Hydrothermal Liquefaction as a Tool to Enable Plastic Circularity

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Plastic circularity is necessary to stop plastic pollution

Global plastic consumption, production, and waste generation has more than doubled since 2000

70% of plastic waste is disposed of by traditional methods

15% of plastic waste is collected for recycling, while 9% of plastic is recycled successfully

Remaining plastic eludes waste management and ends up incinerated or dumped into the ecosystem

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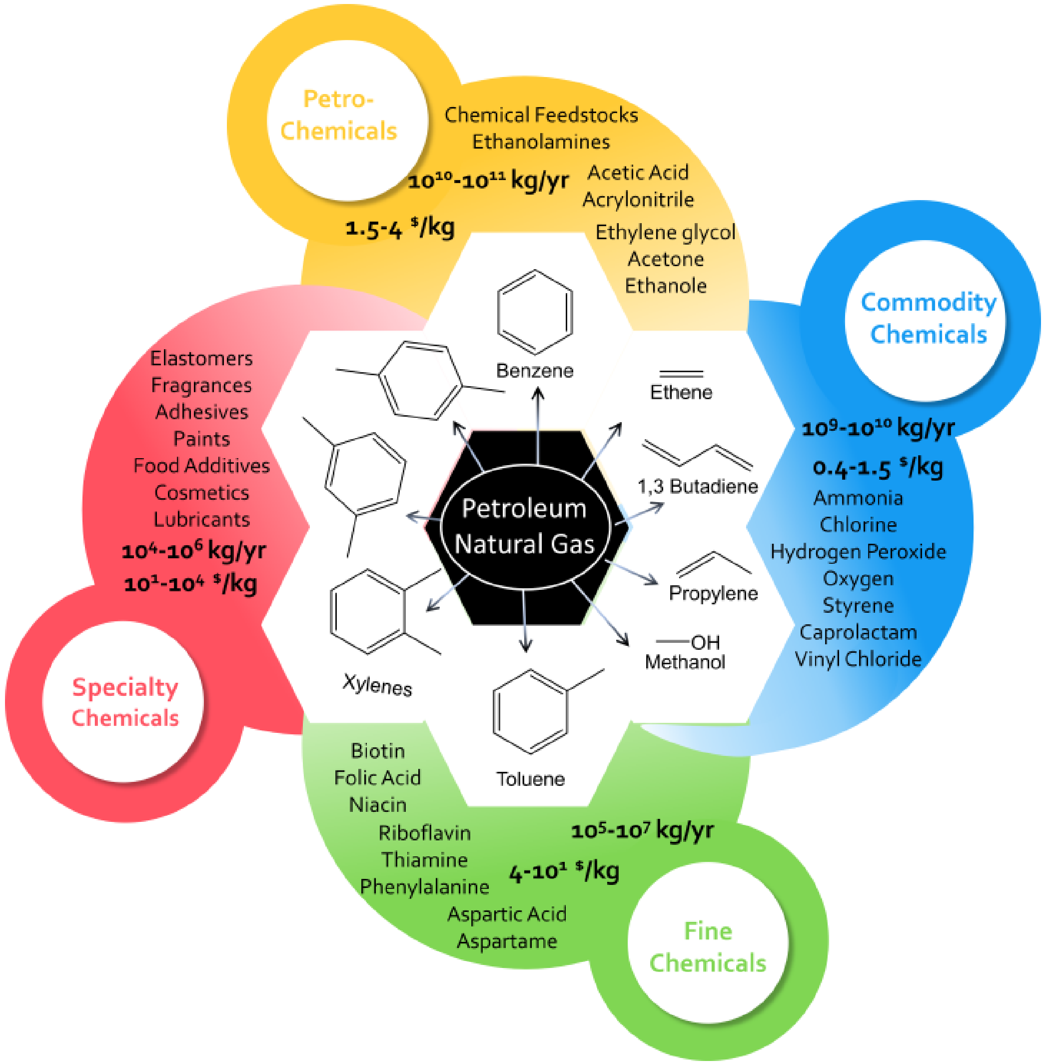
Innovative feedstocks improve sustainable industry



Only 7 petrochemicals are used as feedstocks for 90% of chemical processes

In 2012, petrochemical feedstock processing accounted for roughly 60% of the energy consumed in the chemicals sector

