

Thin-Film PV Technologies

CdTe PV Technology

Week 5.4

Arno Smets

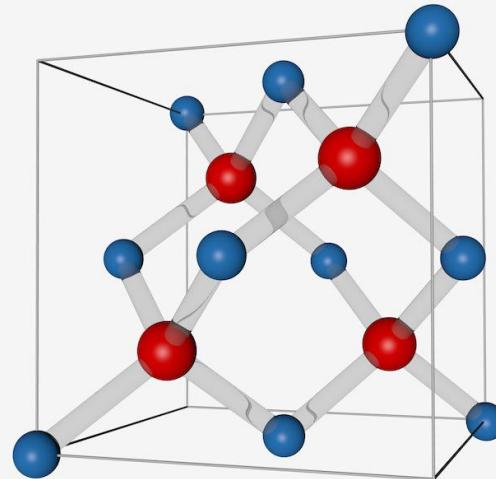


Challenge the future

CdTe

		IV semiconductors							
		III-V semiconductors							
		II-VI semiconductors							
IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA		
29	30	5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	2 He 4.0026		
Cu 63.546	Zn 69.723	13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	18 Ar 39.948		
Ag 107.87	48 Cd 112.41	31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 78.904	35 Br 79.904	36 Kr 83.798		
Au 196.97	50 In 114.82	49 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29			

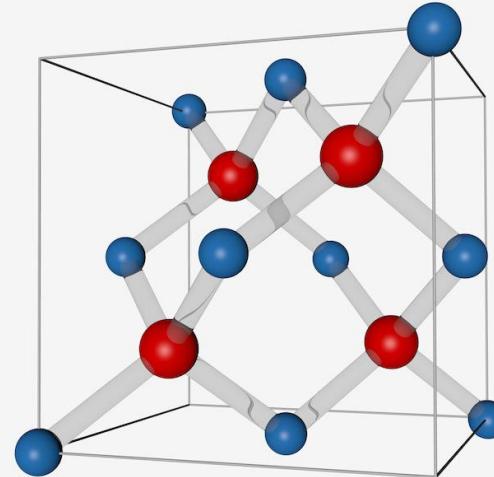
CdTe:



CdTe n-doping

IV semiconductors							
III-V semiconductors							
II-VI semiconductors							
IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
29	30	5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	2 He 4.0026
Cu 63.546	Zn 65.38	13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	10 Ne 20.180
47	48	31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.798
Ag 107.87	Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
Au 196.97	Hg 200.59	80 Tl 204.38	81 Pb 207.2	82 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]

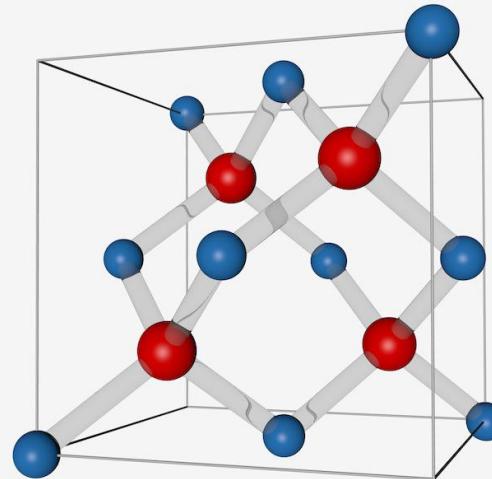
CdTe:



CdTe n-doping

IV semiconductors									
III-V semiconductors									
II-VI semiconductors									
		III A	IV A	V A	VI A	VII A			VII A
		B	C	N	O	F	He		
		10.811	12.011	14.007	15.999	18.998	4.0026		
IB	IIB	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar		
		26.982	28.086	30.974	32.065	33.948			
29	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr		
Cu	65.38	69.723	72.64	74.922	78.96	79.94	83.798		
47	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe		
Ag	112.41	114.82	118.71	121.76	127.60	126.90	131.29		
79	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn		
Au	196.97	200.59	204.38	207.2	[208.98]	[209]	[210]	[222]	

