Recent progress in the generation of value-added lignin derivatives via industrially attractive processes

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Sept 15, 2021

Lignin opportunities

- Abundant in agro- and woody based materials
- Lignin is approximately 1/3 of biomass
- Relatively easy lignin production process (LignoBoost, LignoForce, LignoTall and others)
- Biorefining operations may be feasible if biomass is fully utilized
- Knowledge gap exists for the conversion of lignin to chemicals

Flocculant applications and challenges

- Water and wastewater purification
  - Municipal and industrial
- A large volume of flocculants
  - Inorganic coagulants (e.g., Alum)
    - High dosage
    - Sludge production
  - Synthetic flocculants
    - Expensive
    - Ineffective
    - Oil based
  - Polyacrylamide based
    - Sales in 2013: $3.95 billion (USD)
    - Sales in 2019: $6.91 billion (USD)

https://www.prnewswire.com/news-releases/polyacrylamide-market---global-industry-analysis-size-share-growth-trends--forecast-2013---2019-244707421.html

Dispersant uses and challenges

- **Applications**
  - Water based paints and stains
  - Froth flotation of the mining industry
  - Construction industry; water reducing agent in concrete admixtures
  - Textile industry; pigment dispersion
  - Ceramic industry; clay suspension

- **Current chemicals**
  - Polyacrylic acid, poly methacrylic acid, poly phosphates
  - Sodium naphthalene
- Status
  - Expensive
  - Oil based

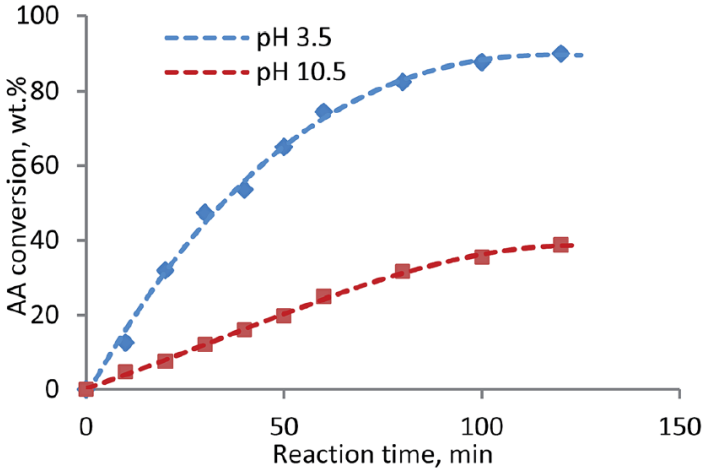
Approaches taken for lignin-based flocculant and dispersant productions

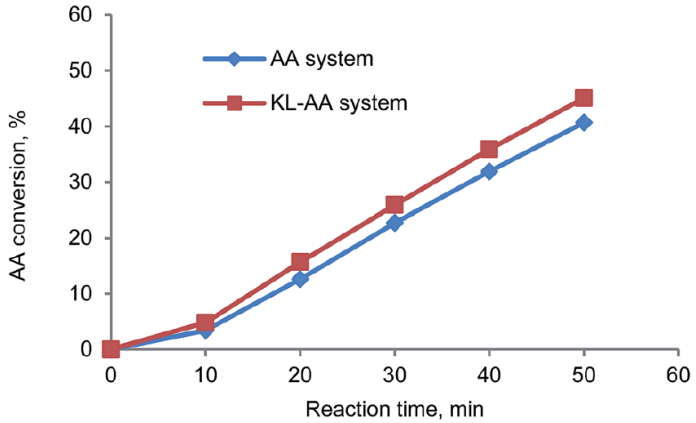
- Oxidation (to produce low MW lignin)
- Grafting (to produce low to medium MW lignin)
- Polymerization (to produce high MW lignin)
- **Among many alternative routes, those seem to be industrially meaningful (e.g., aqueous atmospheric systems) were studied.**

Summary of oxidation and grafting approaches

- Grafting in acidic, alkaline and nonaqueous systems
  - Dispersants for dyes, cement, clay
- Suitable for pulping and chemical companies
- Low to medium MW (<50,000 g/mol)
- Highly charged product (up to almost 4 meq/g)
- The analyses were conducted
  - How different chemicals with different carbon chain lengths and charged groups would react with lignin and make lignin derivatives with different properties/performance
  - Which one is suitable for industrial implementation in terms of production costs, performance, environmental footprints…etc

Lignin polymerization under acidic pH





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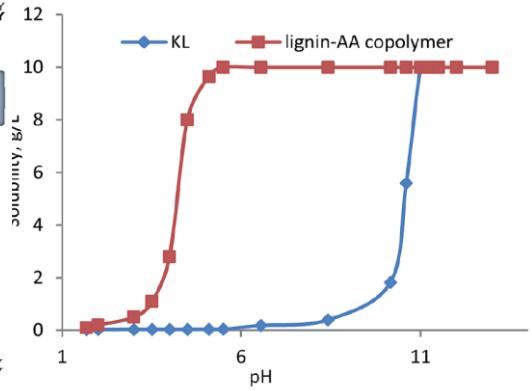
Novel pathway to produce high molecular weight kraft lignin–acrylic acid polymers in acidic suspension systems†

Fangong Kong,[ab] Shoujuan Wang,*[ab] Weijue Gao[b] and Pedram Fatehi*[b]



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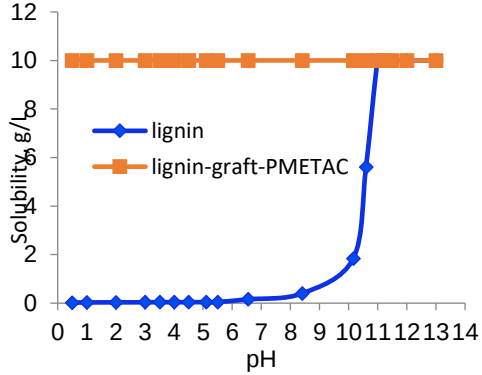
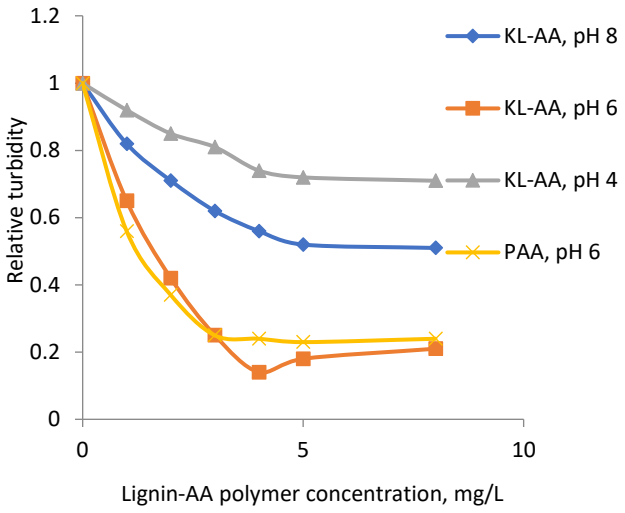
Water soluble kraft lignin–acrylic acid copolymer: synthesis and characterization†

