Evaluation of 4H-SiC epitaxial layers by synchrotron x-ray topography

CRIEPI

Isaho Kamata

Central Research Institute of Electric Power Industry (CRIEPI)

Contents

CRIEPI

Background in electric power field

Properties of SiC

Present status of SiC

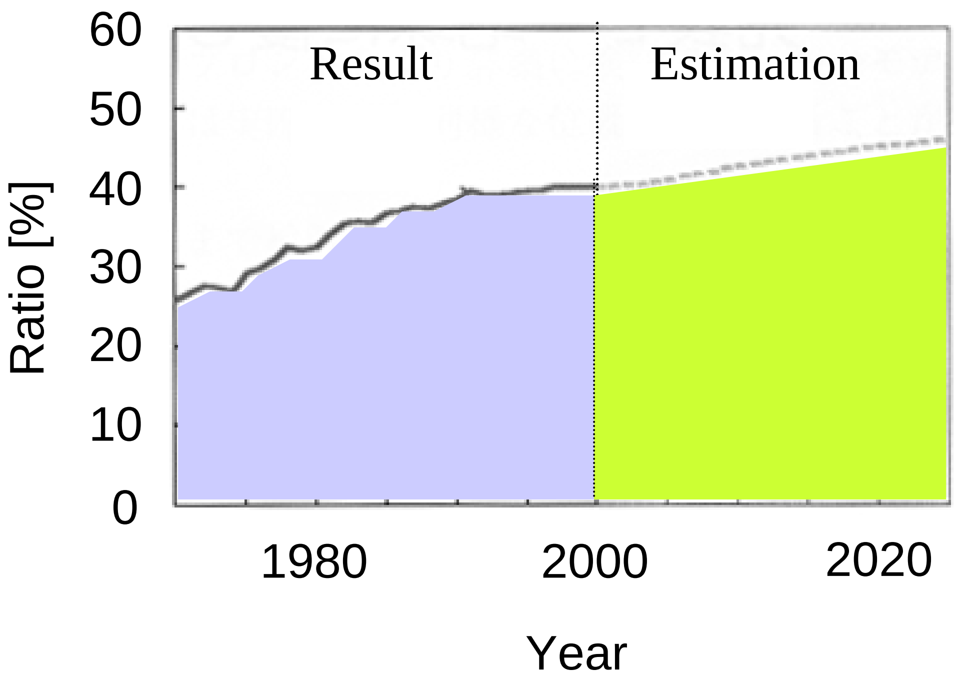
Evaluation of defects -KOH etching

Evaluation of defects -X-ray topography

Summary

Background in electric power field

CRIEPI

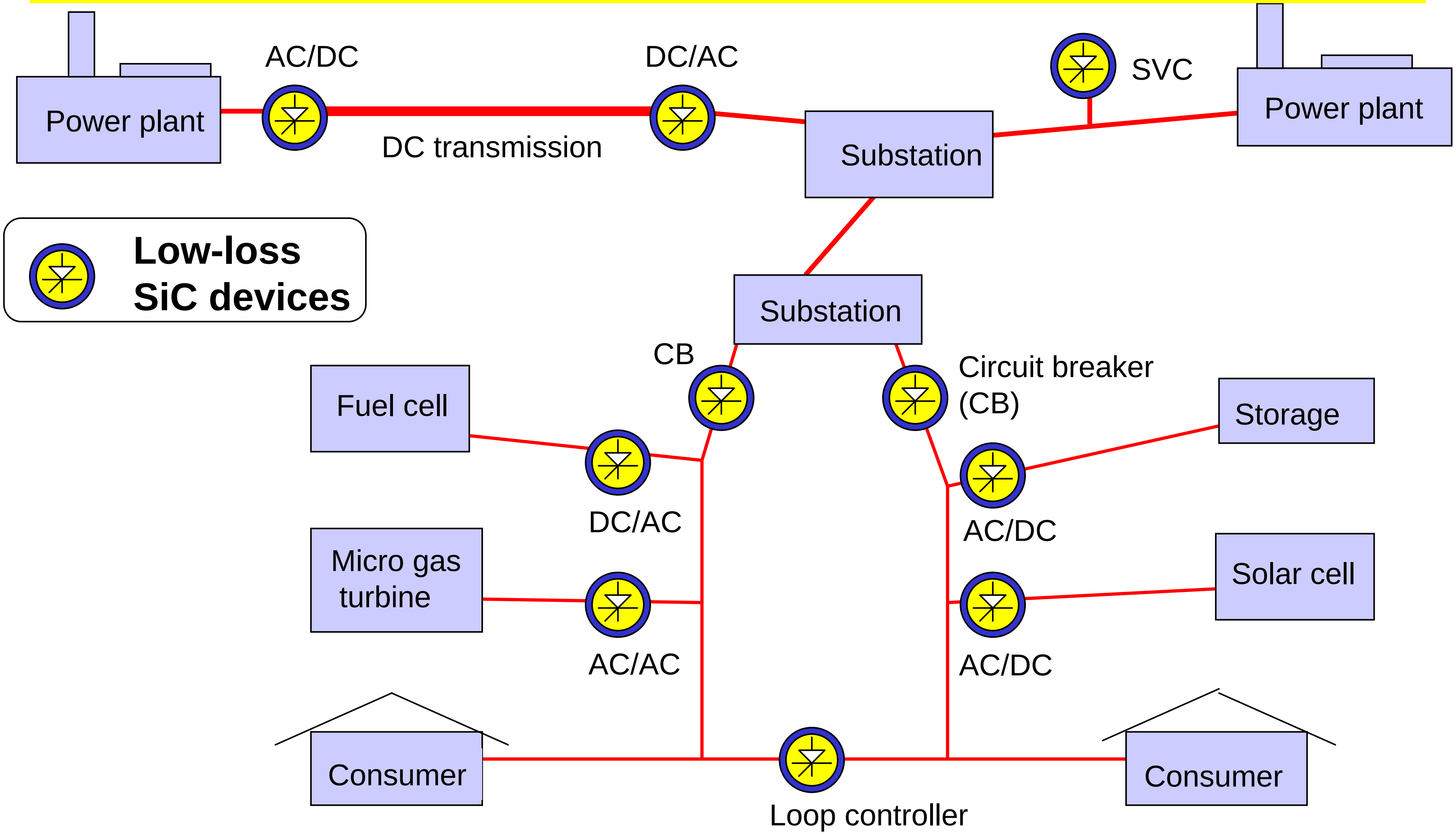


Ratio of electric power in total energy consumed in Japan in each year [1].

[1] A. Nakaoka: The 21st Future Technology forum on Energy (2002) [in Japanese]

Power electronic devices

CRIEPI



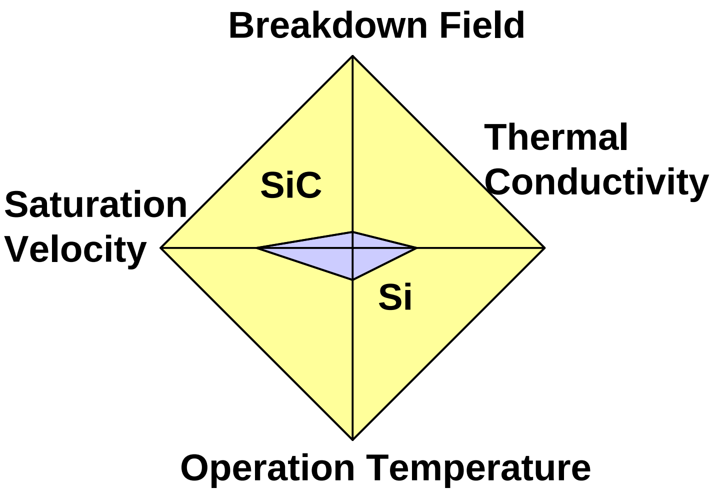
Electric power transmission and distribution systems in near future.

Materials for power electronic devices

CRIEPI

Material		4H-SiC	Si	GaAs	GaN	diamond
Energy Bandgap	[eV]	3.26	1.12	1.42	3.42	5.47
Electron Mobility	[cm2/Vs]	1000	1350	8500	1200	2000
Breakdown Field	[MV/cm]	2.8	0.3	0.4	3	8
Saturation Drift Velocity	[cm/s]	$2.2x10^7$	$1.0x10^7$	$1.0x10^7$	$2.4x10^7$	$2.5x10^7$
Thermal conductivity	[W/cmK]	4.9	1.5	0.46	1.3	20
p-type controll		○	○	○	△	△
n-type controll		○	○	○	○	×
Thermal oxidation		○	○	×	×	×
Conductive Wafer		○	○	○	△(SiC)	×
insulating Wafer		○	△(SOI)	○	△(Sapphire)	×

Table 1. Material property and present situation of 4H-SiC, Si , GaAs, GaN and diamond [2].



