<u>Contemporary Materials for Advanced Energy- ESE-903</u>

<u>Background</u>

1. Give brief rundown of the existing program.

Advanced Energy Materials is a field concerned with the design, manufacture, and use of all classes of materials (including metals, ceramics, semiconductors, polymers, and biomaterials) along with energy, environmental, health, economic, and manufacturing issues relating to materials. Since ancient times, advances in the development of materials and energy have defined and limited human social, technological and political aspirations. The modern era, with instant global communication and the rising expectations of developing nations, poses energy challenges greater than ever seen before. Access to energy is critical to the wealth, lifestyle and self-image of every country. The global use of electricity captures the triumph and the challenge of energy. In the 130 years since Edison, Tesla and Westinghouse installed the first primitive electricity grids, electrical technology has undergone many revolutions. From its initial use exclusively for lighting, electricity now symbolizes modern life, powering lights, communication, entertainment, trains, refrigeration and industry. In the past century, 75% of the world has gained access to this most versatile energy carrier.

2. Such changes in our lives do not come from incremental improvements, but from groundbreaking research and development on materials that opens new horizons. Tremendous opportunities currently exist for transitioning from carbon-based energy sources such as gasoline for engines to electric motors for transportation, as well as from coal-fired electric power generation to renewable, clean solar, nuclear and wind energy sources for electricity and thereby dramatically increasing the capacity and reliability of urban grids in high density and recovering areas. These advances will require a new generation of advanced materials including:

a. Battery materials for massive electrical energy storage
b. High-efficiency and low cost solar cells
c. Corrosion-resistant alloys for high-temperature power conversion
d. Strong, lightweight composites for turbine blades
e. Superconducting power distribution cables

f. Advanced power handling electronics and more.

Such revolutionary advances will be the focal agenda of this specific course.

Rationale

1. Rationale for offering/launching the new course.

Materials scientists are in continually high demand by industry and government for jobs in research, development, production and management. There is a wide range of challenging opportunities in sectors such as energy and the environment, in the electronics industry, in the aerospace industry, in consumer industries and in biomaterials and medical industries.

The subject course aims to produce highly-skilled professionals focused on productive research and development in the vast domains of science and engineering. The course will allow motivated researchers to expand their knowledge and acquire new skills in analysis and problem solving, creating challenging opportunities for a full, rewarding career. The course will also cater the demands and needs of fossil fuel plants and the incoming renewable power plants in addition to strategic organizations of the country. The course has been devised keeping in view the latest market demand and encompasses a broad area covering advanced requirements for the development of energy generation and conversion materials, etc.

Educational Objectives

2. Objectives of the program under which the proposed course will be conducted.

The objectives of the course are as under:

- To create awareness among the students on the variety of materials currently used for energy production/conversion, etc.
- To teach students and professionals the intelligent design of energy materials through conventional and nanotechnology routes
- To cover most of the aspects within the materials developments such as the appropriate selection, design, syntheses, structural/compositional, opto-electrical properties and performance, etc. will be covered with special emphases on Energy Efficiency, Economy and Environment.

- To provide the students with the advanced academic background necessary to contribute effectively to technically demanding projects in the field of energy efficient materials.
- To equip the students with various synthesis and characterization techniques for development of advanced materials, which would finally encourage them to become strong researchers.

International Practice

3. Specify the universities of repute where the proposed course is being conducted.

   a. UC Santa Barbara, USA
   b. University of Waterloo, Canada
   c. University of Washington, Seattle, USA
   d. Stanford University, USA
   e. Heriot-Watt University, UK
   f. Leiden University, Netherlands
   g. Colorado School of Mines, USA
   h. Kyoto University, Japan
   i. University of Canterbury, New Zealand
   j. Korea Institute of Science and Technology, S. Korea

Proposed Timeframe of Commencement

4. Specifying semester with year. Fall 2015

Course Contents

6. Give details of the course, on the following lines:

   a. Course Code - ESE-903
   b. Title - Advanced Energy Materials for the Current Century
   c. Credit Hours - 3
   d. Objectives

7. The objectives of this Advanced Energy Materials course are:

   a. To review the fundamentals and advancements in Materials Science & Engineering.

b. To introduce fuel cells and highlight the advancement in fuel cell science and technology with focus on development of materials and components for electrolytes, electrodes, and interconnections etc.

c. To introduce solar cells and highlight the advancement in photovoltaic science and technology with focus on development of materials and devices for advanced generation solar cells.

d. To cover the state of the art in materials for biofuel applications especially the catalysts, materials for energy/fuel efficient transport sector, and the materials for geothermal applications, etc.

