IOWA STATE UNIVERSITY
Bioeconomy Institute

Thermal Oxo-degradation as an Alternative to Thermal Depolymerization of Plastics

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Conventional fast pyrolysis of plastic

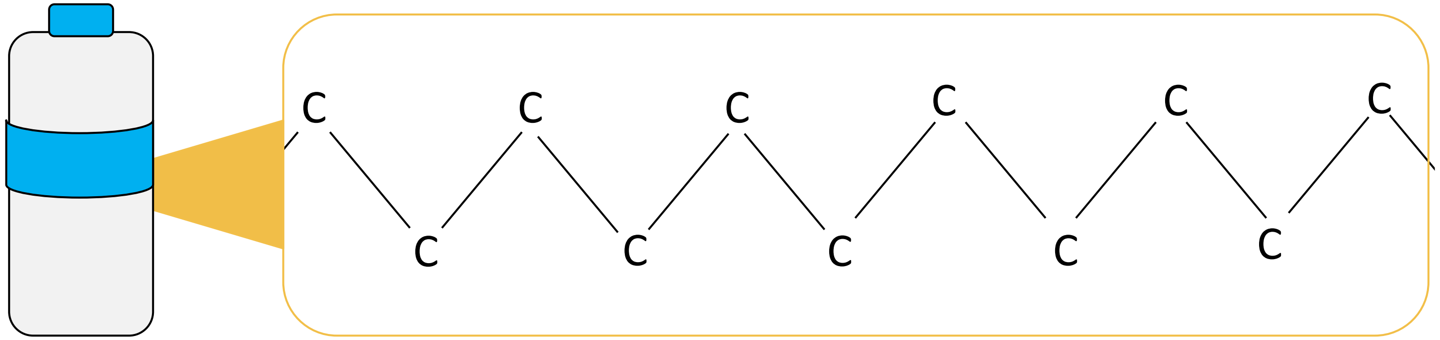
- **Definition of pyrolysis**: “Thermal decomposition of organic compounds in the absence of oxygen.”
  - *Biorenewable Resources: Engineering New Products from Agriculture*

- **Products of plastic pyrolysis**: “Wax, liquid, non-condensable gases, char”
  - *Feedstock Recycling and Pyrolysis of Waste Plastics*

- **Advantages**: “Convert plastic into lower molecular weight products to be used as fuels or feedstock for new chemicals”
  - *A Circular Solution to Plastic Waste*

Challenges of plastic pyrolysis

- Large thermal requirements
- Long reaction times
- Low selectivity



Random scission of carbon backbone of polymers is endothermic

Reducing the timescale of natural degradation of plastics in the environment

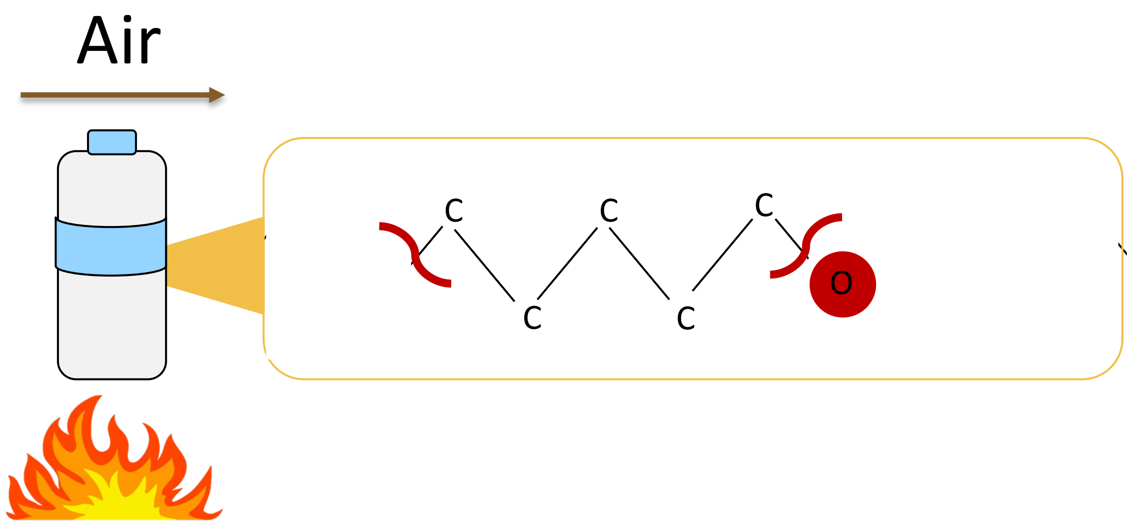
- **Challenge:** Rapidly deconstruct plastic to oxygenated product at high yields while employing less energy than conventional pyrolysis

- **Innovation:** Apply concepts of autothermal pyrolysis to the thermal decomposition of plastics

