



Characterization of dislocations in bulk GaN grown by HVPE

K.Xu

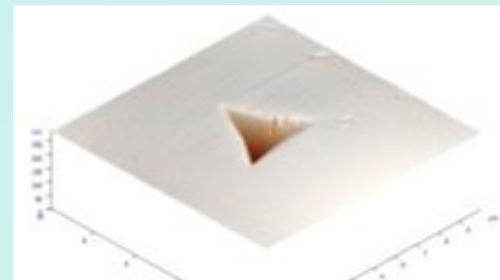
Suzhou Institute of Nano-tech and Nano-bionics, CAS
Suzhou Nanowin Science and Technology Co. Ltd

kxu2006@sinano.ac.cn

Photovoltaic properties of GaN around dislocation local



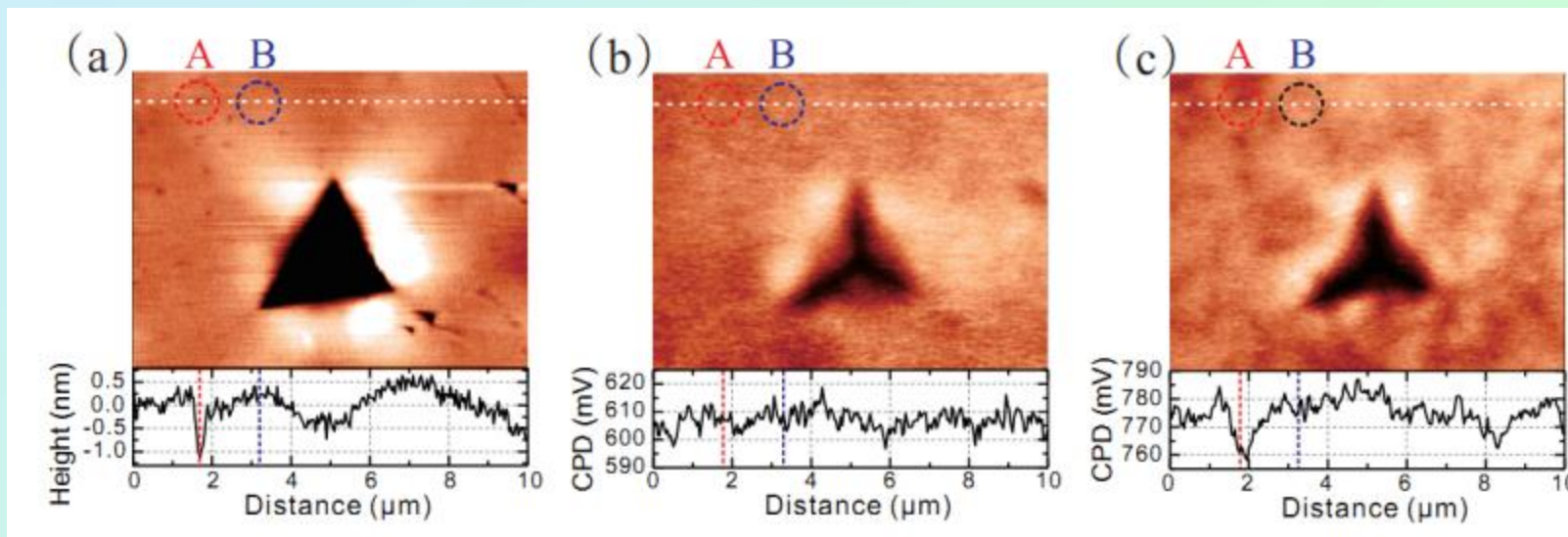
HVPE native n-GaN with indentation



Topography (10 μ m)

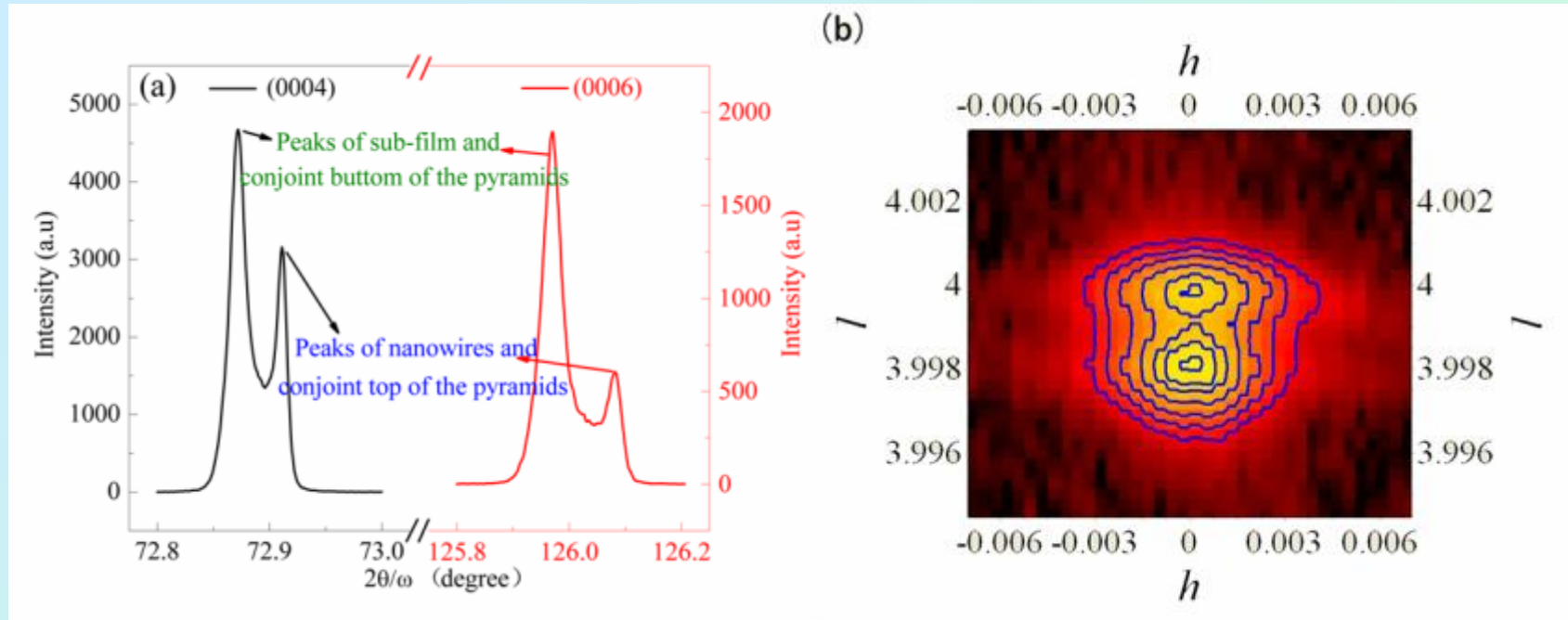
Dark surface potential (10 μ m)