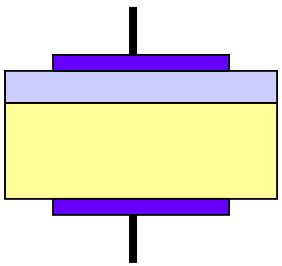
[2] H. Matsunami: *Technology of Semiconductor SiC and Its Application* (2003) [in Japanese]

Present status of SiC

CRIEPI

Excellent properties of SiC

High quality SiC layer



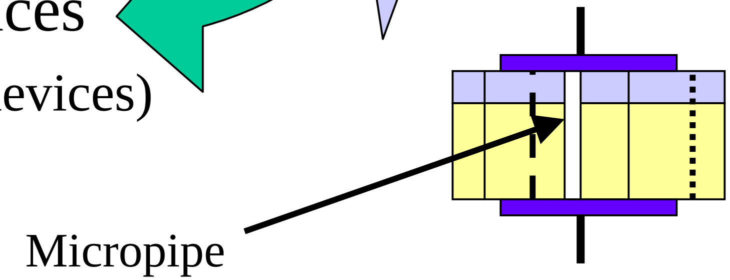
High performance SiC power devices

(High temperature resistant and low-loss devices)

Defects

Impurity

Uniformity

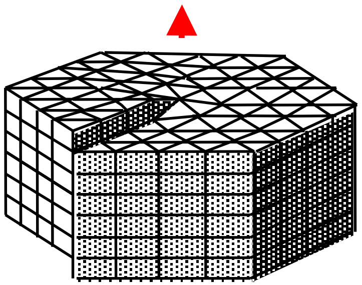


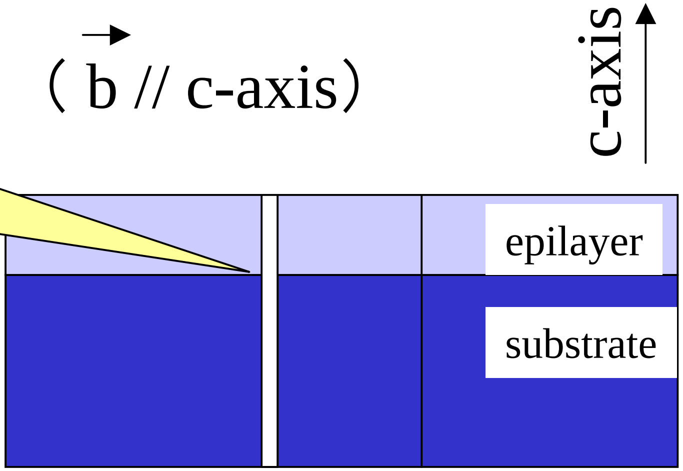
Propagation of micropipe

CRIEPI

Micropipe is a large screw dislocation having a large Burgers vector and it has a hollow core. (|b| > 3c)

Hollow core of micropipe is continued into the epilayer





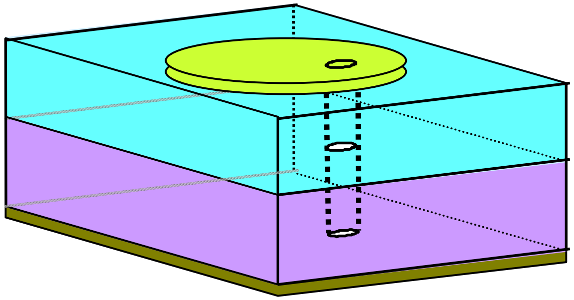
Step of screw dislocation on a substrate surface.

