UNIVERSITY OF TORONTO

King Abdullah University of Science and Technology KAUST

Solution-Processed Semiconductors for Energy and the Environment

Presented by: Dr. Ted Sargent

University of Toronto

The solar energy opportunity

Saudi Arabia occupies ~ 2 million km^2

This instant

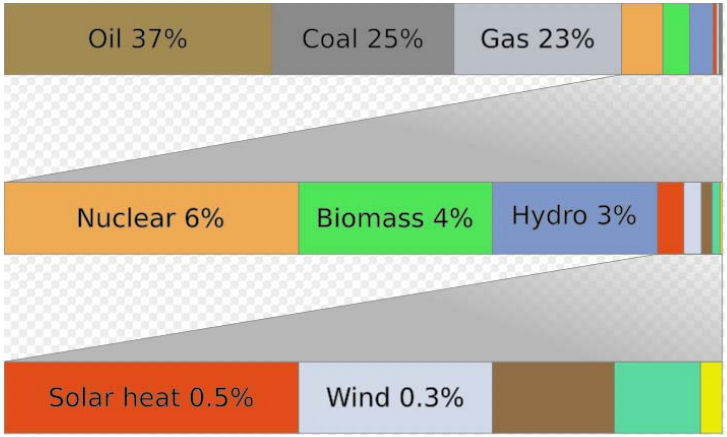
~ 2 PW of power strikes Saudi Arabia

This is over 100x worldwide instantaneous energy consumption.

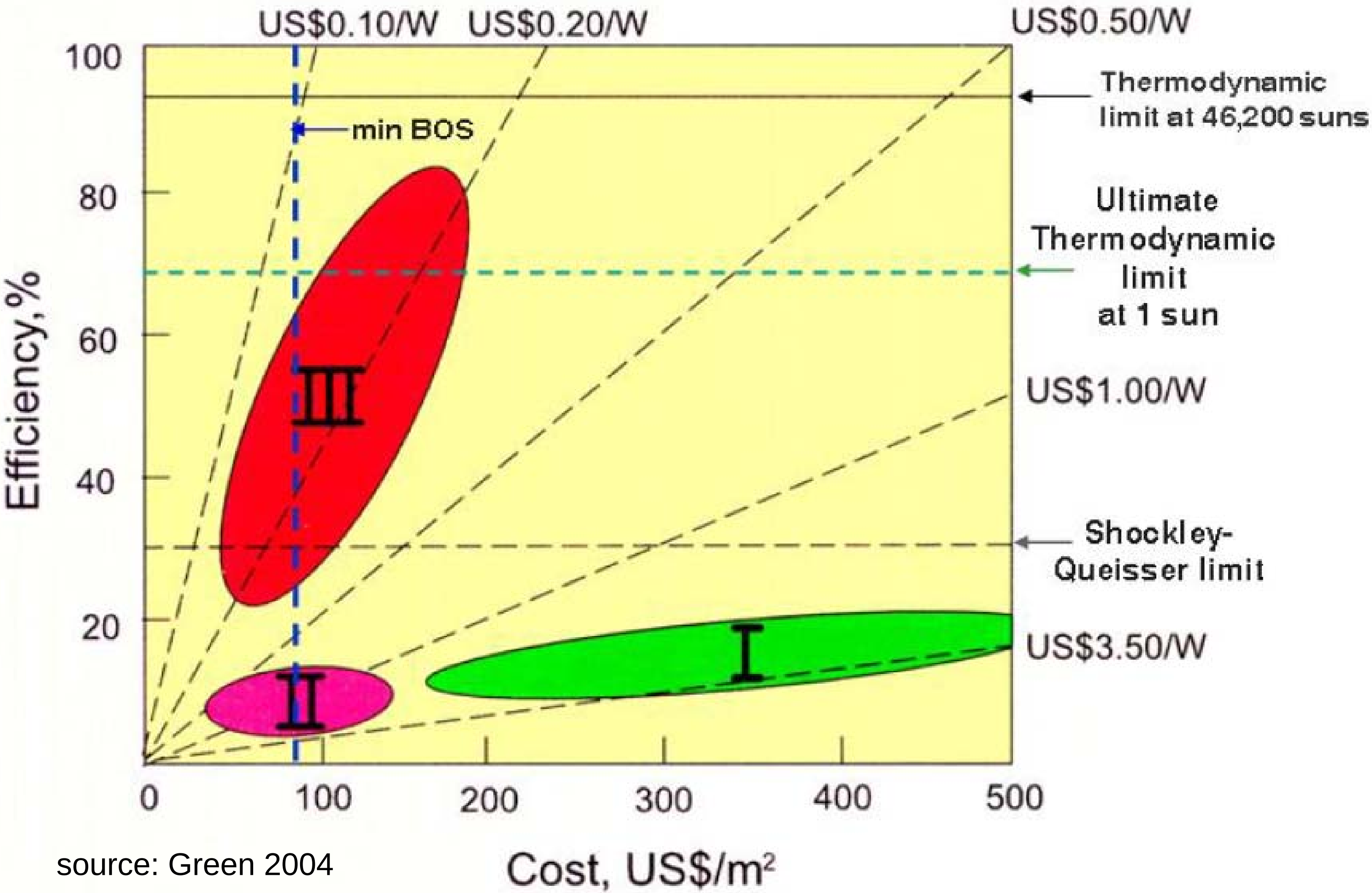
The opportunity:

Diversify and rebalance the portfolio of worldwide energy harvesting

Today:

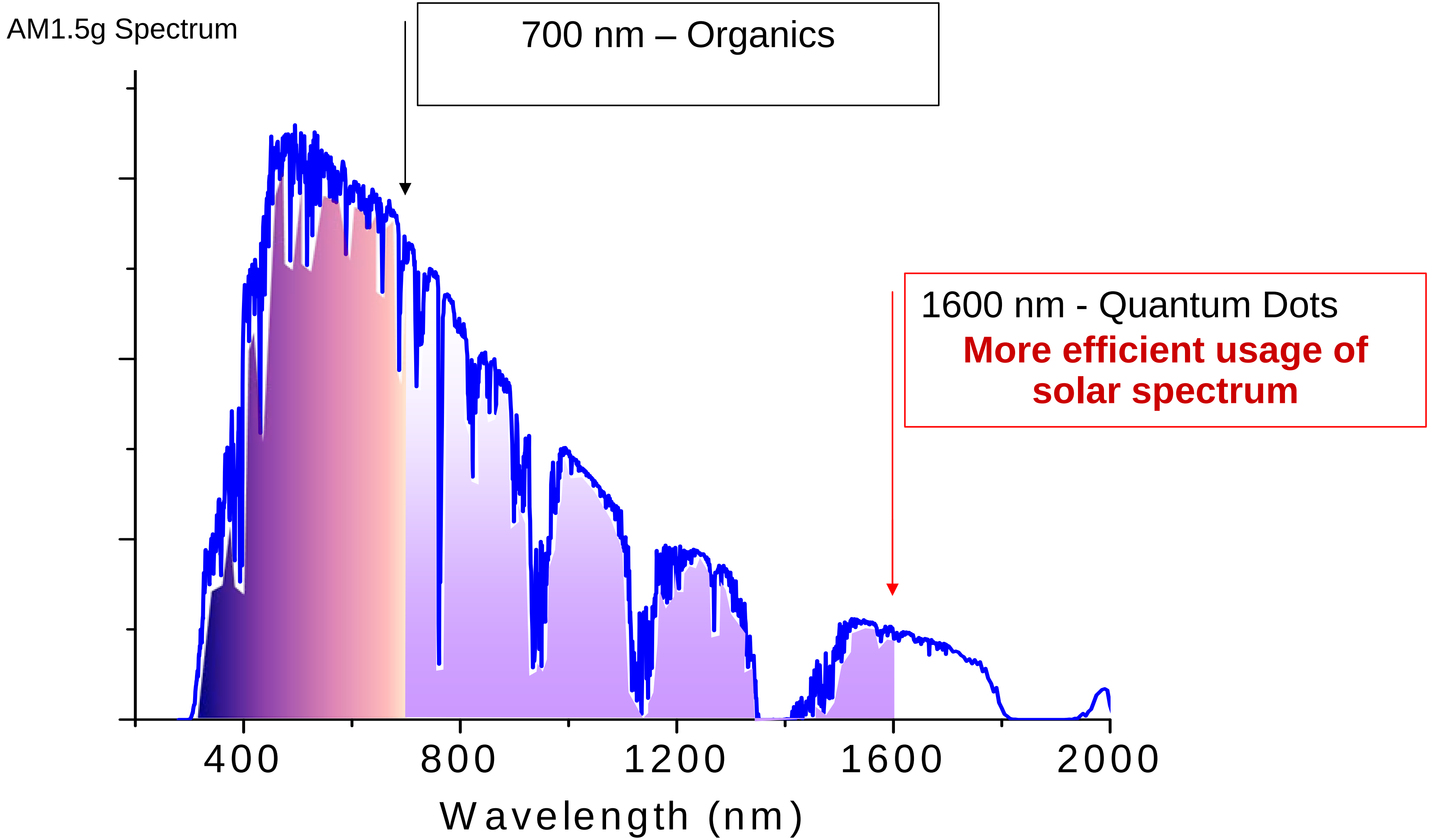


The need for efficiency

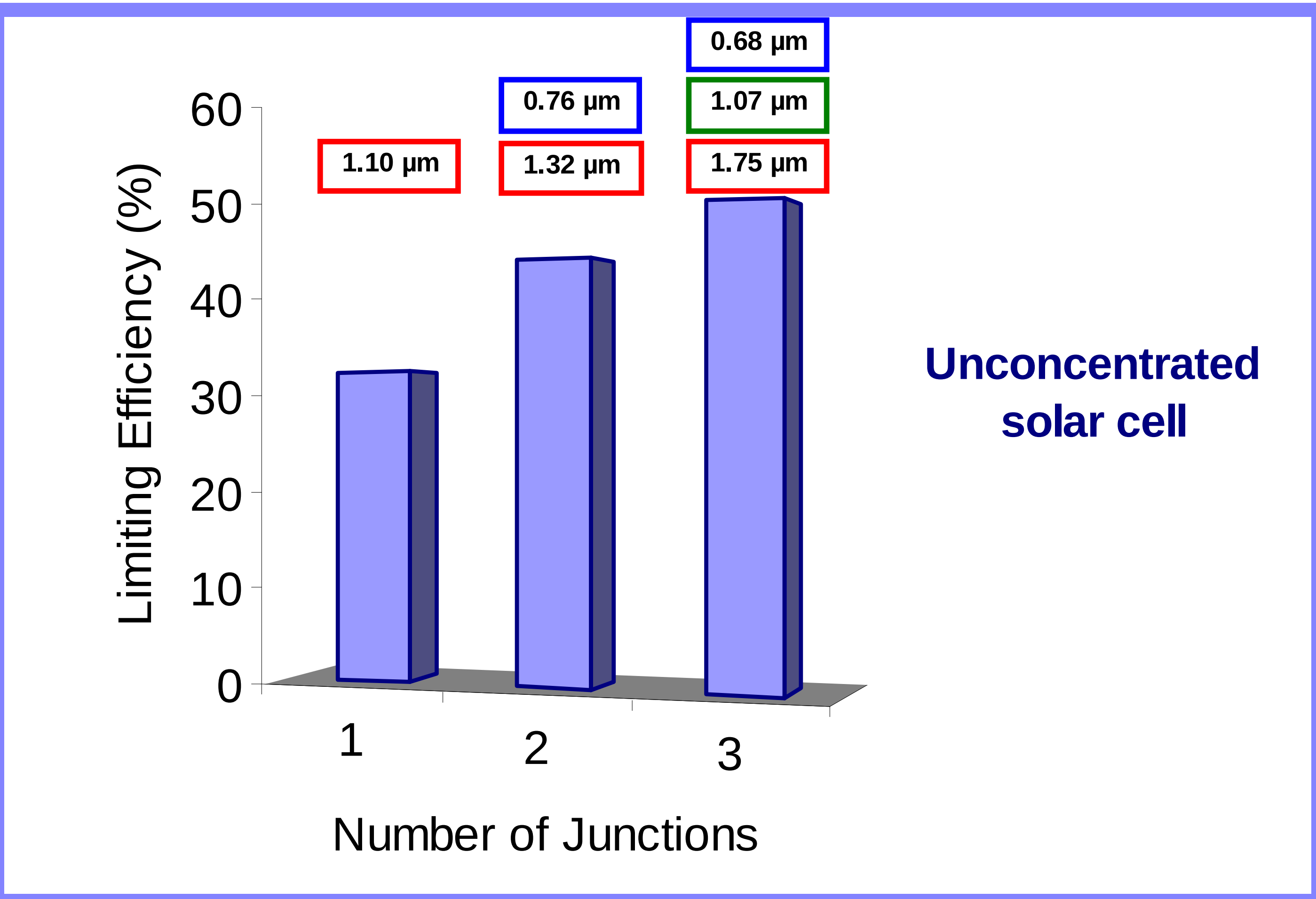


source: Green 2004

The spectral opportunity



