Topic 3 - Plastics and Microplastics

Ulisses

UNIVERSITY OF LISBON
INTERDISCIPLINARY STUDIES
ON SUSTAINABLE ENVIRONMENT AND SEAS

Vítor Alves
Assistant Professor
Instituto Superior de Agronomia
Universidade de Lisboa
email: vitoralves@isa.ulisboa.pt

www.ulisses.ulisboa.pt

UNITE! University Network for Innovation, Technology and Engineering

U LISBOA | UNIVERSIDADE DE LISBOA

Comissão Europeia

Summary

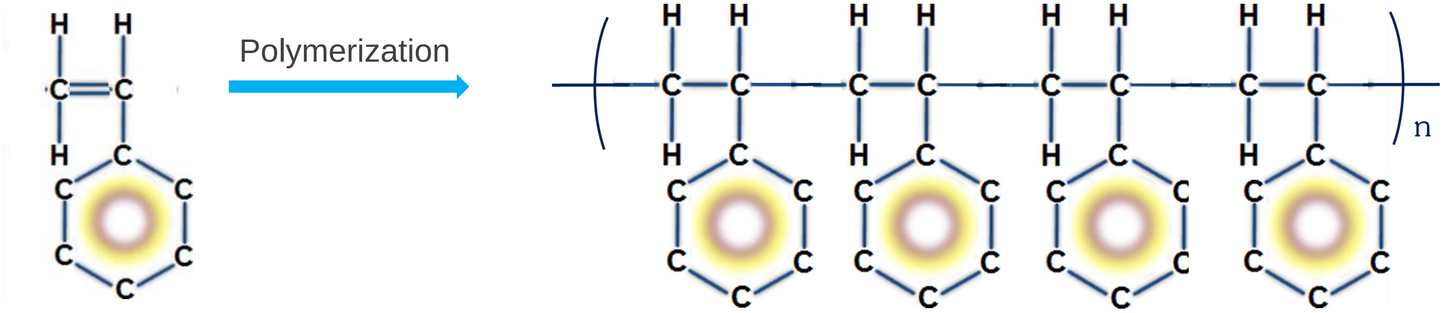
- “Plastics” and “polymers”
- From molecular to macro scale
- Production of plastic parts
- Plastic waste types
- Degradation of polymers in the environment - microplastics

“Plastics” and “Polymers”

- Plastic objects are constituted by polymers
- Polymer molecules: high molecular weight molecules (macromolecules)
- Macromolecules made up of the covalent bonds of low molecular weight molecules (monomers)

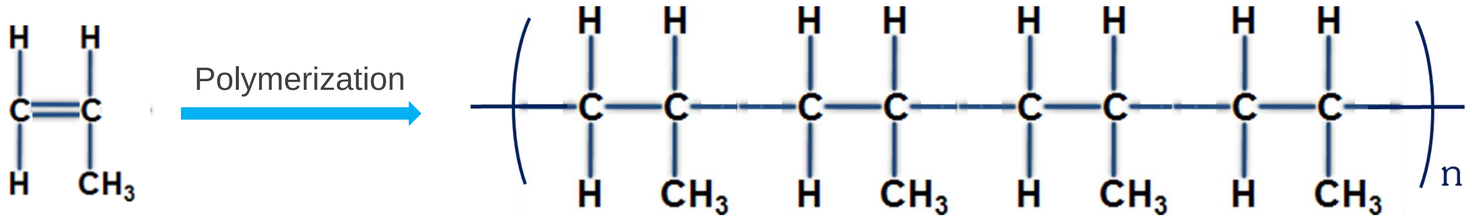
Examples

Styrene



Polystyrene (PS)