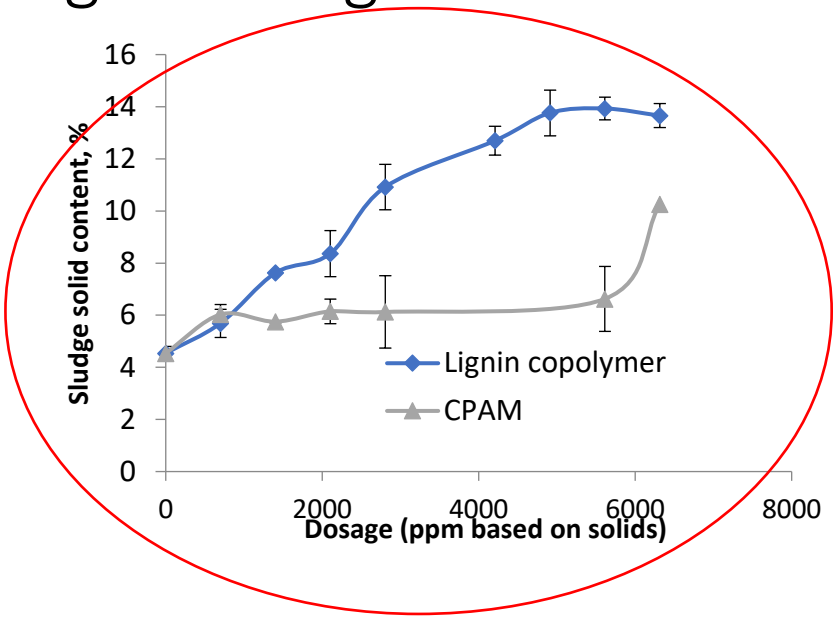
Fangong Kong,[a,b] Shoujuan Wang,[a,b] Jacquelyn T. Price,[b,c] Mohan K.R. Konduri[b] and Pedram Fatehi*[b]

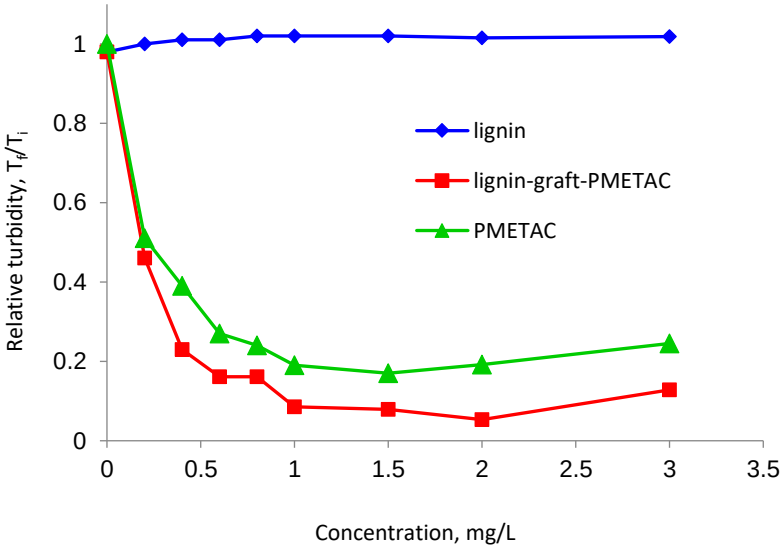


High MW lignin as flocculant

Dynamic Drainage Jar







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I&EC research
Industrial & Engineering Chemistry Research

Article

Cite This: *Ind. Eng. Chem. Res.* 2018, 57, 6595−6608

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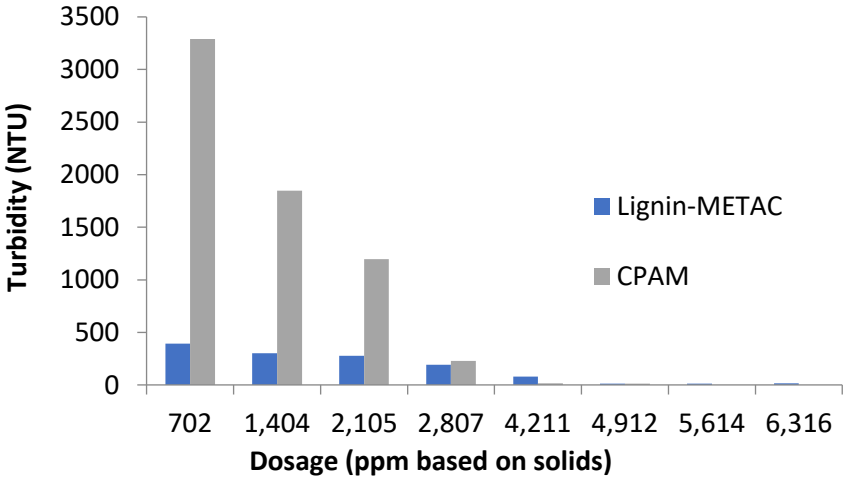
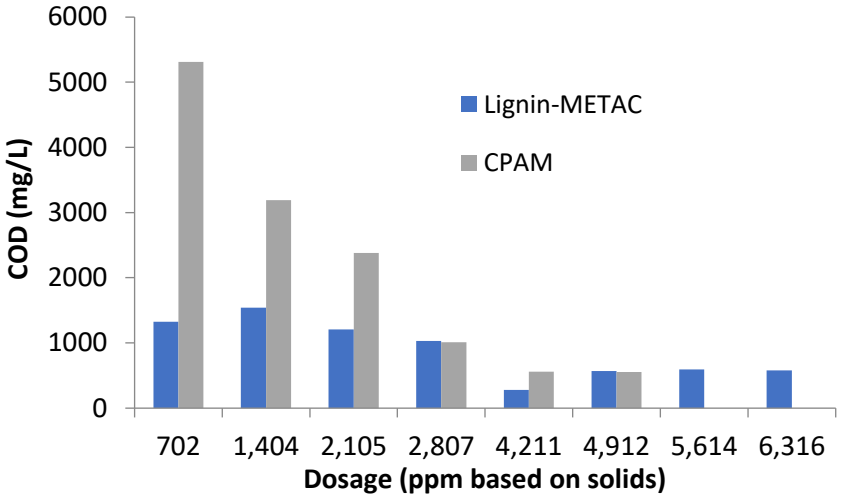
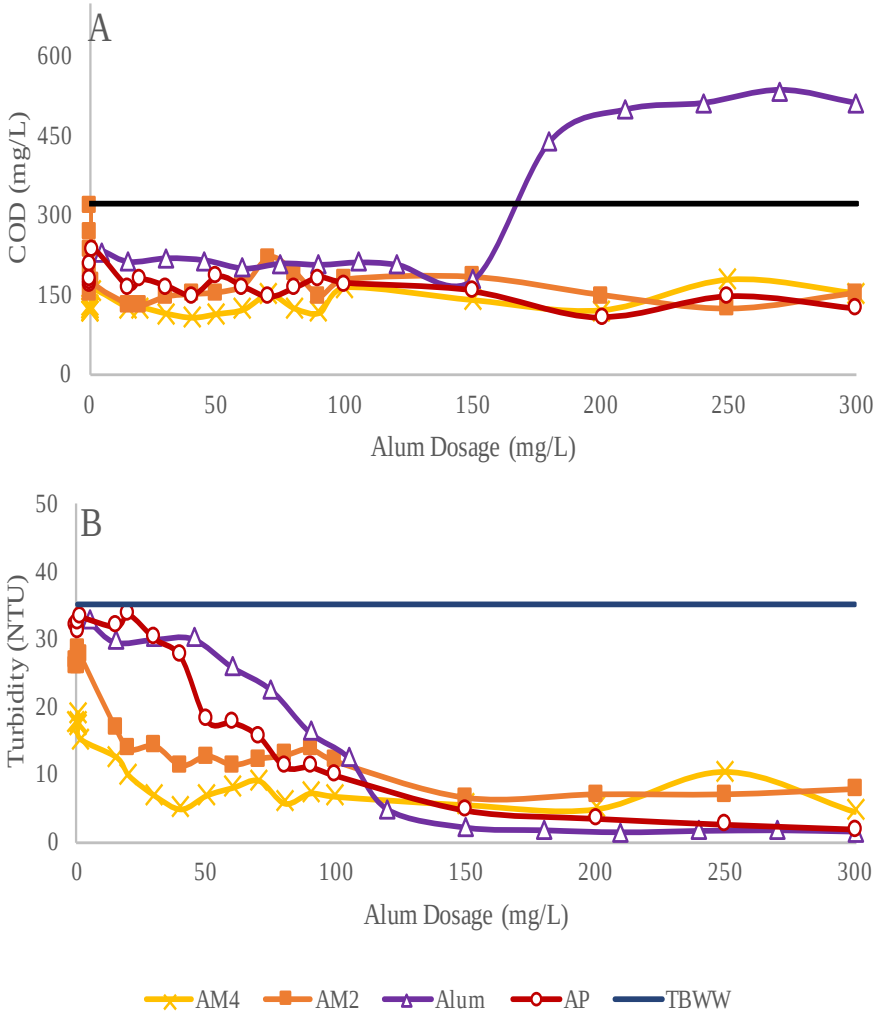
Novel Process for Generating Cationic Lignin Based Flocculant

