XPS measurements of sodium in Bridgman-grown $CuInSe_{2+x}$

by
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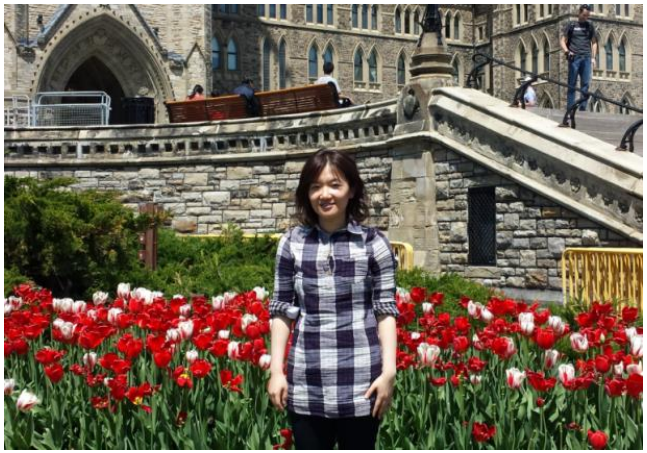

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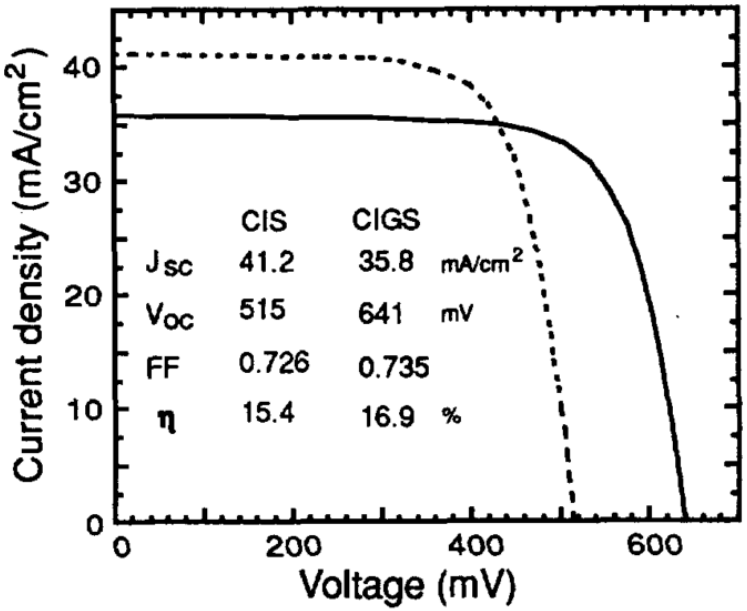
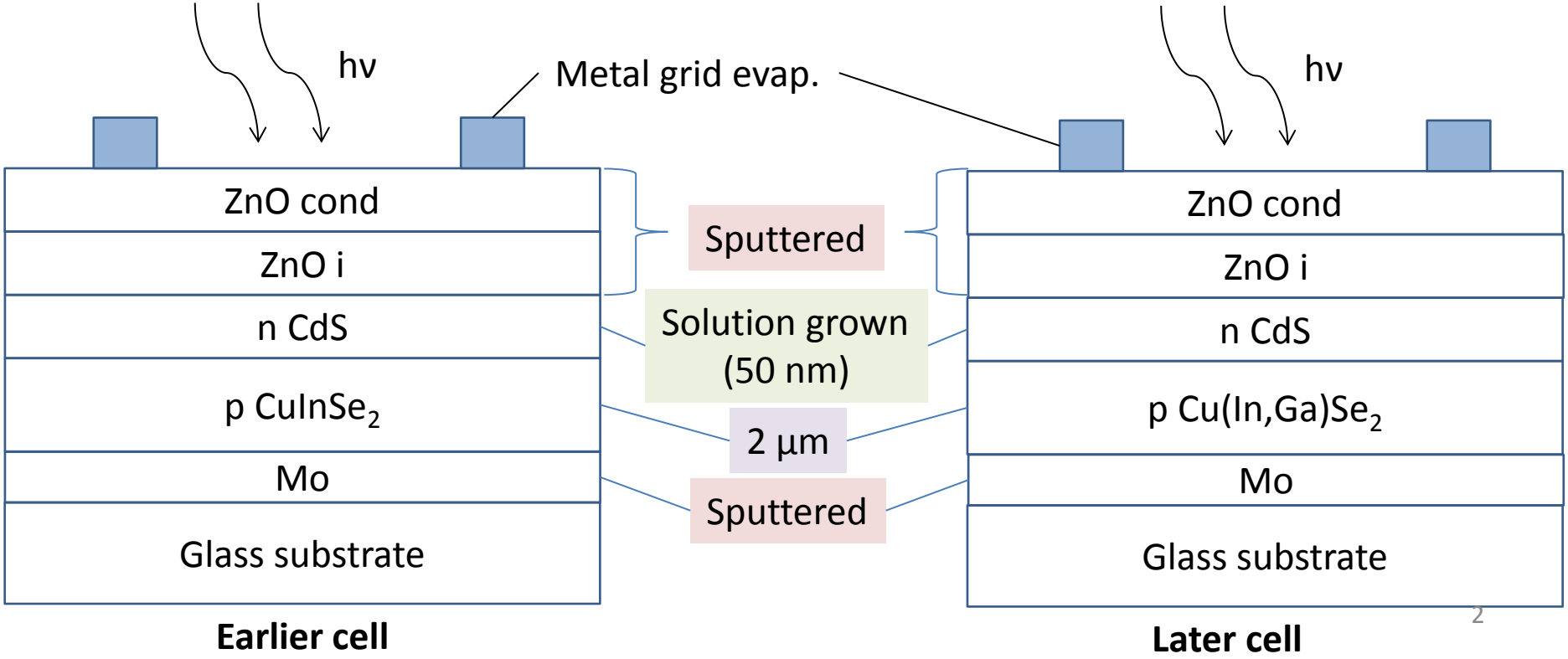
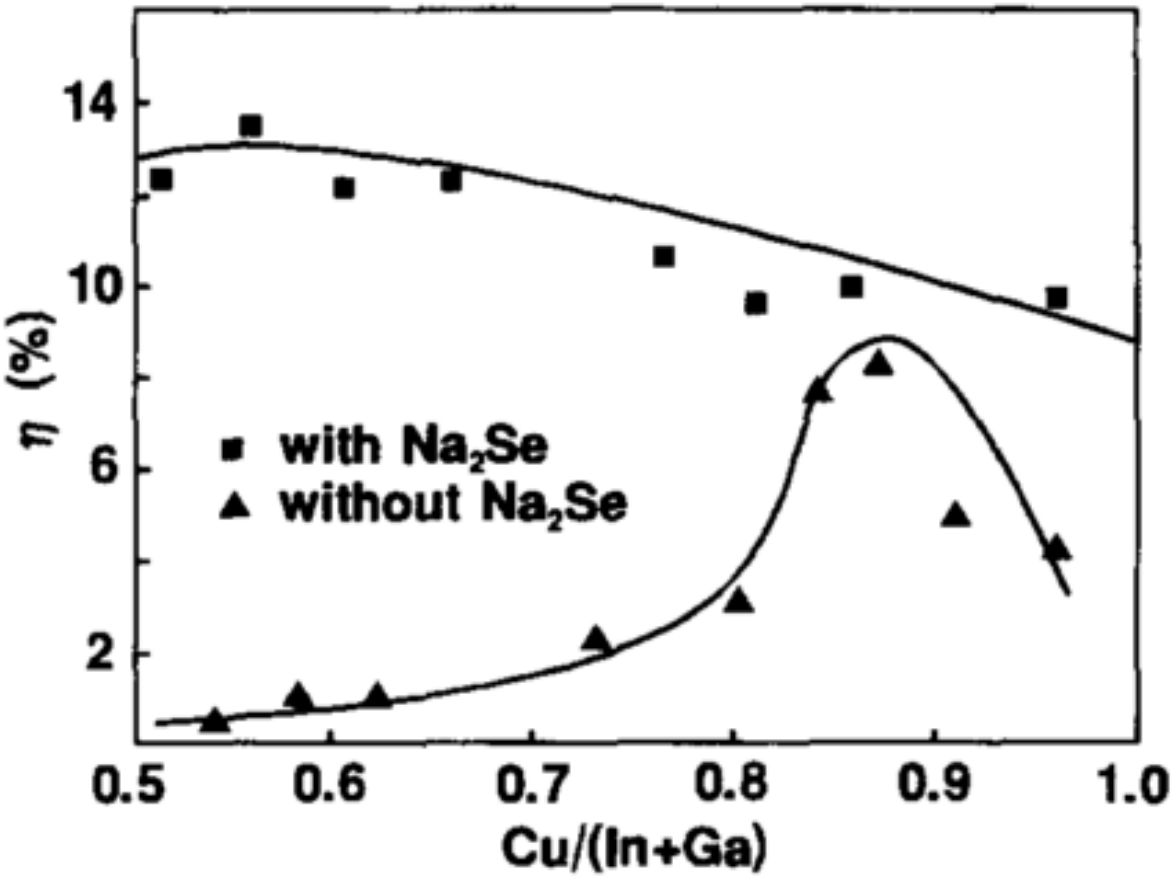
Ph.D. student