SPV @ 360nm illumination



25mV

Structure and stress states



Two peaks appear near the (0004) and (0006) Bragg angles

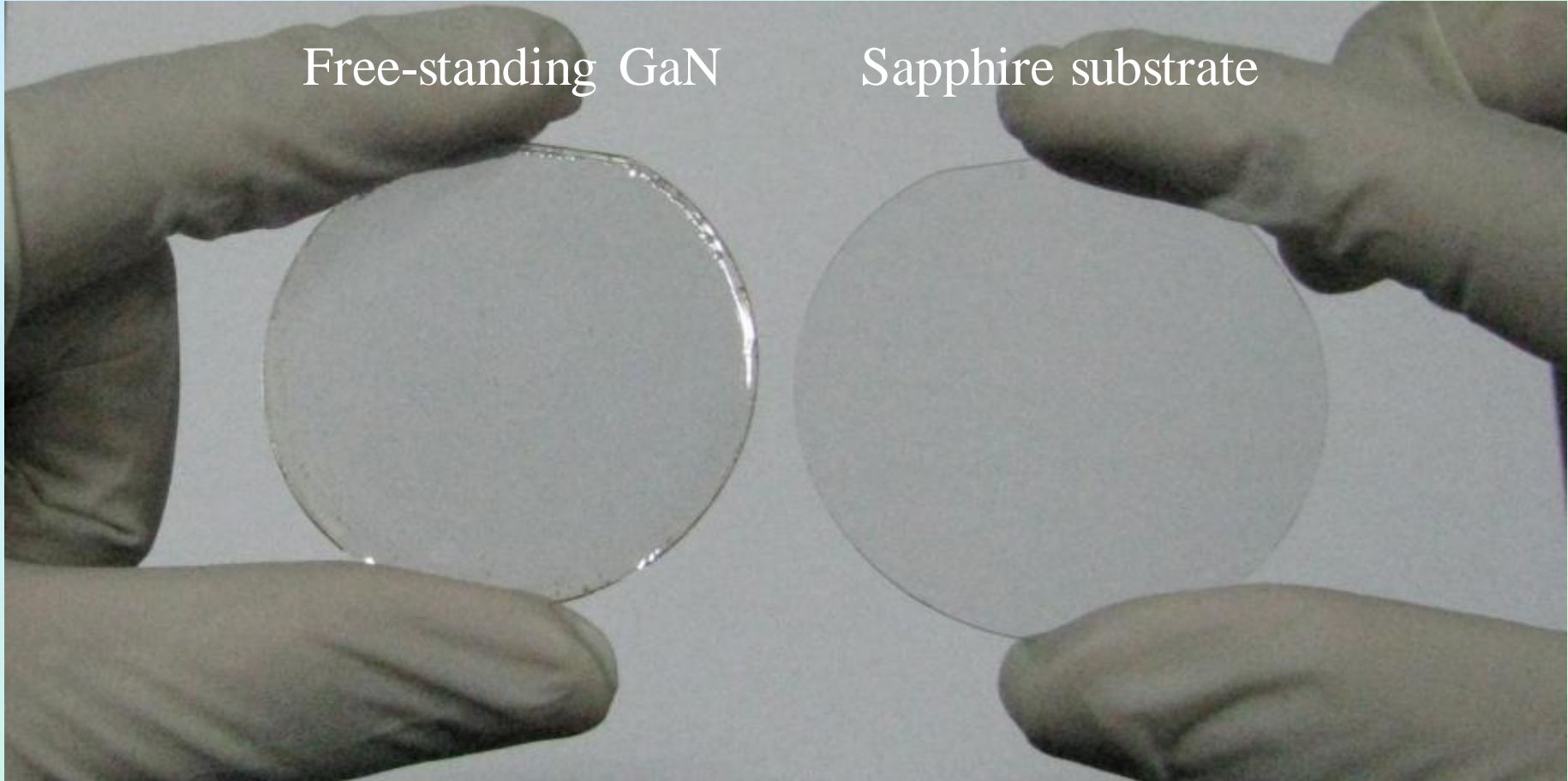
Compared with stress-free bulk GaN ($c_0 = 5.1850 \text{ \AA}$, $a_0 = 3.1890 \text{ \AA}$), the corresponding lattice constants ($c_1 = 5.1885 \text{ \AA}$, $a_1 = 3.1879 \text{ \AA}$, and $c_2 = 5.1853 \text{ \AA}$, $a_2 = 3.1889 \text{ \AA}$) of the two set peaks indicate that a part of the structure is almost stress-free while the other is compressed.

Self-separation of GaN from sapphire

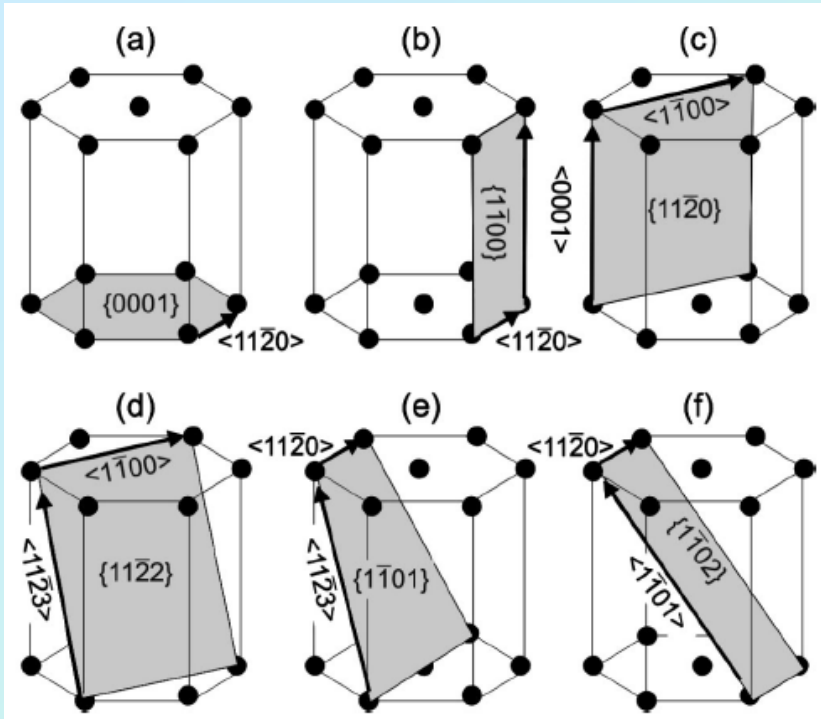


Free-standing GaN

Sapphire substrate



Stress field applied to dislocation in GaN



	Slip system	$\cos\lambda$	
	Basal plane	$\{0001\}\langle 11-20\rangle$	0
	Prism plane	$\{1-100\}\langle 11-20\rangle$	0
		$\{1-100\}\langle 0001\rangle$	0
		$\{11-20\}\langle 0001\rangle$	0
		$\{11-20\}\langle 1-100\rangle$	0
	Pyramidal planes	$\{11-22\}\langle 1-100\rangle$	0
		$\{1-101\}\langle 11-20\rangle$	0
		$\{1-102\}\langle 11-20\rangle$	0
		$\{11-22\}\langle 11-23\rangle$	0.524
		$\{1-101\}\langle 11-23\rangle$	0.454
		$\{1-102\}\langle 1-101\rangle$	0.730

Appl. Phys. Lett. **83**, 5187 (2003)

