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THE UNITED STATES OF AMERICA

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UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

March 03, 2020

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APPLICATION NUMBER: ***62/815,574***
FILING DATE: ***March 08, 2019***

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS ***US62/815,574***

By Authority of the
Under Secretary of Commerce for Intellectual Property
and Director of the United States Patent and Trademark Office

SYLVIA HOLLEY
Certifying Officer

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
62/815,574	03/08/2019		140	54419-3001		

CONFIRMATION NO. 2733

FILING RECEIPT

OC000000106641429

23577
RIDOUT & MAYBEE LLP
250 UNIVERSITY AVENUE
5TH FLOOR
TORONTO, ON M5H 3E5
CANADA

Date Mailed: 03/19/2019

Receipt is acknowledged of this provisional patent application. It will not be examined for patentability and will become abandoned not later than twelve months after its filing date. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Hui Huang HOE, Toronto, CANADA;
Hui Ming HOE, Jalan Johor, MALAYSIA;

Applicant(s)

Hui Huang HOE, Toronto, CANADA;
Hui Ming HOE, Jalan Johor, MALAYSIA;

Power of Attorney:
Matthew Norwood--75730

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 03/15/2019

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 62/815,574**

Projected Publication Date: None, application is not eligible for pre-grant publication

Non-Publication Request: No

Early Publication Request: No
**** SMALL ENTITY ****

Title

Electrochemical Production of Polymers

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

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Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

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Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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Electronic Acknowledgement Receipt

EFS ID:	35366882
Application Number:	62815574
International Application Number:	
Confirmation Number:	2733
Title of Invention:	ELECTROCHEMICAL POLYMER PRODUCTION
First Named Inventor/Applicant Name:	Hui Huang HOE
Customer Number:	23577
Filer:	Kazim Agha/Jennifer Horlings
Filer Authorized By:	Kazim Agha
Attorney Docket Number:	54419-3001
Receipt Date:	08-MAR-2019
Filing Date:	
Time Stamp:	14:23:45
Application Type:	Provisional

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$140
RAM confirmation Number	031119INTEFSW00000610132400
Deposit Account	
Authorized User	

The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	54419-3001
	Application Number	
Title of Invention	Electrochemical Production of Polymers	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Hui Huang		HOE	

Residence Information (Select One) ○ US Residency ● Non US Residency ○ Active US Military Service

City	Toronto	Country of Residence i	CA

Mailing Address of Inventor:

Address 1	88 D'Arcy Street		
Address 2			
City	Toronto	**State/Province**	ON
Postal Code	M5T 1K1	**Country** i	CA

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Hui Ming		HOE	

Residence Information (Select One) ○ US Residency ● Non US Residency ○ Active US Military Service

City	Jalan Johor	Country of Residence i	MY

Mailing Address of Inventor:

Address 1	11, Lorong Seroja, Jalan Parit Haji Yusof, Batu 36		
Address 2			
City	Jalan Johor, Pontian, Johor	**State/Province**	
Postal Code	82000	**Country** i	MY

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	54419-3001
	Application Number	
Title of Invention	Electrochemical Production of Polymers	

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	23577		
Email Address	ridbee@ridoutmaybee.com	Add Email	Remove Email
Email Address	kagha@ridoutmaybee.com	Add Email	Remove Email

Application Information:

Title of the Invention	Electrochemical Production of Polymers		
Attorney Docket Number	54419-3001	**Small Entity Status Claimed**	☒
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)		**Suggested Figure for Publication (if any)**	

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., “Domestic Benefit/National Stage Information” and “Foreign Priority Information”).

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	● Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	54419-3001
	Application Number	
Title of Invention	Electrochemical Production of Polymers	

Customer Number	23577

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the “Application Number” field blank.

