The initial stages of the growth of SrF_2 on InP

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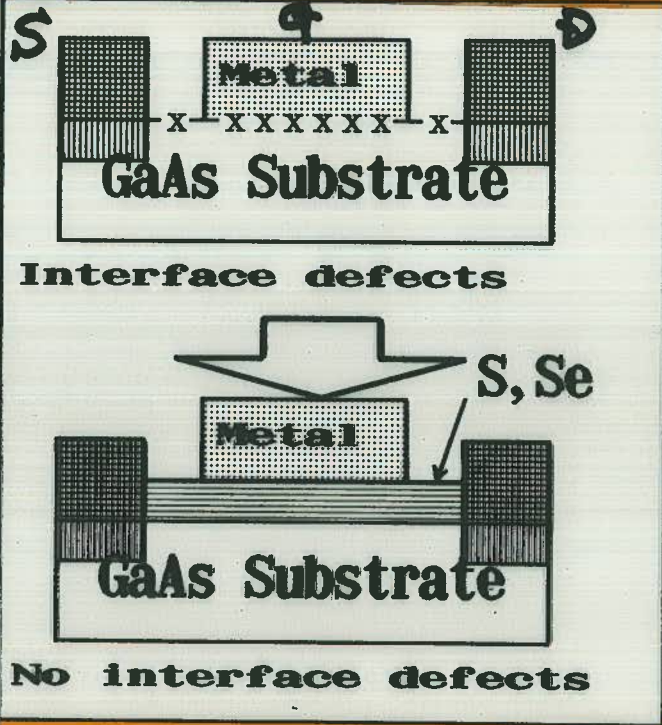
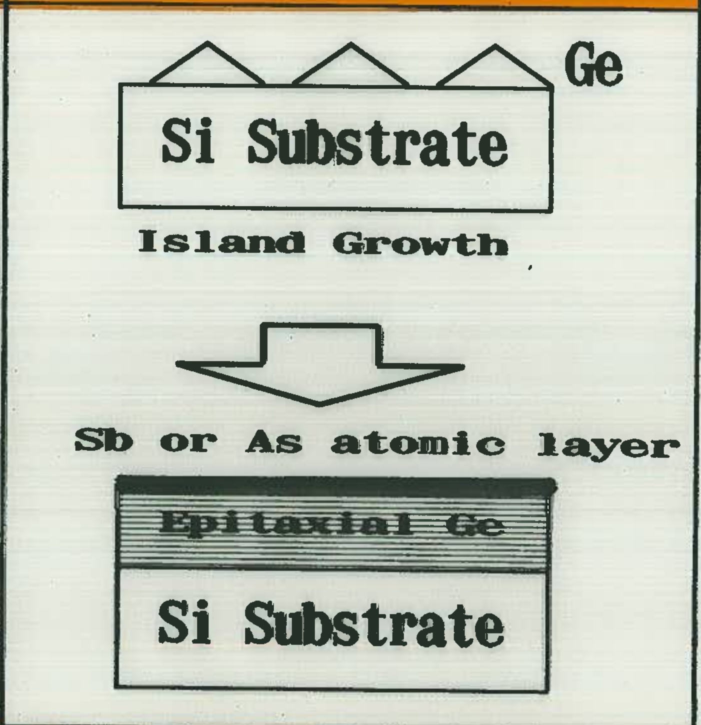
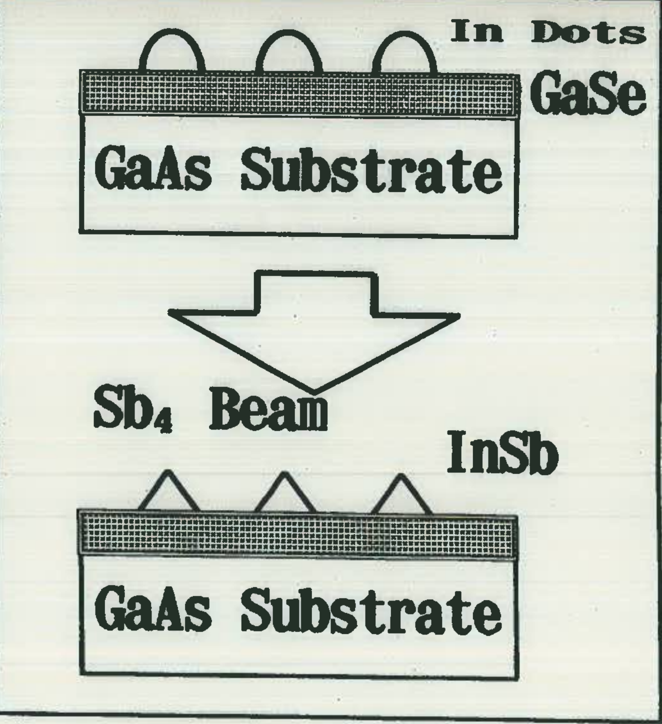
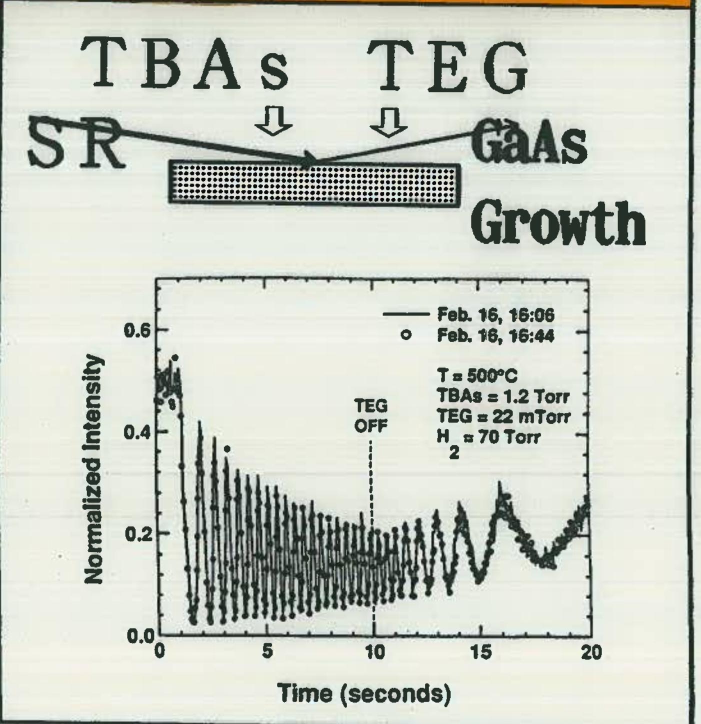
Concept for Surface Engineering

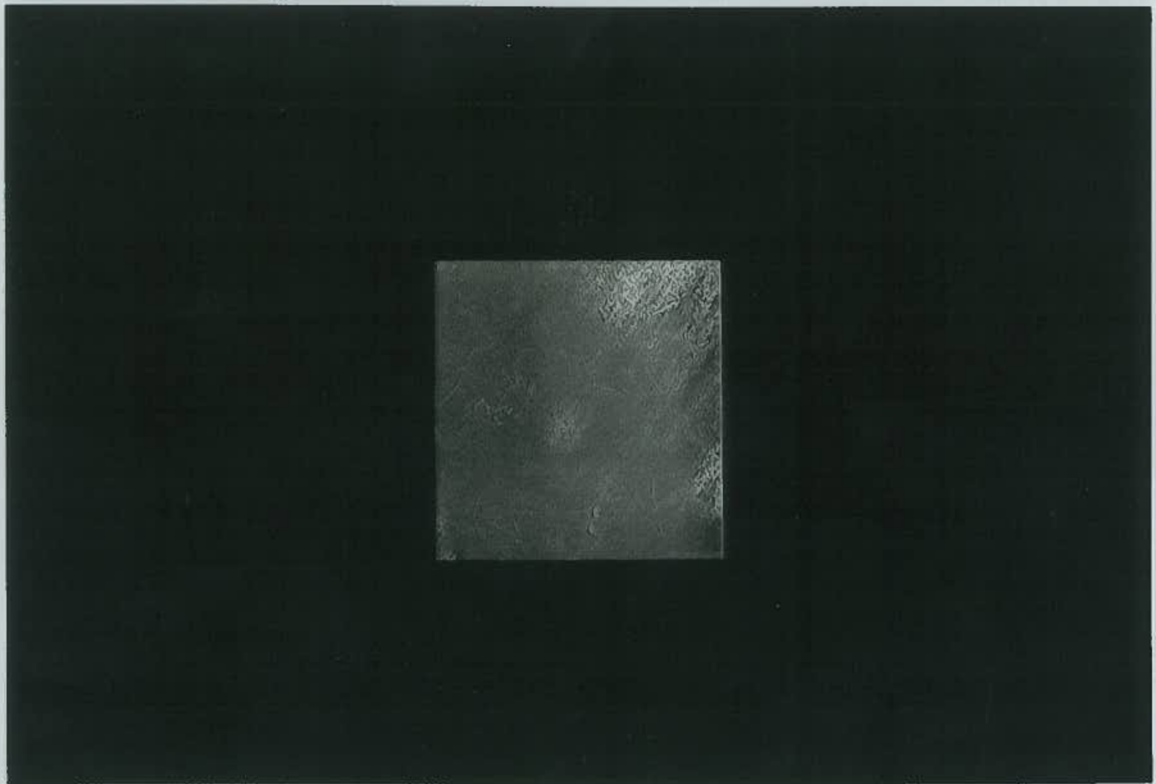
C & C <Characterization and Control>











X-ray topograph of InP(100)

Sample preparation

HF-etching	As-treatment
10 min. in 10% HF 90% ethanol	annealed 500°C/10min under As_4
↓	↓
UHV	cooled to RT
↓	↓
annealed at 300°C for 5 min.	annealed 500°C/10min without As_4

SrF_2 on InP

substrate / procedure		InP (HF-dip)		As / InP	
		(100)	(111)	(100)	(111)
clean surface		X	X	X	X
SrF_2, deposited at RT	8 Å	X	X	X	X
	17 Å	X	X	X	
	25 Å		X	X	
	50 Å	X	X	X	X
annealed to 500°C		X	X	X	X

