Annexe A: New/Revised Course Content in OBTL+ Format

Course Overview

Expected Implementation in Academic Year (New format)	AY2026-2027
Semester/Trimester/Others (specify approx. Start/End date)	Semester 2
Course Author * Faculty proposing/revising the course	Dr Alex van Herk / Dr Hans Heuts
Course Author Email	cs-alex.vanherk@ntu.edu.sg
Course Title	Sustainable Polymeric Materials and Polymer Recycling
Course Code	MS6035
Academic Units	3
Contact Hours	39
Research Experience Components	

Course Requisites (if applicable)

Pre-requisites	
Co-requisites	
Pre-requisite to	
Mutually exclusive to	MS6015 Polymeric Materials Circularity & AI MS7460 Polymer Recycling & Sustainable Polymeric Materials
Replacement course to	
Remarks (if any)	Students who have previously completed MS6015 Polymeric Materials Circularity & AI and/or MS7460 Polymer Recycling & Sustainable Polymeric Materials will not be allowed to read MS6035 Sustainable Polymeric Materials and Polymer Recycling.

Course Aims

1. This course is trying to achieve full awareness of the synthetic and sustainability aspects of polymeric materials. This includes looking at existing materials and their ways of synthesis and recycling as well as redesigning materials on a molecular level.
2. The course should be taken by course students that have a vested interest in sustainability of polymer materials.
3. Any professional in materials will be looking at sustainability aspects of materials, being it facilitating recycling or replacement by more sustainable alternatives. So for a future career in materials (being it in research or industry), this course is very useful.

Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

ILO 1	Apply Excel to address aspects of polymer synthesis and life cycle analysis.
ILO 2	Describe the different (co)polymerization mechanisms, classify the main materials according to key materials properties and polymerization mechanism of formation.
ILO 3	Identify the main environmental issues with polymer waste.
ILO 4	Know the most important aspects of polymer waste collection and sorting.
ILO 5	Name the main aspects and current industrial applications of the four polymer recycling routes.
ILO 6	Name the main aspects of life cycle analysis and know the terminology used in LCA and apply LCA to polymers and polymer recycling.
ILO 7	Know the aspects of (sustainable) manufacturing of polymeric materials, in particular emulsion polymerization.
ILO 8	Name examples of reformulation of materials to make them more sustainable.
ILO 9	Know the main aspects of redesigning materials on a molecular level to make them more sustainable, in particular vitrimers and inserting weak bonds in polymers.
ILO 10	To name the main biobased building blocks and biobased replacements of materials with their pros and cons.
ILO 11	In teamwork write and pitch a presentation (in ppt) on a selected topic of the course.

Course Content

- Materials classification
- Key materials properties
- Step-growth polymerization
- Chain-growth polymerization
- Polymerization techniques with emulsion polymerization as an more in-depth example
- Environmental issues
- Collecting and sorting of materials
- Primary recycling
- Secondary/mechanical recycling with deterioration of properties and remedies
- Tertiary/chemical recycling
- Quaternary recycling (energy recovery and/or compostable materials)
- Life Cycle Analysis
- Aspects of sustainable manufacturing of materials (e.g. emulsion polymerization)
- Reformulation of materials for increased sustainability
    - Monomaterials
    - Additives
- Redesign of materials on molecular level
    - Physical crosslinks (thermoplastic elastomers), reversible crosslinks (vitrimers)
    - Insertion of weak bonds
- Biobased building blocks
- Biobased materials replacements
- Applications of Excel in polymer synthesis and life cycle analysis
- Working in a team on a presentation on one of the course topics

Reading and References (if applicable)

Introductory readings:

1. *Nature* **2021,** 590, p423, Closed-loop recycling of polyethylene-like materials, S. Mecking et al.
2. *The Straits Times* Nov 2, **2019** Biodegradable disposables can harm environment too
3. *Resources, Conservation and Recycling* Vol 145, **2019**, p 67-77, LCA of plastic waste recovery into recycled materials, energy and fuels in Singapore, Hsien H. Khoo