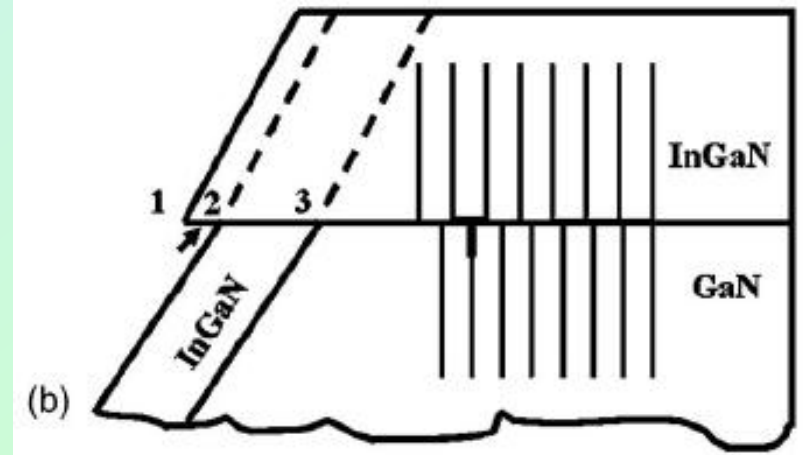
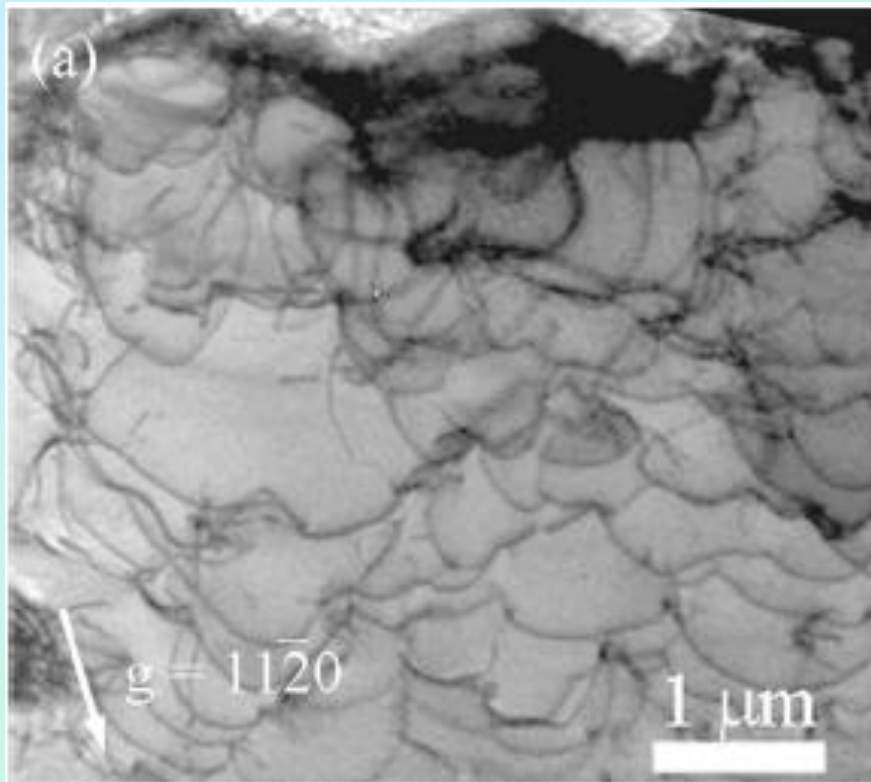
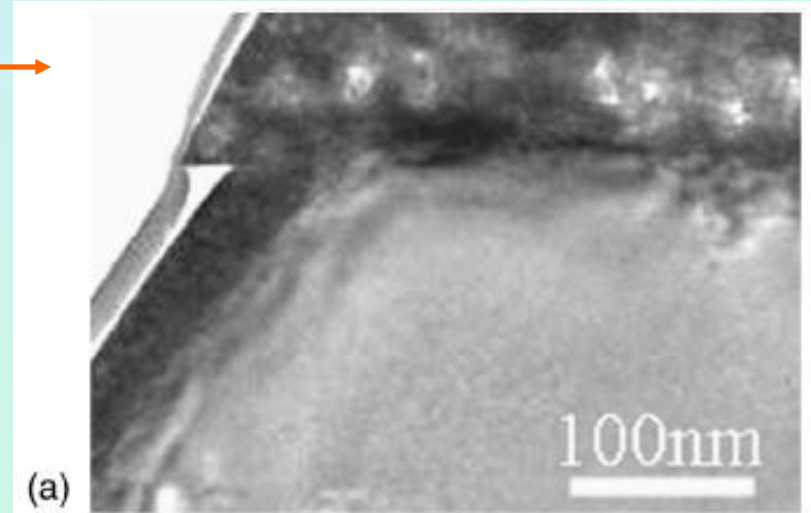
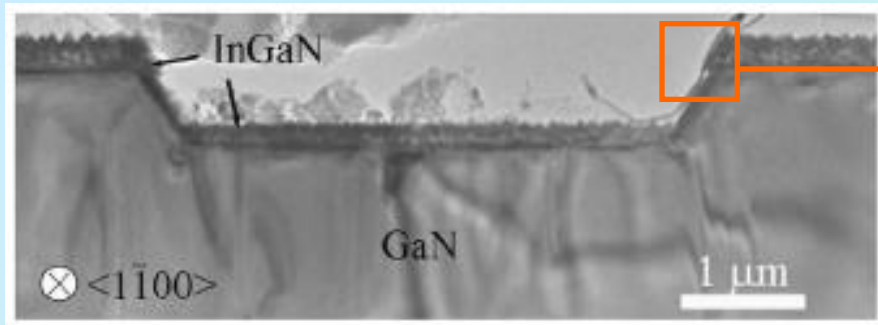
$$F_l = \frac{Gb^2}{4\pi} \frac{1-\nu \cos^2 \alpha}{(1-\nu)} \left[\ln\left(\frac{h}{b}\right) + 1 \right] \quad F_a = 2Gbh\varepsilon \left(\frac{1+\nu}{1-\nu} \right) \cos \lambda$$

$$F_p = 2Gbh \sec \phi \left(\frac{1-\nu \cos^2 \alpha}{1-\nu} \right) \omega \times \exp\left(\frac{-2\pi d(1-\nu \cos^2 \alpha)\omega}{(1-\nu)b} \right)$$

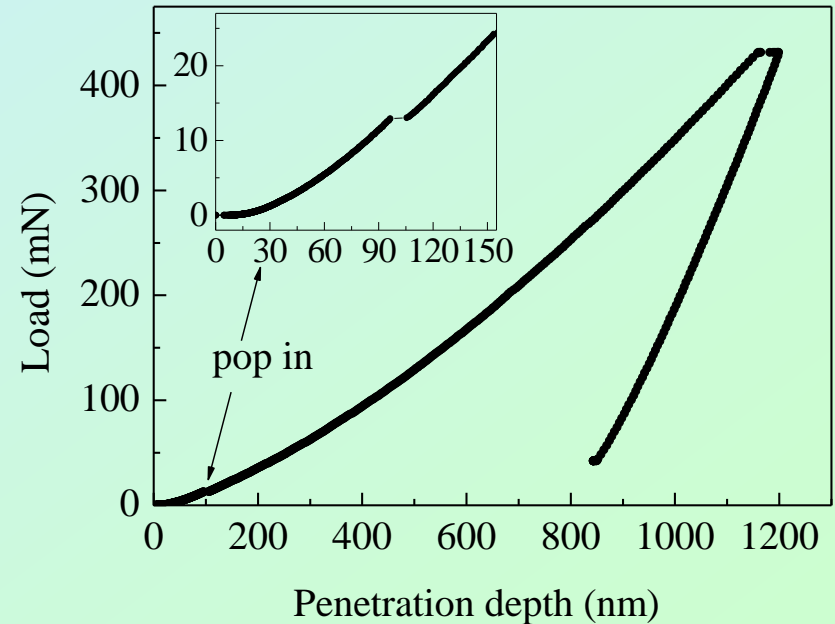
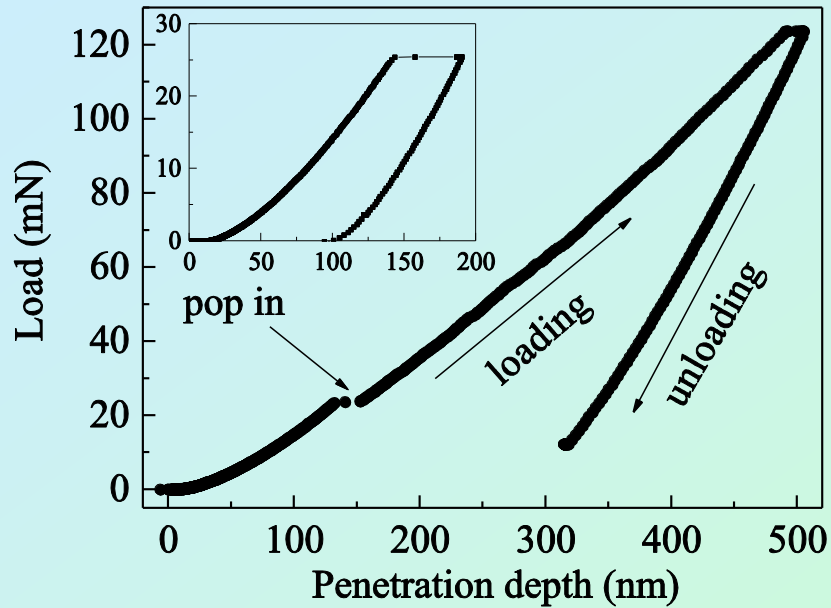
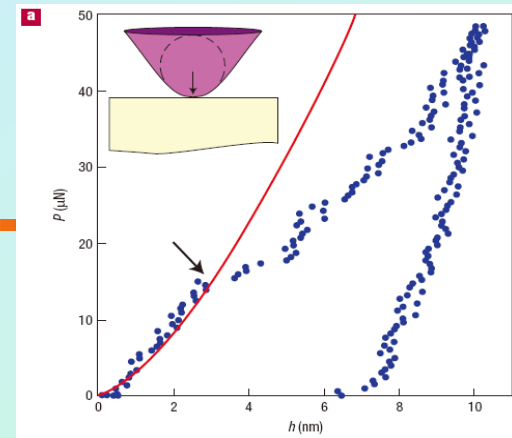
$$F_a = F_l + F_p$$