X : SRPES - measurement

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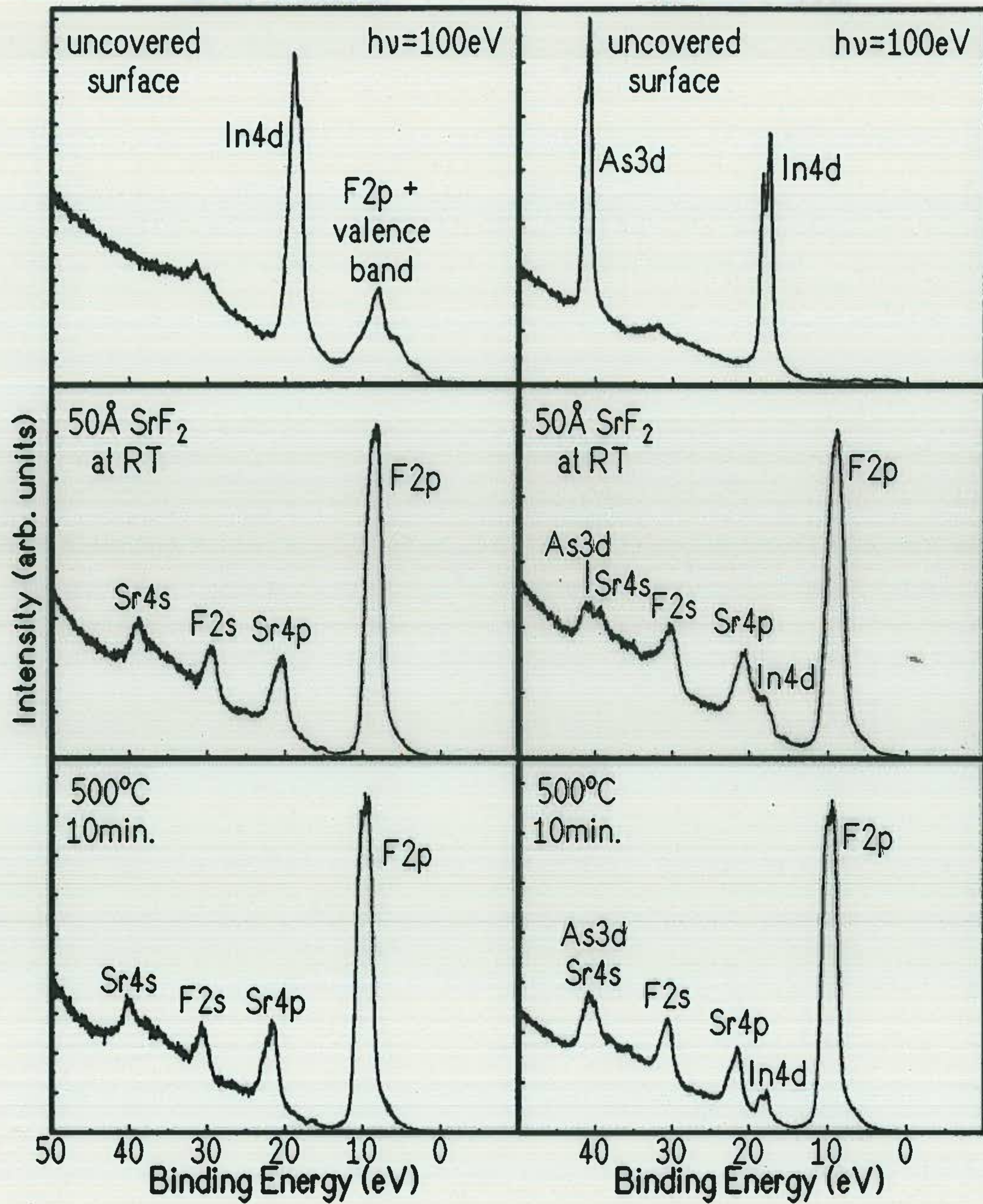
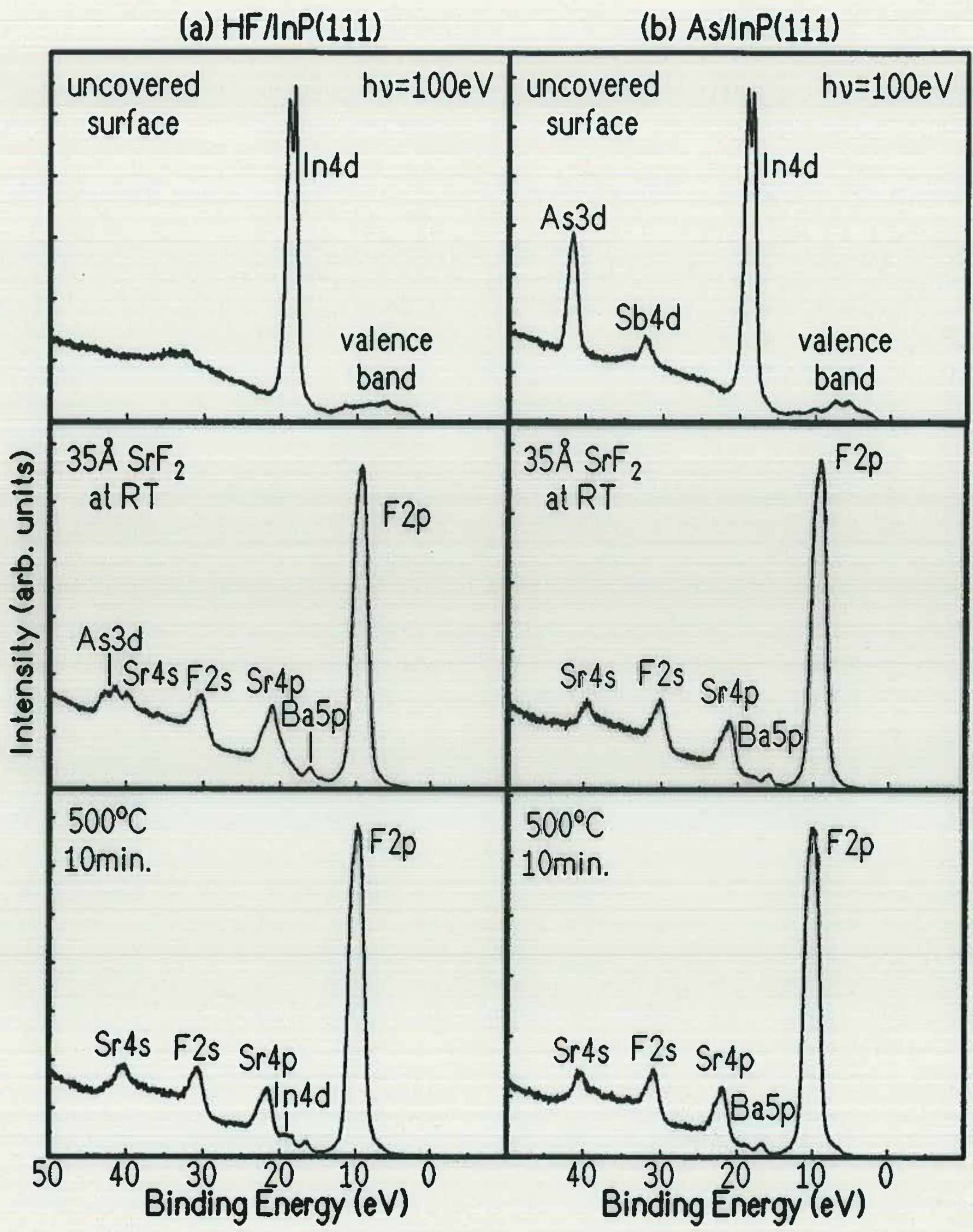
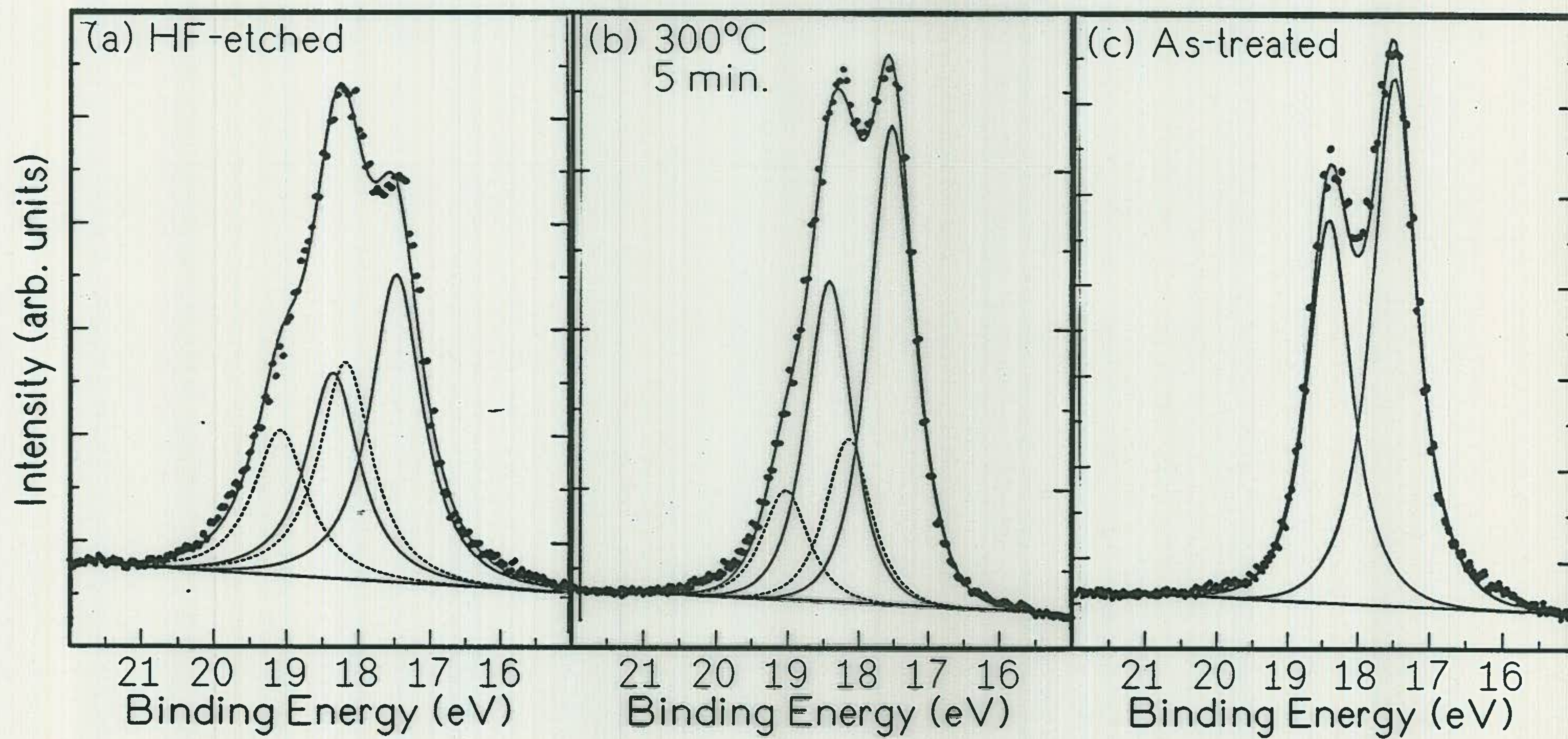

(a) HF/InP(100)
(b) As/InP(100)
uncovered surface
hν=100eV
In4d
F2p + valence band
As3d
50Å SrF_2 at RT
F2p
Sr4s
F2s
Sr4p
500°C 10min.
Intensity (arb. units)
Binding Energy (eV)
50
40
30
20
10
0



(a) HF/InP(111)
(b) As/InP(111)
uncovered surface
hν=100eV
In4d
valence band
As3d
Sb4d
35Å SrF_2 at RT
F2p
Sr4s
F2s
Sr4p
Ba5p
500°C 10min.
Intensity (arb. units)
Binding Energy (eV)
50
40
30
20
10
0


(a) HF-etched
(b) 300°C
5 min.
(c) As-treated
Intensity (arb. units)
21 20 19 18 17 16
Binding Energy (eV)
21 20 19 18 17 16
Binding Energy (eV)
21 20 19 18 17 16
Binding Energy (eV)

clean InP(100)

5000
4000
3000
2000
1000
0
1000
0
Counts per Second

In 4d

valence band

hν = 100eV

hν = 150eV

?

0 10 20 30 40 50
Binding Energy (eV)

NTT

valence band

In 4d

$h\nu = 150eV$

$h\nu = 140eV$

$h\nu = 130eV$

$h\nu = 100eV$

Counts (arb. units)

0 5 10 15 20 25 30 35 40 45 50

Binding Energy (eV)

Peak with constant kinetic Energy → P LVV

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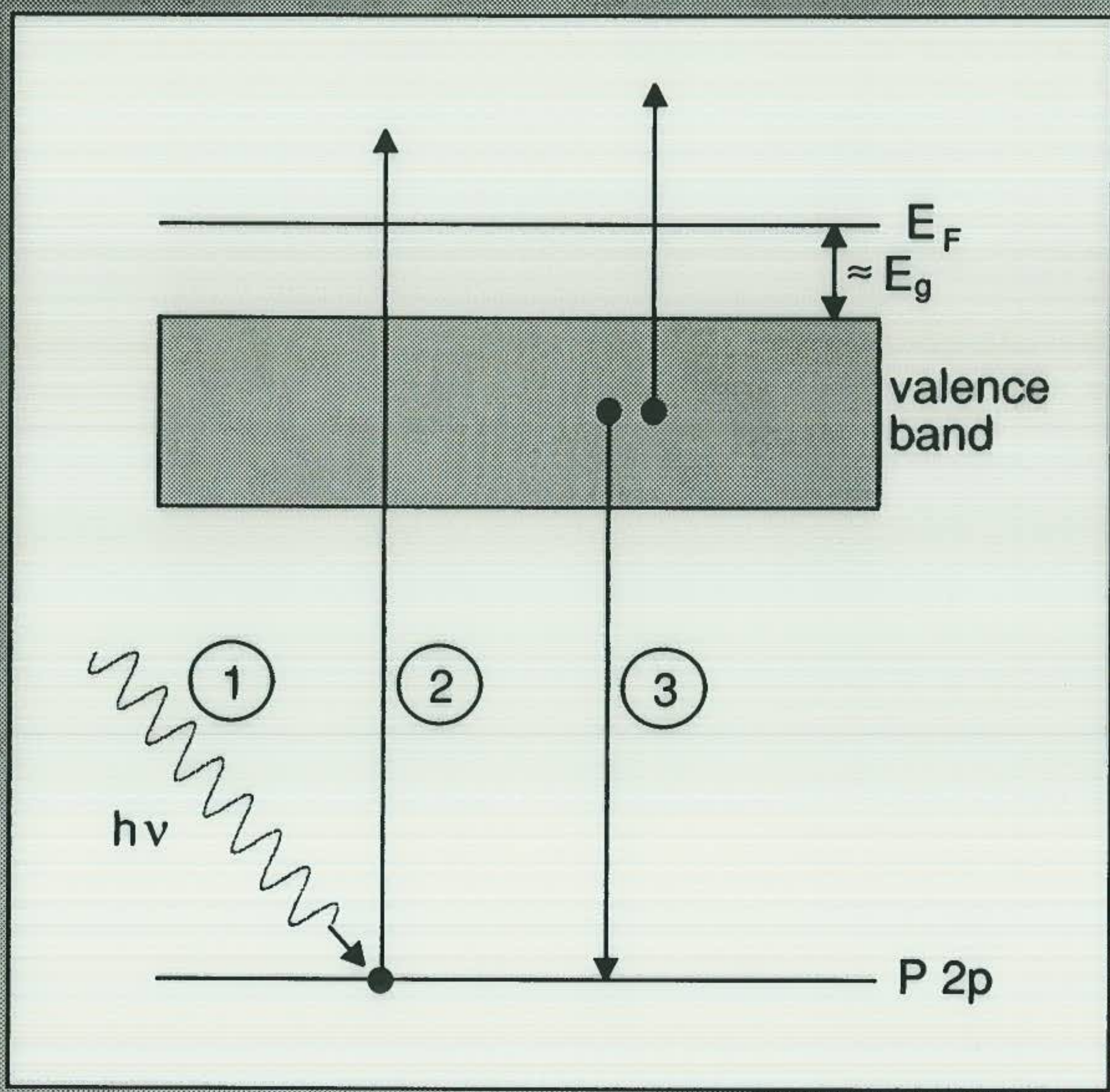
P LVV Auger Line



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clean InP(100)

5000
4000
3000
2000
1000
0
1000
0

Counts per Second

In 4d

valence band

hν = 100eV

hν = 150eV

P LVV

0 10 20 30 40 50

Binding Energy (eV)

