MS3013 Electrochemical Corrosion

Academic Year	AY2023-24	Semester	S1&S2
Course Coordinator	Huang Yizhong & Wu Dongshuang		
Course Type	Core		
Pre-requisites	NIL		
AU	3		
Grading	Letter Grading		
Contact Hours	Lecture: 18 hrs: Tutorials 9 hrs: Laboratory Work 12: hrs		
Proposal Date	1 March 2023		

Course Aims

Theory component:
1. Learn how the environmental affects the properties and performance of engineered metallic and ceramic materials.
2. Understand the prevention of the negative environmental effects on metallic and ceramic using electrochemical methods.
3. Master some of the basic principles of corrosion and degradation of metals and alloys.

Laboratory component:
4. Understand the principles of electrochemistry and experimental-related set-ups.
5. Use the electrochemical approaches to probe the thermodynamic and kinetic aspects of corrosion, including the rate of corrosion.
6. Master certain software and mathematics in dealing with the experimental data.
7. Link the theoretical knowledge with experimental phenomena.

This would be useful for those of you who are interested corrosion engineering of materials applied in material industry.

Intended Learning Outcomes (ILO)

By the end of this course, student will be able to:
Theory component:
1. Identify how the environment affects the degradation or corrosion of metallic and ceramic materials.
2. Determine the prevention or stabilization methods for metallic and ceramic materials degradation due to environmental effects.
3. Determine how metallic and ceramic materials can be used and their reliability in different conditions.

Laboratory component:
4. Get hands-on knowledge on how the environment affects the degradation or corrosion of metallic and ceramic materials.
5. Determine whether electrochemical techniques are of use for a given problem related corrosion.
6. Correlate theoretical concepts to practical phenomena.
7. Draw logical conclusions from experimental data.

8. Produce reports in accordance with established practices of the engineering discipline.

Course Content

No	Topic	Hours
Theory component:		
1.	Electrochemical corrosion mechanism of metallic materials: Corrosion cells; The electrochemical series; Polarization; Evan's diagrams (Tafel plot); Mixed potential theory; Pourbaix diagrams and Passivation	6
2.	Forms of corrosion of metallic materials: Uniform corrosion; Localized corrosion including pitting, crevice corrosion, selective dissolution, intergranular corrosion, environment-sensitive cracking, flow-assisted corrosion, microbiologically influenced corrosion (MIC).	6
3.	Principles of corrosion protection of metallic materials: Materials selection; Design against corrosion; Corrosion inhibitors; Protective coatings; Cathodic protection and anodic protection.	4
4.	Failure of ceramic materials in gaseous and liquid environments	4
5.	High temperature oxidation, oxidation in complex environment and oxidation remedy of non-oxide ceramics	4
6.	Briefing: principle of electrochemistry	2
7.	Lab Course: an introduction to electrochemistry and the general set-ups (EP1)	2
8.	Lab Course: polarization curve analysis (EP2)	2
9.	Lab Course: electrochemical impedance spectroscopy (EP3)	2
10.	Lab Course: current distribution and mass transfer (EP4)	2
11	Lab-Course: For anyone who cannot attend EP2-4 in time or failed in any of the above experiments	2
12	Tutorial or Special lecture from the experts in Electrochemistry related field	3
	Total	39

Assessment (Includes both continuous and summative assessment)

Component	ILO Tested	EAB Graduate Attributes	Weightage	Team / Individual	Rubrics
Theory component					
1. CA1: Quiz 1	1-3	(a), (b)	20%	Individual	NA (Standard test)
2. Final Examination (1 hr)	1-3	(a), (b)	40%	Individual	NA (Standard test)
Laboratory component					
1. Experimental report for EP1	4-8	(a), (b), (e), (i), (j)	10%	Individual	See Appendix 1
2. Experimental report for EP2	4-8	(a), (b), (e), (i), (j)	10%	Individual	See Appendix 1

3. Experimental report for EP3	4-8	(a), (b), (e), (i), (j)	10%	Individual	See Appendix 1
4. Experimental report for EP4	4-8	(a), (b), (e), (i), (j)	10%	Individual	See Appendix 1
Total			**100%**		

EAB Graduate Attributes[1]	
a)	**Engineering Knowledge** Apply the knowledge of mathematics, natural science, engineering fundamentals, and an engineering specialisation as specified in WK1 to WK4 respectively to the solution of complex engineering problems.
b)	**Problem Analysis** Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
c)	**Design/Development of Solutions** Design solutions for complex engineering problems and design systems, components or processes that meet the specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
d)	**Investigation** Conduct investigations of complex problems using research-based knowledge (WK8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
e)	**Modern Tool Usage** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering problems, with an understanding of the limitations.
f)	**The Engineer and Society** Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice and solutions to complex engineering problems.
g)	**Environment and Sustainability** Understand and evaluate the sustainability and impact of professional engineering work in the solution of complex engineering problems in societal and environmental contexts.
h)	**Ethics** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
i)	**Individual and Team Work** Function effectively as an individual, and as a member or leader in diverse teams and in multidisciplinary settings.
j)	**Communication** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
k)	**Project Management and Finance**

[1] *Reference: EAB Accreditation Manual*

	Demonstrate knowledge and understanding of engineering management principles and economic decision-making, and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
l)	**Life-long Learning** Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Formative Feedback

Describe how you would be giving feedback to students on how they are learning in this course.
Theory component

- You will receive feedback on common problems that you face in the CAs and examinations;
- As a course coordinator, I make myself always approachable during the class breaks and daytime work hours in office to conduct the consultation to clear out the questions for you;
- By means of tutorial sessions, you are free to discuss with me in terms of the course contents, the scope of exams and confusions you have.

