Physics of Semiconductors (7)

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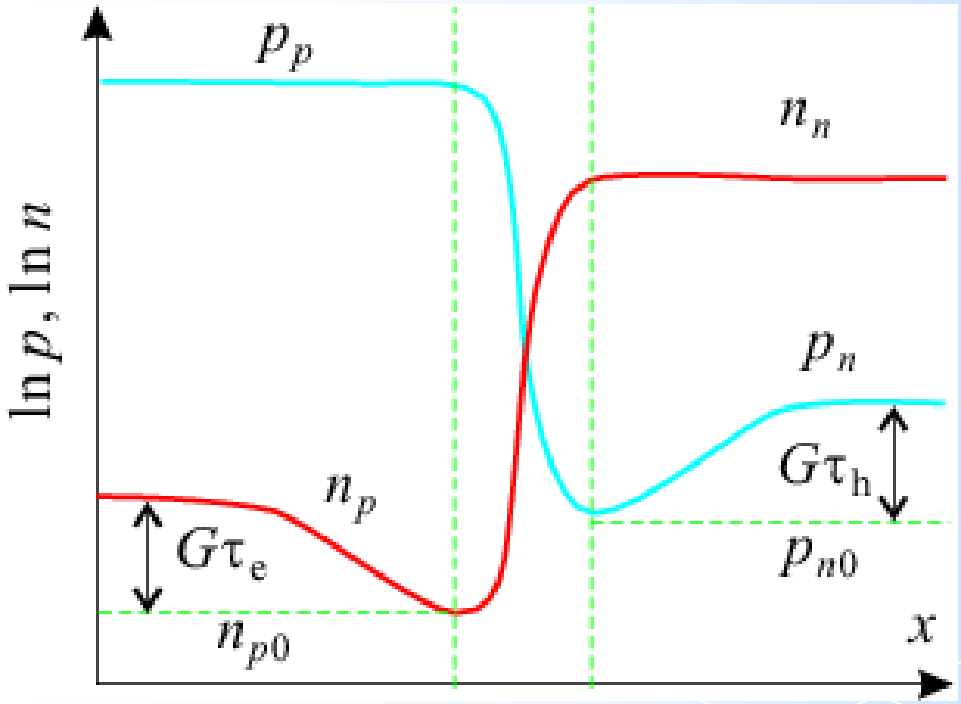
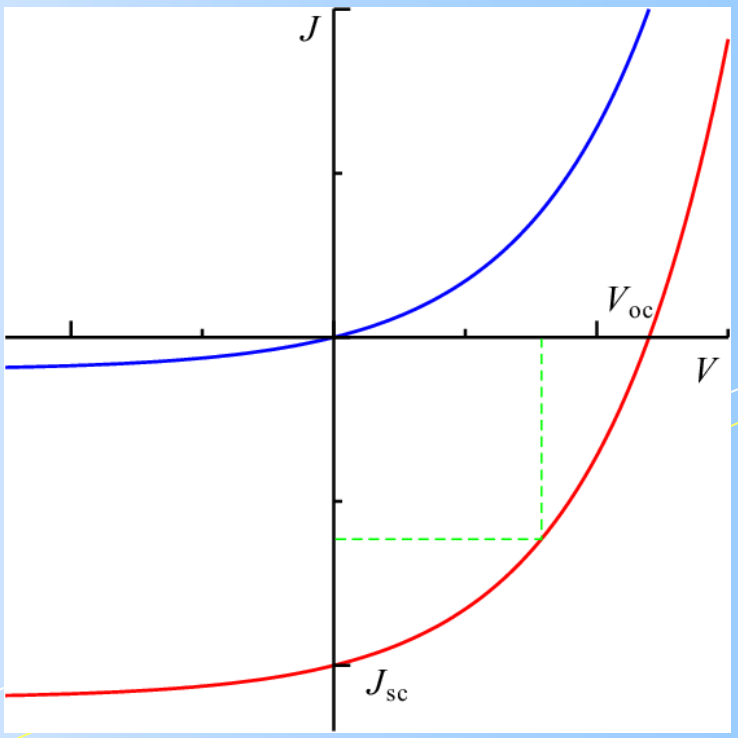
Solar cell (injection of minority carriers)