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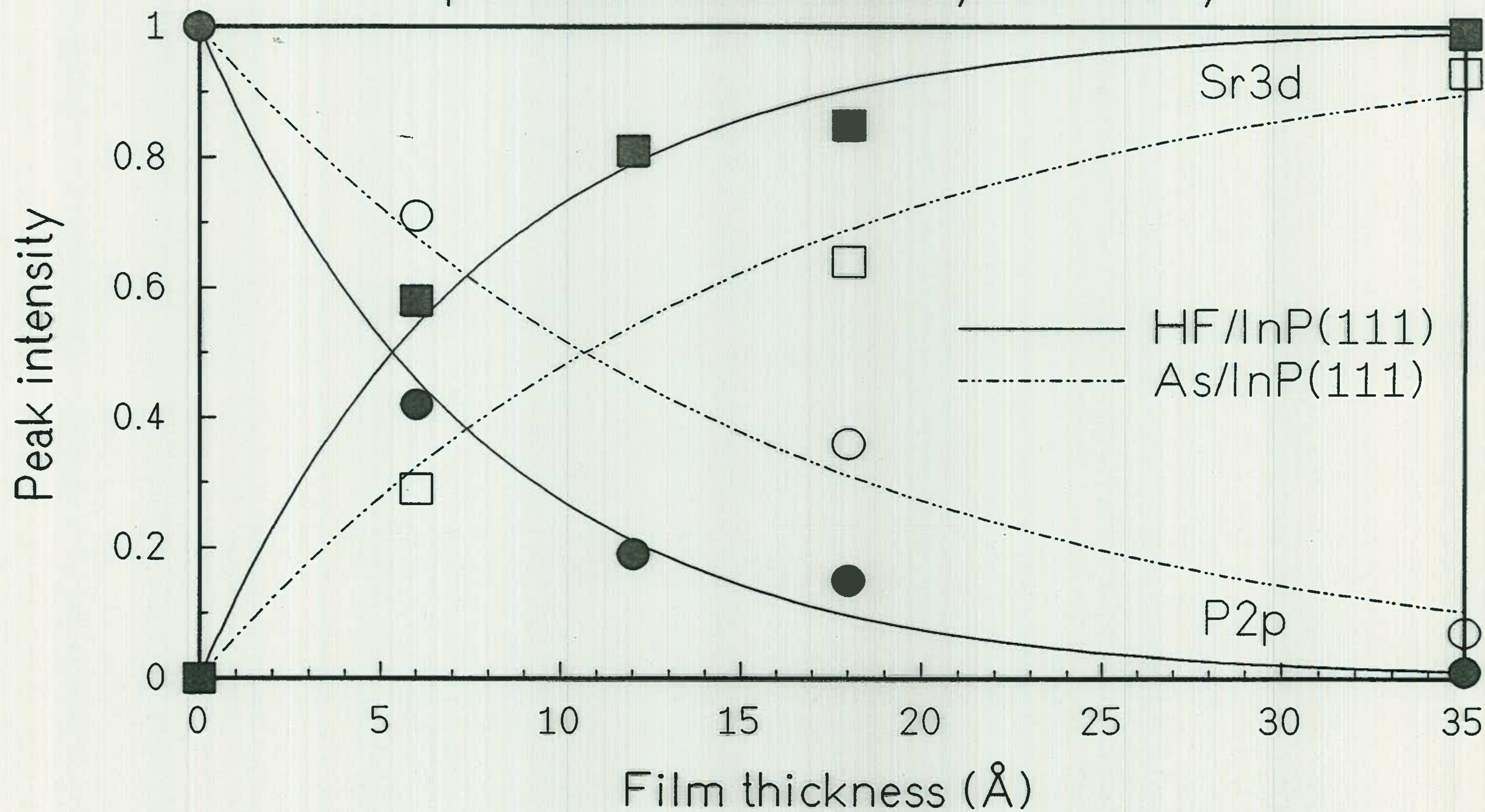
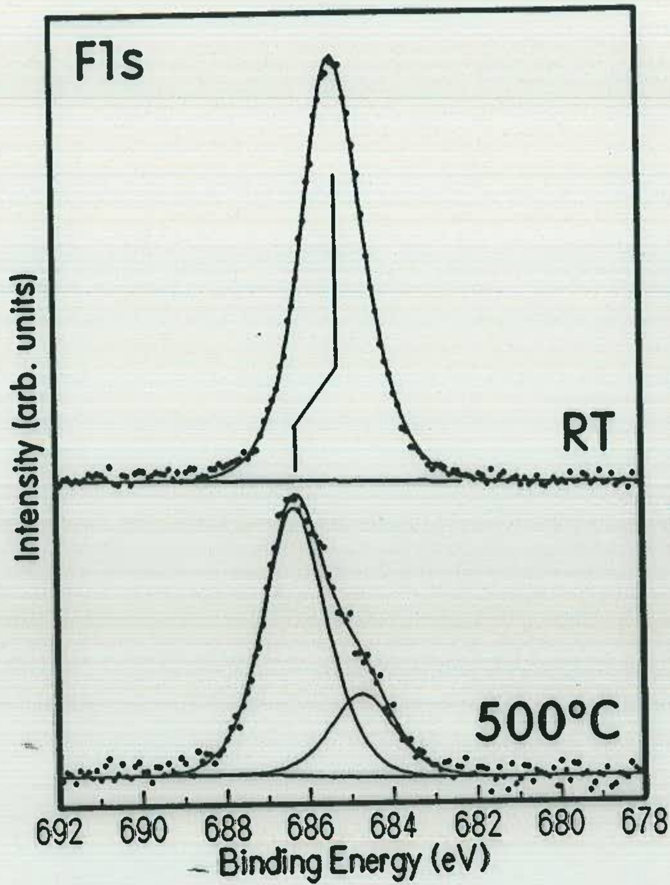
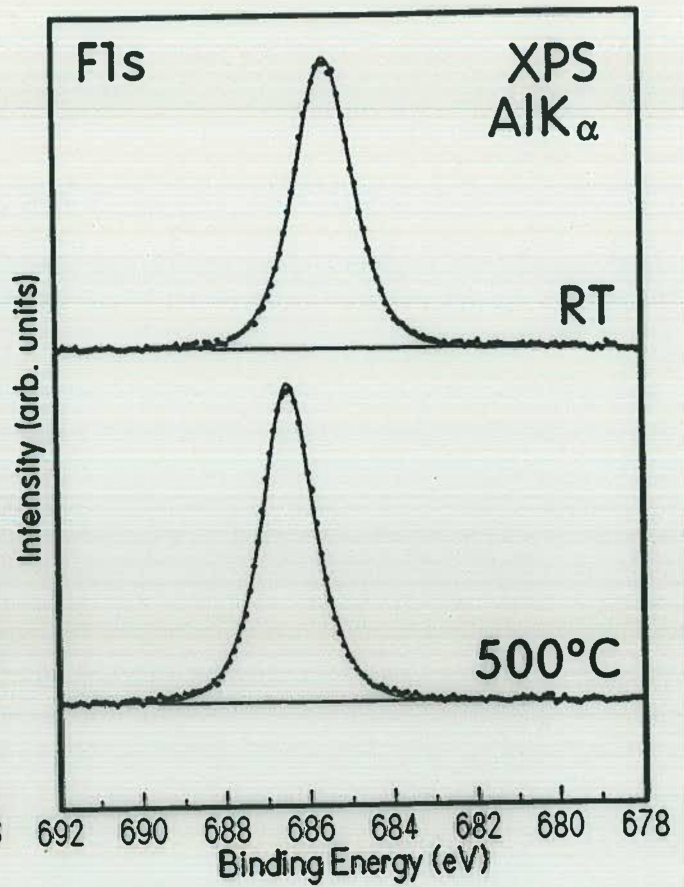

Peak Intensities
peak intensities normalized by total intensity
Peak intensity
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
Film thickness (Å)
Sr3d
P2p
HF/InP(111)
As/InP(111)

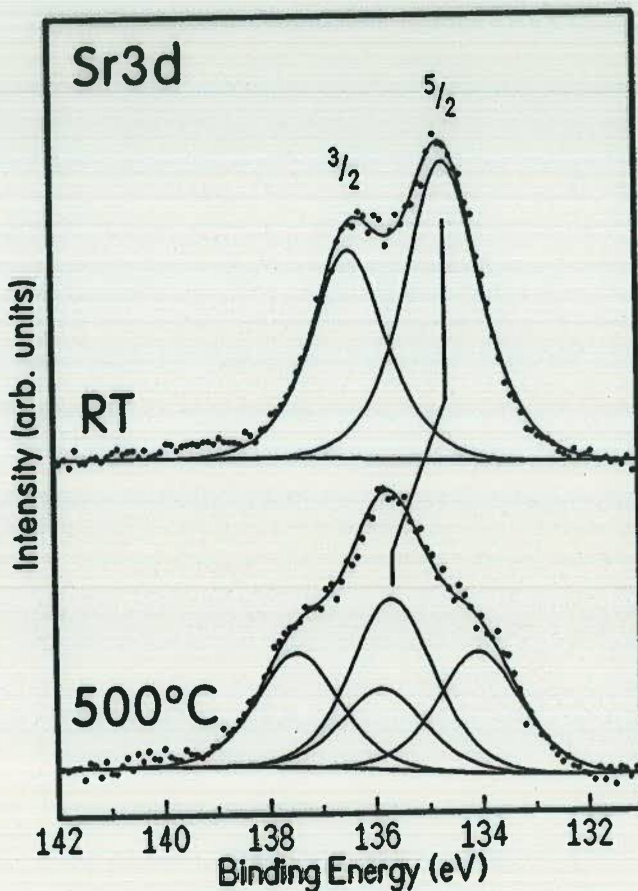
Interfacial Reaction

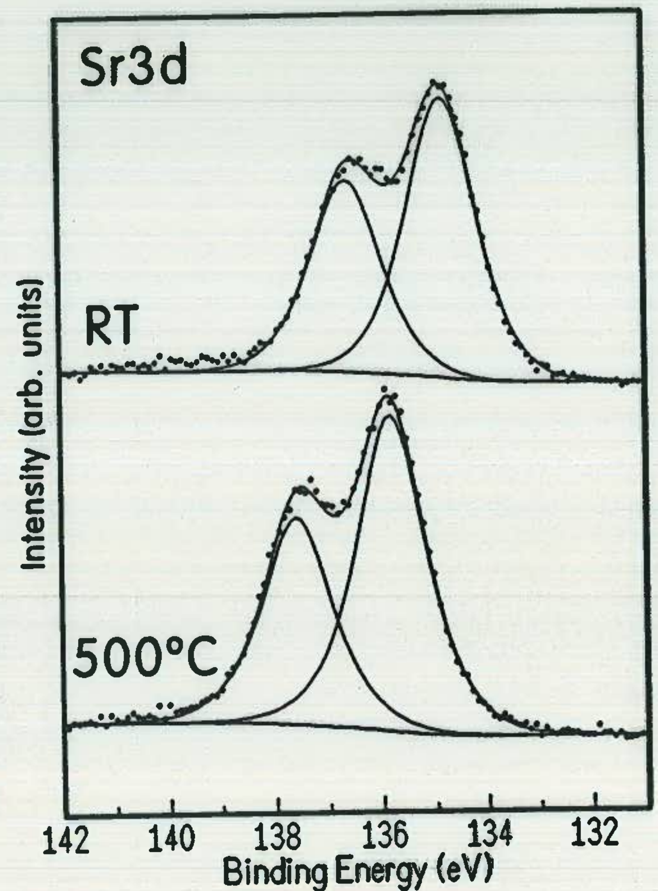
35ÅSrF_2 on HF/InP(111)

35ÅSrF_2 on As/InP(111)

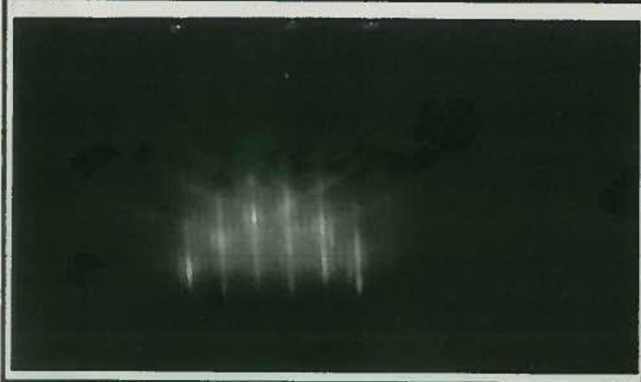




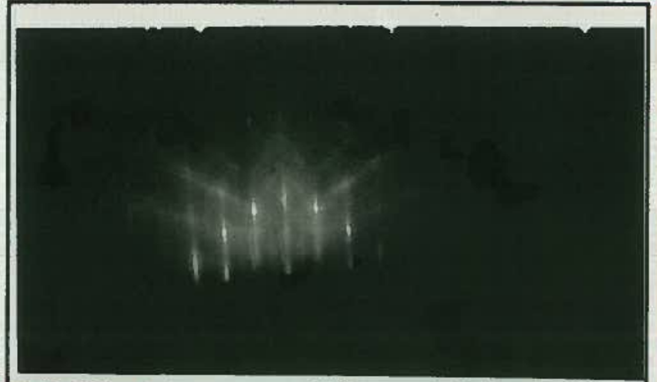




RHEED

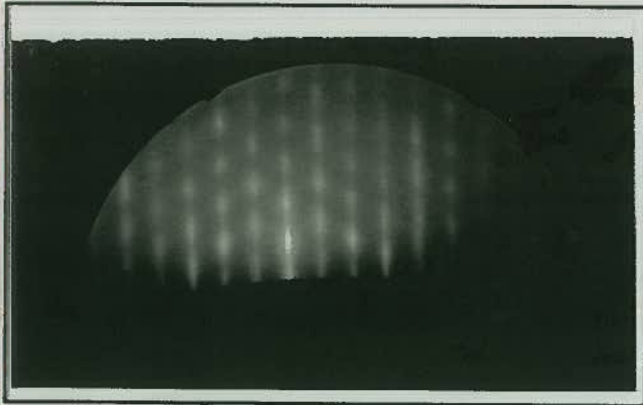


[110]

