Research Institute for Technical Physics and Materials Science of the Hungarian Academy of Sciences

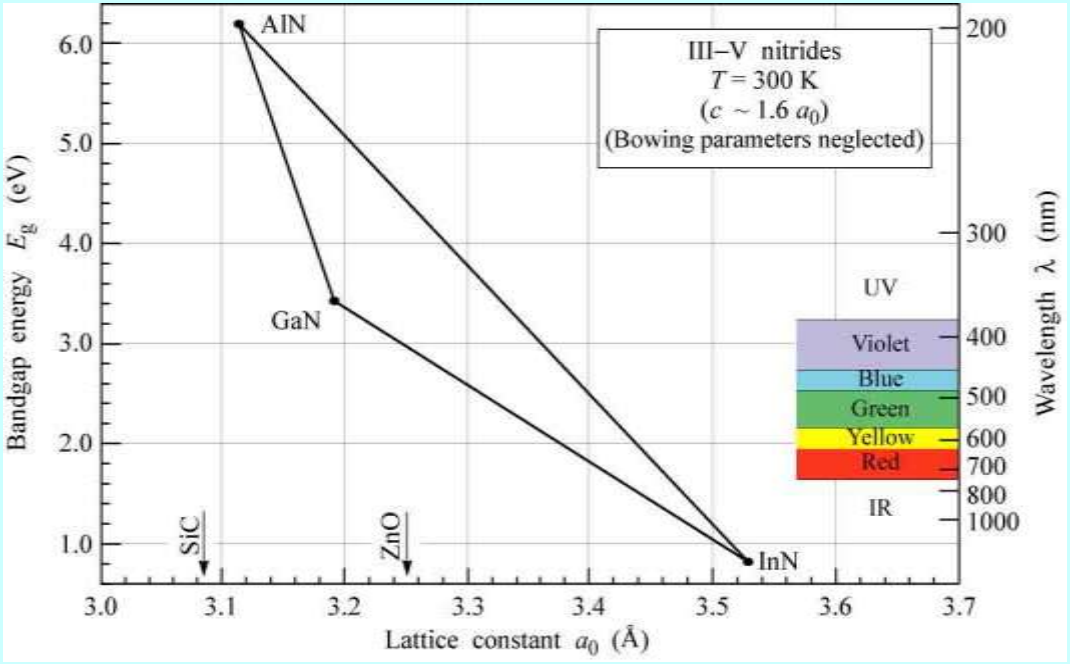
Széles tiltottsávú félvezetők, a kék LED-en túl

Pécz Béla

MTA EK MFA

2018. december 12

Fizikai Tudományok Osztálya



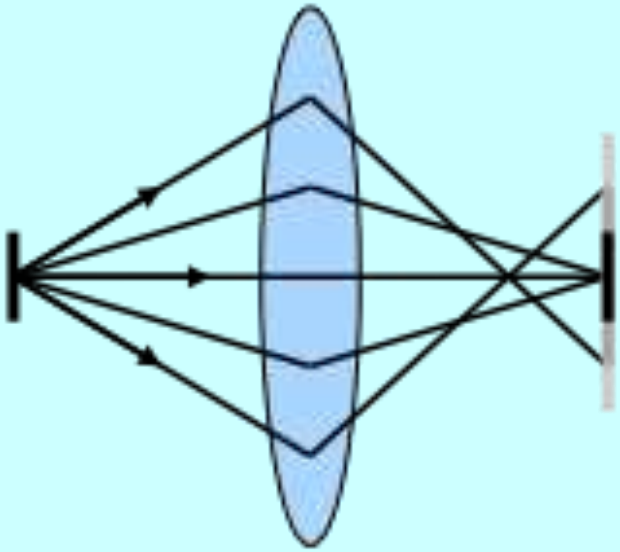
E=hc/λ

High power devices

optoelectronics
blue LED---> Nobel prize 2014

Isamu Akasaki*, *Hiroshi Amano
and ***Shuji Nakamura***

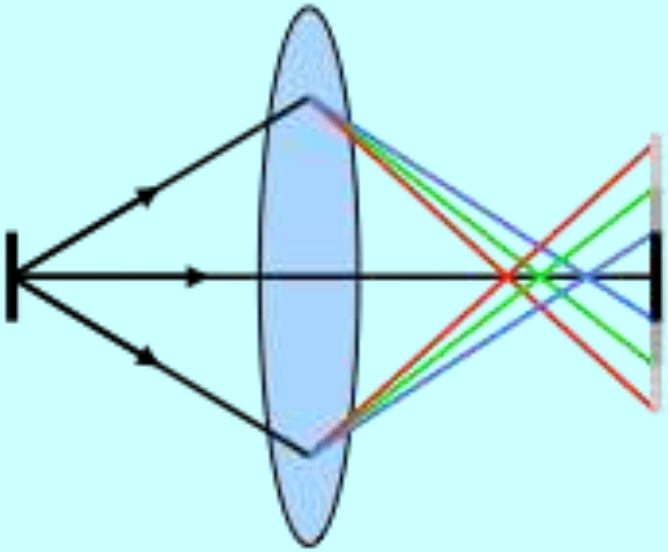
Lencsehibák



Gömbi hiba

feloldás határ

$$R_m/M = r_s = C_s\,\alpha^3$$



Szín hiba

információ határ

$$R_c/M = r_c = C_c \cdot \alpha \cdot \Delta E/E$$

vastag minta…

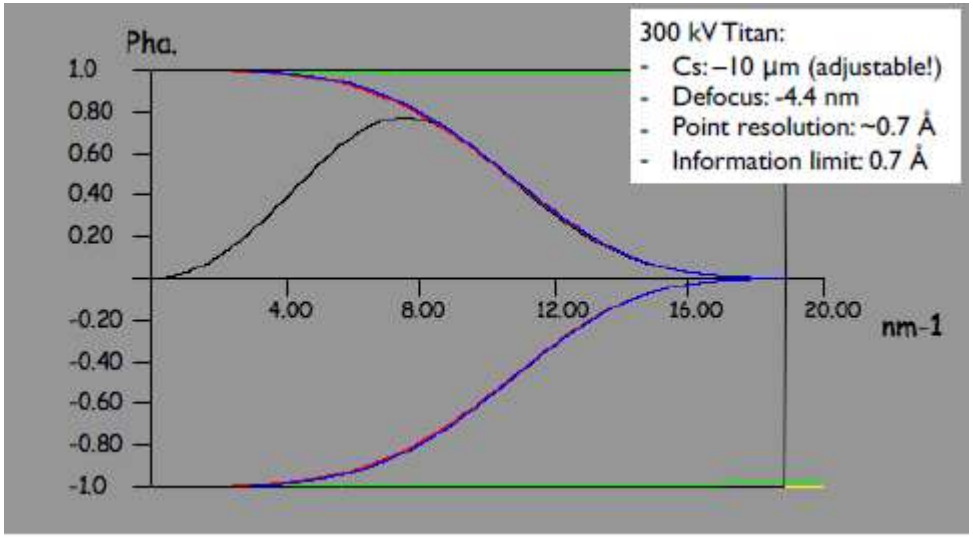
Room temperature variations

0.2 °C/60min

0.1 °C/30min

Air velocity: <5m/min.

Stray magnetic field (50 Hz): 30nT p-p.

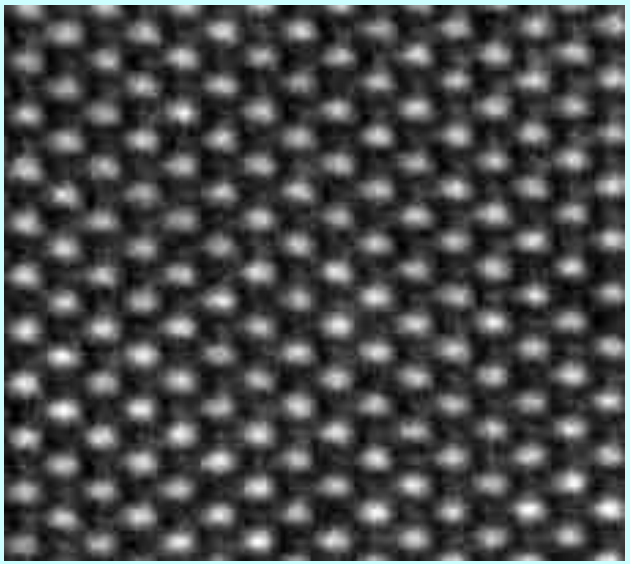


THEMIS 200 image corrected

Rayleigh criterion for VLM

$$\delta = \frac{0.61\lambda}{\mu \sin \beta}$$

Optical microscope: 200 nm resolution



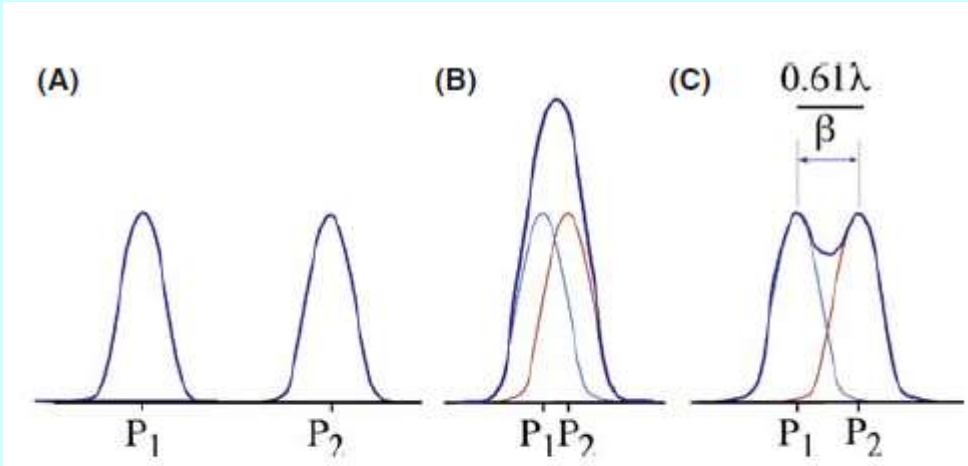
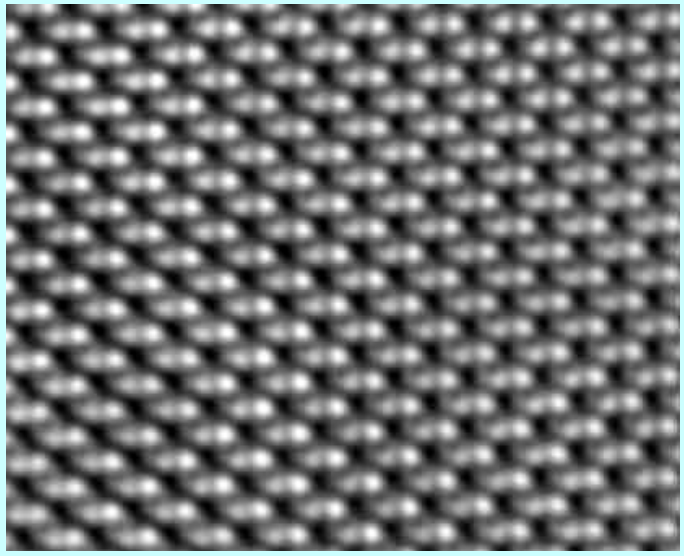


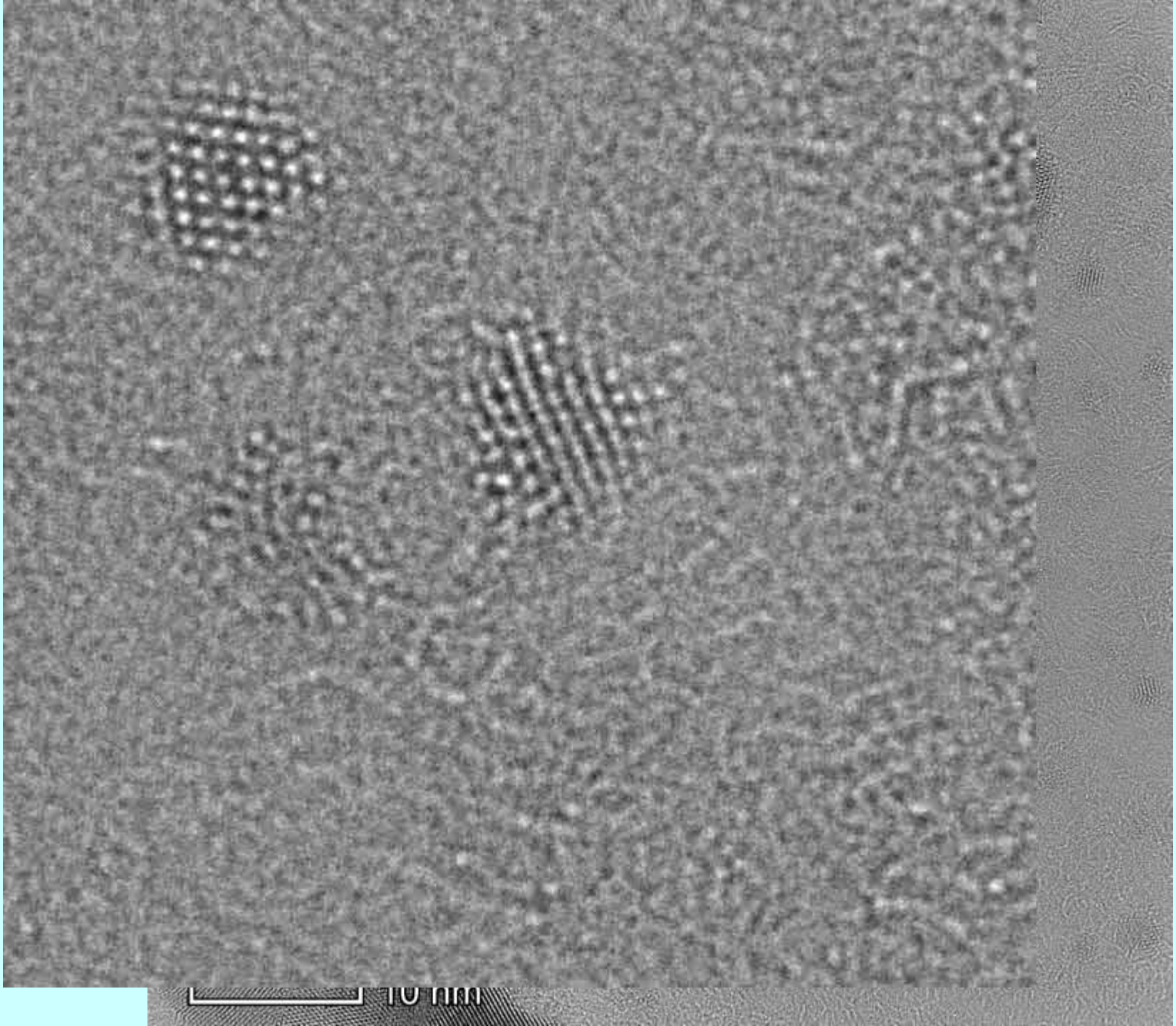
FIGURE 6.14. (A) The Airy-disk intensity profiles from two clearly separated point sources P_1 and P_2. In (B) the two Airy disks are so close that they cannot be distinguished, but in (C) the two are separated such that the maximum in the image of P_1 overlaps the minimum in P_2. This latter situation is the definition of resolution defined by the Rayleigh criterion and is the best (diffraction-limited) resolution.