Influence of micropipe

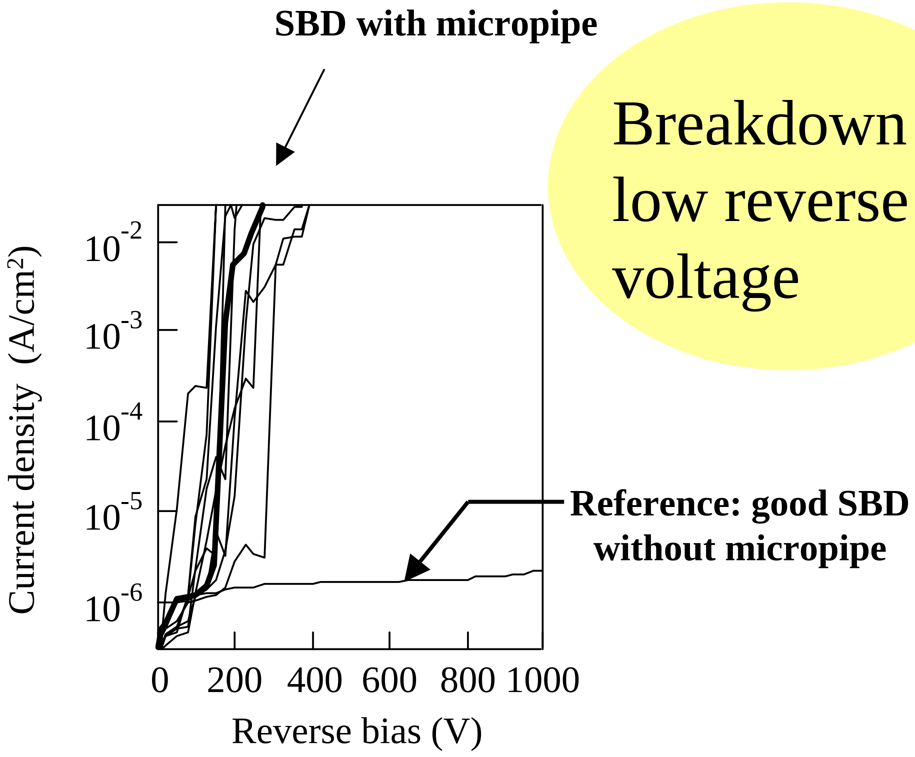
-for electrical property-

CRIEPI

I-V characteristics of SBD



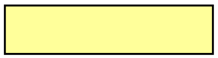
SBD (Schottky Barrier Diode)
with micropipe