Thermal oxo-degradation is combined cracking and oxidation of polymers

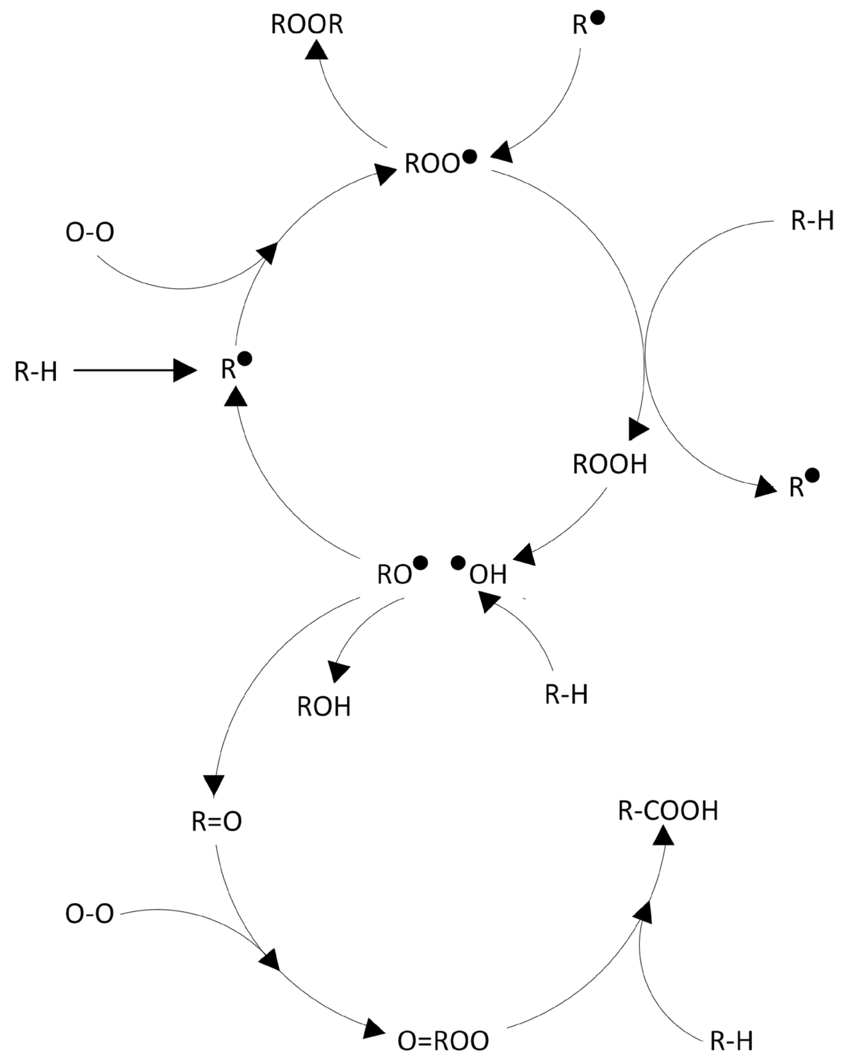
Thermal oxo-degradation:
400°C

Environment:
20°C



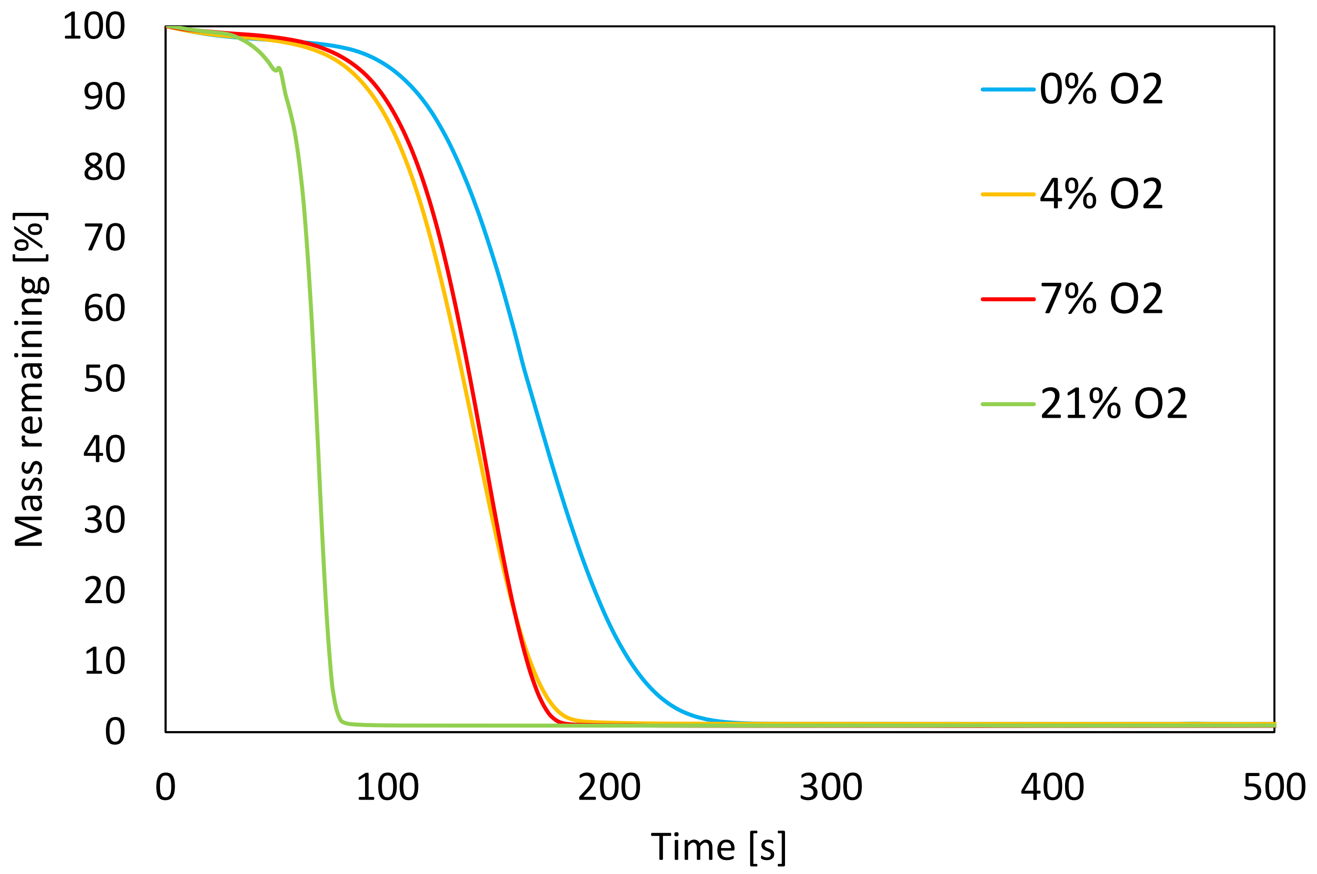
Mechanism of thermal oxo-degradation (TOD)

