The influence of Zn predeposition on the properties of ZnSe/GaAs heterostructures

S. Heun, J. J. Paggel, S. Rubini,
and A. Franciosi
Laboratorio TASC-INFM, Trieste

Motivation:

Enormous technological impact of wide gap II-VI materials for blue-green optoelectronic applications

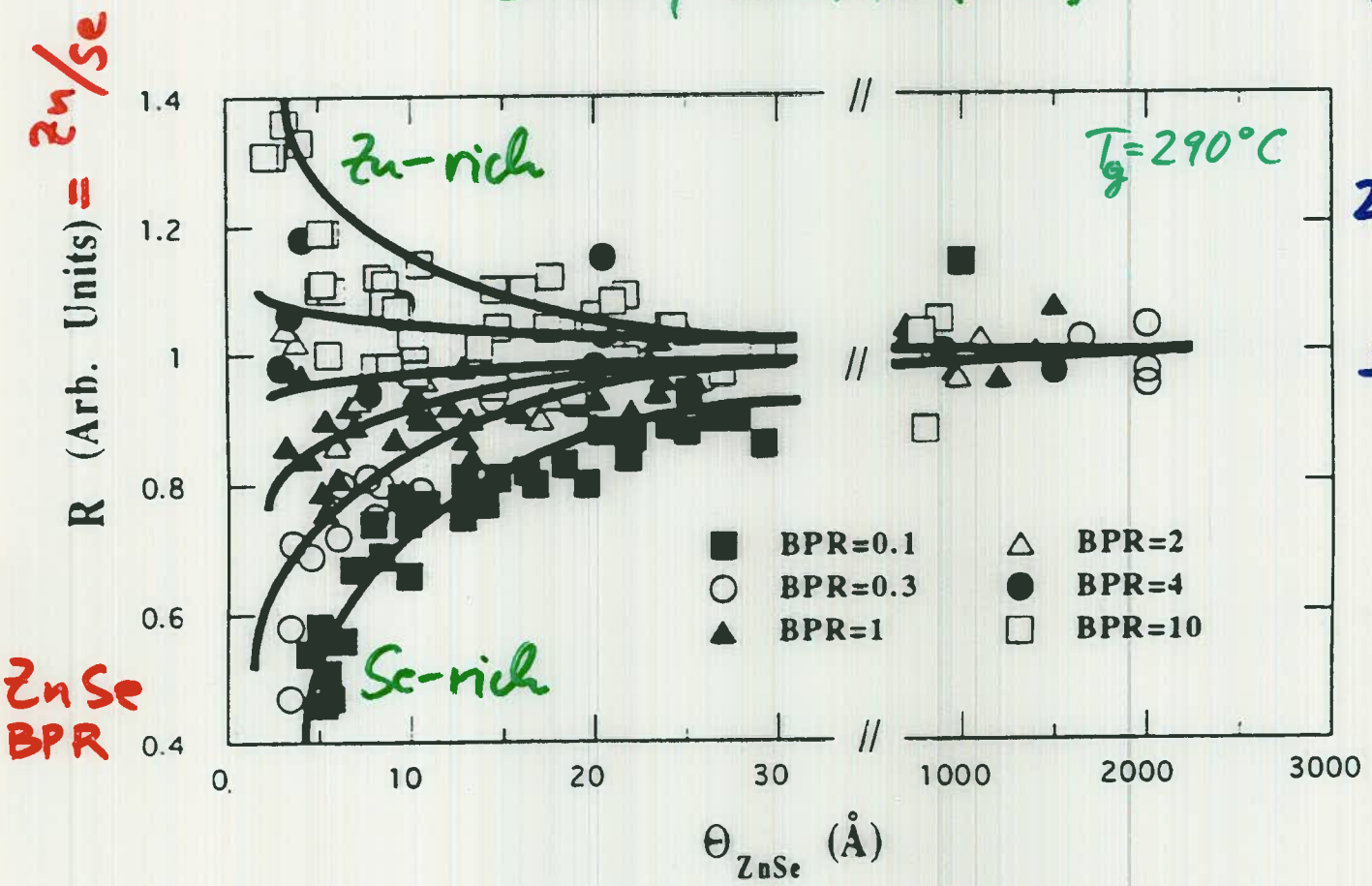
Device degradation: short lifetime in cw mode at RT (Stacking faults)

ZnSe/GaAs heterovalent heterostructures important

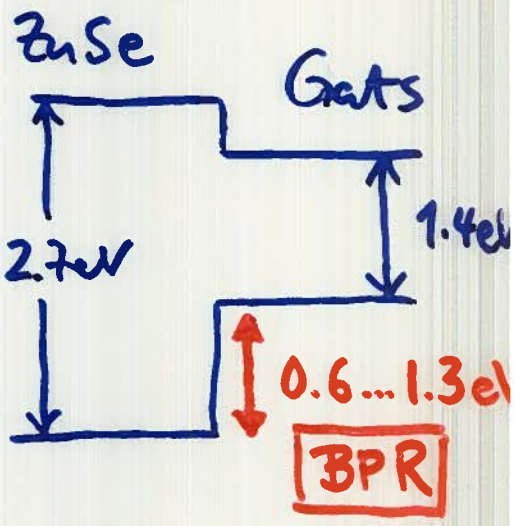
Large valence band offset in ZnSe/GaAs heterostructures hinders hole injection