Prior Application Status		Remove	
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX) i the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Remove

Application Number	Country i	Filing Date (YYYY-MM-DD)	Access Code i (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	54419-3001
	Application Number	
Title of Invention	Electrochemical Production of Polymers	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	54419-3001
	Application Number	
Title of Invention	Electrochemical Production of Polymers	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

○ Assignee ○ Legal Representative under 35 U.S.C. 117 ○ Joint Inventor

○ Person to whom the inventor is obligated to assign. ○ Person who shows sufficient proprietary interest

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix

Mailing Address Information For Applicant:

Address 1			
Address 2			
City		**State/Province**	
Country		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button.

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	54419-3001
	Application Number	
Title of Invention	Electrochemical Production of Polymers	

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		**State/Province**	
Country i		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

Signature:

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Matthew Norwood/			Date (YYYY-MM-DD)	2019-03-08
First Name	Matthew	Last Name	Norwood	Registration Number	75730

Additional Signature may be generated within this form by selecting the Add button.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	54419-3001
	Application Number	

Title of Invention	Electrochemical Production of Polymers

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

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2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3 A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent CooperationTreaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

0. Overview

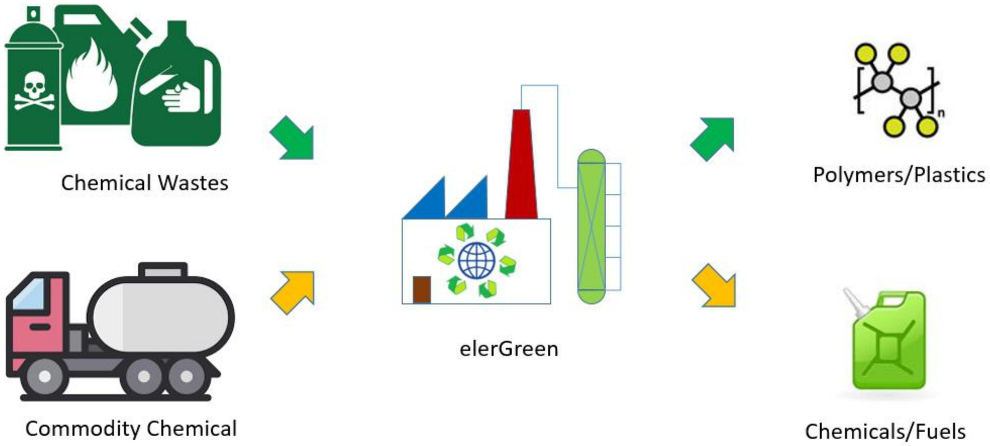


Figure 0-1 General chemical business model of elerGreen Industry

elerGreen Industry is a greentech company that aims to utilize renewable energy/electricity to produce valuable polymers, chemicals and fuels out of chemical waste and commodity chemicals. This enables sustainable economic growth from industrial scale chemical production, based on novel lower cost electrochemical process with minimum, if not positive environmental impacts.

1. *Abstract: Electrochemical Production of Polymers*

A novel process for production of polymers, often with fuels/chemicals as by-products. The invention consists of 3 major elements: device design, addition polymerization process, and condensation polymerization process. The device is a mechanical design to continuously remove any solid deposit, conductive or not, on the electrode surface. The device not only removes the limitation of electrochemical polymer production where the products blocks the electrode from further operation, but also provides potentially cheaper method of operation for electrometallurgy, where the valuable metal formed on electrode is to be harvested. The chemical method/process involves modest modification of conventional polymer production process, by replacing the reactor to electrochemical reactor, minimizing the capital cost involved. The novel reactions consist of 2 major elements, the first one is addition reaction to produce addition polymer, while the other consists of intermolecular condensation/esterification to produce various classes of condensation polymers. The clusters of invention enable the very same valuable polymers and chemicals feedstock to be produced at lower cost (in terms of milder conditions, cheaper equipment), while allowing the use of non-conventional feedstock especially chemical waste, further maximizing both environmental and economic benefits.