e. Materials for gas turbines for thermal power generation and aerospace propulsion

f. To introduce and discuss state of the art in development of materials for nuclear fission and nuclear fusion reactors with technological advancements for in-core and out-core applications

g. To deliberate the energy storage devices such as Batteries and battery materials, Degradation mechanisms of battery materials, recent advancements in Super-capacitors.

h. To introduce and discuss the recent advances in synthesis and development of advanced energy materials. The topics covered will be Solid state methods, wet-chemistry methods, Vapor phase depositions, thermal spraying, etc.

i. To discuss stat of the art in materials analyses using various probes and measurements of transport properties, etc.

e. Outcomes

[1] The students will be given broad flavor of various advancements in energy materials and their development

[2] The course will impart in-depth knowledge in energy materials

f. Contents with suggested contact hours

No.	Topics	Book	Contact Hours
1.	Introduction to the course and quick review of basic concepts in materials science & engineering	A B	2
2.	Fuel cells ➢ Fundamentals and principle of operation ➢ Thermodynamics ➢ Catalysts and electrodes ➢ Ionic conductors ➢ Major types of fuel cells and their applications ➢ Materials for intermediate and low temperature SOFCs ➢ Matrix and cathode development for MCFCs ➢ Materials for low temperature fuel Cells (AFCs and PEMFCs) and proton transport materials etc.	C	4
3.	Photovoltaic materials and devices ➢ Basic mechanism and principle of photoelectricity ➢ Three generations of solar cells ➢ DSSCs ➢ Inorganic semiconductor thin and thick film solar cells ➢ Organic photovoltaics ➢ Specific properties of photovoltaic materials such as light absorption etc.	D E	5
4.	Materials for biofuel applications especially the catalysts	***	3
5.	Materials for energy efficient transport sector	***	2
6.	Materials for geothermal applications	***	1
7.	Materials for gas turbines for thermal power generation and aerospace propulsion	***	4
8.	Materials for hydrogen production and storage ➢ Hydrogen storage ➢ Metal hydrides	***	2

	➢ Hydrogen production (reforming and electrolysis)		
9.	Materials for nuclear fission and nuclear fusion with in-core and out-core applications	***	4
10.	Energy storage devices ➢ Batteries • Principle and types • Fundamental characteristics of battery materials (anode, cathode and electrolyte) • Degradation mechanisms of battery materials ➢ Super capacitors.	L M	4
11.	General discussion about the synthesis and development of advanced energy materials ➢ Solid state reaction method ➢ Wet chemistry routes like sol-gel, co-precipitation etc. ➢ Deposition based routes like PVD, CVD, plasma spraying etc.	F G J K ***	6
12.	General discussion about the characterization of advanced energy materials ➢ XRD, SEM, EDS, EIS, FTIR, Spectrophotometry, CV etc.	H I ***	8
Total			**45**

g. Recommended Reading (including Textbooks and Reference books).

No.	**Title**	**Author(s)**	**Assigned Code**	**Books**
1.	Fundamentals of Material Science and Engineering	Donald Askeland and Pradeep Phule	A	Text
2.	Introduction to physical metallurgy	Avner	B	Text
3.	Fuel Cell Fundamentals,	O'Hayre, Ryan, John	C	Text

	2nd Edition, 2009.	Wiley & Sons		
4.	Next Generation Photovoltaics: High Efficiency through Full Spectrum Utilization, Institute of Physics (Great Britain), 2004	A. Marti, Antonio Luque,	D	Text
5.	Organic Photovoltaics: Mechanism, Materials and Devices, Published by CRC Press, 2005.	Sam-Shajing Sun, NiyaziSerdarSariciftci	E	Ref
6.	The Materials Science of Semiconductors, Published by Springer, 2007.	Angus Rockett	F	Ref
7.	Electronic properties of materials	R.E. Hummel	G	Ref
8.	Materials Science of thin films	Milton Ohring	H	Ref
9.	Physical methods in materials characterization	Flewit and Wild	I	Text
10.	Critical Materials Problems in Energy Production	Stein	J	Text
11.	Energy Materials, 2011.	Duncan W. Bruce, Dermot O'Hare, Richard I. Walton, John Wiley & Sons	K	Text
12.	Nanostructured Materials for Electrochemical Energy Production and Storage,	Edson Roberto Leite, Springer.	L	Text
13.	Advanced Batteries: Materials Science	Huggins, Robert A, Springer,	M	Text

	Aspects, 2008			
14.	Miscellaneous handouts and literature	To be given to students by course instructor from time to time	***	Ref