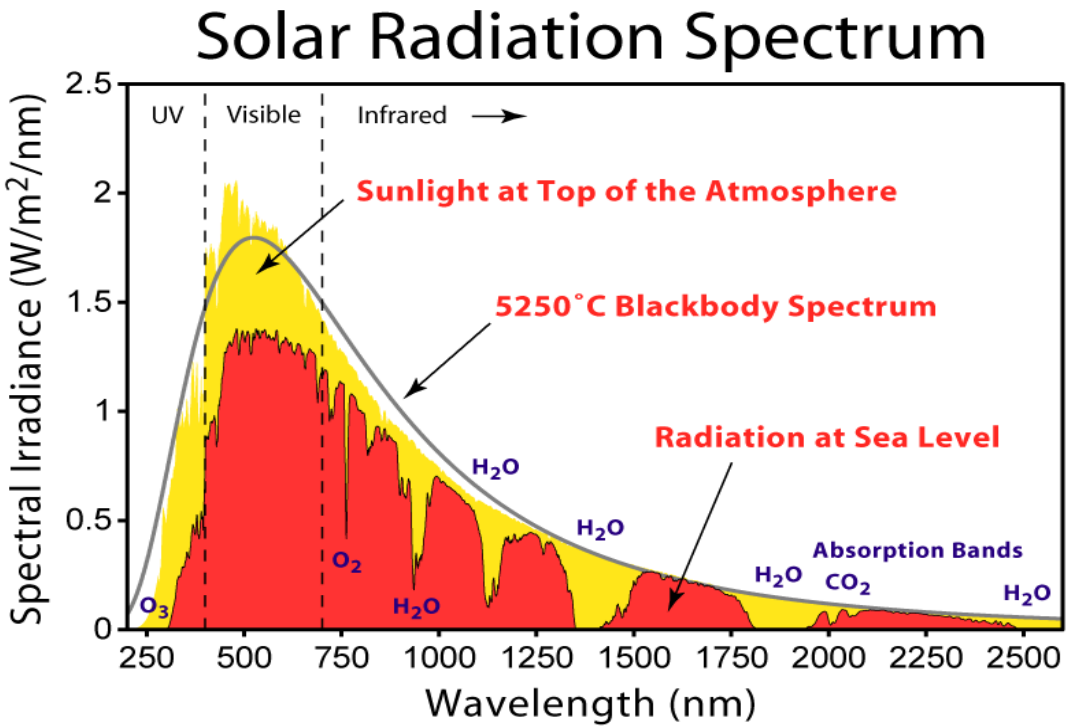
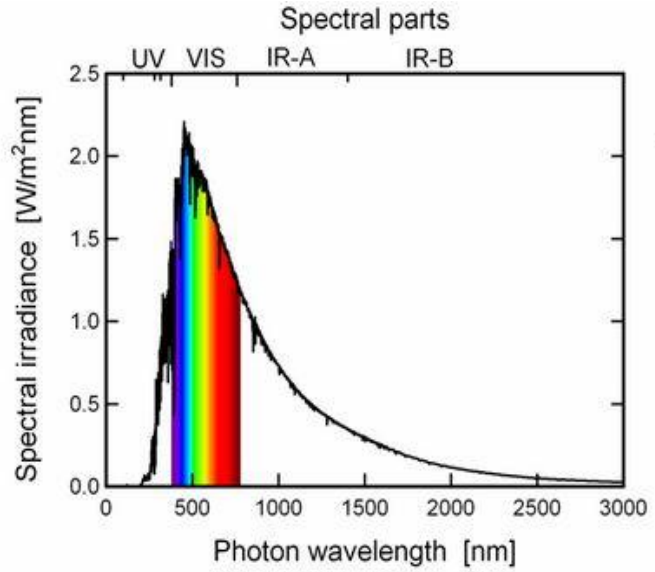
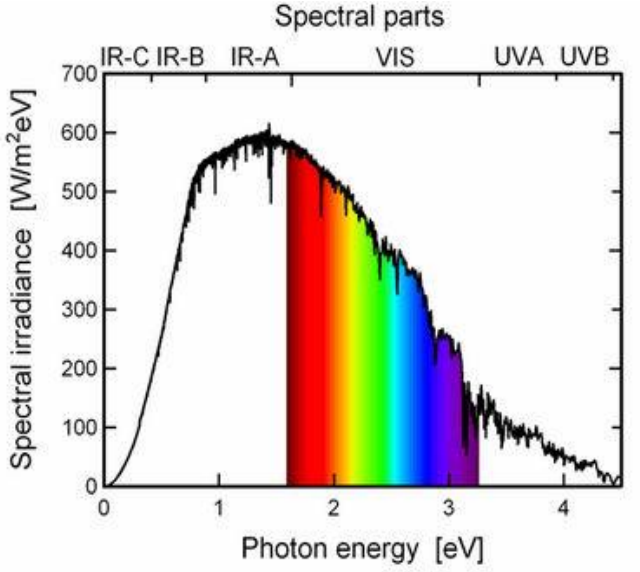
CONVERSÃO DE ENERGIA SOLAR : CÉLULAS FOTOVOLTAICAS







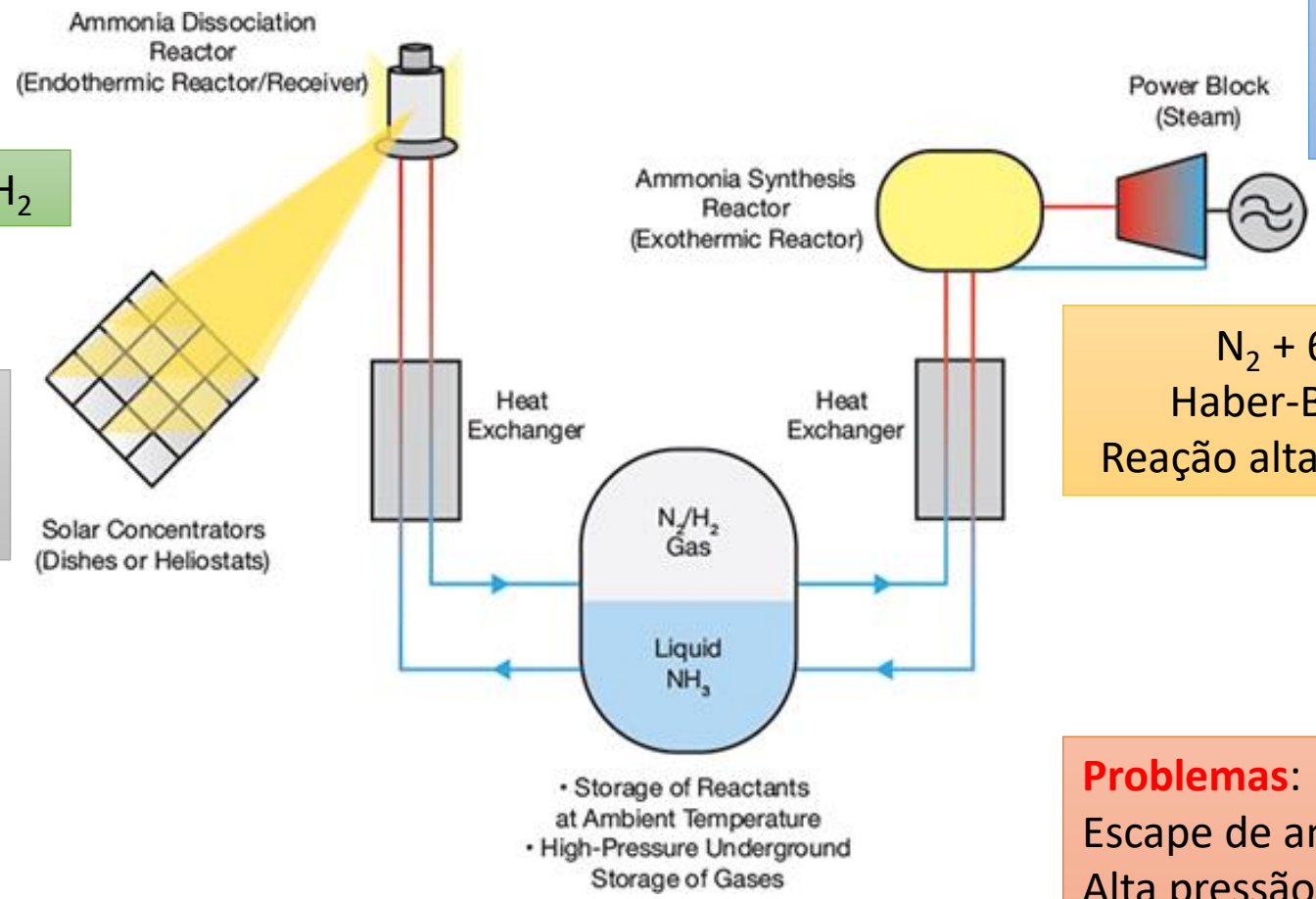
COMO APROVEITAR A ENERGIA SOLAR???