2. Introduction

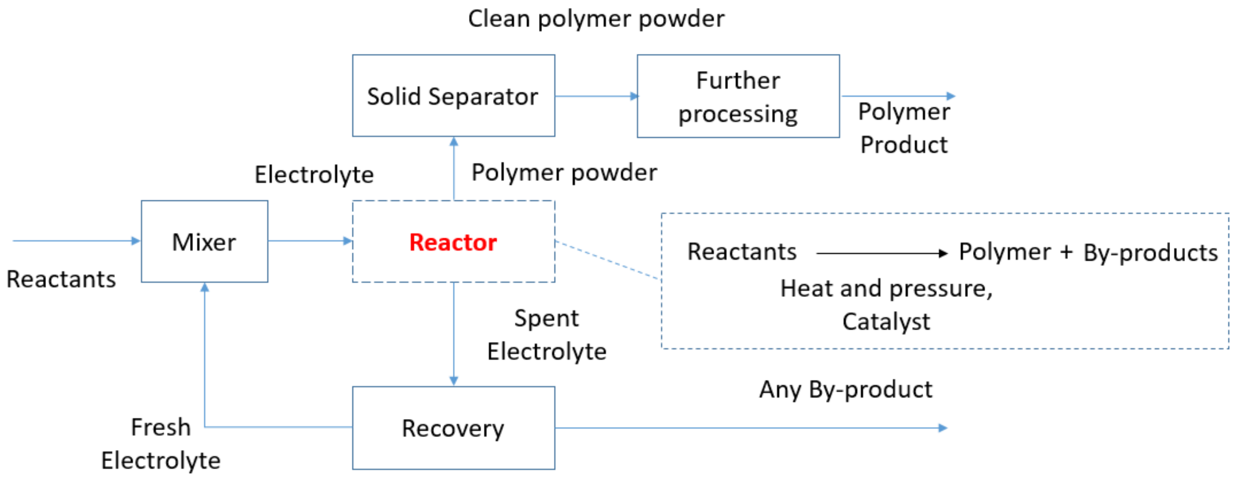


Figure 0-2 Conventional polymer production process with reactor as the key component

The conventional polymer production consists of feeding the reactants to be mixed and sent into conventional reactor where reactions happen with the application of high temperature and pressure. The polymer formed as solid suspension and would be separated out of the liquid phase, for washing and further processing, while the residual reagents would be recovered for any valuable by-product.

The design flaw of conventional polymer production, however, is that it requires the use of high temperature and pressure, while often involves the use of hazardous reagents such as phosgene and expensive catalysts. This can be improved because the reaction of polymerization is fundamentally not energy-intensive, but merely limited by the kinetic bottle neck to initiate the reaction, that led to such high temperature and pressure.