CdTe

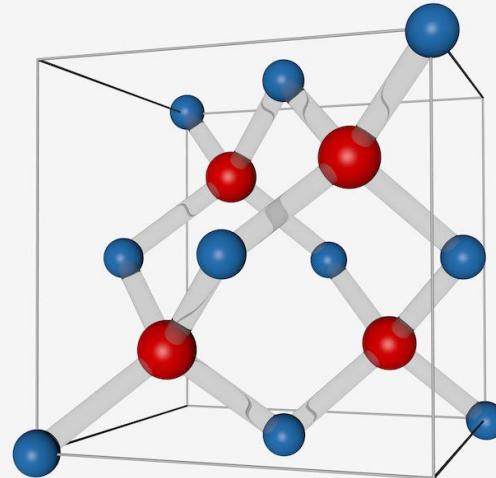


CdTe n-doping

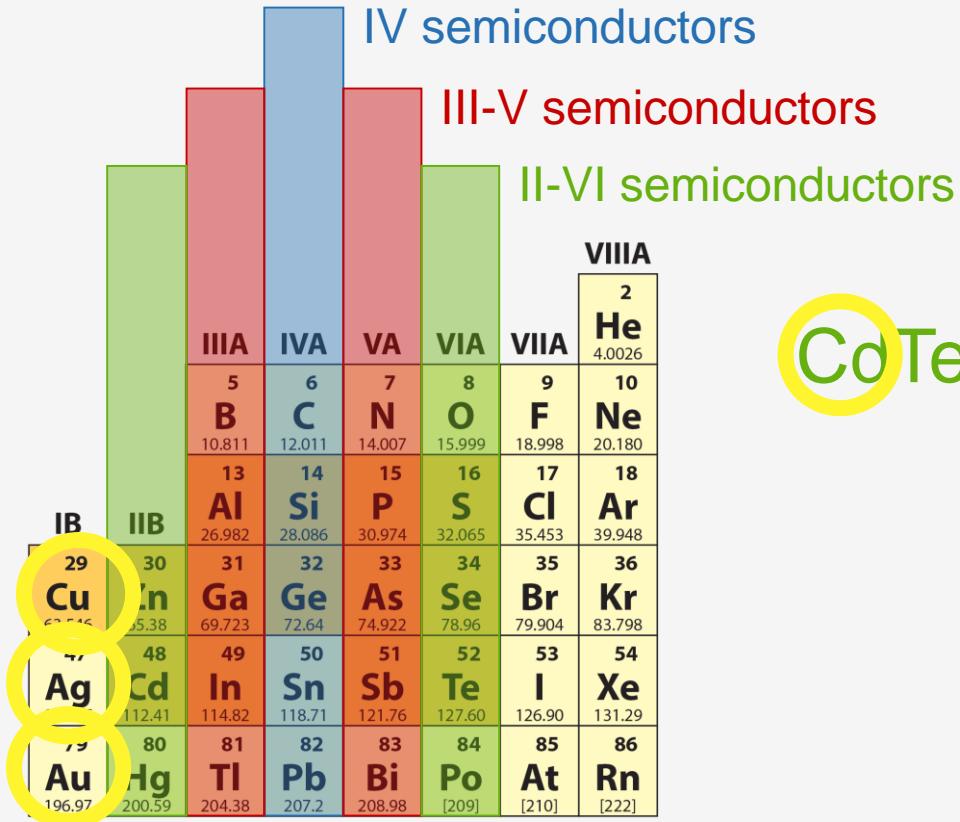
IV semiconductors							
III-V semiconductors							
II-VI semiconductors							
IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
29	30	5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	2 He 4.0026
Cu 63.546	Zn 69.723	13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	10 Ne 20.180
Ag 107.87	48 Cd 112.41	31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 74.922	35 Br 79.904	36 Kr 83.798
Au 196.97	80 Hg 200.59	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29

CdTe:

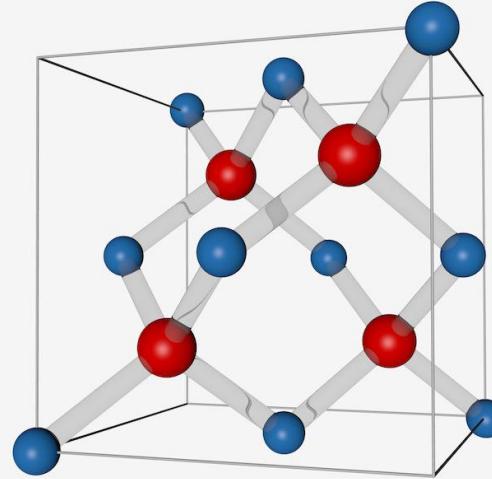
Te vacancy



CdTe p-doping



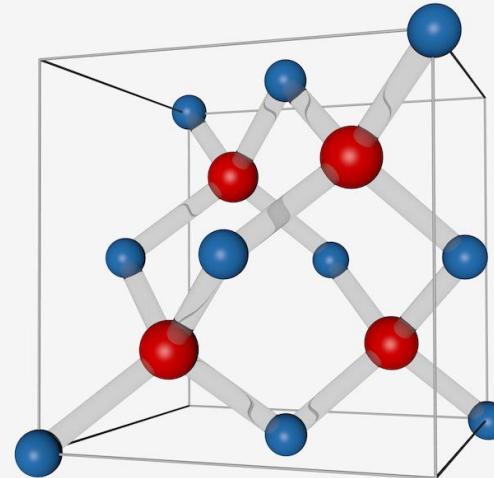
CdTe:



CdTe p-doping

IV semiconductors							
III-V semiconductors							
II-VI semiconductors							
IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
29	30	5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	2 He 4.0026
Cu 63.546	Zn 65.38	13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	10 Ne 20.180
47	48	31 Ga 69.723	32 Ge 72.64	33 As 75.493	34 Se 78.96	35 Br 79.904	36 Kr 83.798
Ag 107.87	Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
Au 196.97	Hg 200.59	80 Tl 204.38	81 Pb 207.2	83 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]

CdTe:

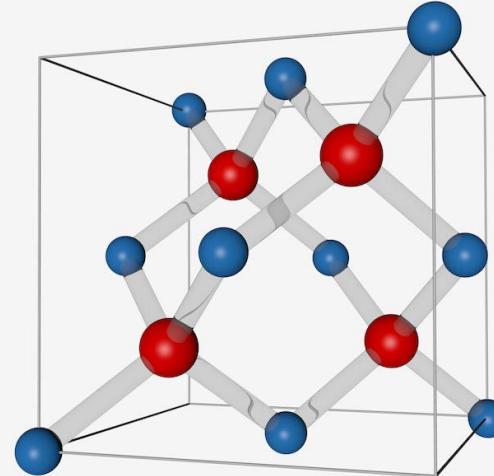


CdTe p-doping

IV semiconductors							
III-V semiconductors							
II-VI semiconductors							
IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
29	30	5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	2 He 4.0026
Cu 63.546	Zn 65.38	13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.065	17 Cl 35.453	10 Ne 20.180
47	48	31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.798
Ag 107.87	Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
79	80	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]