Uso de células fotovoltaicas a base de Si

OUTRAS FORMAS DE UTILIZAÇÃO DA ENERGIA SOLAR
CICLO DA AMÔNIA (NH_3)
Ciclo termoquímico catalítico

Gerador de trabalho mecânico convertido em elétrico

$2NH_3 \rightarrow N_2 + 6\ H_2$



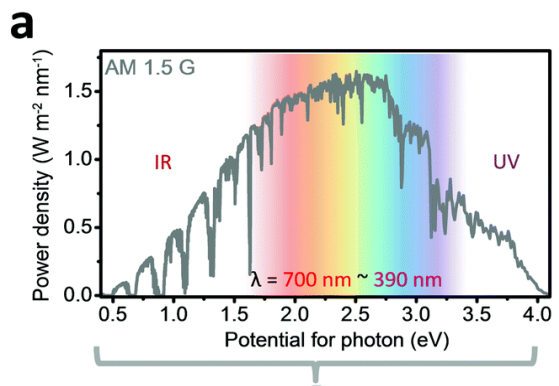
Espelho parabólico para concentrar a radiação solar

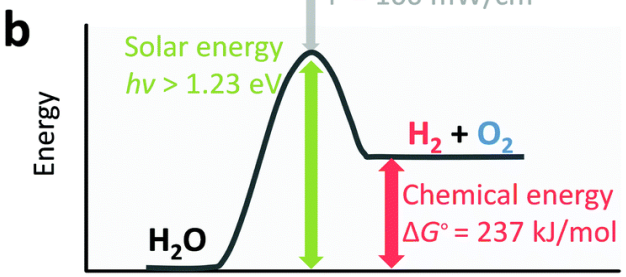
$N_2 + 6\ H_2 \rightarrow 2NH_3$
Haber-Bosch catalítico
Reação altamente exotérmica

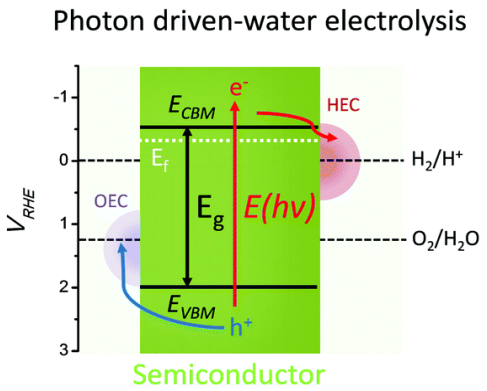
https://www.aiche.org/resources/publications/cep/2017/july/leveraging-ammonia-industry-solar-energy-storage

Problemas:
Escape de amônia
Alta pressão e temperatura
Escape de hidrogênio
Geração de óxidos de nitrogênio poluentes