- Combined **cracking** and **oxidation** of polymers
- Free-radical mechanism which is initiated by heat or light



Rate of devolatilization increases with oxygen concentration

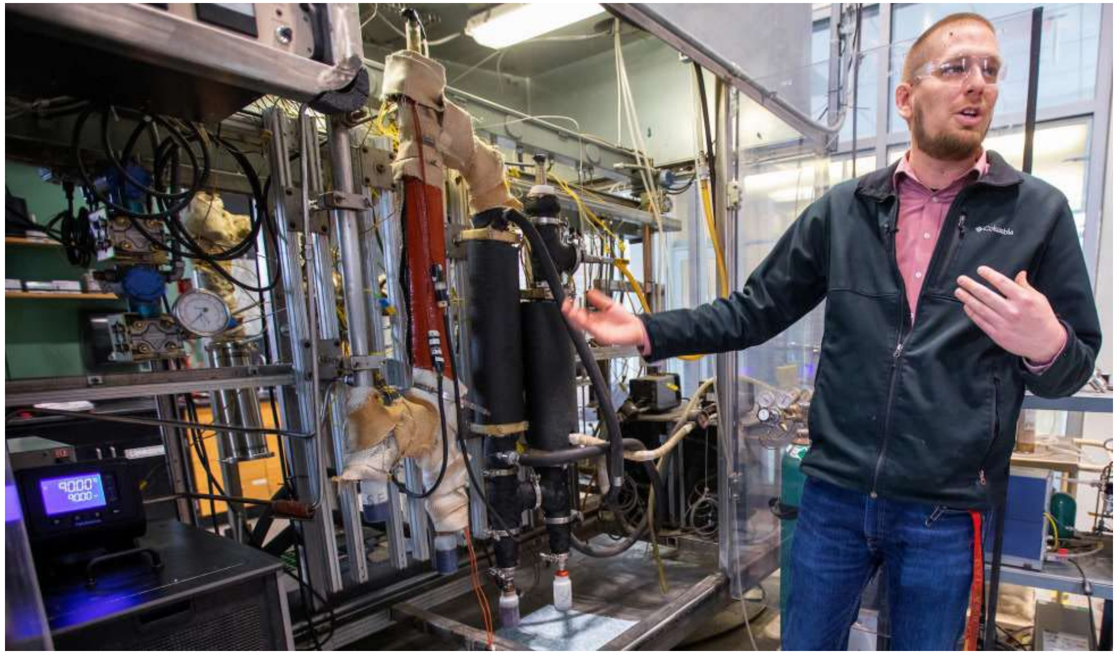
- Introducing small amounts of oxygen into heated atmosphere improves kinetics of devolatilization of plastic