CdTe:

Cd vacancy

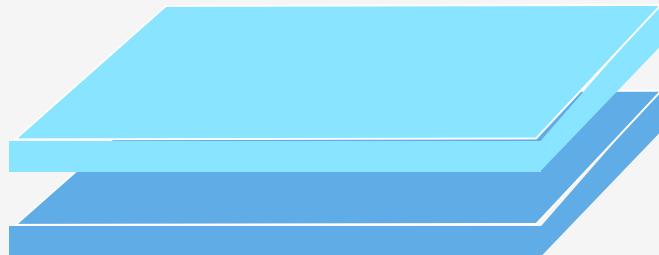


CdTe solar cell



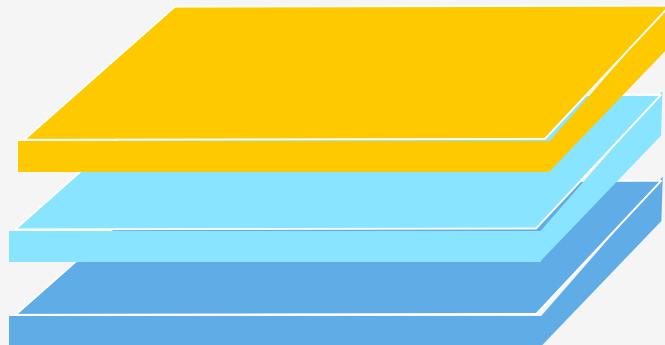
Glass

CdTe solar cell



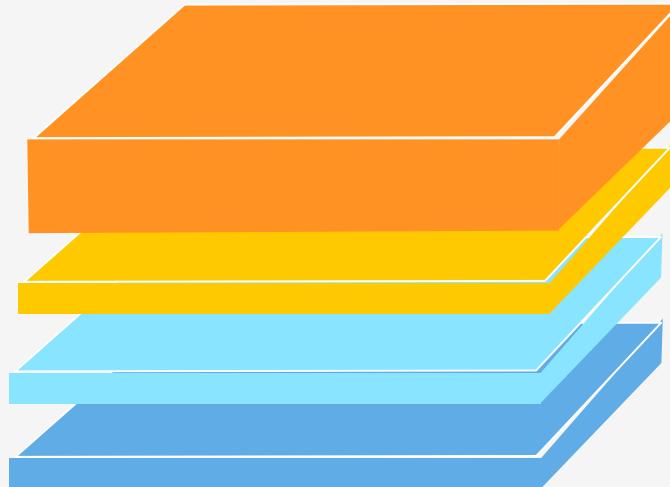
SnO₂
Glass

CdTe solar cell



CdS Buffer
SnO₂
Glass

CdTe solar cell



