UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2017/2018
MASTER'S DEGREE (MSC)	CHEMICAL ENGINEERING
SUBJECT	MATERIALS FOR ENERGY STORAGE AND CONVERSION
TYPE OF EDUCATIONAL ACTIVITY	C
AMBIT	20911-Attività formative affini o integrative
CODE	17364
SCIENTIFIC SECTOR(S)	ING-IND/23
HEAD PROFESSOR(S)	SANTAMARIA MONICA Professore Ordinario Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	6
INDIVIDUAL STUDY (Hrs)	96
COURSE ACTIVITY (Hrs)	54
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	1
TERM (SEMESTER)	2° semester
ATTENDANCE	Not mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	**SANTAMARIA MONICA** Monday 13:00 14:00 Studio personale Edificio 6 secondo piano previa conferma per e-mail Wednesday 12:30 14:00 Studio personale Edificio 6 secondo piano previa conferma per e-mail Friday 12:30 14:00 Studio personale Edificio 6 secondo piano previa conferma per e-mail

DOCENTE: Prof.ssa MONICA SANTAMARIA

PREREQUISITES	Fundamentals od Inorganic Chemistry and Electrochemistry. Thermodynamic's laws. Basic electricity with an emphasis on Ohm's Laws.
LEARNING OUTCOMES	Knowledge and understanding At the end of the course student is expected to have a deep understanding of the mechanism of electrochemical energy conversion and storage. Student will be able to understand both theoretical and technological aspects relating to the investigated devices (primary and secondary batteries, fuel cell, supercapacitors, electrolytic capacitors). Moreover, students will learn about the employed materials for device fabrication and on the physico-chemical properties that make such materials suitable for the corresponding application. Applying knowledge and understanding Student will be able to appropriately use electrochemical tools (polarization curves, cyclic voltammetry, impedance measurements, etc.) for evaluating the device performance. He/she is expected to be able to select the most appropriate device for a specific application knowing the electrical requirements (voltage, power, and so on). Making judgments Student will be able to select the most appropriate device matching the user needs. He/she will be able to select the right tests to assess the device performance. In order to achieve such objective Laboratory and Demonstration Sessions are scheduled where students must select the device according to the operation conditions. Communication Student will be able to describe the technical issues relating the main subjects of the course. He/she will be able to discuss about several aspects of electrochemical energy conversion and storage, being aware about disadvantages and advantages of electrochemical devices with respect to other devices. Student is expected to be able to work autonomously and collaborate with other team members involved in the same project (design, monitoring and/or maintenance). Laboratory experiences are foreseen to make students confident about all these aspects. Learning skills Following a deep understanding of the theoretical aspects and after laboratory experience, student is expected to be able solve technical and scientific problems on the electrochemical energy conversion and storage, and on the materials employed to realize such devices.
ASSESSMENT METHODS	The assessment will be performed through an oral exam with questions focused on two main subjects: - thermodynamic and kinetic aspects of electrochemical processes; - principle of operation and materials for electrochemical energy conversion devices. The student must support the answers qualitatively and quantitatively taking advantage of the technical tools provided by the evaluation committee (Handbook of thermodynamic constants and kinetic parameters, etc.). The student will also discuss the principle of operation and the employed material of a device selected by him (her) self. The interview is aimed at determining the student abilities to process the knowledge gained by using them to solve problems and the ability to express the teaching content using a technically correct language. More specifically, the student must show how he/she is able to use the knowledge of thermodynamic and kinetic aspect of electrochemical reactions to design electrochemical energy conversion devices, to optimize the materials for enhancing the efficiency, to select the device that fits the request of the end-user. The vote is expressed in thirtieths with possible praise. A maximum of 24/30 will be attributed according to the student reply on the proposed questions, while the remaining 6/30 will be attributed according to the discussion on the selected device. In order to get the minimum score for a positive evaluation (18/30), the student must know the general aspects of the course content (correct selection of the device according to the request by the end-user, select the materials for enhancing the efficiency, knowing the experimental techniques to study the device performance, etc.). His/her command of technical language must be sufficient to clearly discuss with the evaluation committee about the main aspects of the course. Higher score will be attributed according to their ability in applying knowledge and skills learned in this course to practical and technical problems, according to what extent students are aware of the steps they go through in solving problems and how well can they explain their problem-solving steps.
EDUCATIONAL OBJECTIVES	The first part of the course is aimed to provide the basic (theoretical and technological) concepts on electrochemical energy conversion, and to explain

	the main electrochemical techniques necessary to evaluate the performance of the devices. The second part will be devoted to the description of the devices (Batteries, fuel cells, supercapacitors, electrolytic capacitors) correlating the device electric performance to the materials used to realize the device and to the electrochemical processes occurring inside the device.
TEACHING METHODS	Frontal lectures, Laboratory and Demonstration Sessions, Laboratory Practice Sessions
SUGGESTED BIBLIOGRAPHY	Modern Electrochemistry 2B, 2nd edition J. O'M. Bockris e A.K.N. Reddy Kluwer Academic/Plenum Publishers NY (2000). Electrochemical Methods 2nd edition, A.J. Bard and L.R. Faulkner; John Wiley and Sons, INC. (2001). Modern Batteries - An Introduction Electrochemical to Power Sources, C A Vincent, B Scrosati, Butterworth-Heinemann, Oxford, 1997 Electrochemical Supercapacitors, B.E. Conway, Kluwer Academic/Plenum Publishers NY (1999). Verranno segnalati recenti articoli scientifici sugli argomenti trattati e fornite delle dispense.