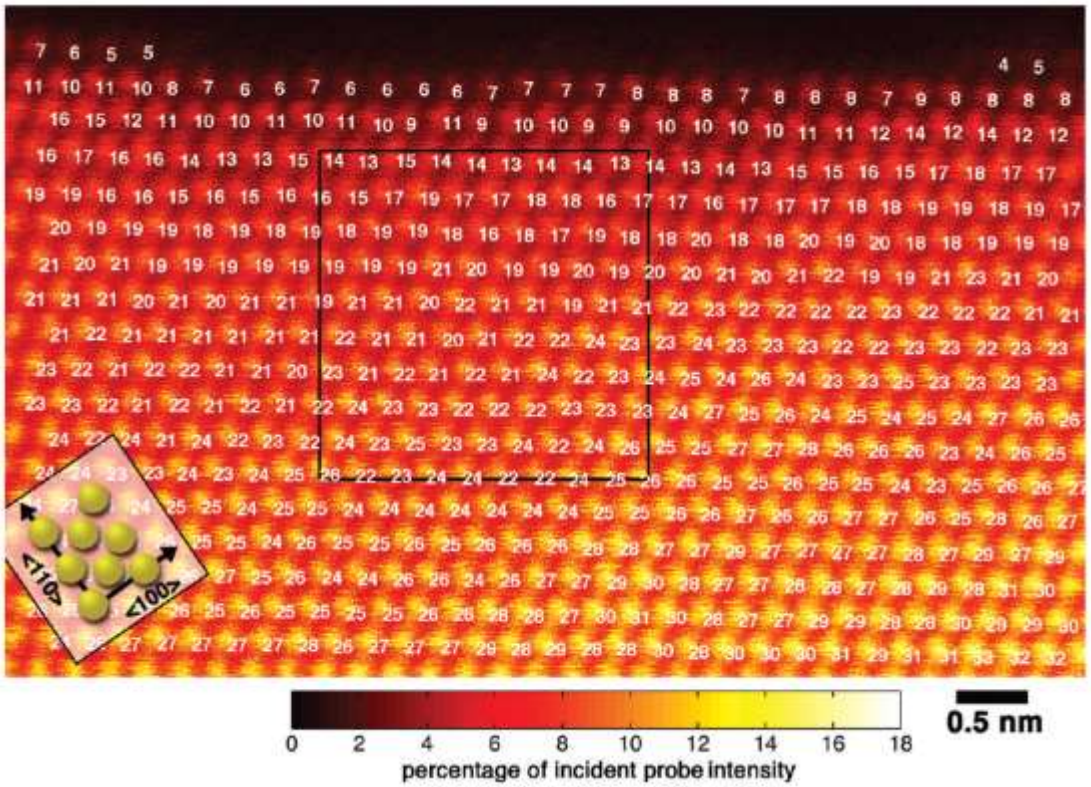
$$\lambda = \frac{h}{p}$$

$$\lambda = \frac{h}{\left[2m_0 eV\left(1 + \frac{eV}{2m_0 c^2}\right)\right]^{1/2}}$$



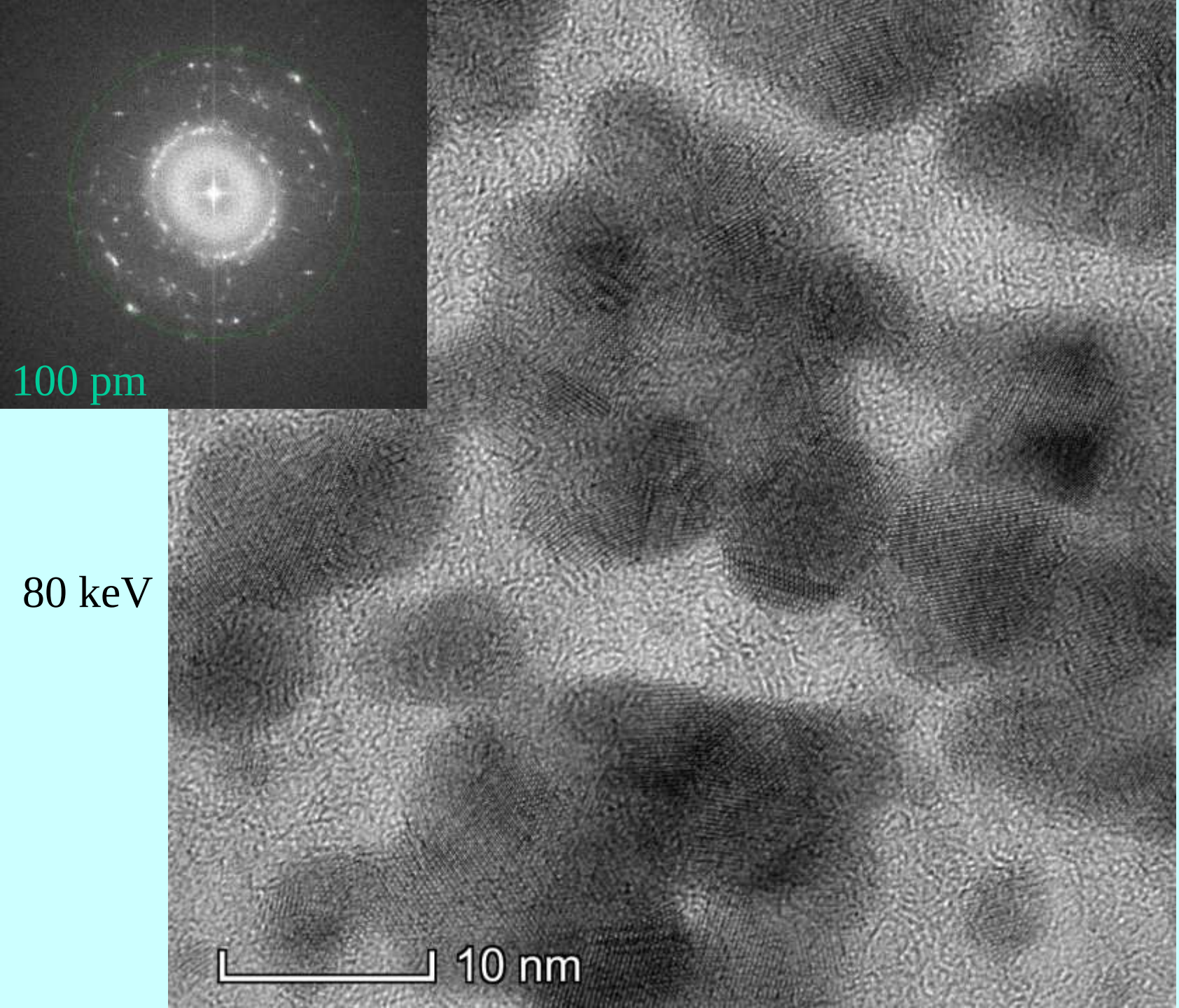
diamond dumbbells 89 pm


10 nm

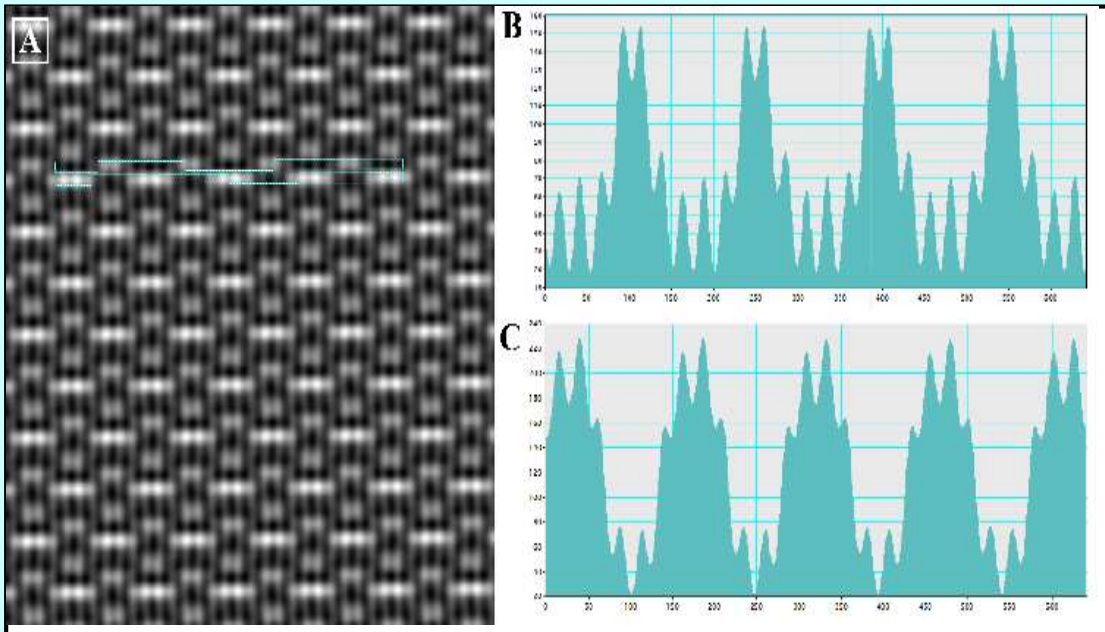


DOI: 10.1021/nl102025s | *Nano Lett.* **2010,** *10,* 4405--4408

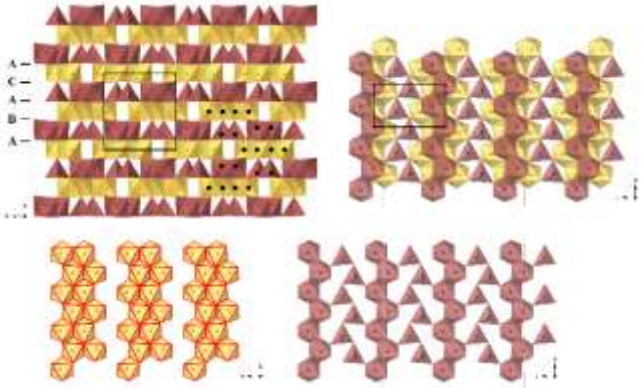
number of gold atoms in columns



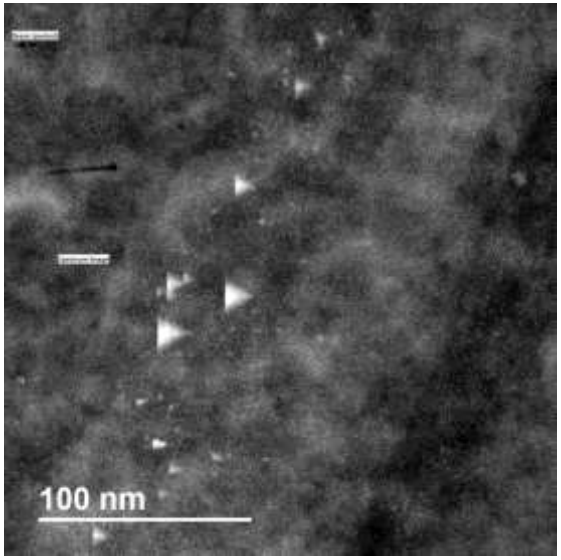
80 keV

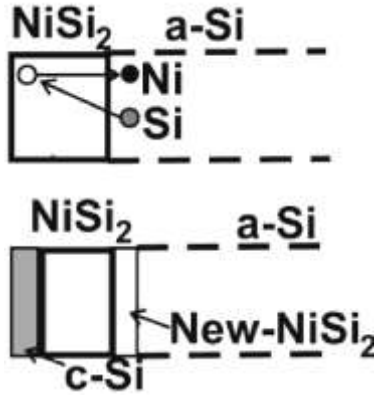


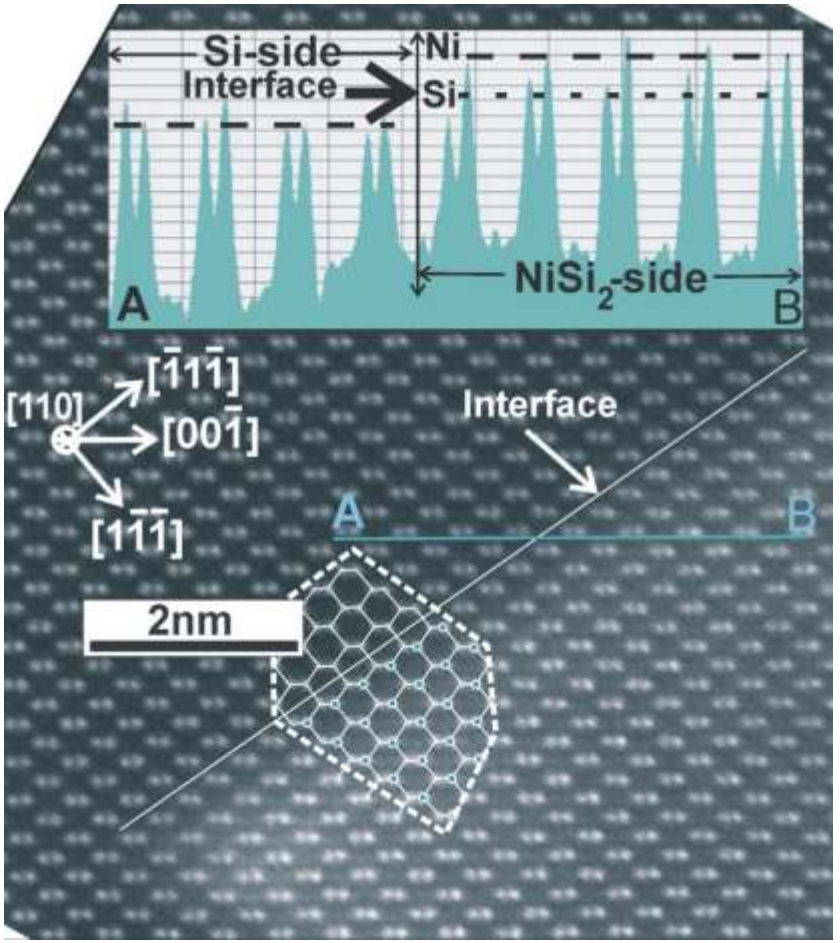
I. Cora et al. CrystEngComm. 2017, 19, 1509-1516



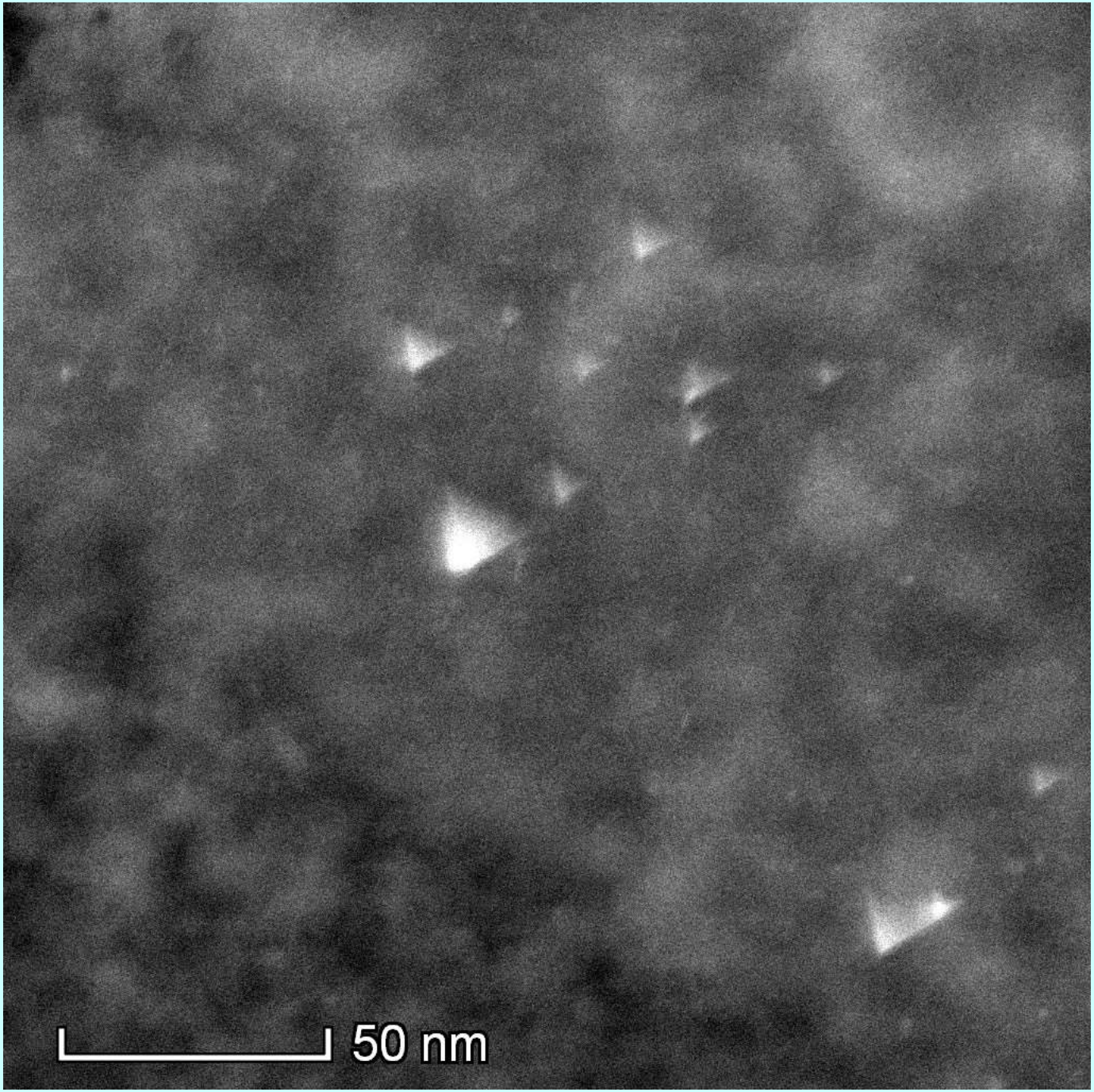
Octahedra and tetrahedra ribbons give the precise 2:3 Ga:O ratio