Shoujuan Wang,[†,‡] Fangong Kong,*[,†,‡] Weijue Gao,[‡] and Pedram Fatehi*[,‡]

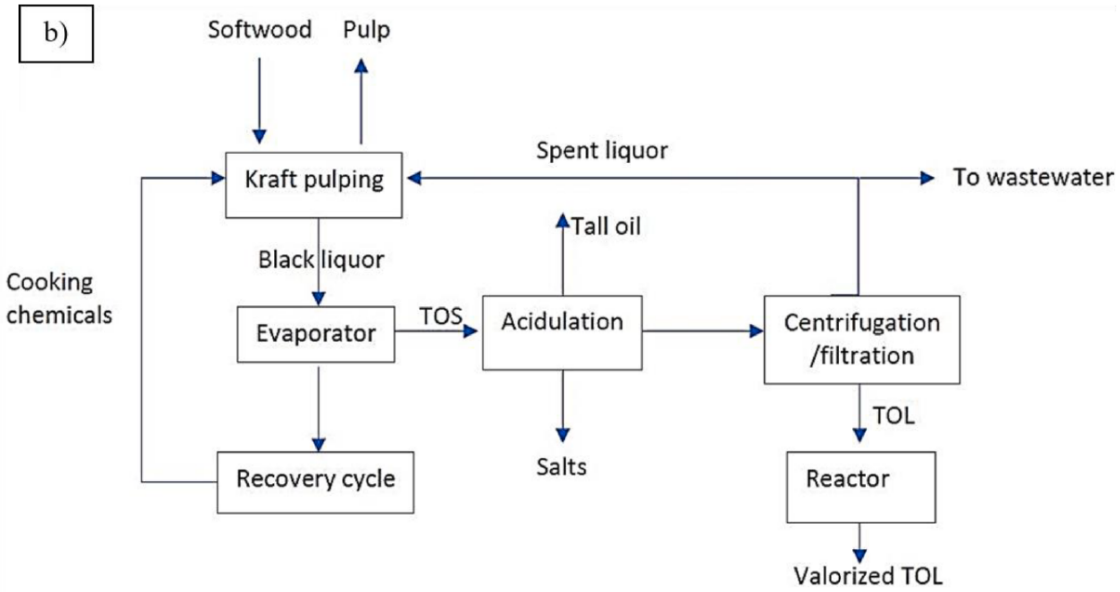
Application in municipal wastewater







Lignotall process



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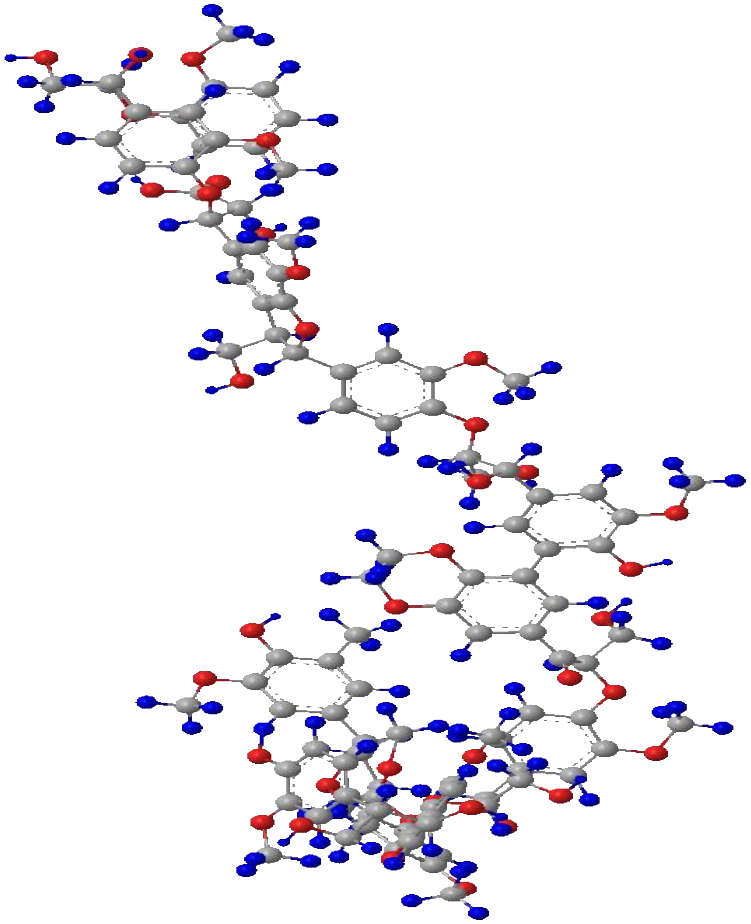
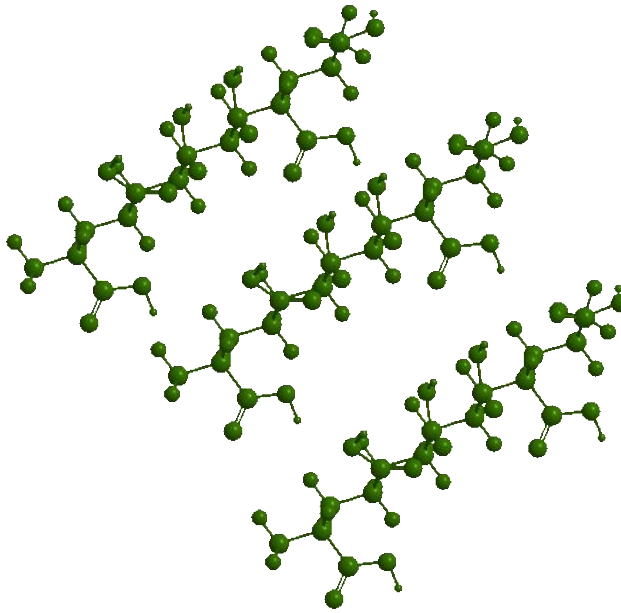
Process development for tall oil lignin production