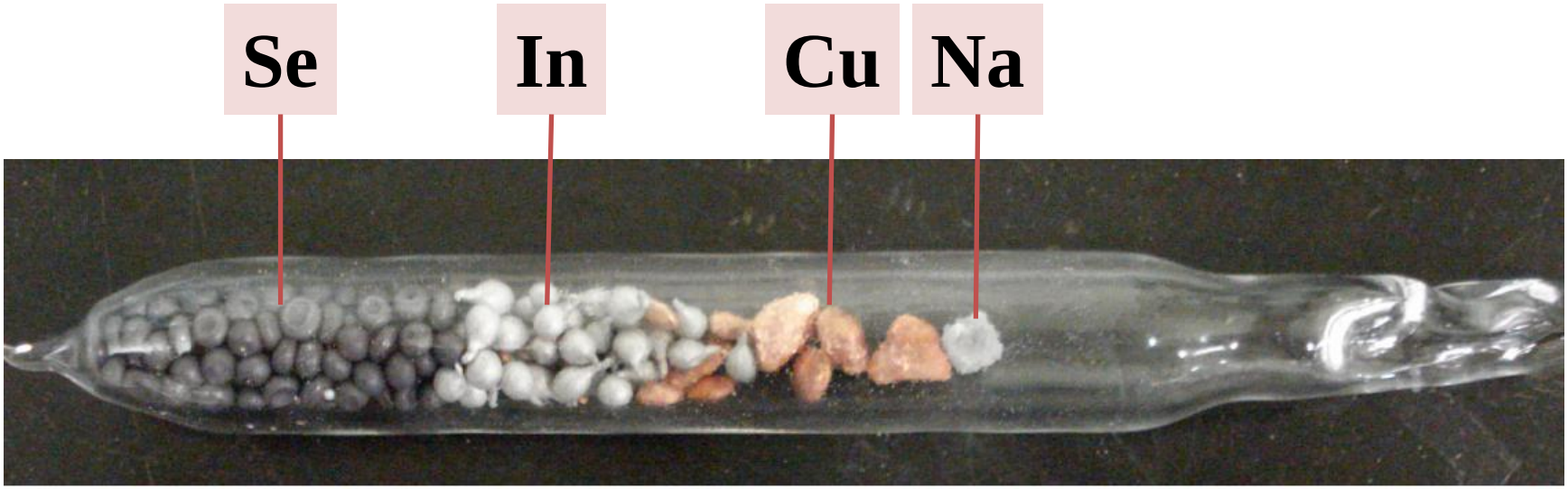
J-V characteristics under simulated AM 1.5 conditions of a Cu(In,Ga)Se and a $CuInSe_2$ cell. The cells are AR-coated.
Cell temperature is 25 °C
(Hedstrom and Ohlsen, 1993)



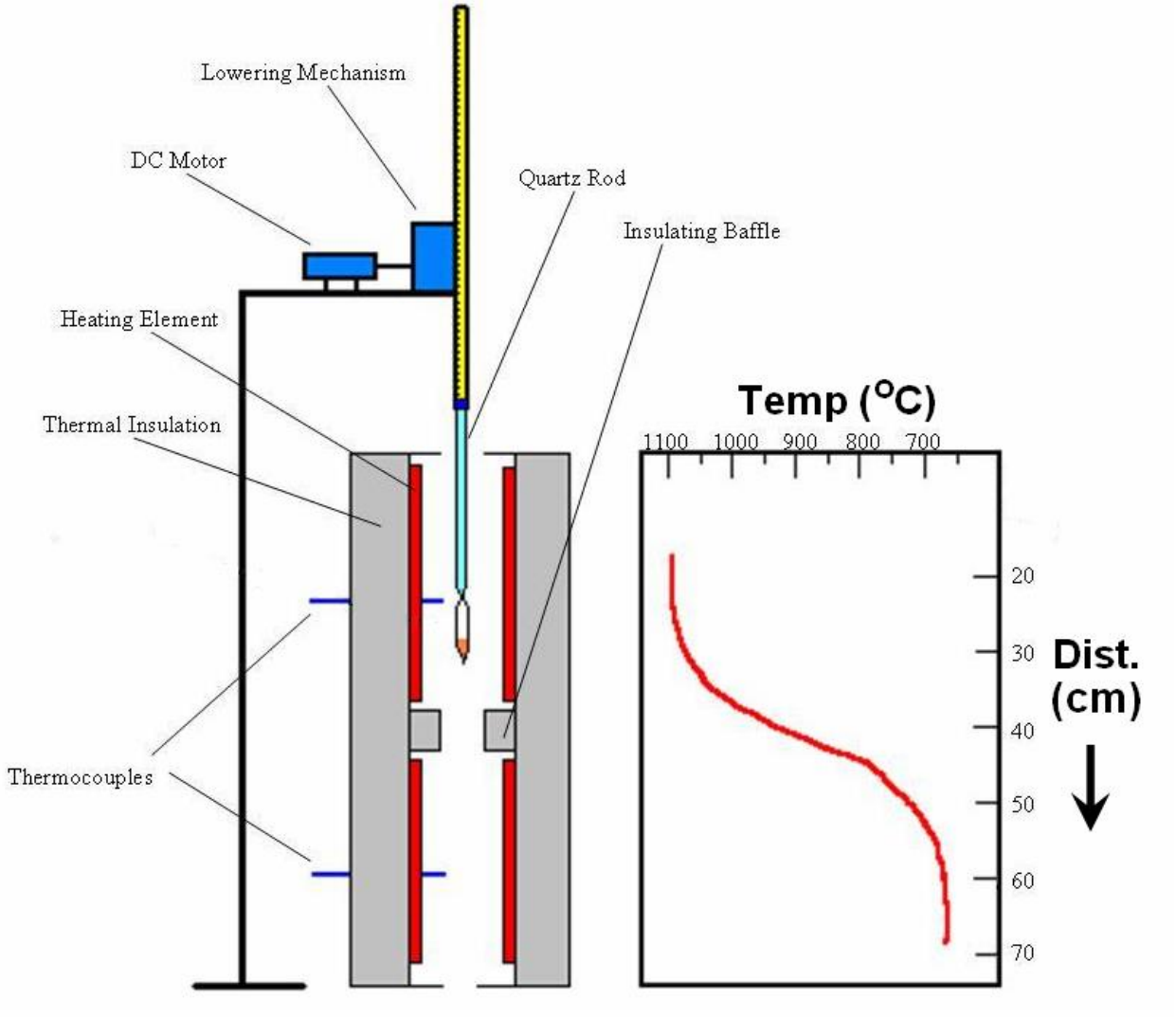
Solar cell efficiency with added Na_2Se (Nakada and Ohbo, 1997)