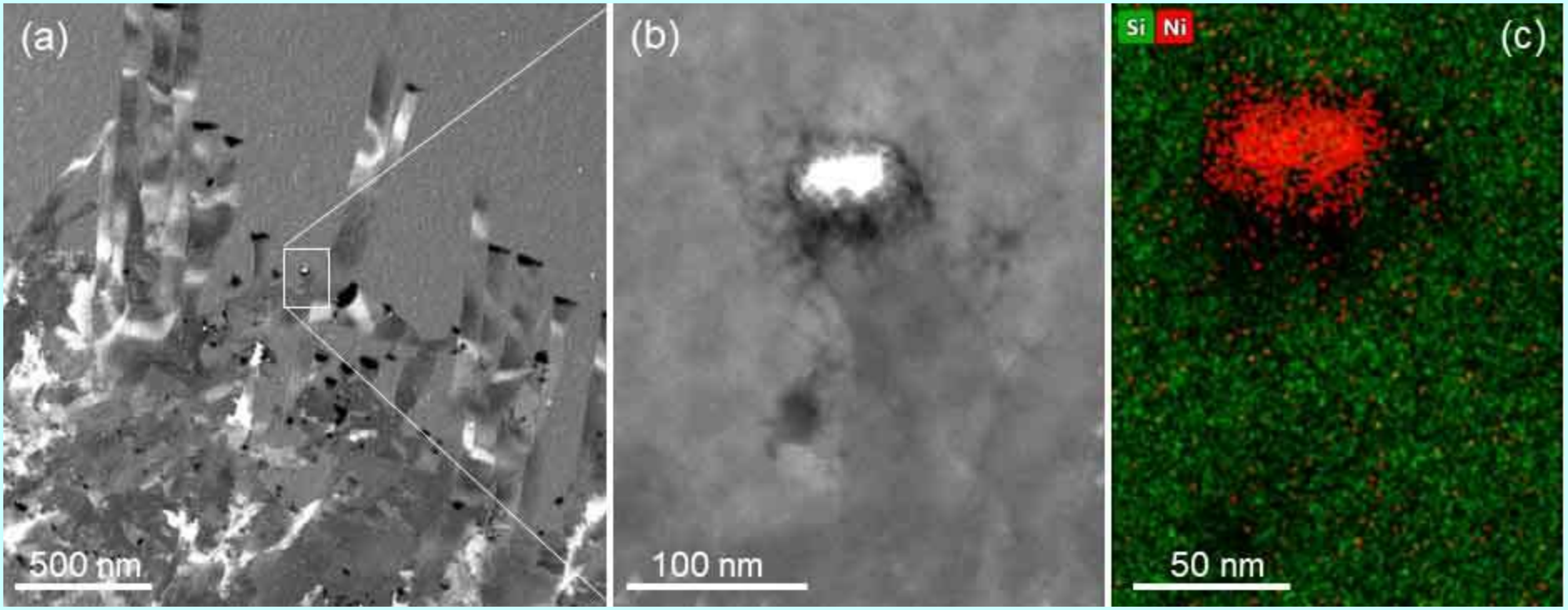




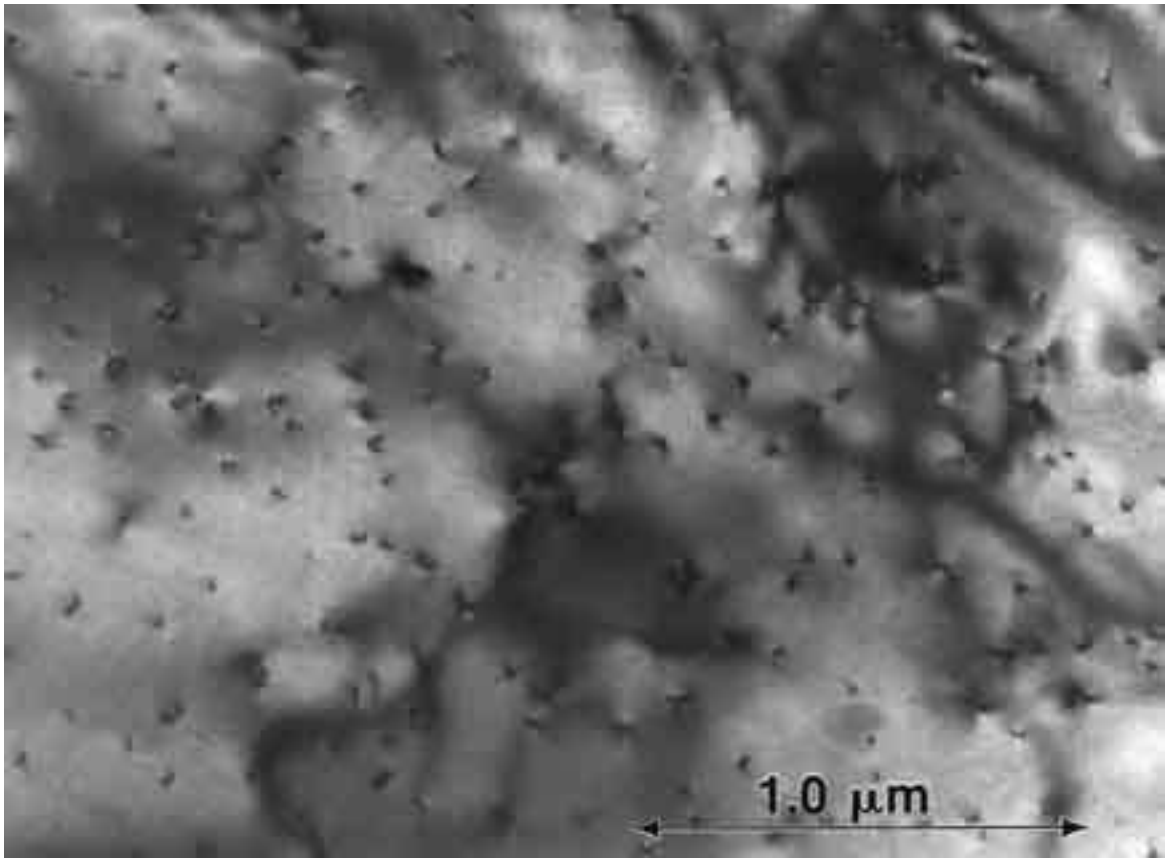


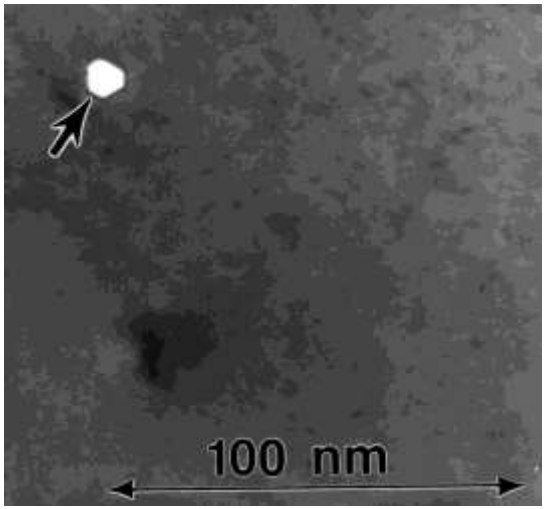
G.Z. Radnóczi D. Knez, F. Hofer,, N. Frangis, N. Vouroutzis, J. Sttoimenos, B. Pécz.
JOURNAL OF APPLIED PHYSICS 121, 145301 (2017)

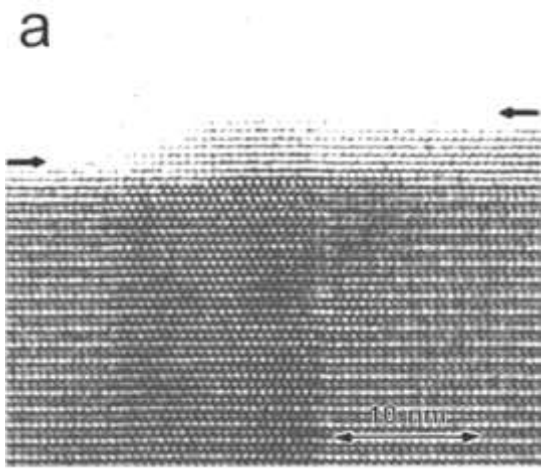

50 nm



N. Vouroutzis, J. Stoemenos, N. Frangis, G.Z. Radnóczi, D. Knez, F. Hofer and B. Pécz under review at Scientific Reports



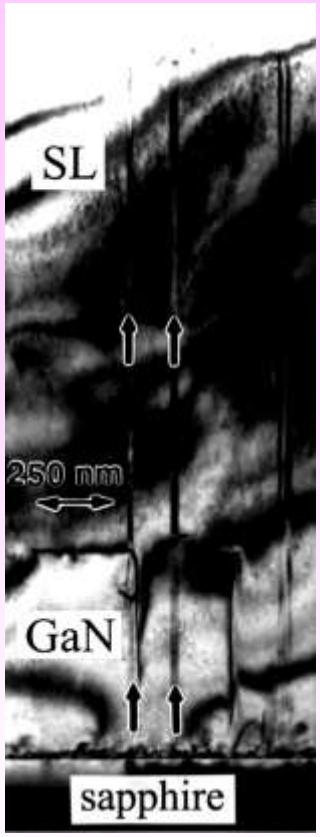


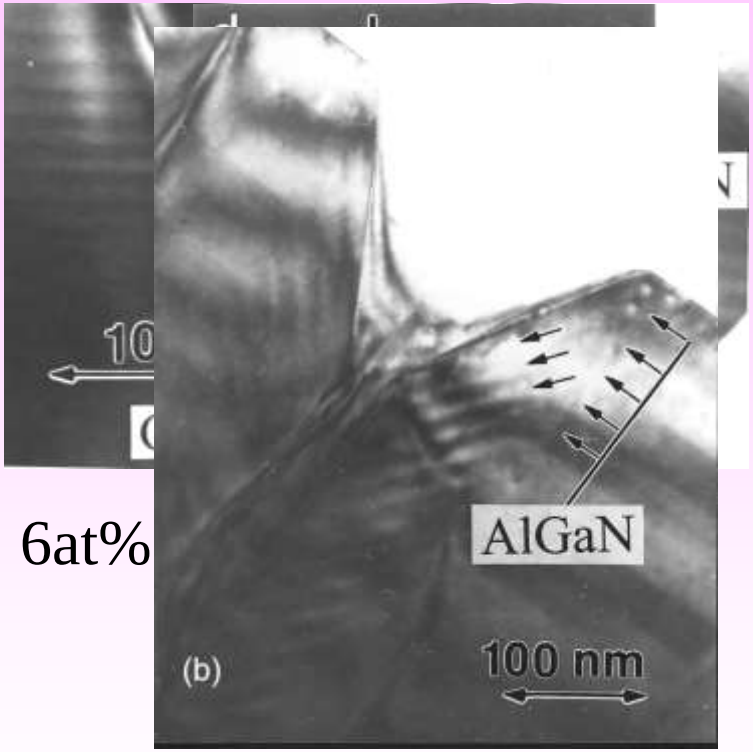


GaN with dislocation density of 4×10^9 cm^{-2}

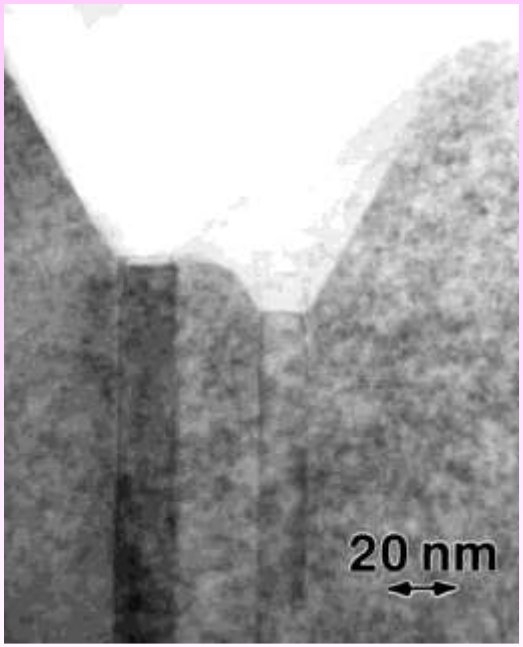
B. Pécz et al. J. Appl. Phys., 86 (1999) 6059-6067

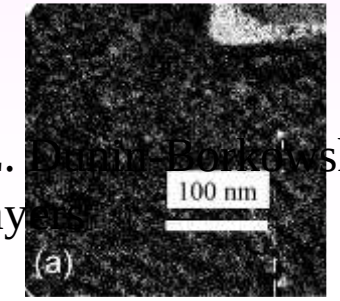
AlGaN/GaN superlattice



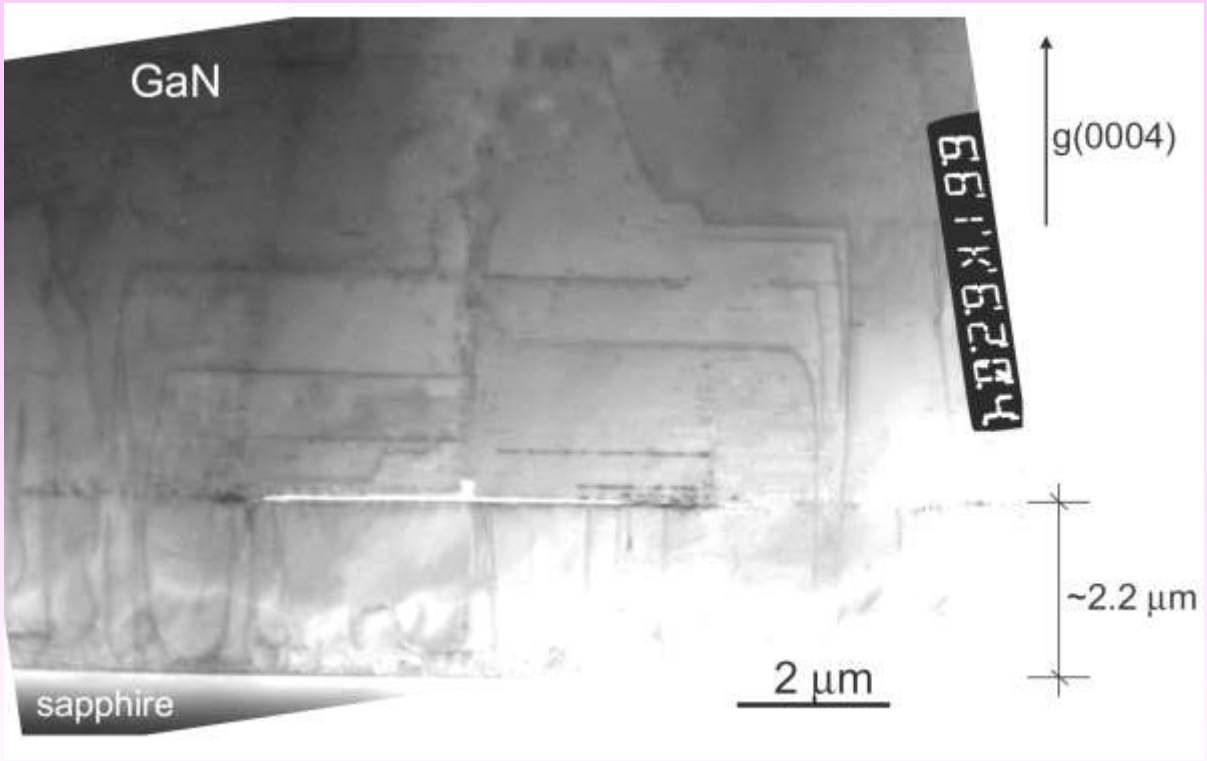


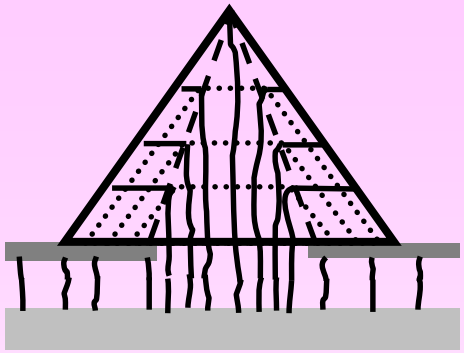
6at%



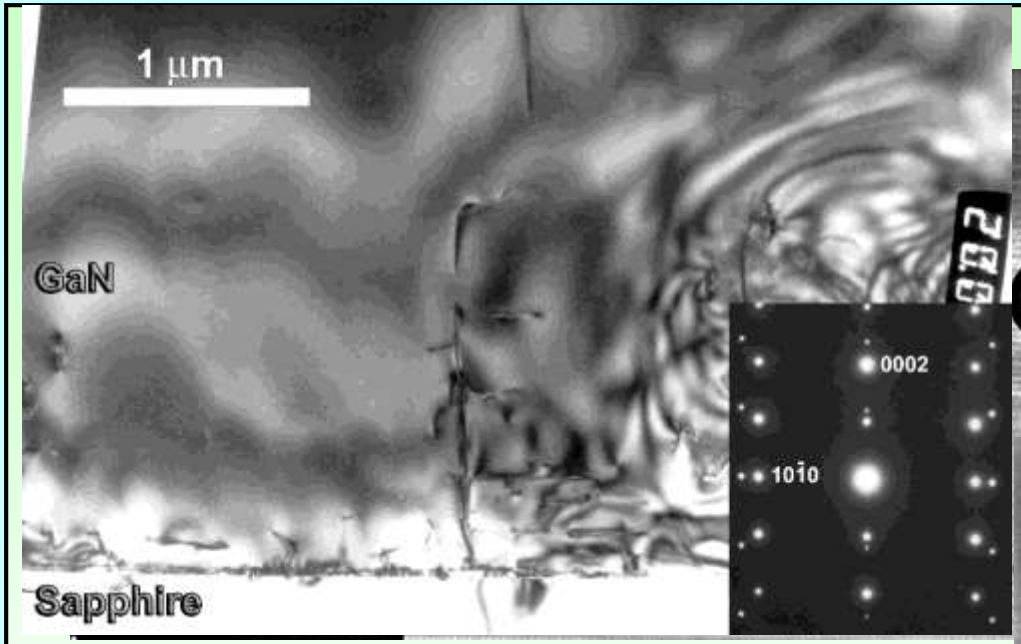


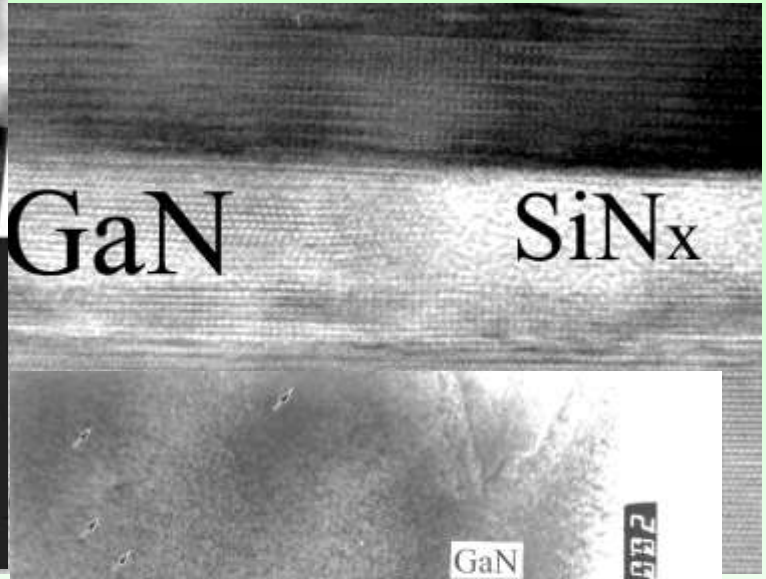
B. Pécz, Zs. Makkai, M. A. di Forte-Poisson, F. Huet and R. E. [illegible]ski
V-shaped defects connected to inversion domains in AlGaN lay[illegible]
Appl. Phys. Lett. 78 (2001) 1529-1531