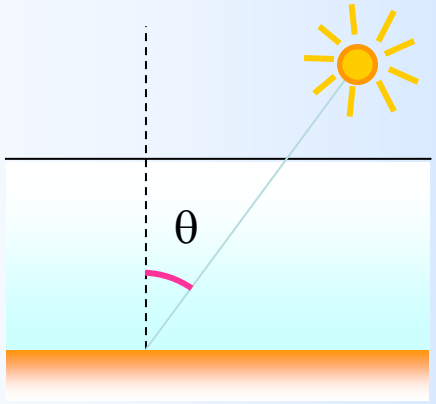


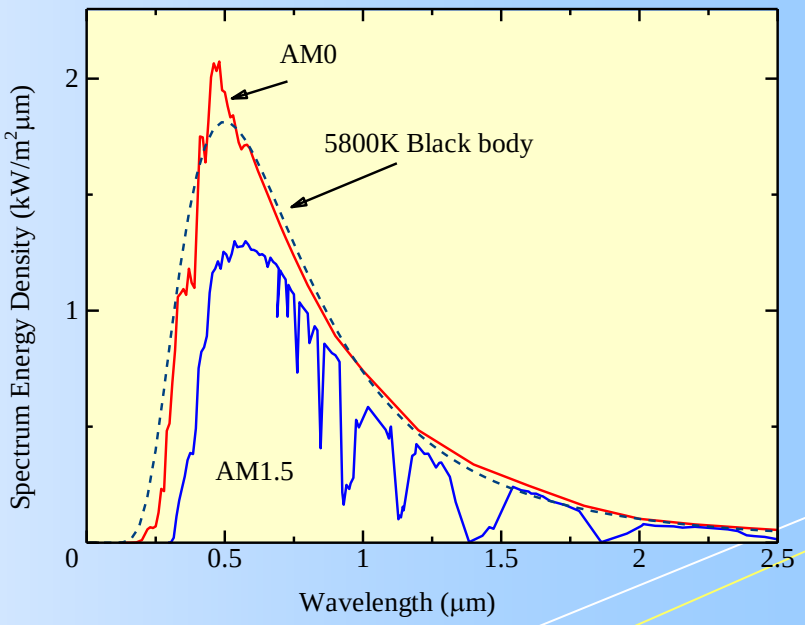


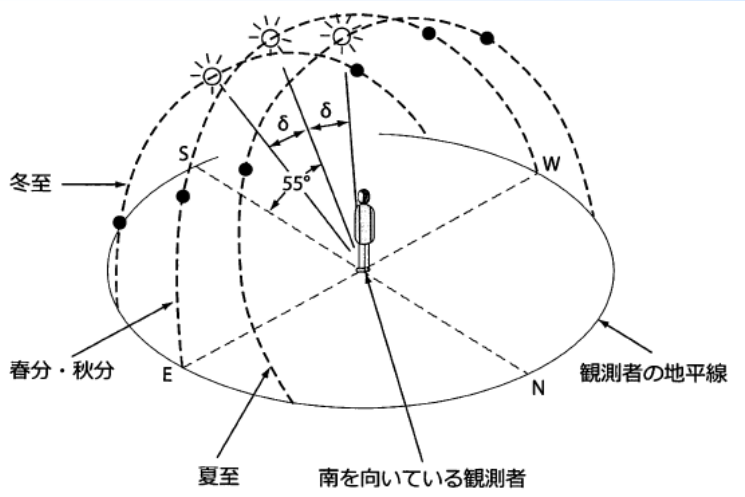
Solar radiation: What is air mass?

Solar spectrum on the earth

$$\text{Air mass} = \frac{1}{\cos\theta}$$







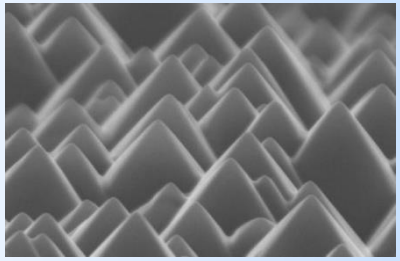
Actual sun from the ground
Air mass changes with time