Jonathan A. Diaz-Baca, Pedram Fatehi *

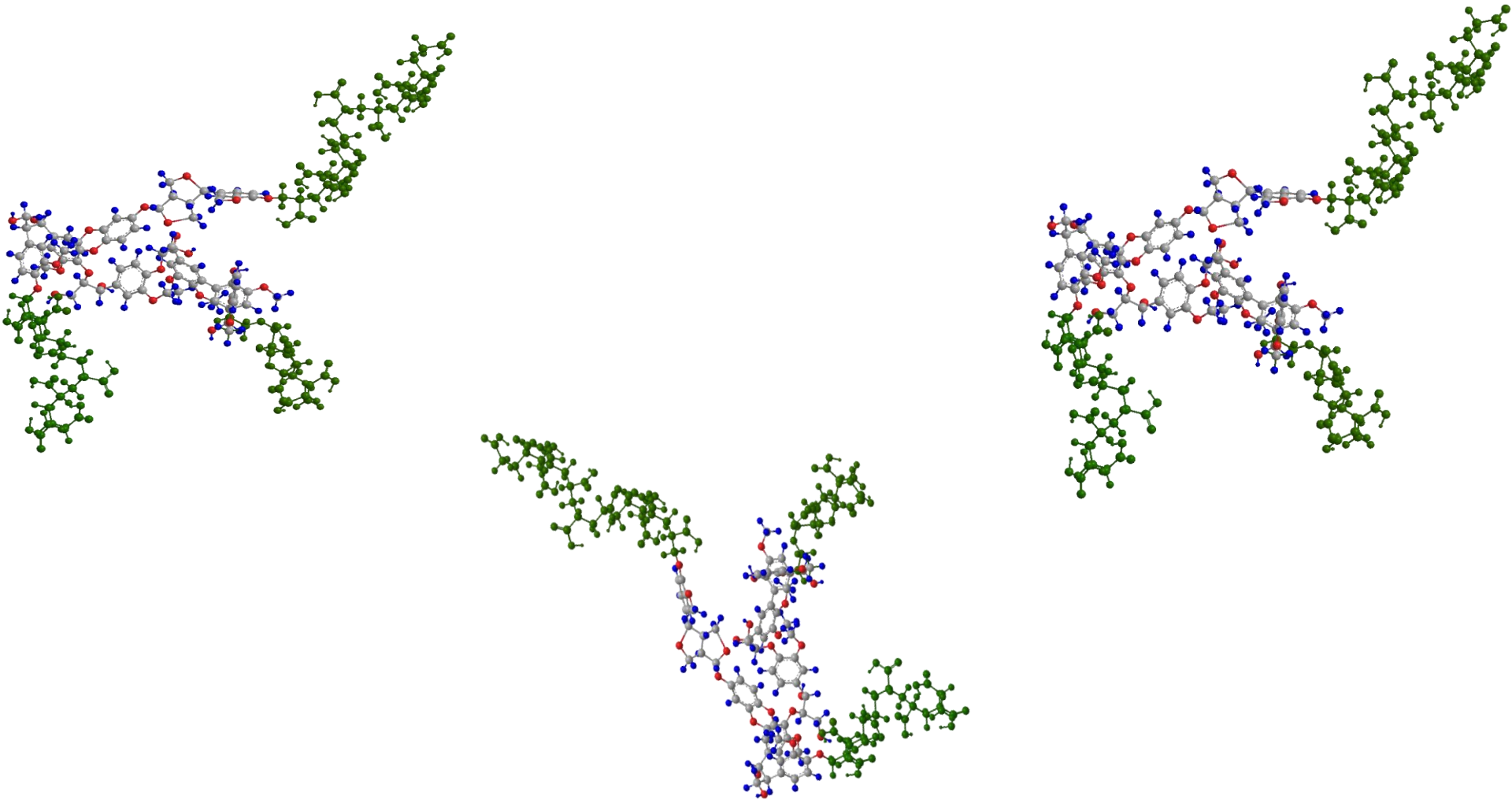
Green Processes Research Centre and Chemical Engineering Department, Lakehead University, 955 Oliver Road, Thunder Bay, ON P7B5E1, Canada