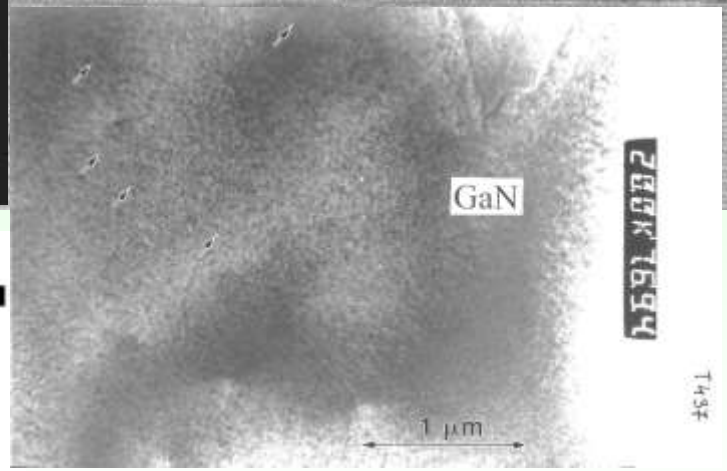




dislocations are bent and defect density is decreased also in window

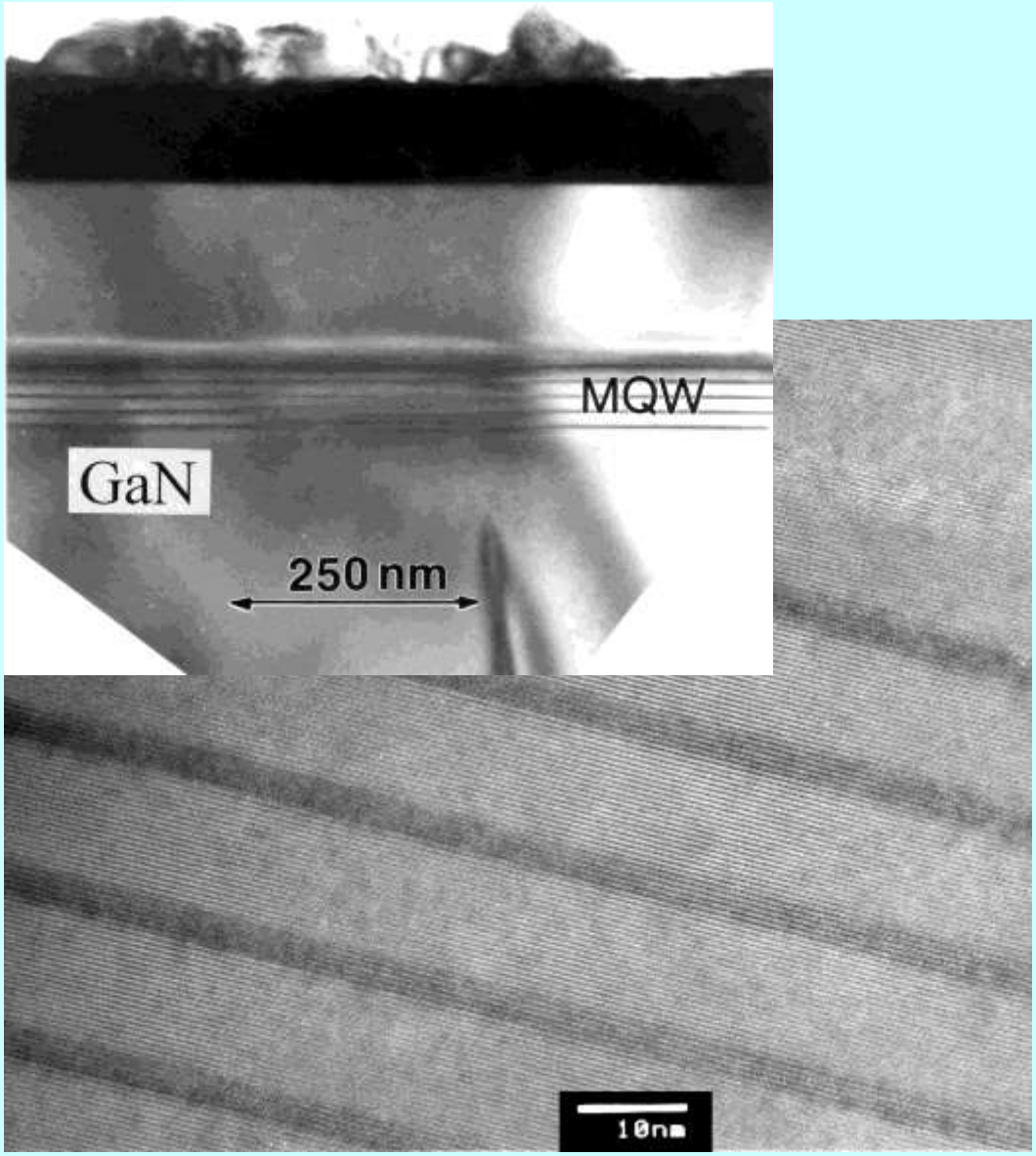


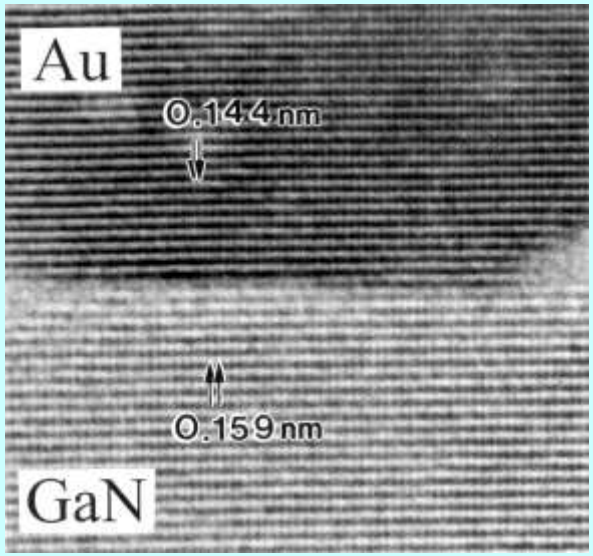


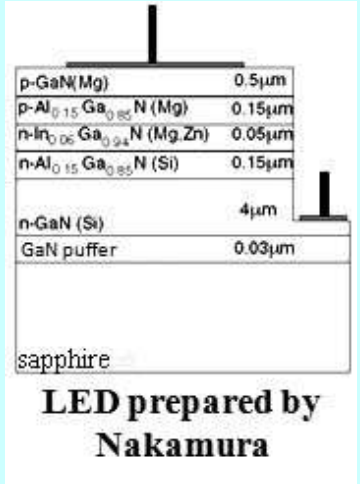


$6 \times 10^{7} cm^{-2}$

MRS Internet Journal of Nitride Semiconductor Research 7, 8 (2002)



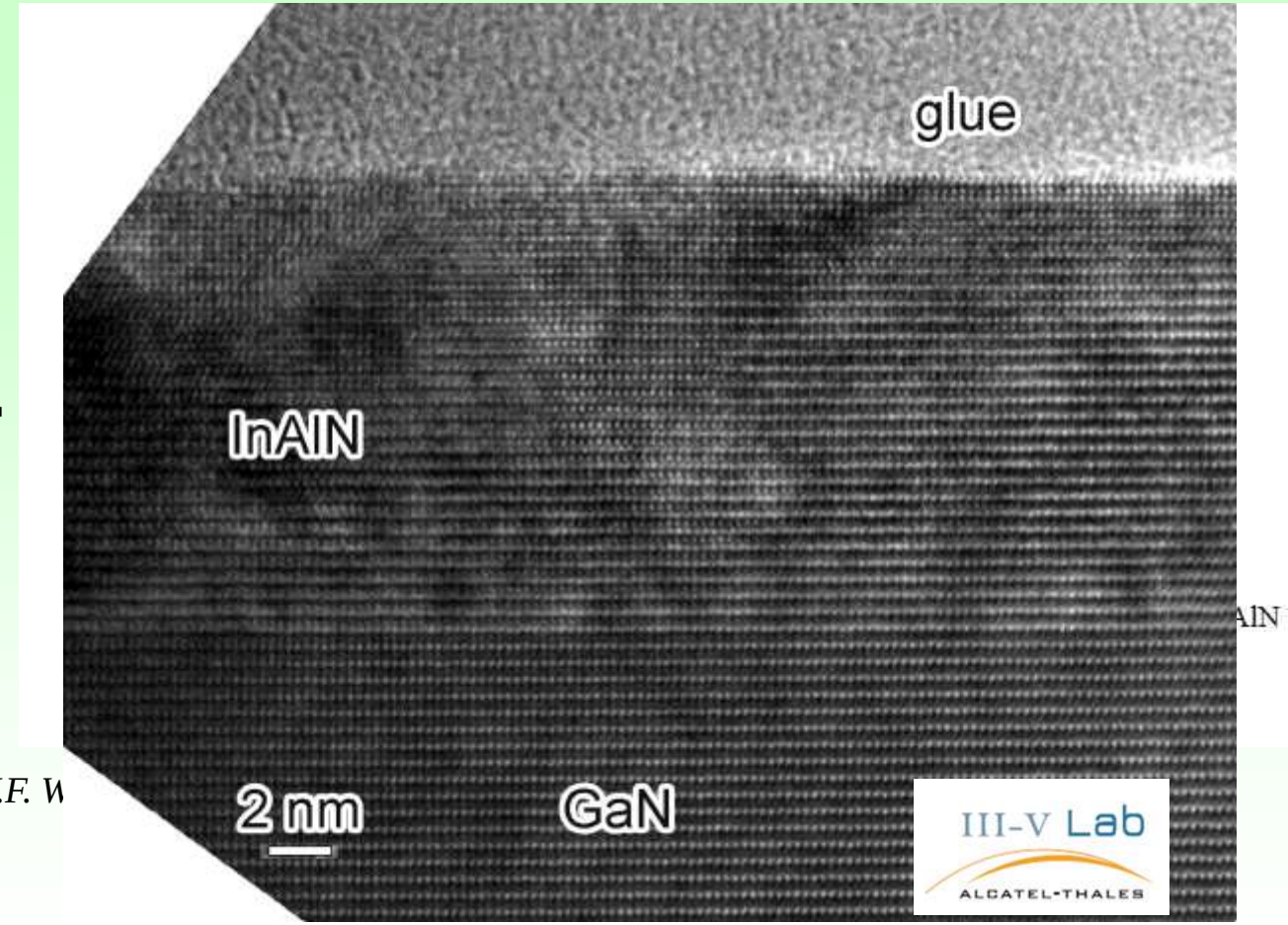




LED prepared by Nakamura

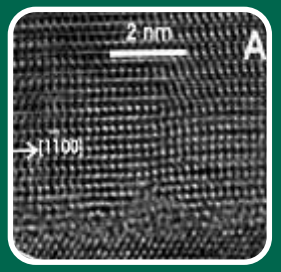
OSRAM blue laser diode based on InGaN, 2000

Typical HEMT
structure
to 160 GHz
10 W/mm

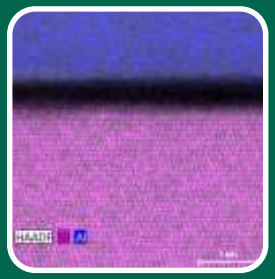


U.K. Mishra, P. Parikh, Y.F. W

Institute for Technical Physics and Materials Science of the Hungarian Academy of Sciences

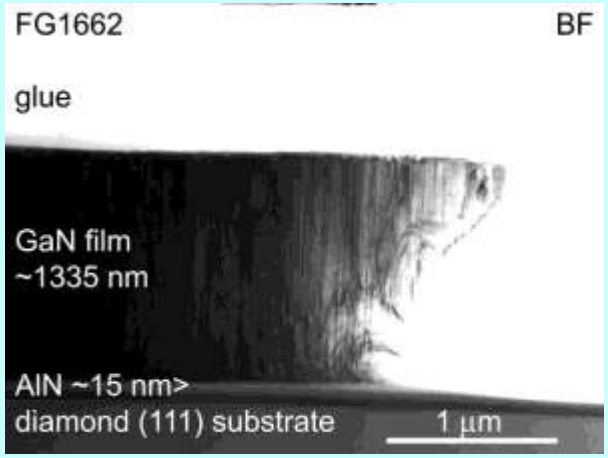


GaN HEMT grown on diamond



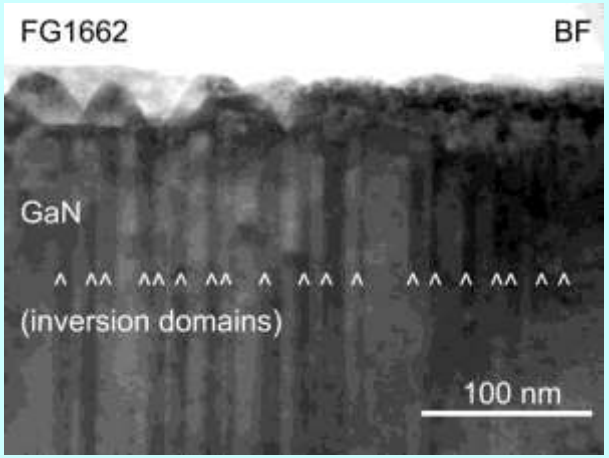
integration of graphene sheets into nitride devices

GaN grown on diamond (111)

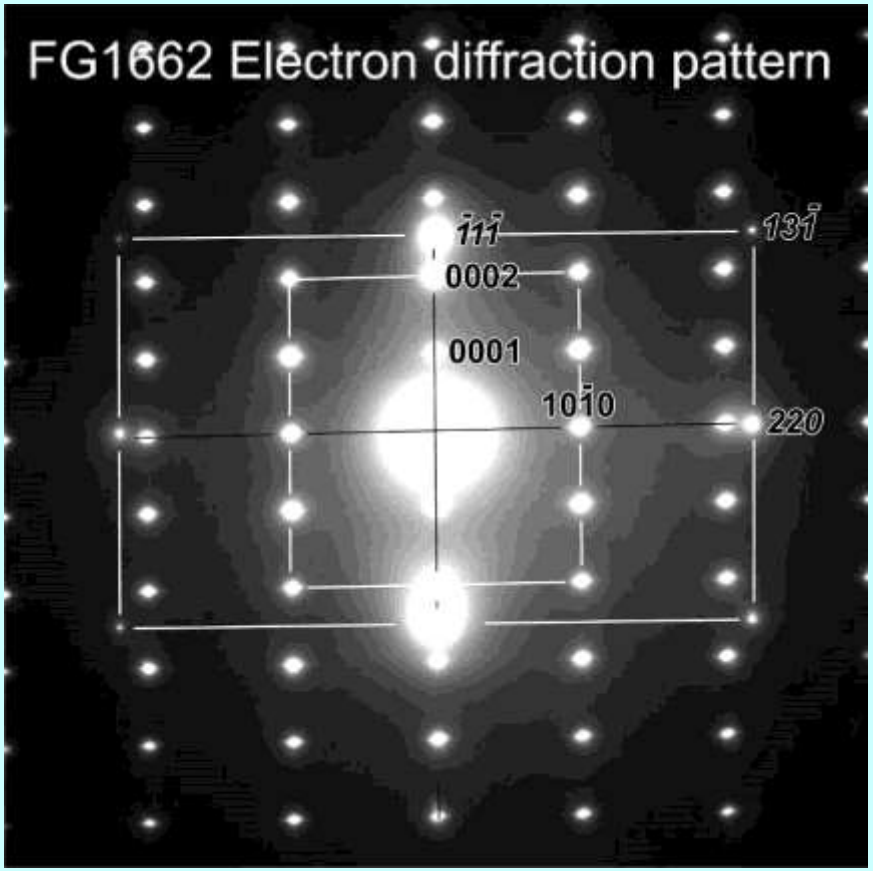


overview of the entire layer

(left after chemical etching)



numerous inversion domains close to the surface

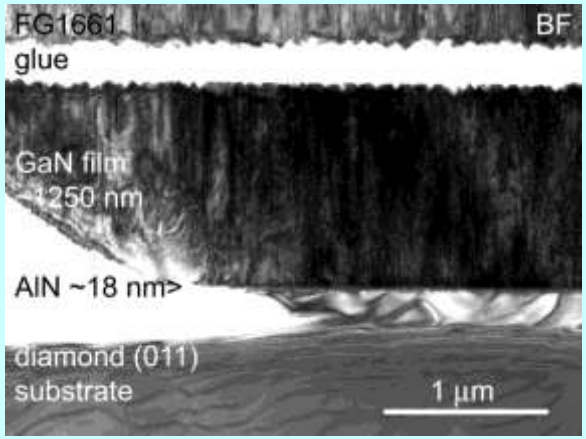


Epitaxy:

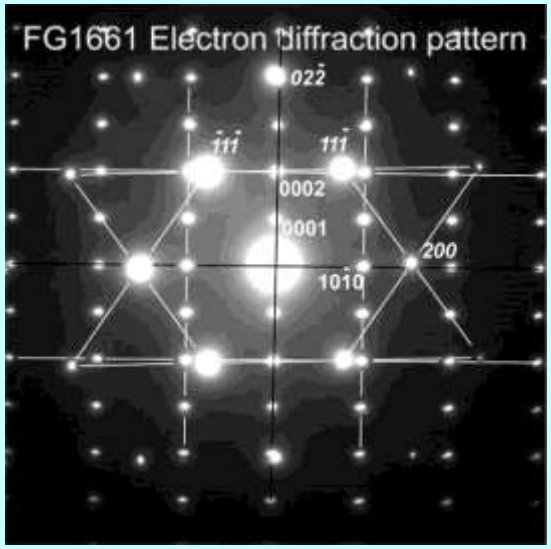
(0002)GaN//(111)diamond

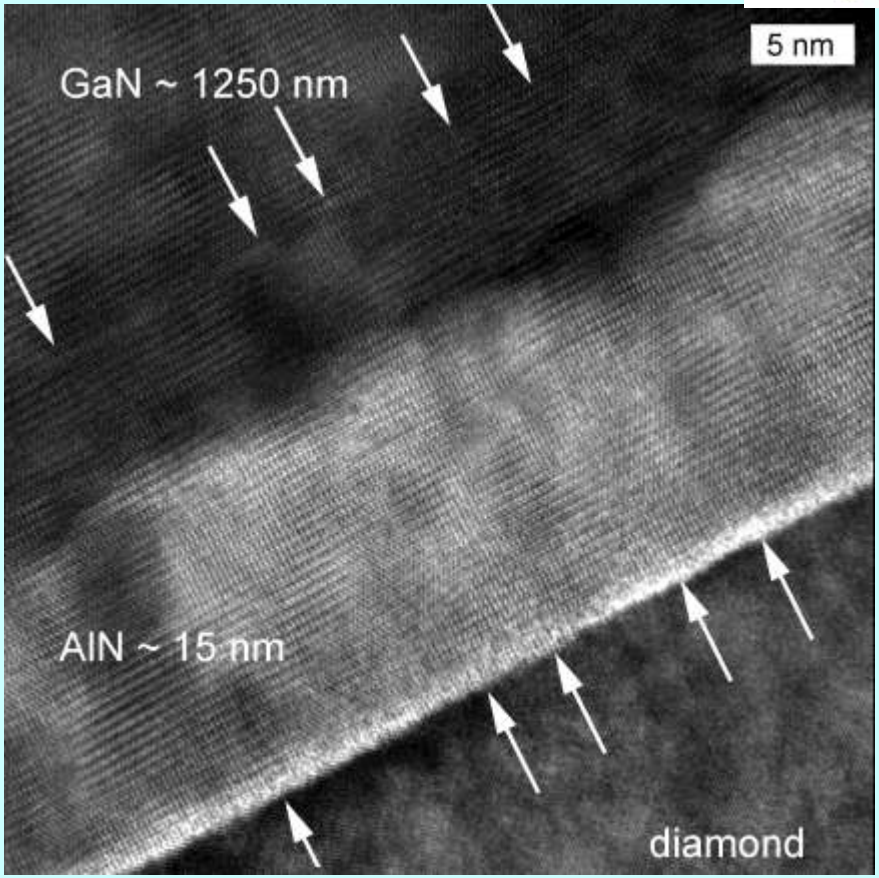
and (10$\underline{1}$0)GaN//(220)diamond.

GaN grown on diamond (110)



overview of the entire layer
(after chemical etching)

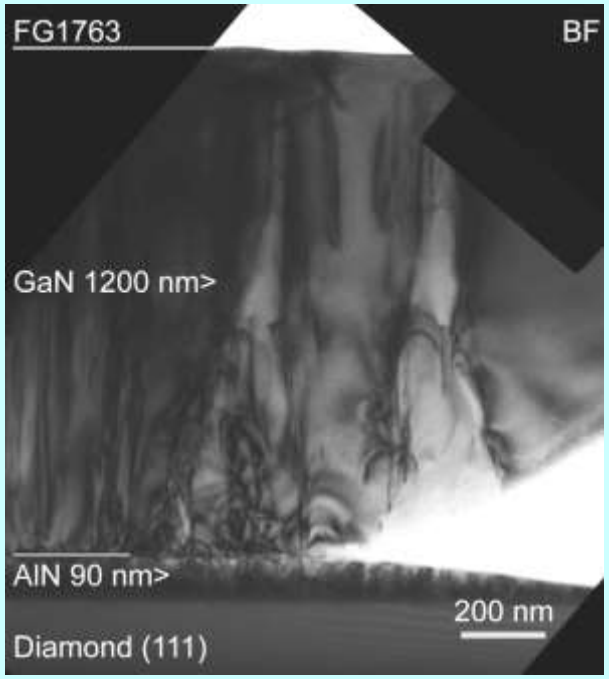




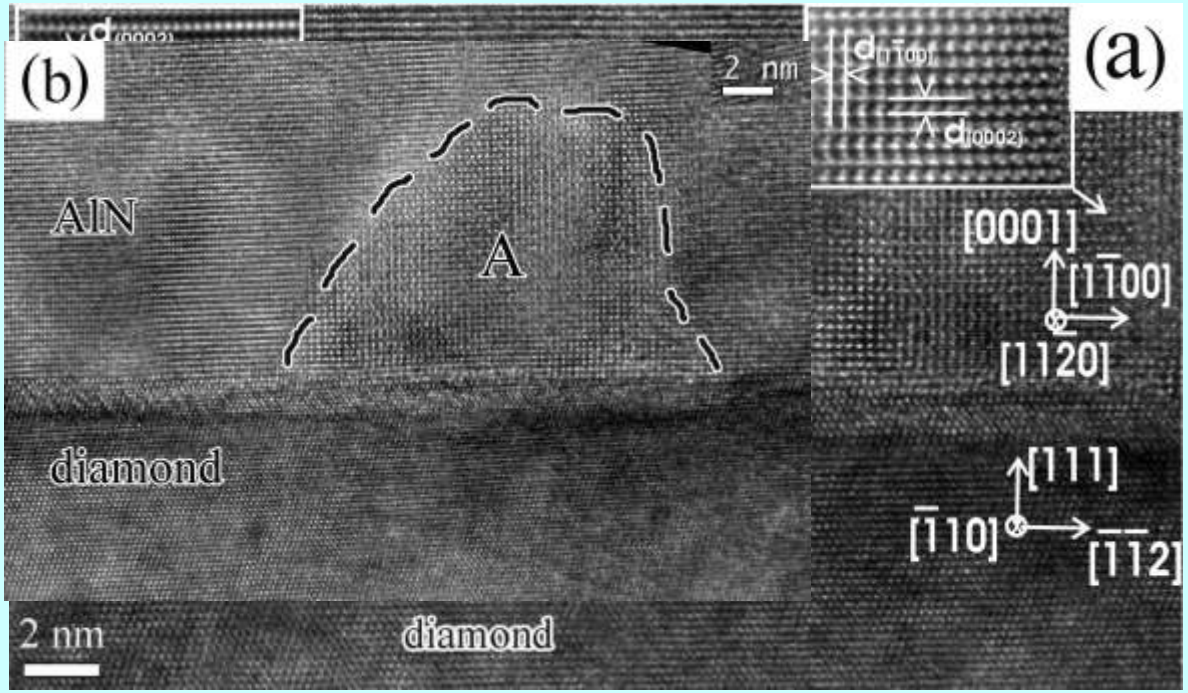
IDs are formed on the surface of diamond during the AlN growth

B. Pécz et al.: GaN heterostructures with diamond and graphene, Semicond. Sci. Technol. 30 (2015) 114001 (6pp)

GaN grown on diamond
(111)



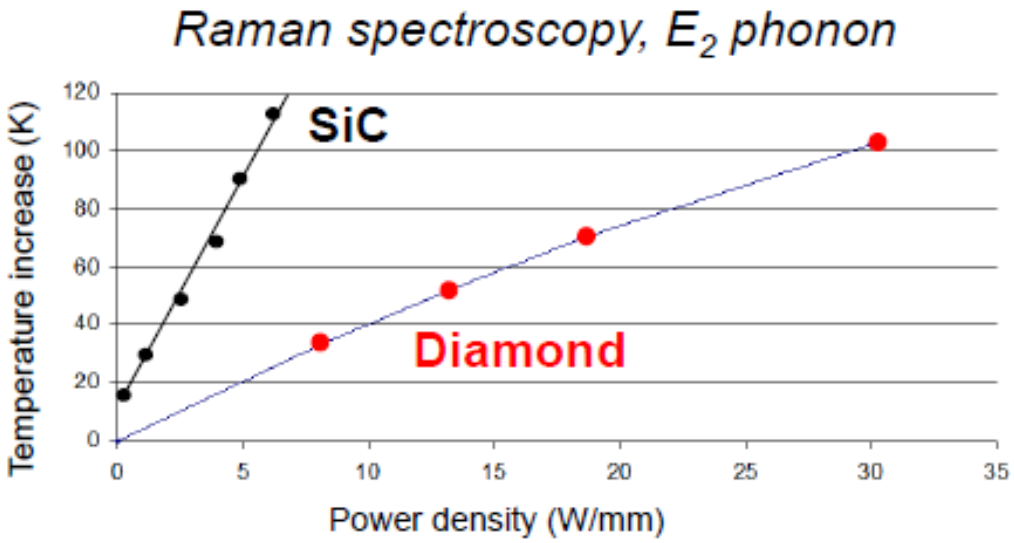
Nitridation supressed the formation of IDs.
60 min at 150°C



B. Pécz et al.
Diamond & Related Materials 34 (2013) 9–12

FEI Titan

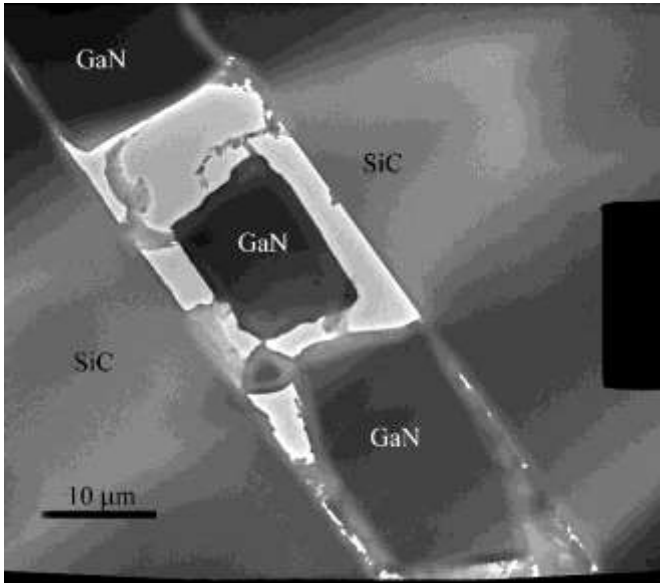
AlGaN/GaN HEMT Grown by Nitride MBE on (111) Diamond

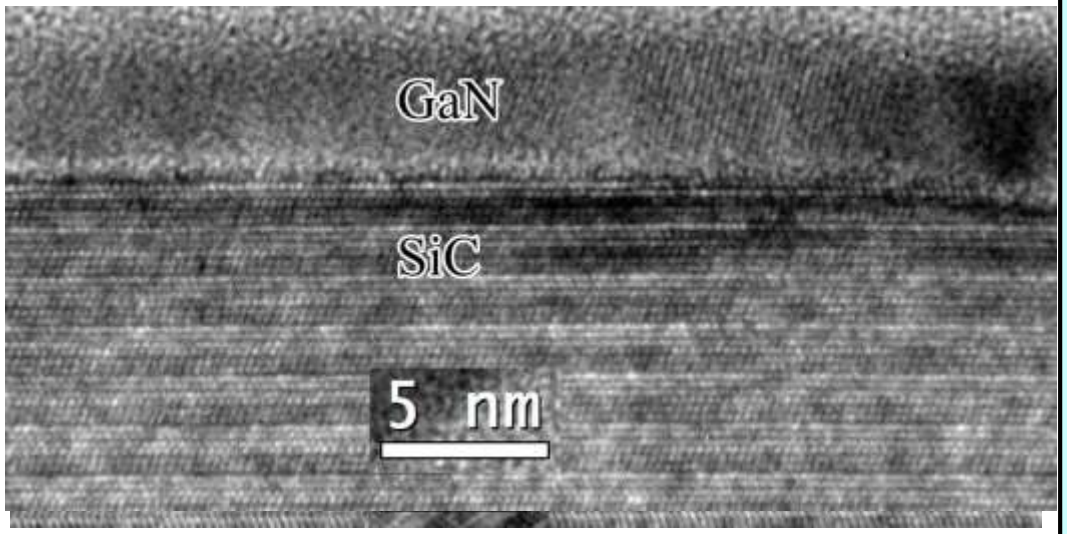


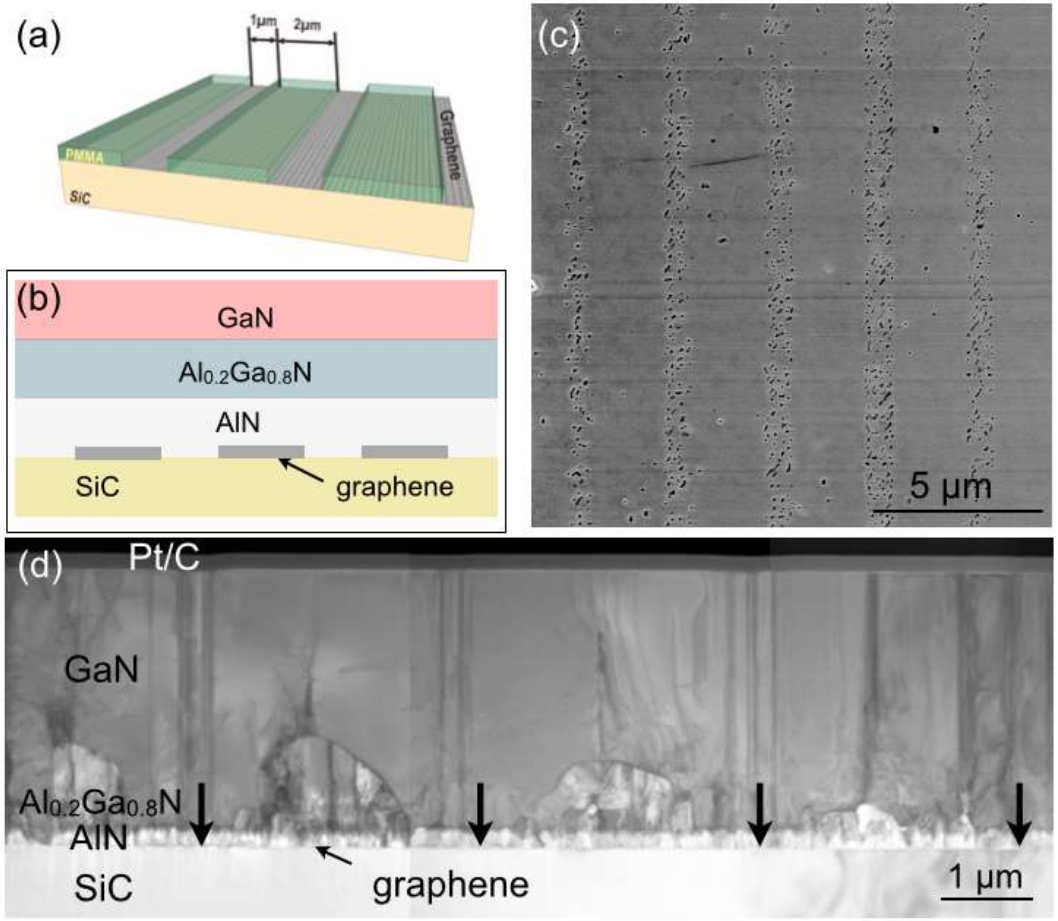
M. Alomari et al.; Electronic Lett., 46 (2010), 299

integration of graphene sheets into nitride devices

Direct growth onto graphene failed.