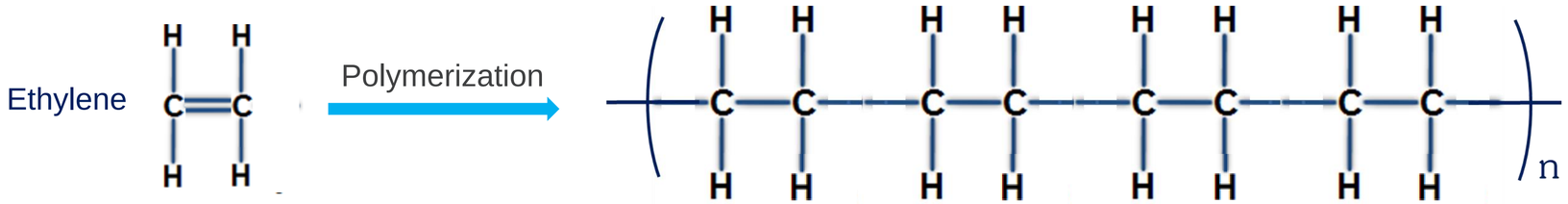
Propylene



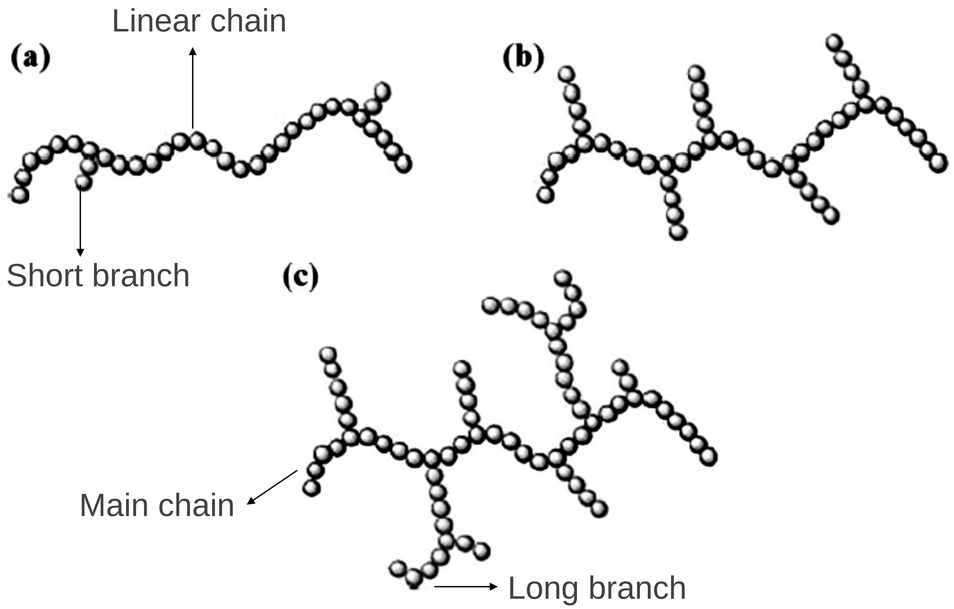
Polypropylene (PP)

Homopolymer – one type of monomer
Copolymer – more than one type of monomers

“Plastics” and “Polymers”



Polyethylene (PE)



(a) **High-density PE (HDPE):** It has the highest degree of crystallinity and is the most versatile among all the PEs. It has less number of short branches, meaning that the chains pack into the crystalline regions very well.

(b) **Linear low-density PE (LLDPE):** It has a linear structure and very high number of short branches, which makes it useful for film applications, given its transparency, flexibility, and high toughness.

(c) **Low-density PE (LDPE):** It is a ductile and flexible material, with unique flow properties. This is because it has a high degree of chain branching, which causes weak intermolecular interactions.

“Plastics” and “Polymers”

Polyethylene (PE)

Polypropylene (PP)

Poly(ethylene terephthalate) (PET)

Polyamides (ex: nylon)

Poly(vinyl chloride) (PVC)

Polystyrene (PS)

Polytetrafluoroethylene (PTFE)

Polycarbonate (PC)

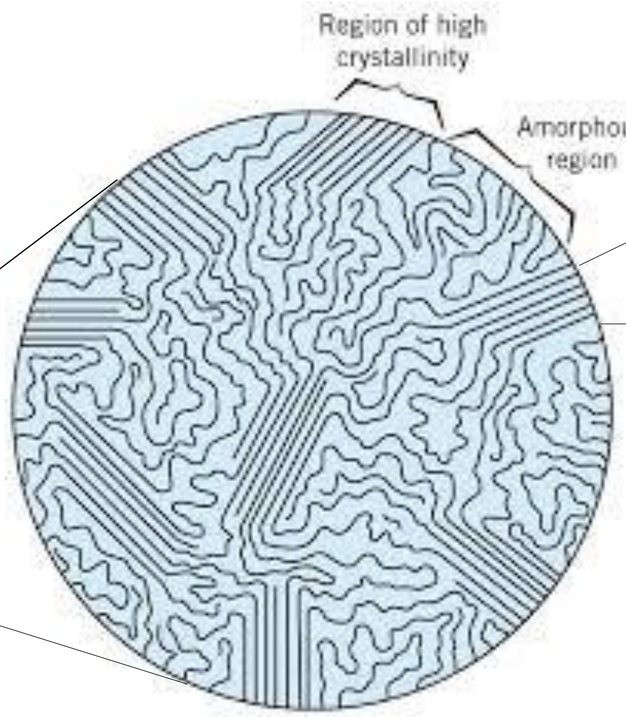
…

1 PET	POLYETHYLENE TEREPHTHALATE Usually clear or green, sinks in water, rigid. Barrier to gas and moisture.	
2 HDPE	HIGH DENSITY POLYETHYLENE Semi rigid, sinks in water. Resistance to moisture, permeability to gas	
3 PVC	POLYVINYL CHLORIDE Semi rigid, glossy, sinks in water.	
4 LDPE	LOW DENSITY POLYETHYLENE Flexible, not crinkly. Ease of processing, Ease of sealing, barrier to moisture.	
5 PP	POLYPROPYLENE Semi rigid, low gloss, resistance to heat, chemicals, greese and oil, versatile barrier to moisture	
6 PS	POLYSTYRENE Often brittle, glossy. easily formed,	
7 O	OTHER often Polycarbonate, acrylic, ABS, mixed / multi layer plastic	

