Materials Science
M.Sc. education program

crei.skoltech.ru/cee/education

msc.skoltech.ru/materials-science

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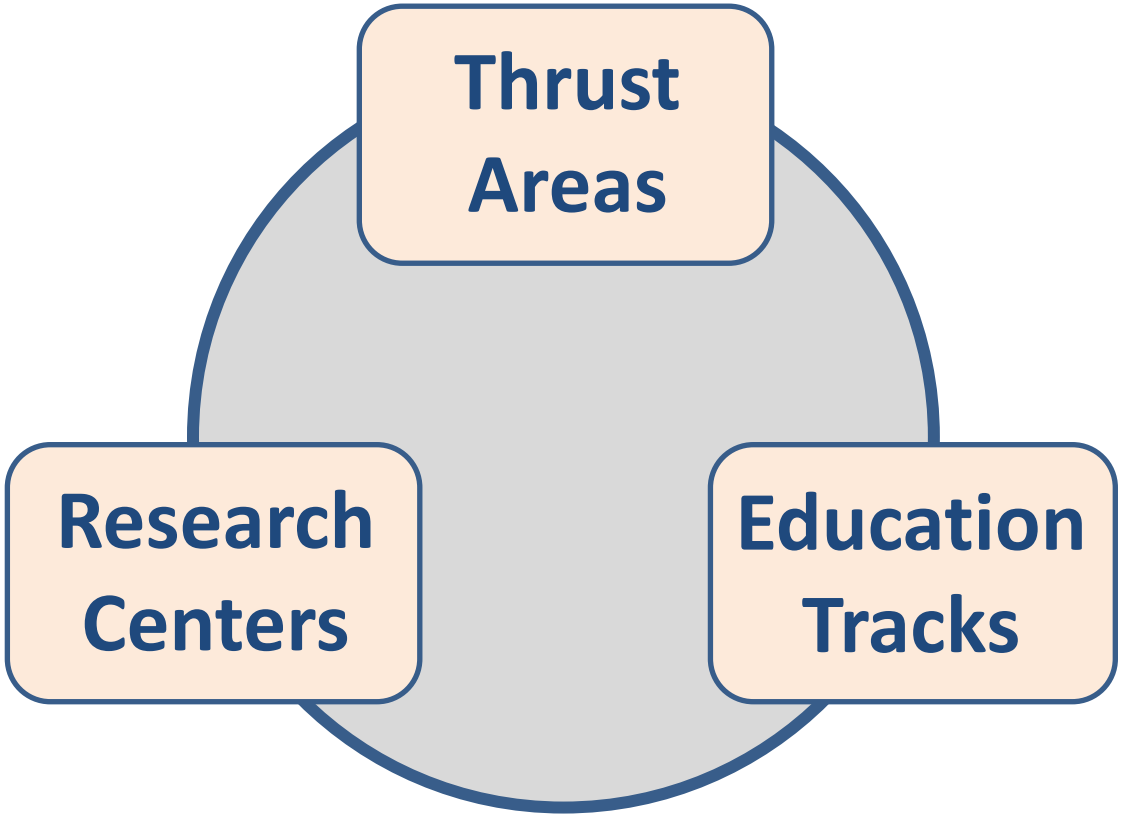
Skoltech
Skolkovo Institute of Science and Technology

Skoltech research & education environment

- No separate theory or experiment departments
- No separate physics or chemistry departments