FOTOELETRÓLISE DA ÁGUA
PARA GERAR HIDROGÊNIO
USANDO FÓTONS COM ENERGIA
MAIOR QUE 1,23 eV
$h\nu \geq 1{,}23$ eV

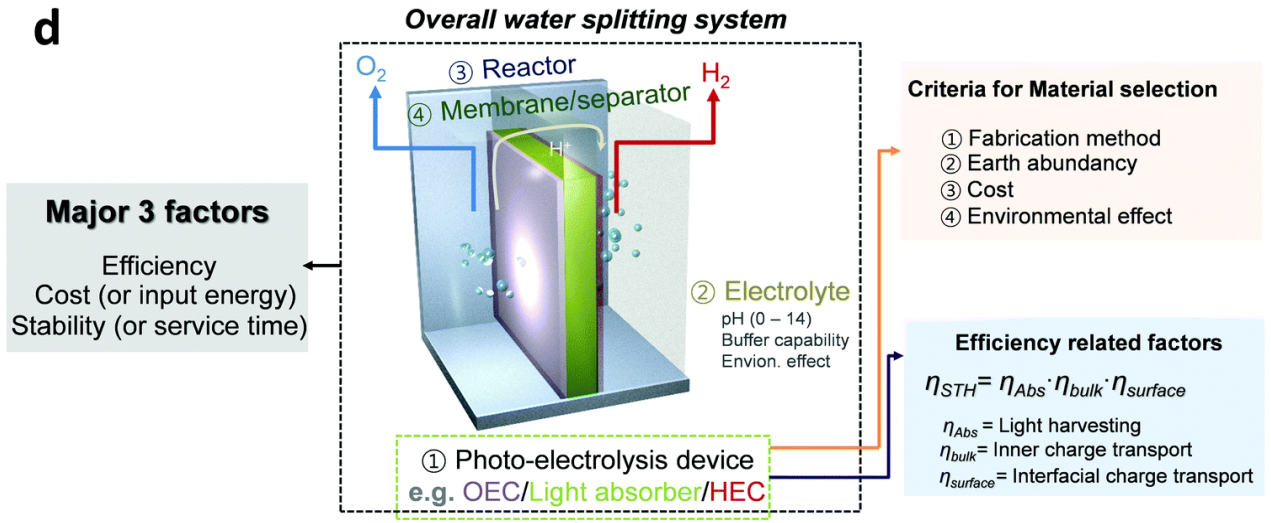






$E(h\nu) \geqq E_g + \eta_{loss} > 1.23$ V

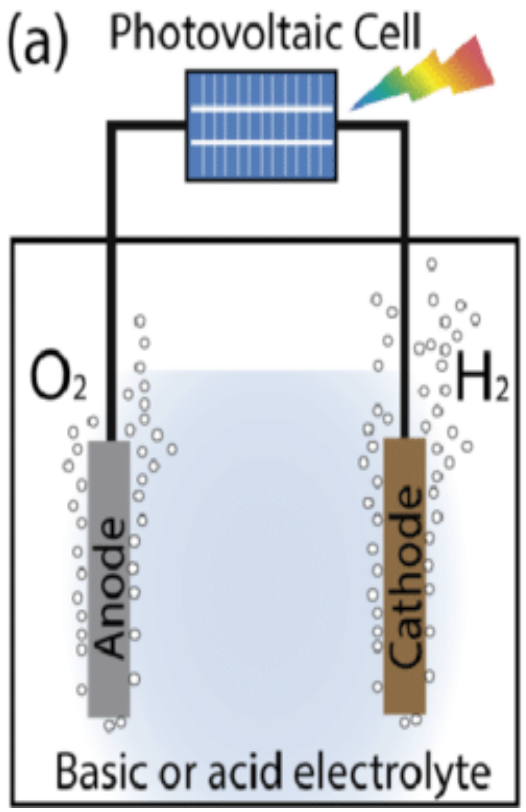
$\eta_{loss} = \eta_{resistance} + \eta_{OER} + \eta_{HER}$

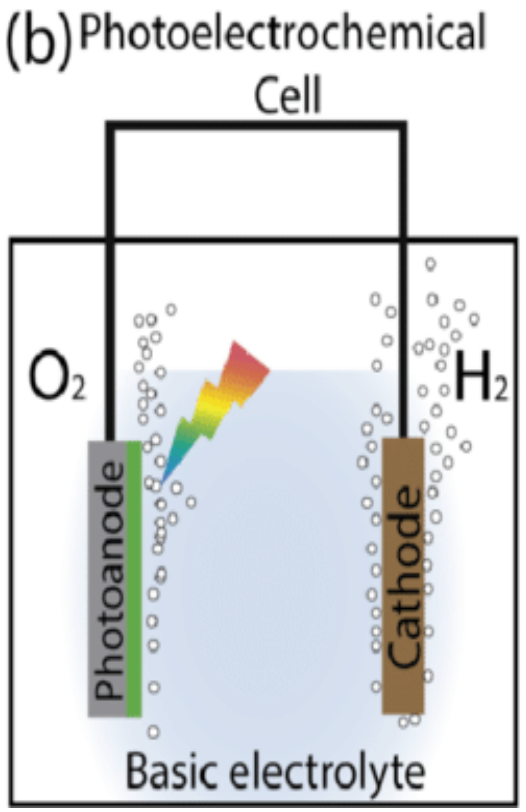


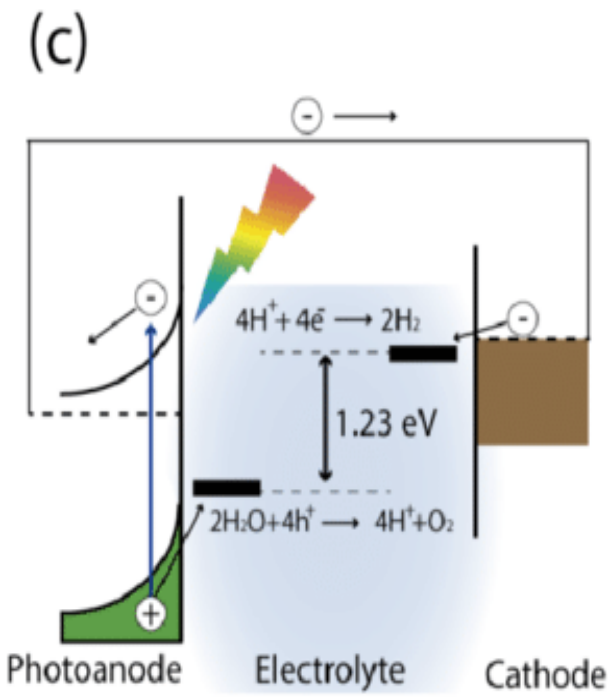
Chem. Soc. Rev., 2019,**48**, 1908-1971

Célula fotovoltaica Si Externa

Célula Fotoeletroquímica (junto ao fotoanodo) formada por sistema gerador de elétrons (e-) e lacunas (h+) a partir da absorção de fótons