Laboratory component

- You will receive feedback on common problems that you face in the experiments.
- As a course coordinator, I will give a briefing about the lab course and principles of each experiment. I make myself always approachable during daytime work hours in office to conduct the consultation to clear out the questions for you.
- By means of experiments, you are free to discuss with me in terms of the experiential contents, results interpretation and confusions you have.

Learning & Teaching Approach

Approach	**How does this approach support students in achieving the learning outcomes?**
Theory component	
Lecture	As your lecturer, I understand that you will feel bored with the subject if you are not clear. Hence, the lecture aims to deliver a clear explanation of the concepts/theories to you. It is the first step to trigger interest in your mind so that you will be engaged in the learning of the course more proactively instead of passively.
Develop your interest in the subject.	Passion is a very important element and plays a key role in your learning. The course intends to motivate your interest and enthusiasm so that you are willing to spend more time to study the subject. The case studies in the course aims to help you visualize and better connect with the significance of the learning contents.
Encourage deeper thinking in the learning activities.	This approach is to challenge you to think deeply about course contents. Giving you something to think about is the best way to clarify questions and advance your understanding of the principles/concepts. Furthermore, the in-depth thinking will allow you to figure out the fundamental knowledge behind these theories (e.g. how these theories are originated).

Tutorial and Consultation	The course aims to provide a friendly, comfortable and active learning environment during tutorials and face-to-face consolation in lecturer's office. You are encouraged to ask any questions that you have, which would make the teaching and learning more effective. These are opportunities for you to get clear of the questions/confusions that your experience during the lecture. Such interactions will also help bring about more information in relation to the subject and aid your understanding
Laboratory component	
Fundamental understanding	This laboratory module introduces the students to electrochemical approaches in the corrosion science together with the co-requisite course MS3013.
Showing practical illustrations/problems in the real world	The students should be able to link the concepts they have learnt in MS3013 with experimental phenomena and further real-world examples and problems
Laboratory training	Laboratory safety and equipment training protocols help the students understand the basic principles of discipline in laboratory setting and to approach their research work. They will learn to draw logical conclusions from experimental data and produce lab reports in accordance with established practices of the engineering discipline.
Teamwork	The students are given full responsibility on how they collaborate with other team members in planning and execution of the laboratory work. They will involve in the intensive discussion on the experimental phenomena and problems met during the experimental sections.

Readings & References

Theory component

Suggested reading:

1. Electrochemistry by Carl Hamann, et. al., 2ed ed. Wiley-VCH press, 2007.
2. Corrosion for Science and Engineering by K. R. Trethewey and J. Chamberlain, 2nd ed., Longman, 1995
3. Fundamentals of Polymer Degradation and Stabilisation, edited by Norman S. Allen and Michelle Edge, Elsevier Science Publishers, England,1992.

Recommended references:

4. Principles and Prevention of Corrosion by Denny Jones, 2nd ed., Prentice-Hall
5. Corrosion Engineering by Mars G. Fontana, 3rd ed.
6. NACE Corrosion Engineer's Reference Book by R. Baboian, 3rd ed, NACE Press
7. Weathering of Polymers, by Anthony Davis and David Sims, Elsevier Applied Science Publishers Ltd, England, 1983
8. Handbook of Polymer Degradation, edited by S. Halim Hamid, Mohamad B. Amin and Ali G Maadhah, Marcel Dekker, Inc. , 1992
9. Compositional and Failure Analysis of Polymer, by John Scheirs, John Wiley & Sons, 2000

Laboratory component

Prescribed texts:

1. Electrochemistry by Carl Hamann, et. al., 2ed ed. Wiley-VCH press, 2007.

2. Corrosion for Science and Engineering by K. R. Trethewey and J. Chamberlain, 2nd ed., Longman, 1995
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3. NACE Corrosion Engineer's Reference Book by R. Baboian, 3rd ed, NACE Press
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Course Policy & Student Responsibility

(1) CA/Experimental reports
Absentees must be supported by a medical certificate or other valid official documents.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognise your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain about the definitions of any of these terms, you should refer to the Academic Integrity Handbook for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office	Phone	Email
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Planned Weekly Schedule

Week	Topic	Course ILO	Readings/Activities
1	Electrochemical corrosion cell of metal-based materials	1	Class lectures
2	Electrochemical polarization of metal-based materials	1,2	Class lectures tutorials on topic 1
3	Electrochemical passivation of metal-based materials	1,2	Class lectures and tutorials on topic 2
4	Electrochemical forms of metal-based materials	1-3	Lectures tutorials on topic 3
5	Electrochemical prevention of metal-based materials	2-3	Lectures and mass tutorials on topics 4 and 5
6	Chemical corrosion of ceramics	1-3	Lectures and mass tutorials on topic 6
7	CA1	1-3	Quiz
8	-	(Recess)	
9	Lab course briefing	1-3	Lab course briefing
10	Experiment 1	1-3	Lab experiments
11	Experiment 2	1-3	Lab experiments
12	Experiment 3	1-3	Lab experiments
13	Experiment 4	1-3	Lab experiments
14	Revision for final exam		Consultation and discussions