Energy for chemical processing could be lowered by creating value-added products or feedstocks from recycled plastics

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Hydrothermal liquefaction effectively breaks down plastics

Conversion of polyethylene waste into clean fuels and waxes via hydrothermal processing (HTP)

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[c] *Departmen*

Influence of reaction parameters on thermal liquefaction of plastic wastes into oil: A review

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Characteristics of polyethylene cracking in supercritical water compared to thermal cracking

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Hydrothermal liquefaction uses water to degrade plastic

Hydrothermal liquefaction is a **thermal depolymerization process** that converts organic waste, biomass, and other macromolecules, into value added products under moderate-extreme temperature and high pressure

Hydrothermal liquefaction uses subcritical and supercritical water as a universal reaction media

Features of supercritical water:

- Low dielectric constant
- Low viscosity
- High diffusivity
- Very low ionic product
- Acts as both solvent and catalyst
- Suitable for free radical reaction

	Normal Water	Sub-critical water	Super-critical water	
Temperature (°C)	25	250	400	400
Pressure (MPa)	0.1	5	25	50
Relative static dielectric constant (ε)	0.997	0.8	0.17	0.58
pK_W	78.50	27.10	5.90	10.50
Thermal Conducitivty (mW/mK)	0.89	0.11	0.03	0.07
Dynamic viscosity (mPAs)	608	620	160	438

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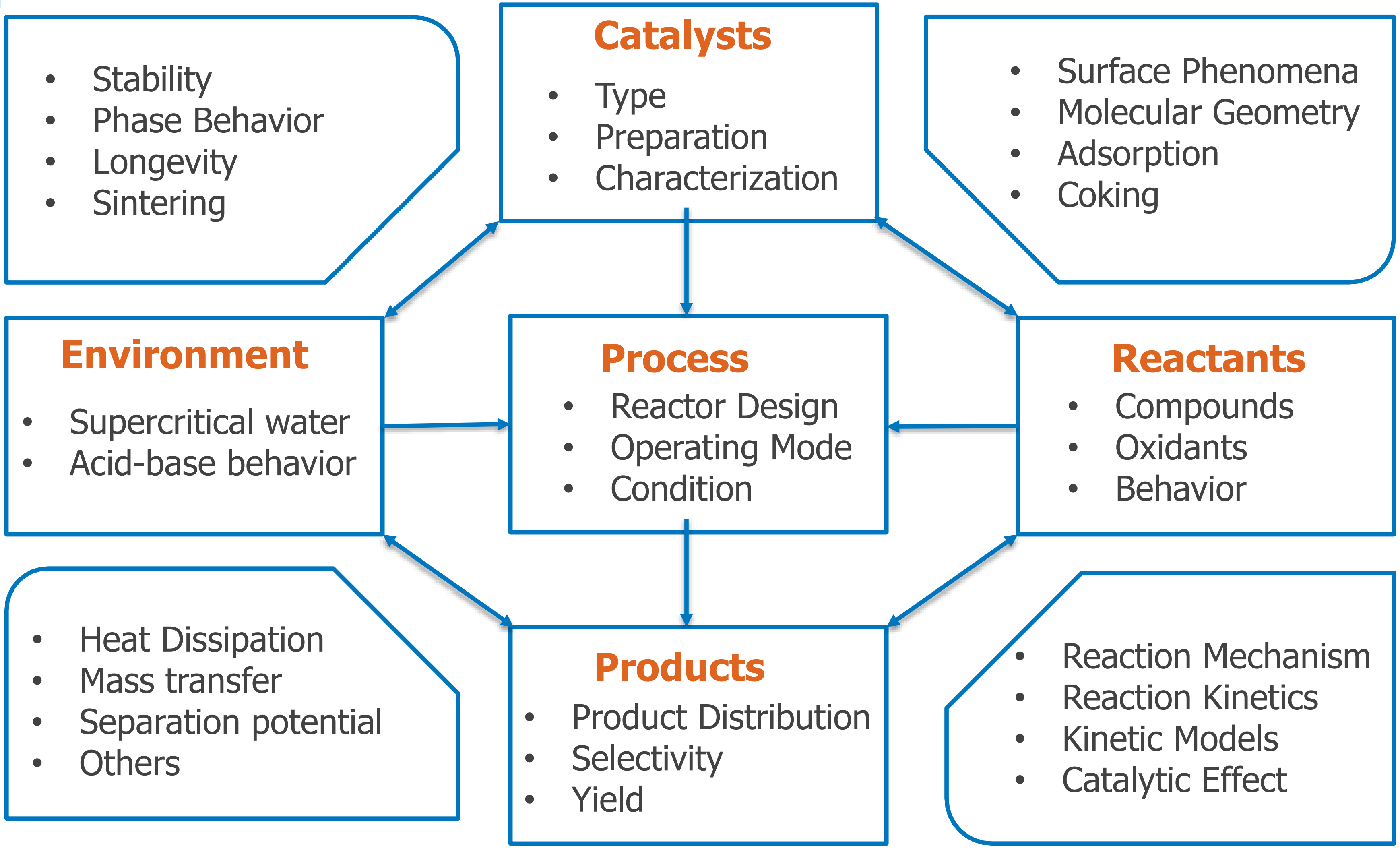
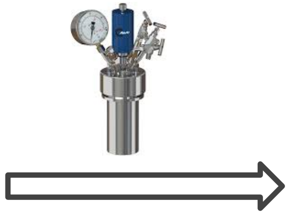
Tunable parameters offer a high level of reaction design