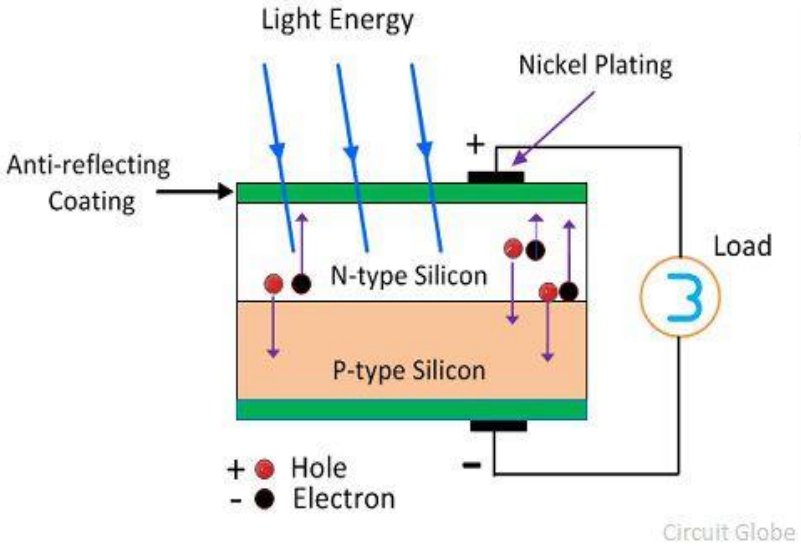


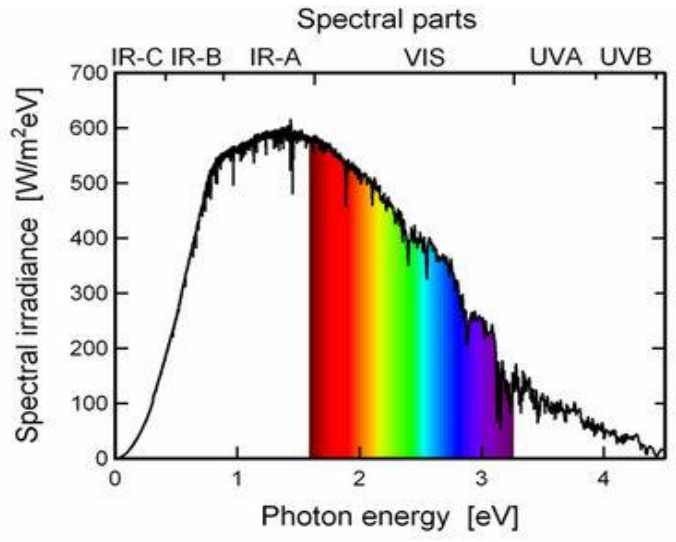


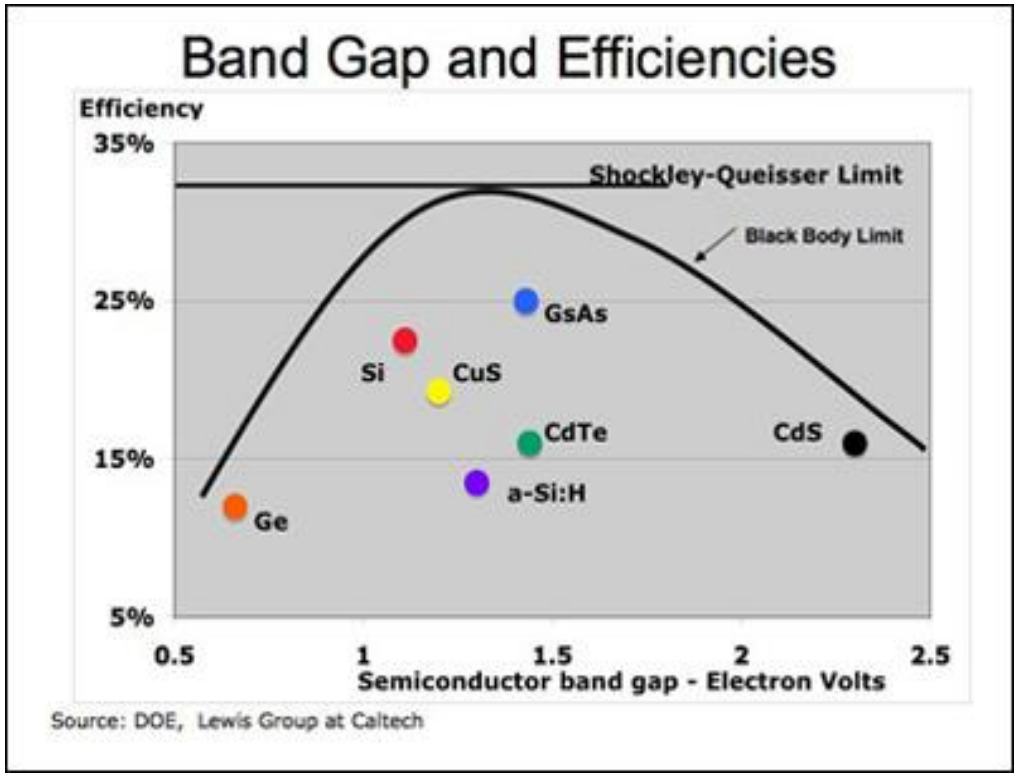


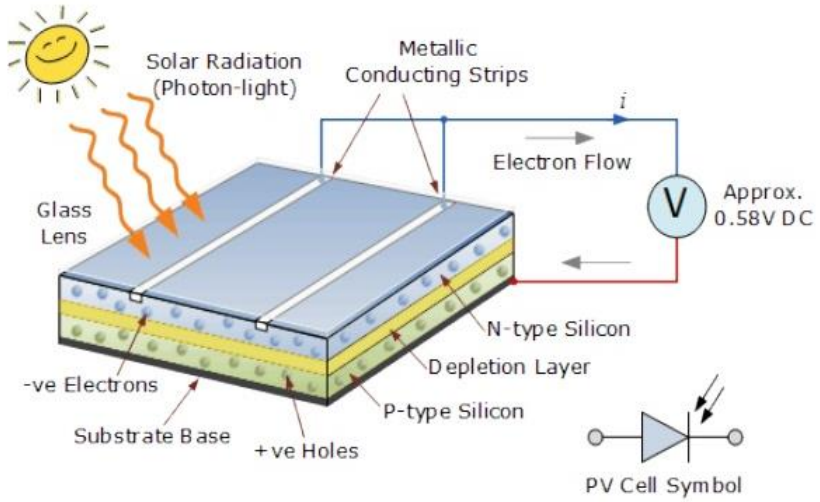
Recyclable Catalysis v. 3, n. 1 (26 April 2016): 1-12

LIMITES DE EFICIÊNCIA DA GERAÇÃO
LIMITE DE SHOCKLEY-QUEISSER









PONTO CHAVE: SEPARAÇÃO DO EXCITON COM BAIXA RECOMBINAÇÃO DOS PORTADORES DE CARGA

EXCITON $\rightarrow e^- + h^+$

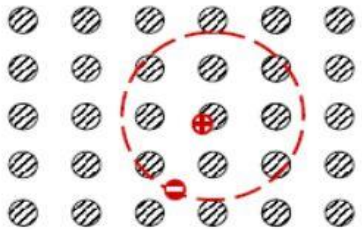
TIPOS DE EXCITONS:
WANNIER (SEMICONDUTORES)
FRENKEL (MATERIAIS E COMPOSTOS ORGÂNICOS)

Excitons
(bound electron-hole pairs)

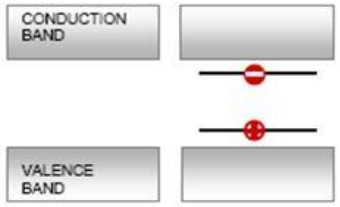
treat excitons as chargeless particles capable of diffusion,

also view them as excited states of the molecule

Wannier exciton
(typical of inorganic semiconductors)



SEMICONDUCTOR PICTURE



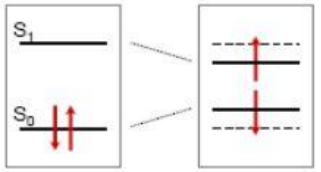
GROUND STATE WANNIER EXCITON

binding energy ~10meV
radius ~100Å

Charge Transfer (CT) Exciton
(typical of organic materials)

Frenkel exciton
(typical of organic materials)

MOLECULAR PICTURE



GROUND STATE FRENKEL EXCITON

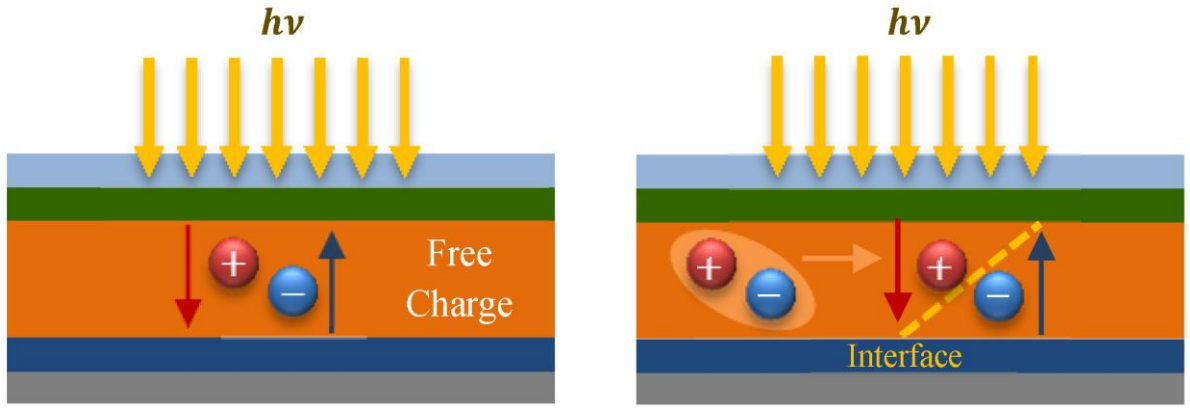
binding energy ~1eV
radius ~10Å

Electronic Processes in Organic Crystals and Polymers by M. Pope and C.E. Swenberg