Maximum Efficiencies and Bandgap for Single- or Multi-junction

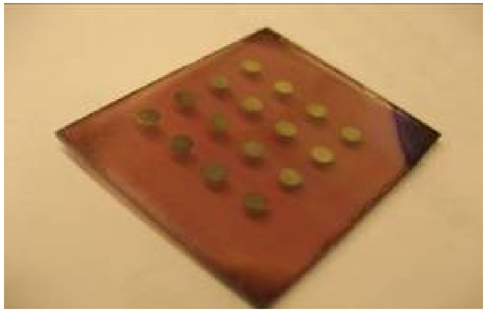


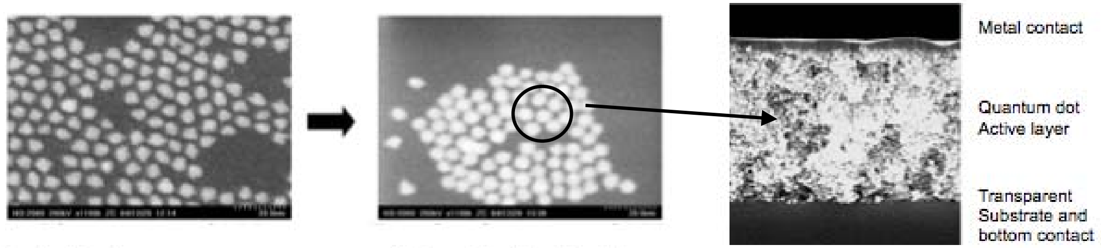
Low Cost Solution-Processing, Low Cost Materials

Synthesis

Spin-coat (Simple Method)