$$F_{net} = F_a - F_l - F_p$$

Misfit dislocation slip in InGaN/GaN heterostructure

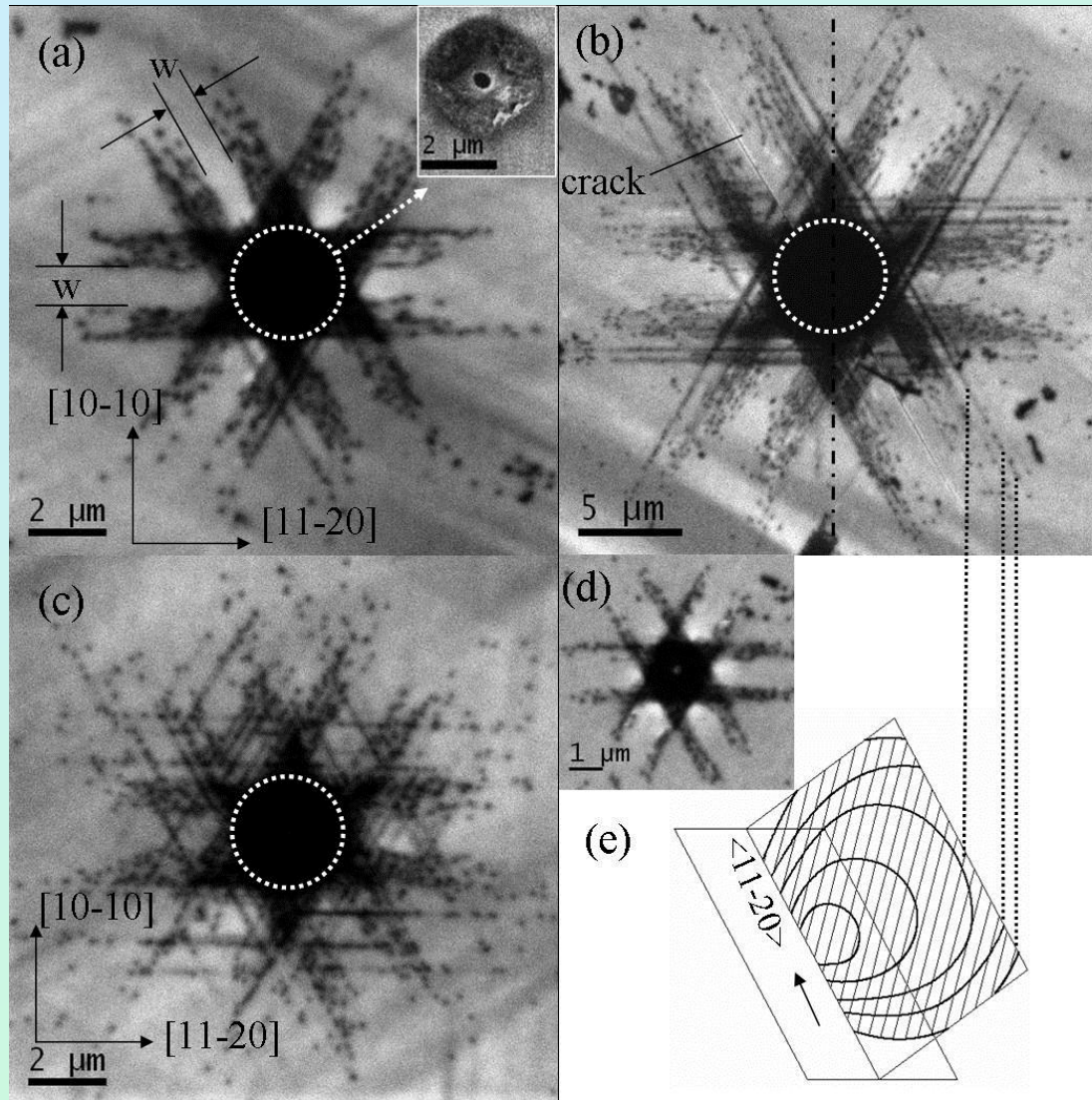


Plastic deformation of GaN

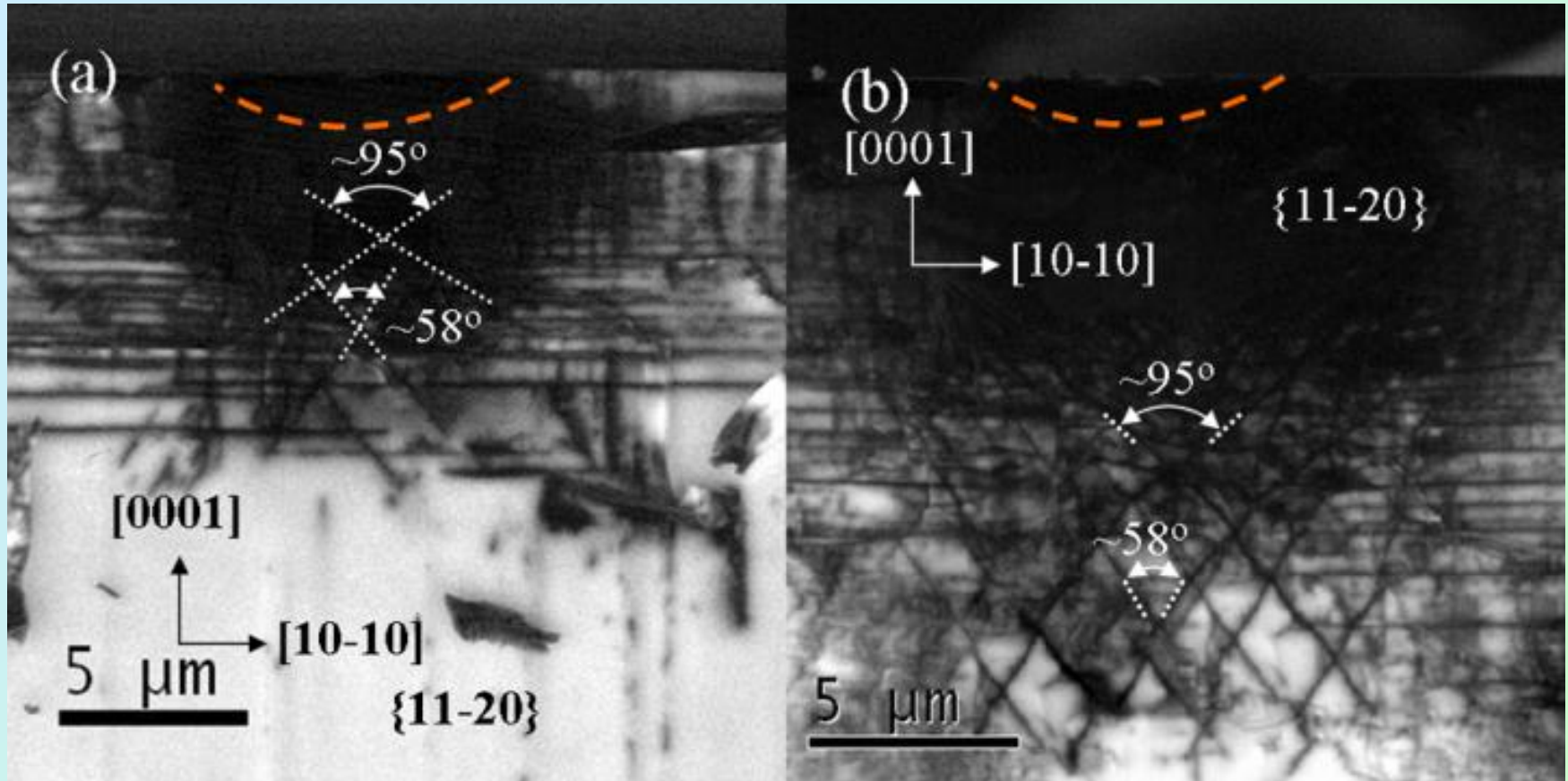


J. Huang, K. Xu et al. Appl. Phys. Lett. 98, 221906 (2011)

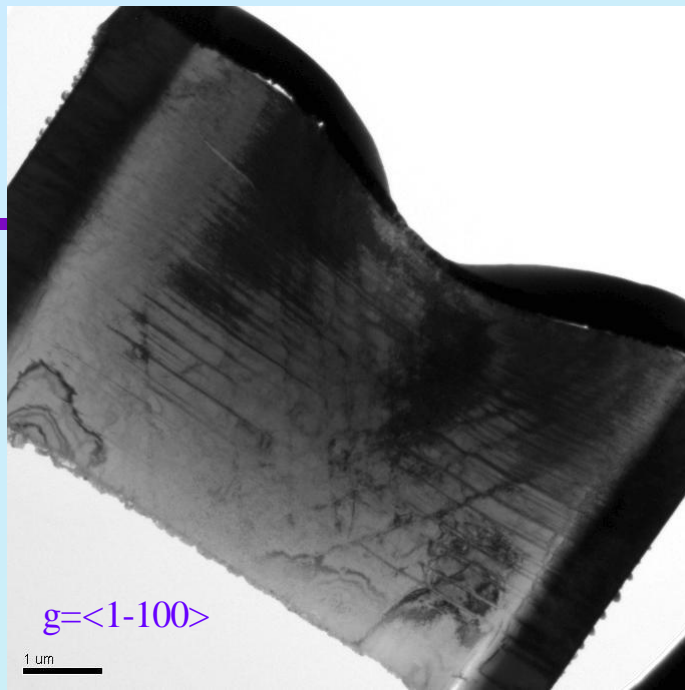
Dislocation slip during GaN deformation