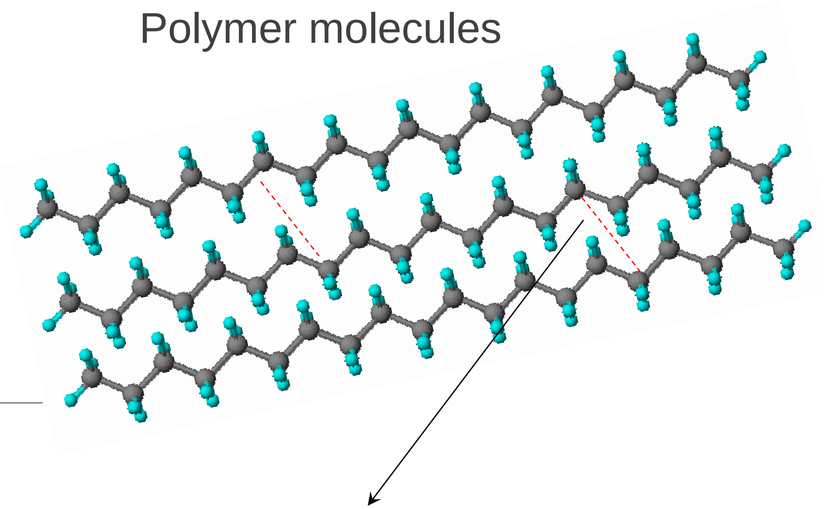
From macro to molecular scale

Macroplastic

Low density polyethylene (LDPE) bag



Polymer molecules

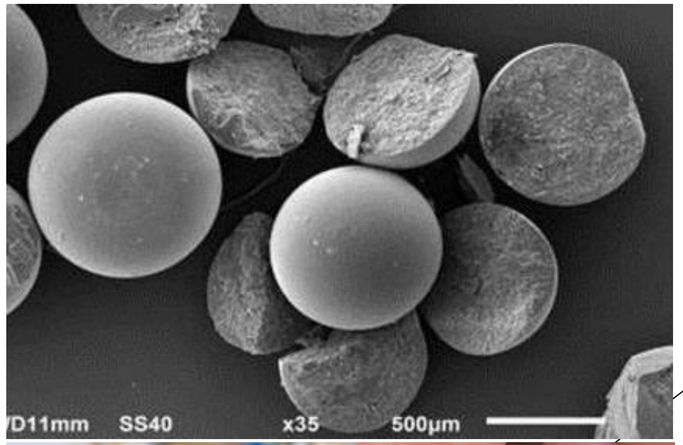


<u>Intermolecular interactions, e.g.:</u>

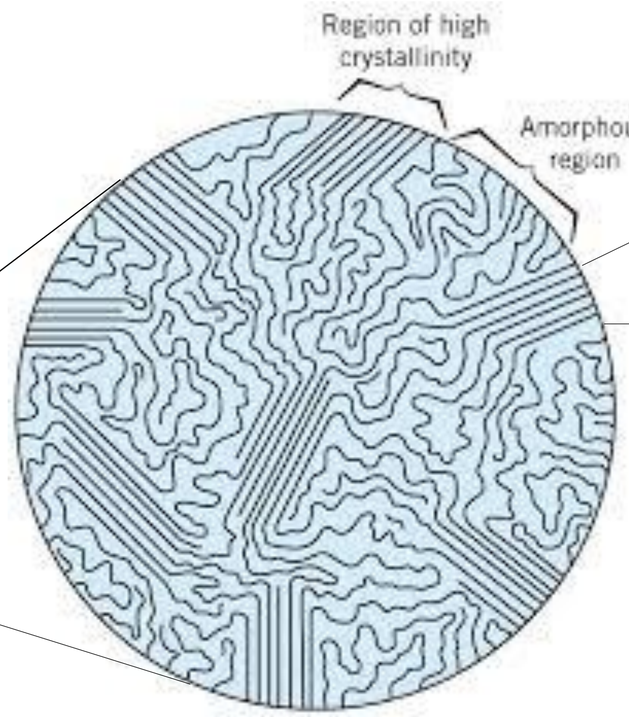
- van der Waals bonds (non-polar molecules)
- Hydrogen bonds (molecules with polar groups)

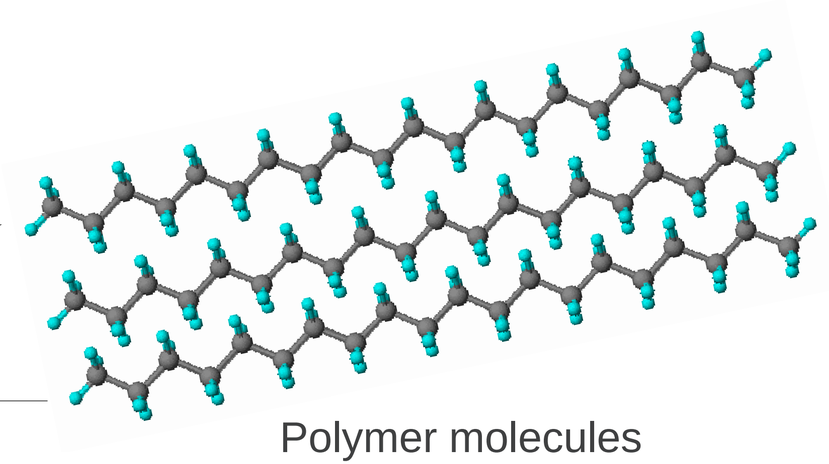
From Macro to molecular Scale

Nanoparticles (Scanning Electron microscopy)