Final Device



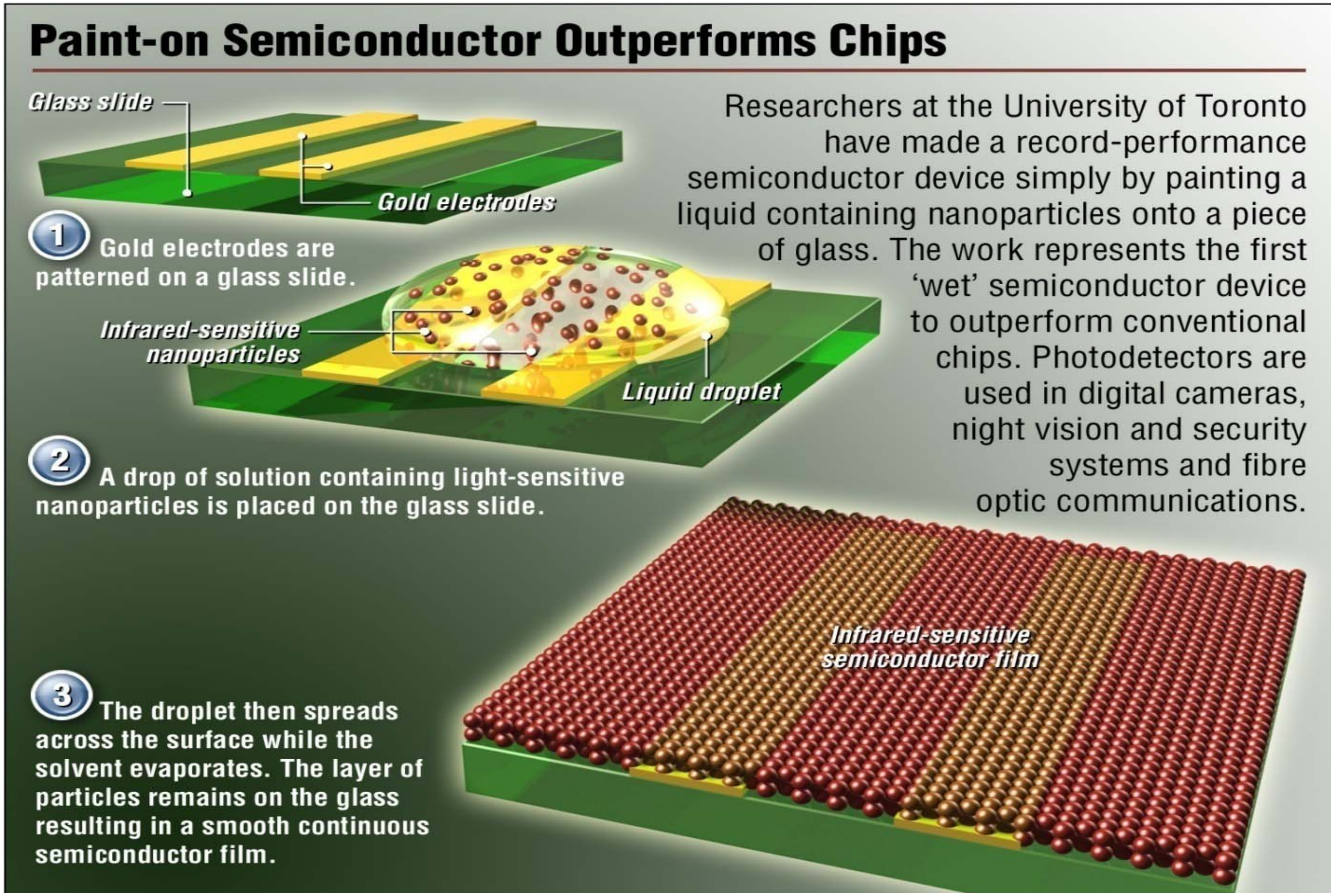


Colloidally
Stable Quantum Dots

Closely-Packed
Quantum Dot Film

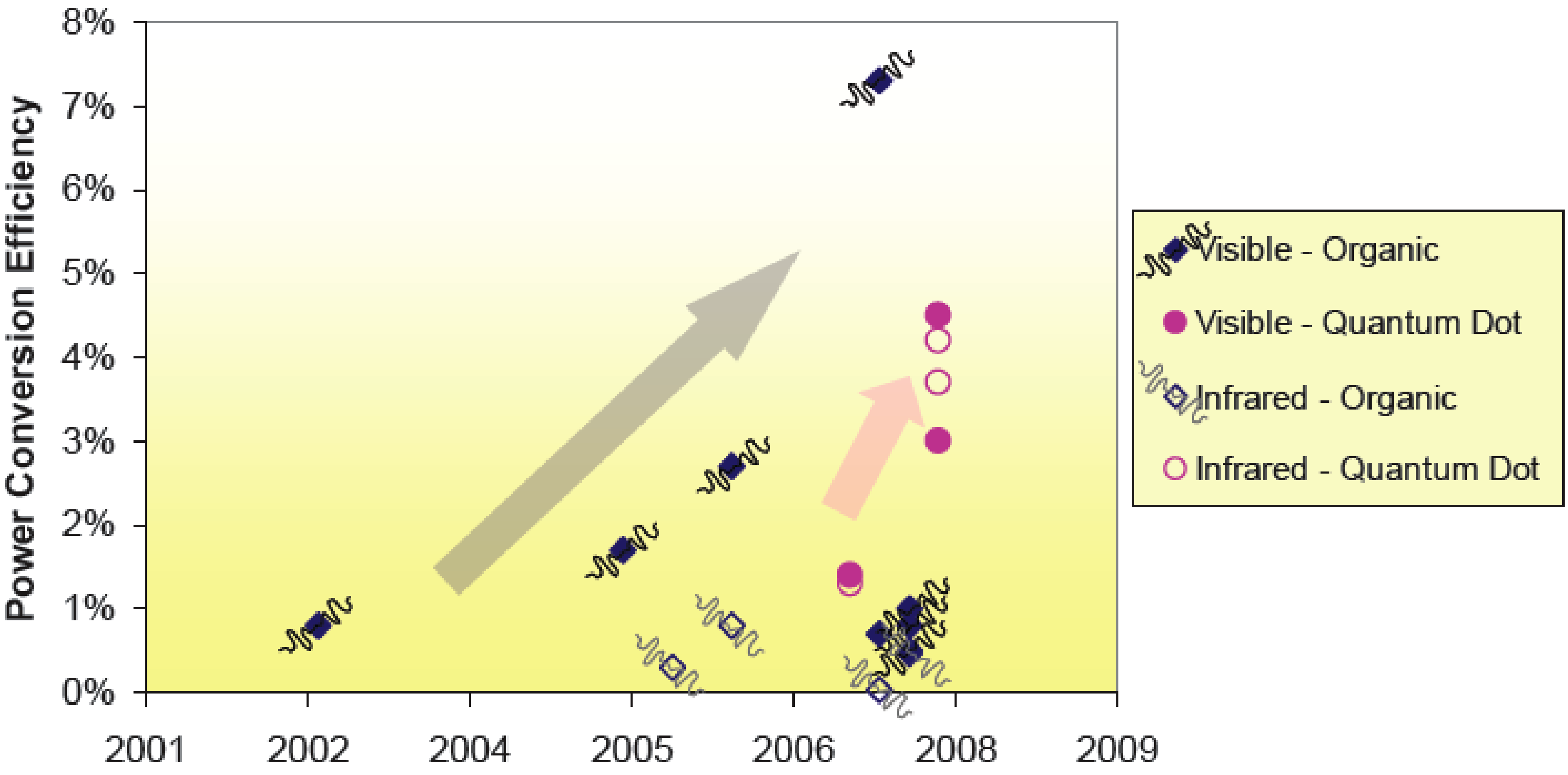
Electrically-contacted
completed device

Ultrasensitive solution-cast quantum dot photodetectors



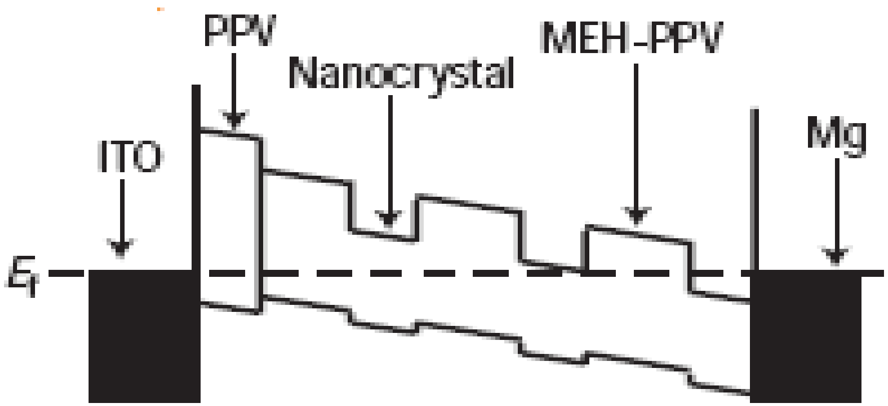
Nature 2006, Gerasimos Konstantatos1, Ian Howard1, Armin Fischer1, Sjoerd Hoogland1, Jason Clifford1, Ethan Klem1, Larissa Levina1 & Edward H. Sargent1