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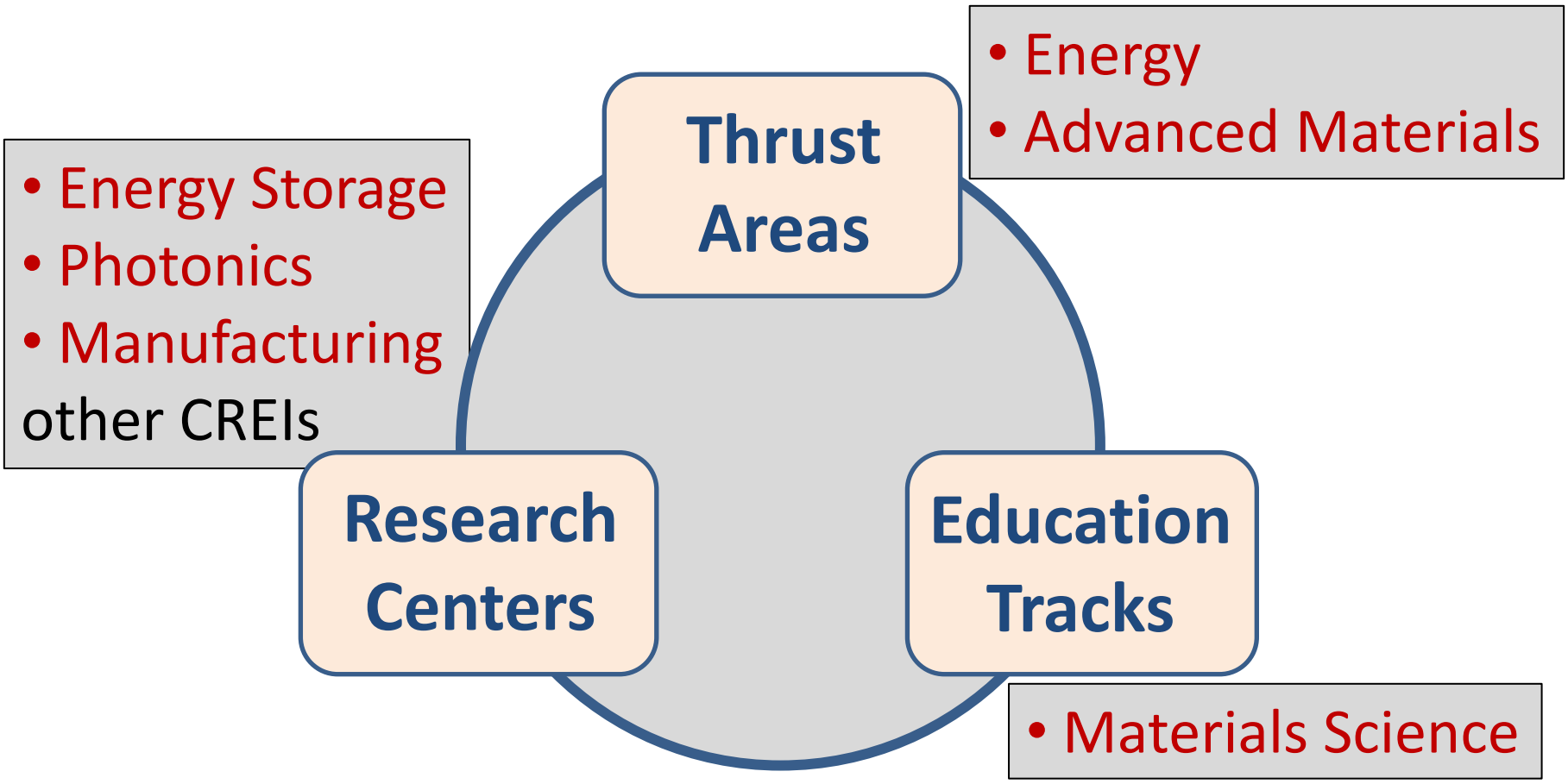

What is (modern) Materials Science?

Would not exist without recent advances in Materials Science

Elementary devices/parts

- box/frame
- processor (transistors)
- ???

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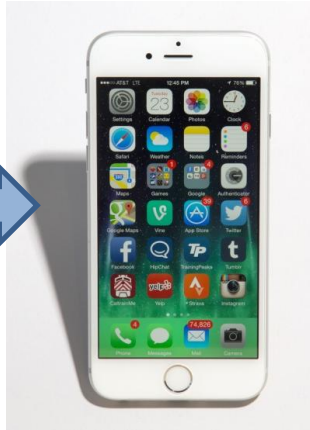

Elementary devices/parts

- box/frame
- processor (transistors)
- display
- battery
- thermal management
- wires, antennas, audio
- …

Functional materials

- mechanical & chemical
- semiconductors
- ???

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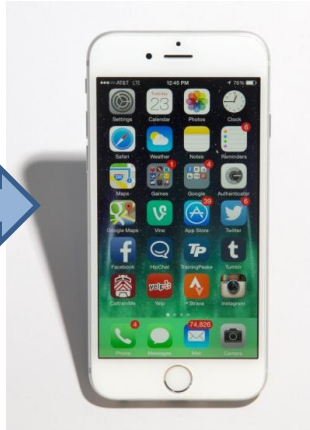

Elementary devices/parts

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Functional materials

- mechanical & chemical
- semiconductors
- light emitter
- battery electrodes
- thermal conductors
- thermal insulators
- …

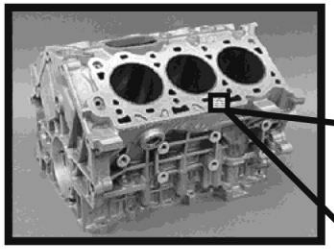
What do Materials Scientists do?