We investigated the influence of reaction parameters on LDPE breakdown

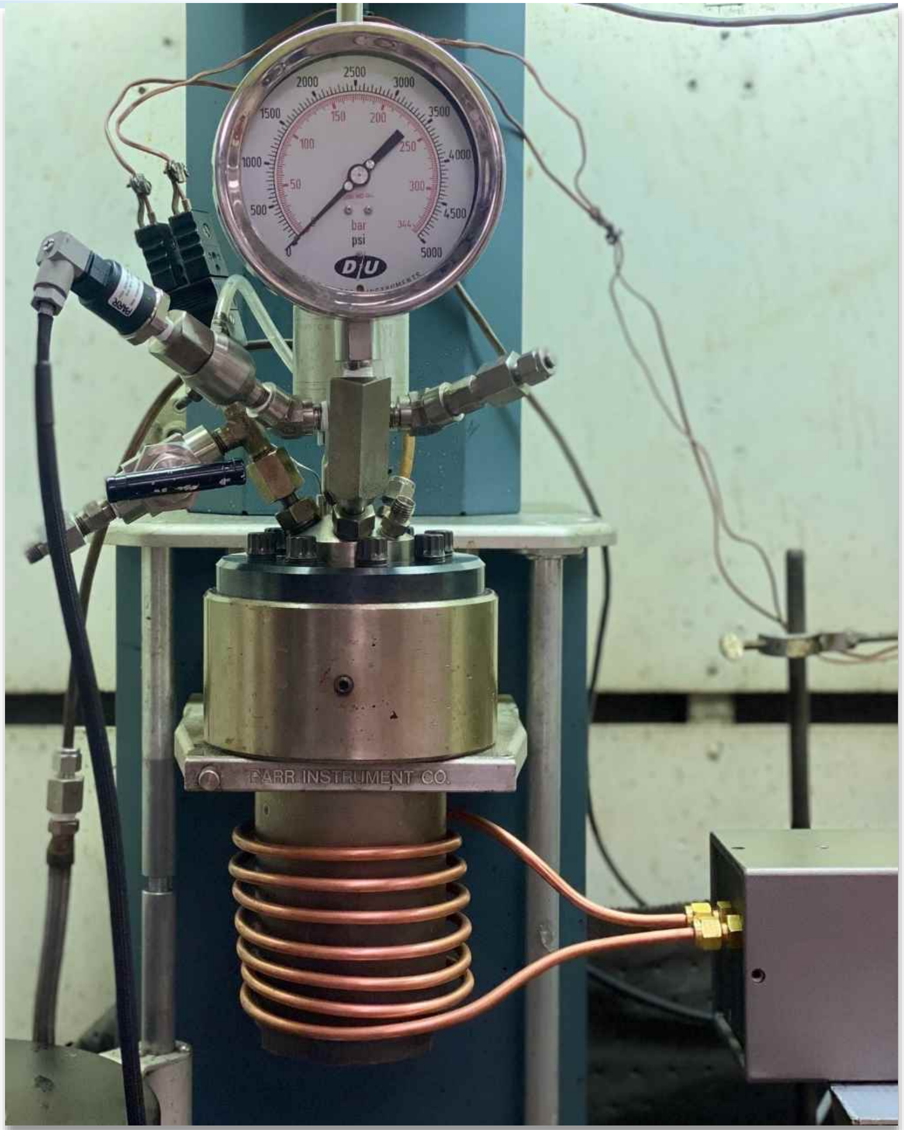
Starting material:
LDPE



Hydrothermal liquefaction

LDPE breakdown

- Temperature
- Pressure
- Reaction time
- Ratio of water to feedstock
- Catalytic influence