Solution-processed photovoltaics – visible and infrared progress



Solution-processed PbS quantum dot infrared photodetectors and photovoltaics

STEVEN A. MCDONALD[1], GERASIMOS KONSTANTATOS[1], SHIGUO ZHANG[1], PAUL W. CYR[1,2], ETHAN J. D. KLEM[1], LARISSA LEVINA[1] AND EDWARD H. SARGENT[1]*



Polymer-Nanocrystal Cells

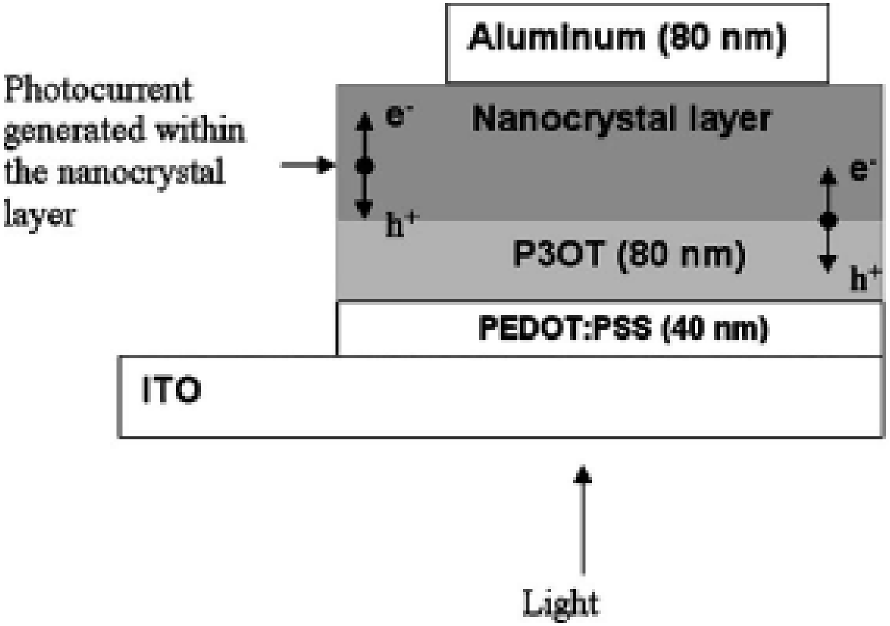
Mobility problems
➔ Poor charge extraction

How to improve mobility?

Applied Physics Letters 87, 213112 (2005)

Solution-processed infrared photovoltaic devices with >10% monochromatic internal quantum efficiency

Ahmed Maria, Paul W. Cyr, Ethan J. D. Klem, Larissa Levina, and Edward H. Sargent[a)]



Pure Nanocrystals with passivation

- Improved electronic transport
- Not enough absorbance

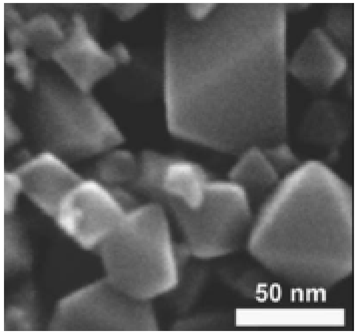
How to improve absorbance?