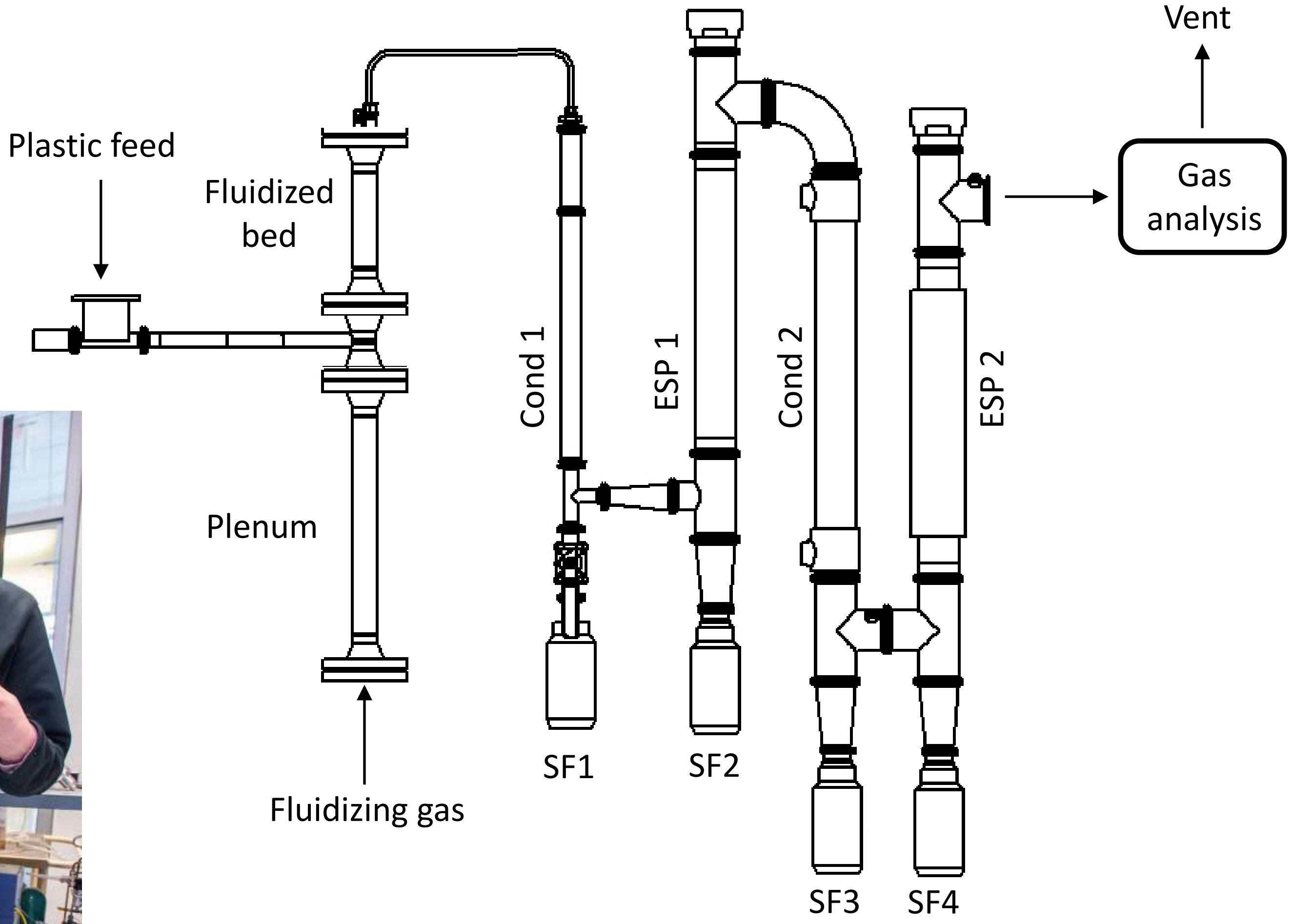


Data generated from introducing HDPE into TGA held isothermally at 500°C

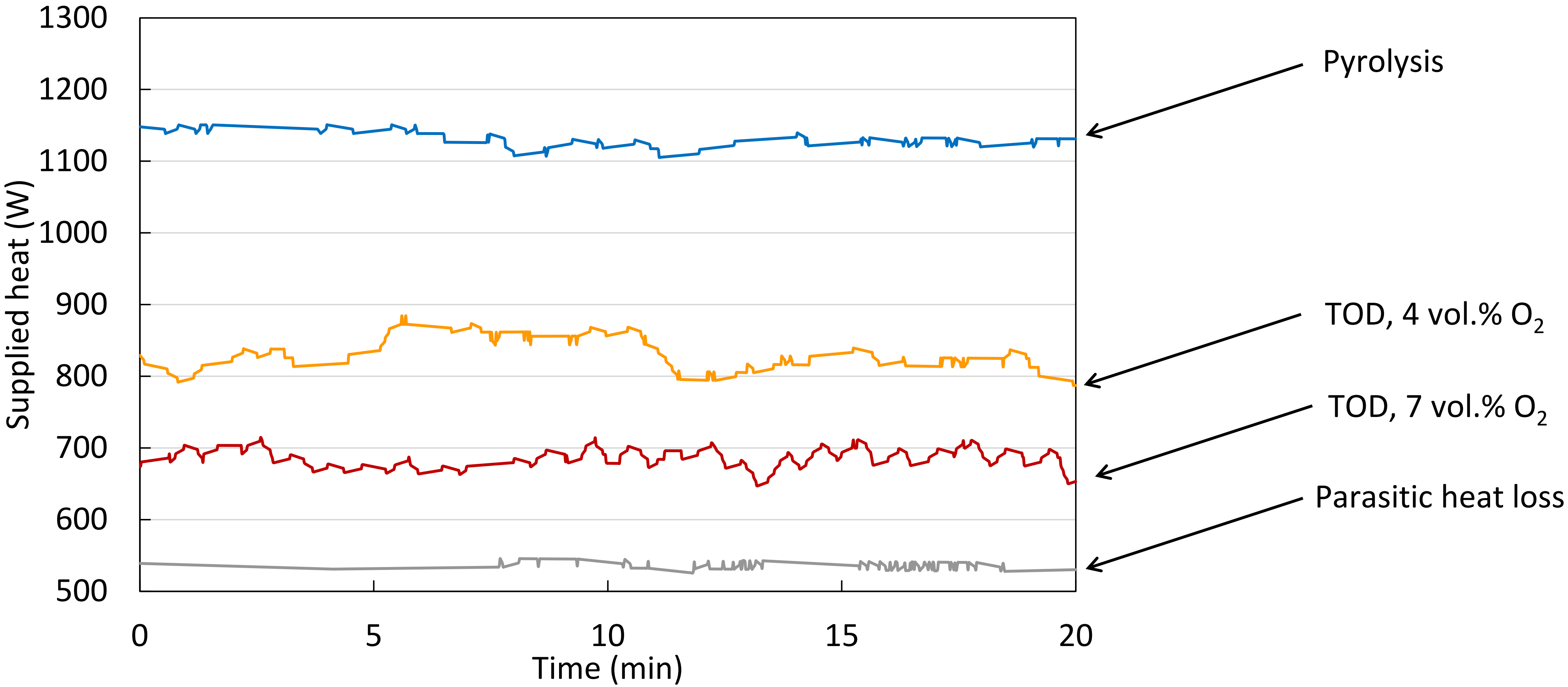
Thermal oxo-degradation in a fluidized bed reactor