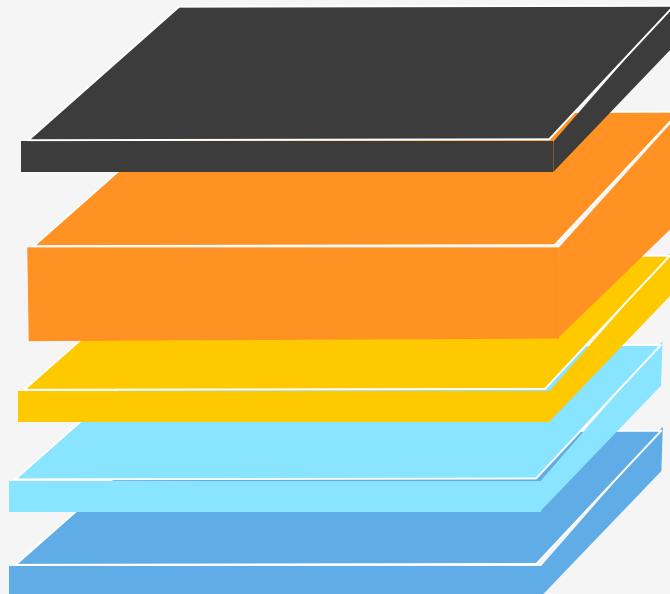
CdTe

CdS Buffer

SnO₂

Glass

CdTe solar cell



metal contact

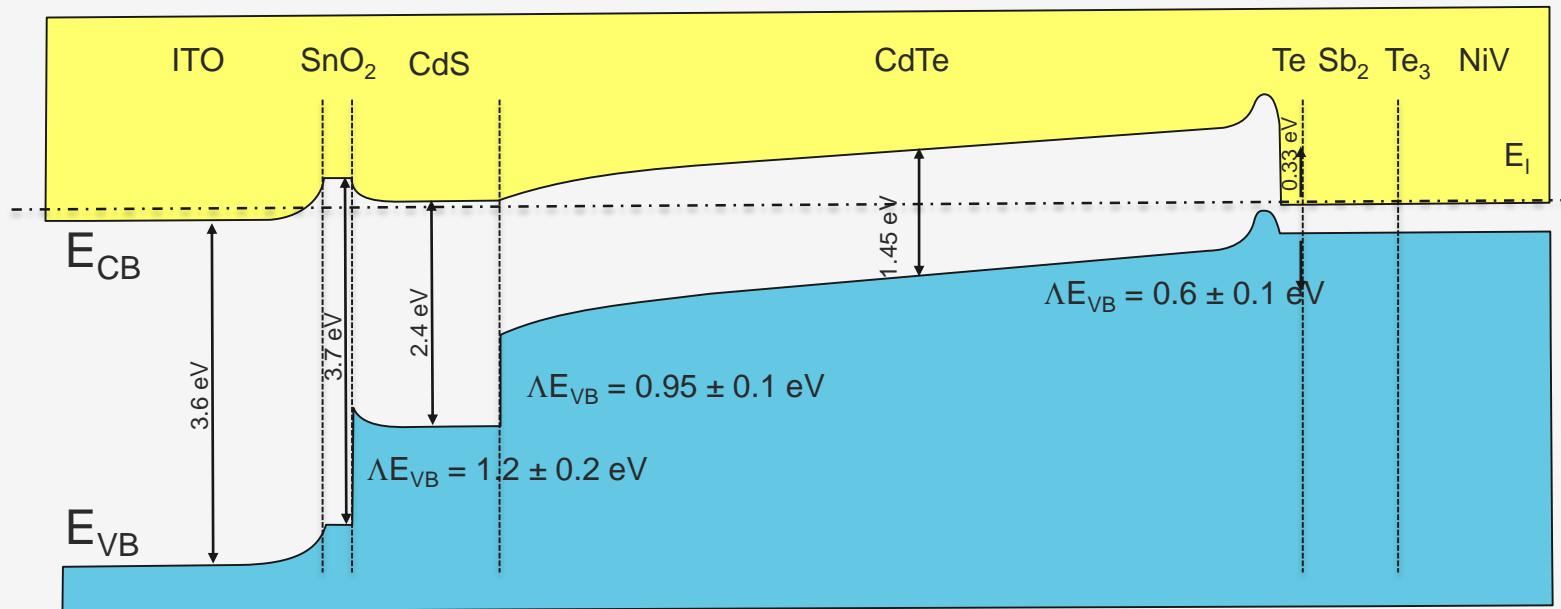
CdTe

CdS Buffer

SnO₂

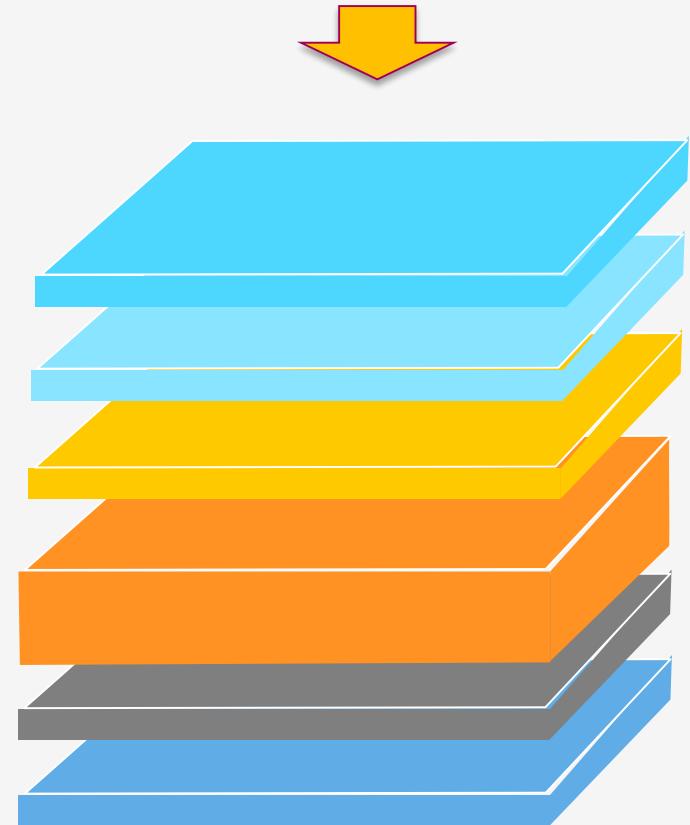
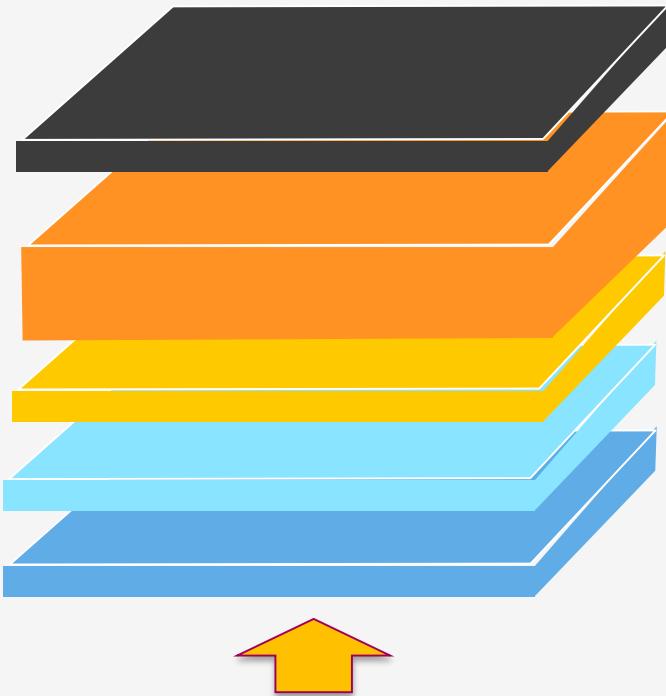
Glass