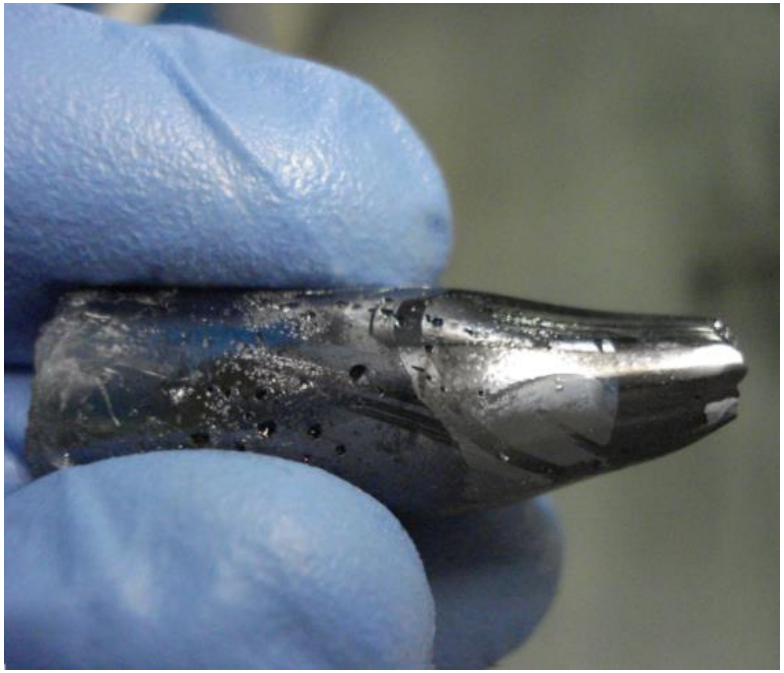
A quartz ampoule with Cu, In, Se, and Na