TIPOS DE CÉLULAS SOLARES E ESCALA TEMPORAL DOS PROCESSOS

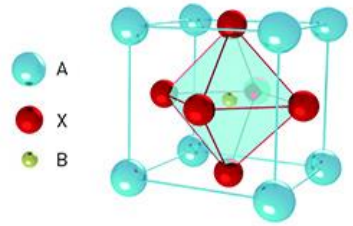
Corantes orgânicos, polímeros conjugados, NP de semicondutores (CdTe)

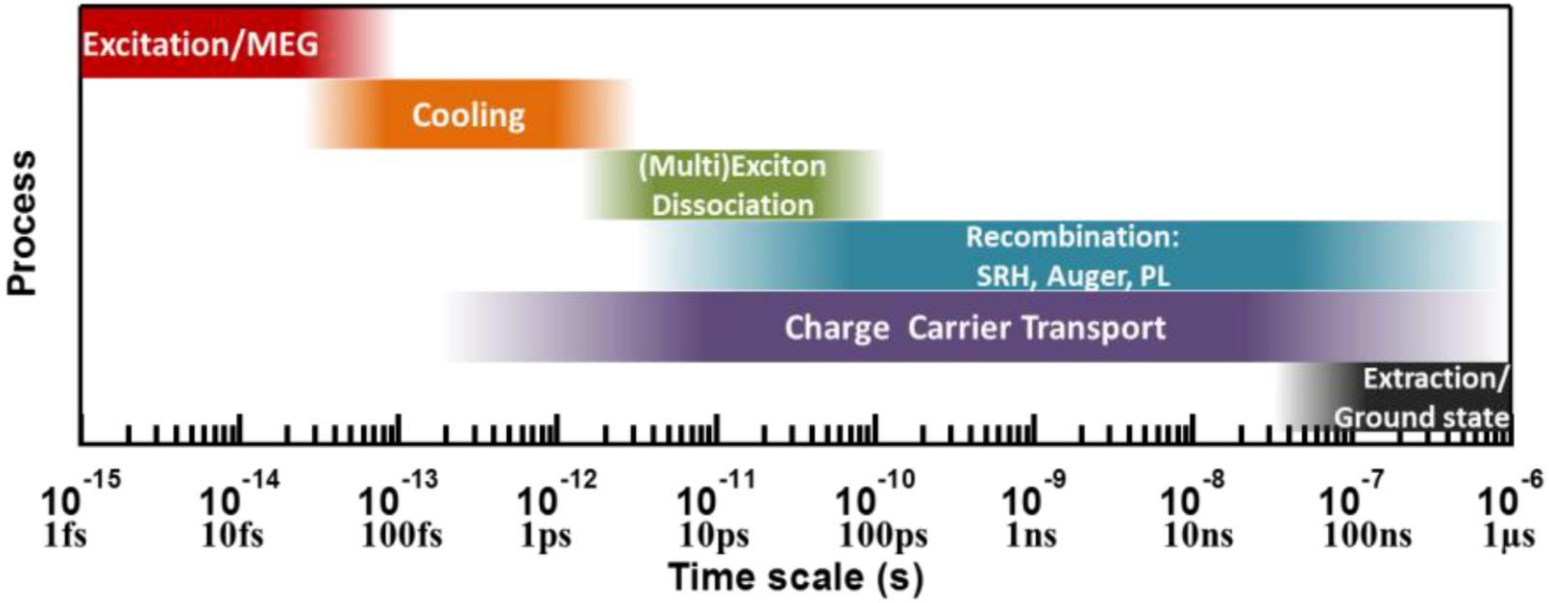
Silício

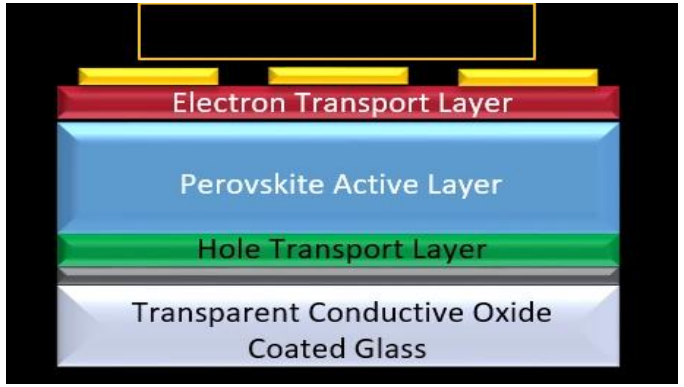


PEROVSKITAS

ABX_3: B= Pb^{2+} , X = I^-, A= Cátion orgânico (NH_3^+, $CH_3NH_3^+$)