Properties dependent on local interface structure

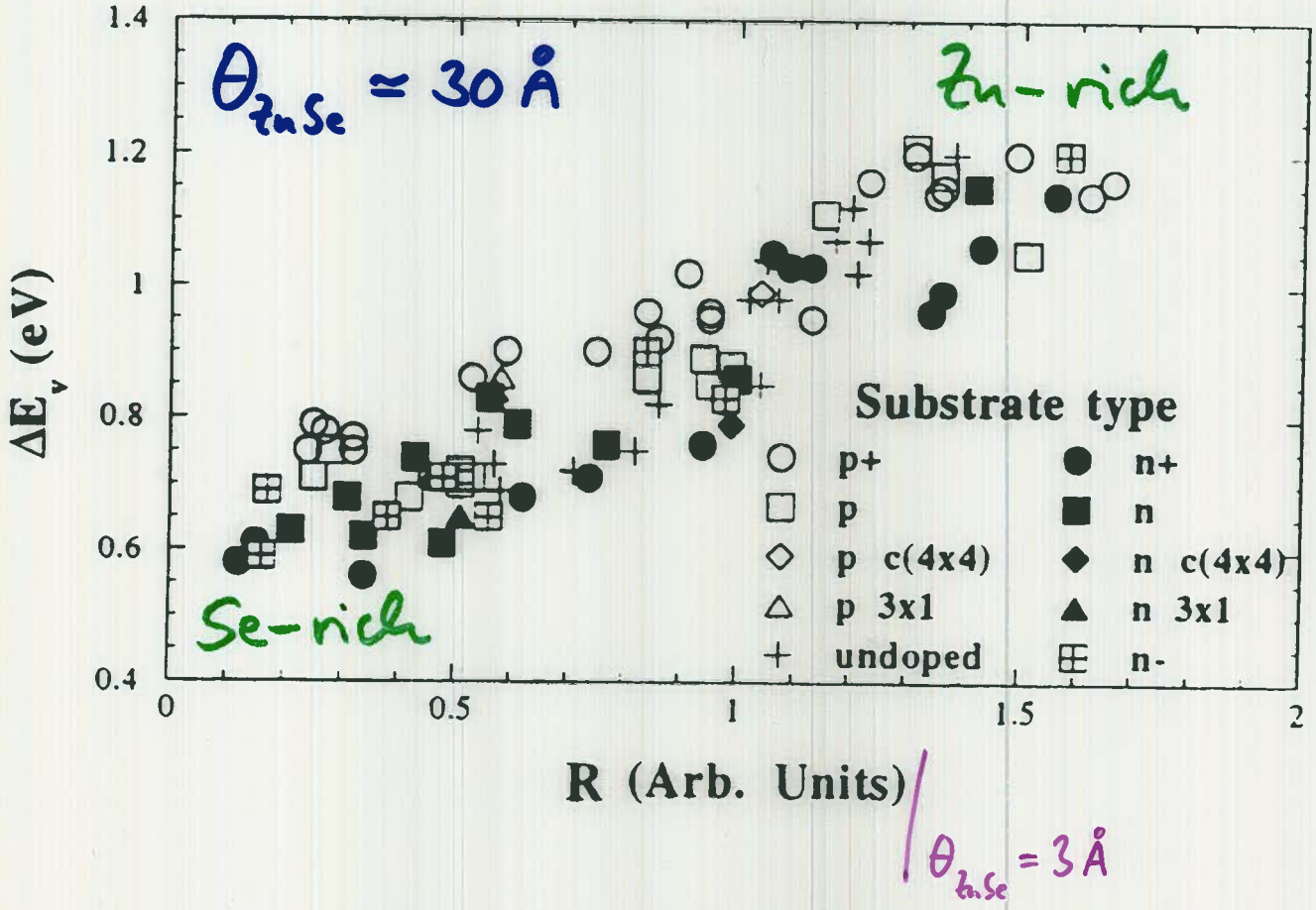
ZnSe / GaAs (100)



VBO



R. Nicolini et al.: PRL 72 (1994) 294



$\theta_{ZnSe} = 3$ Å

R. Nicolini et al.: PRL 72 (1994) 294

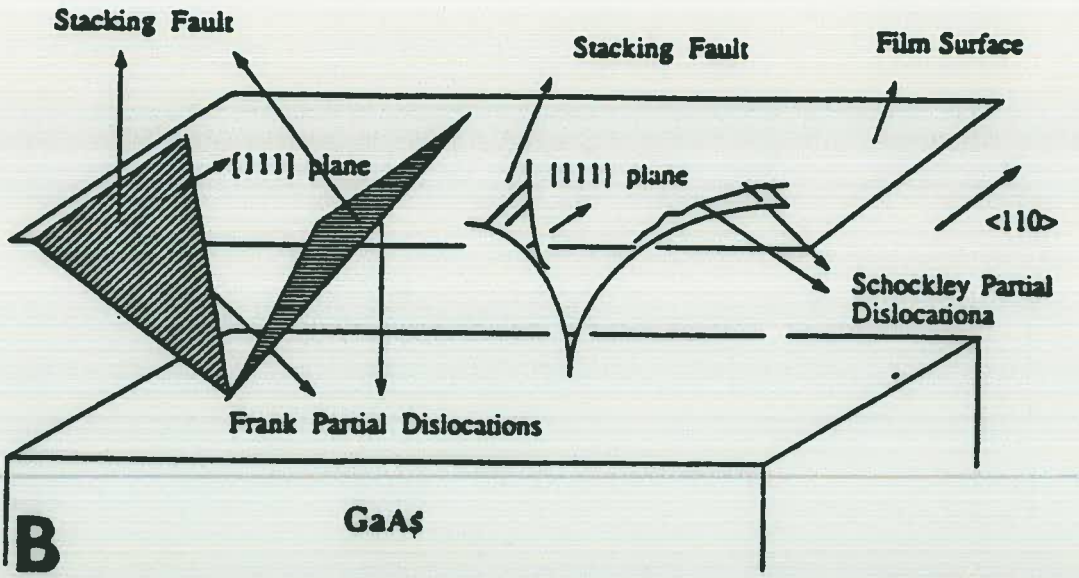


Table I

Density of Faulted Defects in ZnS_xSe_{1-x} as a Function of Growth Conditions

Growth mode	GaAs Surface	Surface Treatment	Density of Frank Partial Dislocations	Density of Schockley Partial Dislocations
2-D within 20 secs	Ga-stabilized	None	$1 \times 10^8/cm^2$	$7 \times 10^7/cm^2$
2-D within 8-9 secs	As-stabilized	Se	$2 \times 10^8/cm^2$	$5 \times 10^7/cm^2$
2-D within 8-9 secs	As-terminated	Zn	$1 \times 10^6/cm^2$	$2 \times 10^8/cm^2$
2-D right away	As-stabilized	None	$1 \times 10^7/cm^2$	$1 \times 10^6/cm^2$
2-D right away	As-rich	Zn	$5 \times 10^7/cm^2$	$< 5 \times 10^4/cm^2$
2-D right away	As-stabilized	Zn	$< 5 \times 10^4/cm^2$	$< 5 \times 10^4/cm^2$