OLED vs LCD visualization

Above: Simulation of the difference in contrast from the AC7 OLED to a traditional LCD.

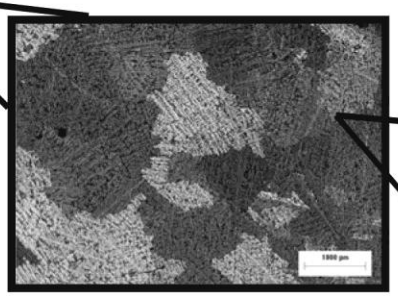
- Create new materials
- Optimize existing materials
- Create/study/optimize elementary devices (lab prototypes)

Materials Science vs. Materials Engineering



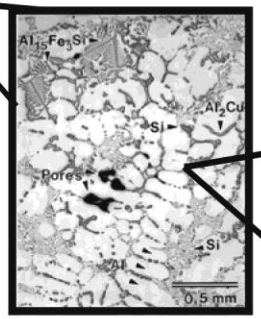
Macro-Scale Structure
Engine Block
≅ upto 1 meter

Performance Criteria
- **Power generated**
- **Efficiency**
- **Durability**
- **Cost**



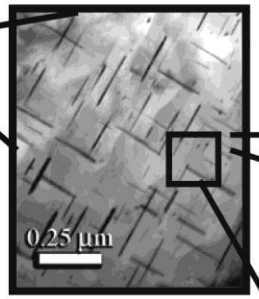
Microstructure
- Grains
≅ 1 – 10 millimeters

Properties affected
- High cycle fatigue
- Ductility



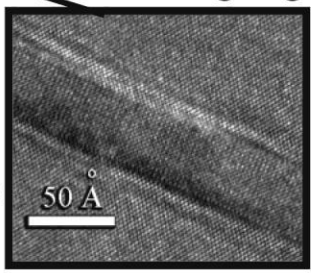
Microstructure
- Dendrites & Phases
≅ 50 – 500 micrometers

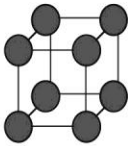
Properties affected
- Yield strength
- Ultimate tensile strength
- High cycle fatigue
- Low cycle fatigue
- Thermal Growth
- Ductility



Nano-structure
- Precipitates
≅ 3-100 nanometers

Properties affected
- Yield strength
- Ultimate tensile strength
- Low cycle fatigue
- Ductility





Atomic-scale structure
≅ 1-100 Angstroms

Properties affected
- Young's modulus
- Thermal Growth

Materials Science

Materials Engineering

A real-world example of important microstructural features at different length-scales, resulting from the sophisticated synthesis and processing used, and the properties they influence. The atomic, nano, micro, and macro-scale structures of cast aluminum alloys (for engine blocks) in relation to the properties affected and performance are shown. The materials science and engineering (MSE) tetrahedron that represents this approach is shown in the upper right corner.

(Illustrations Courtesy of John Allison and William Donlon, Ford Motor Company)

Experimental vs. Computational Materials Science

	Measure	Compute
Research costs		
Research time		
Accuracy		
Reliability		
Relevance for practical use		

Experimental vs. Computational Materials Science

	Measure	Compute
Research costs	✗	✓
Research time	✗	✓
Accuracy	?	?
Reliability	✓	?
Relevance for practical use	✓	✗

Which approach to choose?

Materials Science track: courses

Core courses

- Survey of Materials **(Term 1B)**
- Materials Chemistry **(Term 2)**

Experimental Materials Science

Recommended courses

- Introduction to Solid State Physics**(2)**
- Material Structure Characterization Methods **(3)**
- Organic Materials for Electronics, Energy Conversion and Storage **(3)**
- Electrochemistry **(4)**
- Carbon Nanomaterials **(4)**

Computational Materials Science

Recommended courses

- Computational Chemistry and Materials Modeling **(2)**
- Structure and Property of Materials **(3)**
- Fundamentals of Device Physics **(4)**
- Advanced Solid State Physics **(6)**

Elective courses

- discuss with your advisor

Career paths

- (PhD+) **Research & teaching:**
  - Academic universities (e.g. Skoltech)
- (PhD) **Research:**
  - Universities (Skoltech, MIT)
  - Research institutions (Los Alamos Nat Lab)
  - R&D labs in large corporations (Samsung)
  - other high-tech companies
- (MSc) **Engineering, manufacturing, support etc.:**
  - Startups (batteries, solar cells, electronics)
  - Industry (energy, electronics, chemical)

Skoltech is the right place to start your career of a Materials Scientist or Engineer

Job market: Examples from high-tech industry

Advanced materials

- Boeing, Mitsubishi
- IMEC

Energy storage

- Tesla Motors
- Liotech

Energy conversion

- Heliatek, Solarmer

Electronics

- Samsung, IBM
- Plastic Logic

Chemical

- BASF, Chevron, DuPont

Automotive

- Nissan, KAMAZ

IT (materials modeling)

- Continuum Analytics, Gaussian, MedeA, Simbeyond
- Kintech (Skolkovo resident)

Skoltech will make you competitive on this market

RESEARCH DOMAIN

Changing the world through creative research

Future IT
Advanced Devices
New Materials
Research Paper
Research Infra

New Materials

Cutting-edge new materials is the critical factor of both the current as well future IT industries.