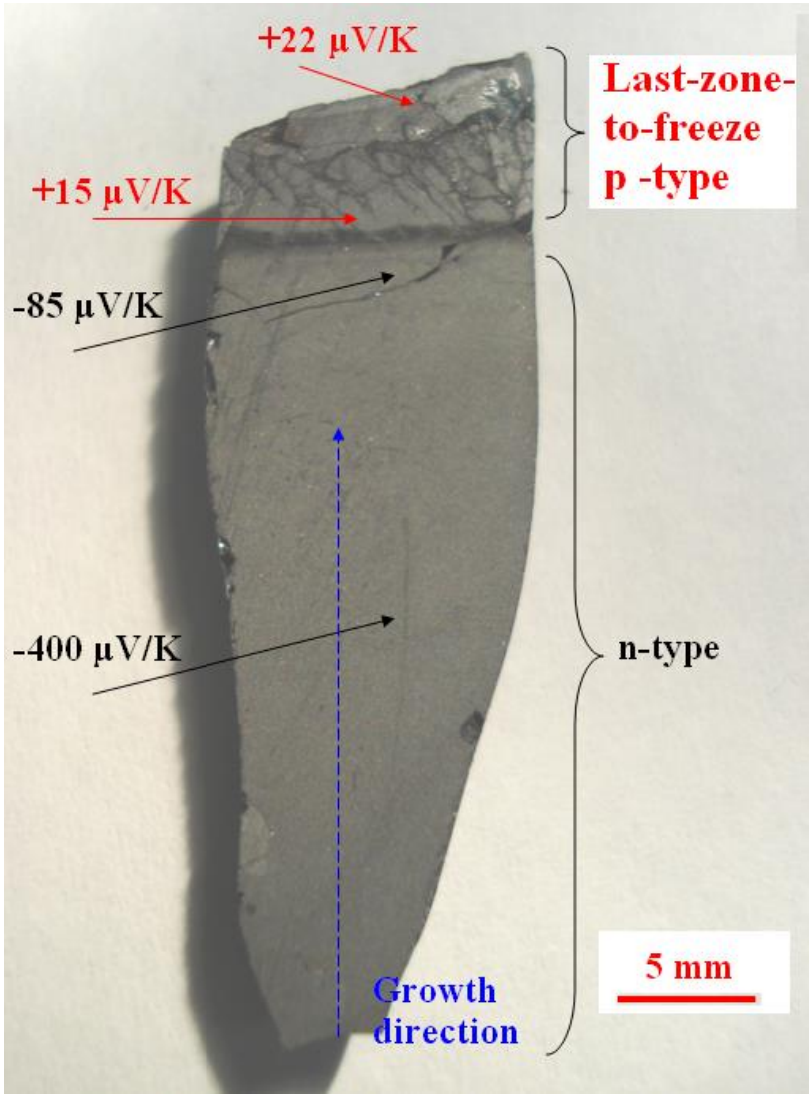
Bridgman Growth Apparatus



Bridgman-grown ingot

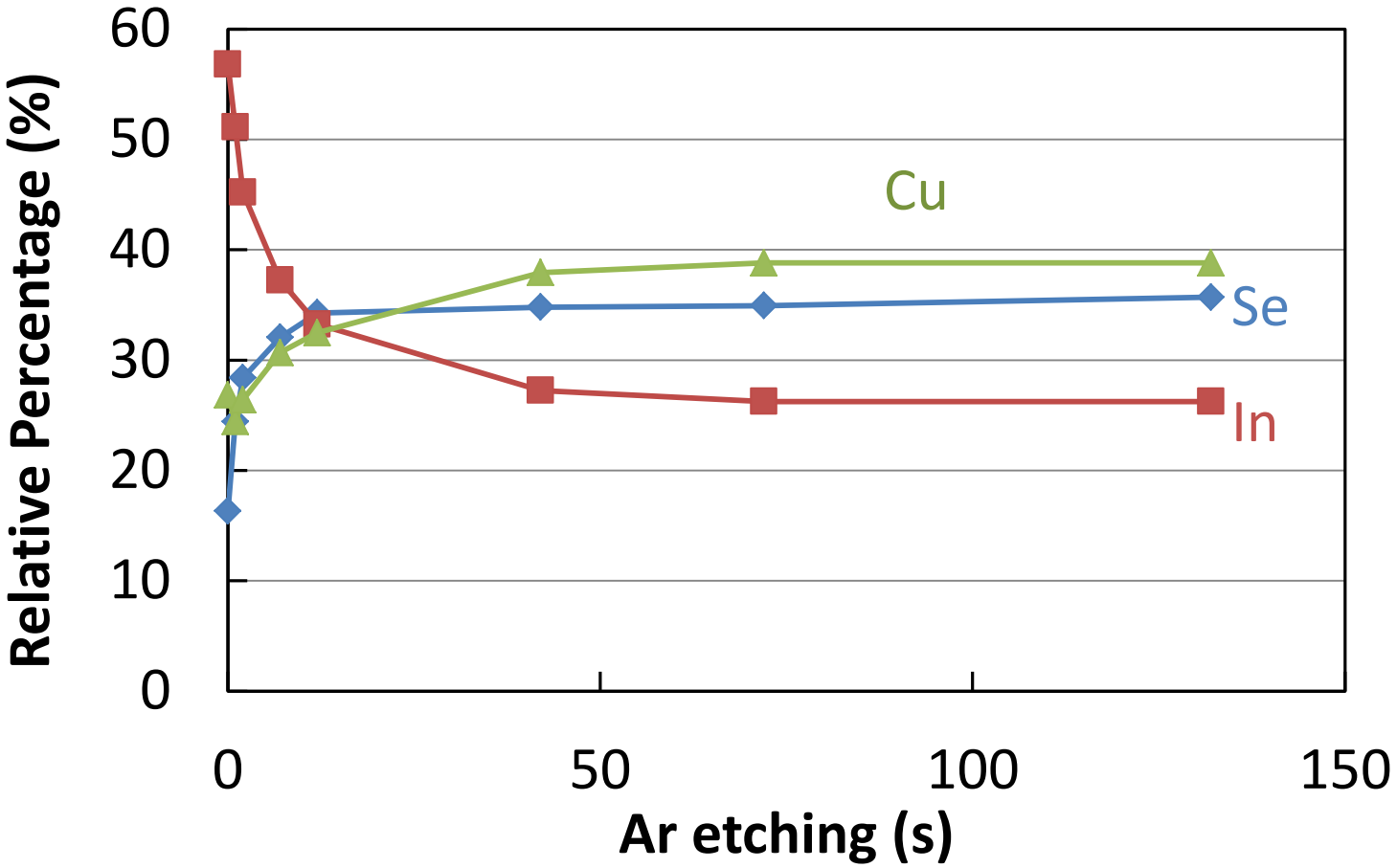


Bridgman-grown ingot

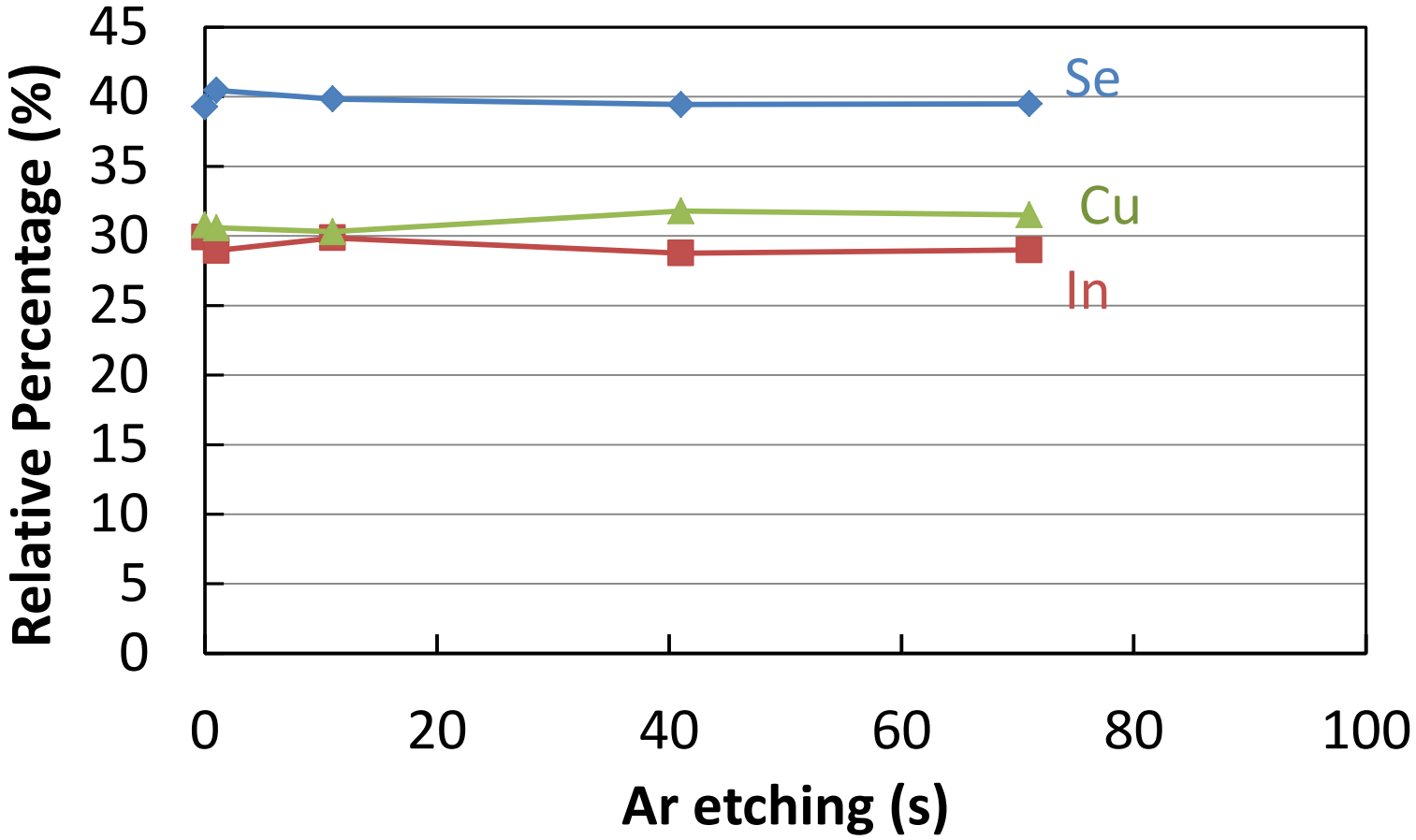


$CuInSe_{2+x}$
n-type
If