L. H. Kuo et al.: SPIE Vol. 2228, p. 144 (1994)

Experimental details

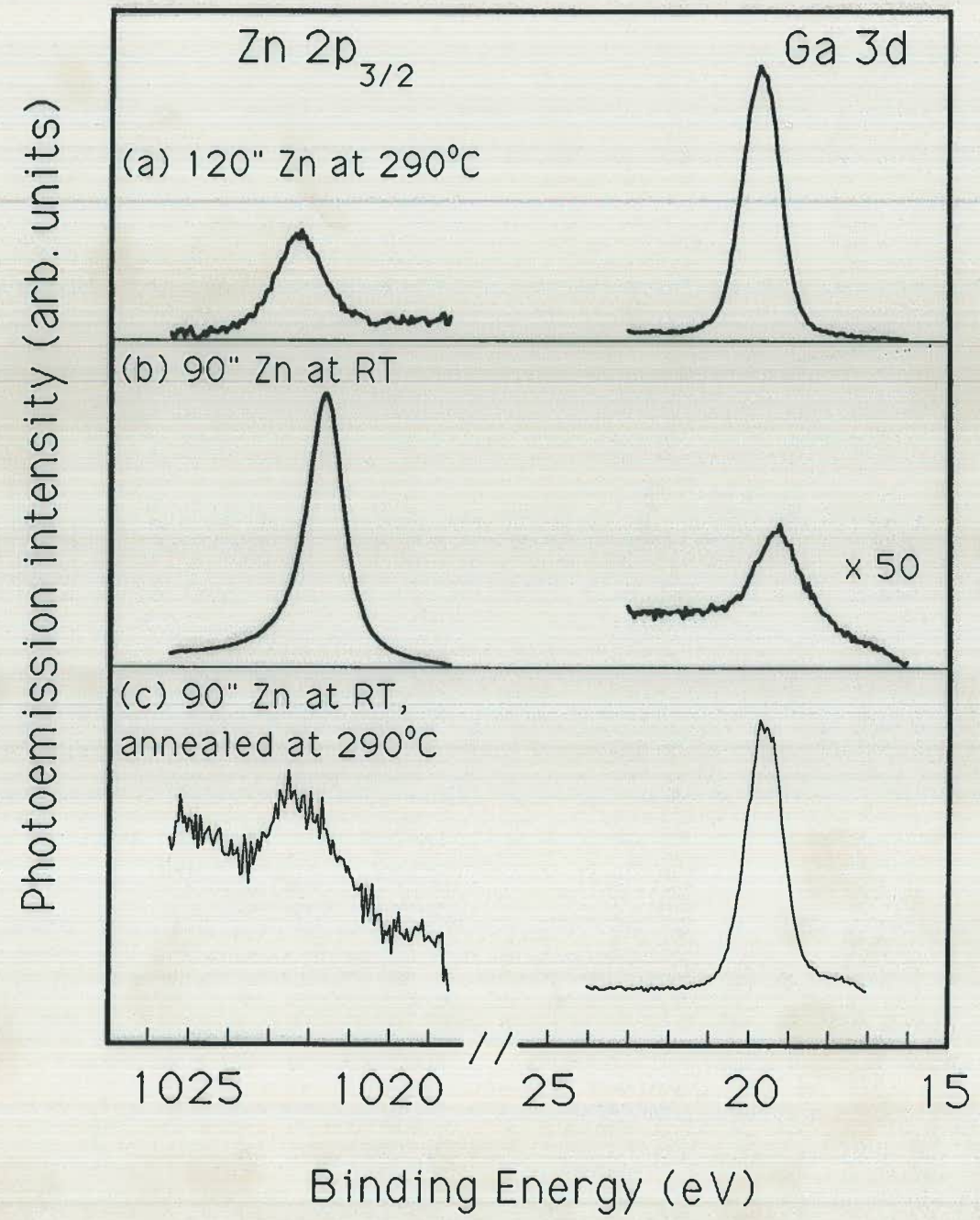
① GaAs (001) - 2×4

② Zn predosing with 1.6×10^{-6} torr

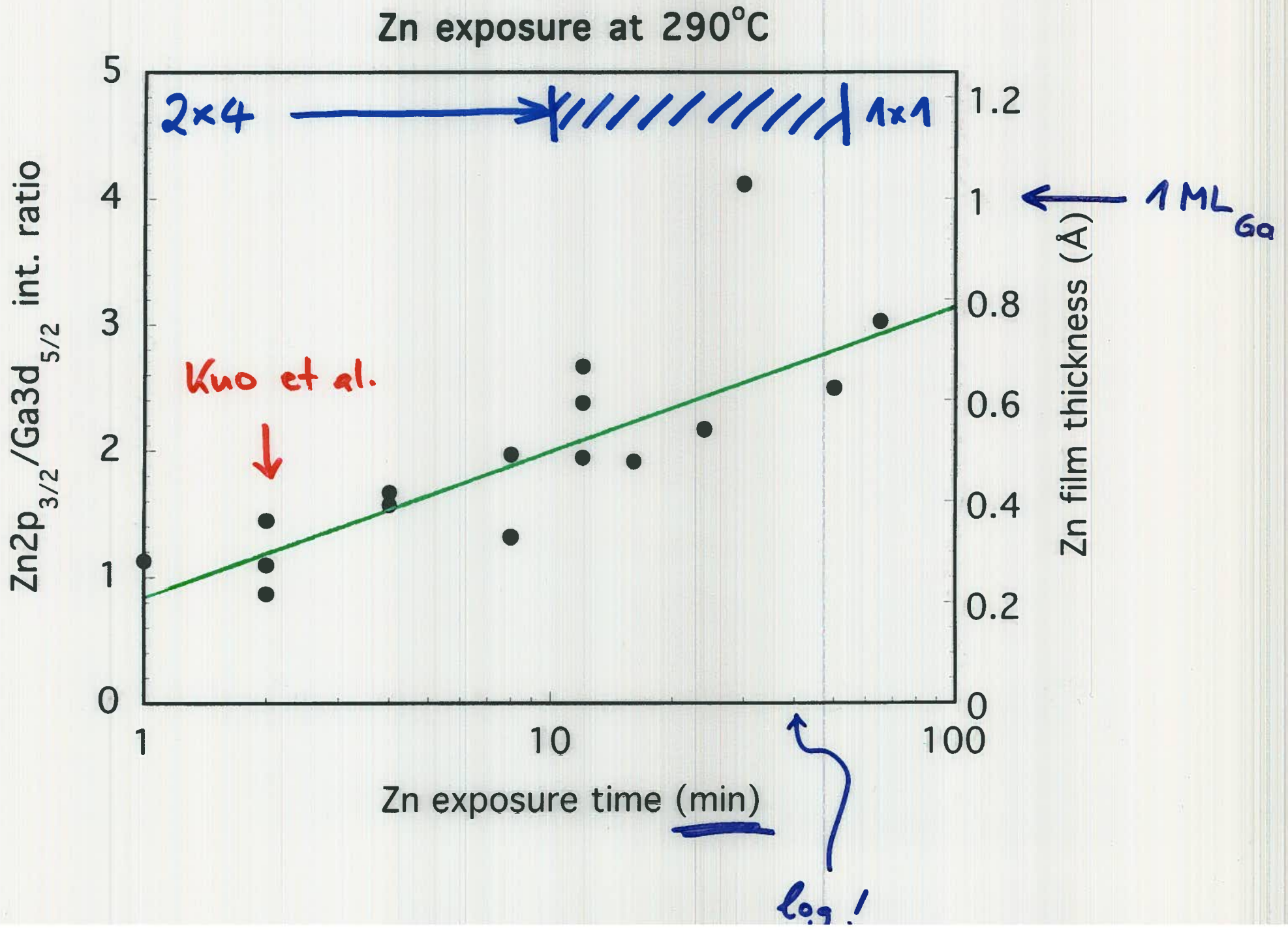
③ ZnSe growth with BPR = 1
growth rate 0.36 µm/h