Cross-section observation by CL and SEM



TEM

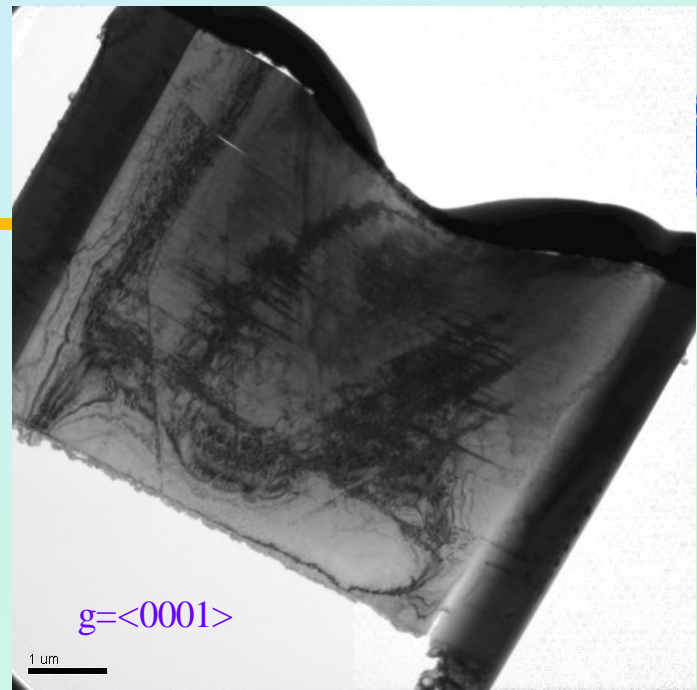


$g=\langle 1-100 \rangle$

1 um

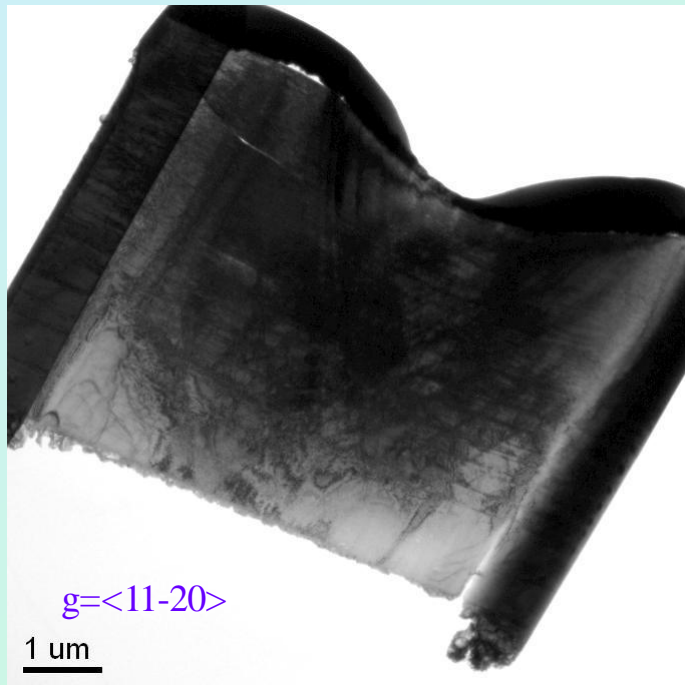
$\{10-11\}$

$\{0001\}$



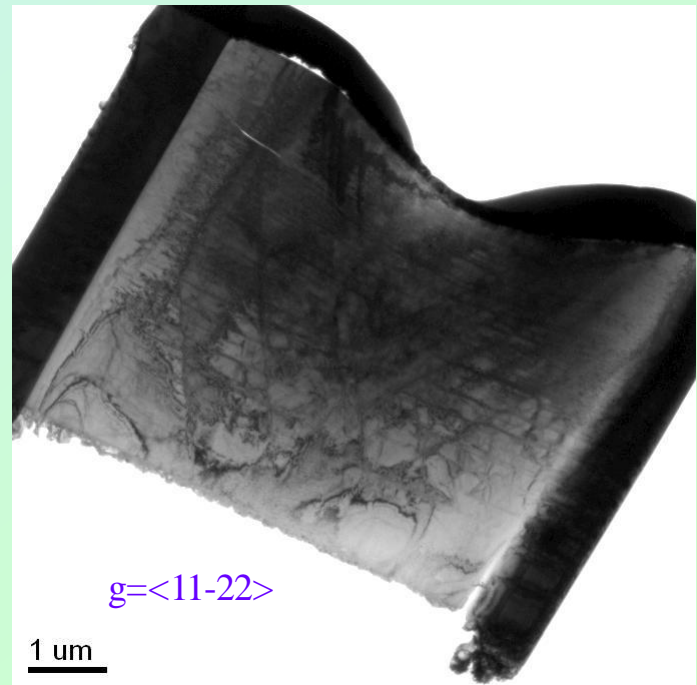
$g=\langle 0001 \rangle$

1 um



$g=\langle 11-20 \rangle$