Plastic is fed at 750g/hr into fluidized bed reactor as 2, 2100W clamshell heaters supply heat for devolatilization

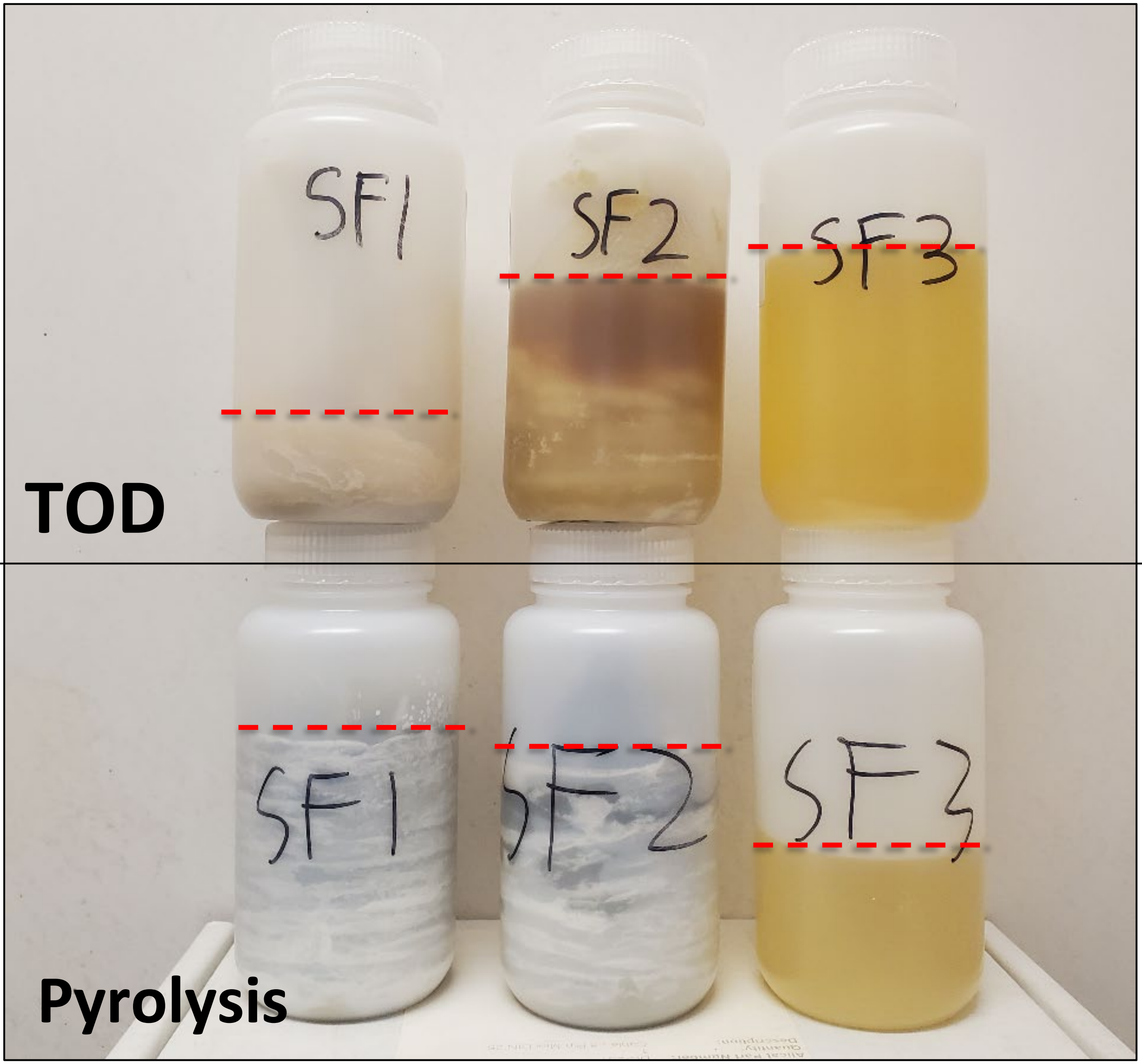




Energy is released during exothermic partial oxidation reactions at 600˚C, leading to decrease in external heat needed for devolatilization