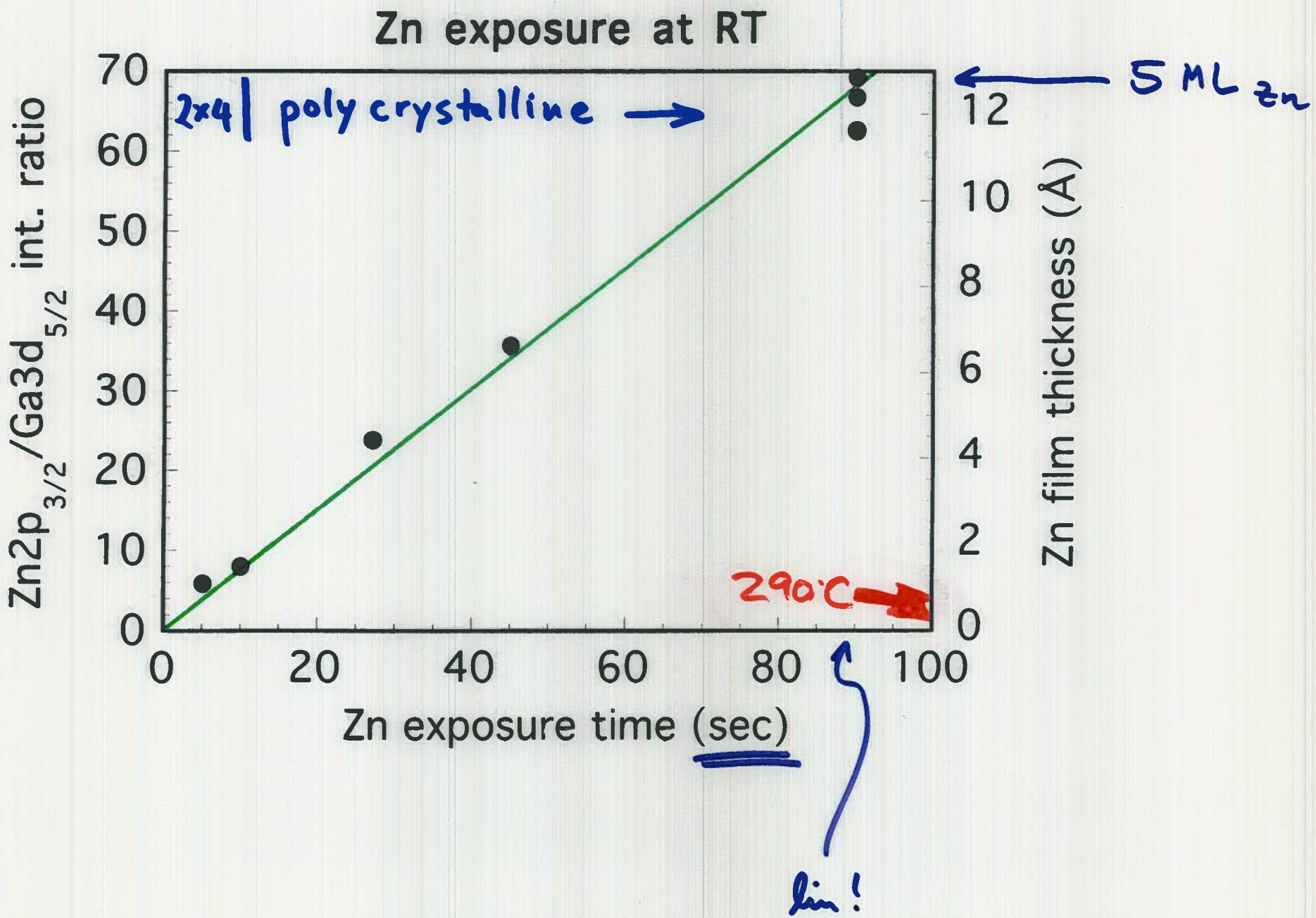
XPS : Al K_α , $\Delta E = 0.7$ eV

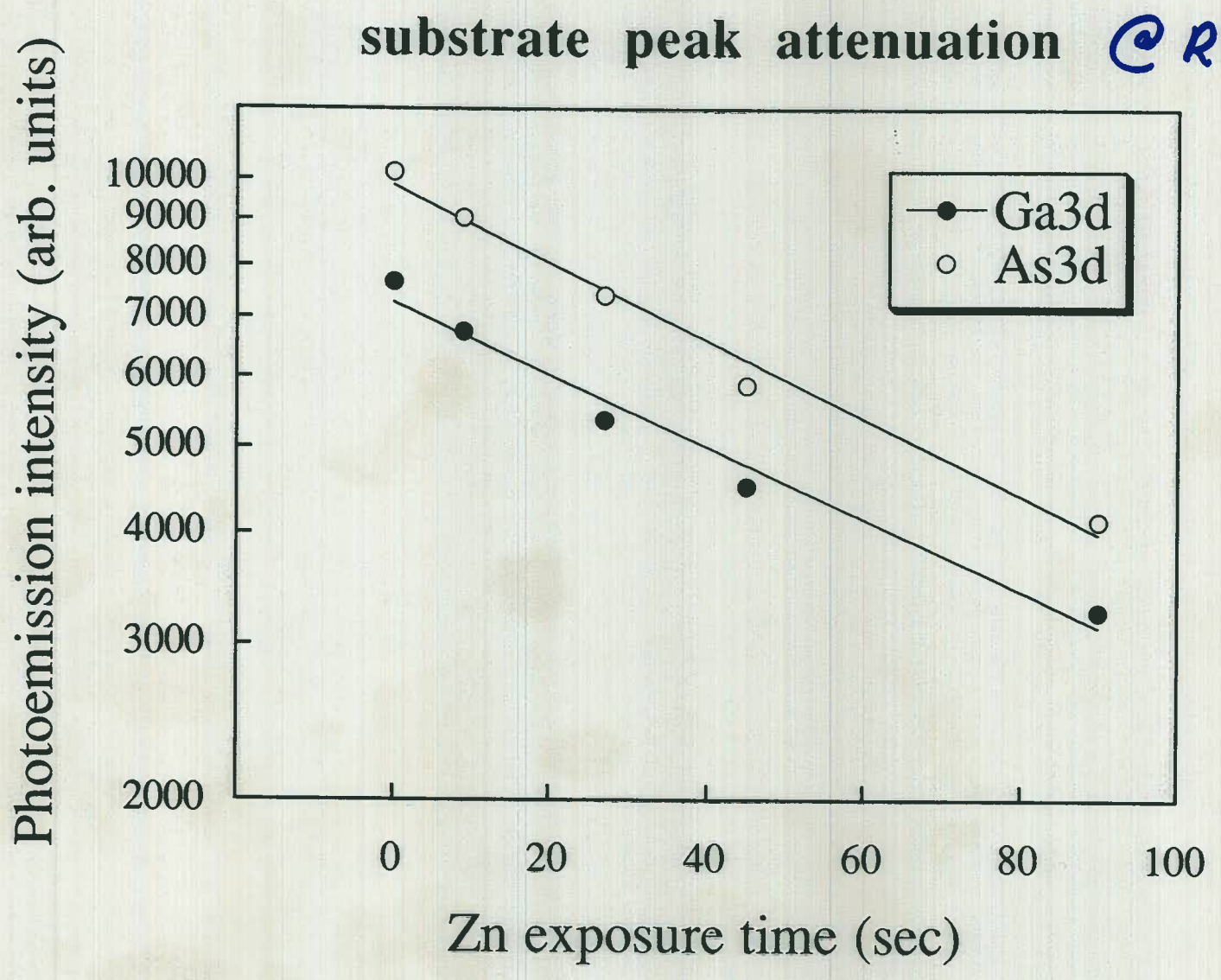