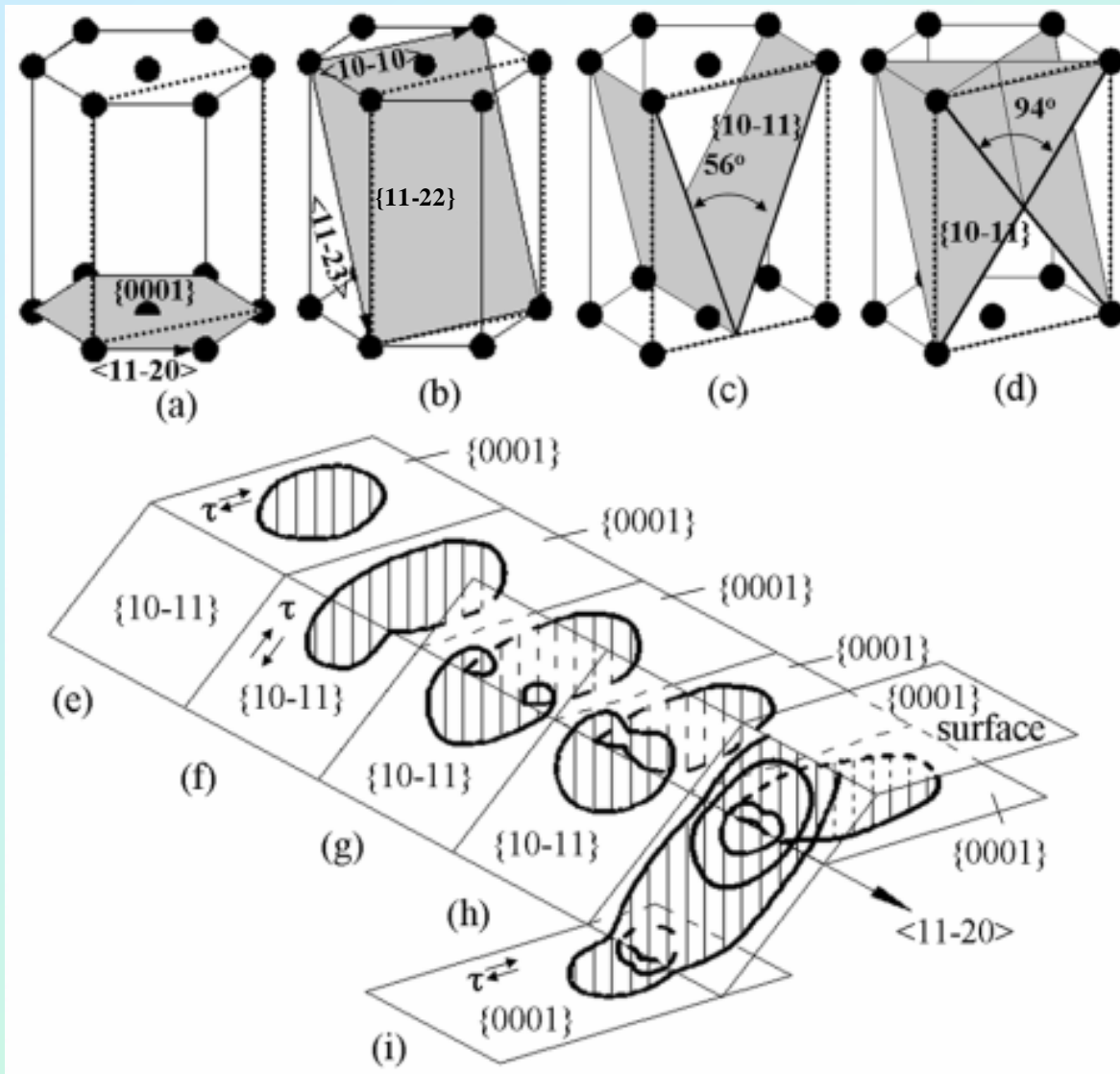
1 um



$g=\langle 11-22 \rangle$

1 um

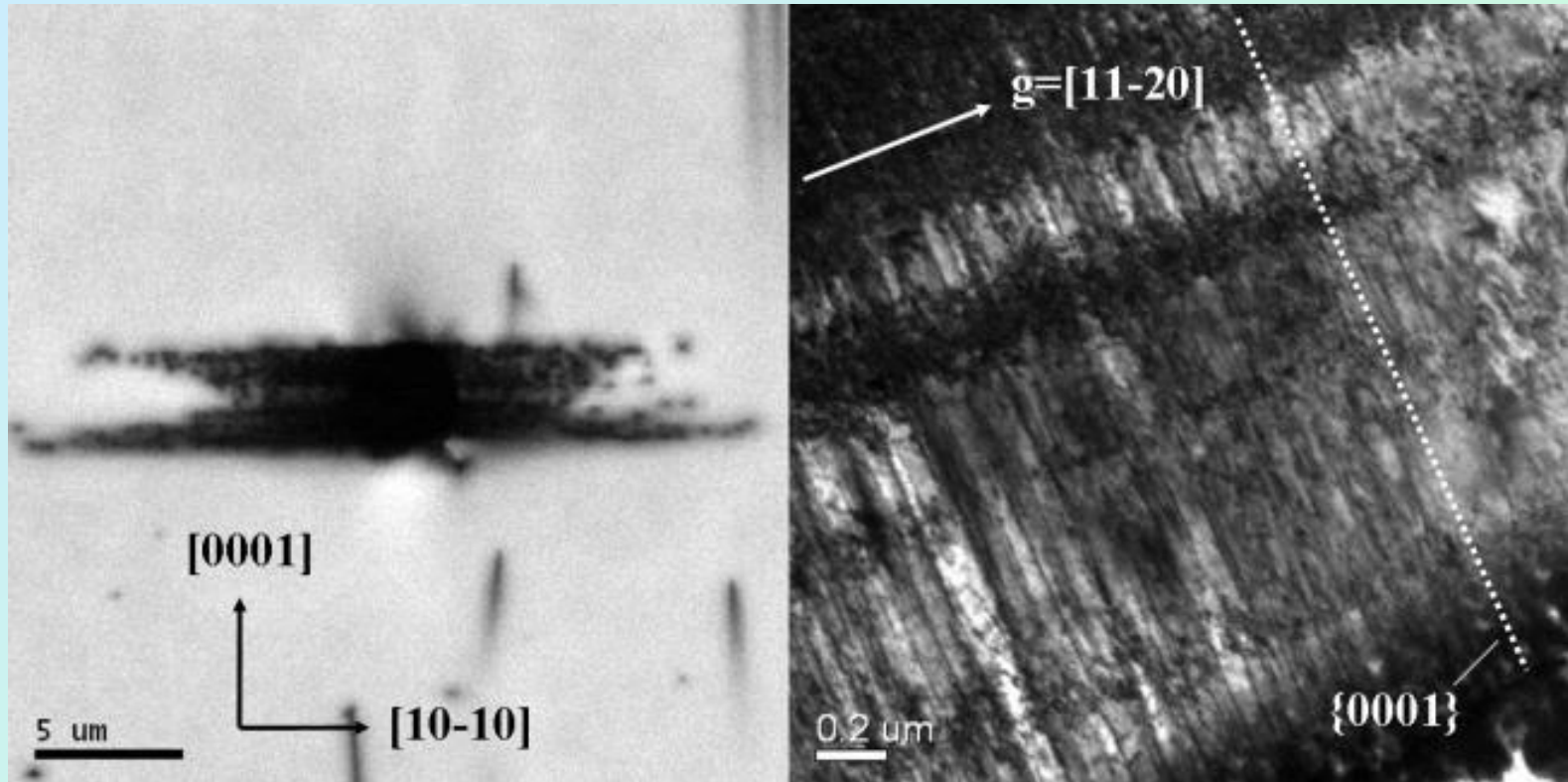
Dislocation multiplication in GaN



GaN局域塑性变形的各向异性

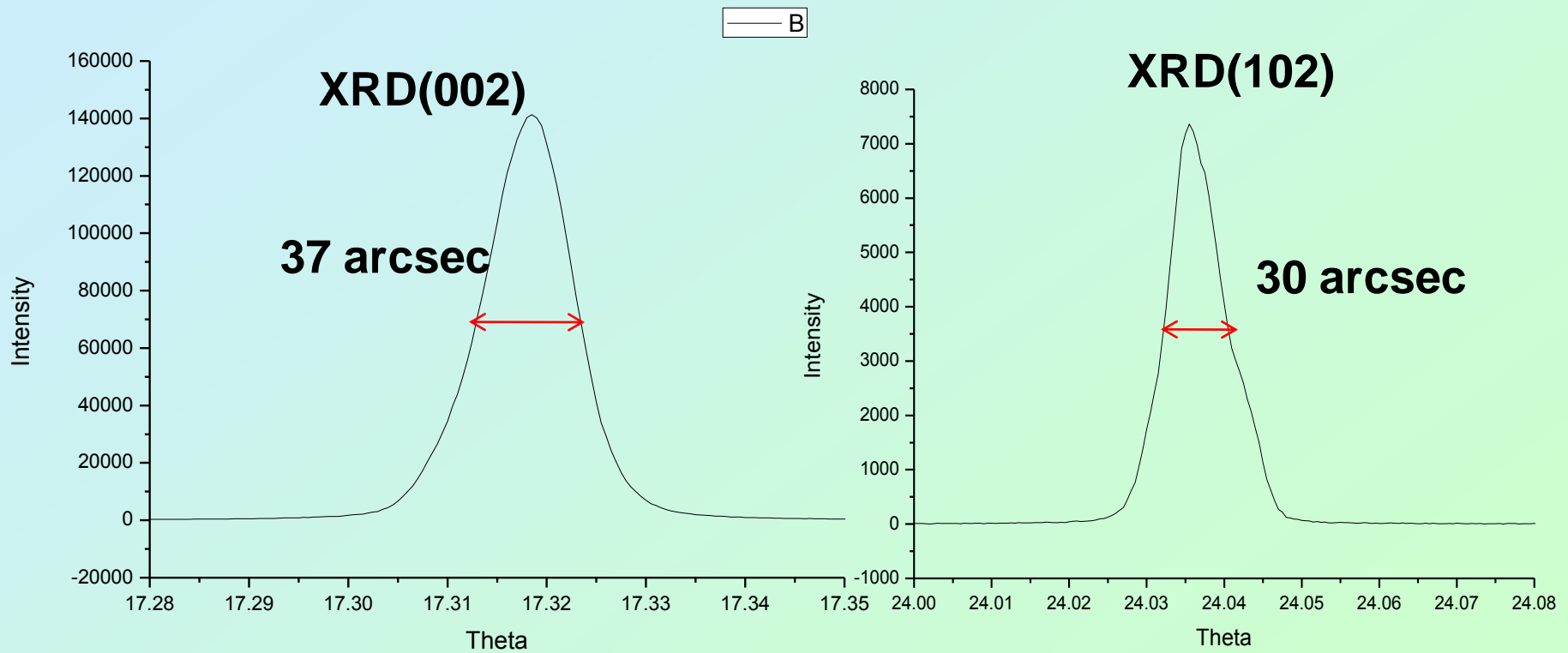


a面的GaN的阴极荧光图和透射电镜图



在C面的GaN上的塑性变形的位错主要滑移面是 $\{0001\}$ 和 $\{10-11\}$ ，而在非极性面GaN上的塑性变形的位错主要滑移面是 $\{0001\}$ ，从而导致其弹塑性力学性质的明显差异。