fine weather → blue sky scattering
cloudy, rainy → cloud scattering

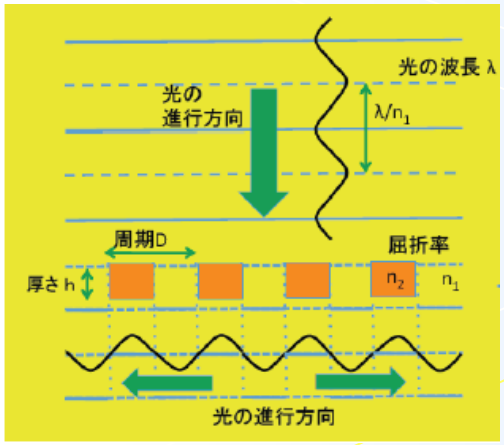
Reflection at surfaces

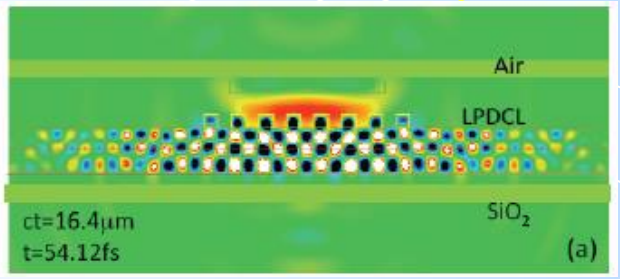
Anti-reflection coating

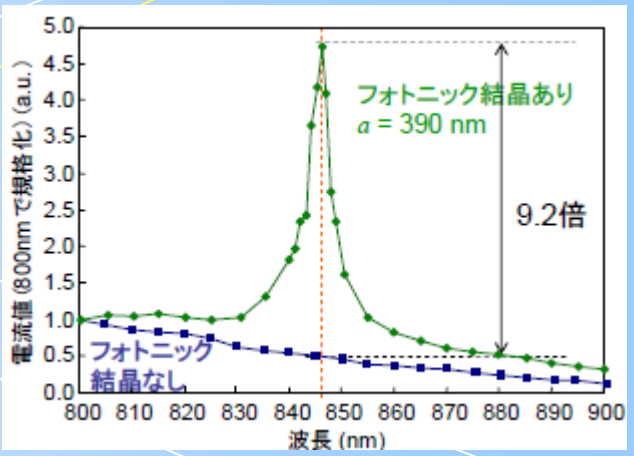
Surface texture



Photonic crystals

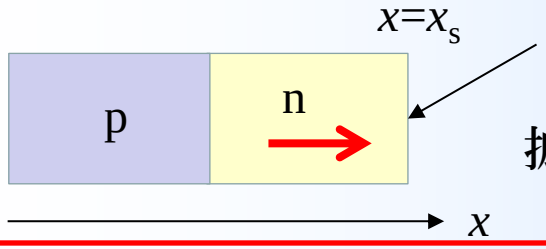






Surface recombination

表面：格子欠陥，不純物を介した無輻射再結合頻度が極めて高い

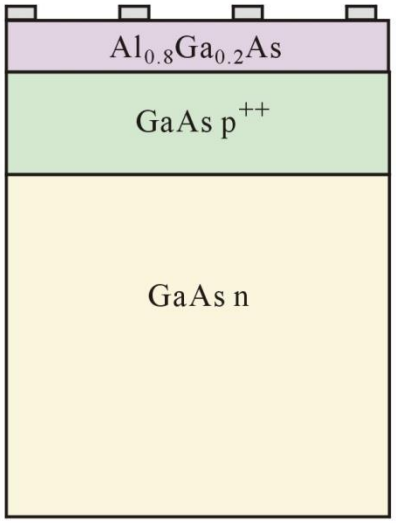


表面再結合速度 S_h

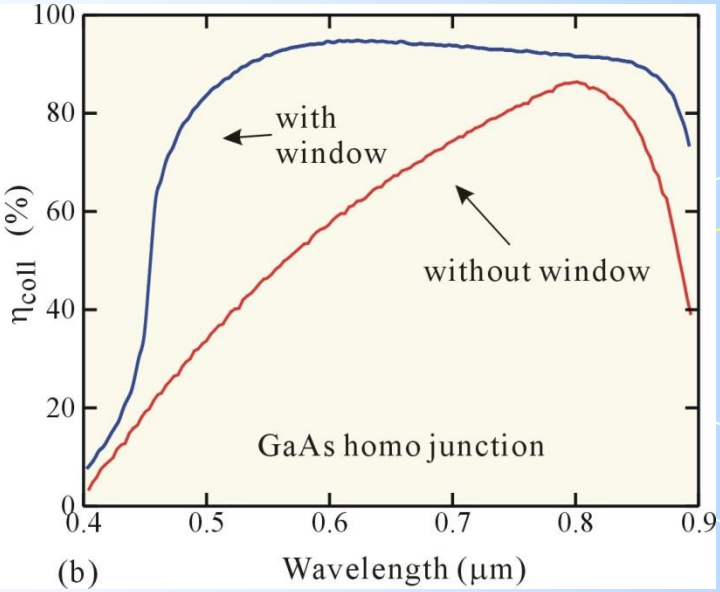
拡散流