Breakdown in low reverse voltage

Study on SiC

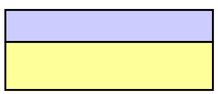
CRIEPI



Substrates

Evaluation → KOH etching, X-ray topography, Microscopy, SIMS

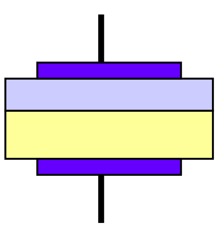
Epitaxial growth



Growth

↕

Evaluation → KOH etching, PL, X-ray topography, Microscopy, SEM, TEM, SIMS, AFM



Device fabrication

Process

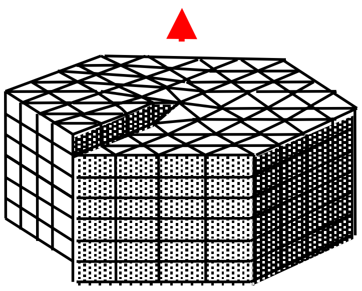
↕

Evaluation → I-V, C-V, DLTS, EL,

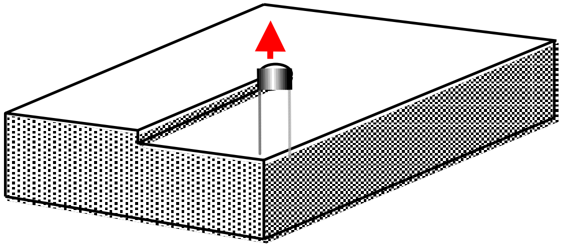
Evaluation of defect -KOH etching-

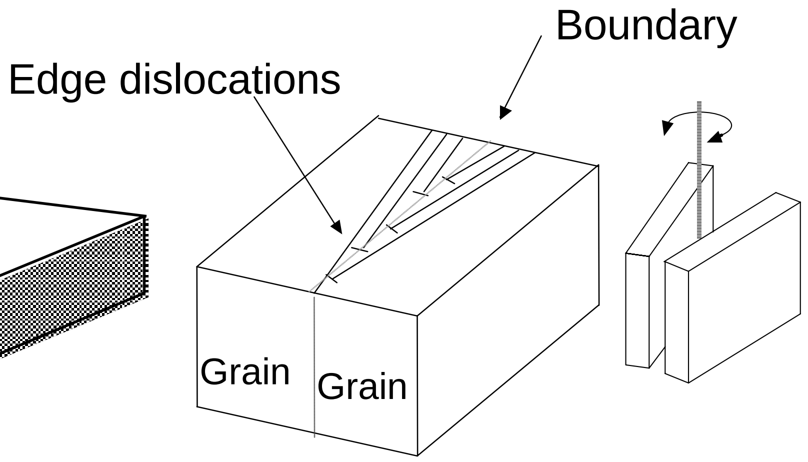
CRIEPI

$|b| = 1c$ or $2c$



$|b| > 3c$





Screw dislocations

Micropipes

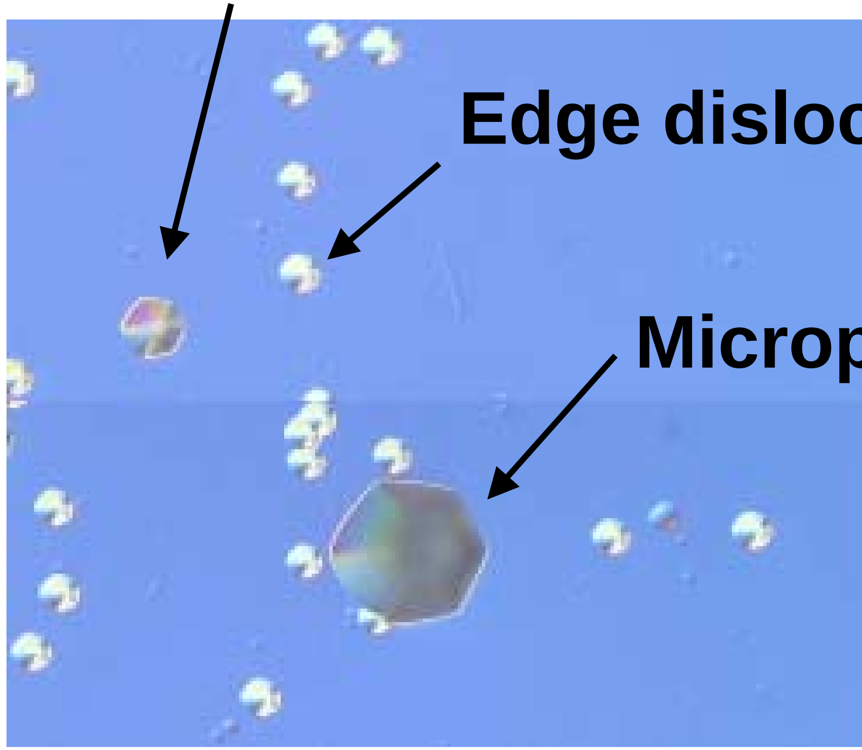
Edge dislocations

KOH etching ~ 500 °C

Etch Pits

Evaluation of defect -KOH etching-

CRIEPI

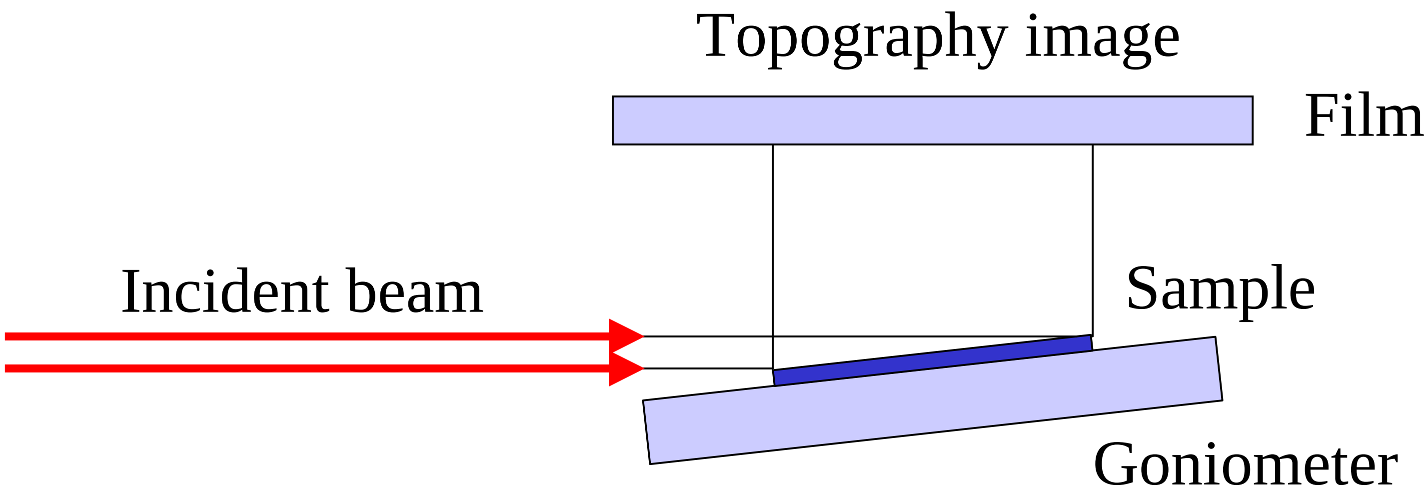