$[Na]>[Na]_{crit} = 2x+\delta$

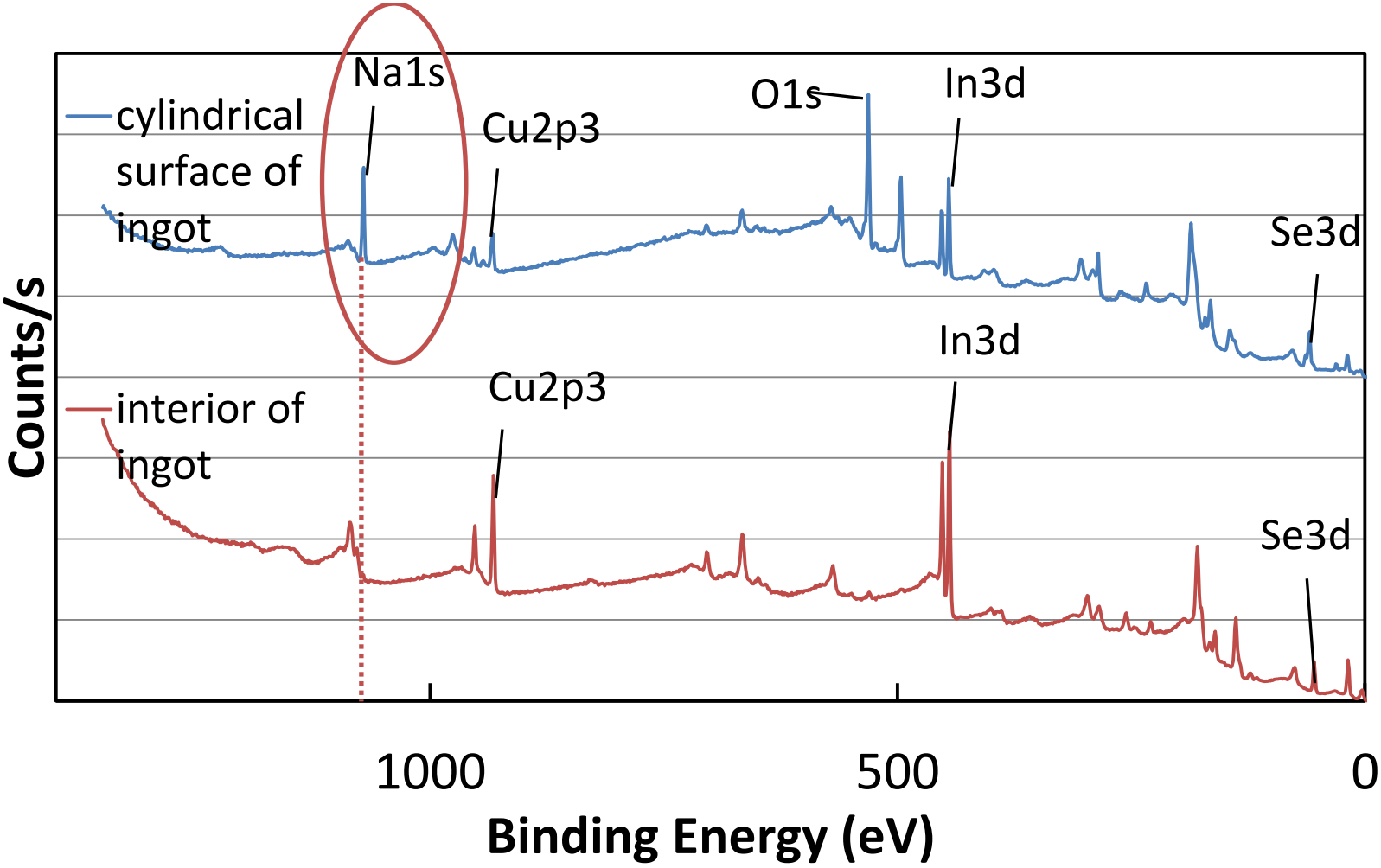
Before abrasion



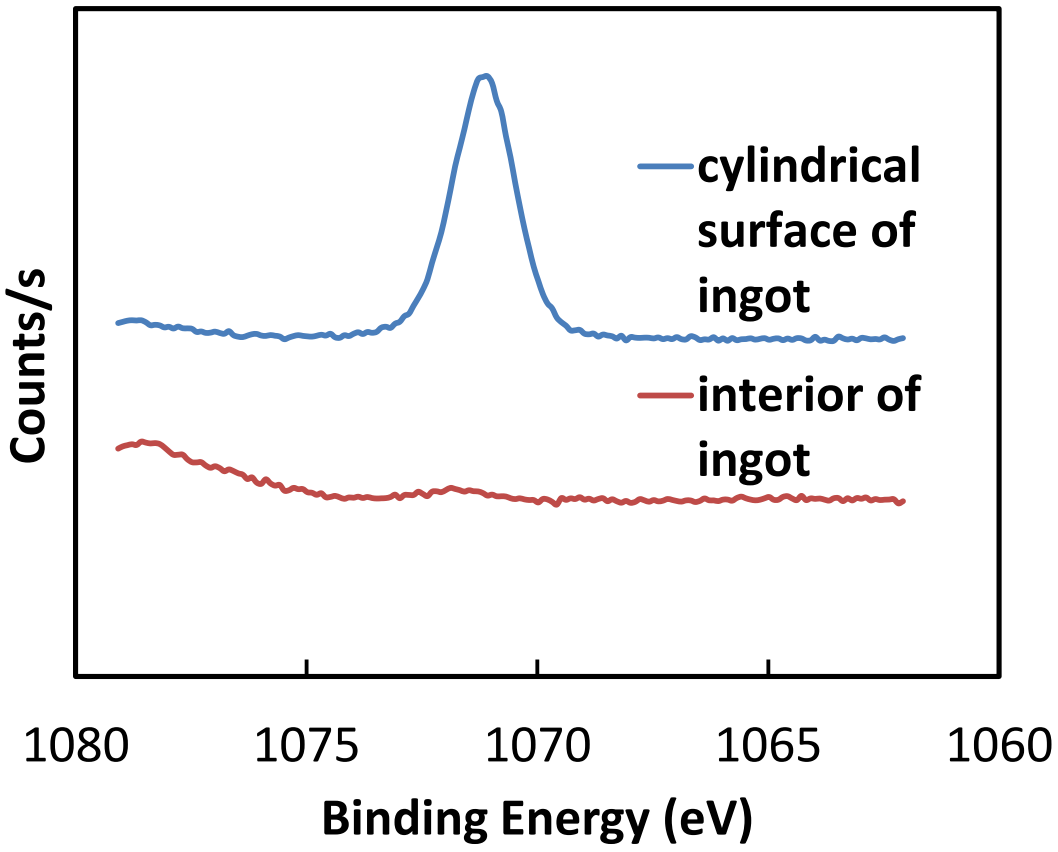
After abrasion

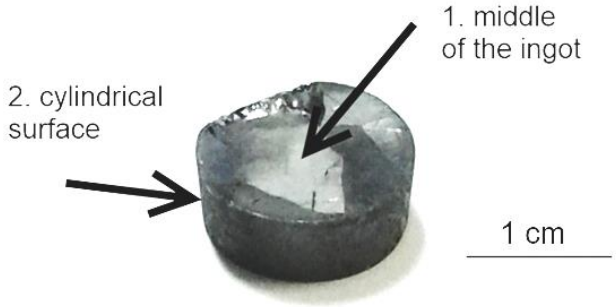


XPS survey scans for different locations of an ingot