<u>Further references for the papers to support the slides</u>

4. *Science* **2021**, 373, 51, Plastics in the earth system, Stubbins et al.
5. *J. Industr. Ecology* **2021**,25,1318 ,recycling pathways, Volk et al.
6. *Recycling*, **2022**, 7, 11, Assessment of performance and challenges in use of commercial automated sorting technology for plastic waste. C. Lubongo and P. Alexandridis
7. *Macro Chem Phys* **2022**, 223, 2100488 Plastic as a resource, Mangold et al.
8. *Environm. Sci. Tech.* **2010**, 44, 8264 Sust Metrics LCA, Tabone et al.
9. *www.Intechopen.com* **2012** Recent Advances in the Chemical Recycling of Polymers, D.S. Achilias et al.
10. *Sci. Adv.* **2020**; 6 : eaba7599, Recycling of multilayer plastic packaging materials by solvent-targeted recovery and precipitation, Walker et al.,
11. *Macromolecules* **2020**, 53, 3994-4011 .Degradable Poly(alkyl acrylates) with Uniform Insertion of Ester Bonds, Comparing Batch and Semibatch Copolymerizations, Lena et al.
12. *J. Am. Chem. Soc.* **2020**, 142, 2100−2104 A Polymer with “Locked” Degradability, Hsu et al.
13. *www.bio-based.eu/markets* Bio-based Building Blocks and Polymers in the World, Pia Skoczinski, et al. Edition **2020**
14. *Canadian Journal of Chemical Engineering*, **2021**, vol 99, p 31–60.Sustainable polymer reaction engineering: Are we there yet?, M. Dube et al.
15. *Macromol. Rapid Commun*. **2021**, 42, 2000415, Mechanical Recycling of Packaging Plastics, A Review, Z.O.G. Schijns, M.P. Shaver
16. *Nature Reviews Materials* **2020**, 5, 501–516 Chemical Recycling to monomer for an ideal, circular polymer economy, G.W. Coates and Y.D.Y.L. Getzler.
17. *Resources, Conservation & Recycling* **2022**, 179, 106126 Monomaterials, Guerritere et al.
18. *Science* **2011**, 334, 965 Silica-like malleable materials from permanent organic networks. L. Leibler et al.
19. *Angew. Chem.* **2024**, 136, e202402436, Photocatalysis, Anastasaki et al.
20. *Procedia*, **2023**, 116, 522, LCA for Singapore, Low et al.

Planned Schedule

Week or Session	Topics or Themes	ILO	Delivery Mode	Activities	Readings
1	Materials classification Key materials properties Step-growth polymerization	1, 2	Online	Pre-recorded lecture (M1L1, M1L2) Live online session 1 (2 hours)	18
2	Chain-growth polymerization	1, 2	Online	Pre-recorded lecture (M1L3)	1, 2
3	Development of molecular weight, copolymerization, LCA on polymer synthesis. Computer-aided learning.	1, 2, 6	In-person	Pre-recorded lecture (M3L1-L2, M4-L3) In-person practicum (5 sessions, 13 hours total)	3, 8
4	Environmental issues, Collecting and sorting of materials, primary recycling Secondary/mechanical recycling	2, 3, 4, 5	Online	Pre-recorded lecture (M2L1-L2-L3)	4, 6, 10, 15
5	Tertiary/chemical recycling	5	Online	Pre-recorded lecture (M2L4) Live online session 2 (2 hours)	5, 9, 16
6	Quaternary recycling (energy recovery and/or compostable materials)	5	Online	Pre-recorded lecture (M2L5)	2
7	Life Cycle Analysis on polymer recycling routes Continual Assessment 1 (CA1): Individual In-person Quiz (Modules 1-3)	1, 6	In-person	Pre-recorded lectures (M3-L3) Live online session 3 (2 hours) Continual Assessment 1 (CA1): Individual In-person Quiz (Modules 1-3)	20

Week or Session	Topics or Themes	ILO	Delivery Mode	Activities	Readings
8	Aspects of sustainable manufacturing of materials, polymerization techniques	7	Online	Pre-recorded lecture (M4L1-L2)	14
9	Aspects of sustainable manufacturing of materials (e.g. emulsion polymerization) Reformulation of materials for increased sustainability - Monomaterials - Additives	1, 7, 8	Online	Pre-recorded lecture (M5L1-L3) Live online session 4 (2 hours)	17
10	Redesign of materials on molecular level; physical crosslinks, reversible crosslinks (vitrimers) Selection of presentation topic for Continual Assessment 3 (CA3): Team Presentations	1, 9	Online	Pre-recorded lecture (M6L1-L2) Selection of presentation topic for Continual Assessment 3 (CA3): Team Presentations	18
11	Redesign of materials on molecular level - Insertion of weak bonds	1, 9, 11	Online	Pre-recorded lecture (M6L3) Live online session 5 (2 hours)	11, 12, 19
12	Biobased building blocks Biobased materials replacements Submit presentation Peer review. Continual Assessment 2 (CA2): Individual In-person Quiz (Modules 4-7)	10, 11	In-person	Pre-recorded lecture (M7L1-L4) Continual Assessment 2 (CA2): Individual In-person Quiz (Modules 4-7)	13