θ from $\frac{I_{Zn}}{I_{Ga}}$ with $\lambda = 15$ Å



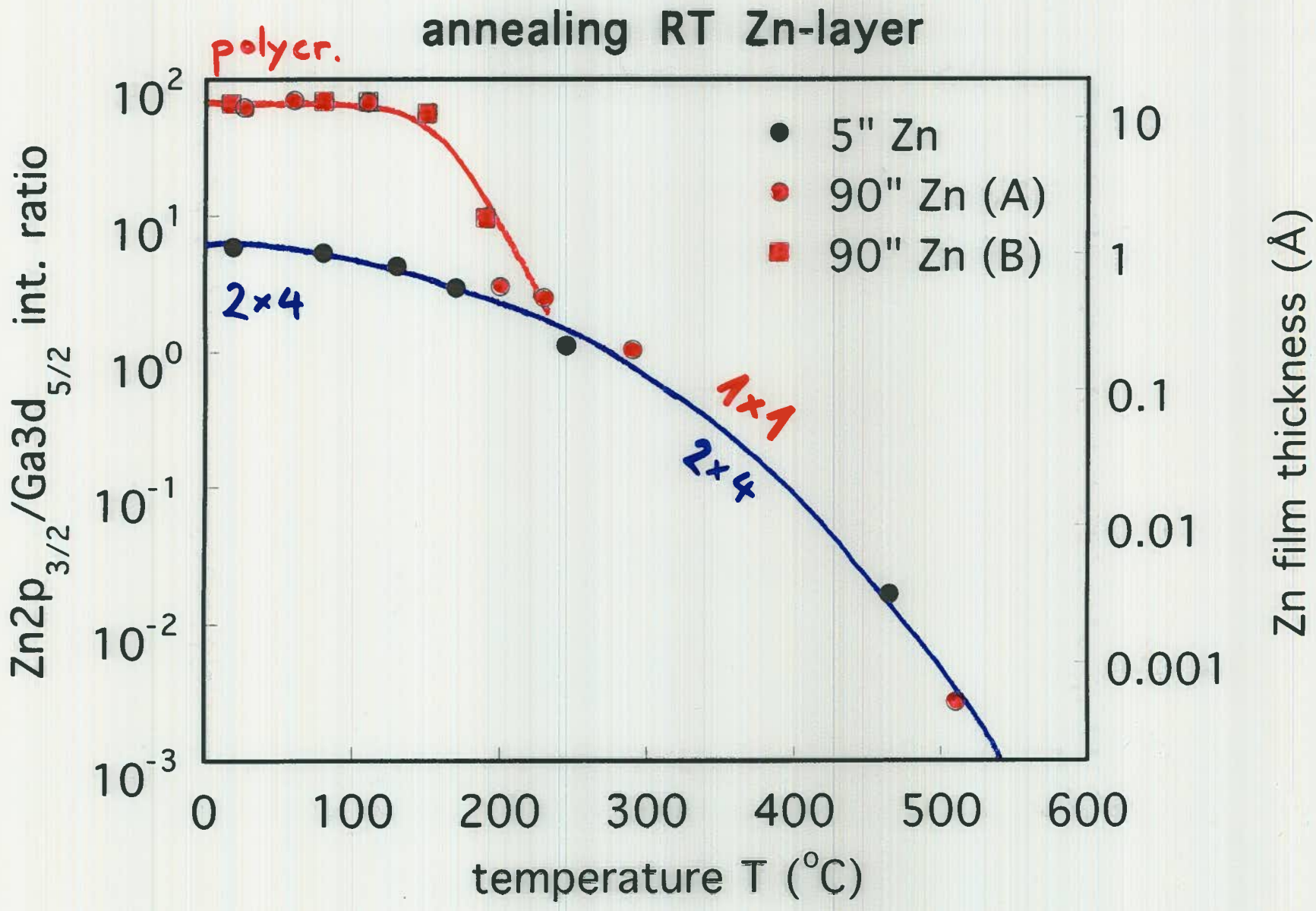
(Heun et al.: JVST B 14 (1996) 2980)