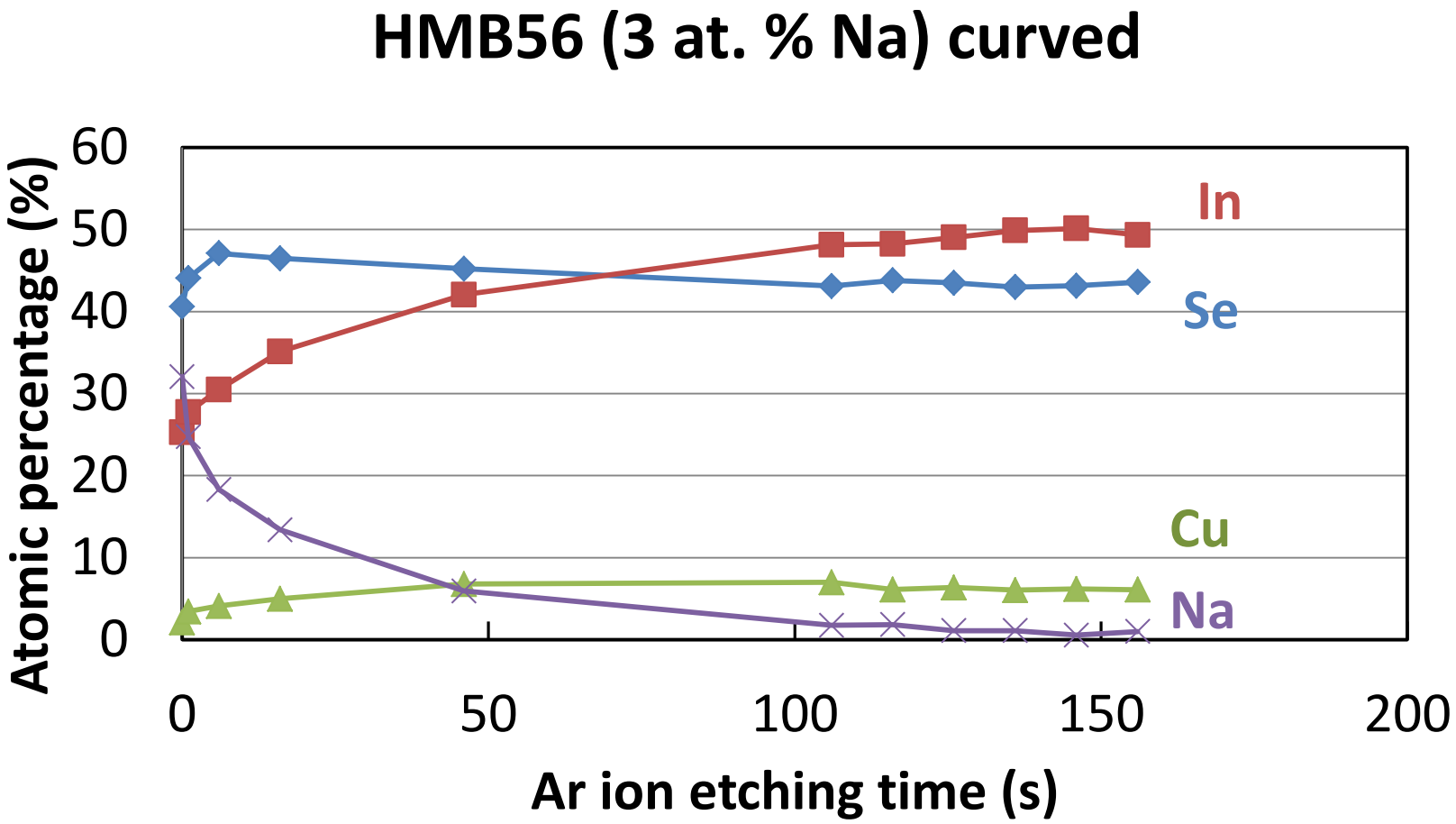


Na1s scan

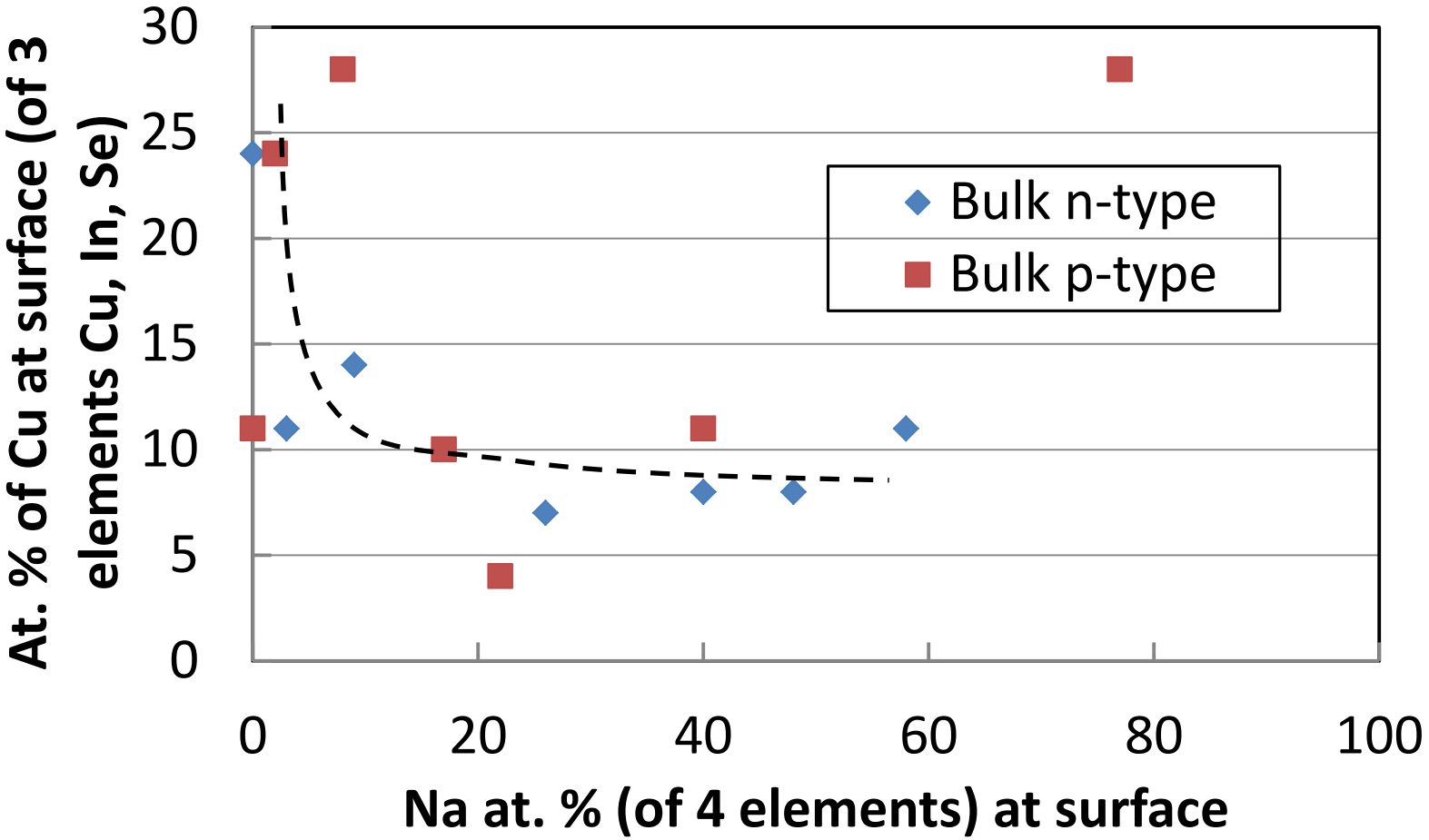

Counts/s
cylindrical surface of ingot
interior of ingot
1080
1075
1070
1065
1060
Binding Energy (eV)