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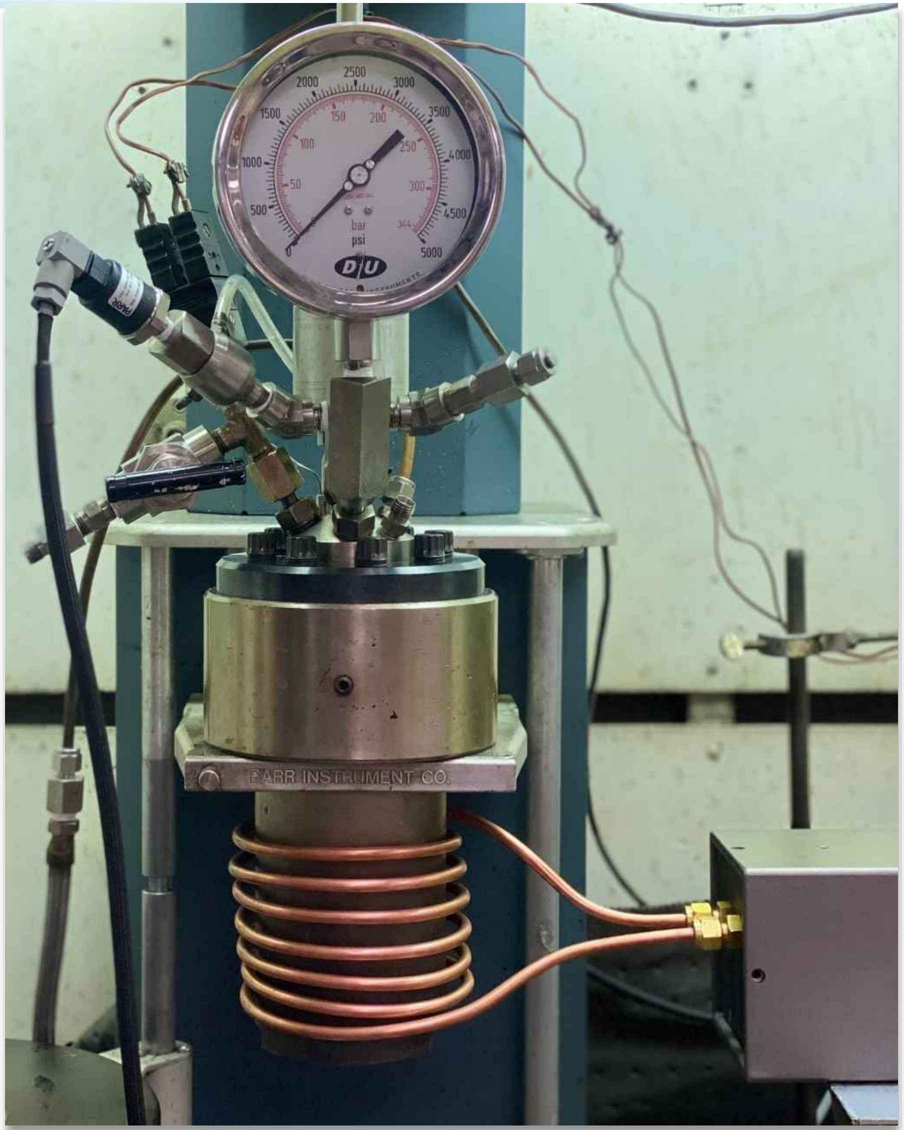