CdTe solar cell band diagram



CdTe solar cell

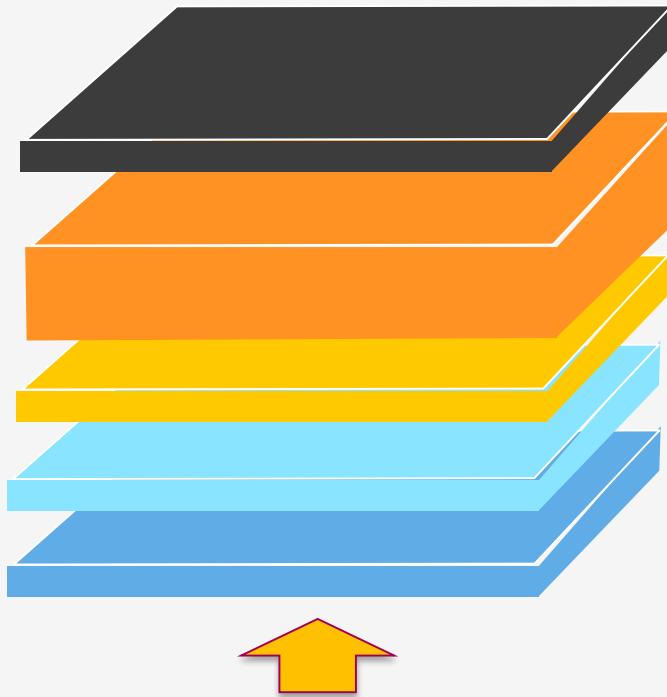
superstrate



substrate

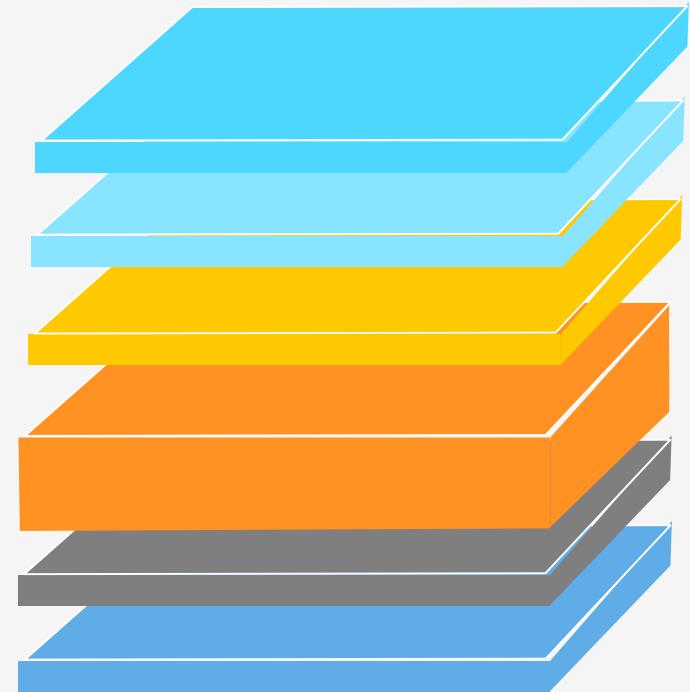
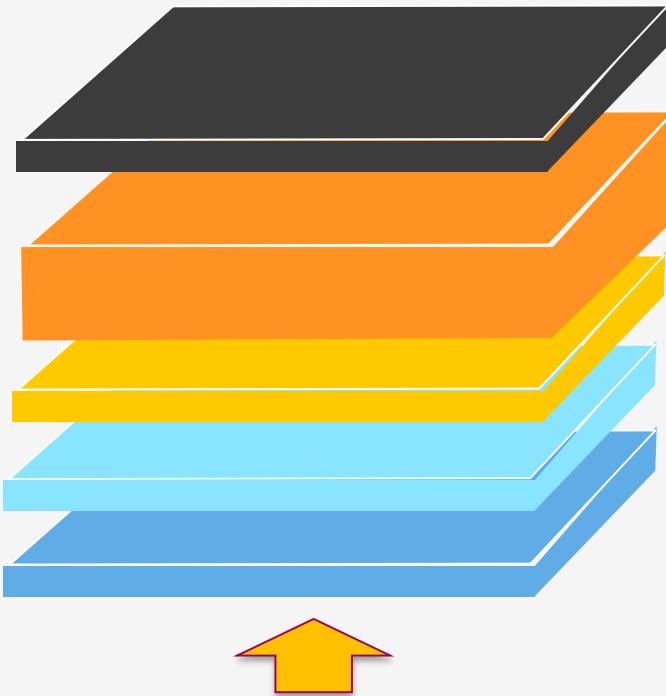
CdTe solar cell