Polymerization

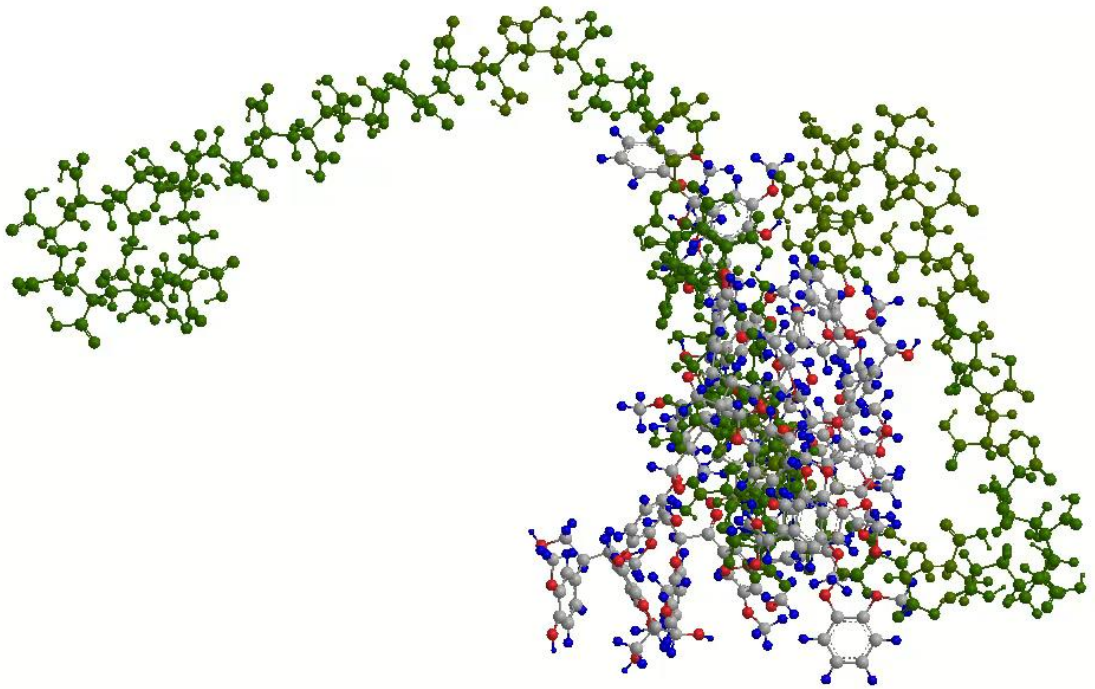




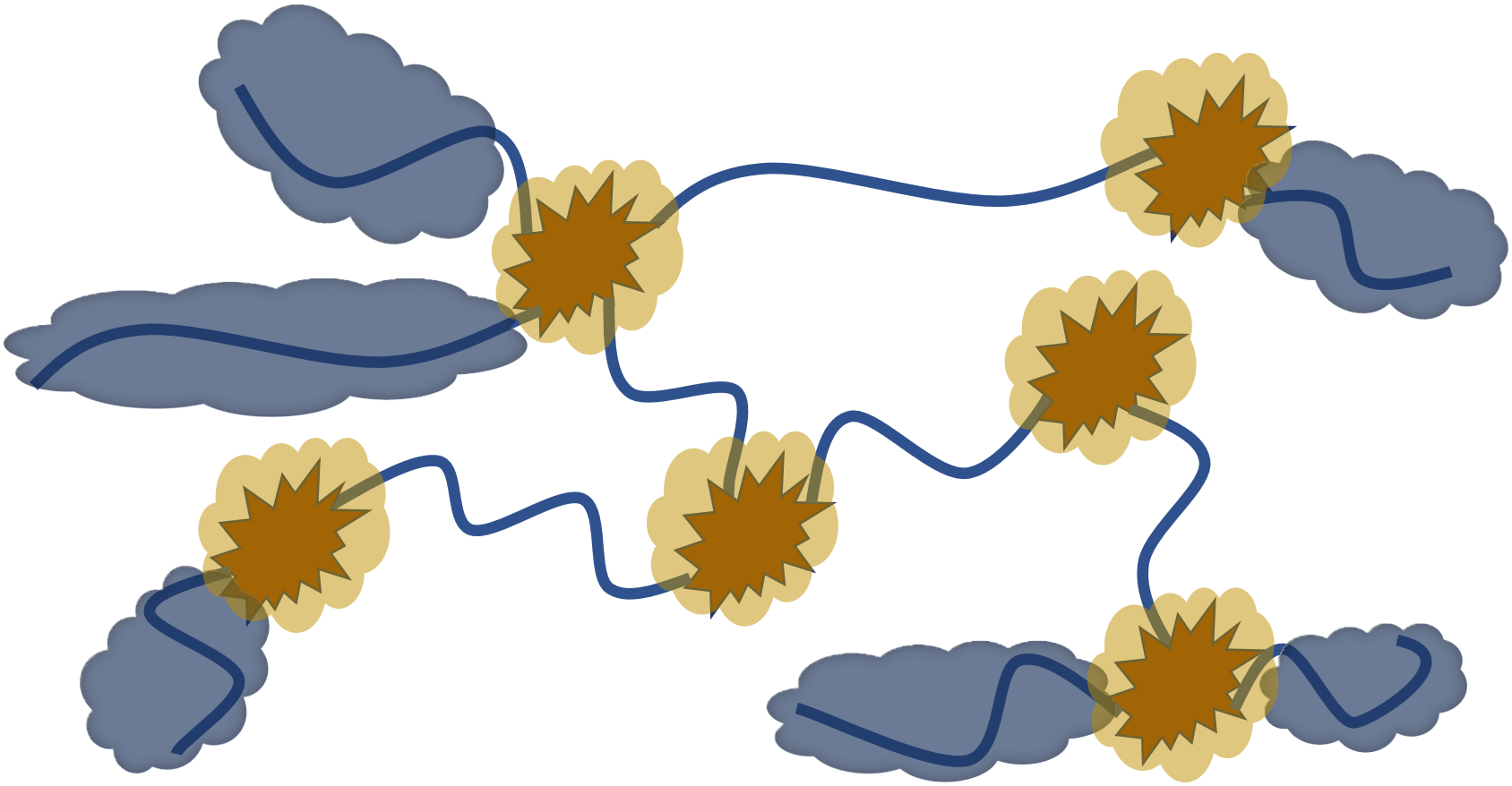
Polymerization

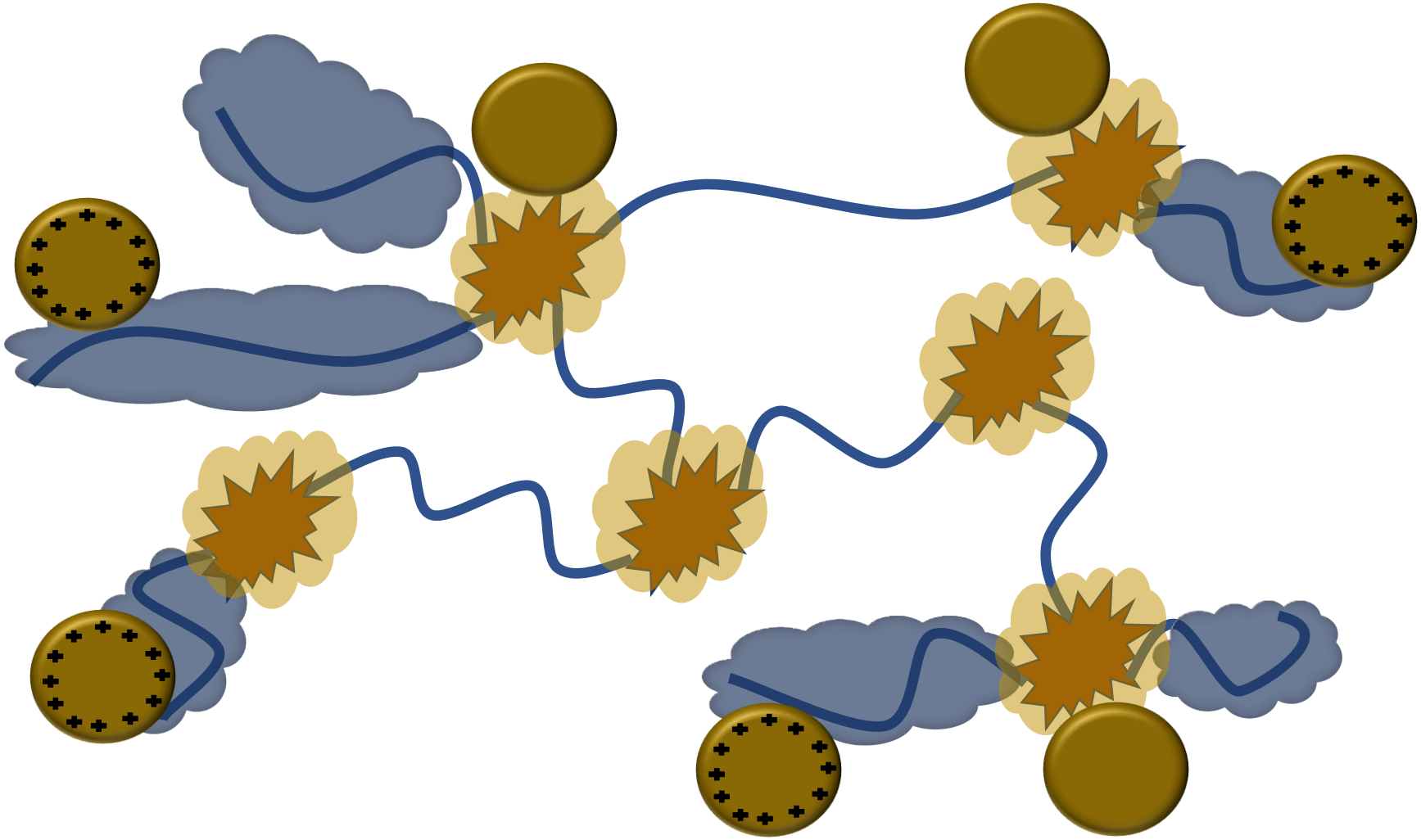


3-dimensional macromolecules with hydrophobic and hydrophilic features



Polymer network with hydrophobic/hydrophilic features



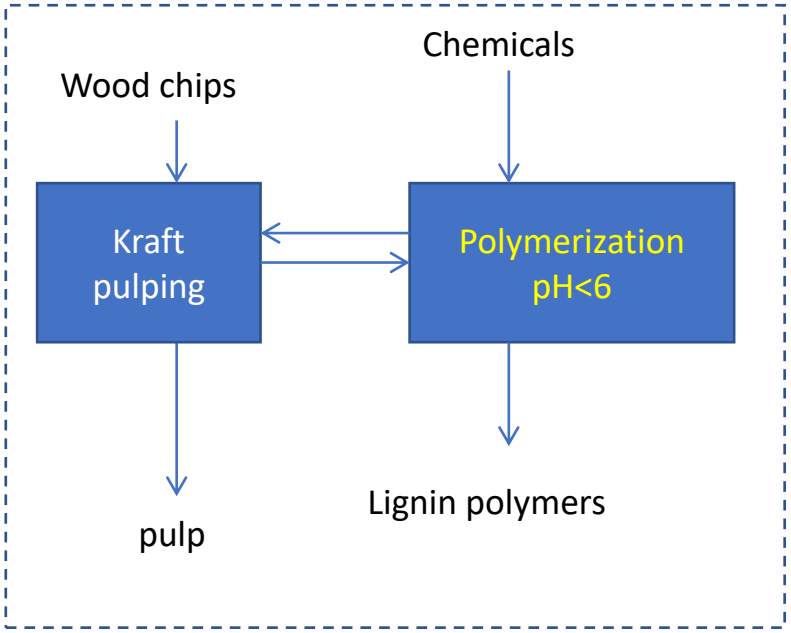


Blanket effect

- A medium size lignin polymer was as effective as large polyacrylamide

Lignin polymerization

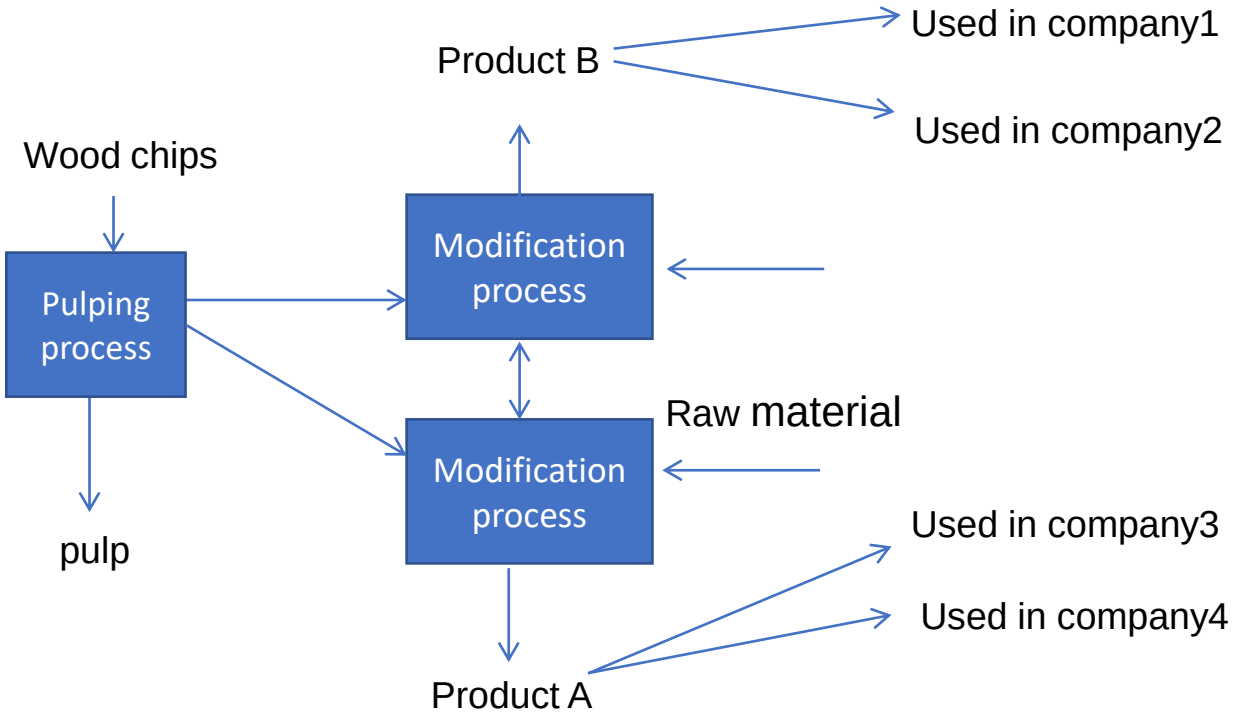
- Lignin polymerization under aqueous acidic environment
- Suspension to start, solution to finish
- Inorganic elements are well in harmony with the chemistry of kraft process



- Many anionic, non ionic and cationic monomers
- Softwood, hardwood
- Kraft, alkali, hydrolysis, soda, lignosulfonate
- Many different sources
- Concentration up to 50 wt.%
- 65-75% lignin polymer
- Less than 5% monomer left
- Minimum monomer use
- Maximum lignin use
- Minimize the price, maintain functionality