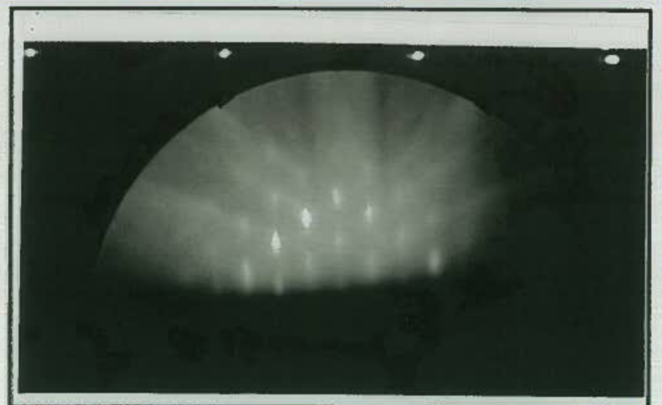


[$1\bar{1}0$]

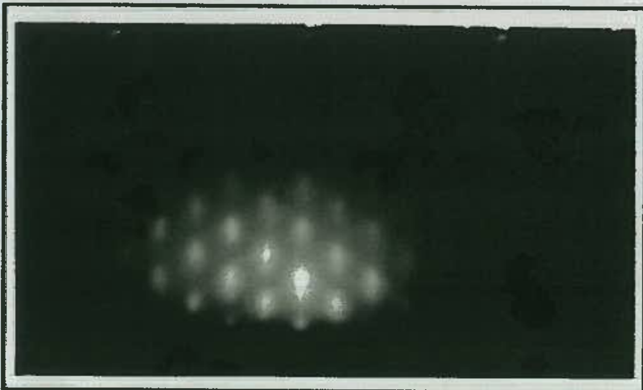
As / InP(100)



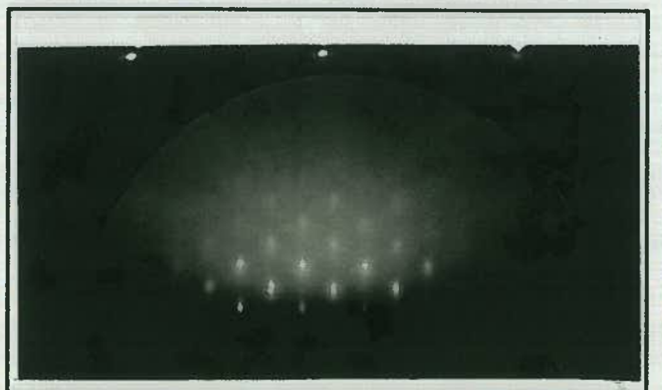
50Å SrF_2 at RT,
annealed at 500°C



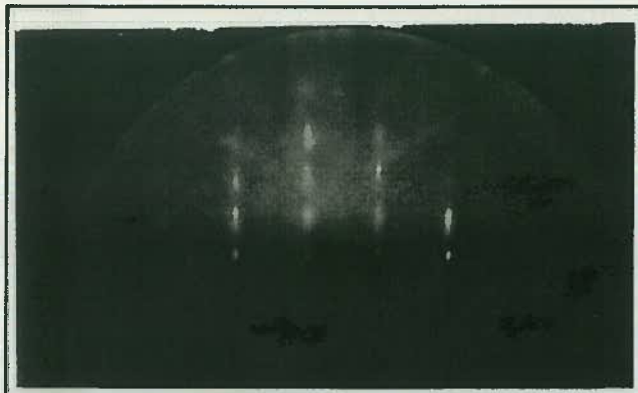
HF-etched InP(100)



50Å SrF_2 at RT



annealed at 500°C



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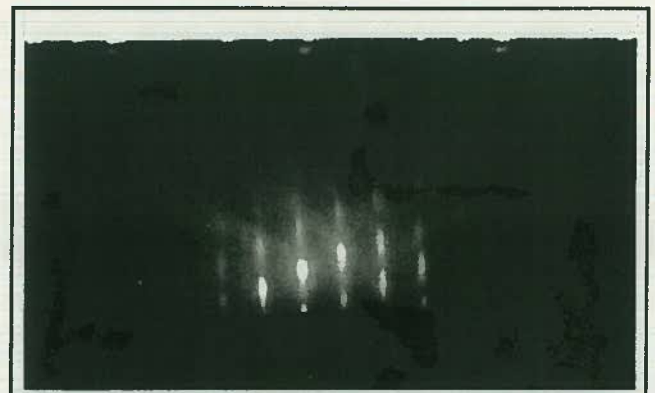

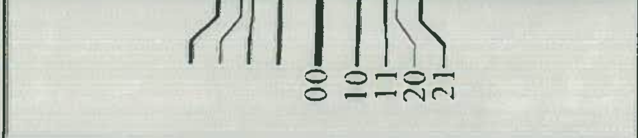

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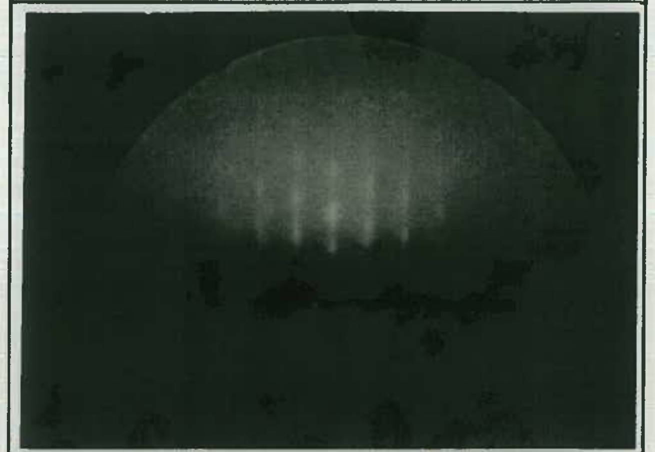

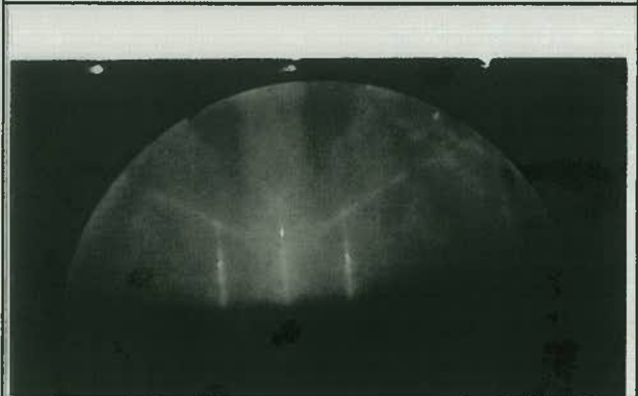

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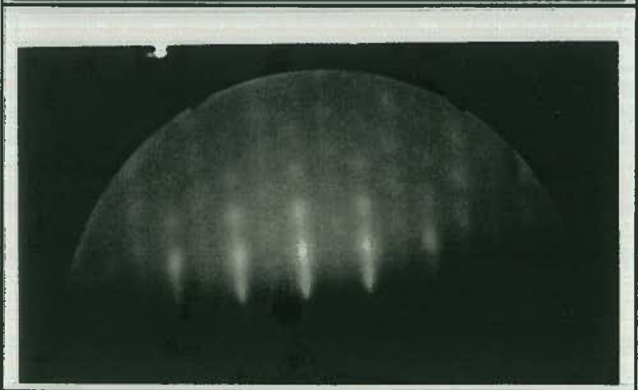

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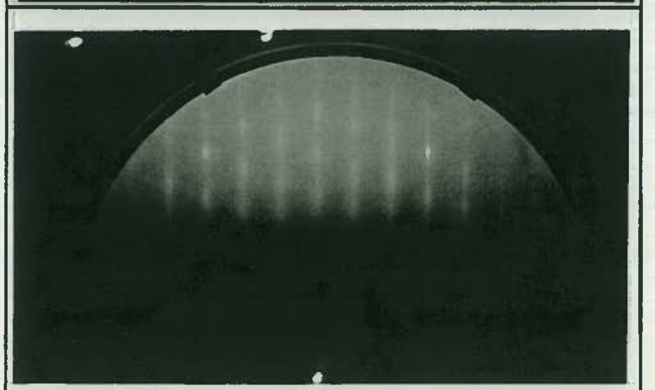


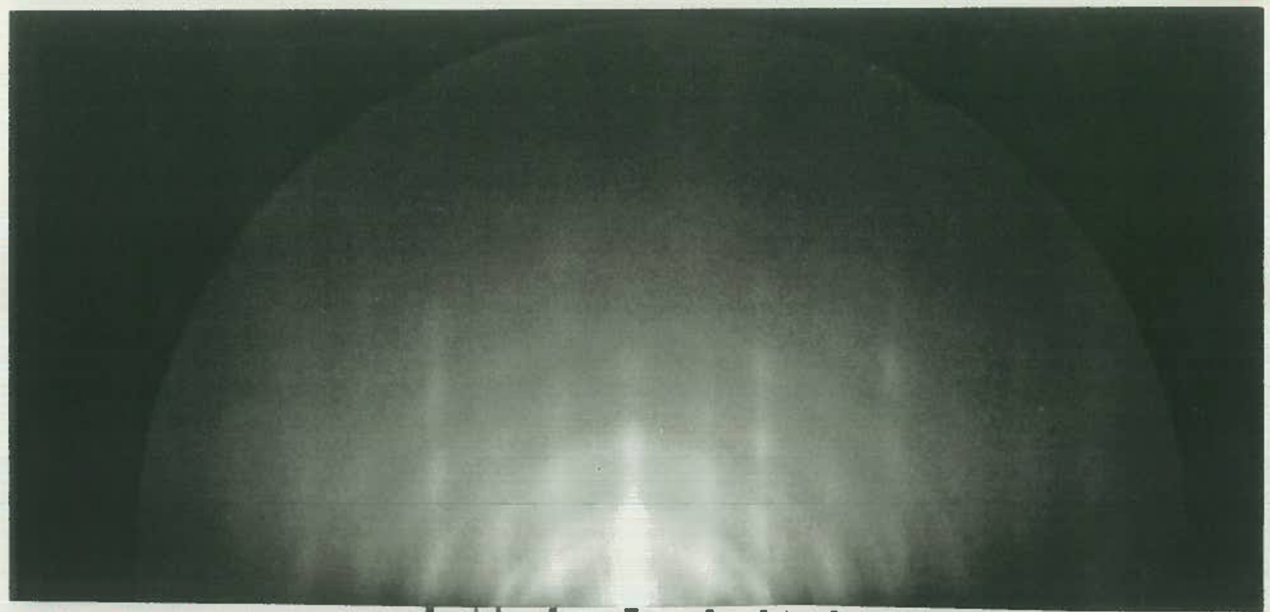
$[01\bar{1}]$ $[\bar{2}11]$

↑ $[01\bar{1}]$ HF-etched InP(111) $[\bar{2}11]$ ↓

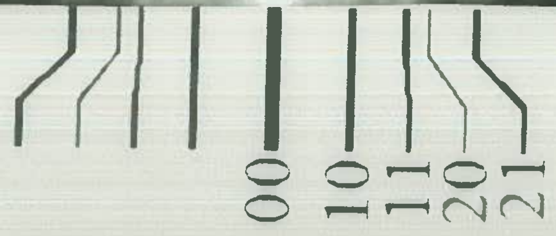
50 Å SrF_2 on HF-etched InP(111)

