Advanced Energy Materials: Synthesis & Characterization ESE-904

Background

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. There are almost no courses at NUST of this nature in which various synthesis and analytical techniques are taught in a comprehensive way. Wet chemistry and vapor deposition techniques will be covered in this course for the development of energy materials. In parallel, a detailed overview at advanced level will be given to attendants on structural, chemical, thermal and electrical characterization of materials/components and devices, etc. The course will provide a strong foundation and understanding to students majoring in diversified fields.

Rationale

2. 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.

There is no course in NUST that covers such a broad spectrum and discusses the various conventional and nanotechnology routes to fabricate/develop the advanced energy materials for applications in systems such as for fossil fuels, renewable energy, and nuclear, etc. Since the appropriate characterizations of such materials/components/devices is of fundamental nature, therefore, enough portion of the course will be devoted to understanding the diversified probes available to scientific community

Educational Objectives

3. The objectives of the course are as under:

- To create awareness among students and comprehend their knowledge-base on variety of techniques currently being used by R&D/industrial community for synthesis/development of materials for energy production/conversion, etc.
- To mainly focus on intelligent synthesis of energy materials through nanotechnology routes along with blend of conventional processes.
- To discuss the instrumentation, working principles, and capabilities of various probes based on photons, electrons, and ions for structural and chemical analyses, etc.
- To know and to use various probes for transport properties such as electrical characterization, optoelectronic performance, etc.
- To provide the students with the advanced academic background necessary to contribute effectively to technically demanding projects in the field of energy efficient materials.

International Practice

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

   i. UC Santa Barbara, USA

   ii. University of Waterloo, Canada

   iii. University of Washington, Seattle, USA

   iv. Stanford University, USA

   v. Heriot-Watt University, UK

   vi. Leiden Universitei, Netherlands

   vii. Colorado School of Mines, USA

   viii. Kyoto University, Japan

   ix. University of Canterbury, New Zealand

   x. Korea Institute of Science and Technology, S. Korea

   xi. Linkoping University, Sweden

Proposed Timeframe of Commencement

5. Specifying semester with year. SP-2015

Course Contents

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

a. Course Code ESE-904

b. Title Synthesis and Characterization of Advanced Energy Materials

c. Credit Hours 3

d. Objectives

- To mainly focus on intelligent synthesis of energy materials through nanotechnology routes along with blend of conventional processes.
- To discuss the instrumentation, working principles, and capabilities of various probes based on photons, electrons, and ions for structural and chemical analyses, etc.
- To know and to use various probes for transport properties such as electrical characterization, optoelectronic performance, etc.

e. Outcomes

The students will be given broad flavor of various analytical and quantitative characterization techniques employed for the study of energy materials.

f. Contents with suggested contact hours

No.	Topics	Book	Contact Hours
1	Introduction about functional materials used in various energy devices such as solar cells and fuel cells etc.	A B	2
2	Crystal structures and defects	D	3
3	Synthesis of energy materials a) Solid state reaction method b) Wet chemistry routes ➢ Sol-gel ➢ Co-precipitation	C E G	10

	➢ Hydrothermal method ➢ Glycine nitrate process c) Deposition based synthesis processes ➢ Physical vapor deposition ➢ Chemical vapor deposition ➢ Plasma spraying ➢ Spray pyrolysis ➢ Dip coating ➢ Spin coating		
4	Properties of energy materials ➢ Physical ➢ Thermal ➢ Mechanical ➢ Electrical ➢ Chemical	H I	5
5	Characterization of energy materials **a)** X-ray diffraction **b)** Analytical imaging of energy materials ➢ Optical microscopy ➢ Scanning electron microscopy ➢ Transmission electron microscopy ➢ Focused ion beam microscopy **c)** Chemical characterization and elemental analysis of energy materials ➢ Energy dispersive X-ray spectroscopy ➢ X-ray photoelectron spectroscopy ➢ Auger electron spectroscopy ➢ X-ray fluorescence **d)** Thermal Characterization of energy materials ➢ Differential thermal analysis ➢ Thermal gravimetric analysis ➢ Dilatometry (Thermal expansion) **e)** Electrical Characterization of energy materials	F K	25

	➢ Electrochemical impedance spectroscopy ➢ Cyclic voltammetry ➢ I-V characteristics ➢ Two-probe and four-probe method to determine resistivity/conductivity **f)** Raman spectroscopy **g)** Spectrophotometry (UV/Visible/IR) **h)** Surface area (BET), particle size and porosimetry **i)** Measurement of strength, toughness and hardness		
Total			**45**

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

No.	**Title**	**Author(s)**	**Assigned Code**	**Books**
1.	The Physical Chemistry of Materials: Energy and Environmental Applications, CRC Press	Rolando M. A. Roque-Malherbe	A	Text
2.	Fundamentals of Mat. Science and Engineering	Donald Askeland and Pradeep Phule	B	Text
3.	Fundamentals of Solid State Engineering, 3rd Edition, Published by Springer	ManijehRazeghi	C	Text
4.	Fundamentals of Semiconductors: Physics and Materials Properties, 4th Edition, Published by Springer	Peter YU, Manuel Cardona	D	Ref
5.	Ceramic Processing and Sintering, 1995	M. N. Rahaman	E	Ref

6.	Advanced Characterization Techniques for Thin Film Solar Cells	Daniel Abou-Ras, Thomas Kirchartz, Uwe Rau, Wiley-VCH	F	Text
7.	Handbook of Physical Vapor Deposition Processing, Published by Elsevier Inc. 2010	Donald M. Mattox	G	Text
8.	Electronic properties of materials	R.E. Hummel	H	Ref
9.	Materials Science of thin films	Milton Ohring	I	Ref
10.	Introduction to physical metallurgy	Avner	J	Ref
11.	Physical methods in materials characterization	Flewit and Wild	K	Text
12.	Critical Materials Problems in Energy Production	Stein	L	Ref