Small plastic particles





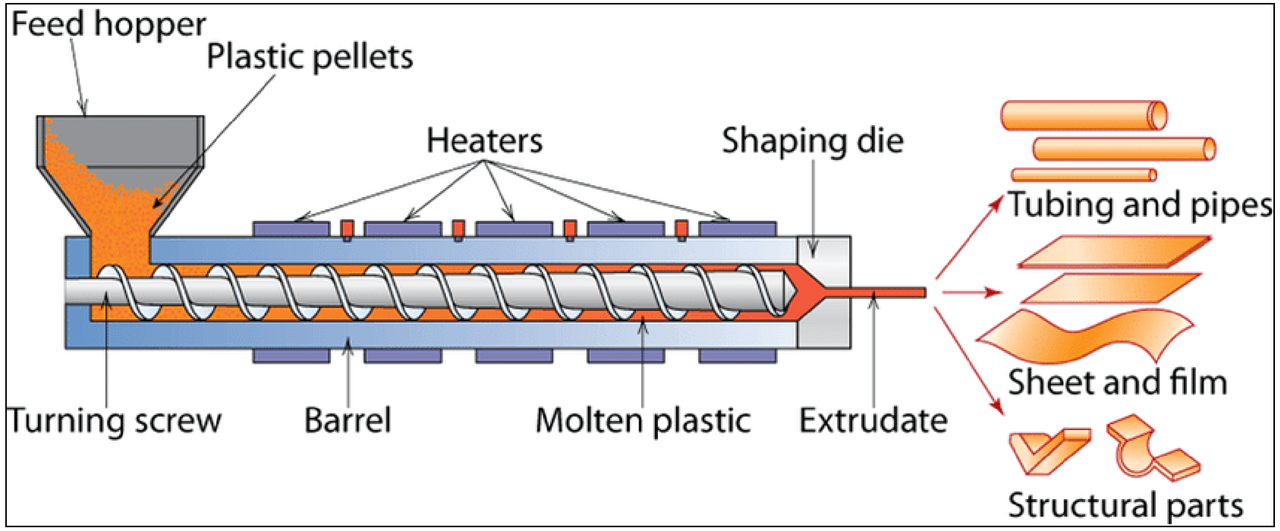
Polymer molecules

Molecular structure is indepentent of plastic material size

Thermoplastic polymers

Thermoplastics are a class of polymers that can be softened and melted by the application of heat, and can be processed either in the liquid state (e.g. by extrusion and injection molding) or in the heat-softened state (e.g. by thermoforming)

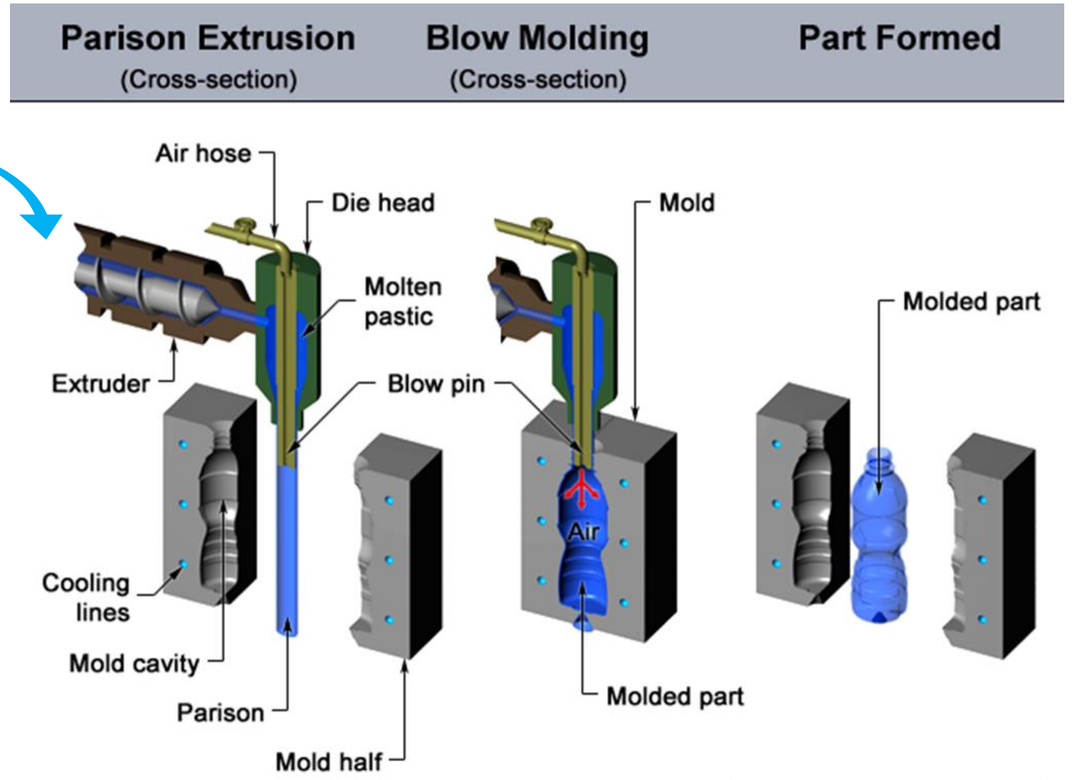
Extrusion process



Production of plastic objects

Polymer granules

Thermoplastic polymers



Example of polymer molding

Properties of plastic parts are highly dependent on the polymers properties, e,g,:

- Average molecular weight
- Melting temperature
- Glass transition temperature
- Resistance to polymer degradation

Fabrication processes of plastic objects

https://youtu.be/qn16JtE_vLc

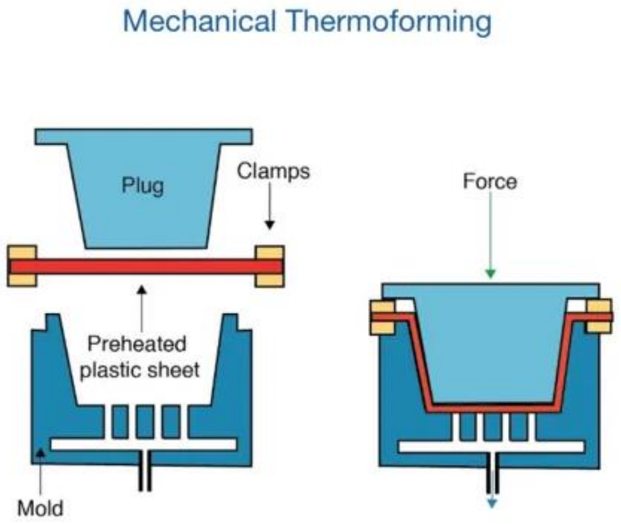
Thermoplastic polymers

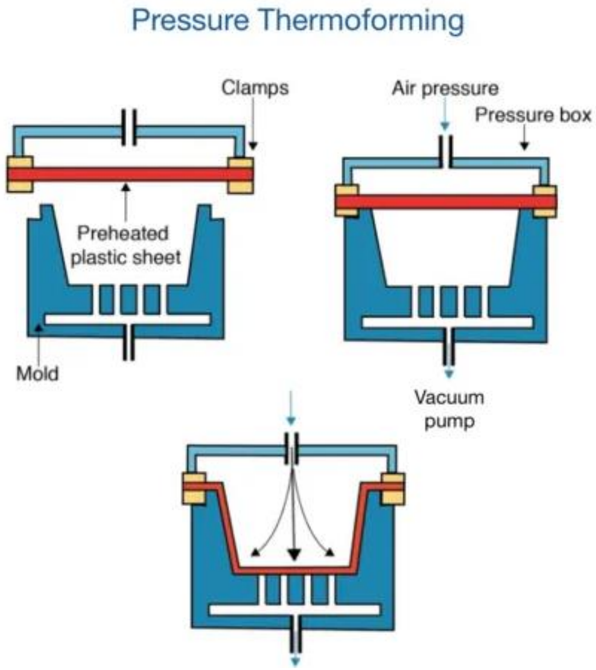
Thermoplastics that can be softened by the application of heat, and can be processed in the heat-softened state (e.g. by thermoforming)

Fabrication processes of plastic objects by thermoforming process

https://www.youtube.com/watch?v=Oh-MXjMFxT4
https://www.youtube.com/watch?v=kLdCORXk3gQ