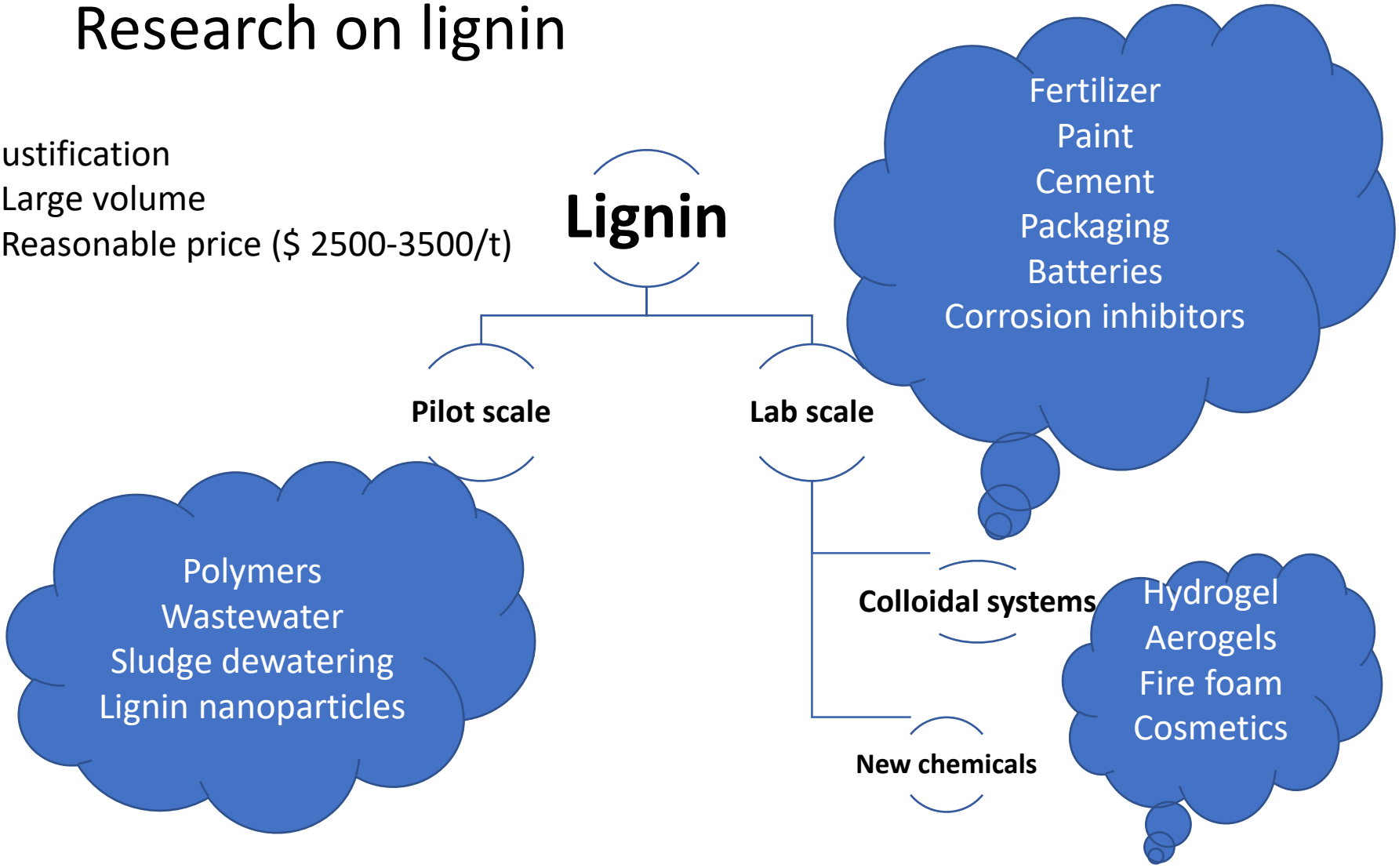
Fatehi, Paleologou et al., US patent, 62/468,981, 62/468,982

Production of value-added product for various customers



Research on lignin

Justification
-Large volume
-Reasonable price ($ 2500-3500/t)

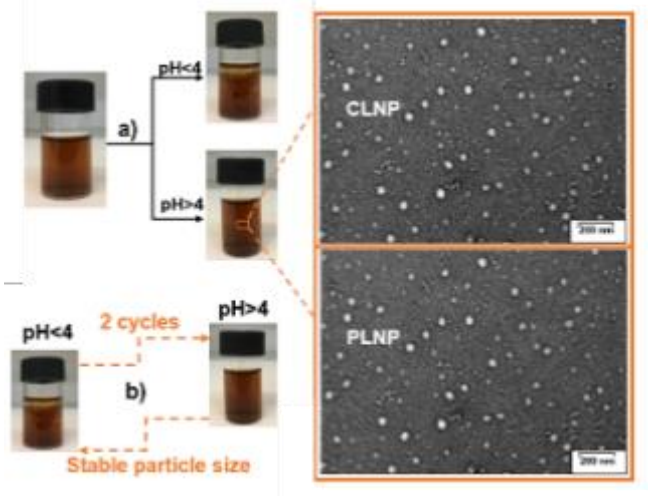


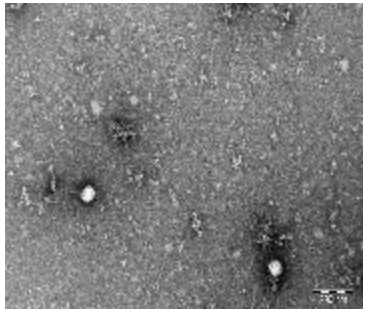
Functional lignin nanoparticles

Carboxyalkylation prior to nanoparticle formation

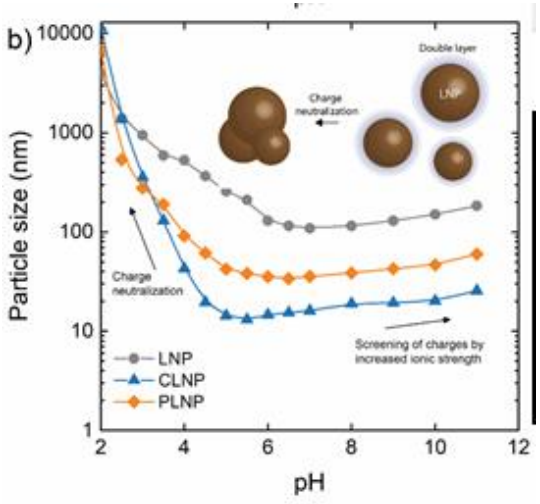
3) high tolerance against ionic strength