$$D_h \frac{d(p_n - p_{n0})}{dx} = S_h(p_n - p_{n0})$$

窓層：　連続して成長した接続性の良い界面は再結合速度が低い．
バンドギャップの大きな半導体は，透明で拡散キャリアに対して障壁として働く．



(a)



(b)

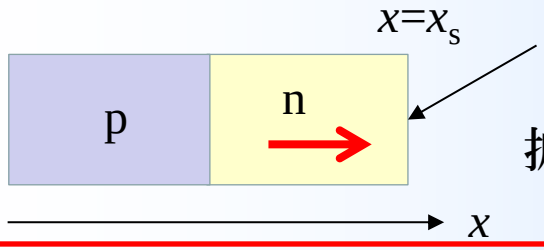
特に吸収係数の大きな短波長側で効果が大きい．

η_{coll}　（量子効率）

$$= \frac{\text{短絡光電流}}{e \times (\text{単位時間あたり入射光子数})}$$

Surface recombination

表面：格子欠陥，不純物を介した無輻射再結合頻度が極めて高い



表面再結合速度 S_h

拡散流

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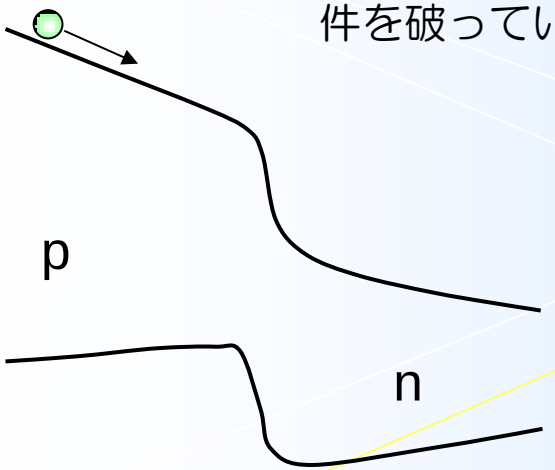
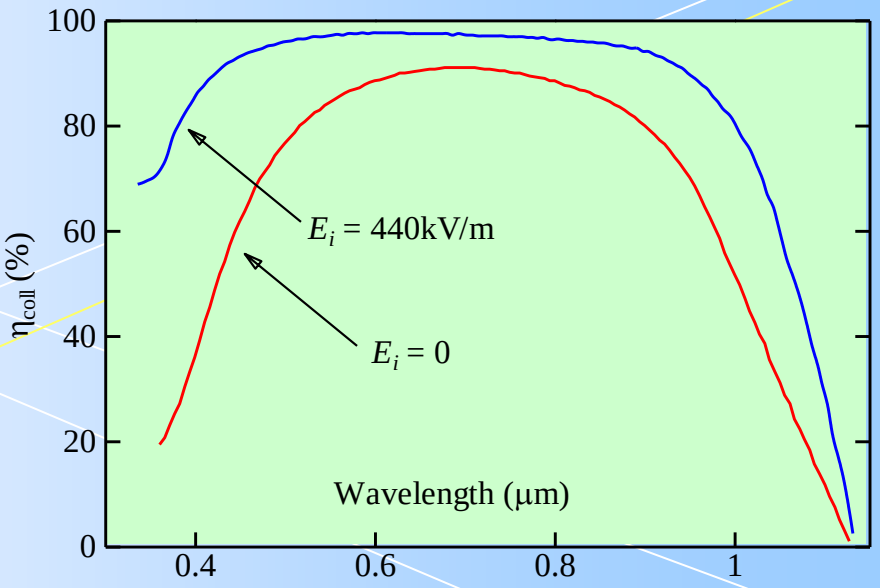
グレーディング層：