RT

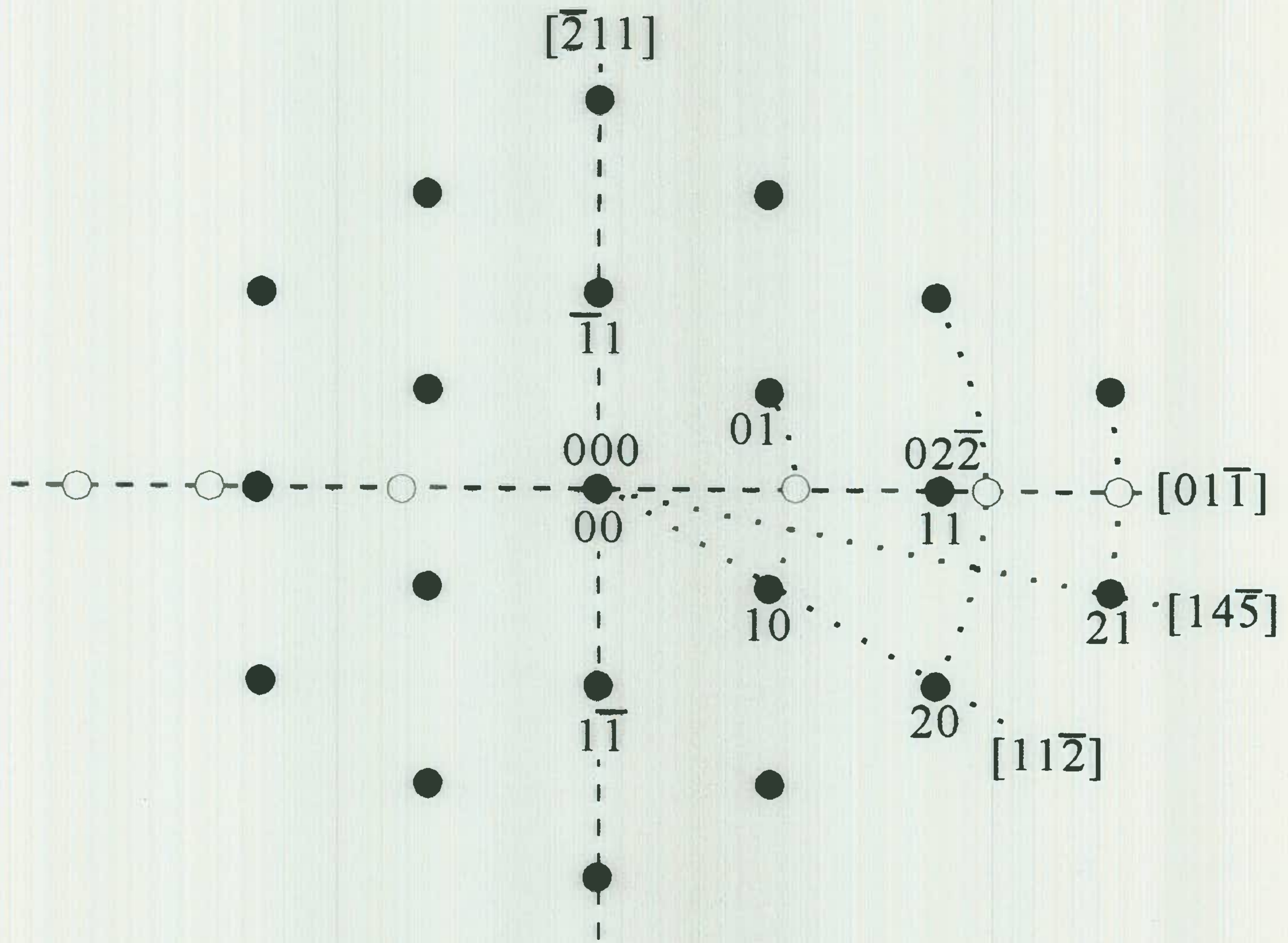
500°C



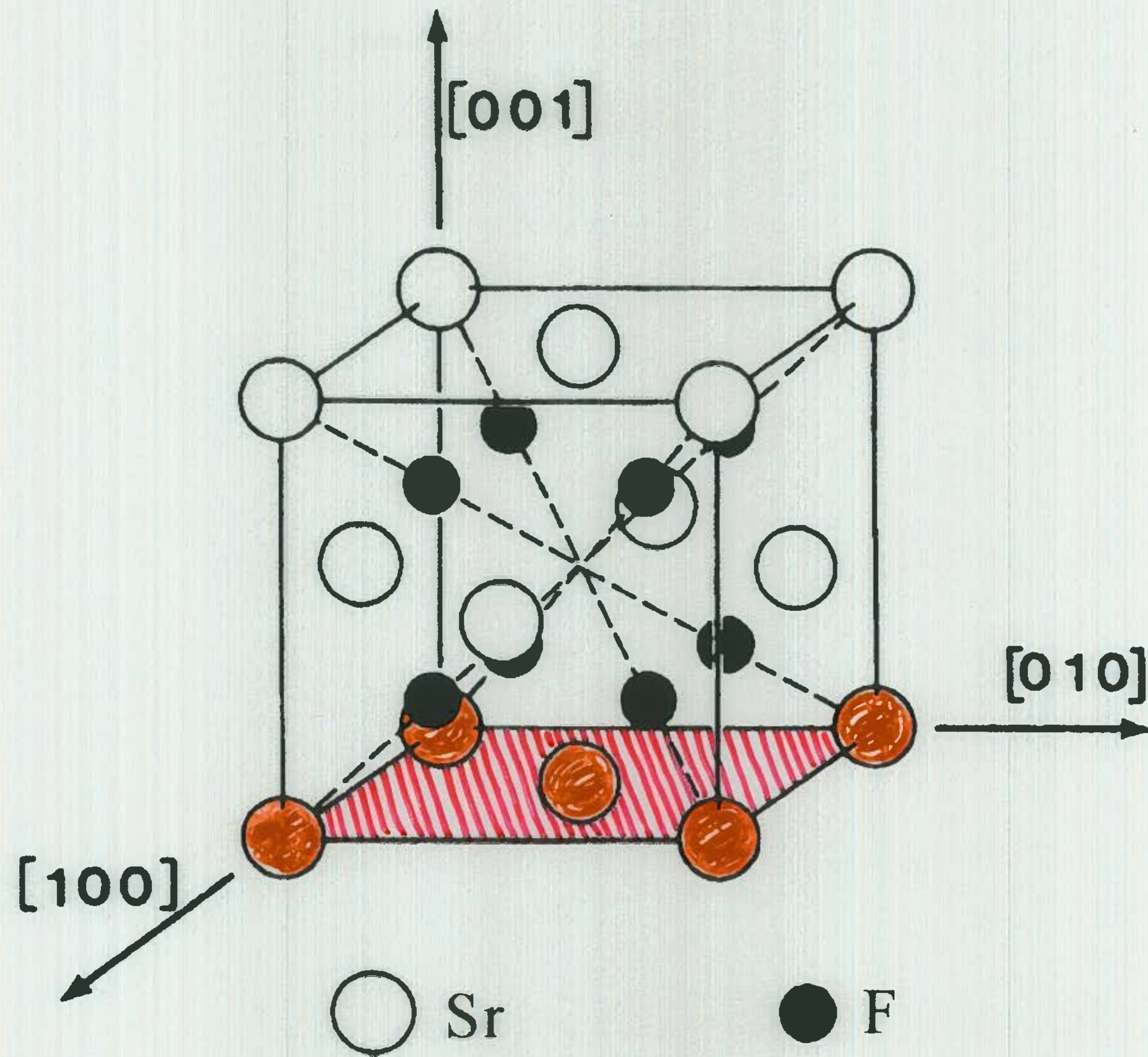
[01$\bar{1}$]



[$\bar{2}$11]

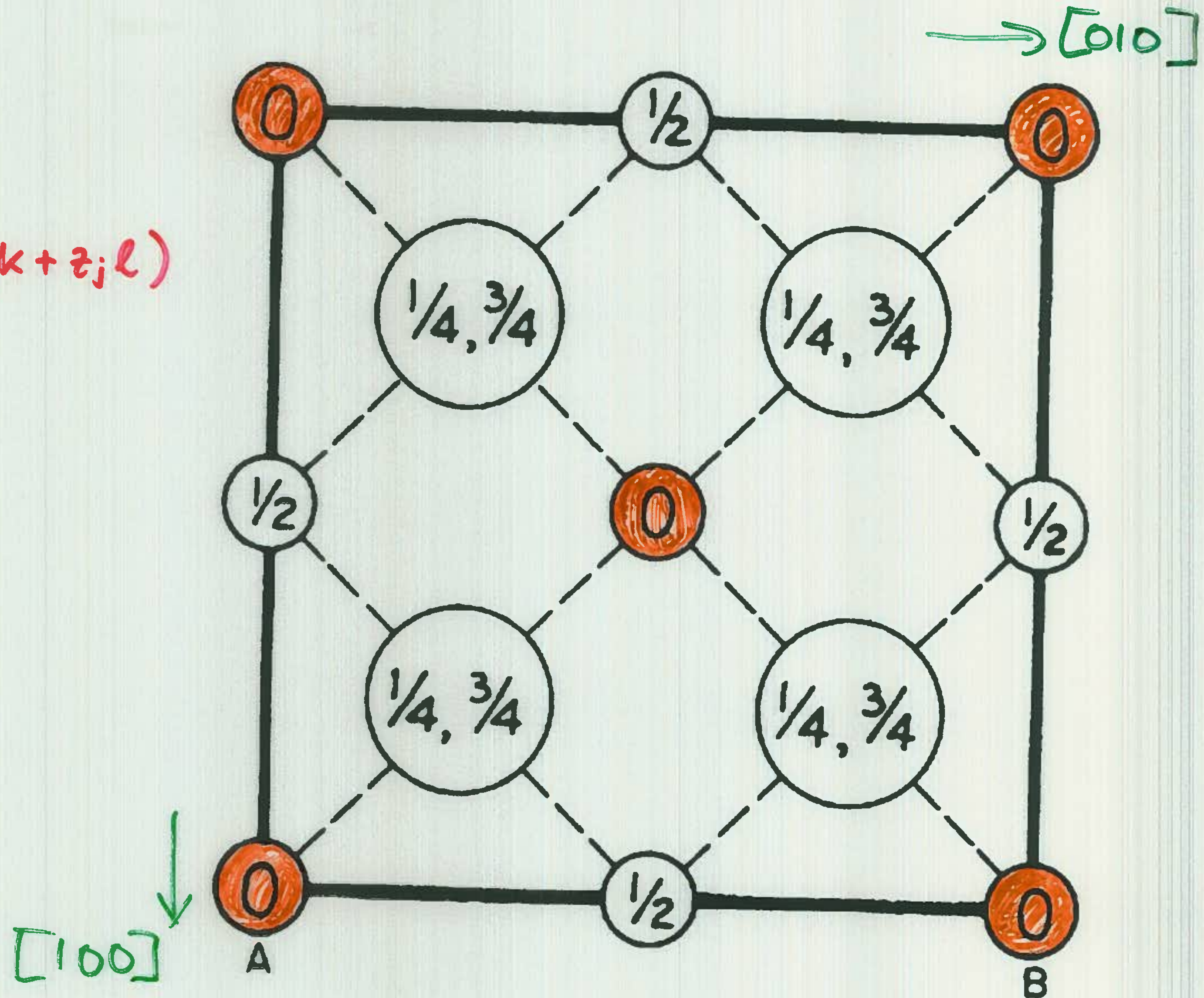

[$\bar{2}$11]
$\bar{1}$1
01
000
02$\bar{2}$
00
11
[01$\bar{1}$]
10
21
[14$\bar{5}$]
1$\bar{1}$
20
[11$\bar{2}$]

(hk)	00	10	11	20	21
distance between (00) and (hk) in model	0	1	$\sqrt{3}$ ≈ 1.7	2	$\sqrt{7}$ ≈ 2.6
distance between (00) and (hk) in measurement	0	1	1.7	2	2.6
first bulk bragg point on (hk)-rod	(000)	$(11\bar{1})$	$(02\bar{2})$	$(22\bar{2})$	$(13\bar{3})$
structure factor S of this bulk bragg point	11.6	6.9	4.6	2.2	6.9 - 1.2i
intensity = S S*	135	48	21	5	49


[001]
[010]
[100]
Sr
F

Structure factor

$$S(hkl) = \sum_j f_j e^{-i2\pi(x_j h + y_j k + z_j l)}$$



As-treated InP(111) 1x1

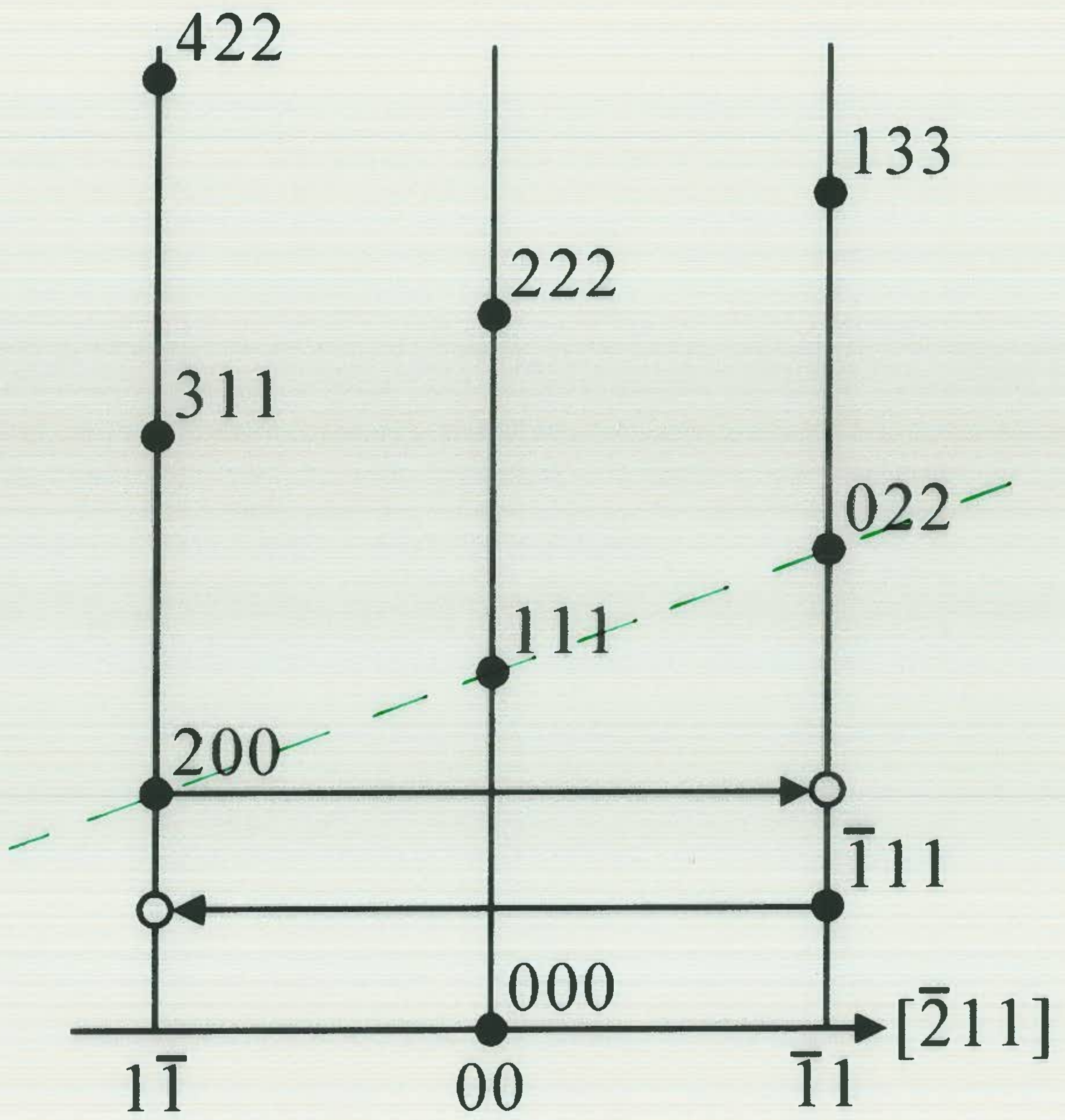
[01$\bar{1}$]