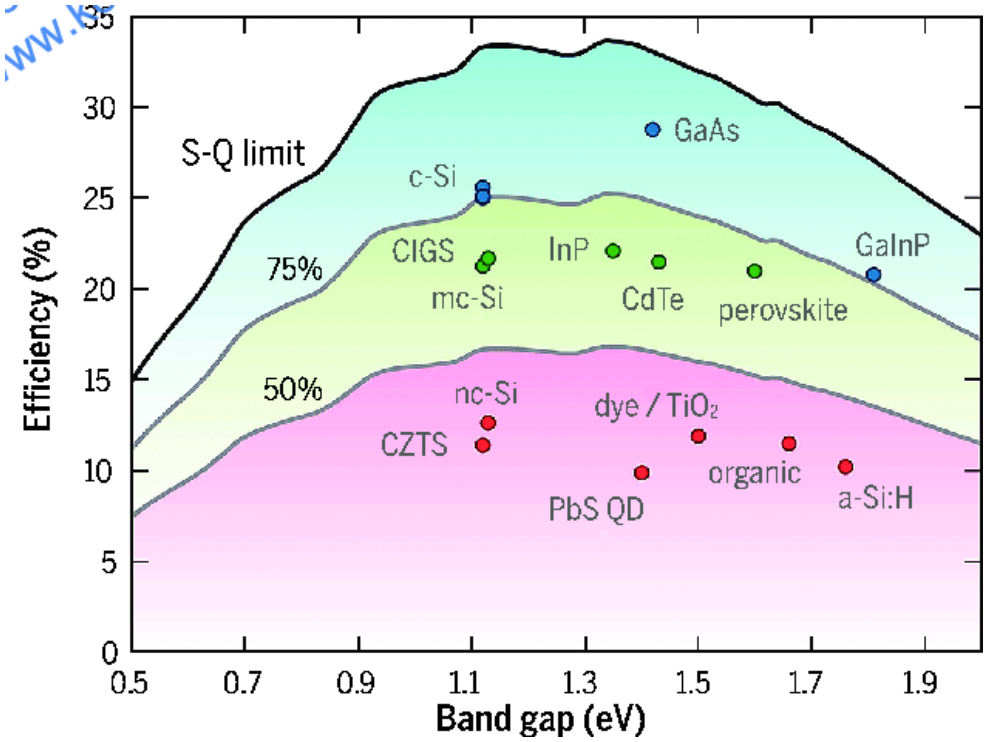


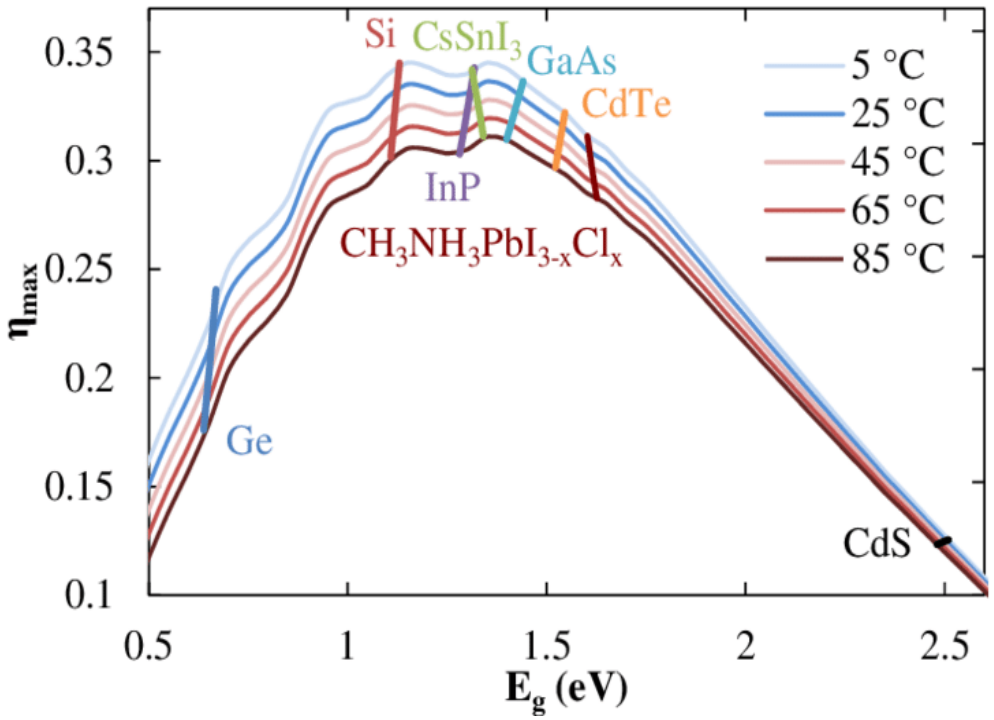




https://www.ossila.com/pages/perovskites-and-perovskite-solar-cells-an-introduction

EFICIÊNCIA COMPARATIVA

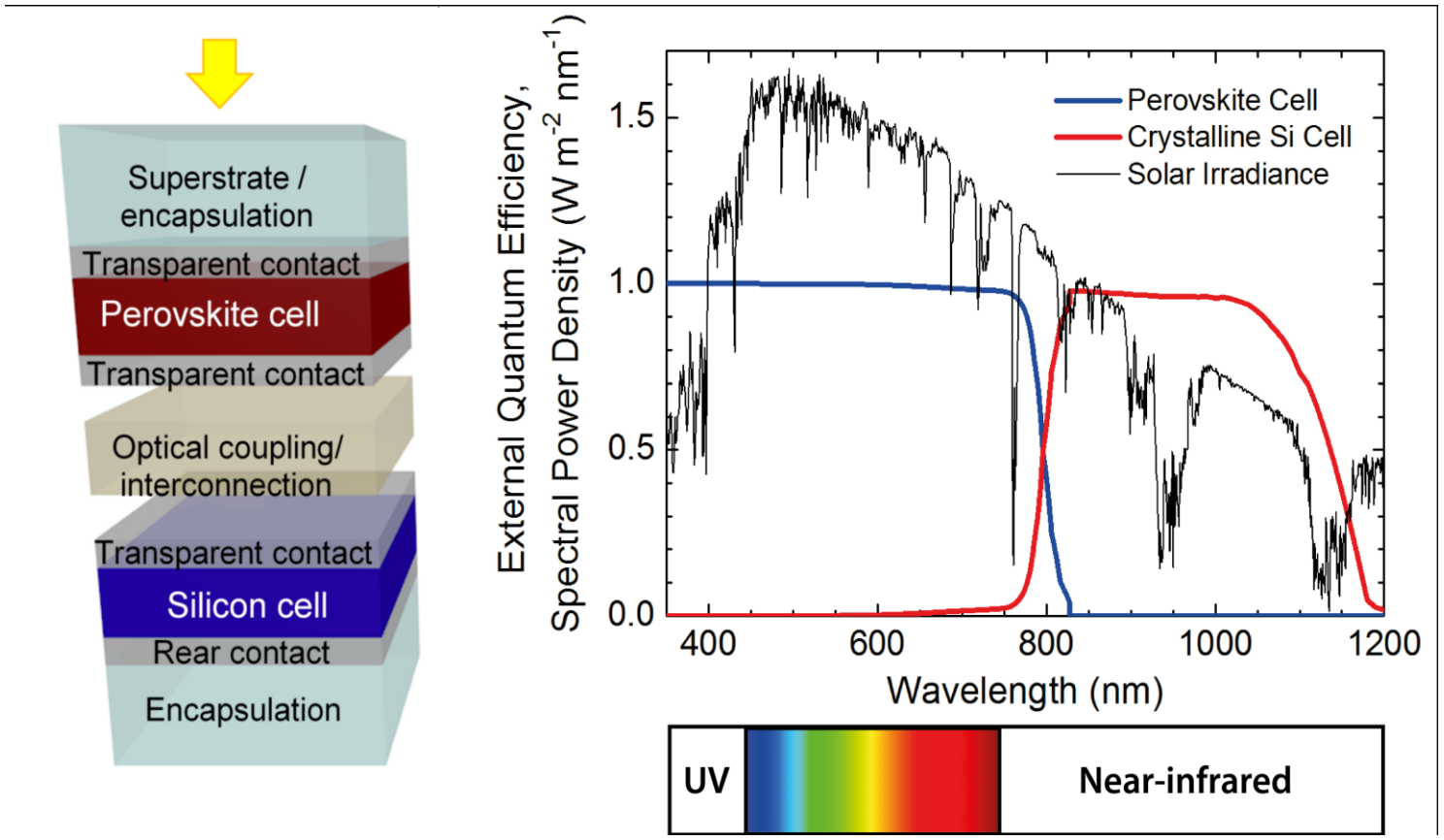




CONCLUSÃO: EFICIÊNCIA DE UMA ÚNICA CAMADA LIMITADA 1/3

QUESTÃO: COMO AUMENTAR A EFICIÊNCIA???