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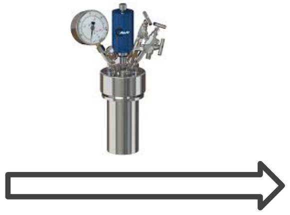
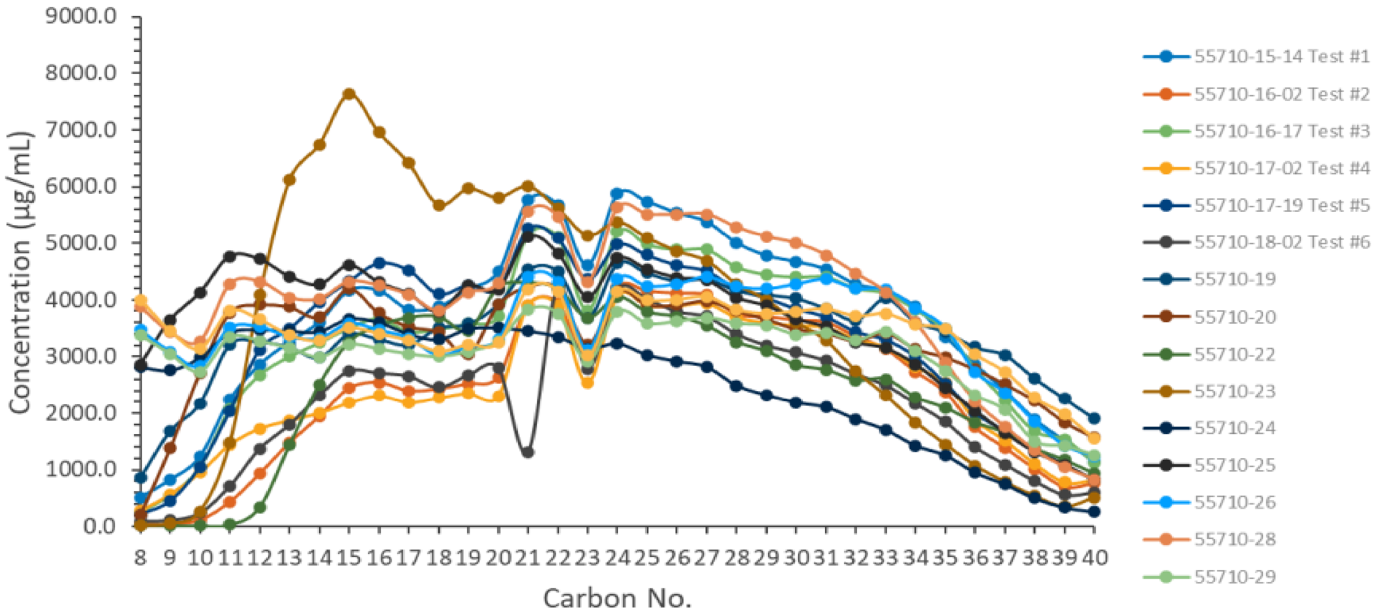
Reaction products vary from solids to oils

Starting material:
LDPE



Hydrothermal liquefaction

LDPE breakdown



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The majority of LDPE was converted to alkanes

#	Temp °C	Time	Feedstock LDPE	Feedstock: water ratio	% alkane	% alkene	% aromatic	Avg chain length
23	425 °C	60 min	25g	<1	High	Med	Low	17.3
24	425 °C	60 min	100g	1	High	Low	Low	18.8
25	425 °C	60 min	5g	<1	High	Med	Low	14.6
26	425 °C	60 min	5g	<1	High	Med	Low	16.3
32	425 °C	60 min	10g	>1	High	Med	Low	13
33	425 °C	60 min	10g	1	High	Med	Low	12.6
34	425 °C	60 min	10g	<1	High	Med	Low	12.7
48	435 °C	60 min	100g	1	High	Low	Low	13.5

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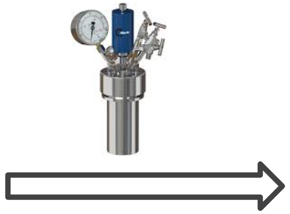
26	425 °C	60 min	5g	<1	High	Med	Low	16.3
32	425 °C	60 min	10g	>1	High	Med	Low	13
33	425 °C	60 min	10g	1	[illegible]	[illegible]	Low	12.6
34	425 °C	60 min	10g	<1	[illegible]	[illegible]	[illegible]	12.7
48	435 °C	60 min	100g	[illegible]	[illegible]	[illegible]	[illegible]	13.5

Water content, feedstock:water ratio, and temperature influence average chain length