superstrate



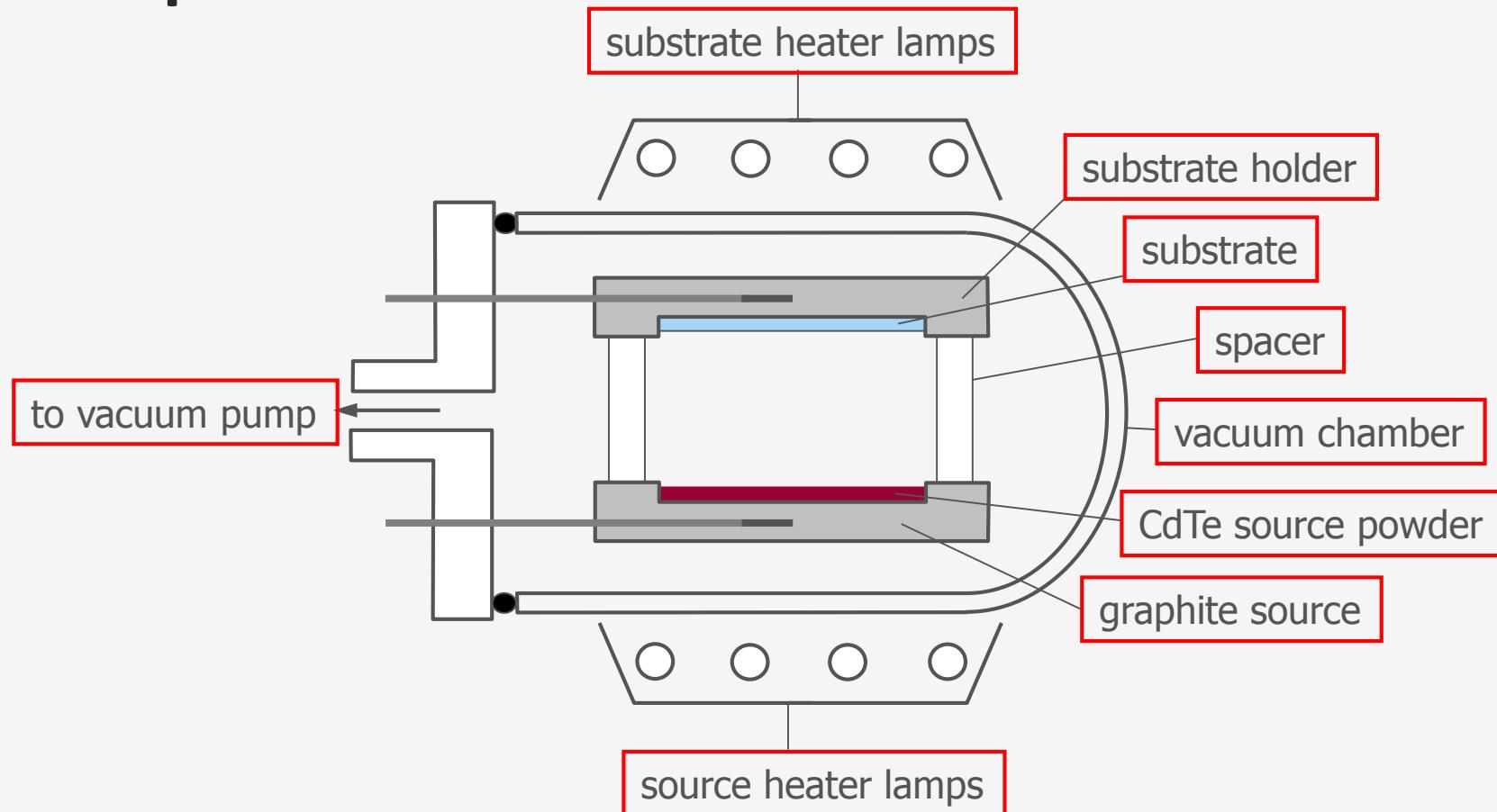
CdTe solar cell

superstrate

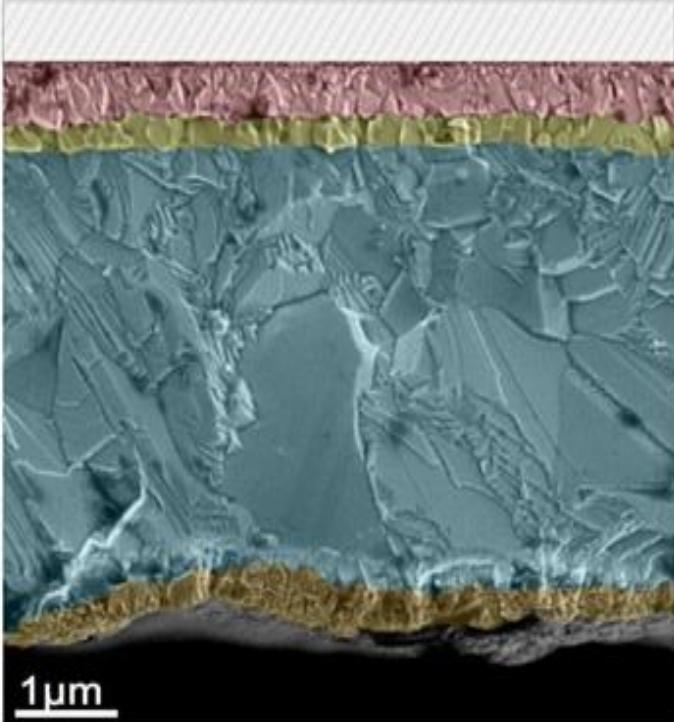


substrate

Closed Space Sublimation