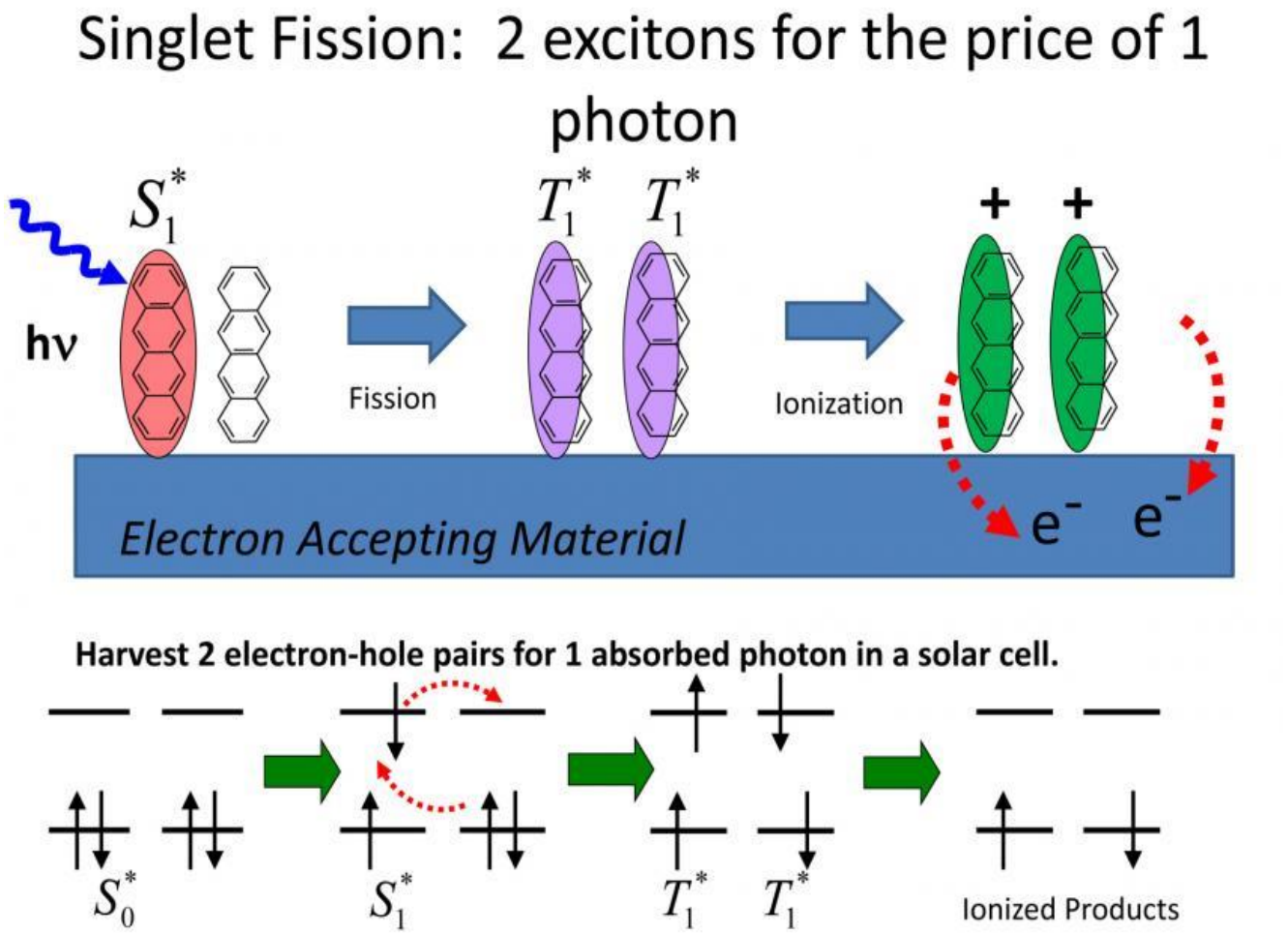
COMBINAÇÃO DE SISTEMAS: CÉLULAS DE MÚLTIPLAS CAMADAS (TANDEM)
PROMISSORA: PEROVSKITA + SILÍCIO



https://www.epfl.ch/labs/pvlab/research/page-124775-en-html/

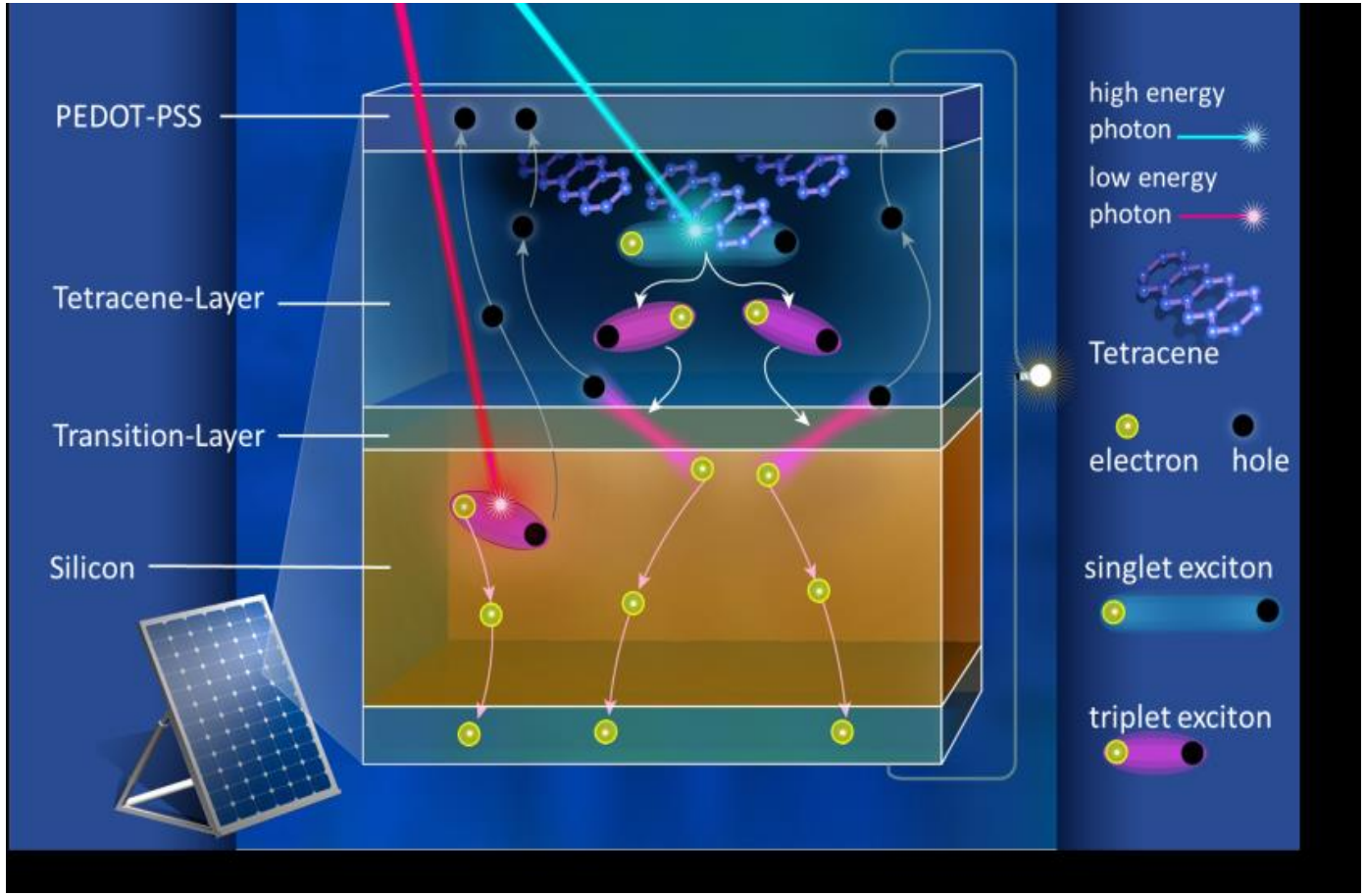
COMO AUMENTAR AINDA MAIS O RENDIMENTO???
RESPOSTA: COMBINANDO PROCESSOS COM MAIOR EFICIÊNCIA DE GERAÇÃO DE PORTADORES DE CARGA (elétrons e lacunas)