Research on new material enabling new display formats, such as reflective, transparent, and/or flexible displays and high-performance optical films and color-converting organics and inorganics are examples of activities necessary for such paradigm shifts.

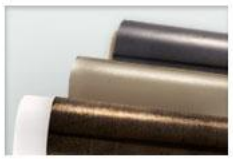
In addition to active electronics materials, SAIT is conducting research on new materials and processing technologies to foster High-performance yet environmentally friendly electronics technologies. Nanomaterial technologies offer an opportunity to reduce consumption of natural resources and energy in manufacturing as well as in the use of electronic devices.

Synthesis and incorporation into devices of graphene, quantum dots are examples of activities that SAIT is pursuing, based on our anticipation of a better future based on technology.

Organic Emitting Materials Flexible Electronics

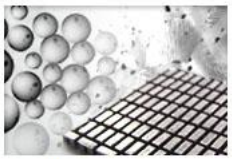
OLED (Organic Light Emitting Diodes) is ... More

Advanced Optical Film



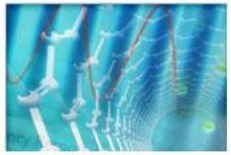
Advanced optical film technology ... More

Functional Inorganics



Functional inorganics technology ... More

Nano Carbon Composite



Quantum Dot

Next-generation Battery

Energy Harvesting

Job market: Established partners for CEE CREI

- Multiple joint projects with MIT, MSU, MIPT

Joint Labs

- Joint Lab with MSU "Advanced Materials for Green Energy"
- Joint Lab with Institute of Problems of Chemical Physics
- Joint Lab with Mendeleev University

Academic – research and internships

- Los Alamos National Lab, University of Texas at Austin, Nanjing University, Johannes Kepler University/Linz Institute for Organic Solar Cells

Academic – research

- University of Bayreuth (Volkswagen), University of Antwerp (research contract), University of Ulm (Helmholtz Institute), University at Albany (CRDF)
- EU framework project COST Action 1307 StableNextSol

Industry

- Systems for Microscopy and Analysis (memorandum, two research contracts)
- KAMAZ, SMA, TAGRAS, Nissan, TEEMP, Samsung, Bosch, InEnergy

Small companies

- SuperOx, Skolkovo startups

At Skoltech you will have access to partners via Research & Industrial "immersion"

M.Sc. Research in Materials Science

In brief

- *Highly interdisciplinary*
- Materials for energy storage – Abakumov, Antipov, Stevenson
- Materials for optoelectronics – Nasibulin, Troshin
- Computational Materials Science – Oganov, Perebeinos, Shapeev, Tretiak, Zhugayevych
- Theoretical Materials Science – Buchachenko, Fine, Skvortsov
- *… with details on faculty web-pages: example*

M.Sc. Thesis 2016-2018

- Materials for energy conversion and storage (11 students)
- Materials for optoelectronics (3 students)
- Other materials (2 students)

At Skoltech you will do world-level research at cutting edge of science

Laboratories in Materials Science

Experiment (visit Lab Tours)

- CEE CREI Lab (multifunctional)
- Laboratory of Nanomaterials
- partners (MSU, MIPT, IPCP, MendeleevU)

Theory (software+hardware)

- CEE CREI Lab (multifunctional)
- USPEX Lab (computational materials discovery)
- partners (MSU, LANL)

Main Campus Labs (2018-2019)

At Skoltech you will have access to unique labs and facilities

What is special about Materials Science at Skoltech?

1) Broad coverage of topics

- 11 special courses
- Several state of the art Labs

2) Distinguished faculty – median h-index > 30

- Cutting edge of science (worldwide)
- Great presenters (worldwide)

3) General Skoltech excellence

- Broad selection of elective courses
- Entrepreneurship and innovation support
- Industrial immersion
- Modern education – interactive learning

Welcome to Skoltech

Further information:

crei.skoltech.ru/cee/education

msc.skoltech.ru/materials-science