smooth surface

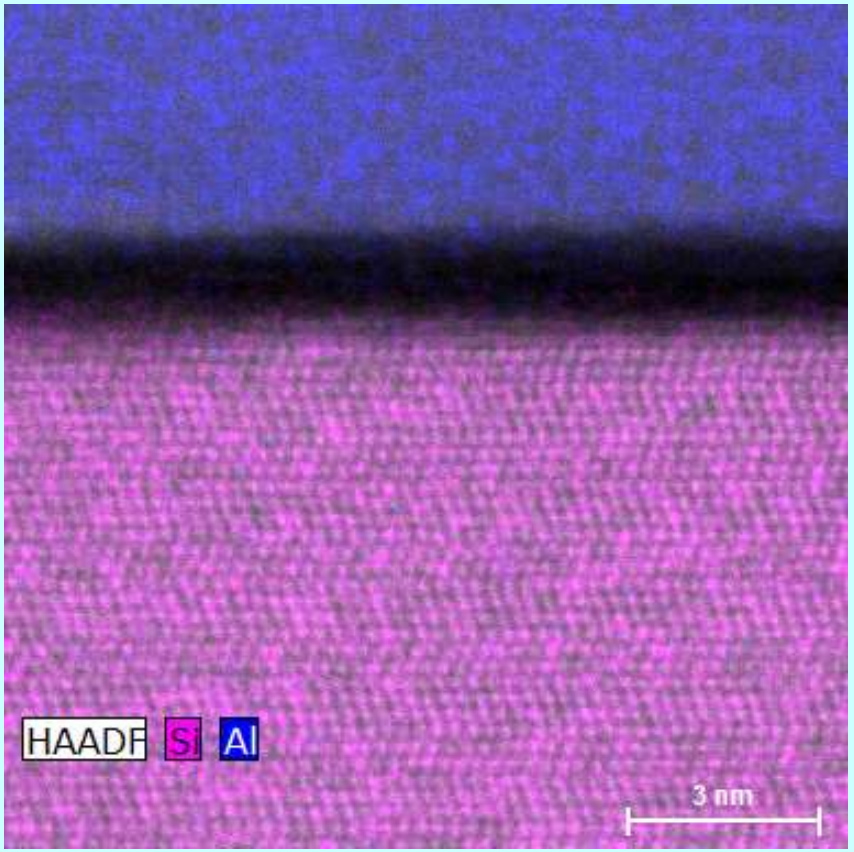
dislocation density

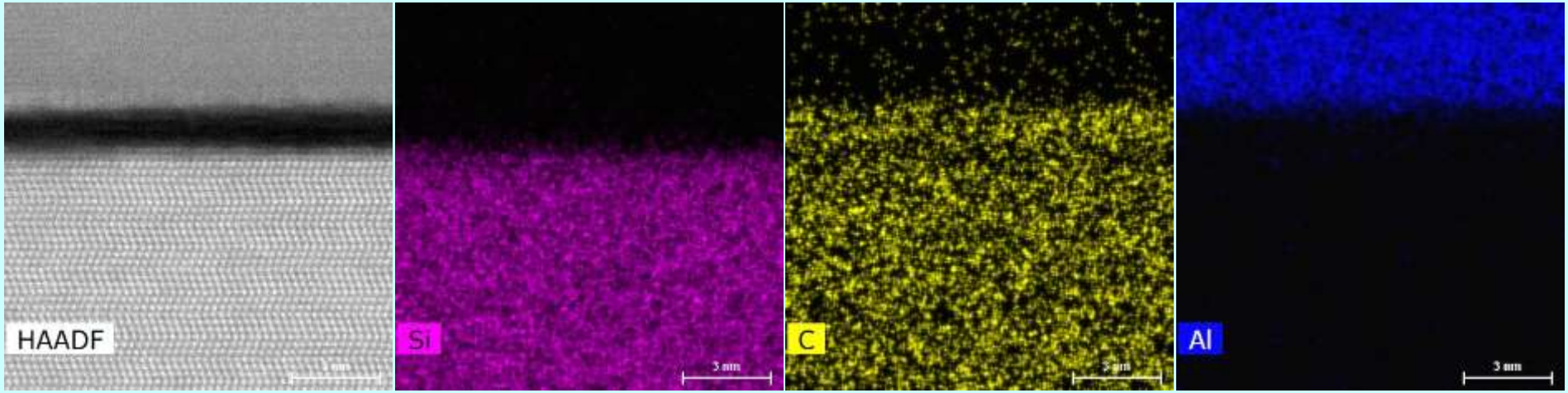
~3 x 10^9 cm^{-2}

A. Kovács, M. Duchamp, R.E. Dunin-Borkowski, R. Yakimova, P. L. Neumann, H. Behmenburg, B. Foltynski, C. Giesen, M. Heuken and B. Pécz**:** Graphoepitaxy of High-Quality GaN Layers on Graphene/6H–SiC, Advanced Materials Interfaces, 2 (2015) DOI: 10.1002/admi.201400230

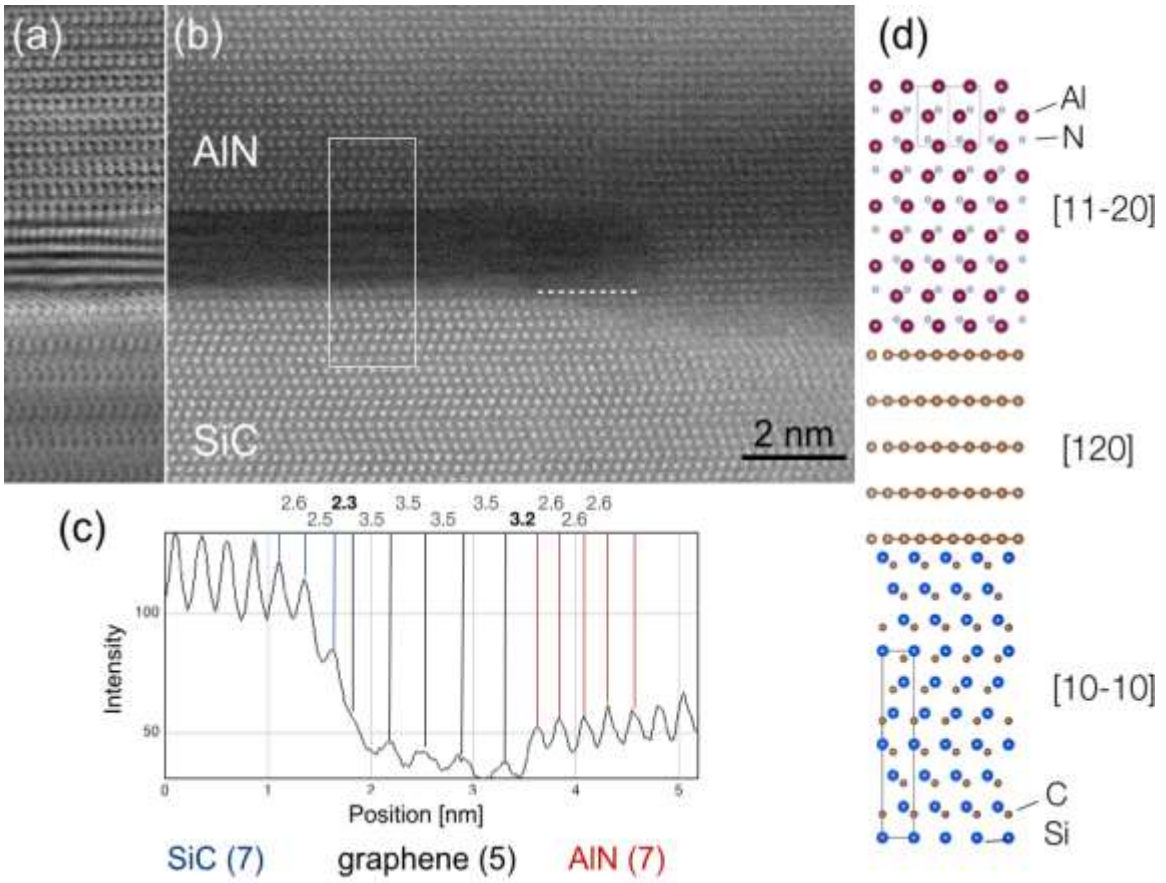
AlN growth on continuous graphene

Al and Si EDXS maps superimposed onto a HAADF STEM image



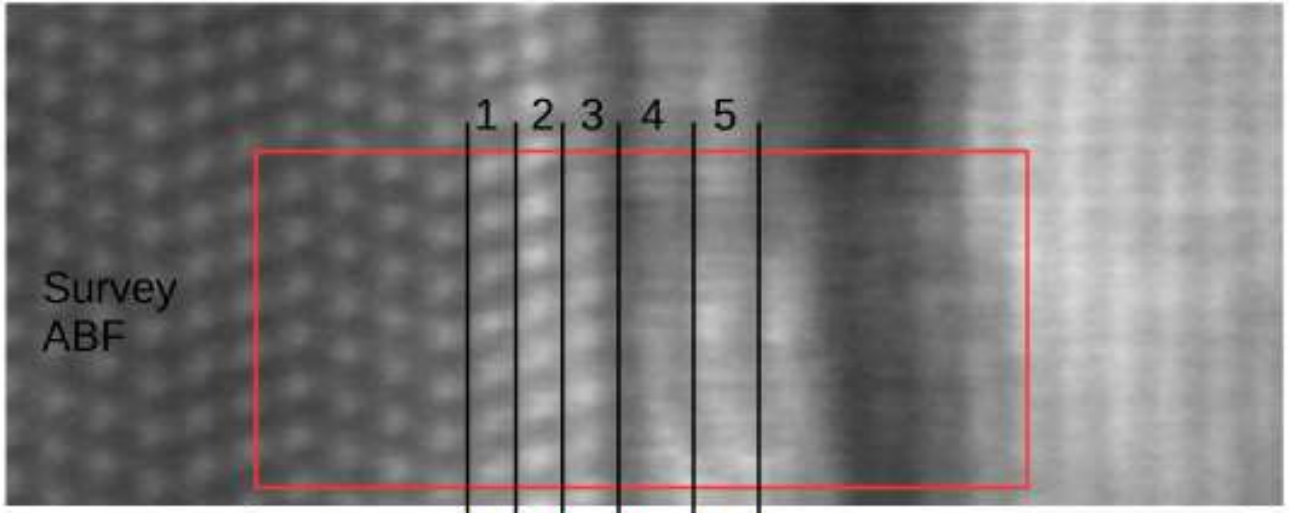


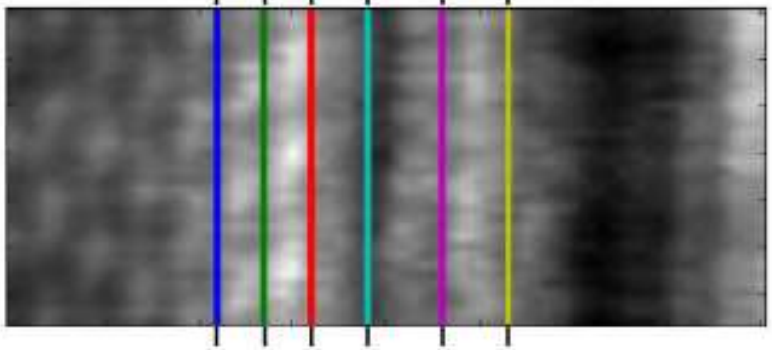
HAADF STEM image, Si, C and Al EDXS maps recorded using a FEI Titan ChemiSTEM at 200 kV.



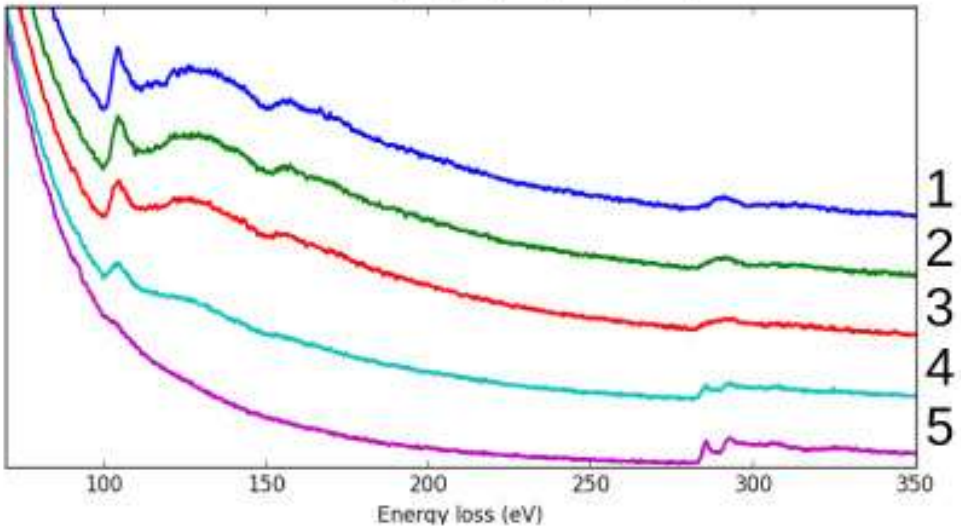
typically 3 layers of graphene, but sometimes 5 are observed

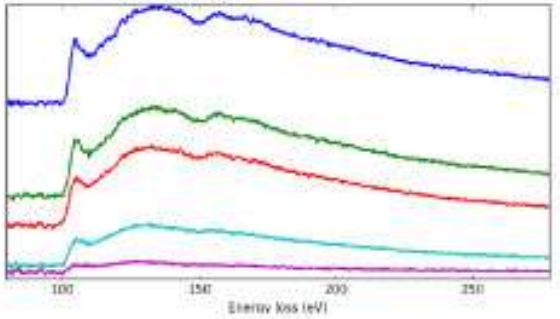
017 Interface

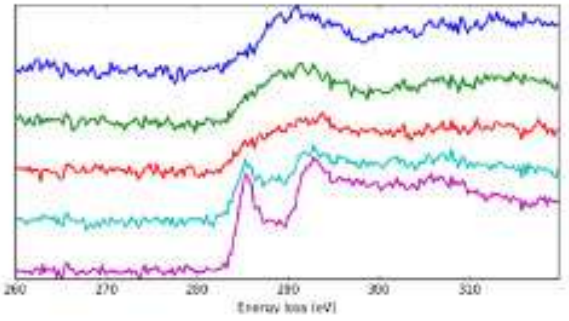


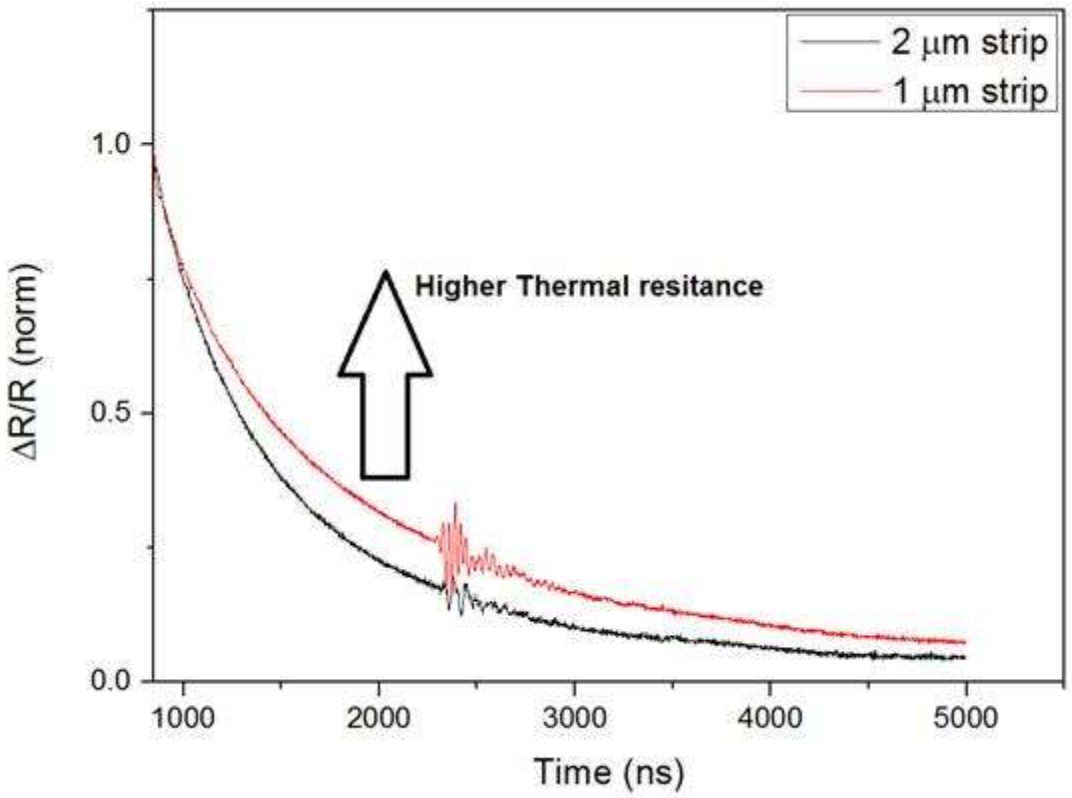


Carbon K edge
Layer 1 and 2: sigma only
Layer 3: soft pi and sigma
Layer 4 and 5: strong pi and sigma








