Computational Photonics

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Photolithography

source: www.jcmwave.com
Nanostructures for photon management in solar cells

Commercial a-Si:H module

η ≈ 7%

ZnO (~80nm)
Aluminum (~100nm)
a-Si:H pin (~475nm)
Asahi U-type, ~625nm

Protective Pt layer for FIB slicing
Solar Cell Reconstruction

milling with focused ion beam

slice recording with SEM
Reconstructed Interfaces: TCO

FIB Slicing Parameters:
Step size (y) = 25 nm
Pixel size (x, z) = 4.47 nm
Reconstructed Interfaces: Metal Back Contact

FIB Slicing Parameters:
Step size (y) = 25 nm
Pixel size (x, z) = 4.47 nm
Surface Statistics

Height Distribution TCO

\[ \sigma_{RMS} = 37.7 \text{ nm} \]

Height Distribution Metal

\[ \sigma_{RMS} = 34.7 \text{ nm} \]
Electro-Optical Properties

EQE / Absorption

Absorption back contact?

wavelength [nm]

EQE / Absorption

EQE

1 – R
Simulation of light trapping properties

- Silicon (µc-Si, no abs.)
  - 66 nm
- Silicon (µc-Si)
  - 133 nm
- ZnO - 80nm
- Aluminum / Silver
  - 100 nm
- Glass (no abs.)
- Glass (no abs.)
Simulation of light trapping properties
Dependence on symmetries

Comparison Periodic / Symmetric

- Si
- TCO
- Al
- Si sym.
- TCO sym.
- Al sym.

Absorptance vs. Wavelength [nm]

400 500 600 700 800 900 1000

$10^{-4}$ $10^{-3}$ $10^{-2}$ $10^{-1}$ $10^0$
Quantify surface roughness effects
Integrated optical ADD/DROP multiplexer
SOI ring resonator

source: www.jcmwave.com
Coupled microresonators
Coupled microresonators
Coupled microresonators

- 10 µm

**Calculated intensity distribution**

- Anti-symmetric mode
- Symmetric mode

**Simulated intensity**

**Experimental reflection**

**Mapped intensity distribution**

(Reflection signal)
Photonic crystal

source: www.jcmwave.com
Photonic crystal fibers

source: www.jcmwave.com
Necessary to overcome experimental restrictions

Au spirals

rigorous solution of Maxwell’s equations including complex material models

Poynting vector
Photonics Computing Cluster
PhoClus

- 282 nodes with 2388 CPU cores (up to 2.7 GHz clock rate)
- Nodes with up to 1 TB main memory $\rightarrow \Sigma$ 12 TB main memory
- Nodes connected by InfiniBand QDR with **40 GB/s**
- RAID-5 lustre file system
- Green IT system = energy-saving low-voltage processors (~50 W)
High Performance Computing ≠ High Availability Data Systems

Blue Gene/P supercomputer at Argonne National Lab with >250,000 processors
NVIDIA Tesla K80 (not a GeForce)

- up to 4992 cores (clock 1.33GHz)
- up to 24 GB memory
- 512-bit memory bus
- peak memory bandwidth of 480 GB/s
- X00 W
GRID Computing = slow communication
Supercomputing power [kW]

Evolution of the #1 supercomputer: power (kW)

Data source: Top500
Computing efficiency

Evolution of the #1 supercomputer: GFLOPS / kW

Data source: Top500

www.pingdom.com
Research
Institute of Condensed Matter Theory and Solid State Optics
  • Prof. Peschel – nonlinear optics, nonlinear dynamics, nano optics
  • Prof. Botti – condensed matter theory

Institute of Material Science and Material Technology
  • Prof. Sierka – computational material science

Institute of Theoretical Physics
  • Prof. Brügmann – numerical relativity

Institute of Applied Physics
  • Prof. Pertsch – experimental and computational nano optics