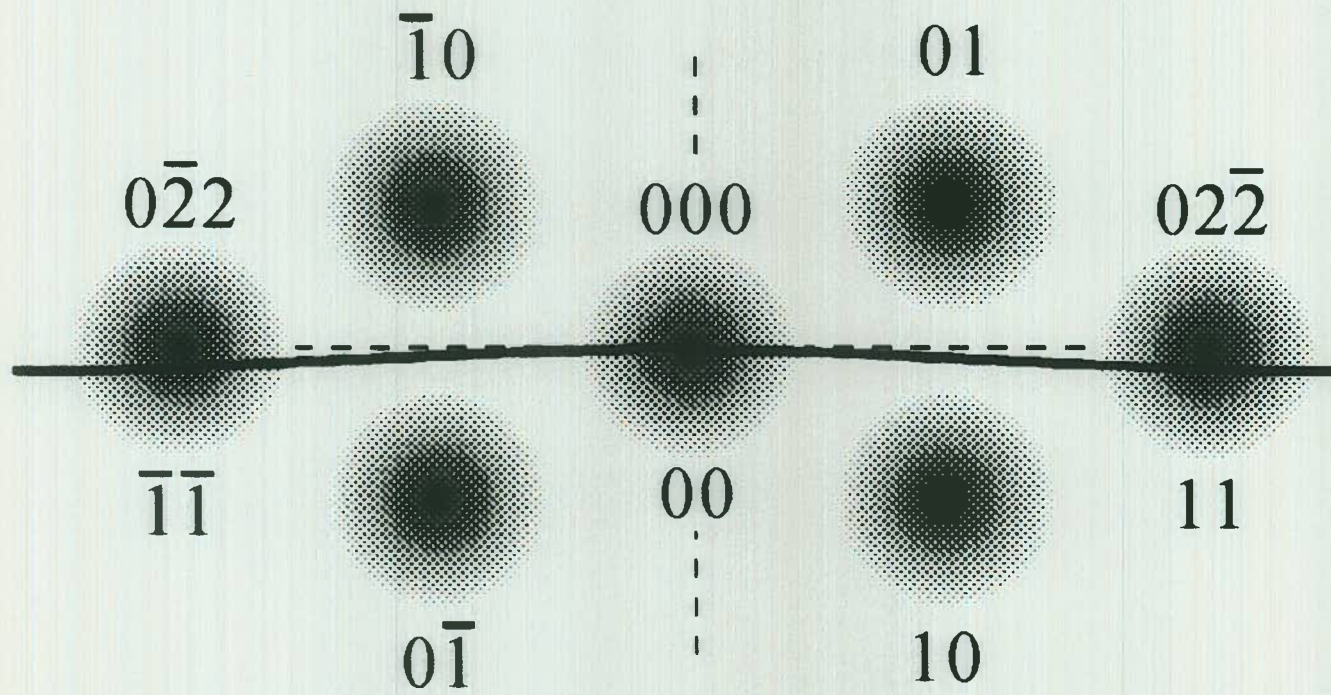
[211]

50Å SrF_2 on As-treated InP(111), RT, 500°C

[01$\bar{1}$]

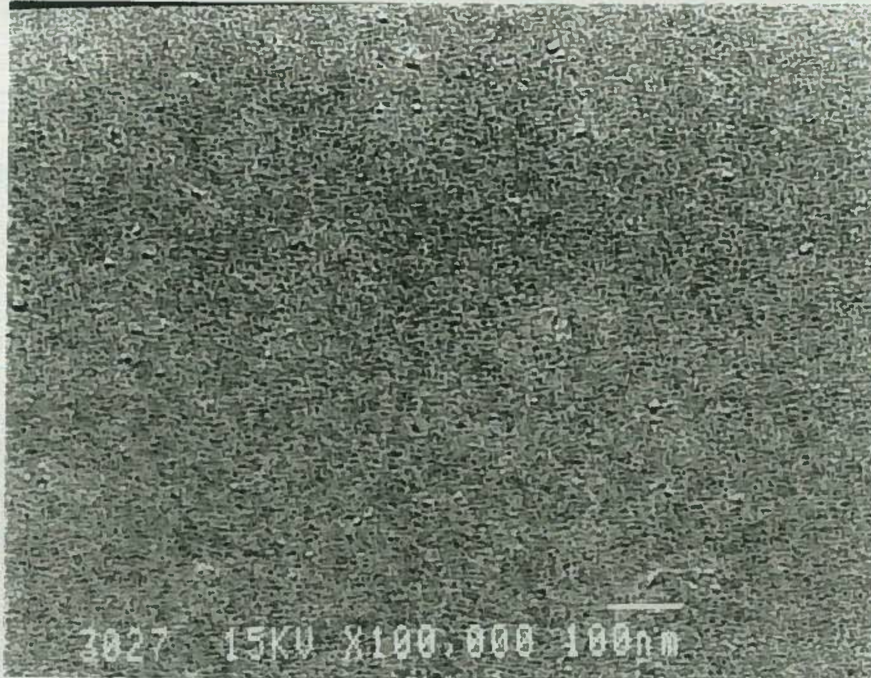
[$\bar{2}$11]


422
133
222
311
022
111
200
$\bar{1}11$
000
$[\bar{2}11]$
$1\bar{1}$
00
$\bar{1}1$

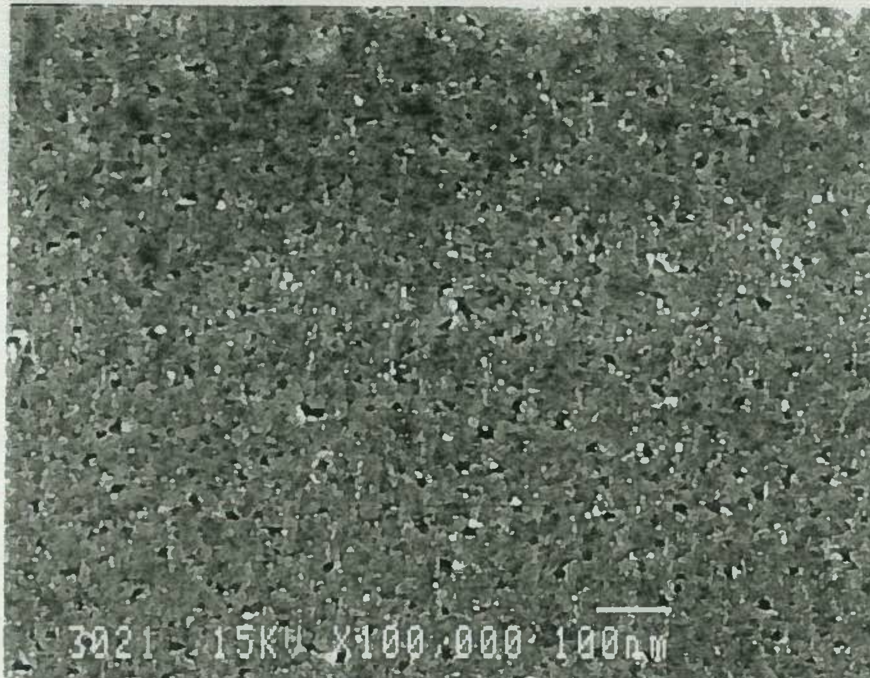

$\bar{1}0$
01
$0\bar{2}2$
000
$02\bar{2}$
$\bar{1}\bar{1}$
00
11
$0\bar{1}$
10

SEM

50Å SrF_2, deposited at RT on



HF-etched InP(100)



As/ InP(100)

and annealed at 500°C for 10 min.