2 μm strip
1 μm strip
Higher Thermal resitance
ΔR/R (norm)
1.0
0.5
0.0
1000
2000
3000
4000
5000
Time (ns)

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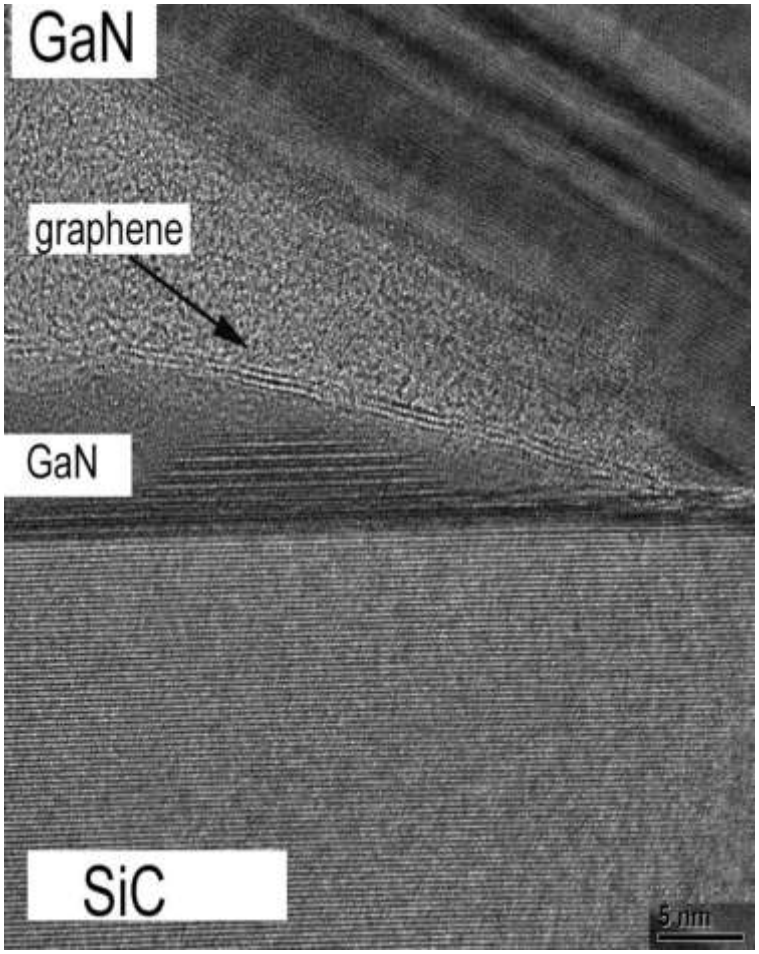
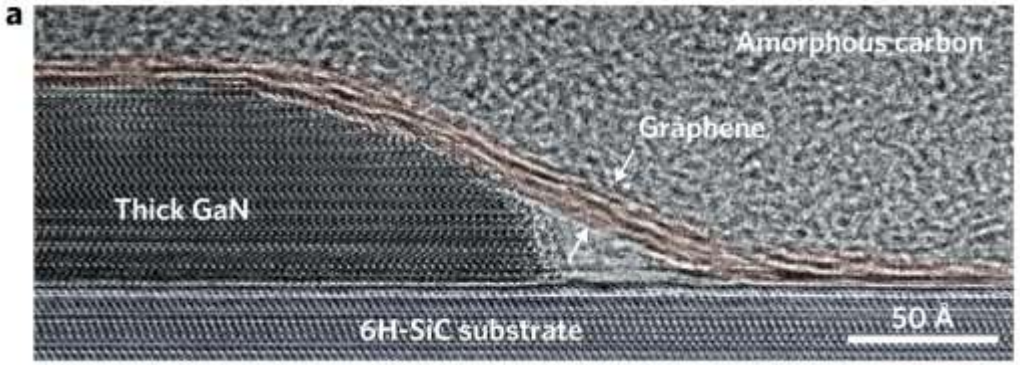
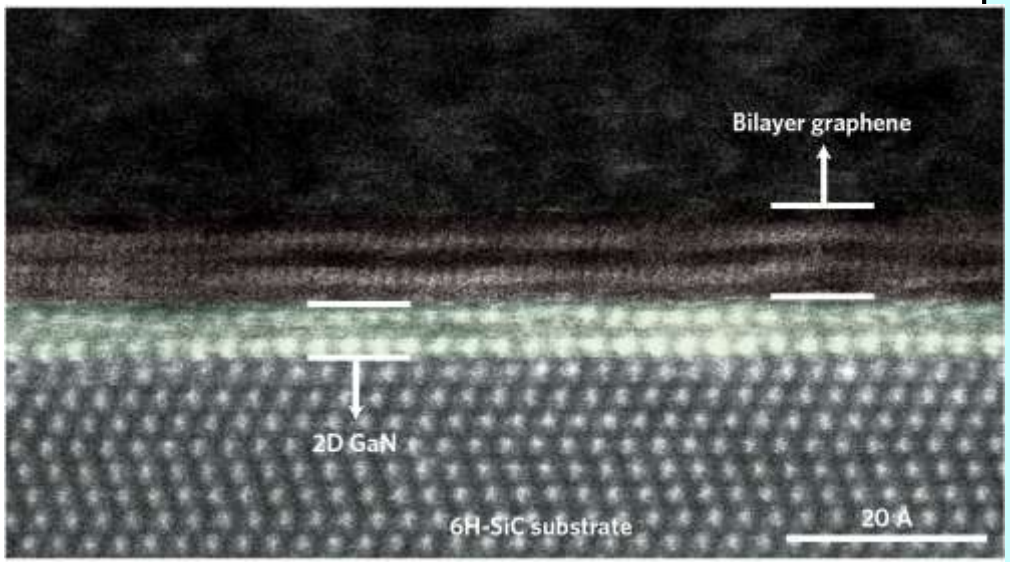
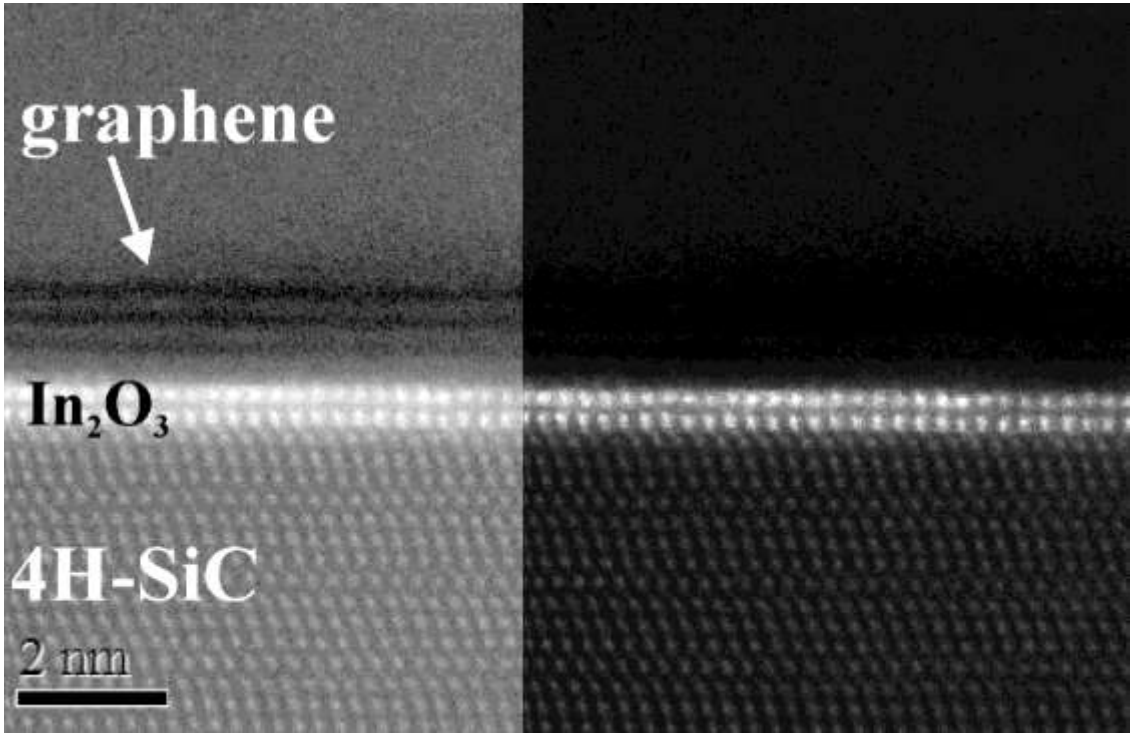
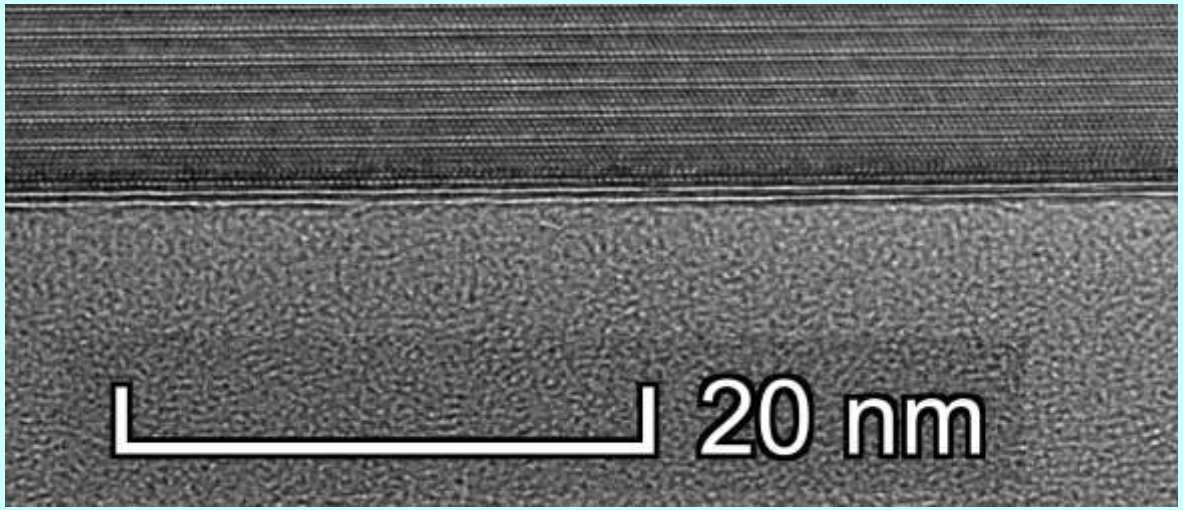