1. middle of the ingot
2. cylindrical surface
1 cm

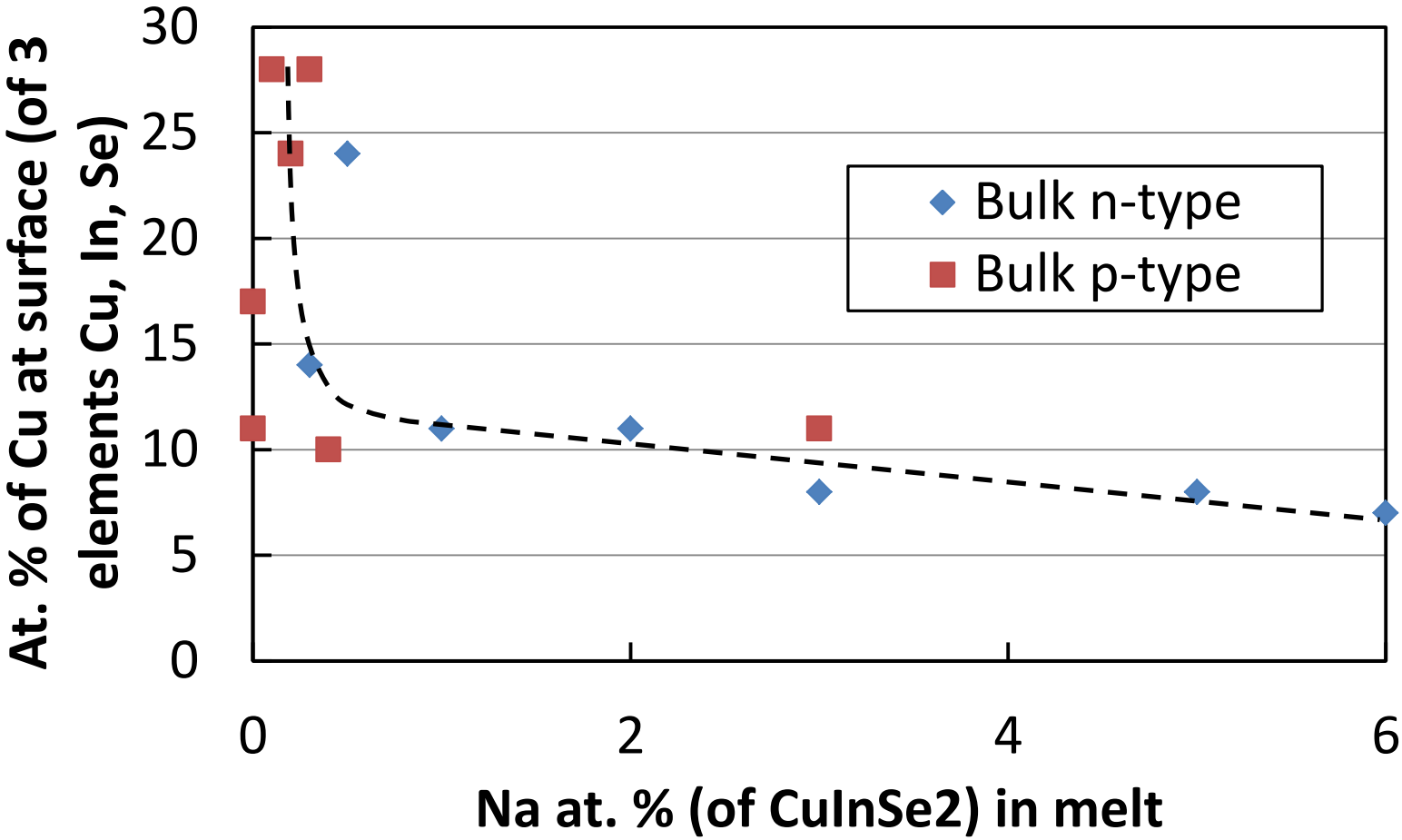
Na1s scan


HMB56 (3 at. % Na) curved
Atomic percentage (%)
60
50
40
30
20
10
0
0
50
100
150
200
Ar ion etching time (s)
In
Se
Cu
Na

