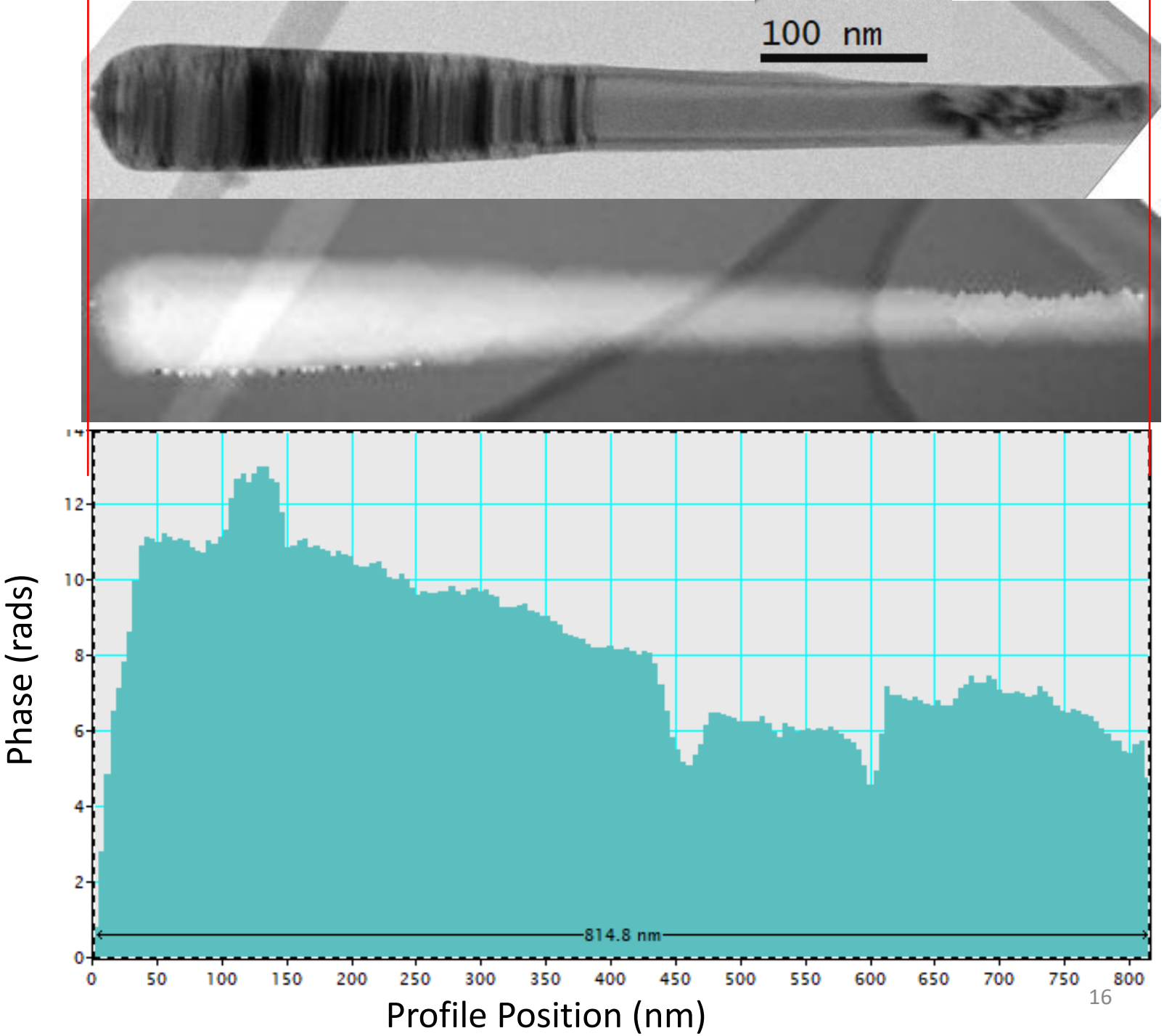


Expected Potential

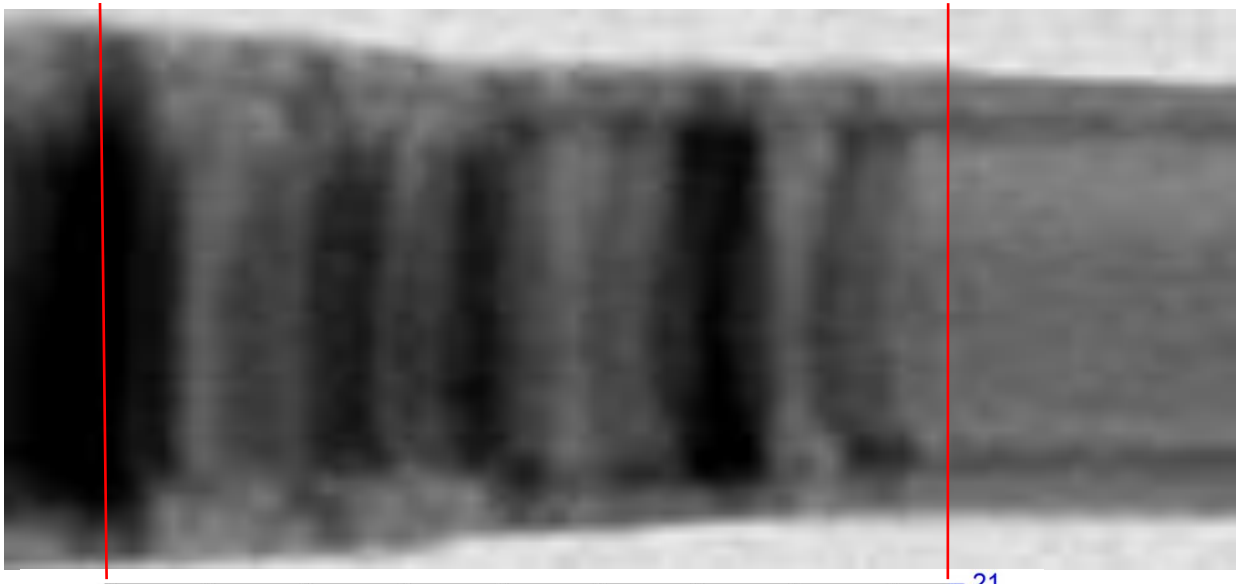


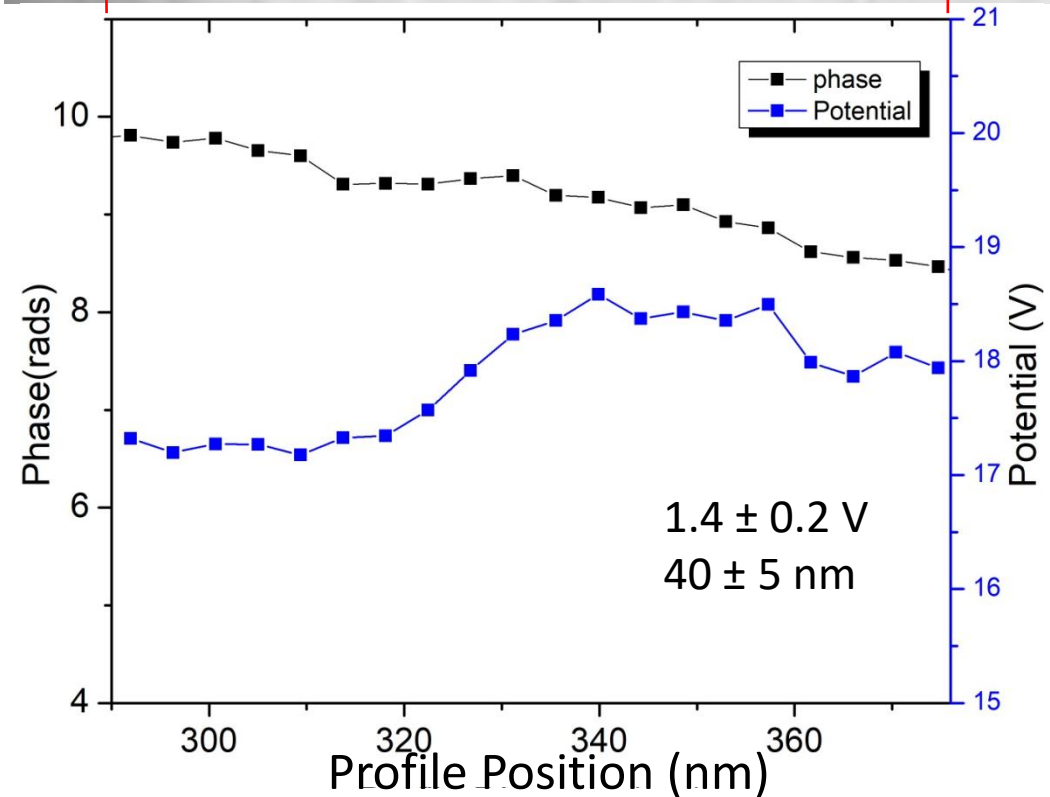
Potential Profile of the NW




100 nm
Phase (rads)
0
2
4
6
8
10
12
814.8 nm
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
Profile Position (nm)

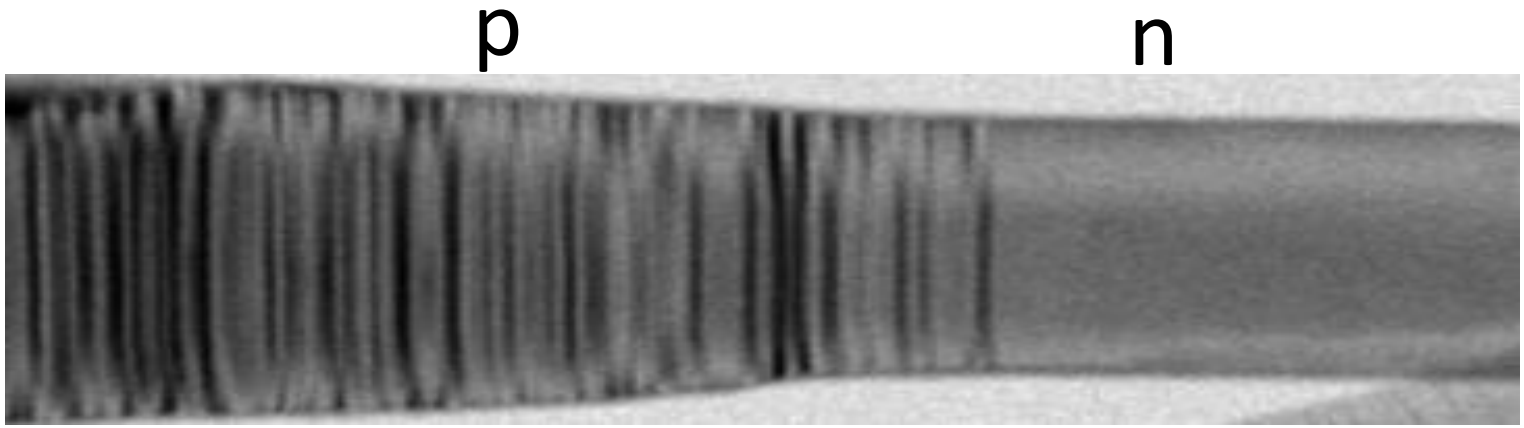
Potential Profile





Conclusions

- p-type side was wider with high density of basal plane stacking faults compared to n-type side.



- The position of the junction was close to the area with an abrupt change in diameter.

- The p-n junctions had an average built-in potential of 2.0 ± 0.6 V and a depletion width of 40 ± 9 nm.

- possible reasons - lower dopant activation or beam-induced electron-hole generation.

References

1. S. M. Sadaf, *et al.* Alternating-Current InGaN/GaN Tunnel Junction Nanowire White-Light Emitting Diodes, Nano Letters, 15, 6696-6701. (2015)

2. Lehmann, M. & Lichte, H. Tutorial on Off-Axis Electron Holography, Microscopy and Microanalysis, 8,447–466. (2002).

3. Darbandi, A *et al*. Direct Measurement of the Electrical Abruptness of a Nanowire p–n Junction, *Nano Letters,* 16, 3982–3988. (2016).

4. Cristina Cordoba *et al,* Three-Dimensional Imaging of Beam-Induced Biasing of InP/GaInP Tunnel Diodes, Nano Letters. (2019).

5. Wong*, et al.* The mean inner potential of GaN measured from nanowires using off-axis electron holography, *Mater. Res. Soc. Symp. Proc,* 892, 1–6 (2019).

Thank You