We investigated the influence of catalysts on LDPE breakdown

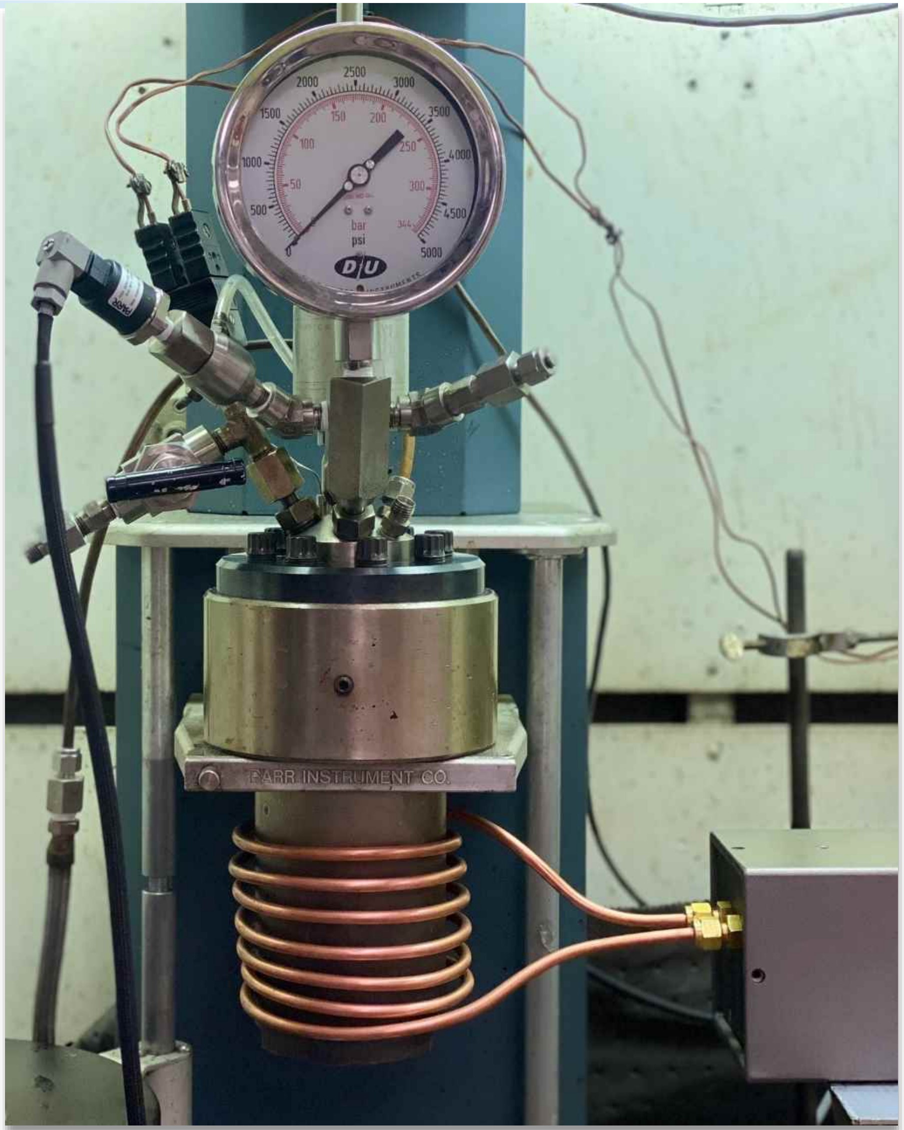
Starting material:
LDPE



Hydrothermal liquefaction

LDPE breakdown

- Temperature
- Pressure
- Reaction time
- Ratio of water to feedstock
- Catalytic influence



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Catalyst promotes aromatic production under supercritical conditions

#	Temp °C	Time	Feedstock LDPE	Solid Catalyst	Feedstock: water ratio	% alkane	% alkene	% aromatic	Avg chain length
32	425 °C	60 min	10g		>1	High	Med	Low	13
33	425 °C	60 min	10g		1	High	Med	Low	12.6
34	425 °C	60 min	10g		<1	High	Med	Low	12.7
35	425 °C	60 min	10g	0.5g	>1	High	Low	Med	9.3
36	425 °C	60 min	10g	0.5g	1	High	Low	Med	9.0
37	425 °C	60 min	10g	0.5g	<1	High	Low	Med	9.5

