Speaker introductions

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Agenda

1. Introduction
2. Imagining a BBC future
3. Polymer essentials
   • Types
   • Markets and opportunities
   • Concerns
4. Polymer production processes
5. Fundamental challenges
6. Insights and conclusions
7. Webinar Series: Recap
Introduction to the webinar

Bitumen Beyond Combustion
Recap: Imagining a BBC future
Polymers from bitumen: key questions

• What polymers to make?
• How to make them from bitumen?
What are polymers?

• **Plastics are encountered daily**
  • Plastics - generally a synthetic material made from single / combination of polymer(s) and various additives (e.g. pigment)
  • Consumer / industrial / medical applications
  • Adhesives, bubble-gum, carpeting, clothing, cosmetics, drill muds, flooring/furniture, hygiene products, packaging / bottles, paint, piping, sealants, siding, water treatment etc.

• **Polymers - products used to make plastics**
  • Made from monomers
  • Mono(mer) – ‘one’ unit
  • Poly(mer) – many units
  • Polymerization: the joining of monomers to create a “polymer chain”
  • Chain length: can be varied by design; can be very long e.g. flocculants (water treatment)
    • The chain can contain more >1 monomer, randomly distributed or not

• **Where do polymers come from?**
  • Natural     Semi-Synthetic     Synthetic
Natural polymers

- **Polysaccharide** (storage (energy) / structure)
  - Cellulose (glucose)
  - Other: chitin, cotton, keratin, starch

- **Natural rubber**
  - Poly-Isoprene

- **Polyaromatic**
  - Lignin

- **Proteins (amino acids)**
  - Silk (glycine, serine, alanine)
  - Gelatin, keratin
Semi-Synthetic polymers

• Example
  • Cellulose acetate (chemically modified cellulose)
  • Feed: purified natural cellulose from cotton linters or wood pulp
  • Use
    • Cigarette filters
    • Lego bricks (1949 - 1963)
    • Magnetic tape (IBM)
    • Photographic film (Eastman Kodak)

• Transition - 1950’s
  • Natural to synthetic polymers
    • 1950: 2 million tons
    • 2015: 380 million tons
  • Enabler
    • Rapid development in synthetic chemistry / material science
    • Example:
      • Tupperware – developed by Earl Tupper in 1937 at DuPont
      • Teflon – Du Pont (1938)

Synthetic polymers

• **Synthetic polymers**
  - Produced from monomers
  - Monomers: produced from (petro)-chemical feeds / intermediates

• **Polymer development was / continues to be driven by**
  - Demand for improved product
  - Advantage of synthetics: range of monomers offers the opportunity for molecular design
  - Technology development in refining / petrochemical sectors
  - Geographic availability of natural polymers e.g. natural rubber (tire industry)
  - Politics / economics / society

• **Global production of major polymers**
  - 1950: 2 million tons
  - 2015: 380 million tons

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Common modern synthetic polymers

- **PA** - Polyamides (e.g. Nylon)
- **PE (LD, LLD, MD, HD)** - Polyethylene series
- **PET** - Polyethylene terephthalate
- **PP** - Polypropylene
- **PS** - Polystyrene
- **PUR** - Polyurethane
- **PVC** - Polyvinyl chloride
- **SBR** - Styrene Butadiene Rubber
Market segments

• Commodity plastics
  • Ease of use, convenience

• Engineering plastics
  • Mechanical / thermal performance

• High performance plastics
  • Mechanical / thermal performance
Opportunity

- Plastics / polymers - an essential part of everyday life
- Global plastics market (forecast): US$ 654 billion (2020). By 2030, expected to grow to US$ 1 trillion
- Growth (2015 – 2020): 3.9%
  - Drivers: population, urbanisation, growing middle class, environmental aspects (bio-polymer)

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Mt/y (1)</th>
<th>Bitumen bpd (2)</th>
<th>% Split</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP</td>
<td>68</td>
<td>1,256,000</td>
<td>23%</td>
</tr>
<tr>
<td>LD, LDPE</td>
<td>64</td>
<td>1,182,000</td>
<td>22%</td>
</tr>
<tr>
<td>PP &amp; A</td>
<td>59</td>
<td>810,000</td>
<td>15%</td>
</tr>
<tr>
<td>HDPE</td>
<td>52</td>
<td>961,000</td>
<td>18%</td>
</tr>
<tr>
<td>PVC</td>
<td>38</td>
<td>315,000</td>
<td>6%</td>
</tr>
<tr>
<td>PET</td>
<td>33</td>
<td>445,000</td>
<td>8%</td>
</tr>
<tr>
<td>PUR</td>
<td>27</td>
<td>381,000</td>
<td>7%</td>
</tr>
<tr>
<td>PS</td>
<td>25</td>
<td>498,000</td>
<td>9%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>407</strong></td>
<td><strong>5,350,000</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

NOTE: Given the rate of change in the polymer sector, challenges of obtaining / verifying market data, the table to be read for illustrative purposes


(2) Alberta Innovates - rough approximation

**What do power and poly refer to here?**
Concerns with existing polymers
Definitions

• Biodegradable
  • A materials deterioration both chemical / mechanical (size) by natural means (air, light, micro-organisms)
  • Biodegradable materials and products of biodegradation are not necessarily compostable nor environmentally safe

• Compostable
  • Materials that break-down chemically under composting and anaerobic digestion conditions
    • Domestic composting: <55°C (unstable), lower humidity and oxygen levels
    • Industrial composting: 55-60°C, high humidity, oxygen. European Standard EU 13432
Plastic / polymer waste