Labscale CdTe solar cells



Glass
SnO₂
CdS

CdTe

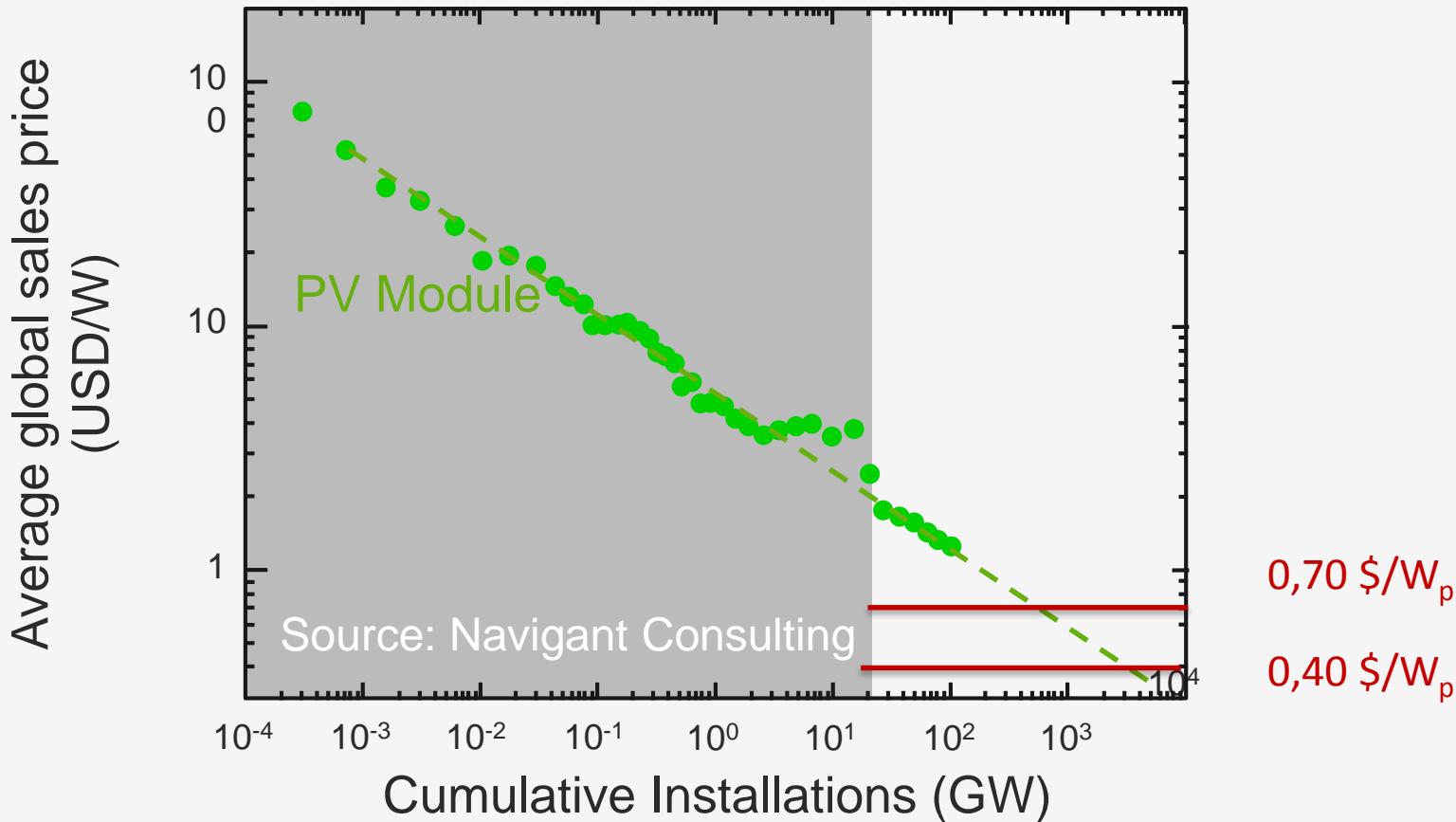
ZnTe:Cu
Ti

First solar
Eff = 18.7 %
Voc ~ 852 mV
 $J_{sc} \sim 28.6 \text{ mAcm}^{-2}$
FF = 76.76 %