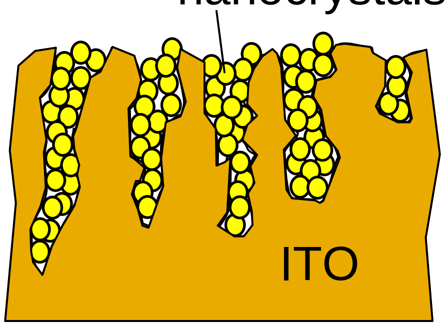
Applied Physics Letters 90, 183113 (2007)

Efficient solution-processed infrared photovoltaic cells: Planarized all-inorganic bulk heterojunction devices via inter-quantum-dot bridging during growth from solution

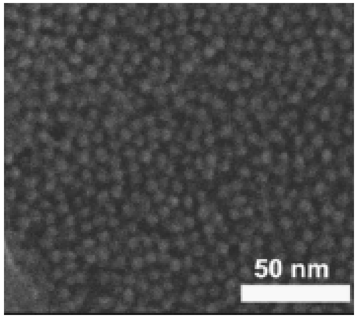
Ethan J. D. Klem, Dean D. MacNeil, Paul W. Cyr, Larissa Levina, and Edward H. Sargent[a)]

Textured ITO





Continuous nanocrystals over textured ITO



Record PCE through
1. absorbance improvement
2. a large surface area junction

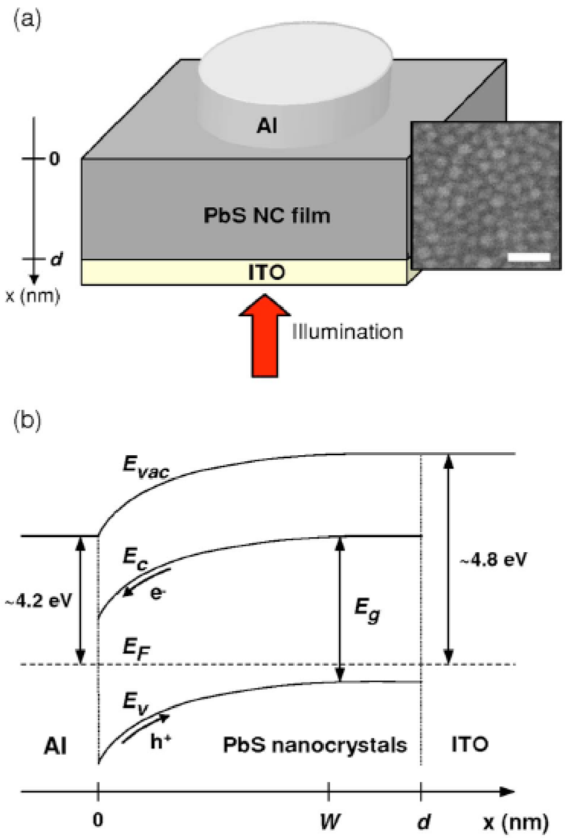
How to improve efficiency further?

Applied Physics Letters 92, 122111 & 151115 (2008)

Efficient Schottky-quantum-dot photovoltaics: The roles of depletion, drift, and diffusion

Schottky-quantum dot photovoltaics for efficient infrared power conversion

Keith W. Johnston, Andras G. Pattantyus-Abraham, Jason P. Clifford, Stefan H. Myrskog,
Dean D. MacNeil, Larissa Levina, and Edward H. Sargent[a)]



Understanding contribution of PCE from depletion, drift and diffusion

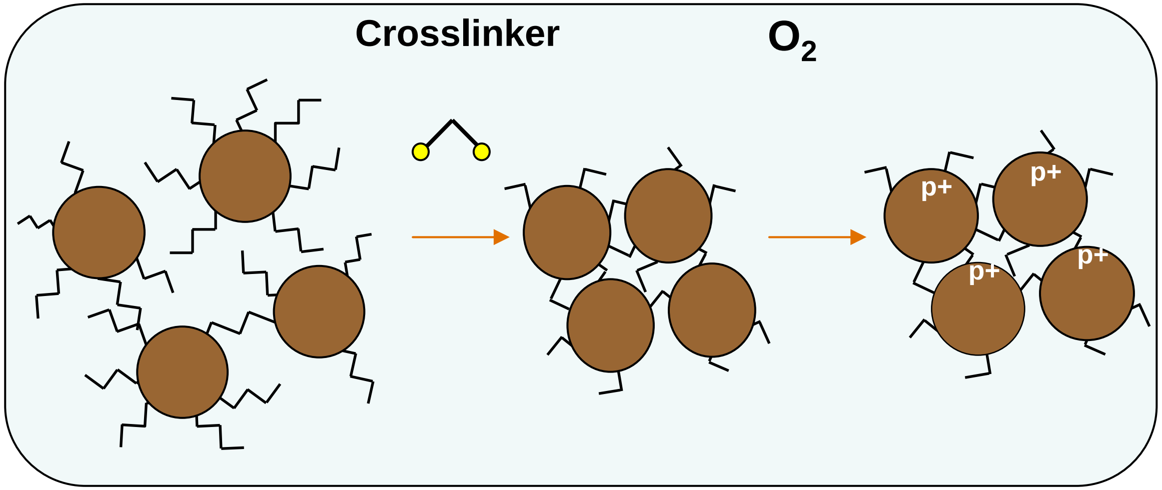
Improvement in efficiency

How to make it stable?