Dislocations are easily investigated by KOH etching as etch pits.

However, the KOH etching is destructive evaluation.

X-ray topography measurements

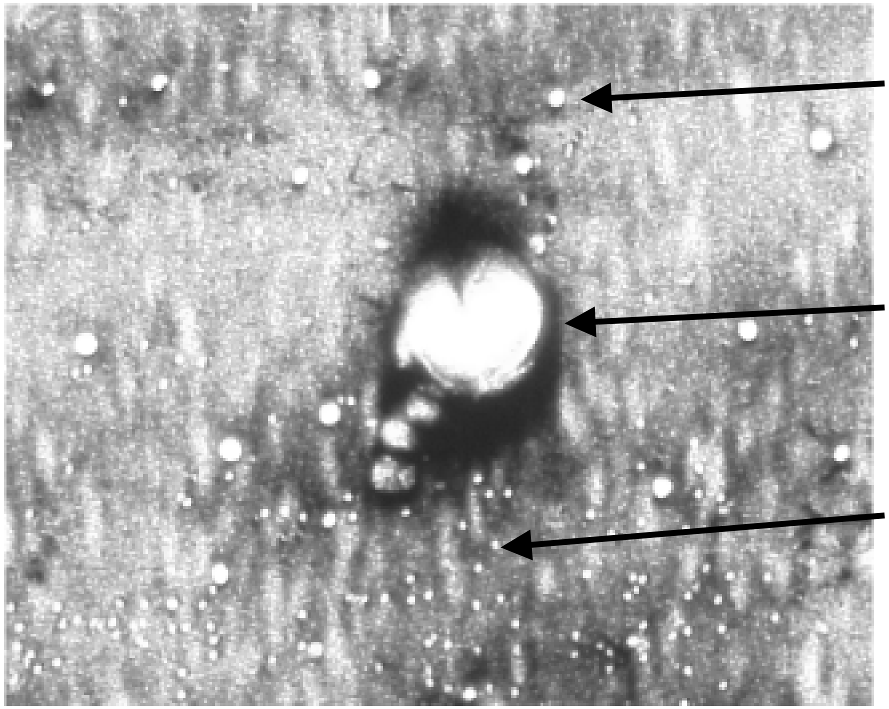
CRIEPI



Energy [keV]	Wavelength [Å]	Diffraction
~8 [keV]	~1.54 [keV]	$(1\bar{1}08)$ $(11\bar{2}8)$

Evaluation of defect -X-ray topography-

CRIEPI



Dislocations are observed by X-ray topography.

Moreover, the X-ray topography is non-destructive evaluation.

Summary

CRIEPI

To investigate dislocations and defects in SiC epilayers, proper methods to evaluate the dislocations and defects are needed.

KOH etching can be used for evaluation of the dislocations in SiC, however, the KOH etching is destructive evaluation.

Dislocations (screw dislocations, edge dislocation and micropipes) are observed by the Synchrotron X-ray topography as a non-destructive evaluation.