Survey of Materials

Introduction

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September 30, 2019

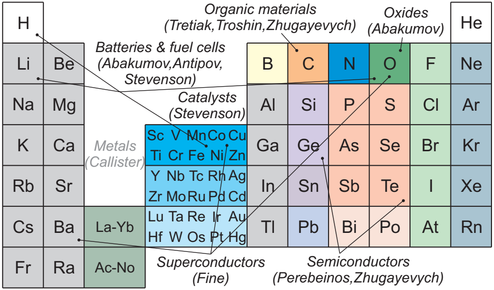
Outline

- What is this course about
- Case study 1: solar cells – energy generation
- Case study 2: batteries – energy storage
- Course logistics
- Part II overview

What is this course about

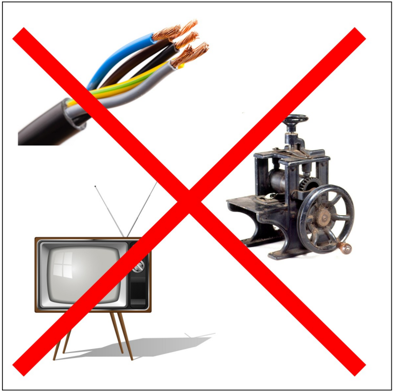
- Part I (1 week): Fundamentals of Materials Science to be able to understand Part II

- Part II (2 weeks): A set of independent lectures about materials given by experts in the corresponding field



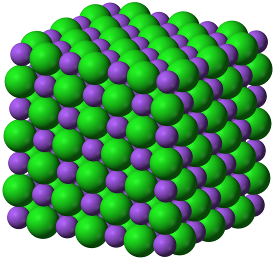
Also: Perovskites for optoelectronics (Tretiak,Troshin), Carbon nanomaterials (Nasibulin), Materials at high-pressure (Oganov), Hierarchically structured materials (Korsunksy)

What materials are covered



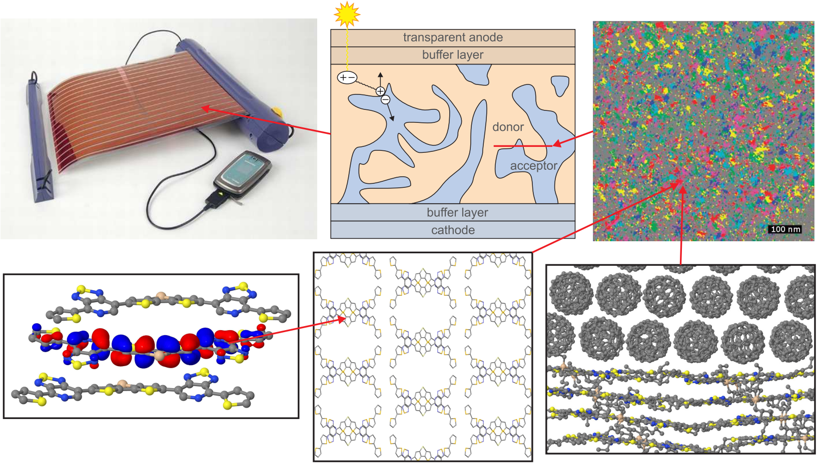
- New materials or new technologies
- Under research at Skoltech

What scales are covered



- Materials Science starting from microscopic scale
- Don't forget about other scales (meso-, macro-, device) and Materials Engineering and Technology

What scales are covered



Level of coverage

Basics + Overview + Readiness to special courses in Materials Science:

- *General courses*
  - Materials Chemistry
  - Materials Physics (Introduction to Solid State Physics)
  - Materials Engineering (Materials Selection in Design)
- *Modeling*
  - Materials Modeling (& Computational Chemistry + Advanced)
  - Advanced Solid State Physics
  - Structure and Property of Materials
- *Characterization*
  - Materials Structure Characterization
  - Electrochemistry
- *Specific materials*
  - (Electrochemical Energy Storage Materials)
  - Organic Materials
  - Carbon Nanomaterials