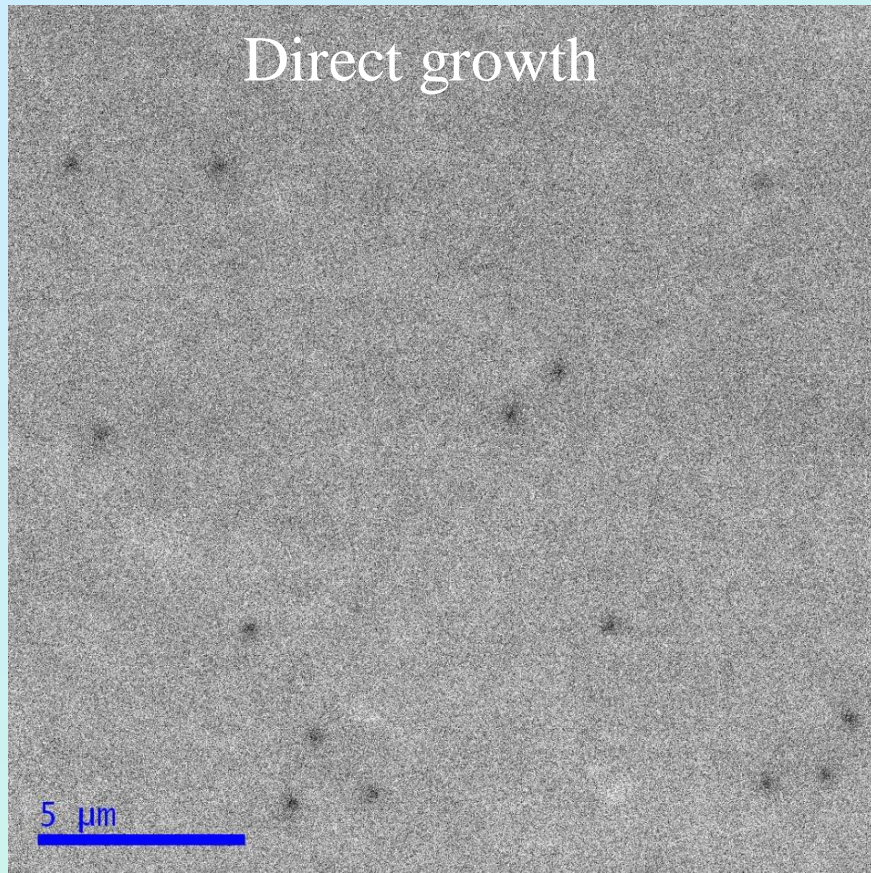
XRD characterization of GaN substrate



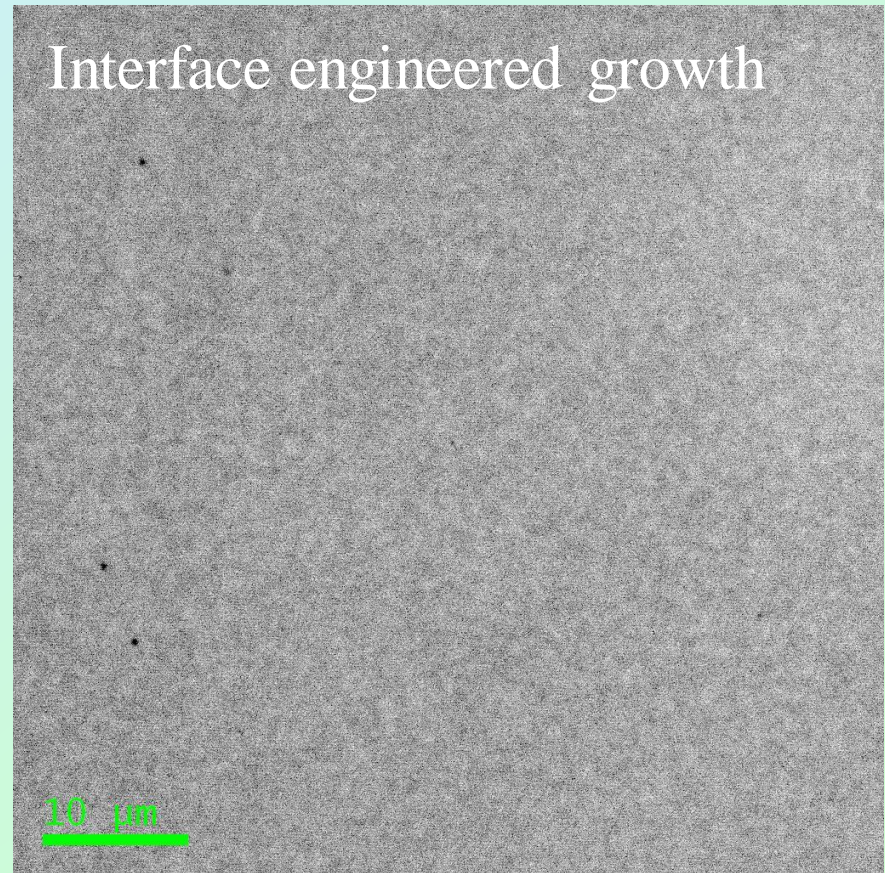
CL characterization of GaN substrate



Panchromatic CL image

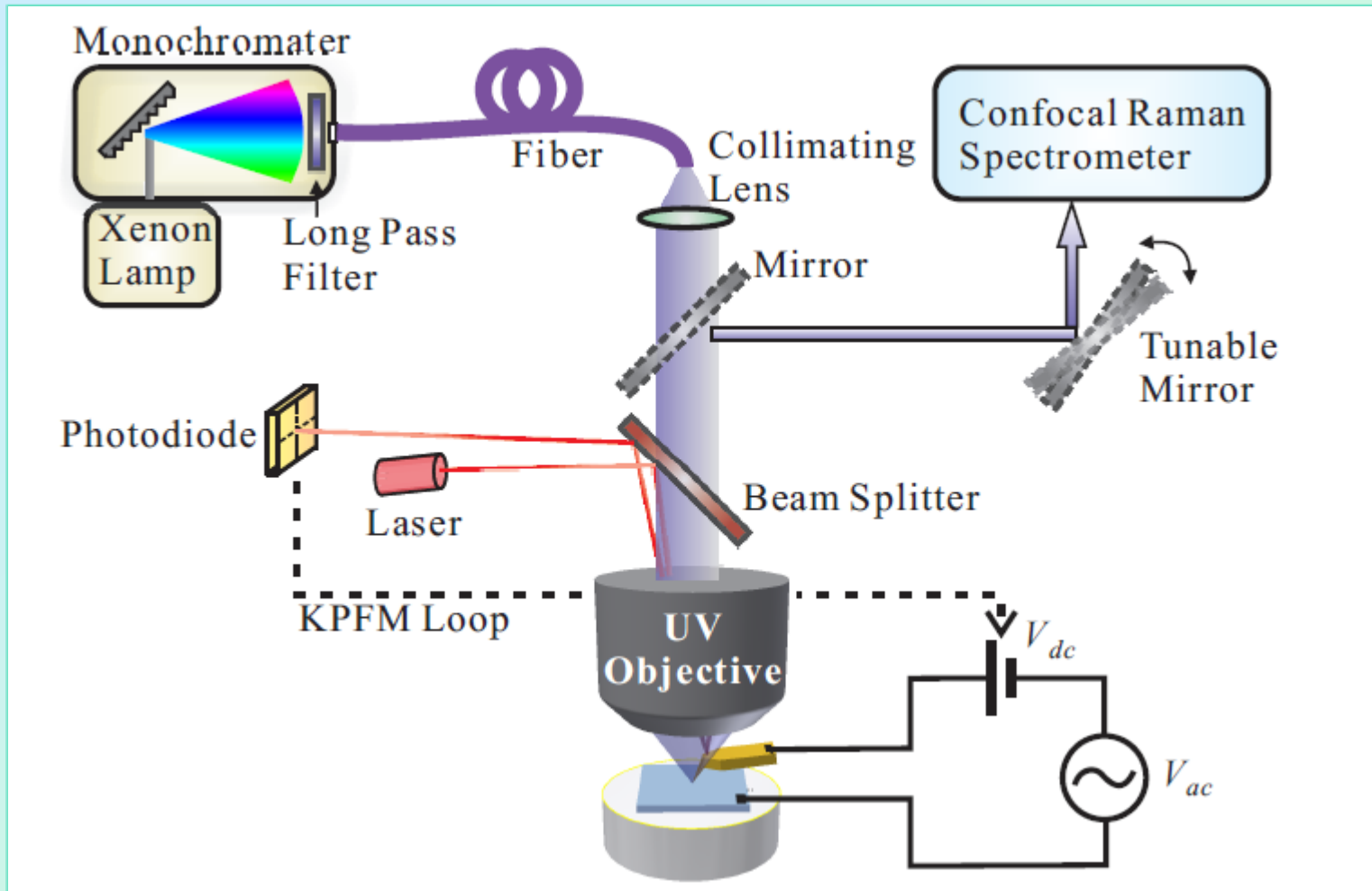


Panchromatic CL image



Average dislocation density: $<1.0 \times 10^5 \text{cm}^{-2}$

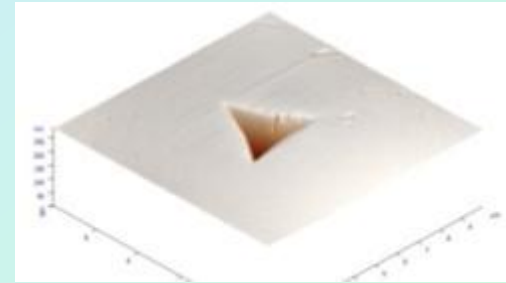