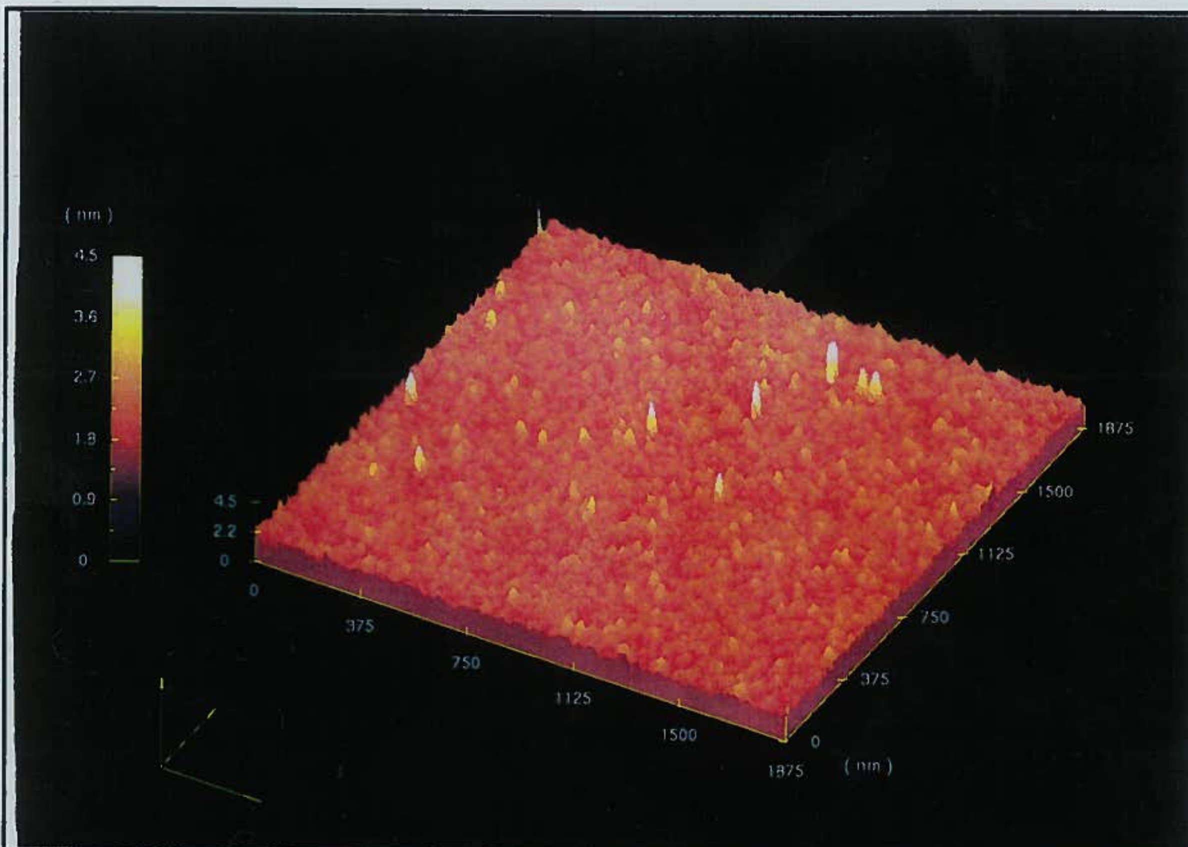
a) 35Å SrF_2 on HF/InP(100), RT/500°C

100Å

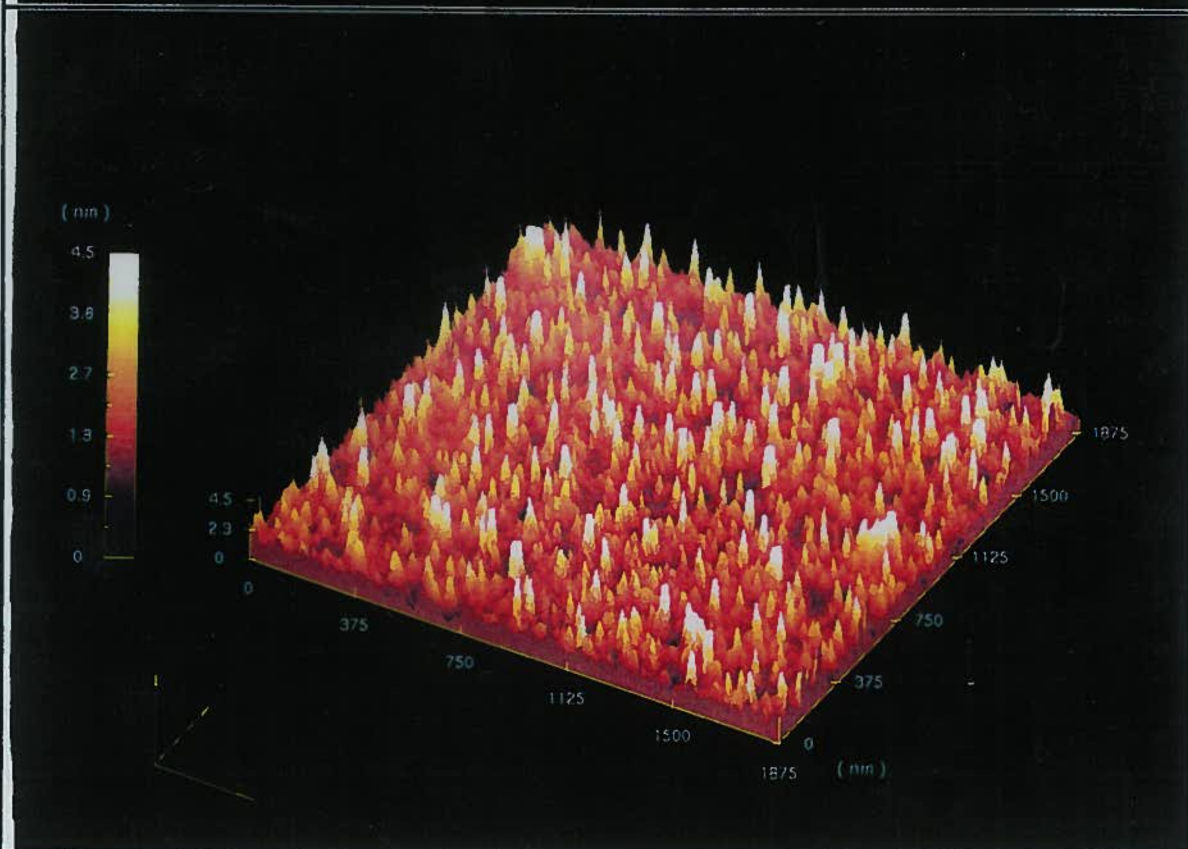
b) 35Å SrF_2 on As/InP(100), RT/500°C

AFM

50Å SrF_2, deposited at RT on

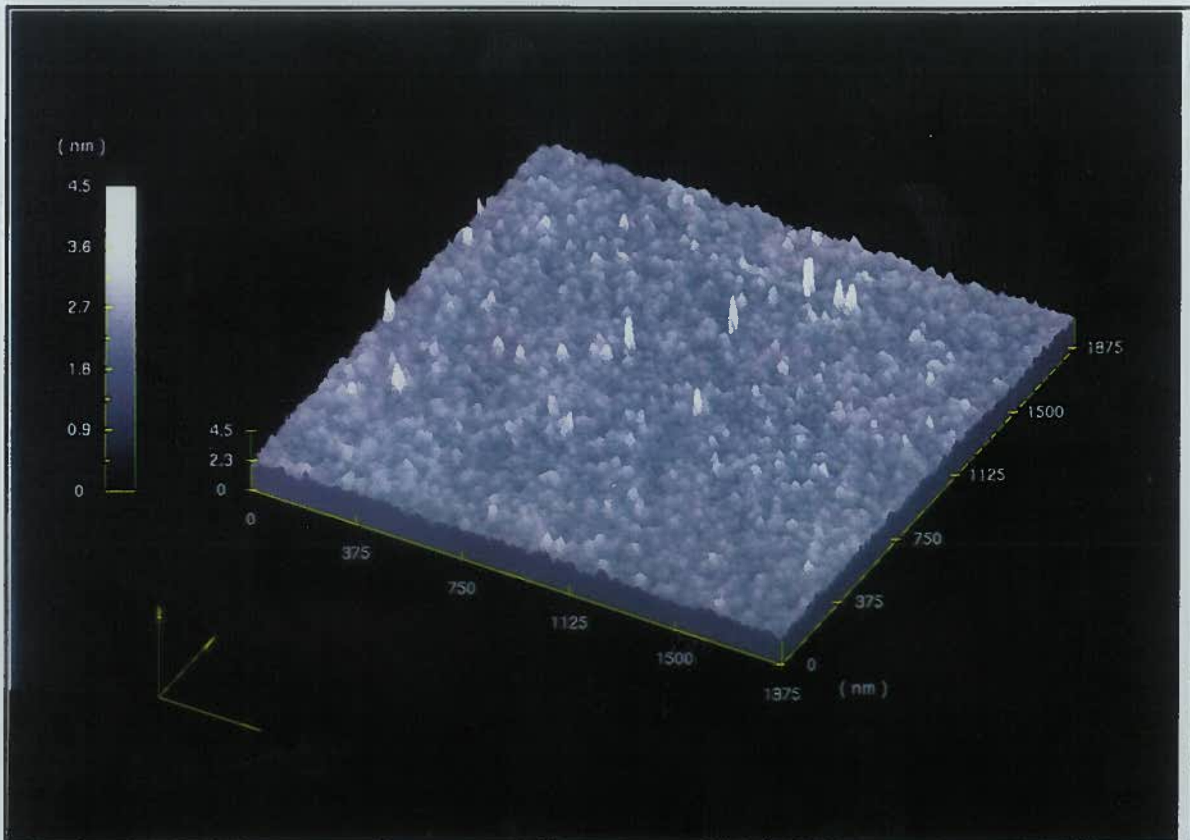


HF-etched InP(100)

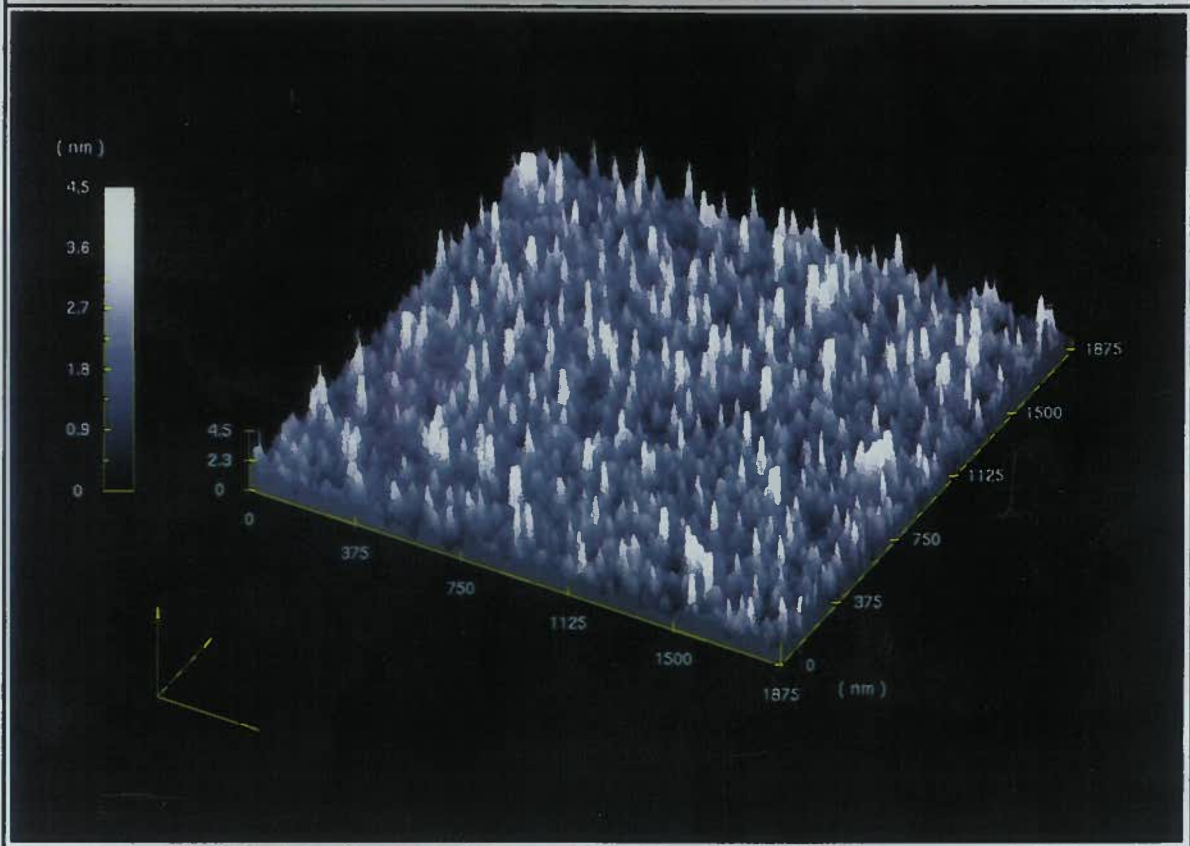


As/ InP(100)

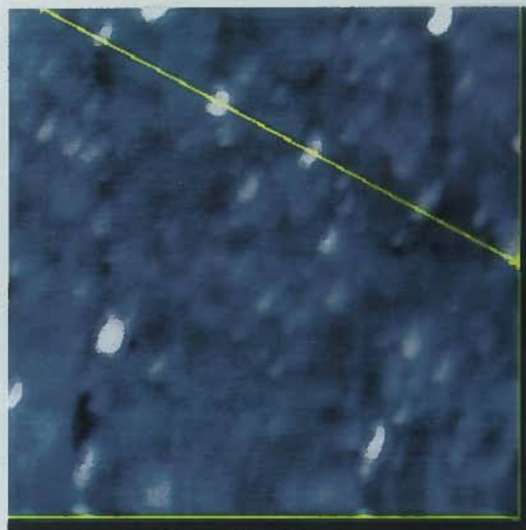
and annealed at 500°C for 10 min.

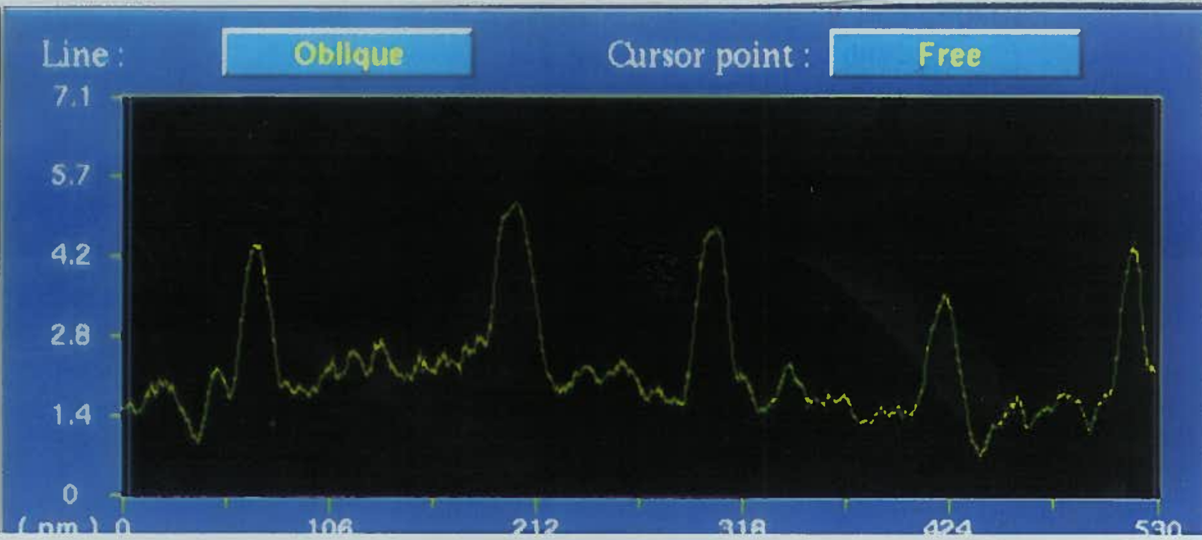


(a)



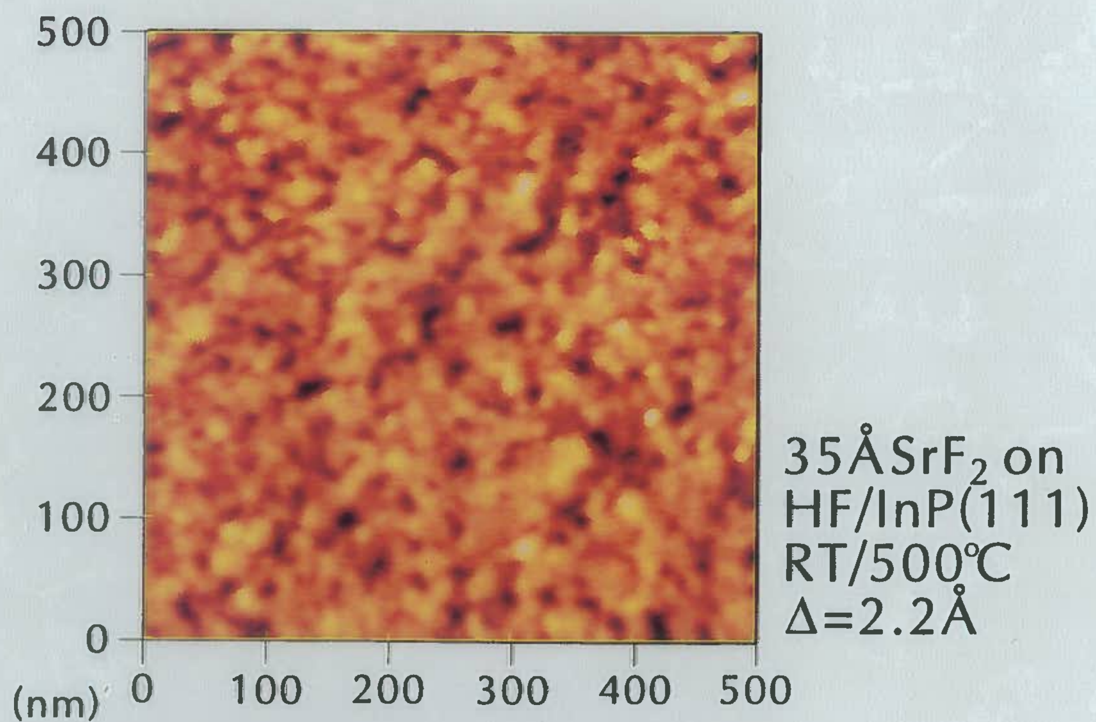
(b)