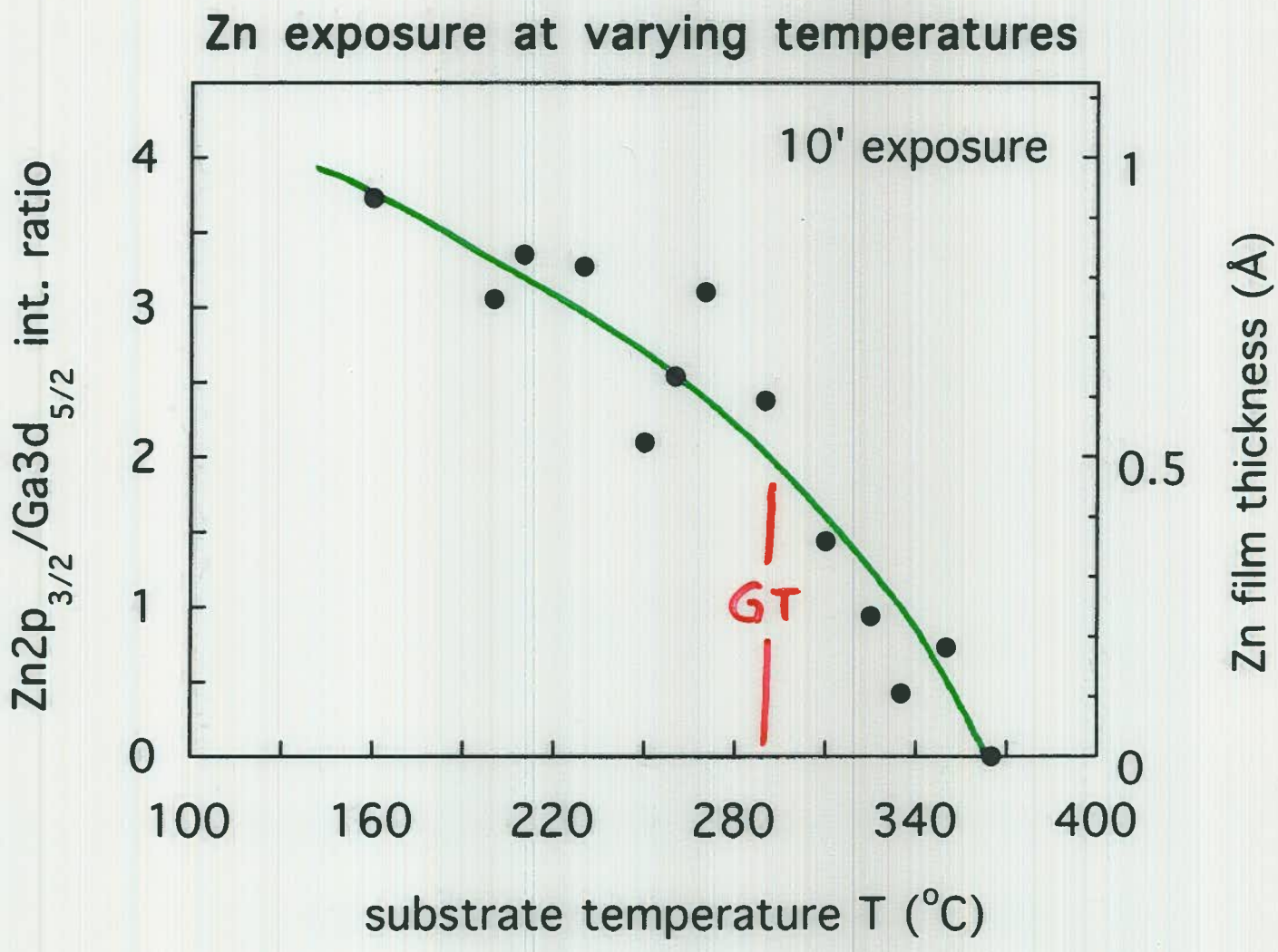

Zn exposure at 290°C
2×4
1×1
Kuo et al.
1 ML Ga
Zn2p3/2/Ga3d5/2 int. ratio
Zn film thickness (Å)
Zn exposure time (min)
log !
0
1
2
3
4
5
0.2
0.4
0.6
0.8
1
1.2
1
10
100