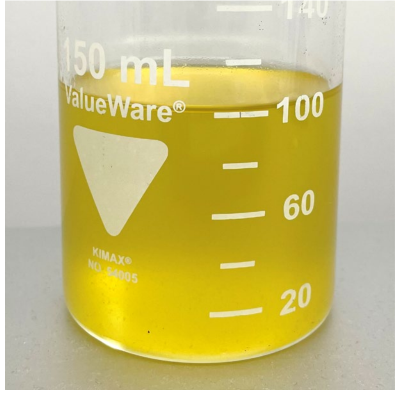


Comparison of TOD and pyrolysis products

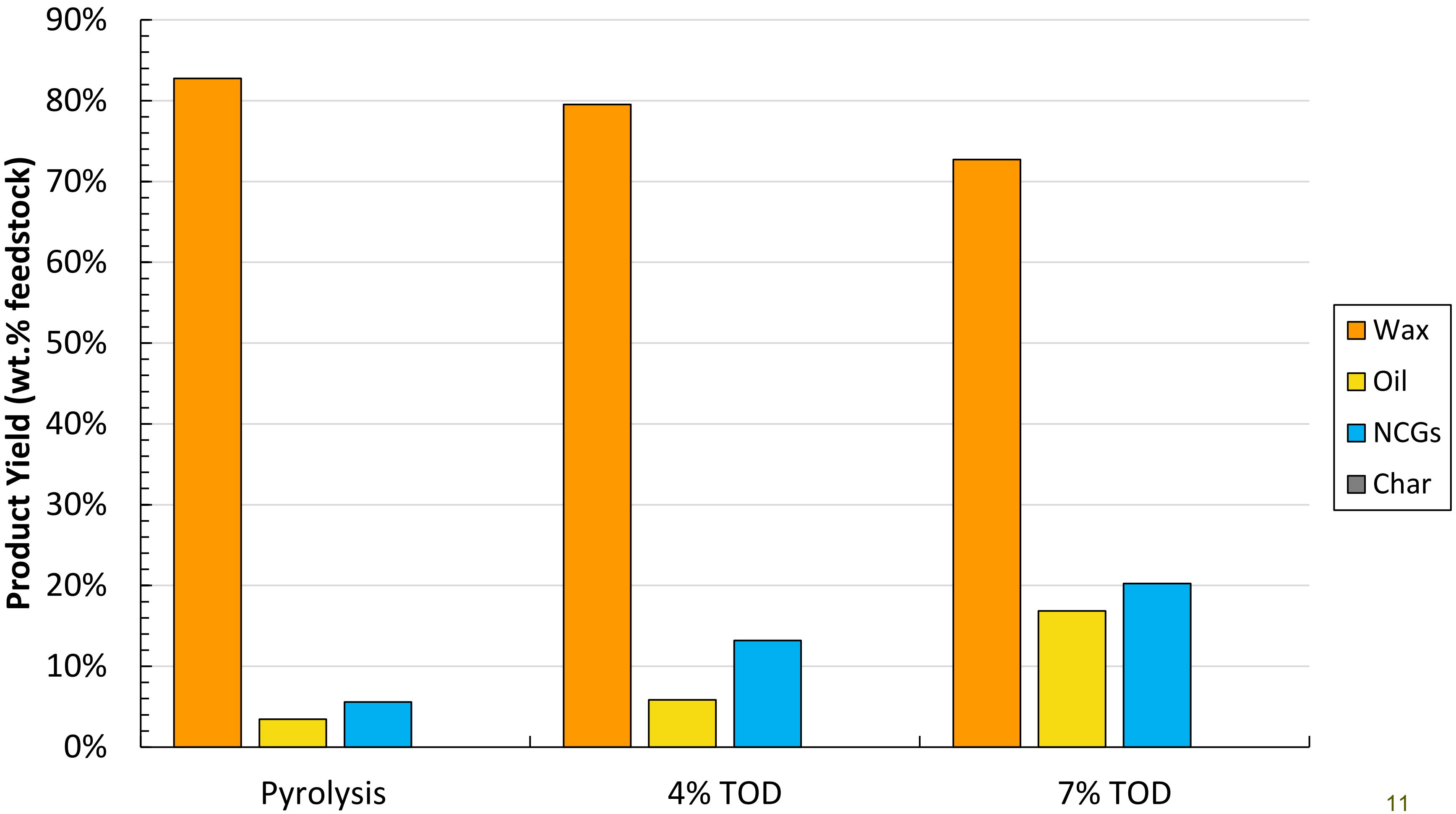


Effect of pyrolysis and thermal oxo-degradation on product distribution of polyethylene (HDPE)