表面側の組成を連続的に変化させることでpn接合面以外にも緩やかな電場を作って電圧と光吸収を稼いでいる．

細かく言うと，
Shockley-Queisserの条件を破っている．

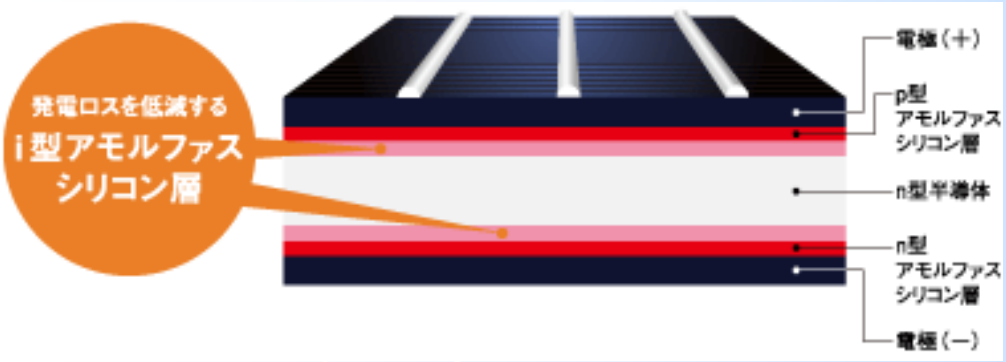


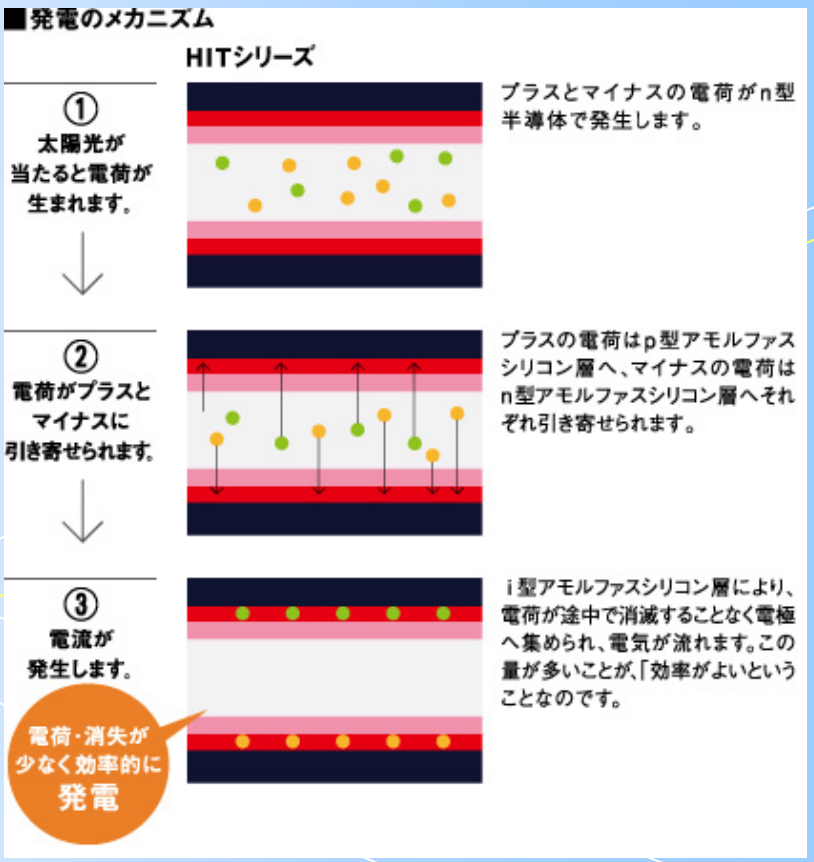


HIT solar cells by SANYO (now Panasonic)