NANOCRISTAIS DE TETRACENO



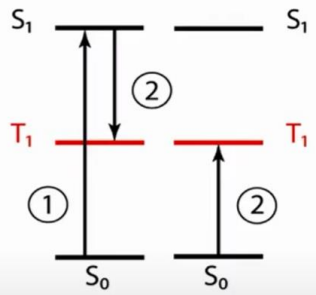
J. Phys. Chem. Lett. 2014, 5, 13, 2312–2319

MODELOS HÍBRIDOS (TANDEM CELLS)



Principle of a silicon singlet fission solar cell with incorporated organic crystals. (Source: M. Künsting / HZB)

SINGLET FISSION



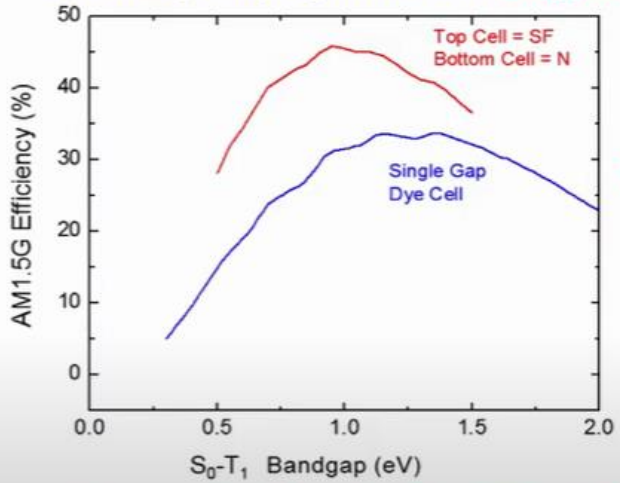
spin allowed - **triplet yield up to 200%**

singlet fission is exoergic when $\Delta E_S > 2\ \Delta E_T$

T-T annihilation is endoergic when $\Delta E_Q, \Delta E_{T2}, \Delta E_S > 2\ \Delta E_T$

SOLAR CELL: THEORETICAL EFFICIENCY

Ordinary single-junction vs. singlet fission solar cell



Assumptions:

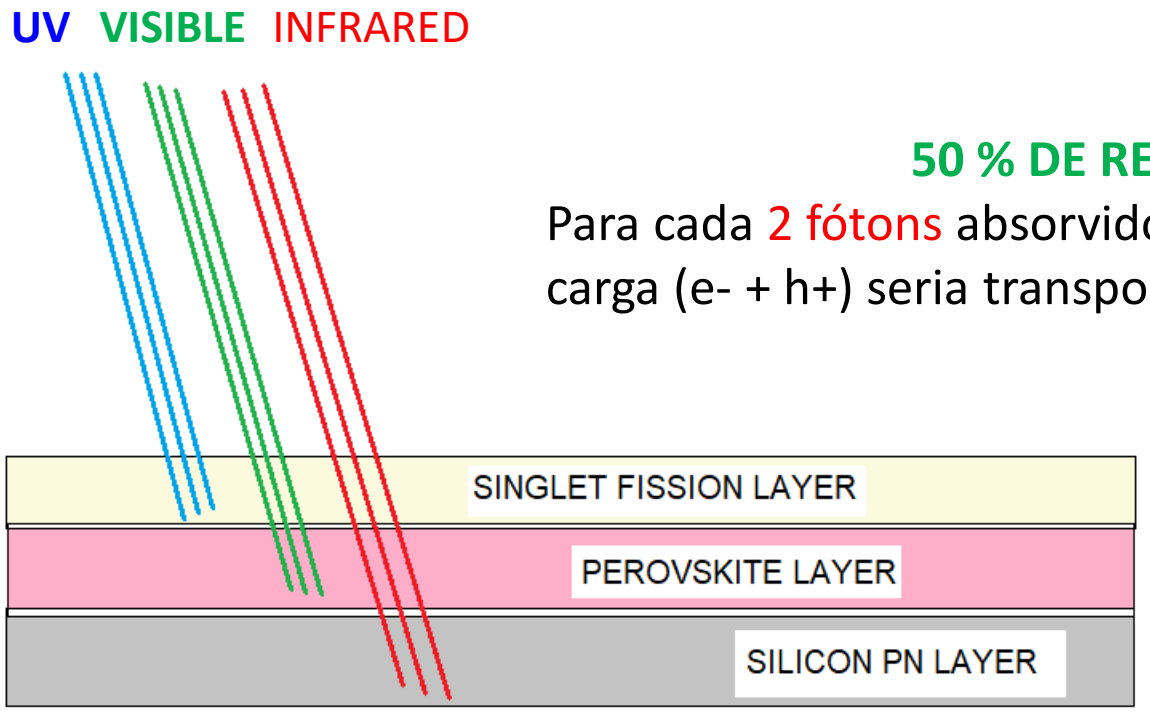
- **200% triplet yield**
- **each triplet yields e + h**
- detailed balance
- -1 Sun illumination
- full absorption of incident solar light above 1.1 eV

M. Hanna, A. J. Nozik, *J. Appl. Phys.* **2006**, *100*, 074510;

Shockley, W.; Queisser, H.J. *J. Appl. Phys.* **1961**, *32*, 510-519.

Fonte: Prof. J. Michl

QUAL SERÁ NO FUTURO A CÉLULA SOLAR DE ALTA EFICIÊNCIA ?



50 % DE RENDIMENTO !!

Para cada 2 fótons absorvidos uma separação efetiva de carga (e- + h+) seria transportado para corrente elétrica

QUÍMICA + FÍSICA + ENGENHARIA
ENGENHARIA MOLECULAR