SYLLABUS

Hrs	Frontal teaching
5	Brief introduction. Classification of energy conversion devices. Schematic representation of a galvanic cell. Thermodynamics of galvanic cells. Dependence of electromotive force on concentration (Nerst equation), on temperature and pressure. Electrolytic solution: conductivity and thermodynamic stability window. Aqueous and non aqueous solutions.
5	Kinetic aspects of electrodic reaction: overvoltage. Charge transfer at the electrode electrolyte interface. Exchange current density. Activation losses. Butler and Volmer equation: linear characteristic at small overvoltage. Butler and Volmer equation: Tafel behaviour at large overvoltage. Concentration overvoltage: Nerst diffusion layer. Problems on kinetics of electrode reactions. Dependence of cell voltage on electrodic losses. Polarization curves.
2	Faradaic and not Faradaic interfaces. Electrode/electrolyte interface. Helmholtz double layer. Gouy-Chapman model for eletrode/electrolye interface. Potential distribution across the electrode/ electrolyte interface.
2	Fundamentals of Electrochemical Impedance Spectroscopy: R, C and L. RC series and RC parallel. Bode and Nyquist diagrams. R(RC) circuit to simulate an electrode/electrolyte interface.
1	Electrochemical energy conversion and storage: advantages and disadvantages. Application of battery, fuel cell and capacitors.
6	Primary conventional battery: Leclanche' cells. Primary conventional battery: Zn alkaline, Zn-HgO, Cd-HgO. Primary conventional battery: Zn-Ag2O, Zn-air. Primary lithium cell: advantages and disadvantages of lithium anode. Primary lithium cell: solid cathode Primary lithium cell: liquid cathode. Primary lithium cell: solid electrolyte. Reserve Batteries.
6	Secondary cells: discharge reaction mechanisms. Lead - acid battery. Seconday cells: Ni-Cd, Ag-Zn. Secondary advanced cells: Zn- alkiline, Ni-H2, Ni.MH. Secondary advanced cells: Zn-air, Al-air, ZEBRA. Secondary advanced cells: lithium metal batteries. Secondary advanced cells: lithium ion batteries. Carbon based intecalation negative electrodes. Secondary advanced cells: lithium ion batteries. Co, Ni and Mn oxides positive electrodes. Polymer-based practical cells: 1) Lithium polymer batteris and 2) plastic lithium ion batteries.
1	Hydrogen production and storage. Water photosplitting. Reforming.
10	Fuel cells: classification and general aspects. Kinetic of hydrogen and oxygen evolution: effect of electrode material. Polarization curve features and dependence of power density on current density. Alkaline fule cell. Polymer Electrolyte membrane fuel cell: general aspect, operating conditions, proton exchange membrane. Polymer Electrolyte membrane fuel cell: electrode materials, MEA preparation and performance, gas diffuser. Direct methanol fuel cell. Portable fuel cell. Micro fuel cell. Phosphoric acid fuel cell. Molten carbonate fuel cell. Defects in ionic solids. Ionic conductor. Oxygen ions conductor. Yttria stabilized zirconia.Solid oxide fuel cell.
6	Electrochemical capacitors. EDLC. Active carbon. Electrolyes for EDLC and their corresponding perfomance. Carbon nanotubes and Y carbon for EDLC electrodes. Characterization of the device performances.Pseudo-supercapacitors: intercalation electrodes and conducting polymers. Asymmetric electrochemical capacitors. Electrolytic capacitiors: anodizing, electrochemical etching and perfomances.
1	General overview of the eletrochemical energy conversion and storage devices. Ragone plot.

Hrs	Practice
1	Exercises on thermodynamic of galvanic cells. Nerst equation and estimate of electromotive force.
2	Reference electrodes. Electrode potential measuremet. Open circuit potential measurement. Daniell's cell assembly.
2	Excercises on kinetics. Exchange current density and Tafel slope estimate. Estimate of charge transfer resistance and limiting diffusion current.

Hrs	Practice
1	Kinetic of oxidation of $K_4Fe(CN)_6$ to $K_3Fe(CN)_6$ and reduction of $K_3Fe(CN)_6$ to $K_4Fe(CN)_6$: charge transfer control and mass transfer control with rotating disk electrode. Hydrogen evolution on Pt and Pb. Tafel plots. Oxygen reduction.
1	Lab course on Impedance of RC circuit on bread board. Resistance to mass transfer: Warburg impedance. Bode and Nyquist diagram. Reduction and oxidation of iron complexes under mass transfer control. Levich plot. EIS measurements with Au electrode during electrochemical reactions with roating disk eletrode.
2	Electrode catalysis. MEA preparation.Polarization curve recording with H_2 fed and methanol fed fuel cell. Evaluation of fuel cell performance from the polarization curve. Diagnostic criteria.