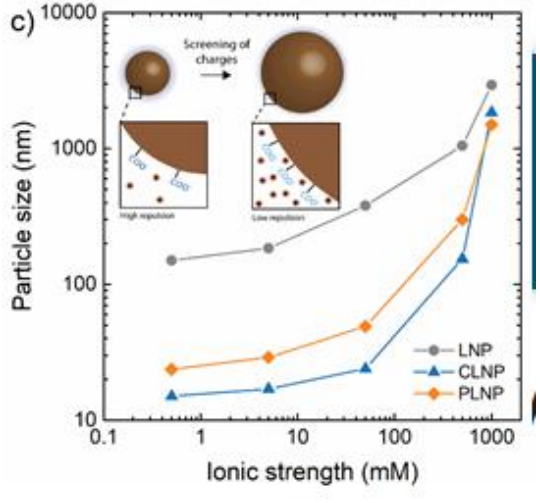
4) High tolerance against pH





Unmodified LNP





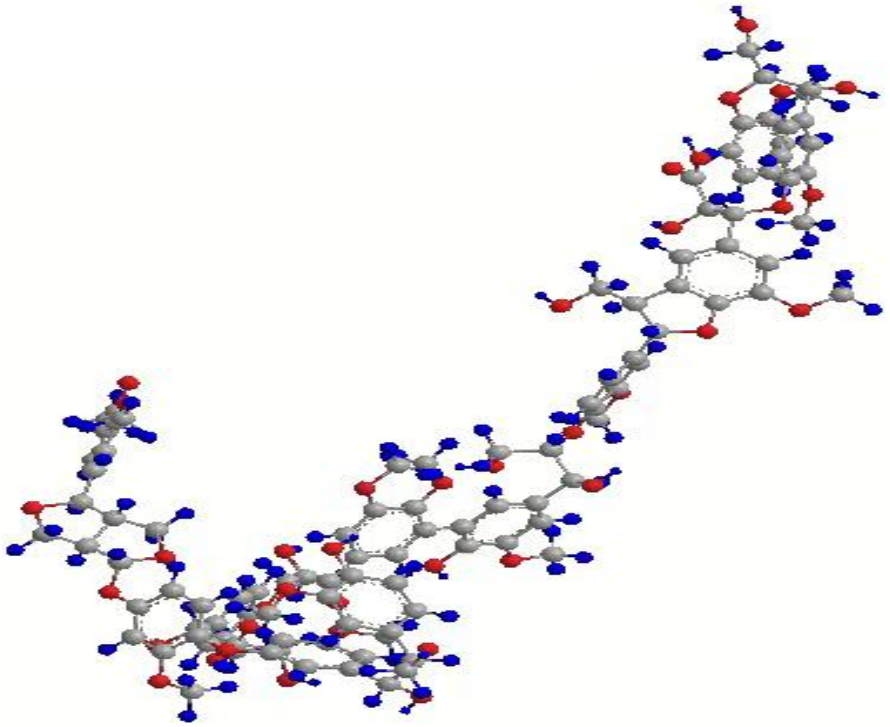
Functional Lignin Nanoparticles with Tunable Size and Surface Properties: Fabrication, Characterization, and Use in Layer-by-Layer Assembly

Niloofar Alipoormazandarani, Tobias Benselfelt, Luyao Wang, Xiaoju Wang, Chunlin Xu, Lars Wågberg, Stefan Willför, and Pedram Fatehi*

Cite this: *ACS Appl. Mater. Interfaces* 2021, XXXX,


You can make everything but money from lignin!

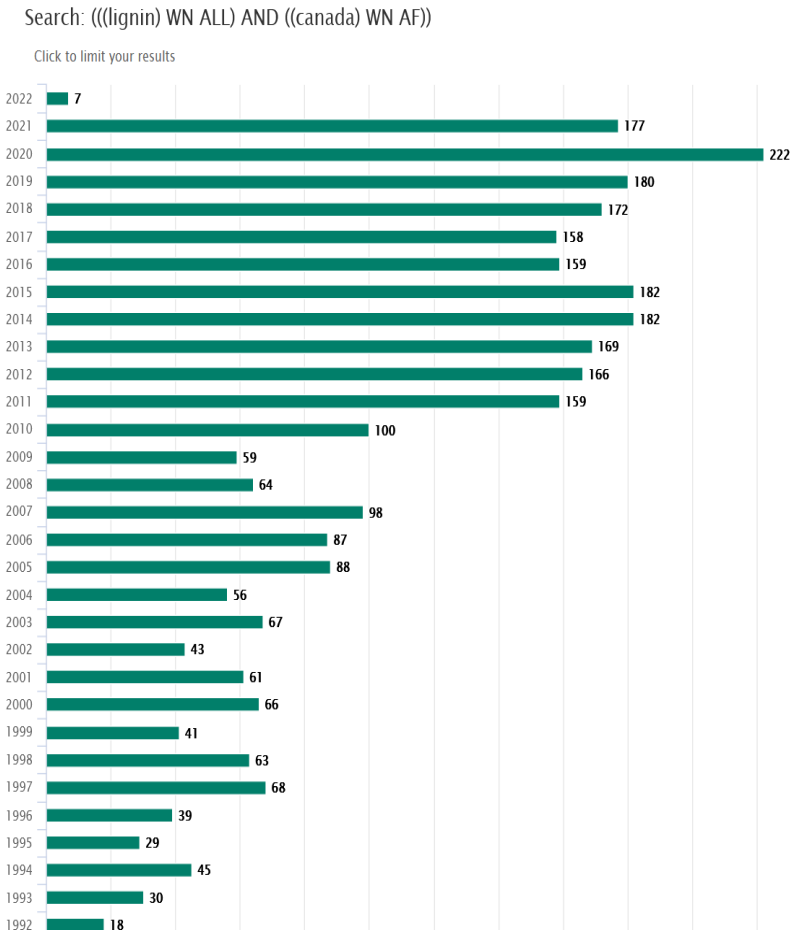
- Lack of knowledge
- Limited analysis
- Lack of courage



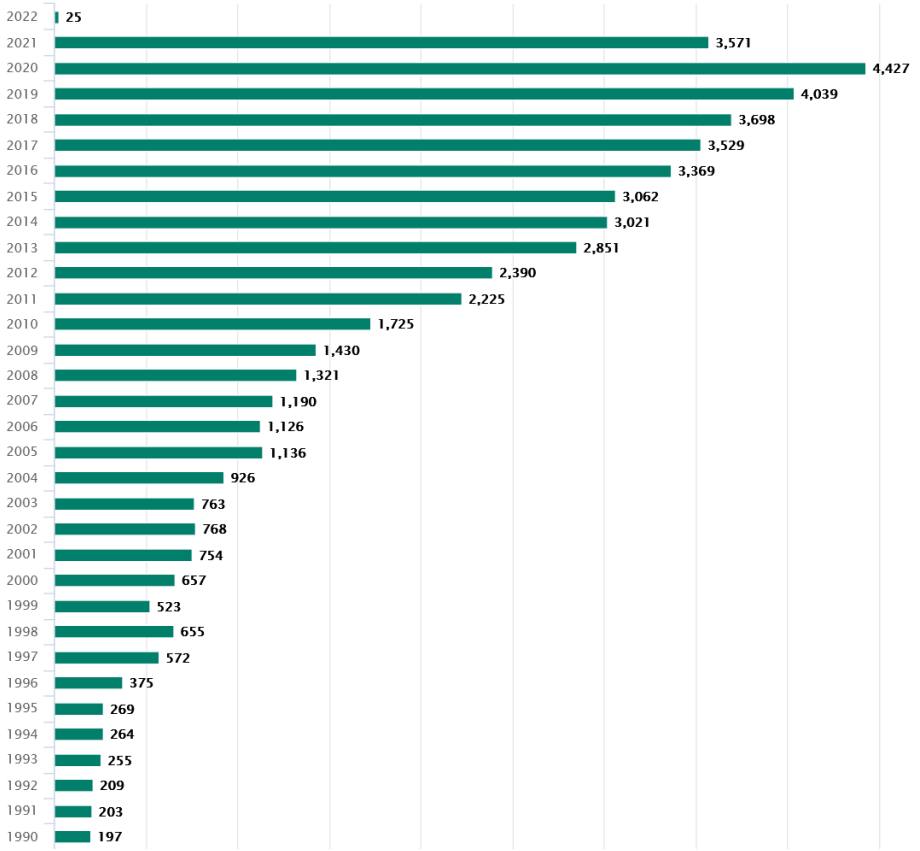
Technical challenges

- Not all chemical sites may be available for reactions
- Physical or chemical constrains
- Should not underestimate the complexity of lignin molecules and reaction!

Outputs on lignin research
source: Engineering village, Sept 8, 2021



Canada



Global

Future directions

- Funding is necessary for developing new technologies
- Funding is necessary for pilot scales
- None-IP research activities
- Domestic and International collaborations
- Biorefining Research Institute has investment of more than $ 15M on lignin research
  - Advanced tools
  - Pilot plants of FPInnovations

Collaborations/sponsors