See roadmap here:
crei.skoltech.ru/cest/education/materials-science-program

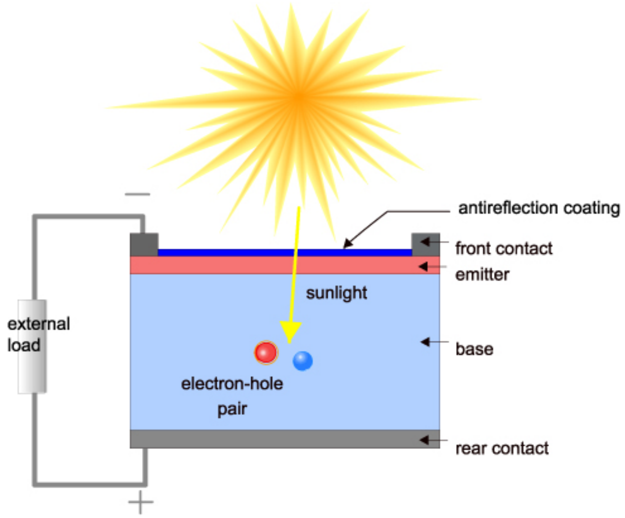
Addressing regional challenges in high-tech manufacturing

Where is the bottleneck?

- feedstock
- materials
- parts
- assembly
- software
- sales
- service

MSE addresses materials + parts

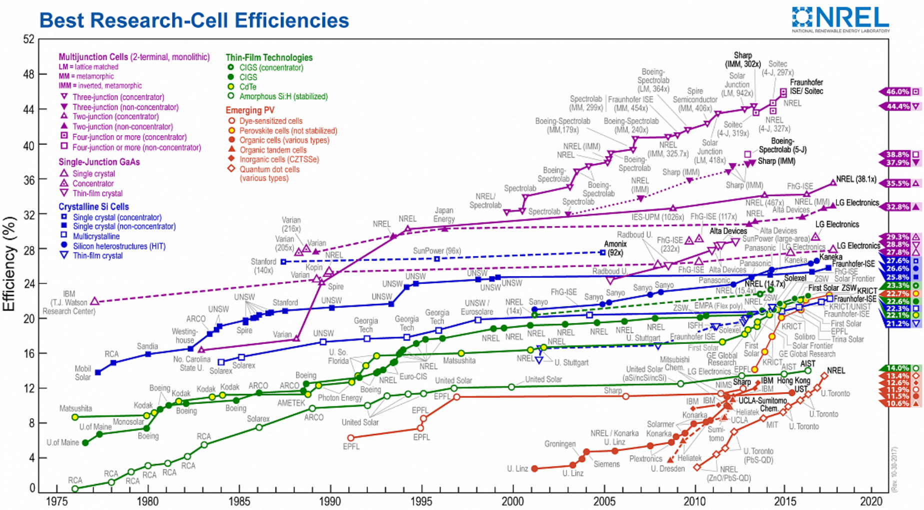
Case study 1: Solar cells



www.pveducation.org

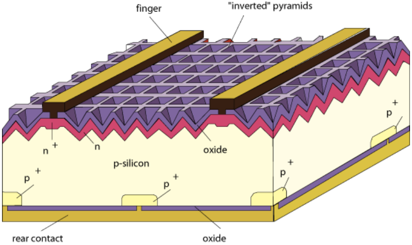
Understand → Optimize → Design → Manufacture

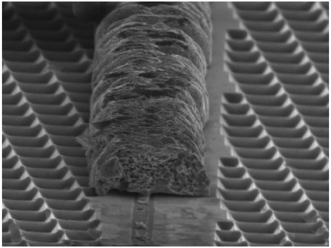
Power conversion efficiency



75-year evolution of Si solar cells: from 0 to 25%

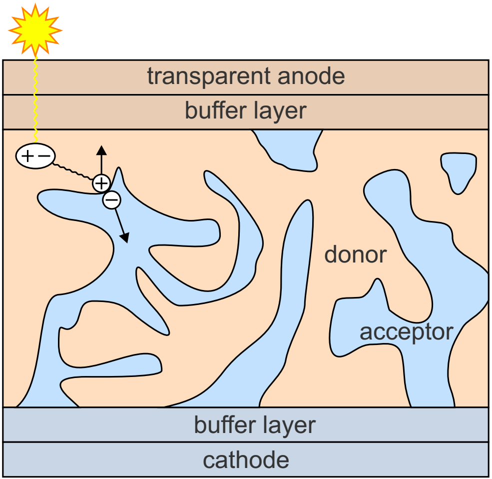
PERL – passivated emitter with rear locally diffused cell:





Reference: pveducation.org

Bulk-heterojunction solar cells



Optimize performance:

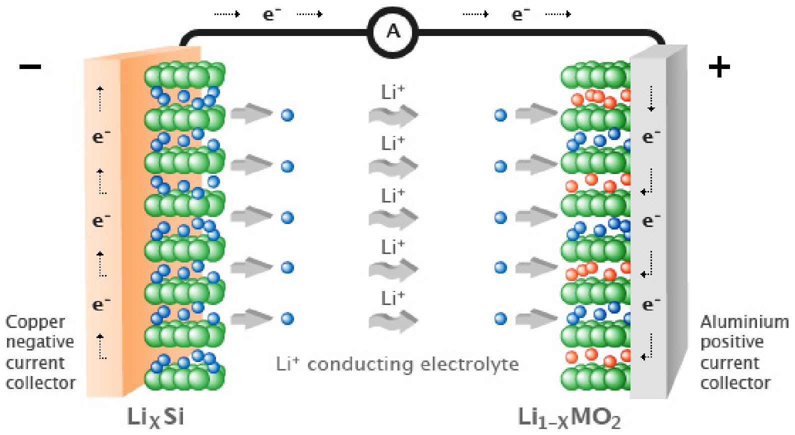
- Donor material
- Acceptor material
- Interface
- Morphology
- Contacts
- Light absorption
- Aging
- ...

$\Longrightarrow$ Structure & properties: 1) bulk material, 2) surface/interface

Properties to study and optimize

- Sunlight harvesting efficiency
- Exciton diffusion length
- Energy of charge carriers
- Mobility of charge carriers
- Efficiency of charge separation
- Degradation and aging

Case study 2: Li-ion batteries



nexeon.co.uk

Properties to study and optimize

- Energy of charge carriers
- Diffusivity of charge carriers
- Cathode/anode capacity
- Charge/discharge reversibility
- Degradation and aging

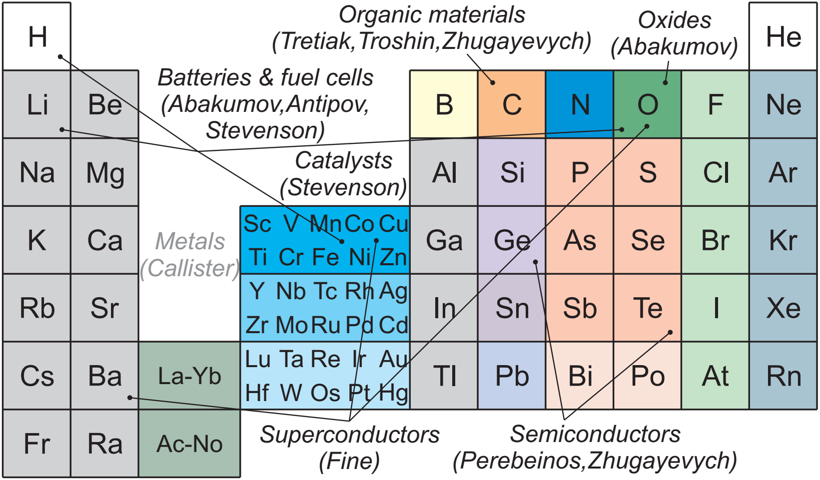
Course logistics

- Course web-page
- Syllabus
- Schedule and timeline
- Required software
- Part I exam: theory
- 40 hours per week:
  - 12 in class
  - 10-20 homeworks and projects
  - 10-20 reading and self-study

Part II overview: learning outcomes

- Level your background (not to replace background courses)
- Be able to understand Materials Science papers and talks
- Learn about a class of materials
- Know state of the art in a specific research area
- Be familiar with Materials Science research at Skoltech
- Here you can find or start research project

Part II overview: chemical composition perspective



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Part II overview: applications perspective at Skoltech

- Energy conversion and storage (CEST CREI):
  materials for energy generation, conversion, storage
  Abakumov, Antipov, Korsunksy, Oganov, Stevenson, Tretiak, Troshin, Zhugayevych

- Photonics and quantum materials (CPQM CREI):
  materials for electronics, spintronics, photonics
  Fine, Nasibulin, Perebeinos

- Design, manufacturing and materials (CDMM CREI): composites

- Hydrocarbon recovery (CHR CREI): hydrocarbons

- Space CREI: materials and devices

- Life Sciences CREI: devices, "biomatter", drugs