Wax product from thermal oxo-degradation

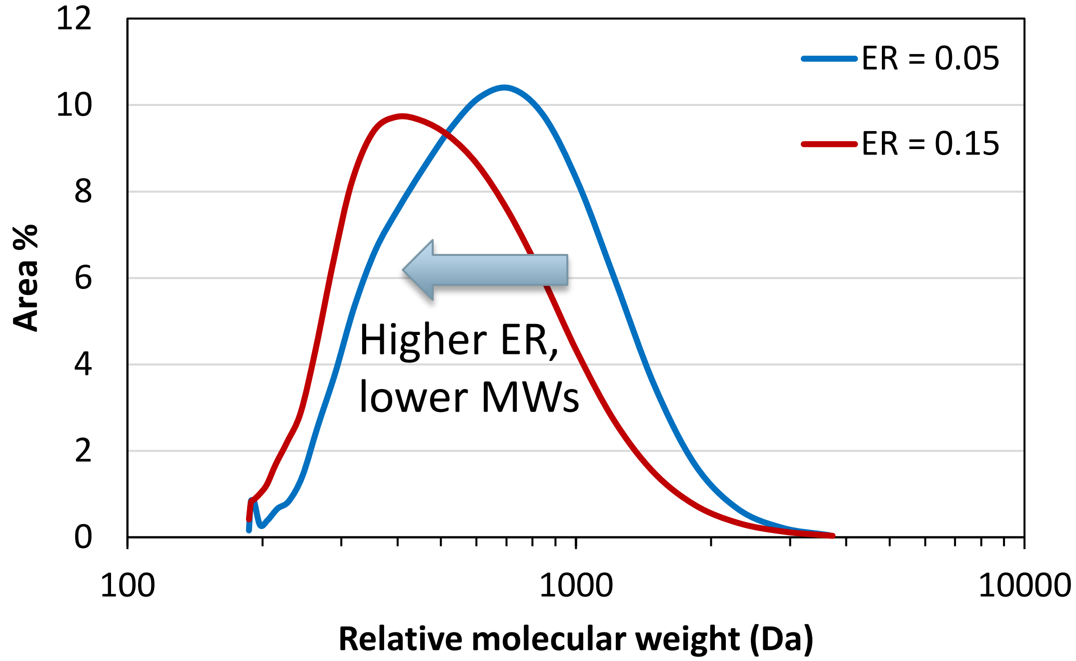


Liquid product from thermal oxo-degradation

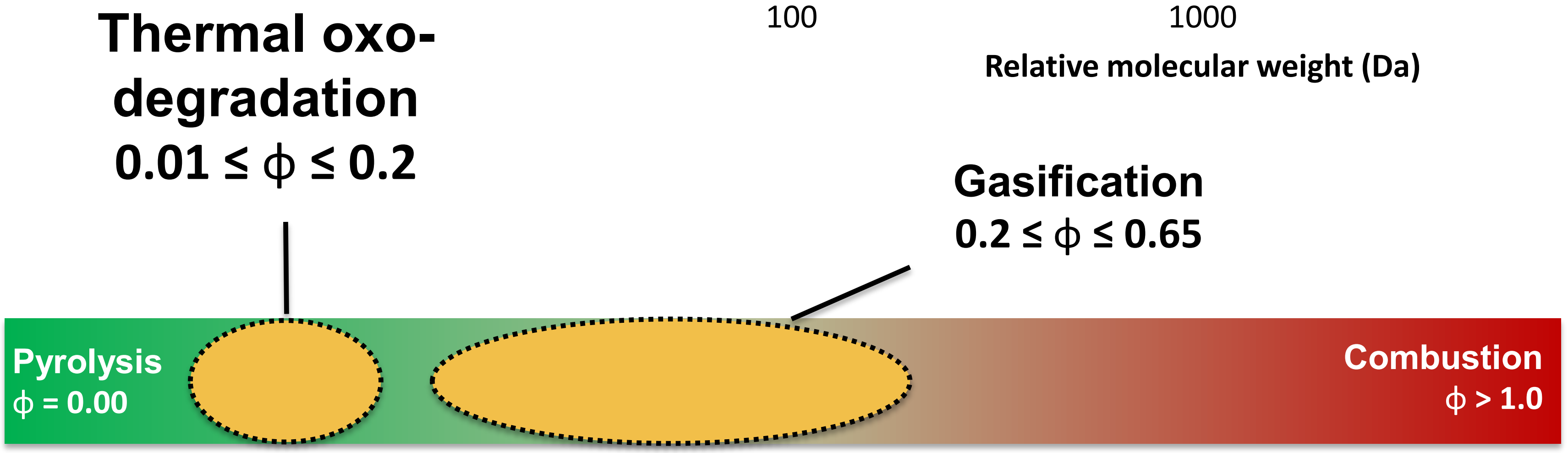


Factors affecting thermal oxo-degradation products

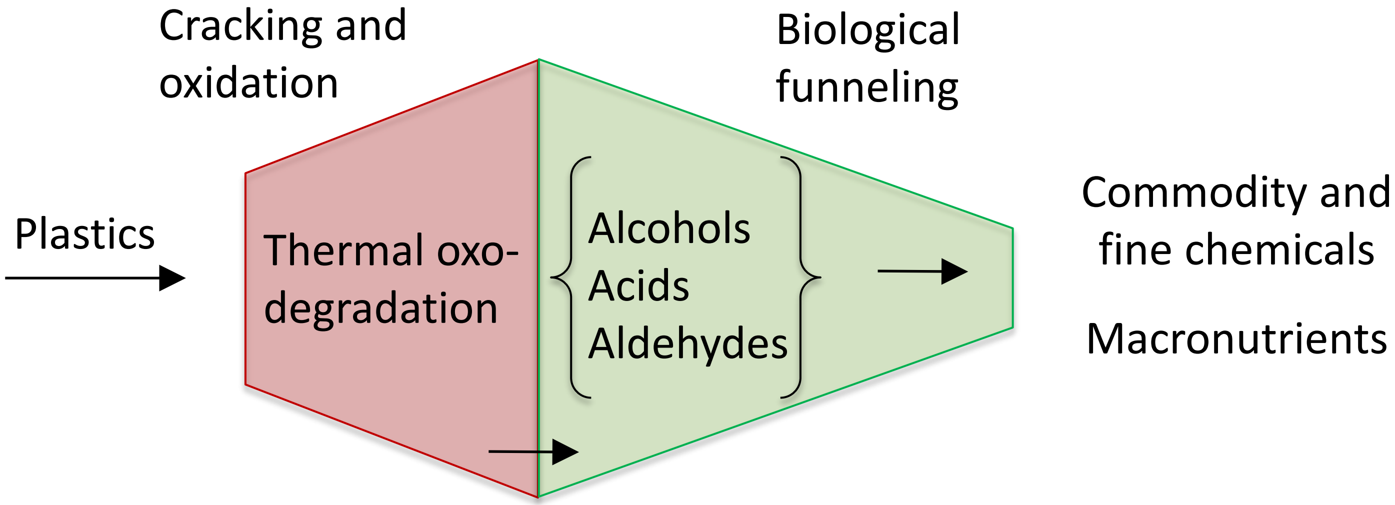
- Temperature
- Vapor residence time
- Oxygen concentration
- Equivalence ratio



$$\phi = \frac{Air}{Air_{Stoich}}$$



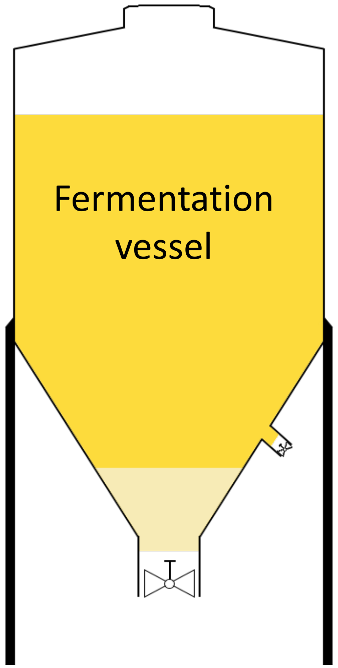
Product from thermal oxo-degradation can be biologically funneled to specific biochemical products



