MCS New Course Proposal Form

Course Title: Introduction To Sustainable Energy Science

Instructors: Dr. Rongchao Jin

Course Number: 09-529/729  Cross Listing: Click here to enter text.

Prerequisites/Corequisites: 09-105 and 09-106 and (33-121 or 33-141 or 33-151) and (33-122 or 33-142 or 33-152) and (09-348 or 27-201 or 27-796) or permission of the instructor

Semesters Offered:

- X Fall
- □ Spring
- □ Summer-All
- □ Summer 1
- □ Summer 2

Semester Length:

- □ Mini 1
- □ Mini 2
- □ Mini 3
- □ Mini 4
- X Full Semester

Location

- X Pittsburgh
- □ Doha

Course Offering Frequency: Every fall semester

Suggested Days and Times: TBD (3 hours lecture per week) probably TR but dependent upon other course offerings and timing

Learning Format

- X In Person
- □ Online
- □ Combination

Course Evaluation type:

- X Letter Grade
- □ Pass/Fail

Course Unit Justification:  Total Units  9 for 09-529 and 12 for 09-729

  In Class Hours:  3

  Recitation Hours: none

  Lab Hours: none

  Out of Class Hours:  6 for 09-529 and 9 for 09-729

Target Population: Chemistry, materials science, chemical engineering

Anticipated Enrollment: 15-20 students

Rationale for Course (Background): This course differs from other energy-relevant courses in its focus on the materials aspects for various energy processes such as photovoltaics, fuel cells, water splitting, solar fuels, and CO₂ reduction. All the energy processes heavily rely on innovations in materials. This course is intended to offer perspectives on the materials/physical chemistry, e.g., how the atomic and electronic structures of materials impact the energy harvest and transfer. The development of this
course is well aligned with the goals of Scott Institute for Energy by filling the gap of a missing course on materials/physical chemistry perspectives for energy.

**Special Facilities Needed:** none

**Textbooks and/or Other Materials:** No textbook. Other references will be available through the literature or posted to a course management system.

**Assessment:** Undergraduate version 09-529:

Midsemester + Final exam + Weekly quizzes + others (e.g. attendance/class disc.)

40% 40% 15% 5%

Graduate version 09-729:

Midsemester + Final exam + Quizzes + Term paper (written) + others.

30% 35% 15% 15% 5%

For the term paper, students will be required to write a mini-review on a topic of their own choice (but must be related to nanoscience and nanotechnology). Length 2000-3000 words.

**Topics Covered:** 1. Introduction to Energy (2-3 lectures)

- What is energy
- Energy forms
  - kinetic vs potential
  - chemical energy: fossil fuels & $\text{H}_2$
  - electricity
  - nuclear, thermal, magnetic, wind, hydro, and other forms
- Renewable energy

2. Energy Conversion/Storage (10-12 Lectures)

- Industrial catalysis for fuels (refining, cracking, steam methane reforming, partial oxidation of hydrocarbons, and coal gasification)
- Biomass conversion to biogas/fuels
- Photosynthesis and Artificial photosynthesis
Photovoltaics/Solar cells (DSSC, QDSSC, Si, etc)

Photocatalysis (water splitting & CO₂ reduction)

Photoelectrocatalysis (water splitting)

Electrocatalysis (Oxygen reduction reaction, Hydrogen evolution reaction, CO₂ reduction)

Thermoelectrics (waste heat to electricity)

Fuel cells (H₂/methanol/ethanol)

Batteries (metal-air, Li-ion, metal-sulfur, photorechargeable batteries, etc)

Supercapacitors

3. Materials for Energy Conversion/Storage (~12 Lectures)

Molecular materials (only briefly, refer to Stefan’s courses)

--Chromophores/Conjugated polymers

--Organometal complexes

Solid state materials

--Pt/Pd/Au/Ag

--RuO₂/IrO₂

--Non-precious metals based materials (porous carbon, earth-abundant transition metals, etc)

--Si (films, nanowires)

--TiO₂

--Quantum dots/rods/wires, Cu₂ZnSnS₄, etc

--Graphene

--Two dimensional layered materials (transition metal dichalcogenides: MoS₂, WS₂)

--Organic-inorganic hybrid perovskite

--Semiconductor telluride

--Doping/Alloying in materials
4. Future perspectives (Large-scale production, environmental concerns, & technological challenges) (One lecture)

Course Catalog Description: This course focuses on the chemistry aspects of sustainable energy science. It introduces the major types of inorganic and molecular materials for various important processes of energy conversion and storage, such as photovoltaics, fuel cells, water splitting, solar fuels, batteries, and CO₂ reduction. All the energy processes heavily rely on innovations in materials. This course is intended to offer perspectives on the materials/physical chemistry that are of importance in energy processes, in particular, how the atomic and electronic structures of materials impact the energy harvesting and conversion. In current energy research, intense efforts are focused on developing new strategies for achieving sustainable energy through renewable resources as opposed to the traditional oil/coal/gas compositions. This course offers students an introduction to the current energy research frontiers with a focus on solar energy conversion/storage, electrocatalysis and artificial photosynthesis. The major types of materials to be covered include metals, semiconductors, two-dimensional materials, and hybrid perovskites, etc. The material functions in catalysis, solar cells, fuel cells, batteries, supercapacitors, hydrogen production and storage are also discussed in the course. The lectures are power-point presentation style with sufficient graphical materials to aid students to better understand the course materials. Demo experiments are designed to facilitate student learning.