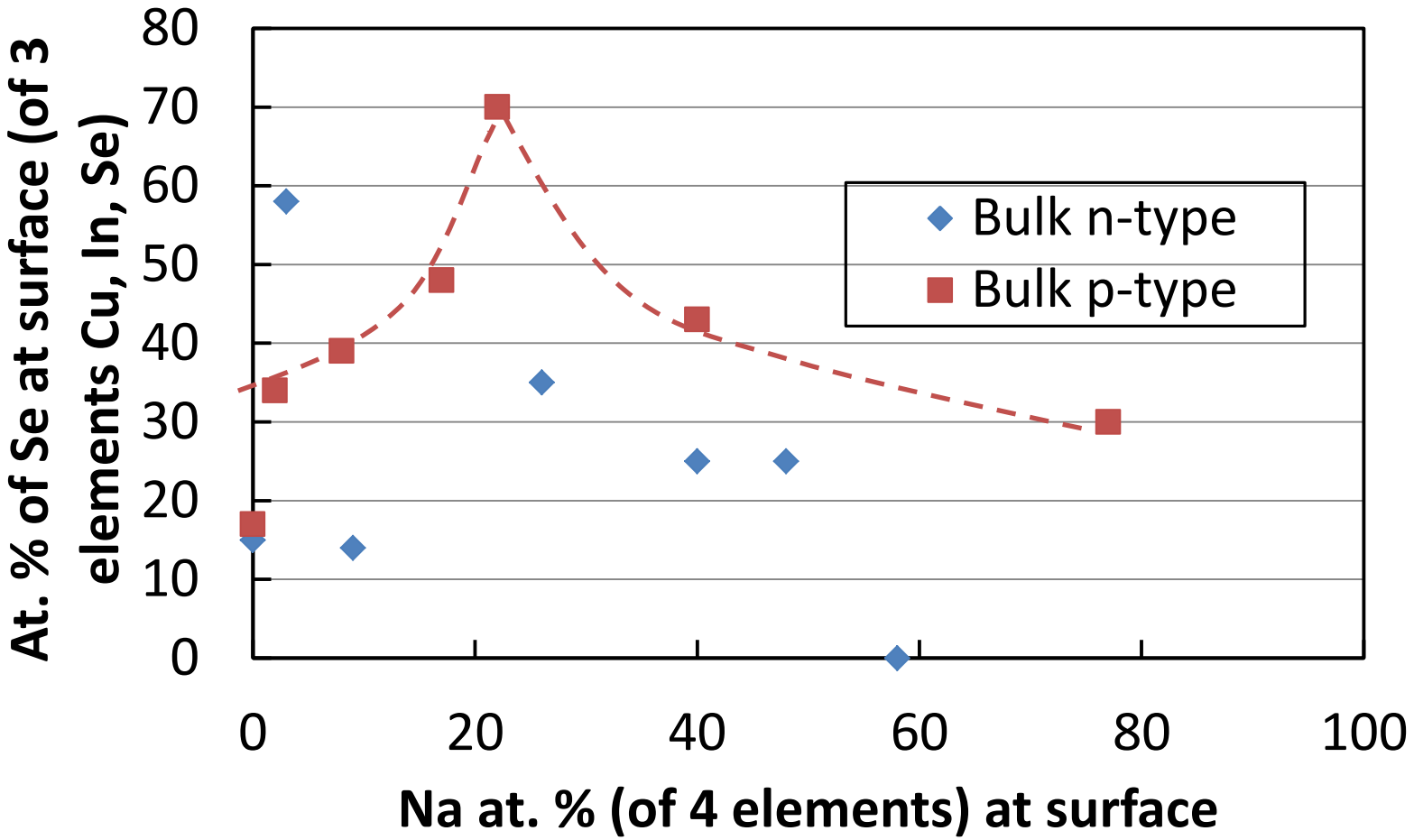
$[Cu]_{surf}$ vs. $[Na]_{surf}$



$[Cu]_{surf}$ vs. $[Na]_{melt}$



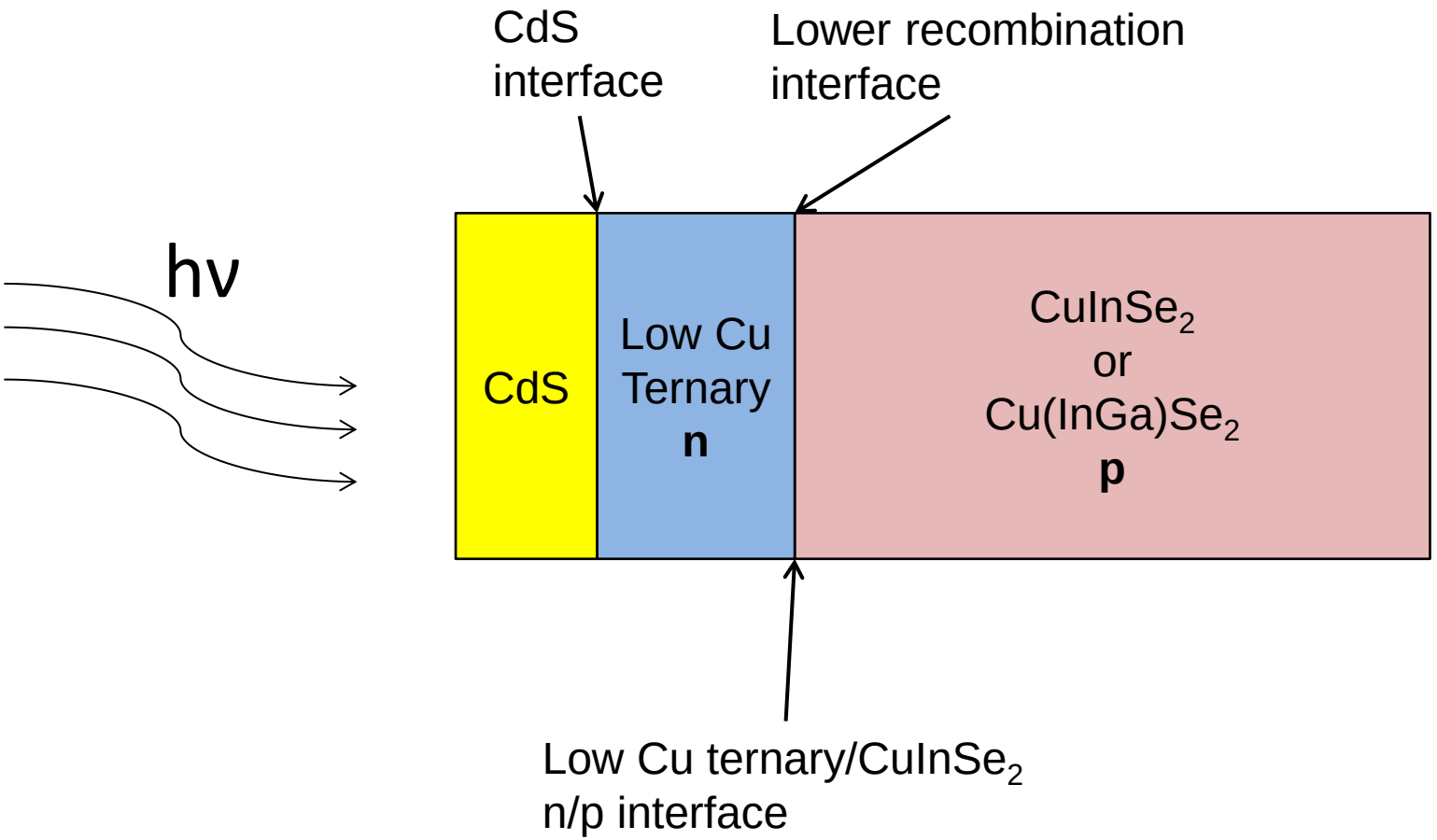
$[Se]_{surf}$ vs. $[Na]_{sulf}$



Conclusions

- The present results in Bridgman-grown $CuInSe_{2+x}$ demonstrate that:
- (1) The main variations in ternary composition occur in the first 100 nm from the ingot surface, even without Na addition.
- (2) With increase of up to about 1 at. % of added elemental Na to the melt, the relative surface concentration of Cu is decreased and that of Se, in p-type (bulk) material, is increased.
- (3) The Na is mostly present in a 0.2 micron surface layer and none is detected by XPS in the bulk.
- (4) The reduction of Cu proportion at the surface occurs with and without added Na but is accentuated with up to 1 at. % of added Na in the melt.
- (5) Some of the XPS results may have been affected by the abundant carbon present.
- (6) For samples exposed to air, the addition of Na gives rise to the extra compounds $CuSe_2$, Na_2SeO_4, and Na_2SeO_3, at least at the surface.

Speculation



The End

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