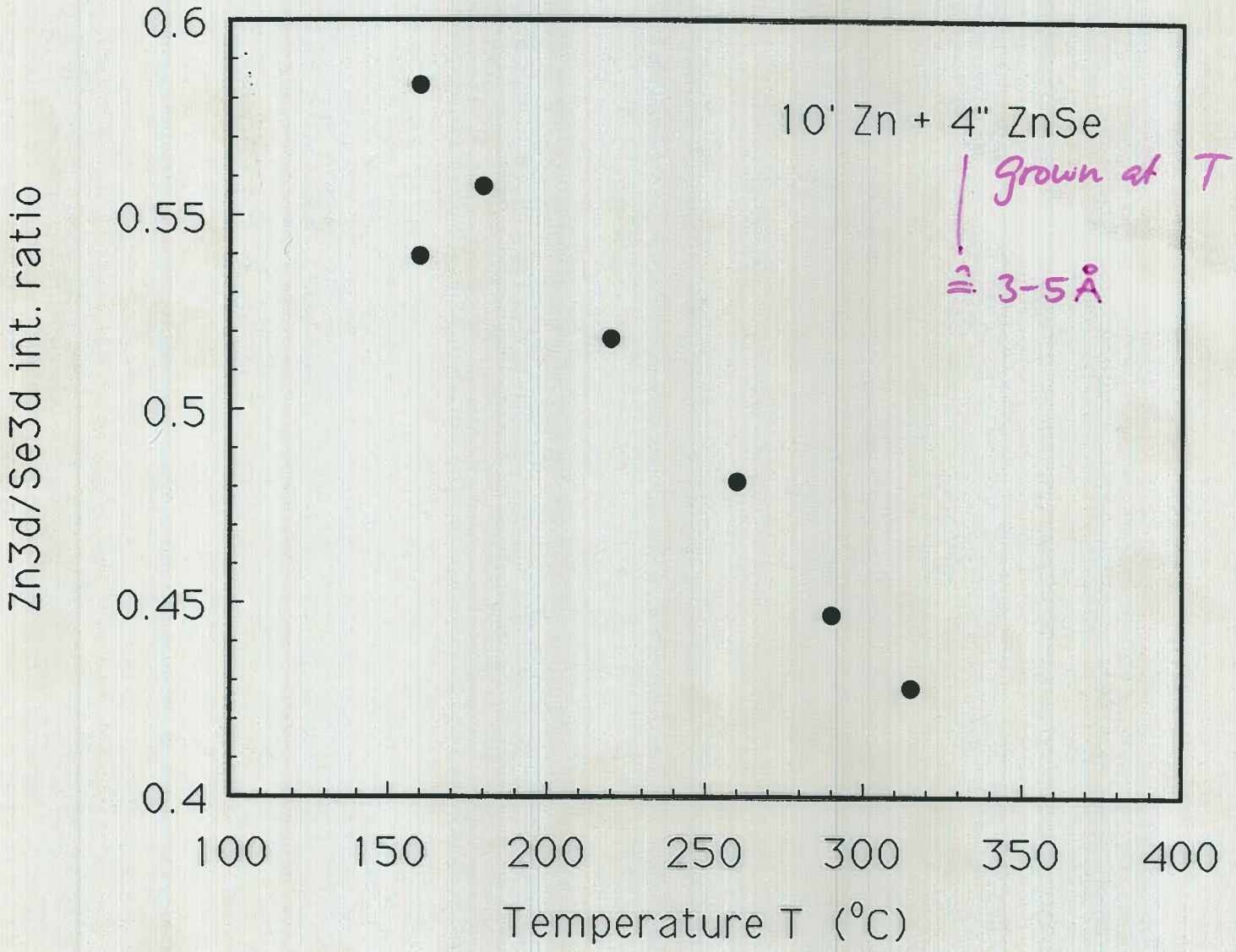

Zn exposure at RT
2x4 | polycrystalline
5 ML Zn
290°C
lin!
Zn2p3/2/Ga3d5/2 int. ratio
Zn film thickness (Å)
Zn exposure time (sec)
0
10
20
30
40
50
60
70
0
2
4
6
8
10
12
0
20
40
60
80
100