Week or Session	Topics or Themes	ILO	Delivery Mode	Activities	Readings
13	Continual Assessment 3 (CA3): Team Presentations	11	Online	Live online session 6 / Continual Assessment 3 (CA3): Team Presentations (3 hours)	N/A

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Prerecorded lectures	The lecture materials are accompanied by self-practice questions (not part of the assessment), not only help to build the fundamental technical knowledge required for this course, but also help to develop your individual learning abilities and attitudes toward active learning.
Live sessions (online)	These sessions will allow you to ask specific questions and for the teacher to assess you understanding of the course materials. Your engagement level during the course (asking questions, giving answers etc, either by the chat, direct questions or questions by email) is part of the assessment of the live sessions.
Practicum (in-person)	These sessions take place in the computer room of MSE. Topics will be the use of the computer in polymer synthesis and in particular molecular weight development in step-growth and chain-growth polymerizations. Furthermore, copolymerization and life cycle analysis of polymers will be addressed through computer calculations. 5 sessions in total.
Practice tests (online)	There are practice questions offered during the live sessions. They are not part of the assessment but simply give you the opportunity to see where you stand in your learning process and anticipate the kind of question that are asked during the quizzes.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
1	Continuous Assessment (CA): Test/Quiz(Continual Assessment 1 (CA1): Individual Quiz)	1-6		20	The quiz is conducted in person at NTU. Each quiz contains between 25 and 30 multiple-choice questions. The students are given 60 minutes to complete each quiz.	Individual	Analytic	Multistructural
2	Continuous Assessment (CA): Test/Quiz(Continual Assessment 2 (CA2): Individual Quiz)	7-10		20	The quiz is conducted in person at NTU. Each quiz contains between 25 and 30 multiple-choice questions. The students are given 60 minutes to complete each quiz.	Individual	Analytic	Multistructural
3	Continuous Assessment (CA): Class Participation(In-class participation and discussions (6 live online sessions), engagement in the course)	1-10		18	The live online sessions themselves contain continual assessment through interaction with the instructor. The students can ask questions beforehand by email and during the live online sessions (all part of the level of engagement in the course), also the instructor will ask questions to the students.	Individual	Holistic	Multistructural

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
4	Continuous Assessment (CA): Others(In-person practicum (5 in person sessions))	1		25	With the use of computers polymer synthesis, copolymerization and life cycle analysis of polymers will be studied. Aspects of molecular weight development in step-growth and chain-growth polymerizations will be studied. Development of chemical composition (distributions) in copolymerizations is an important topic returning in several modules in the course. Life cycle analysis of several polymers will be conducted through the use of databases.	Individual	Holistic	Multistructural

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
5	Continuous Assessment (CA): Presentation(Continual Assessment 3 (CA3): Team Presentations (50% peer, 50% course instructor))	11		17	The presentation is collated on a topic of choice in sustainable materials by the team of students. The students should be able to show that they can comprehensively summarize the recent literature (after 2024) on the topic and apply the concepts of the course in what is written and presented. 50% of the mark is through peer review within the group, the other 50% through course instructors' assessment with one mark for the whole group.	Individual and Team	Holistic	Multistructural

Description of Assessment Components (if applicable)

Formative Feedback

Feedback is an important aspect to this course. You will receive the scores per question in the practice quiz after the practice quiz. In the next live session, the practice quiz questions and answers will be explained. Also your scores on CA1 and CA2 will be shared. Peer review is included in CA3. Email feedback can be expected from me about your performance during the live sessions if needed.

NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Care for Environment	Intermediate
Care for Society	Intermediate
Ethical Reasoning	Intermediate
Global Perspective	Intermediate
Design Thinking	Intermediate

Course Policy

Policy (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 recognize 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 of the definitions of any of these terms, you should go to the academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (General)

You are expected to complete all assigned video viewings and readings, attend all classes punctually and complete all scheduled quizzes and submit the powerpoint presentation within the allocated times. You are expected to take responsibility to follow up with assignments and course related announcements. You are expected to participate in all class discussions and activities.

Policy (Absenteeism)

In-class activities make up a portion of your course grade. Absence from class without a valid reason will affect your participation grade. Valid reasons include falling sick supported by a medical certificate and participation in NTU's approved activities supported by an excuse letter from the relevant bodies. There will be no make-up opportunities for in-class activities.

Policy (Others, if applicable)

Use of AI in preparing the team presentation is allowed, however the students should "own" the contents of their presentation.

Technical Skills To Be Developed

All skills to be developed for this course:

Last Updated Date: 23-10-2026 19:39:36

Last Updated By: Tan Yong Lay Hayden