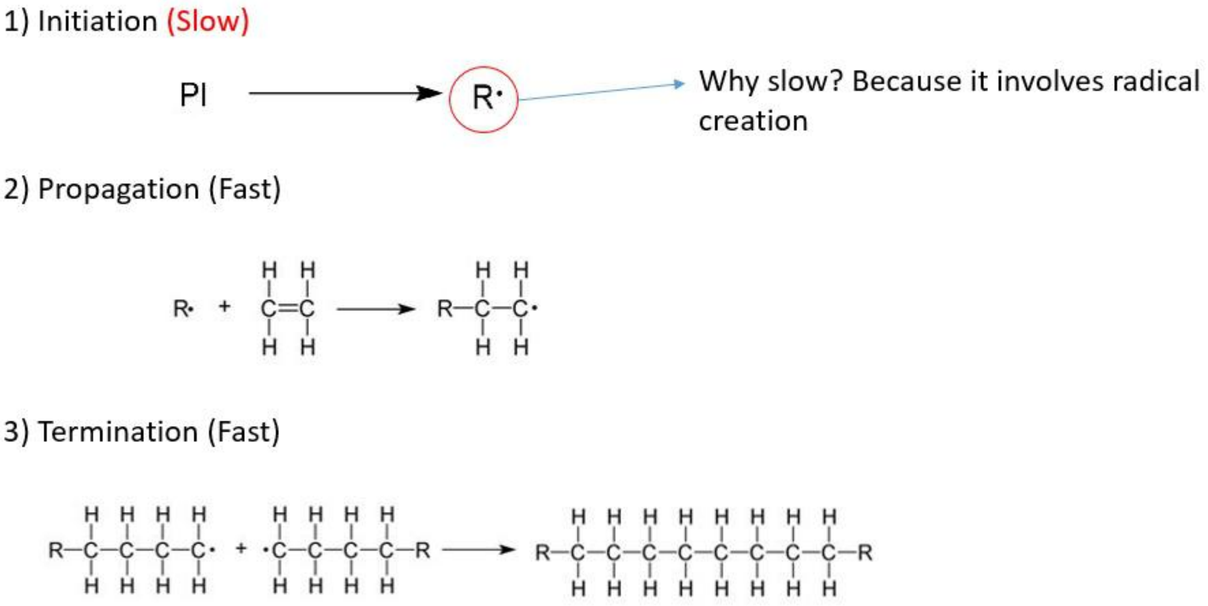


Figure 0-3 Representative explanation of why the conventional chemical process requires high temperature and pressure to create radicals to initiate the reaction

To overcome the traditional limitations of conventional polymer production, the electrochemical production has been invented where electricity is concentrated on the electrode surface to initiate the reaction at milder temperature and pressure. While there could be fundament limitation of non-conductive polymer blocking the electrode surface and halting the electrochemical reaction, such limitation is being overcome by a novel simple yet elegant design feature of device that removes the polymer formed, continuously from the electrode.

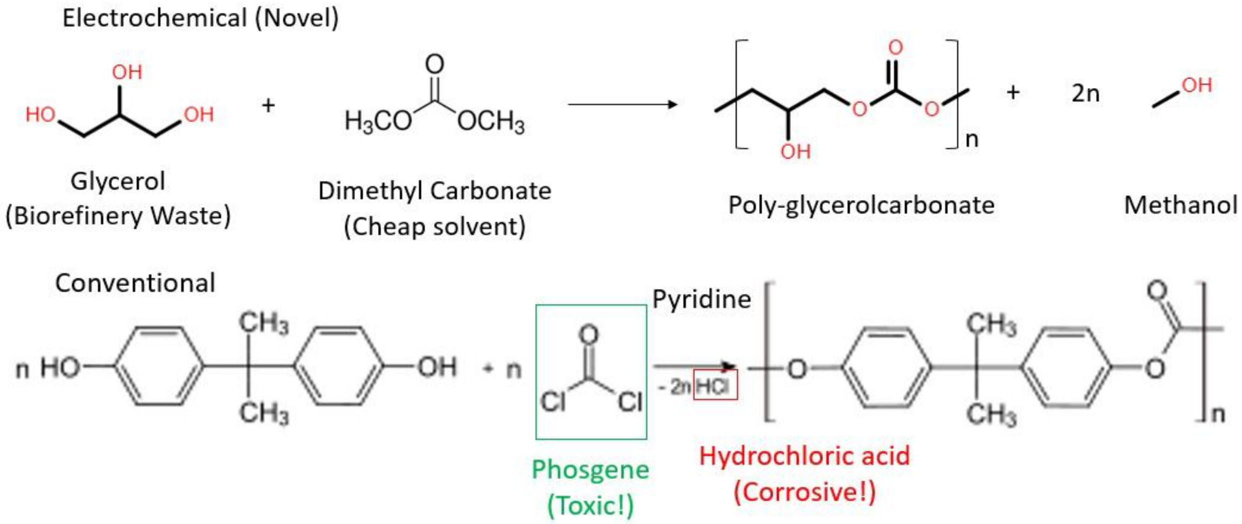


Figure 0-4 Examples of advantages offered by the novel electrochemical process

The boost in kinetics of the reaction offers a bunch of advantages including:

- Milder temperature and pressure which reduces cost (capital cost for these equipment and operating cost for the energy input)
- Less dependence of catalyst which is often costly and with some environmental impacts
- Integration with existing renewable electricity instead of using fossils fuels to drive reaction
- Compatibility with downstream polymer processing since the products are the same, which allows fast and easy implementation since a conventional plant can be purchased and just have the reactor changed to electrochemical reactor, instead of redesigning/rebuilding the entire system

More importantly, the use of electrochemical method reduces the need to use reactive yet hazardous/toxic feedstock that has negative environmental impacts. It also allows many types of chemical wastes that are otherwise unreactive, to participate in reaction to be converted into valuable polymers and secondary products such as fuels, which is a novel idea instead of the cost to dispose of the wastes. Possible feedstocks include but are not limited to:

1. Waste sludge/solvent (toxic):
- Ethylene glycol (cheap!)
- Propylene glycol

2. Petrochemical waste (toxic)
- Halohydrin

3. Common waste/feedstock:
- Urea (cheap!)

4. Biomass:
- Glycerol
- Ethanol

1. Electrochemical Polymer Production: Variant 1

The first variant of the electrochemical polymer production process is that very similar to the conventional process, but instead with the conventional reactor requiring significant heat, pressure and catalysts, replaced by electrochemical reactor that uses electricity and salt. While heat and pressure is generally not needed, it can still be added to the electrochemical reactor as necessary depending on the type of reaction, and even in that case often with substantially lower temperature and pressure than the conventional process.

While many other greentech process involves rebuilding the entire different process, the novel electrochemical polymer production process involves replacing the core reactor with electrochemical reactor, while retaining (if not minimally adjust) the complementary operation units or existing industrial standards. This allows buying a regular plant and just renovate the reactor into electrochemical reactor, in contrary to building a wholly different chemical plant from scratch. As a result, the pitfalls of over-budget as in many greentech can be avoided, while the acquisition of conventional plant itself also serves to allow the project to take much shorter time to implement, besides offering a stream of income to serve the bonds/loans used for acquisition, besides making use of the established market share since the products remains the same after renovation, just substantially lower cost.

The general variant, Variant 1, can be used when the by-products are valuable but harmful to be discharged to environment, such as amines and alcohols. For this case, recovery unit is used to recover the valuable yet harmful chemicals for sale instead of discharging/disposal, at the cost of more complex process.

Variant 1:

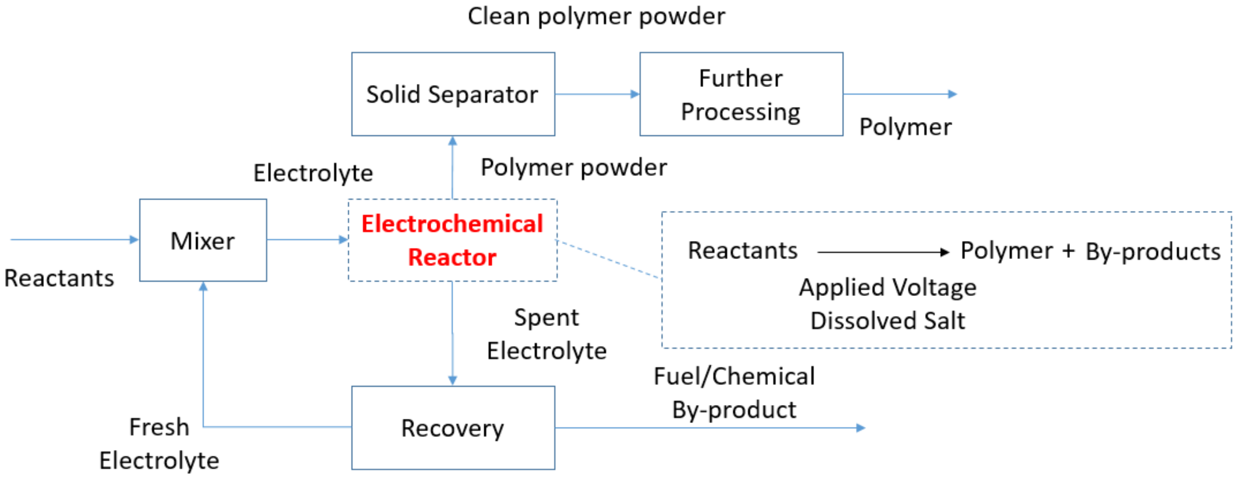


Figure 0-5 General variant of the novel electrochemical polymer production process, where the reactor is replaced by electrochemical reactor, where the by-products would still be recovered using similar recovery unit

Note: Dissolved Salt acts as conducting ion, not necessary participate in reaction, could be inorganic (such as sodium chloride/table salt) or organic (sodium stearate/common soap)

2. Electrochemical Polymer Production: Variant 2

Another variant, Variant 2, is a simpler case than Variant 1, in that the by-product is not recovered. This can be used when the by-products are neither harmful nor valuable, such as water in many cases of reaction. This allows the cost to be even lower due to the elimination of recovery unit which incurs capital and operating costs.

Variant 2:

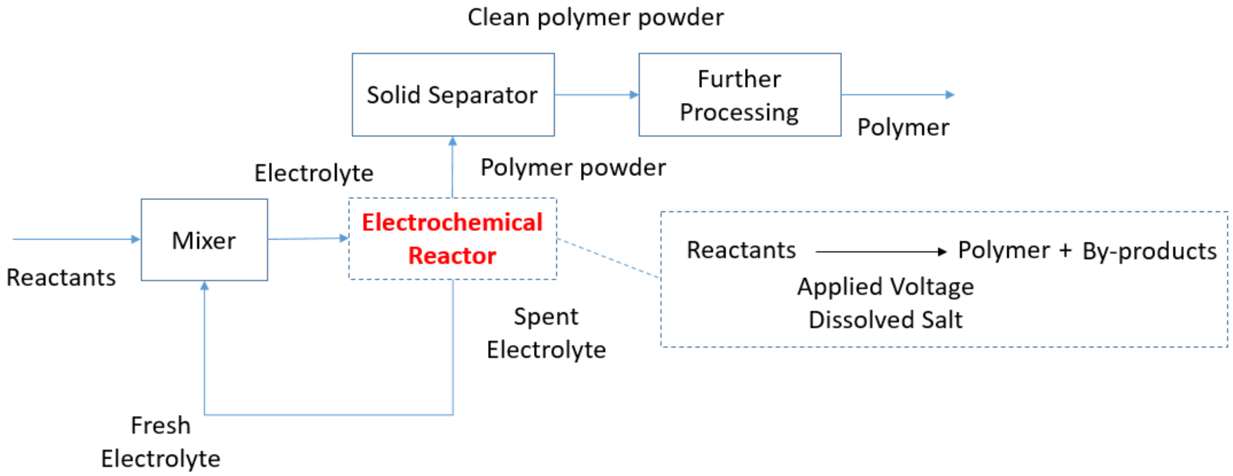


Figure 0-6 A variant of the novel electrochemical polymer production process, where the recovery unit is not needed when the by-products are easier to deal with

3. *Invention Breakdown*

The invention of electrochemical polymer production involves 3 major elements: Device, Addition Polymer and Condensation Polymers.