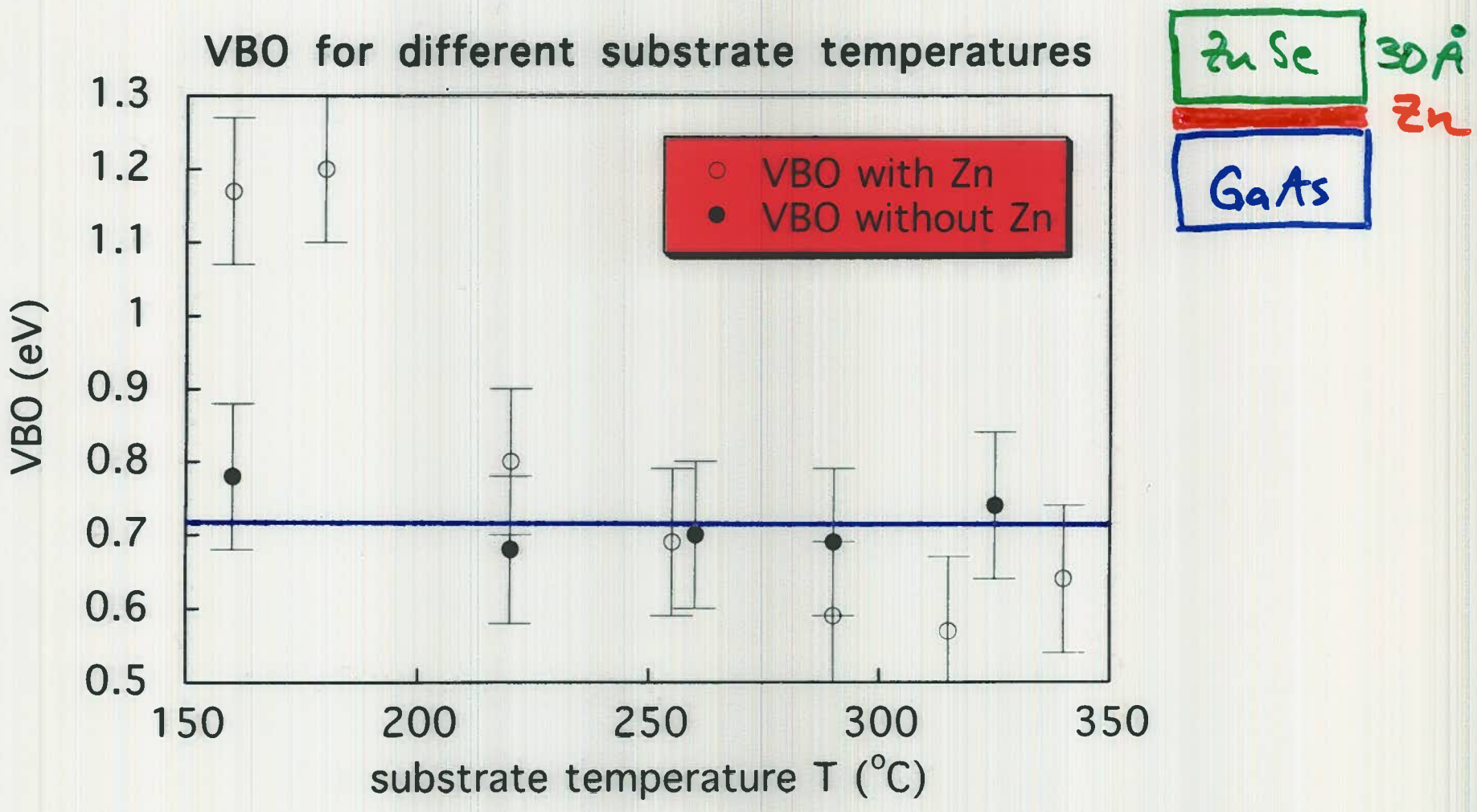


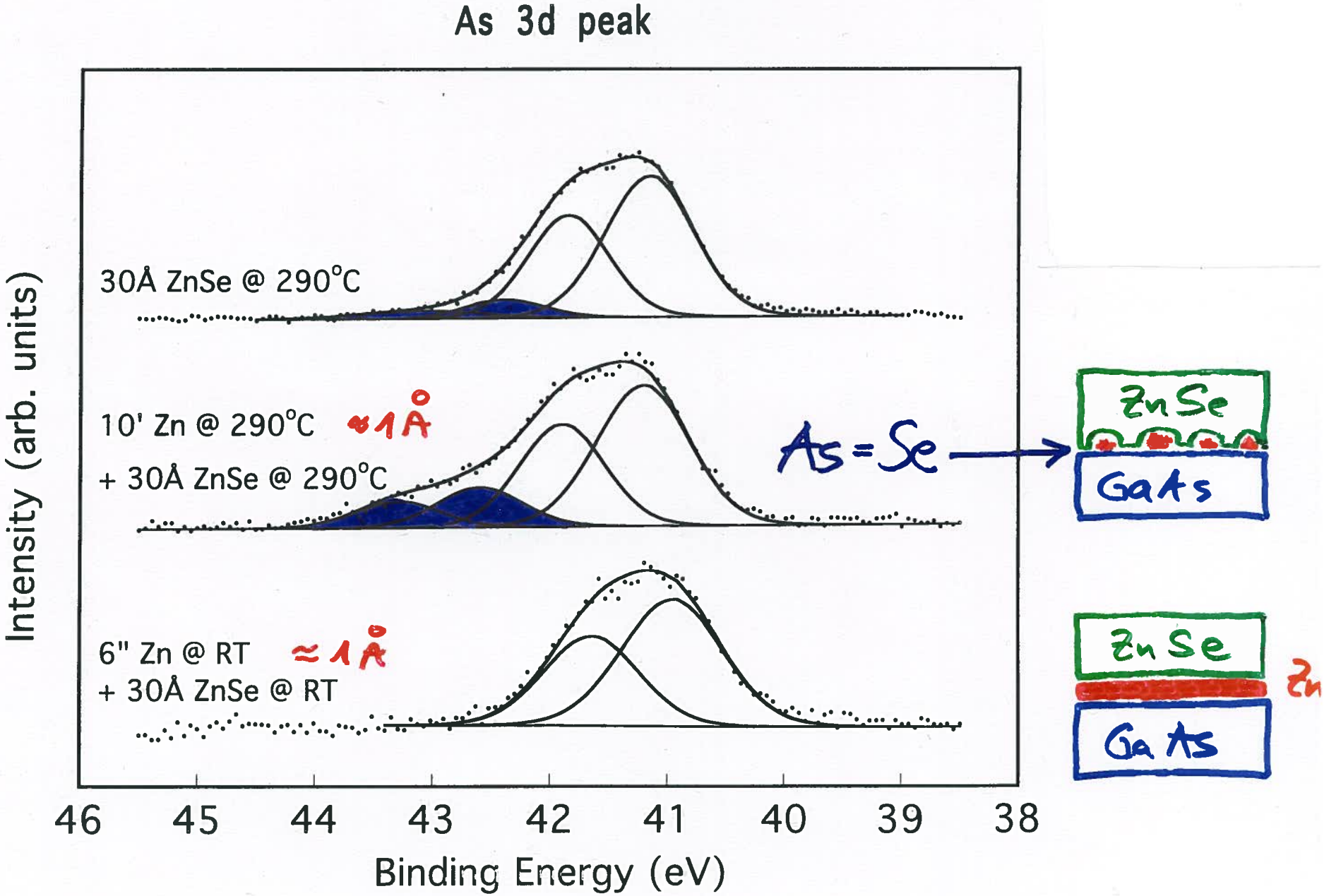
→ Zn grows in layer-by-layer mode


annealing RT Zn-layer
polycr.
5" Zn
90" Zn (A)
90" Zn (B)
2×4
1×1
2×4
Zn2p3/2/Ga3d5/2 int. ratio
Zn film thickness (Å)
temperature T (°C)
10^2
10^1
10^0
10^-1
10^-2
10^-3
10
1
0.1
0.01
0.001
0
100
200
300
400
500
600


Zn exposure at varying temperatures
10' exposure
GT
Zn2p3/2/Ga3d5/2 int. ratio
Zn film thickness (Å)
substrate temperature T (°C)
0
1
2
3
4
0
0.5
1
100
160
220
280
340
400


0.6
0.55
0.5
0.45
0.4
Zn3d/Se3d int. ratio
10' Zn + 4" ZnSe
Grown at T
≅ 3-5Å
100
150
200
250
300
350
400
Temperature T (°C)


VBO for different substrate temperatures
VBO with Zn
VBO without Zn
VBO (eV)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
150
200
250
300
350
substrate temperature T (°C)
ZnSe
30 Å
Zn
GaAs


As 3d peak
30Å ZnSe @ 290°C
10' Zn @ 290°C ≈1Å
+ 30Å ZnSe @ 290°C
6" Zn @ RT ≈1Å
+ 30Å ZnSe @ RT
Intensity (arb. units)
46
45
44
43
42
41
40
39
38
Binding Energy (eV)
As=Se
ZnSe
GaAs
ZnSe
Zn
GaAs

Conclusion

Exposure at GT (290°C):

only submonolayer coverages

no change in VBO

no difference in atomic interdiffusion
(As = Se bonds)

Exposure at RT: (T < 150°C)

monolayer and multilayer coverages
annealing @ GT removes most of the Zn
increased VBO

reduced atomic interdiffusion (no As = Se bond