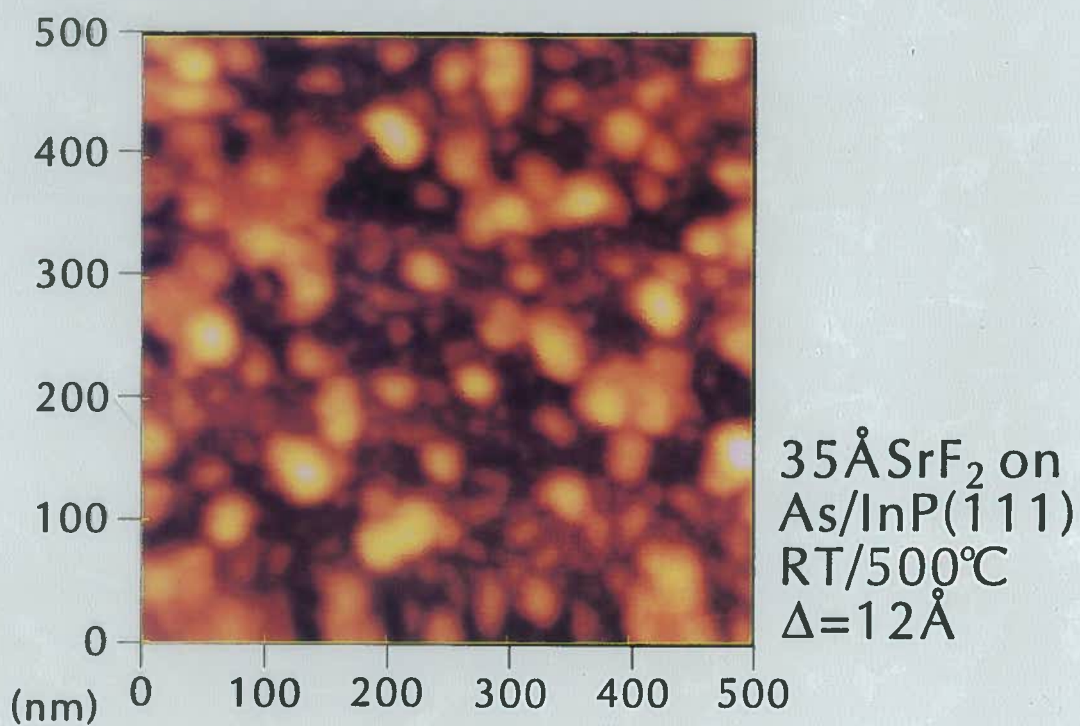


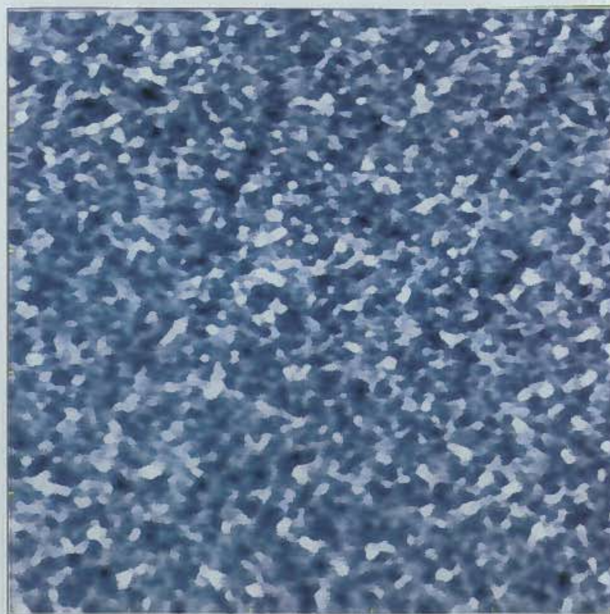


Line :
Oblique
Cursor point :
Free
7.1
5.7
4.2
2.8
1.4
0
(nm) 0
106
212
318
424
530

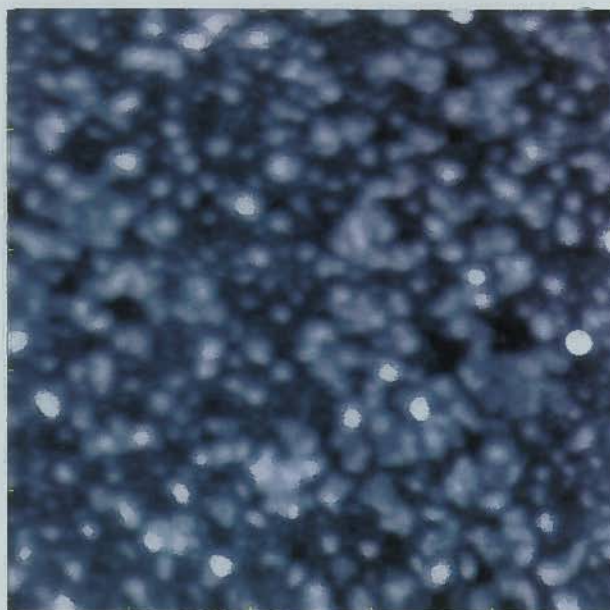
Atomic Force Microscopy







a) 35Å SrF_2 on HF/InP(111), RT/500°C

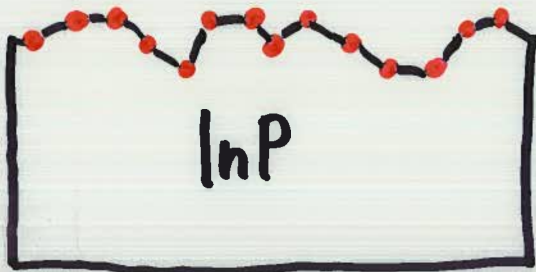


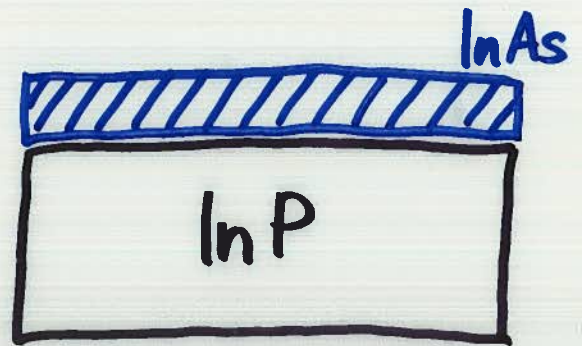
b) 35Å SrF_2 on As/InP(111), RT/500°C

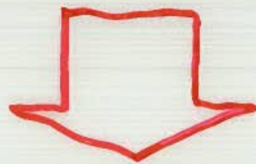
Growth model

HF-etched

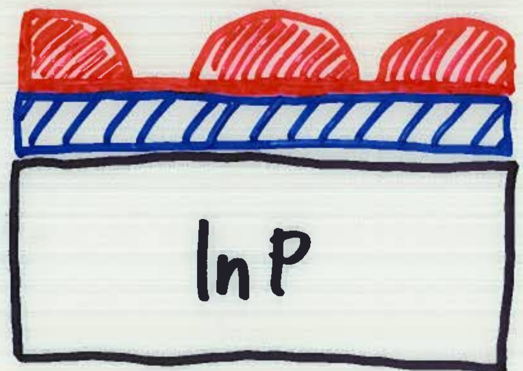
As-treated







50 Å SrF_2 at RT



Conclusion

HF-etching:

- rough surface
- F atoms remain at the surface ($\theta_F = 1$ML)
- annealing (300°C/5min): F partly removed ($\theta_F = \frac{1}{2}$ML)

As-treatment:

- flat surface
- InP(100): 2ML InAs, 4×2
- InP(111): 1ML InAs, 1×1

50Å SrF_2 on HF-etched InP(100):

- film continuous and flat
- polycrystalline
- surface roughness 1.8Å

35Å SrF_2 on HF-etched InP(111):

- film continuously and flat
- layer-by-layer mode
- texture
- surface roughness 2.2Å
- interfacial reaction after annealing

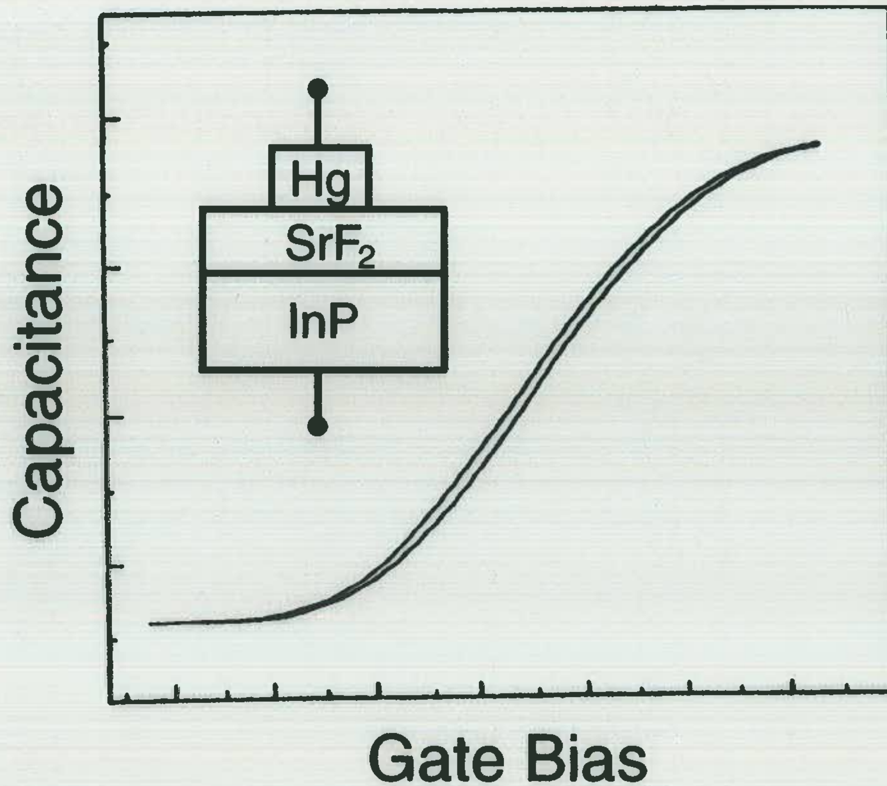
50Å SrF_2 on As-treated InP(100):

- Stranski-Krastanov mode, base layer 2ML
- epitaxial islands
- surface roughness 4.5Å
- no As segregation on top of the film

35Å SrF_2 on As-treated InP(111):

- rough, but continuous film
- epitaxial, no twinning
- surface roughness 12Å

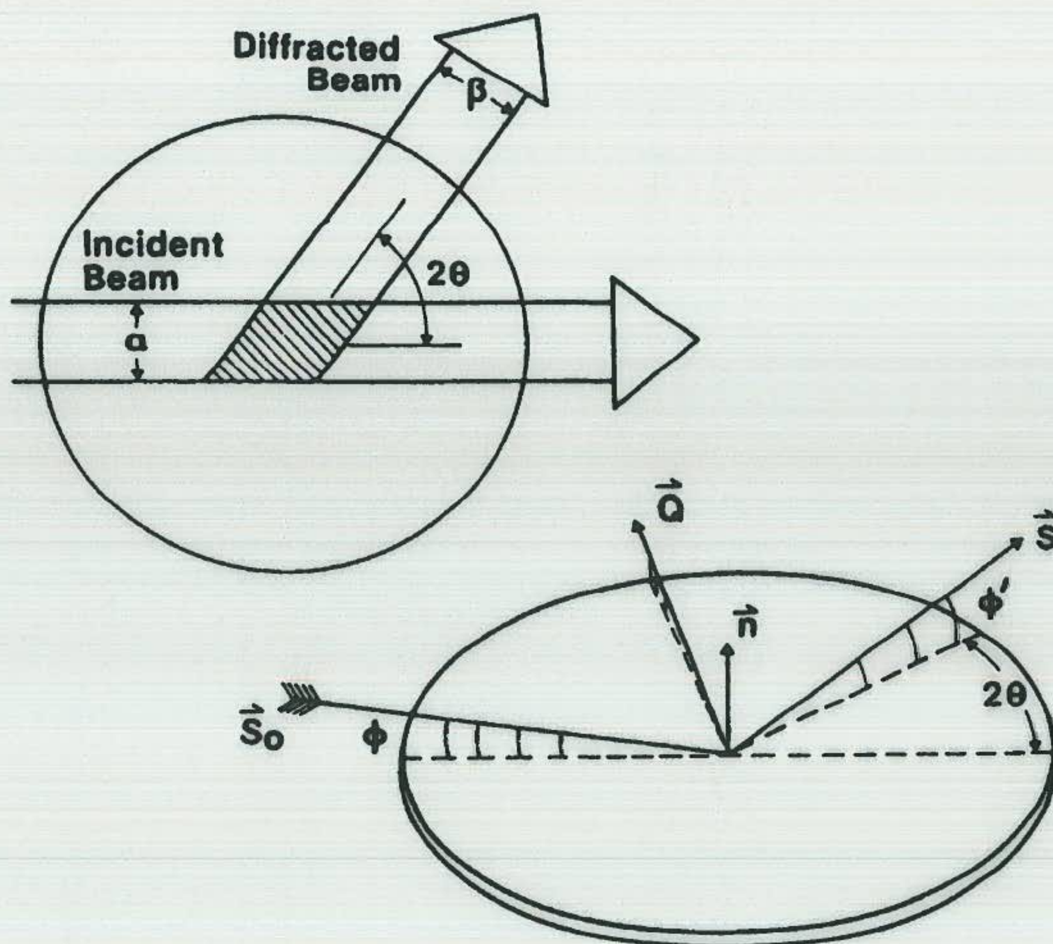
C - V - Curves



→ Electrical properties

- Interface state densities
- Time constants for (de)charging

X-Ray diffraction



→ Film Morphology

- vertical roughness
- lateral correlations (island size)
- oscillations (like RHEED) during growth

XEROX

"I left my heart in Hannover!"

Singing KARAOKE with Dr. Oshima and Mr. Menz, trainee from Aachen Technical Univ.