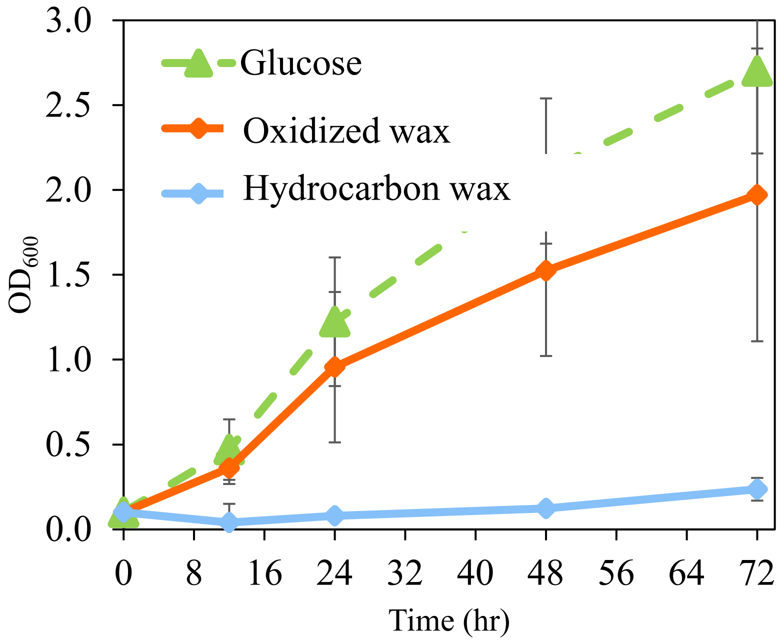
Thermal oxo-degradation as precursor to biochemical conversion

Yeast

TOD-derived wax



Dry and lyse product biomass



Single-cell protein produced from yeast grown on TOD

Commercially available yeast products

Next steps

Deriving TOD kinetics with various feedstocks

Determining reaction conditions which enhance microbial growth on TOD products

Performing technoeconomic analysis on TOD to prove commercial value

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