Catalyst promotes aromatic production under supercritical conditions

#	Temp °C	Time	Feedstock LDPE	Solid Catalyst	Feedstock: water ratio	% alkane	% alkene	% aromatic	Avg chain length
32	425 °C	60 min	10g		>1	High	Med	Low	13
33	425 °C	60 min	10g		1	High	Med	Low	12.6
34	425 °C	60 min	10g		<1	High	Med	Low	12.7
35	425 °C	60 min	10g	0.5g	[illegible]	[illegible]	[illegible]	Med	9.3
36	425 °C	60 min	10g	0.5g	[illegible]	[illegible]	[illegible]	Med	9.0
37	425 °C	60 min	10g	0.5g	<1	High	Low	Med	9.5

Catalyst promotes aromatic products and reduces average chain length

Conclusions

Degrading chemically resistant plastics can be challenging. Hydrothermal liquefaction is a promising technology for degrading and re-functionalizing plastic waste.

The reaction parameters for hydrothermal liquefaction can be tuned to change products and physical properties. Use of catalysts increases the variety of products available using hydrothermal liquefaction.

Currently, the influence of reaction parameters, catalysts, and solvent selection is being used to investigate hydrothermal liquefaction of different plastics and mixed waste.

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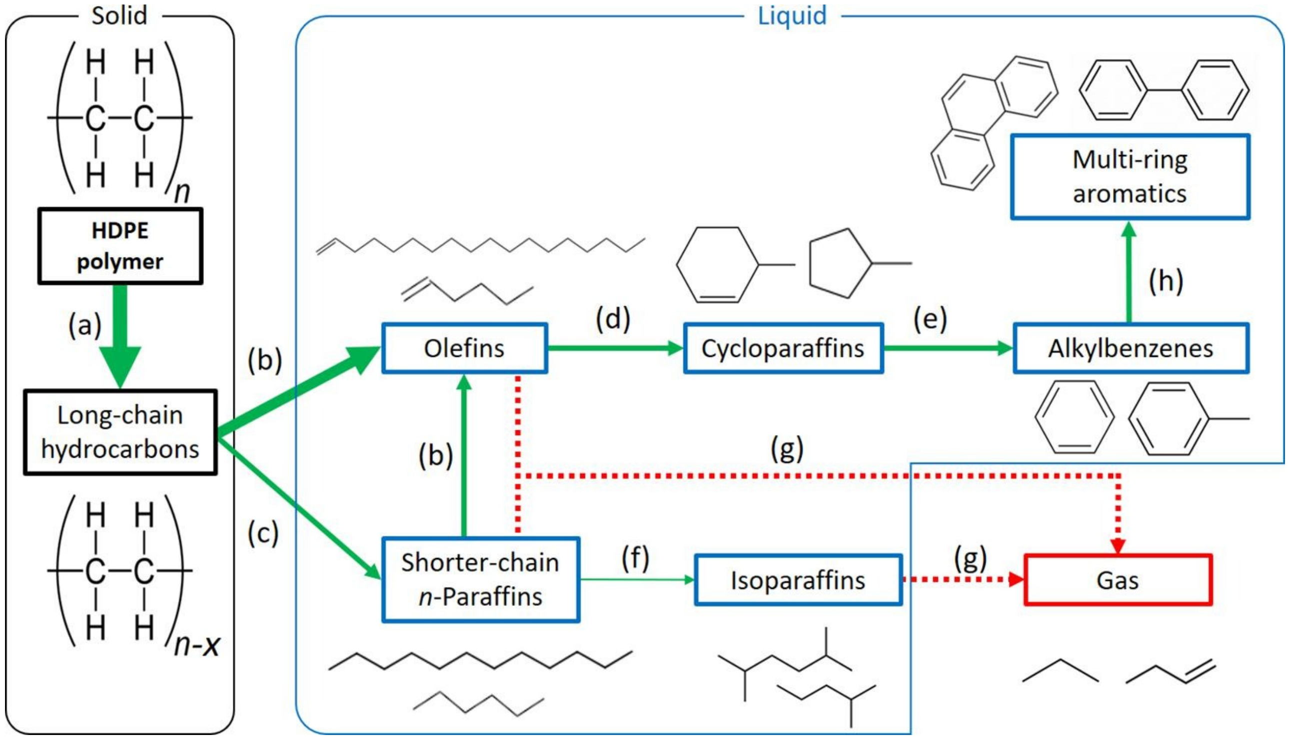
Thank you for your time!

