

## Chapter 6

# Recycling of Polymers



# Plastics recycling

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- material recycling
  - one polymer ~ **primary**
    - thermoplastics, reprocessing, usually with virgin resin
  - mixed plastics ~ to lower grade ~ **secondary**
- chemical recycling ~ **tertiary**
  - degradation to monomer
  - degradation to raw material
- energy recycling ~ **quaternary**
  - incinerating plastics only
  - burning with other wastes ~ refuse derived fuel [RDF]

- state of waste
  - post-consumer
    - contaminated, mainly with paper
    - hydrolyze paper (cellulose) → composite
  - industrial
    - variety of materials ~ separation
    - 'monomaterial approach' ~ PP
- selection of method
  - recycling or not
  - material, chemical, energy
  - economical vs environmental
  - ❖ life-cycle assessment [LCA]

- 3rd volume waste – 1st volume recycled
- All methods are possible.
  - material recycling
    - re-extrusion or melt recovery
    - most economical
    - need well-defined PET ~ cleaned or in-house
    - transesterification and degradation ~ MW control critical
    - may be added to extrusion of virgin PET
  - chemical recycling
    - contaminated PET
    - hydrolysis, methanolysis, glycolysis ~ to monomer a/o oligomer
    - ammonolysis ~ to phenylene diamine

- energy recycling
  - incineration
  - least economical
  - highly contaminated PET
  - calorific value similar to coal
  - need high oxygen, produce high soot, excessive heat, toxic

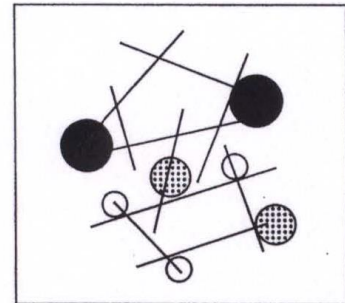
- largest volume in car parts ~ thermoset and TPU
- material recycling
  - thermopressing
    - granulate and mold; hardness, IS –; EB, appearance ↓
  - kneader process
    - thermal decompose, cooled, crush, and mold w/ isocyanate
- chemical recycling
  - hydrolysis
    - polyamine + polyol (+ CO<sub>2</sub>), need separation (impractical)
  - glycolysis
    - glycols, can be used directly (practical)
  - ammonolysis
    - with supercritical NH<sub>3</sub>, amine + polyol, not economical

- Recycling of PVC is problematic.
  - usually mixed with other plastics, plasticizers, --
  - thermally weak
  - incineration byproducts ~ dioxine, HCl, ---
- material recycling
  - in-line scrap ~ re-extrusion
  - floor coverings, roofing ~ ground and reformed
  - bottles ~ sorting critical (PET)
  - cable ~ copper recovery
- chemical recycling
  - HCl recovery, rarely done

# Mixed plastics waste

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- post-consumer + industrial ~ 2/3 of plastic wastes
  - PE+PP+PS+PVC+PET major
- separation then recycling ~ primary
  - better properties, not economical (separation)
- reprocessing of MPW ~ secondary
  - direct extrusion
    - need compaction ~ crammer, ram, dual dia
    - temp and retention time ~ PVC (210 °C, 6 min)
  - Radlite technology
    - physical compatibilization with glass fiber
- liquefaction ~ tertiary
  - separation with water ~ PE+PP+PS from PET+PVC
  - thermal then catalytic cracking to raw HC





- post-consumer PE films
  - grocery, packaging, agricultural, ---
  - cleaning, granulating, drying, and
  - reformed to
    - lower-grade (dyed and opaque) films
    - other plastic products
  
- grounded rubber tire [GRT]
  - added as filler to other polymer or tire
  - w/ or w/o compatibilizer
  - particle size – cost

# Recycling procedure

- collection and transportation
  - infrastructure, compactors
- size reduction
  - shredding, cutting, granulating, grinding
- separation ~ cleaning and selection
  - molecular separation ~ solvent
  - microseparation
    - density (air, water), solubility, electrostatic, melt
  - macroseparation
    - manual, X-ray (PVC), NIR (transparency), camera (color)
- recycling process

# Upcycling

- recycling is downcycling (to less value to landfill)
- upcycling to more value
  - chemically recycled to raw material
    - PET to acid to PHV
  - polymer as carbon source of CNT, graphene---

- life-cycle assessment [LCA]
  - from raw material to disposal
  - plastic packaging
    - metal, glass reusable; paper degradable
    - what if use glass/metal/paper instead of polymer?
      - double energy use (high processing temp)
      - double waste volume
      - 4 times packaging weight and transportation energy
      - increase in consumption of pulp [tree]

- 현대차 제네시스 시트, 가죽 버리고 플라스틱 쓴다 [2019.12.03]
- 현대자동차 제네시스 모델에 쓰이는 좌석용 시트 소재로 가죽을 버리고 재활용이 가능한 고기능성 플라스틱을 선택한 것으로 알려지면서 업계에 적잖은 파장을 불러일으키고 있다. 최고급 자동차 전용 브랜드인 제네시스 내장재이기 때문이다.
- 고기능성 플라스틱인 '열가소성 폴리에스테르엘라스토머(TPEE)'를 사용키로 했다.
- 가죽은 소를 키워 도살한 뒤 가죽을 벗겨내고, 다시 대량의 화학 약품을 써서 가공해야 한다. 또 가죽 원단을 재단해 자동차 내장재를 만드는 데 버려지는 부분도 많이 발생한다. 하지만 고기능성 플라스틱은 환경 문제에서 시비가 덜하고, 재활용이 가능하다.
- 앞서 현대차는 미국 유명 디자이너 마리아 코르네호와 협업해 시트를 만들고 남은 자투리 가죽으로 옷을 만들어 미국 뉴욕 패션 위크에 참석하는 이색적인 '업사이클링(단순 재활용이 아니라 새로운 가치를 창출하는 것)' 이벤트를 선보이기도 했다.