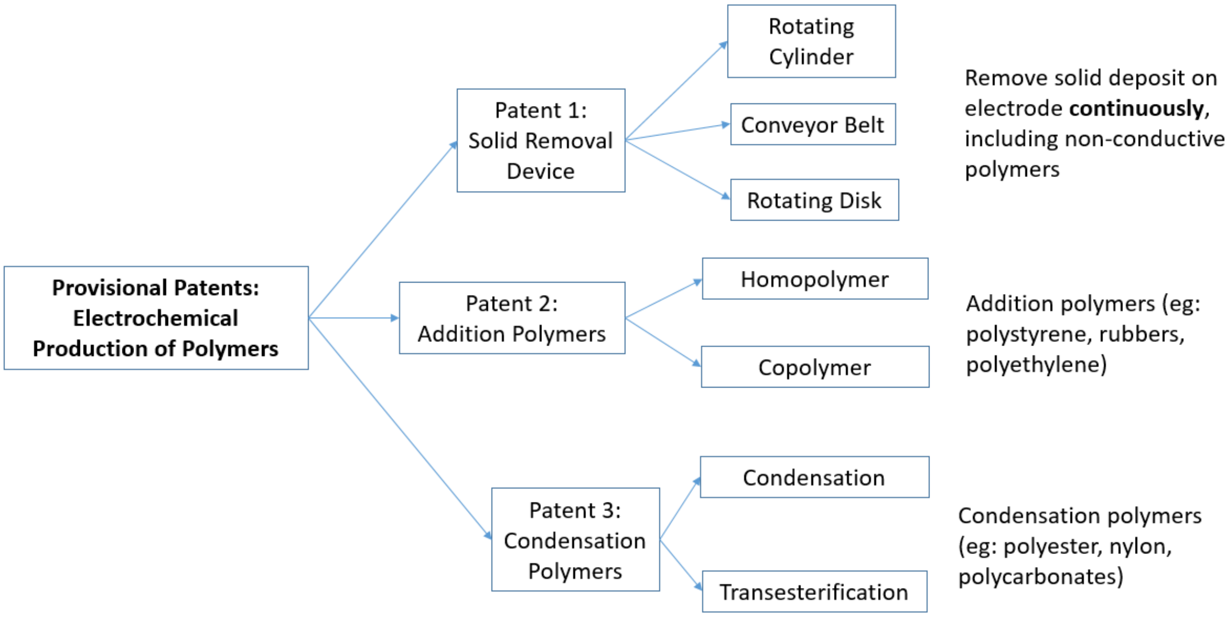


Figure 0-3 Breakdown of the subsequent inventions to be filed

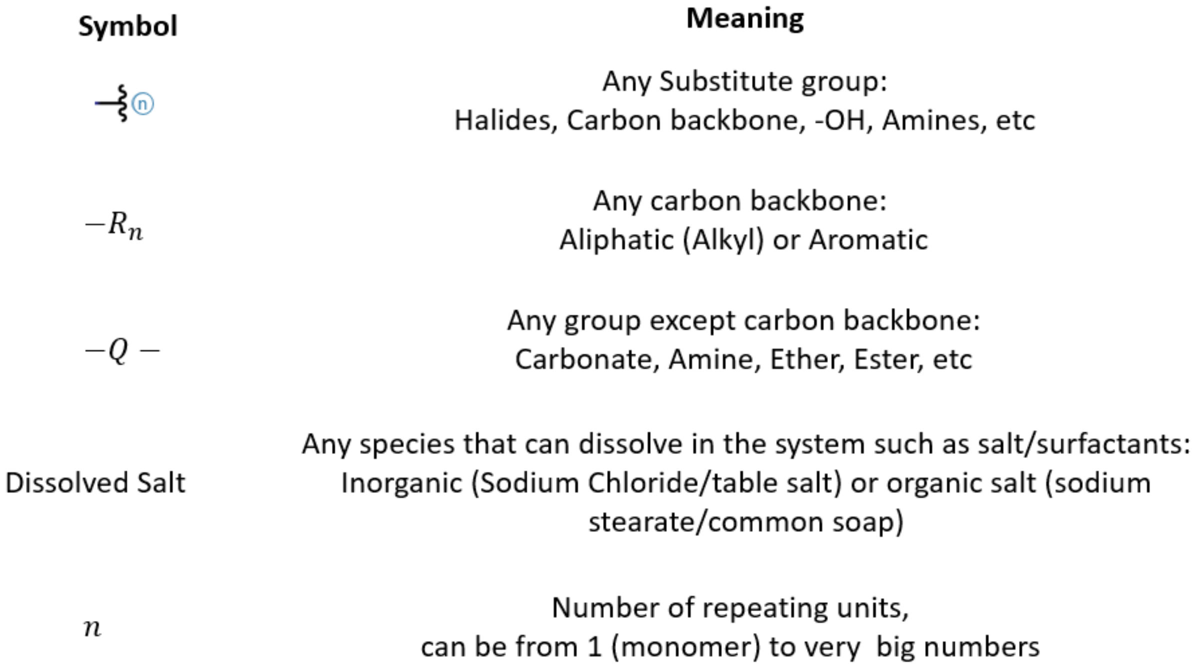
The device involves a novel design of solid removal device that can continuously remove solid formed onto electrode, regardless of conductivity. It involves the use of circular/cyclic motion of electrode surface in contact of a device to remove solid on continuous process basis, without having to remove the electrode. While many other arrangements are possible, the major 3 variants are rotating cylinder, conveyor belt and rotating disk.