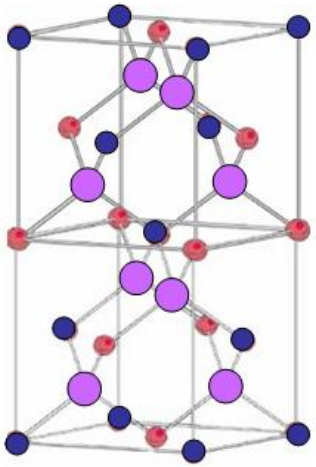
Heterojunction with Intrinsic Thin layer, HIT

a-Siは結晶Siよりも有効バンドギャップが大きい
→ 窓層と表面p層，内部電場印加 (接合内再結合防止) を兼ねる



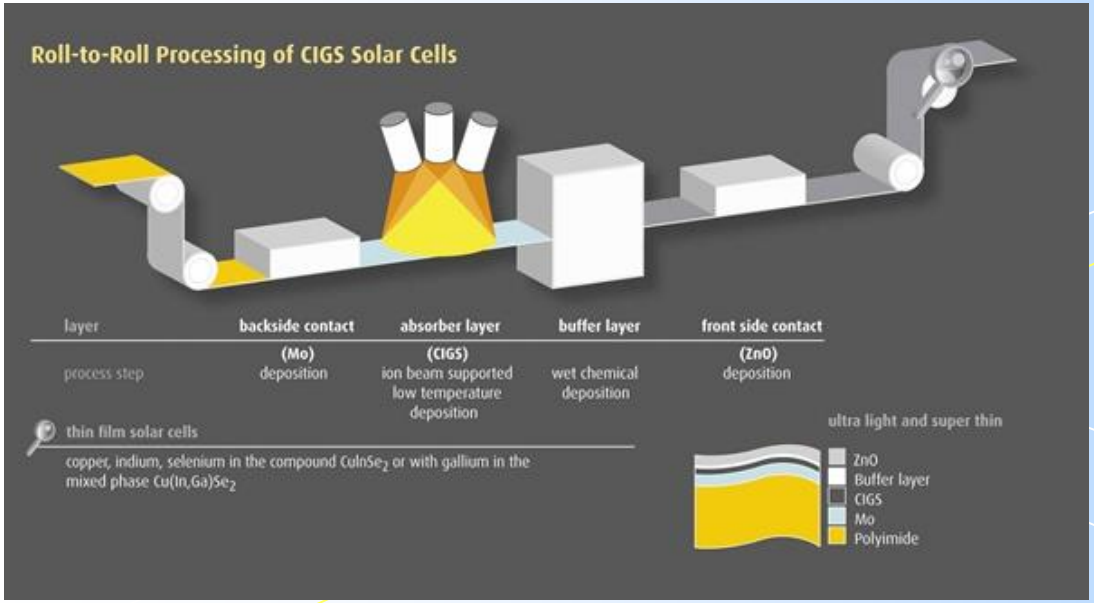


Low cost production



カルコパイライト $CuInSe_2$

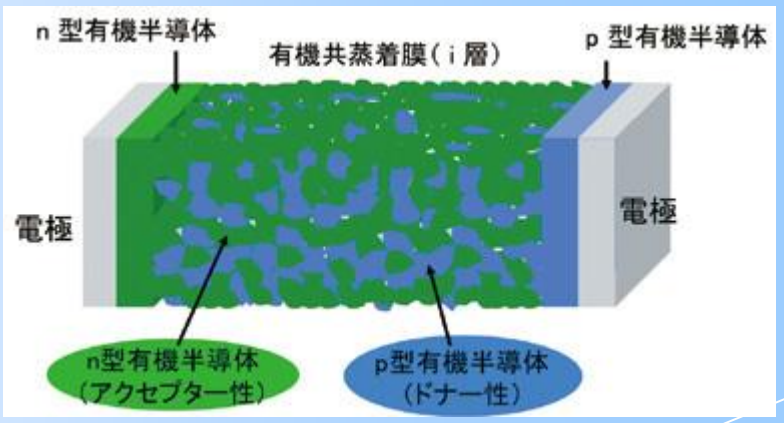
Roll-to-Roll deposition process



Organic semiconductor solar cells

Very short minority carrier diffusion length

“Bulk hetero-junction solar cells



Flexible, light weight, low cost

Competition in conversion efficiency