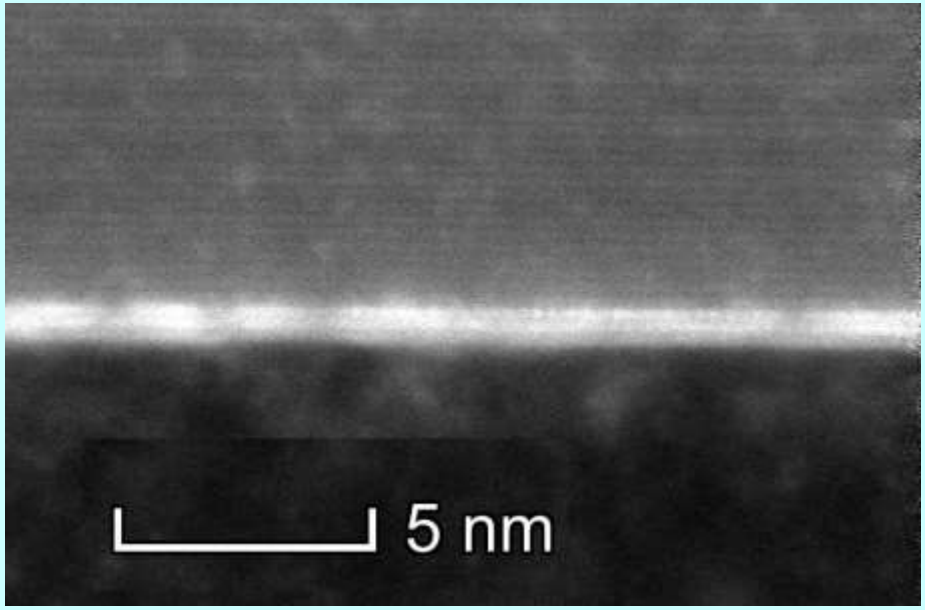


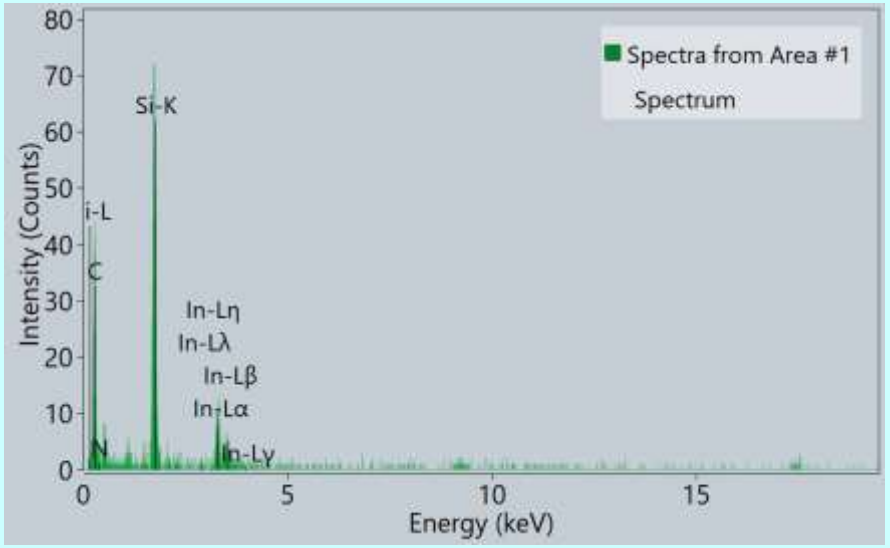




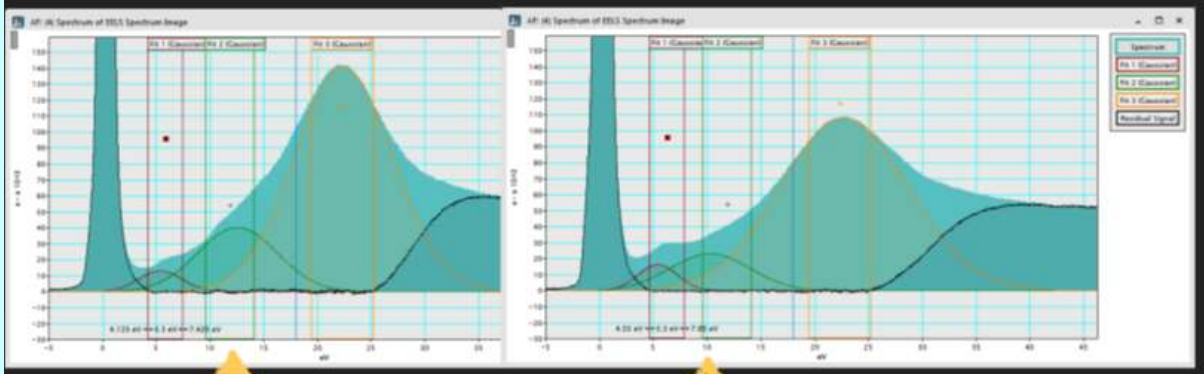
In2O3 2D semiconductor intercalated







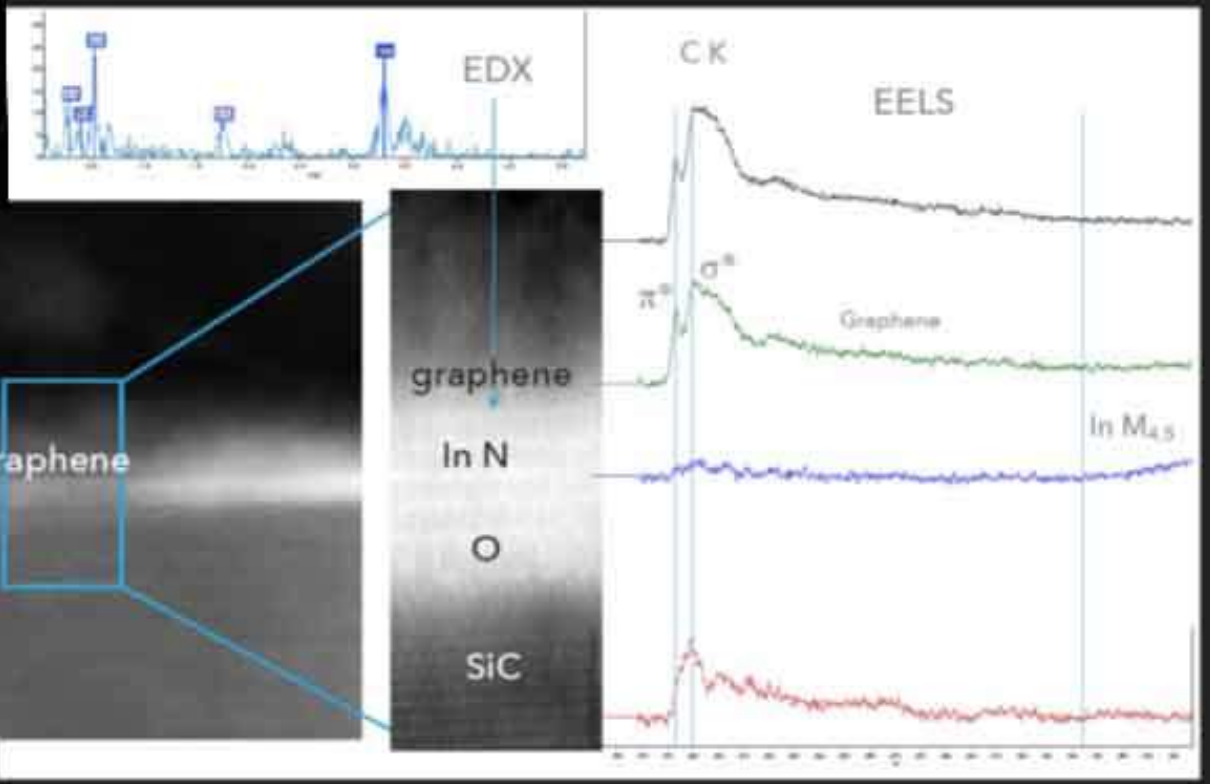
3 layers of InN



11.7eV

10eV

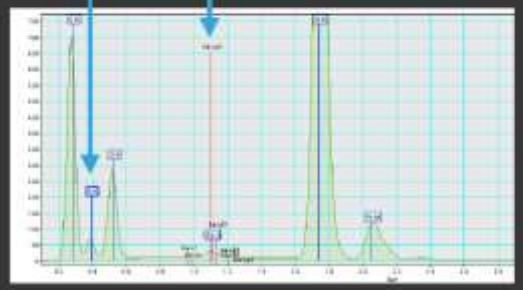
BEYOND NANO CATANIA

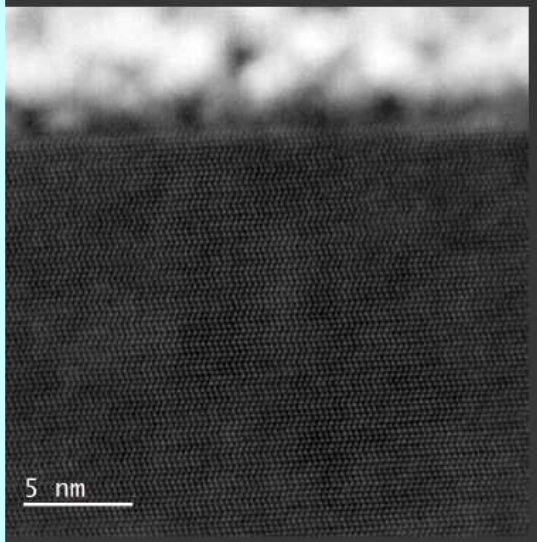


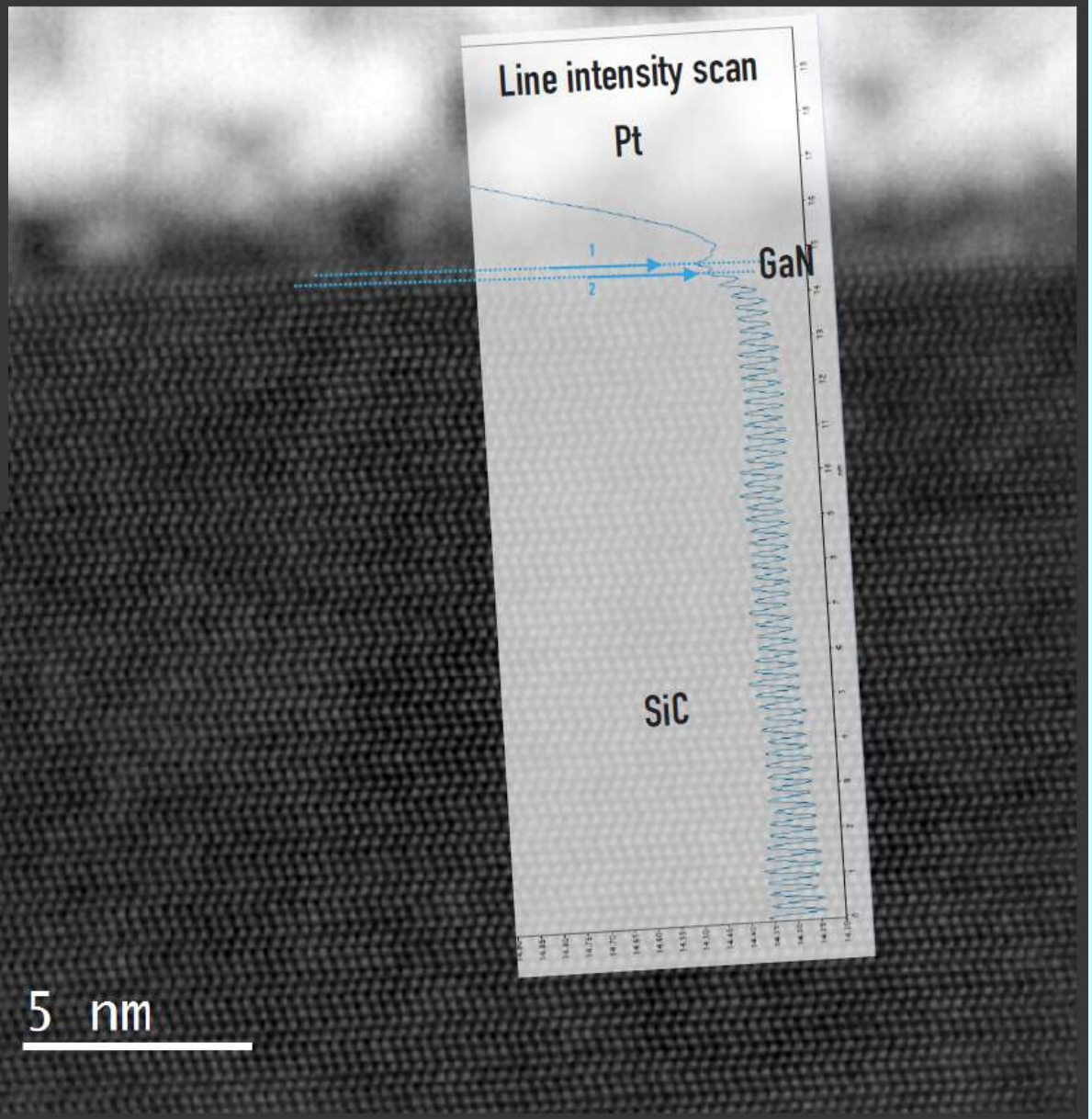
8C 8cm

HAADF Z-CONTRAST S/TEM @60KEV

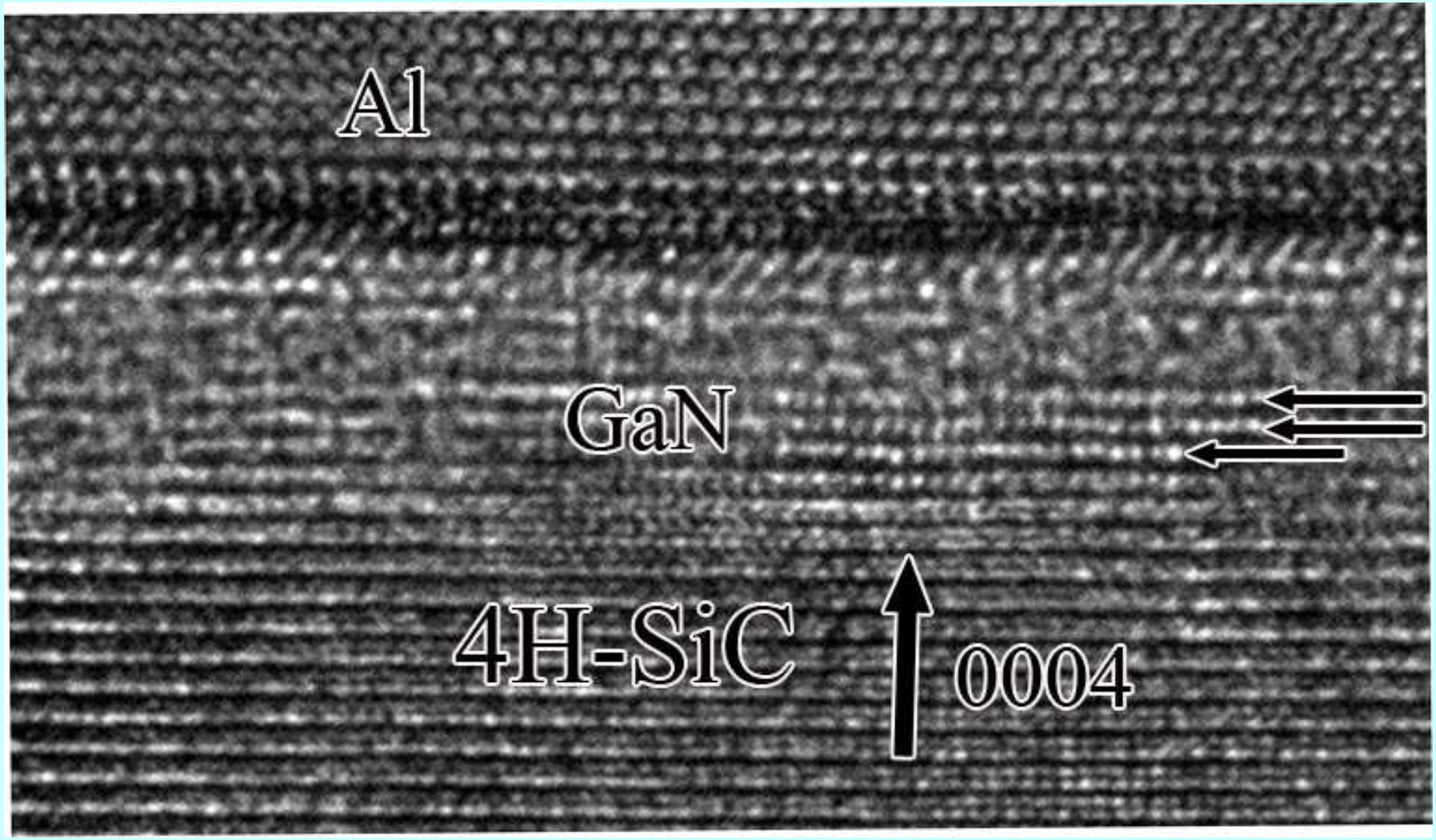
EDX spectrum integrated over the whole SI area shows Ga and N presence







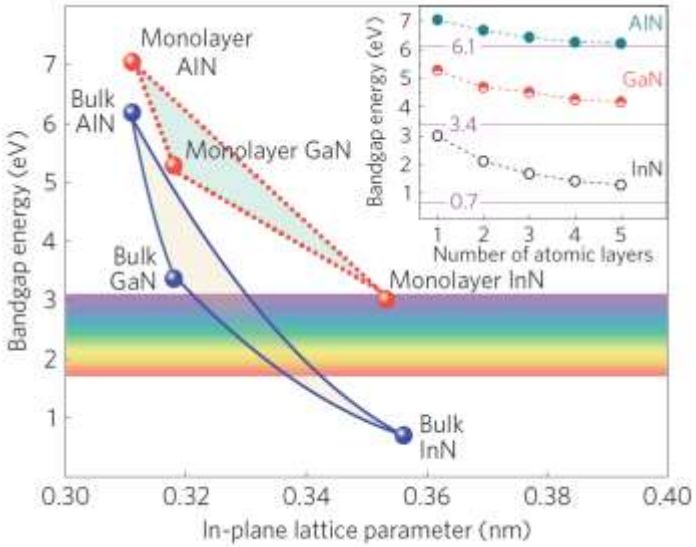
HRTEM



Summary and outlook:

Microscopy is useful in the research of compound semiconductors

2D nitrides will be grown with different properties (bandgap)



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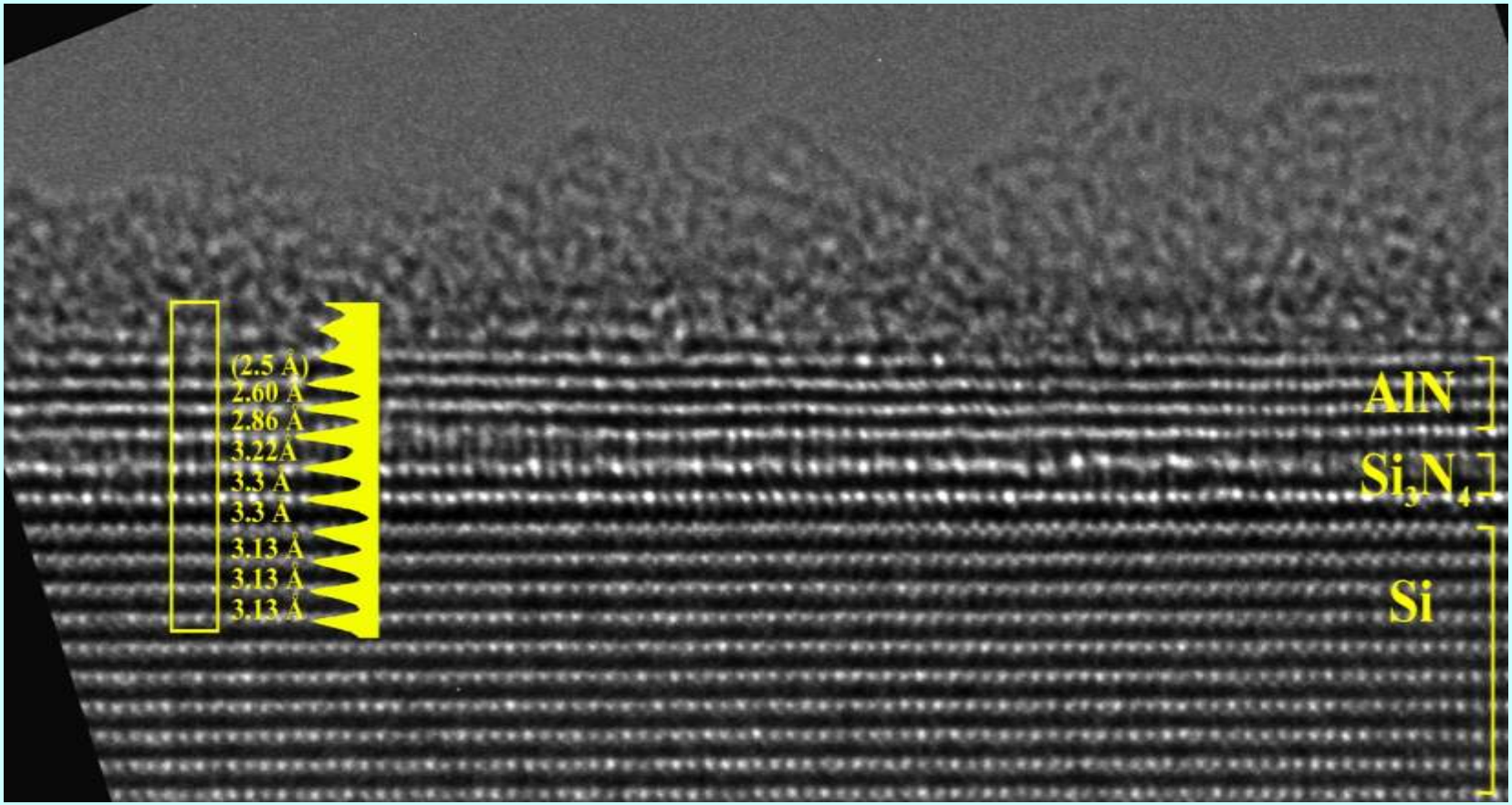
VEKOP-2.3.3-15-2016-00002 of the European Structural and Investment Funds



3 eV
2.2 eV

V. G. Mansurov, Yu. G. Galitsyn, T. V. Malin, S. A. Teys, E. V. Fedosenko, A. S. Kozhukhov, K. S. Zhuravlev, Ildikó Cora, Béla Pécz, Semiconductors, 2018, Issue 12

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Thank you for your attention!

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