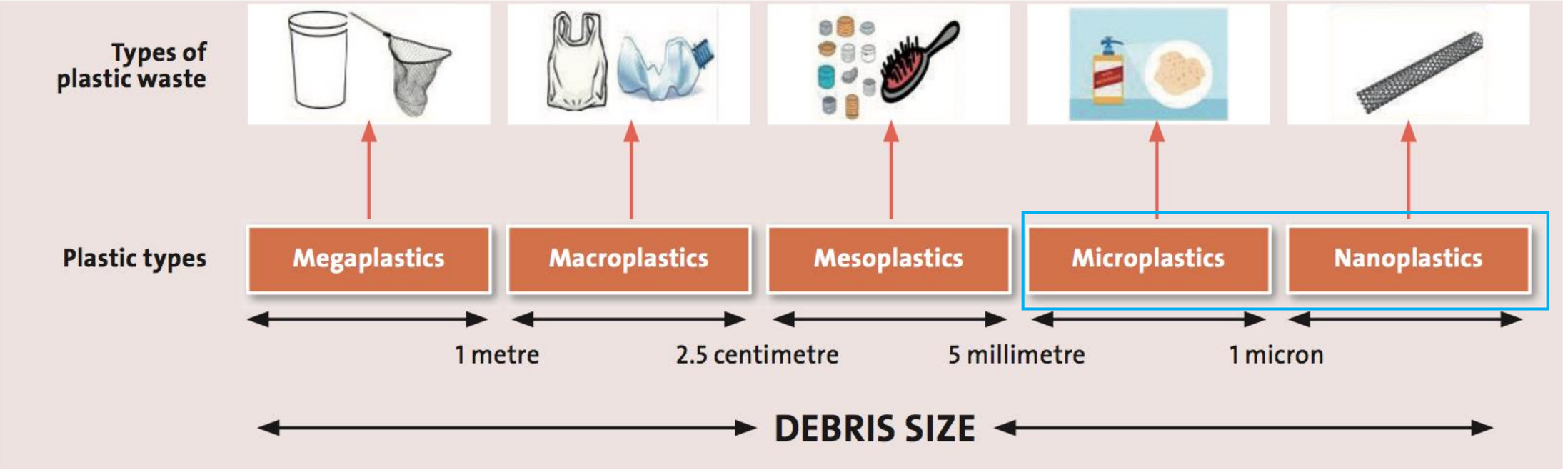
Thermoforming process





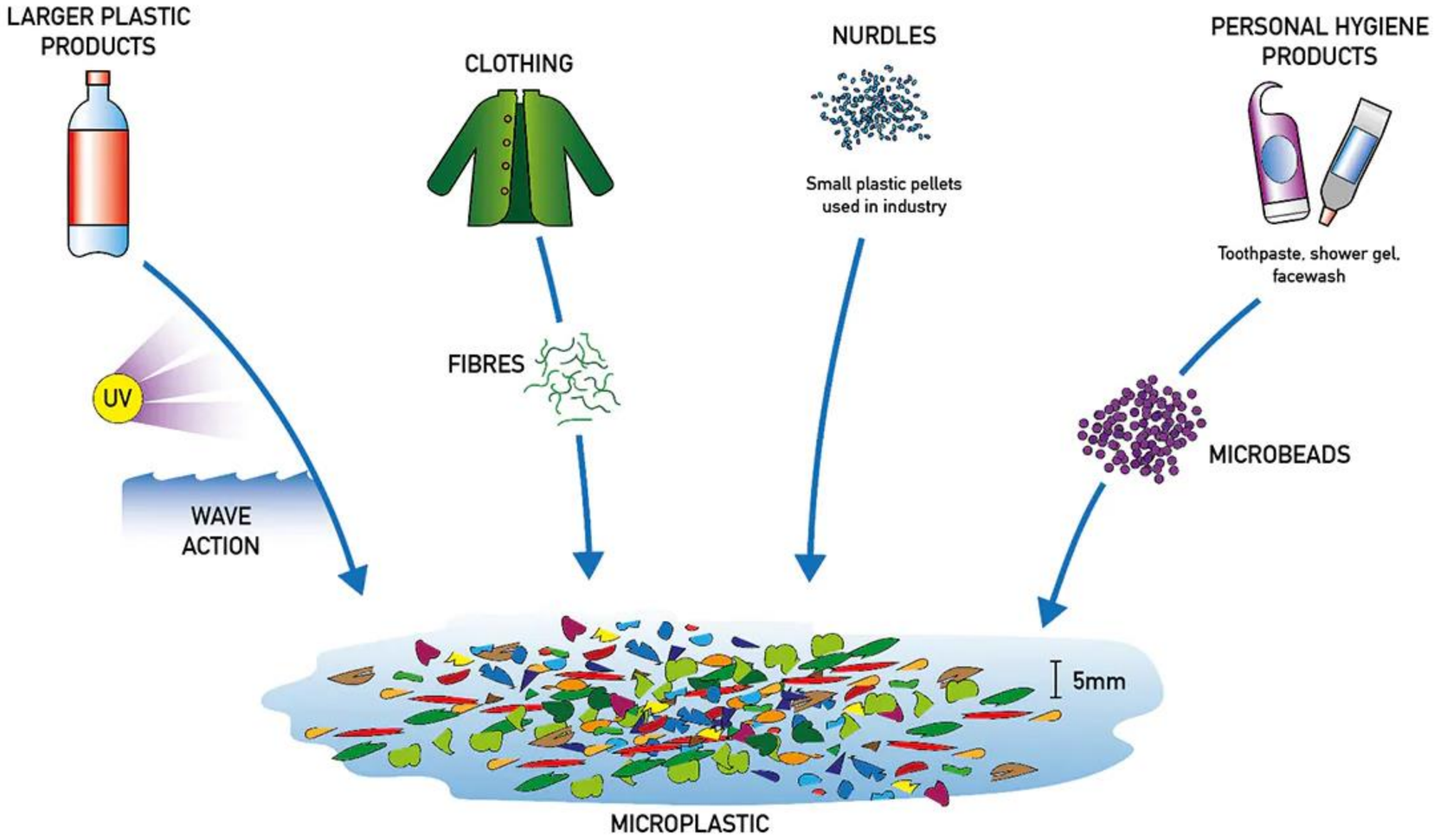
Plastic waste

Types of plastic waste according to size



Sources of microplastics

Key sources of microplastics found in the sea



Degradation of polymers- production of microplastics

Degradation is generally classified according to the process causing it:

Chemical Reactions

Photo-oxydadion – action of light (usually sunlight in outdoor exposure) and oxygen