- **Beverage bottles**
  - Polyethylene Terephthalate (PET)
  - Properties
    - Flexible / strong, light, non-toxic, 100% recyclable / not biodegradable
    - Recycling complexity increases with mixed waste
  - Volume
    - USA: ~50 billion plastic water bottles / annum. 153 disposable bottles / person / annum
  - Waste (globally)
    - 2015: 6,300 million tons plastic waste. Landfill 79%; incinerated 12%, 9% recycled

- **Carpets**
  - Not biodegradable, highly complex mix of inseparable materials (adhesives, anti-statistics, pigments, UV stabilizers (fading)
  - European Union
    - 1.6 million tons are disposed of, 960ktpa (60%) landfilled
    - Germany: 400ktpa incinerated, landfilling prohibited
  - United States
    - 2014: produces 1 billion m² of carpet / rugs
    - Reference: [https://changingmarkets.org/about/](https://changingmarkets.org/about/)
Slow degradation - synthetic polymers

- **Degradation mechanisms**
  - Mechanical: river / sea action
  - Chemical
    - Microbial / aerobic / anaerobic
    - Photo-chemical: sunlight (UV)
    - Thermal: cold / heat

- **Design**
  - Synthetic polymers are typically not designed to degrade
  - Modern polymers
    - Chemically different to natural polymers
    - Most modern polymers largely biochemically inert
    - Degradability: function of the polymers chemical composition / structure

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**Polyethylene**
![Polyethylene](https://accendoreliability.com/polyethylene-properties-uses/)

**Cotton**
![Cotton](http://textileleamer.blogspot.com/2013/04/structure-of-cotton-fiber.html)

Ref: [https://accendoreliability.com/polyethylene-properties-uses/](https://accendoreliability.com/polyethylene-properties-uses/)
Opportunity

- **Plastics / polymers**
  - An essential part of everyday life
  - Growth (2015 – 2020): 3.9%
    - Drivers: population, urbanisation, growing middle class, environmental aspects

- **‘Biopolymers’ outlook**
  - Growth(2015-2016): 4.4%
  - 2016
    - 6.6 million tons produced
    - <1% of global polymer production
  - 2021 (forecast)
    - 8.5 million tons
  - 2030 (forecast)
    - ~25 million tons (@ 5% of total polymer)

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Are the figure and table repeated for emphasis?

Does the term ‘biopolymers’ survive?

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### World Plastic Consumption (1960 - 2015) and forecast

<table>
<thead>
<tr>
<th>Year</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>500 million tons</td>
</tr>
<tr>
<td>2020</td>
<td>700 million tons</td>
</tr>
<tr>
<td>2030</td>
<td>900 million tons</td>
</tr>
</tbody>
</table>

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**Polymer** | **Mt/y** | **Bitumen bpd** | **% Split**
--- | --- | --- | ---
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Total | 407 | 5,350,000 | 100%

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Polymer production processes
Current **synthetic** polymer production processes:

Schematic flowsheet with Bitumen as feedstock

- **Extensive Conversion/ Separation**
  - Pure HC feedstock
- **React**
  - High T
  - High P
  - Catalysts
  - Fast
- **Separate/ Combine**
- **Form**

**Other feedstocks**

**Polymer**

Generally not biodegradable/ compostable
Natural polymer production processes: Schematic

- Mixed Feed
- React
  - Low T
  - Low P
  - Enzymes
  - Slow
- Separate/Combine
- Form
- Polymer
- Biodegradable/compostable
Potential polymer production processes:
Schematic flowsheet with Bitumen as feedstock
Polymer production processes: **Generic flowsheet** with Bitumen as feedstock

Bitumen → Pre-treatment → Feedstock → React

- $T$
- $P$
- **Catalysts**
- **Enzymes**

Separate/Combine → Form → Polymer

Other → Energy

Output: Biodegradable/compostable – if desired
Technical challenges
Challenges to produce polymers from bitumen

• **Choice of polymers**
  - Meeting expectations: performance, cost, biodegradability / compostability, reuse, recyclability, end-of-life disposition, environment, and social acceptance
    - Conventional synthetic polymers: inherently challenged
    - Unconventional synthetic polymers (e.g., cross-linked, protein-based, and ‘irregular’ polymers): promising

• **Selection of polymer pathways and flowsheets for complex bitumen feedstock**
  - Conventional synthetic polymers: integrated with traditional bitumen refining
  - Unconventional synthetic polymers: largely undeveloped

• **Quantification of energy requirements and GHG emissions**
Insights and conclusions
Insights and conclusions: Polymers

- Synthetic polymer industry: large, global, and growing
- Current major synthetic polymers: environmental and other concerns
- New (biologically inspired and irregular polymers) and their processes may lead to fundamentally new approaches and uses of bitumen
Webinar Series Recap
• Rising populations and prosperity drive large-scale demands for materials (e.g., housing, vehicles, consumer goods)

• Producing materials from bitumen (‘BBC products’) diversifies Canada’s oil sands sector

• BBC products pose fruitful business, scientific, technical, environmental, and social challenges

• Four major BBC product categories (with >100,000 bpd bitumen requirements) have emerged to date:
  • Carbon fibres and their combination products
  • Asphalts and asphalt transportation
  • Polymers
  • Vanadium for electricity storage

• Alberta Innovates supports the development of these and other BBC products, their production, and uses
Questions?

Quick Links

View the reports

News release
https://albertainnovates.ca/bitumen-beyond-combustion-program-invests-2-million-in-research/

View all webinars
https://vimeo.com/cosia

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