Extra slides

PE degradation mechanism & insight

- Bockhorn *et al* suggest mechanism for PE decomposition is radical chain mechanism
- Initial polymer chain random cracking will form alkenes by b-scission and hydrogen abstraction
- The alkene/alkane ratio is determined by the contribution of b-scission and intermolecular hydrogen reaction

- Alkene/alkane ratio and selectivity of alkadienes increase with increasing b-scission
- The product distribution helps narrow down which pathway our reaction is taking
- Zhang suggests in flow reactor primary radicals surrounded by flowing SCW reduces hydrogen abstraction and enhances unimolecular b-scission



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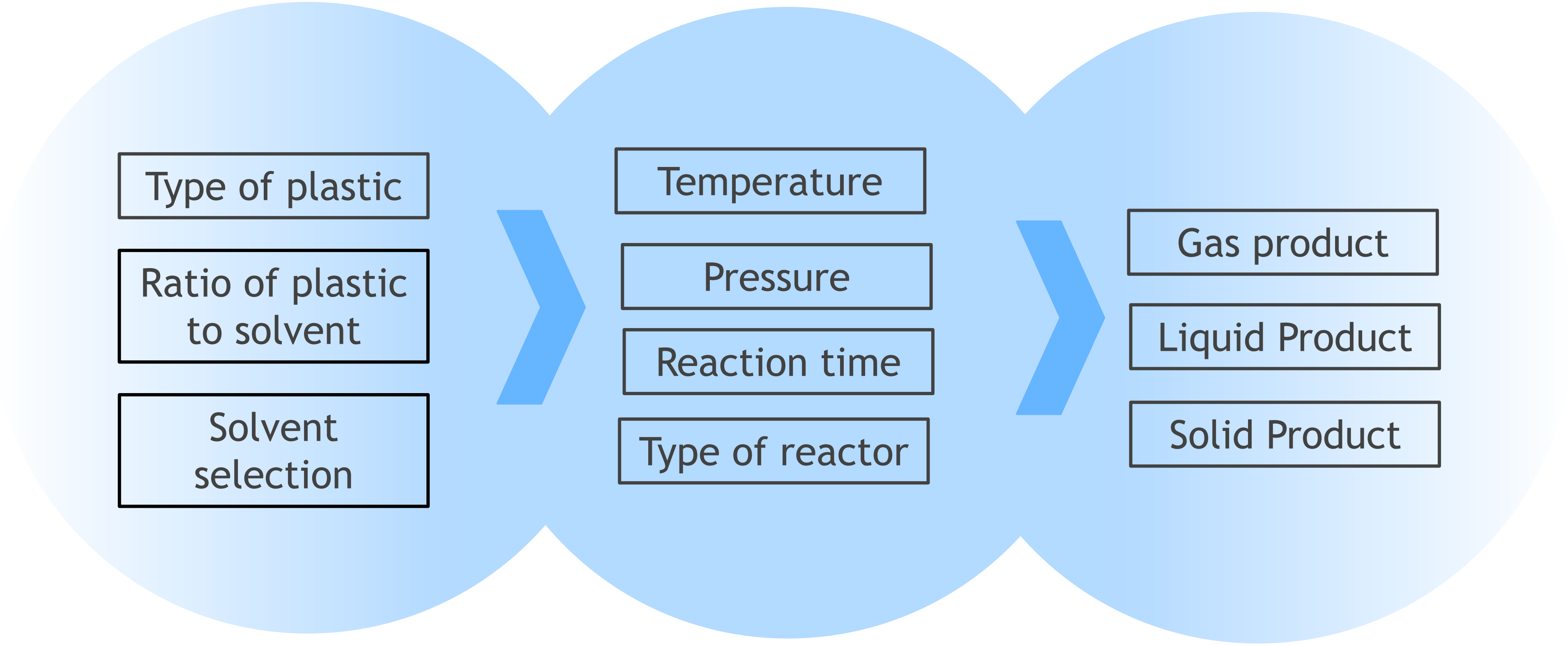
Type of plastic
Ratio of plastic to solvent
Solvent selection
Temperature
Pressure
Reaction time
Type of reactor
Gas product
Liquid Product
Solid Product