Thermo-oxidation – slow oxidative breakdown at moderate temperatures

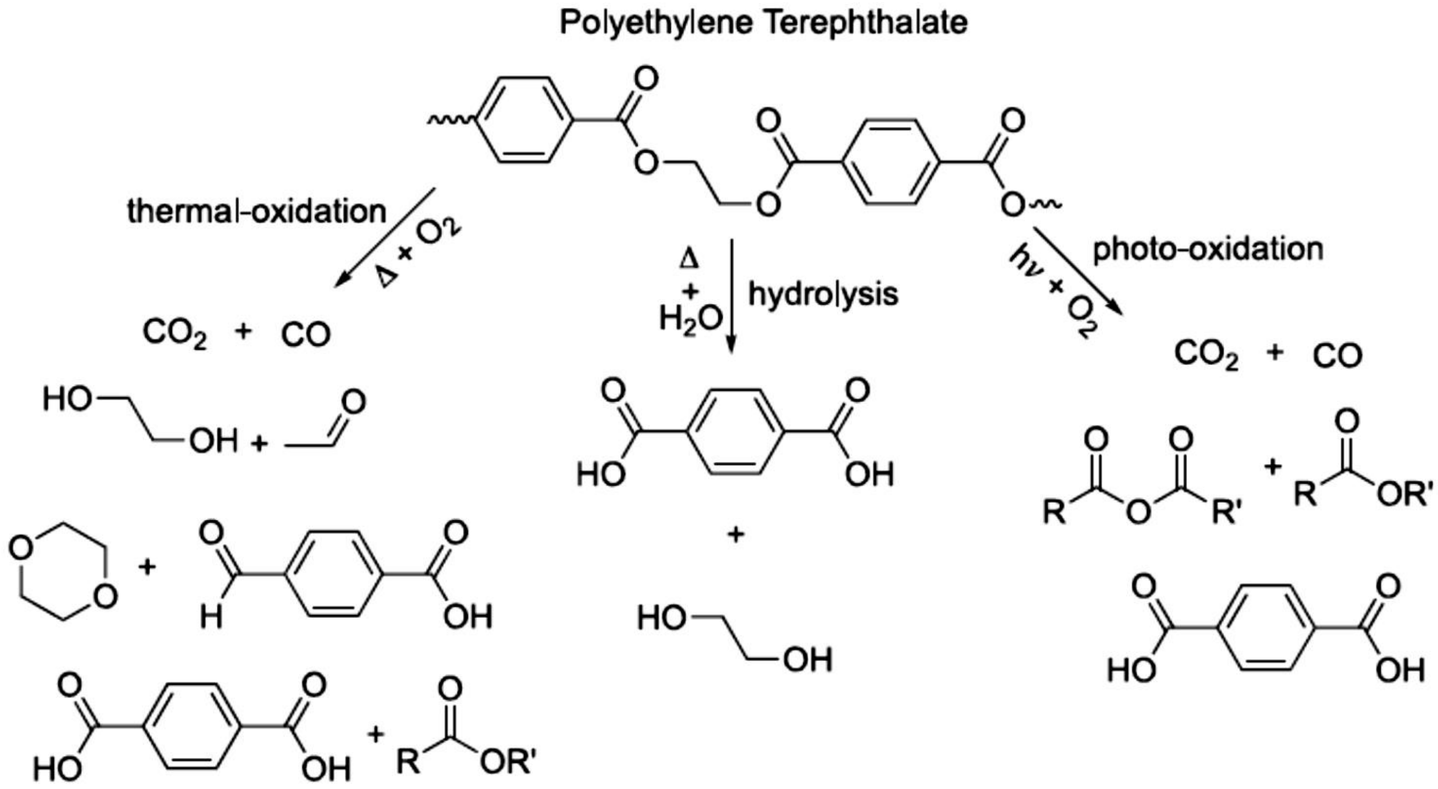
Hydrolysis – reaction with water

Biodegradation – action of living organisms usually microorganisms.
The petrochemical based polymers used extensively nowadays are not biodegradable

Degradation of polymers into small molecules

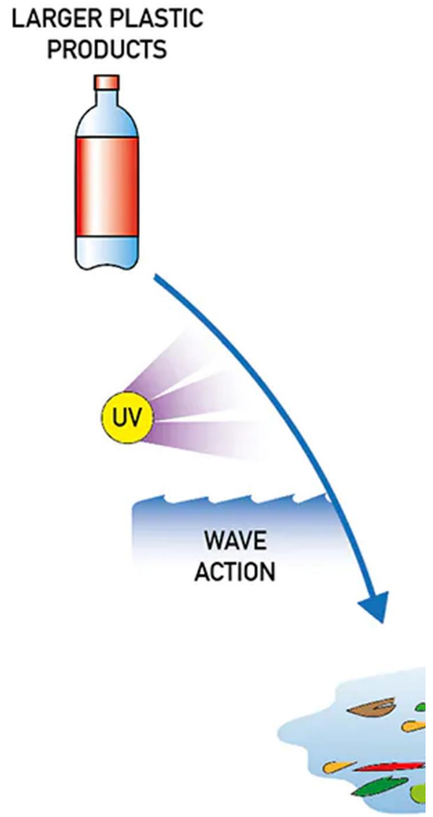
Example:

Degradation reactions of Polyethylene Terephtalate (PET)



Degradation of polymers in the environment

- Degradation is a chemical change that drastically reduces the average molecular weight of the polymer. Since the mechanical integrity of plastics invariably depends on their high average molecular-weight, any significant extent of degradation inevitably weakens the material.
- Extensively degraded plastics become brittle enough to fall apart into powdery fragments, specially under mechanical stresses like wave action.
- Fragmentation into pieces that may be small enough to become undetected but which are still similar to the original material
- The amount of time to have a certain degree of degradation depends on the type of polymer, morphology, molecular size, and the conditions to which it is subjected (light, moisture, pH, salt, oxygen, mechanical stresses).