Experiment setup for single dislocation characterization



Experiment measurement of photovoltaic property around a single dislocation emerged site



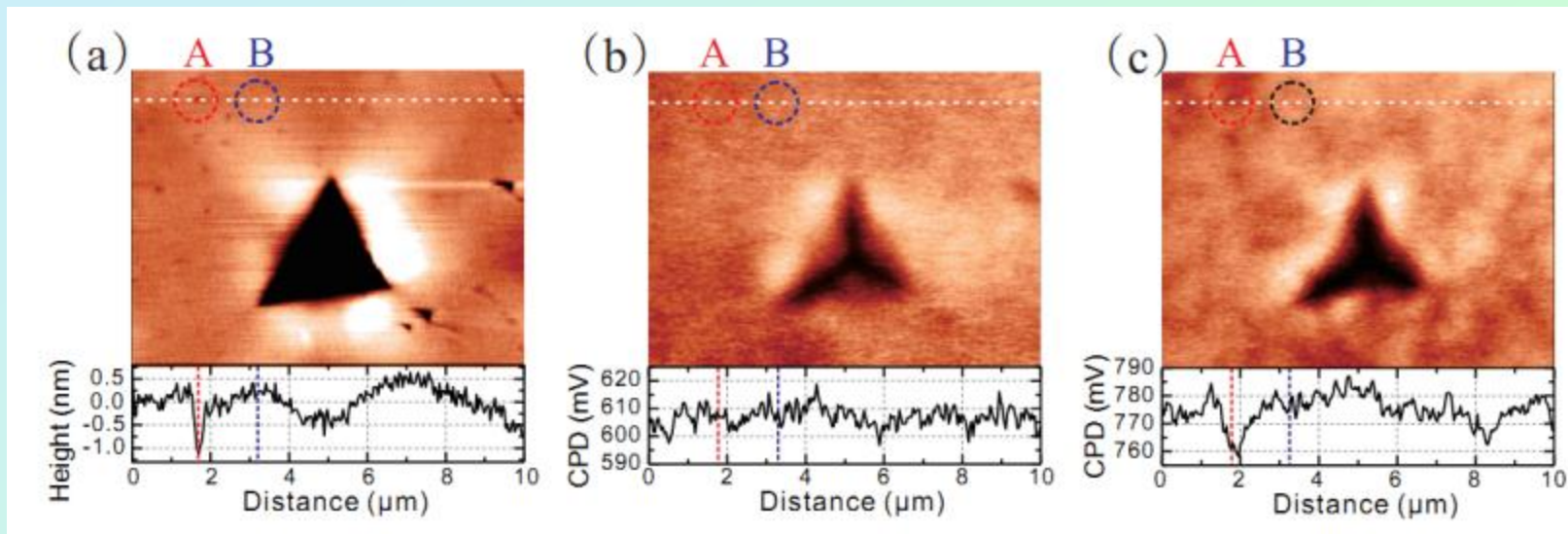
HVPE native n-GaN with indentation



Topography (10 μ m)

Dark surface potential (10 μ m)

SPV @ 360nm illumination



Surface recombination rate, experiment and simulated results