GE Research

Eff: 18.3 %

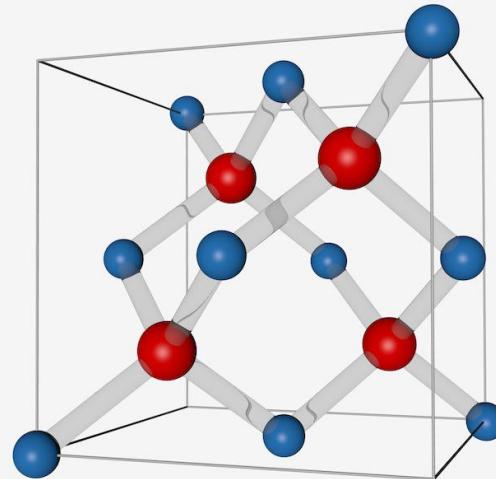
Learning curve: PV modules, systems

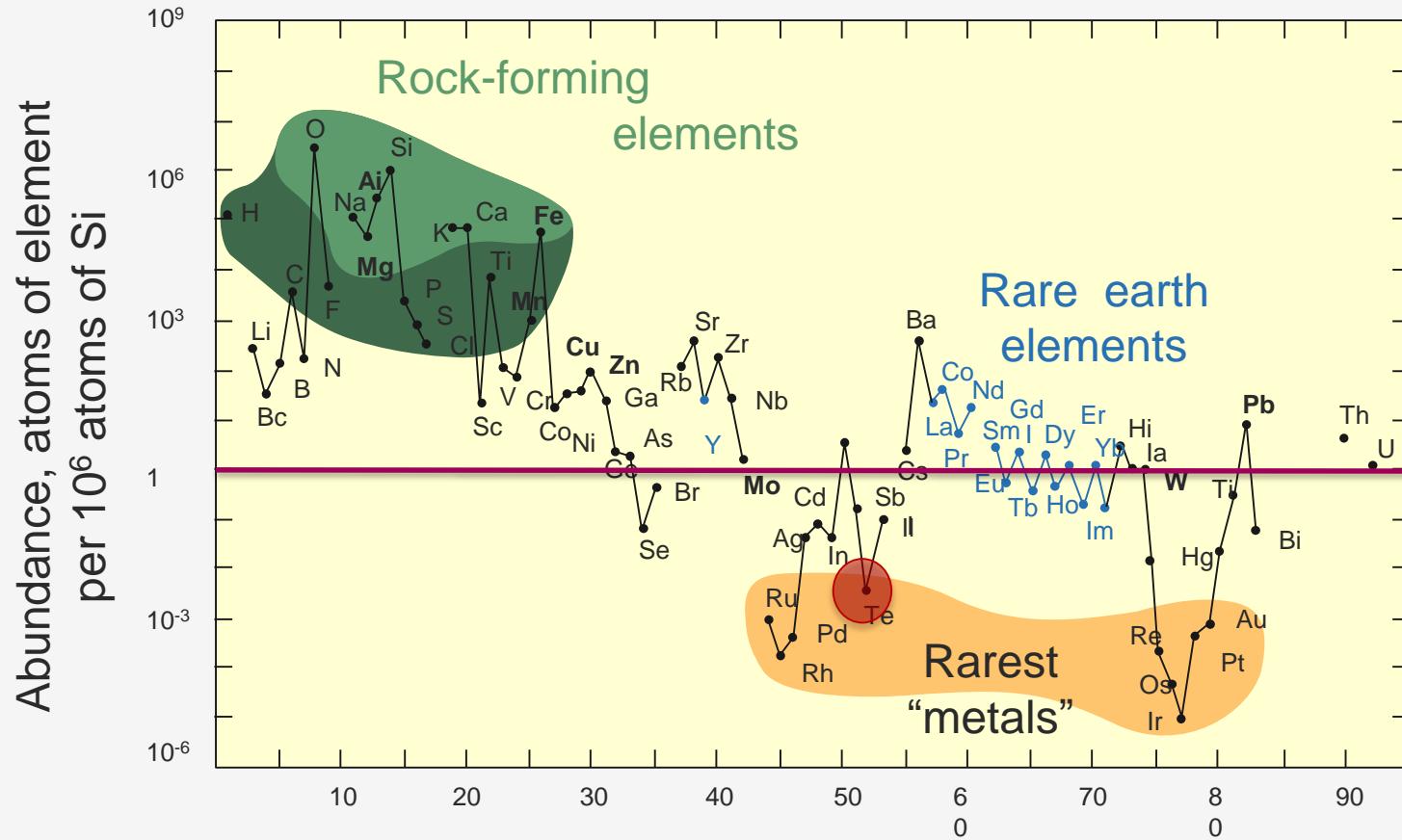


Concerns: toxicity

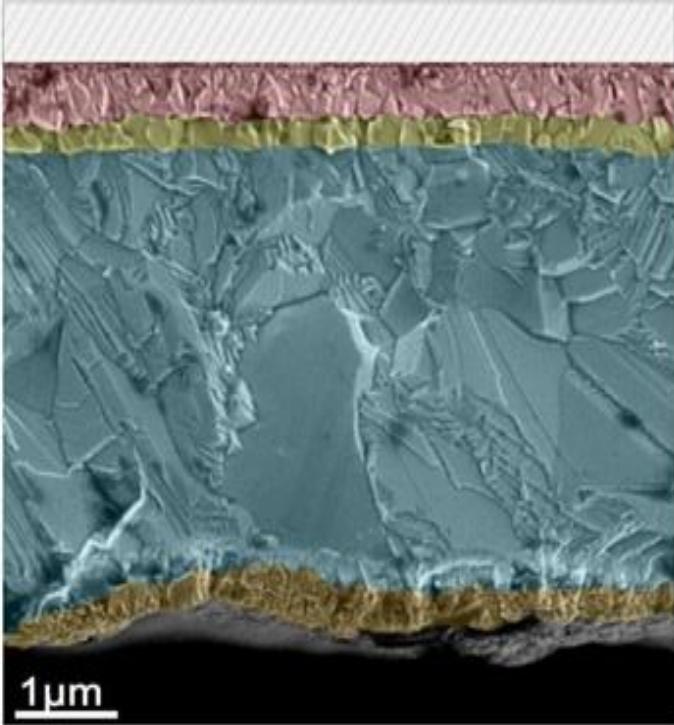
		IV semiconductors				III-V semiconductors				II-VI semiconductors			
		IIIA	IVA	VA	VIA	VIIA	VIIIA						
IB	IIB	5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	2 He 4.0026						
29	30	31	32	33	34	35	36						
Cu 63.546	Zn 65.38	Ga 69.723	Ge 72.64	As 74.922	Se 78.96	Br 79.904	Kr 83.798						
47	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29						
79	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]						

CdTe:





Labscale CdTe solar cells



Glass
SnO₂
CdS

CdTe

ZnTe:Cu
Ti

First solar
Eff = 18.7 %
Voc ~ 852 mV
 $J_{sc} \sim 28.6 \text{ mAcm}^{-2}$
FF = 76.76 %

GE Research

Eff: 18.3 %