Degradation of polymers in sea water

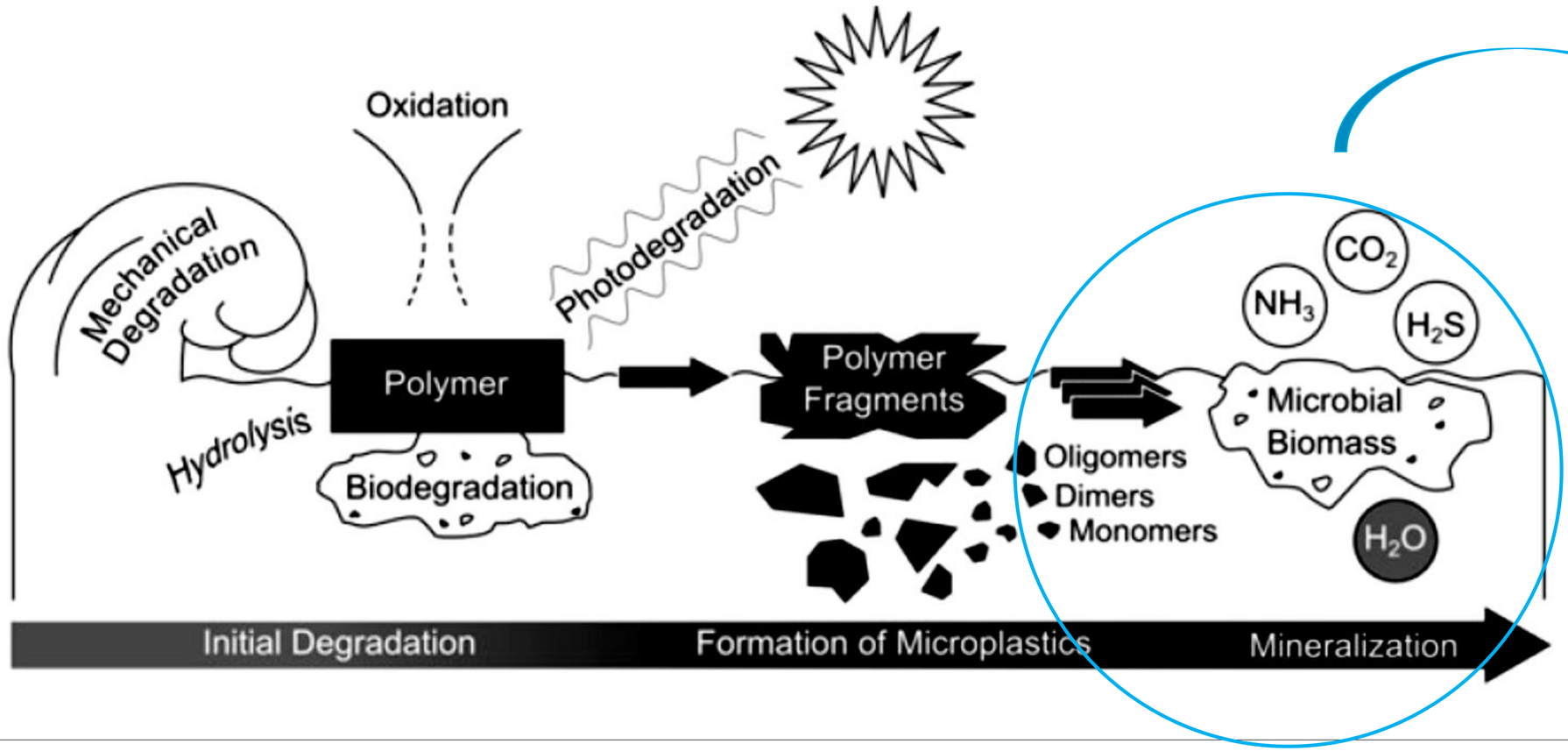
- Degradation initiated by solar UV radiation is a very efficient mechanism in plastics exposed in air or lying on a beach surface.

- But when the same plastic material is exposed to sunlight at the same location but while floating in seawater, degradation is severely retarded.

- The retardation of degradation in plastics exposed to the elements while floating in sea water is primarily the result of the relatively lower temperatures, lower oxygen concentration and lower UV radiation incidence in water environments.

Degradation of polymers

Degradation pathways of synthetic polymers in the aquatic environment with degradation processes involved and intermediate steps until complete mineralization



In the case of petrochemical-based polymers (e.g. PE, PP, PET, PS and PVC), in marine environment, the formation of monomers and the biodegradation step are quite slow, giving rise to the high persistence of plastics.

Future topic

Biodegradable polymers

Sources

Properties

Applications

Biodegradation in several environments


Ulisses
UNITE!
University Network for Innovation, Technology and Engineering
U LISBOA
UNIVERSIDADE DE LISBOA