Learning Objectives: Click here to enter text.

To provide an introduction to the energy research frontiers. Students will gain an understanding of the important concepts and research themes of energy science and technology, and develop their abilities to integrate multi-disciplinary knowledge to analyze and solve complex problems.

By the end of this course, students should be able to:

— Understand the fundamental concepts and major research activities in the energy field

— Understand the basic design principles of materials with functions in different energy processes

— Summarize research critically, identify new research directions and develop their abilities to pursue highly disciplinary research

Departmental Approval Date: Friday, January 27, 2017

CUA Recommendation Date: Approved 2/3/17

College Council Approval Date: Click here to enter text.

Comments: Click here to enter text.
* Please attach a copy of the proposed syllabus
New Course Proposal:

**Introduction to Sustainable Energy Science**

09-529/729  
Fall Semester, 2017

**Instructor:** Prof. Rongchao Jin  
**Office:** MI 543  
**Email:** rongchao@andrew.cmu.edu  
**Phone:** 268-9448

**Lectures:** Tuesdays and Thursdays,  
xx-xx am, MI xxx

**Office hours:** Fridays: 2:00-3:00 PM or by appointment

**Course level:** Advanced undergraduates & Graduate students

**Course Justification:** This course differs from other energy-relevant courses in its focus on the materials aspects for various energy processes such as photovoltaics, fuel cells, water splitting, solar fuels, and CO₂ reduction. All the energy processes heavily rely on innovations in materials. This course is intended to offer perspectives on the materials/physical chemistry, e.g., how the atomic and electronic structures of materials impact the energy harvest and transfer. The development of this course is well aligned with the goals of Scott Institute for Energy by filling the gap of a missing course on materials/physical chemistry perspectives for energy.

**Course Goals:** To provide an introduction to the energy research frontiers. Students will gain an understanding of the important concepts and research themes of energy science and technology, and develop their abilities to integrate multi-disciplinary knowledge to analyze and solve complex problems.

By the end of this course, students should be able to:  
— Understand the fundamental concepts and major research activities in the energy field  
— Understand the basic design principles of materials with functions in different energy processes  
— Summarize research critically, identify new research directions and develop their abilities to pursue highly disciplinary research

**Course Description:** This course focuses on the chemistry aspects of energy science. The current worldwide energy consumption of 14 terawatt and a projected rapid ramp to 30 terawatt by the year of 2050 have posed major challenges and stimulated intense research efforts in developing strategies for achieving sustainable energy through renewable resources as opposed to the current oil/coal/gas composition. This course introduces the current energy research frontiers with a focus on solar energy conversion/storage, electrocatalysis and artificial photosynthesis. The major types of materials to be covered include metals, semiconductors, two-dimensional materials, and hybrid perovskites, etc. The material functions in catalysis, solar
cells, fuel cells, batteries, supercapacitors, hydrogen production and storage will be covered. The lectures are power-point presentation style with sufficient graphical materials to aid students to better understand the course materials. Demo experiments will be designed to facilitate student learning.

Prior Knowledge Basis:
09-105 and 09-106 and (33-121 or 33-141 or 33-151) and (33-122 or 33-142 or 33-152) and (09-348 or 27-201 or 27-796) or permission of the instructor

Grading: A, B, C, and D. (scales: TBA)

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40% 40% 15% 5%

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Midsemester + Final exam + Quizzes + Term paper (written) + others.
30% 35% 15% 15% 5%

- For the term paper, students will be required to write a mini-review on a topic of their own choice (but must be related to nanoscience and nanotechnology). Length 2000-3000 words.

Textbook: None

References: TBA

Course materials will be posted on Blackboard:
http://www.cmu.edu/blackboard/ Click on "Login", enter your Andrew User ID and your Andrew Password. The "My Blackboard" page should appear. Locate the "My Courses" module and click on a course link to enter.

Tentative Topics

1. Introduction to Energy (2-3 lectures)
   What is energy
   Energy forms
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   --chemical energy: fossil fuels & H2
   --electricity
   --nuclear, thermal, magnetic, wind, hydro, and other forms
   Renewable energy

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   --Organic-inorganic hybrid perovskite
   --Semiconductor telluride
   --Doping/Alloying in materials
   --Composite/hybrid materials

4. Future perspectives (Large-scale production, environmental concerns, & technological challenges) (One lecture)