ACSNANO (2008)

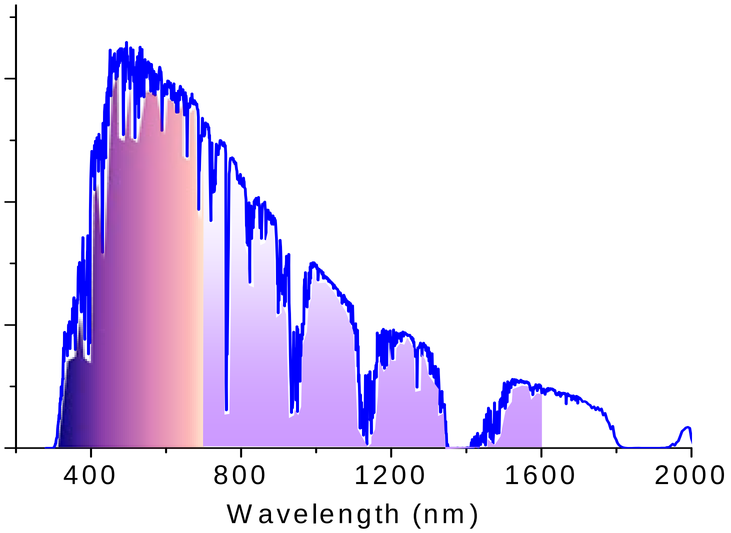
Efficient, Stable Infrared Photovoltaics Based on Solution-Cast Colloidal Quantum Dots

Ghada I. Koleilat, Larissa Levina, Harnik Shukla, Stefan H. Myrskog, Sean Hinds, Andras G. Pattantyus-Abraham, and Edward H. Sargent*



Benzenedithiol crosslinker provides enhanced stability

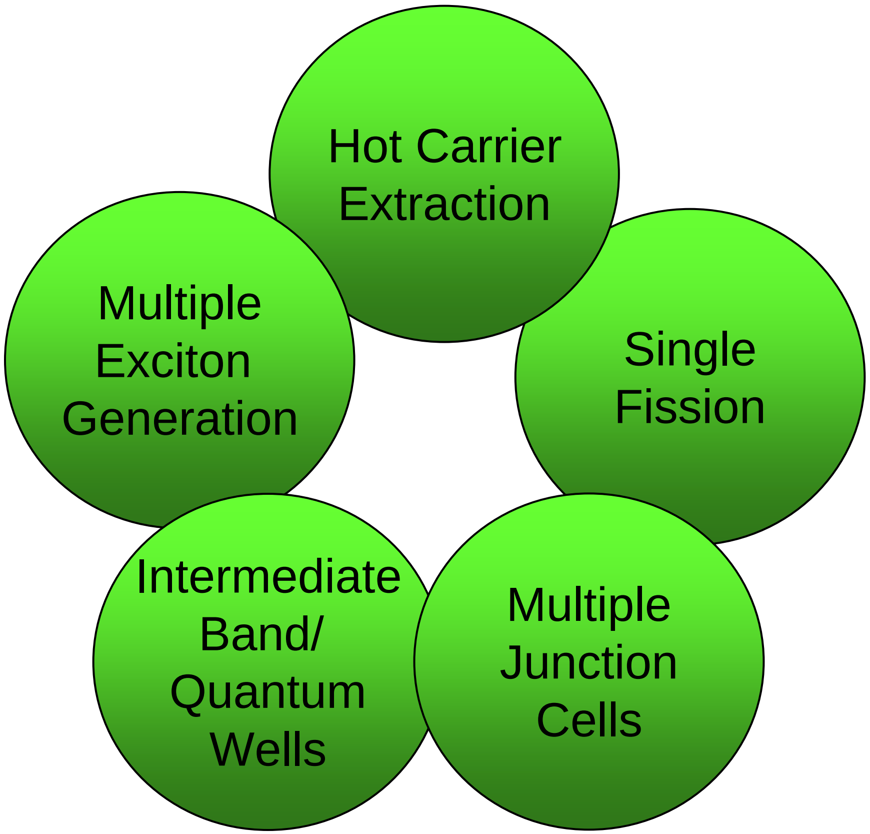
Research Effort on 3rd Generation PV



Low cost, high performance (η > 30%)

Efficient usage of solar spectrum

Research Effort:



KAUST – University of Toronto Synergy

Sargent

- >= 3 weeks per year at KAUST
- KAUST Solar Energy Director hiring

Sargent group

- Building highly controlled prototyping facility
- Building advanced characterization facility
- Attracted Program Director and
  - Senior Materials Scientist from industry

Growing the KAUST-University of Toronto engagement

- Exchanges of personnel
- Annual joint solar workshop