The addition polymer results from an electrochemical addition reaction, in which no by-product is formed. For example, some addition polymers includes polymers where the backbones are generally carbon atoms (usually those polyvinyl polymers such as polyethylene, polystyrene and polyvinyl chloride). In some embodiments, the polymerization reaction happens by intramolecular elimination to form alkene, which subsequently undergo addition reaction *in situ* (right in the reagent) to form the polymeric products. It has variants of homopolymer where only one type of starting feedstock in used, or copolymer where different starting feedstock can be mixed together to make polymer with more complex structure.

The condensation polymer results from an electrochemical condensation reaction. For example, some condensation polymers include polymers where the backbones contain heteroatom such as oxygen atom (polyether and polyester) or nitrogen atom (polyamides as in protein and nylon). It involves intermolecular elimination where the monomer end up joining together. It comprises mainly of condensation where simple elimination happen, and transesterification where more complex condensation and/or exchange reactions happen.

4. Terminology

Before proceeding to describe the invention in further detail, some symbols to be used in later section is outlined as terminology.



Symbol	Meaning
ⓝ	Any Substitute group: Halides, Carbon backbone, -OH, Amines, etc
$-R_n$	Any carbon backbone: Aliphatic (Alkyl) or Aromatic
$-Q-$	Any group except carbon backbone: Carbonate, Amine, Ether, Ester, etc
Dissolved Salt	Any species that can dissolve in the system such as salt/surfactants: Inorganic (Sodium Chloride/table salt) or organic salt (sodium stearate/common soap)
n	Number of repeating units, can be from 1 (monomer) to very big numbers

Figure 0-4 The specific terminology/symbols and the corresponding representation in the description

First, the substitute group is represented with a chemical bond and a wavy curve with number, where the number simply is the index number of the substitute group.

The carbon backbone, be it aliphatic (alkyl) or aromatic (aryl), is represented with R_n and any nearby chemical bond that applies, n is simply the index number of the carbon backbone group.

The substitute group besides carbon backbone is often the active site of reaction, and would be represented with Q and any nearby chemical bond that applies.

For simplicity, dissolved salt refers to any species that dissolve in the system such as salt/surfactants. It is used in the electrochemical system to provide electrical conductivity to facilitate electrochemical reaction. The salt can be inorganic such as sodium chloride (table salt) or organic salt (sodium stearate), depending on polarity of the system.

Lastly, the number n would be used in many chemical equations as subscript of a bracket, which simply means the number of repeating units in the polymer. It can range from 1 (monomer) to a big number up to ten of thousands or even more.

1. Continuous Removal Device for Solid Deposit on Electrode

An electrochemical reaction cell consists of electricity supply connected to electrodes dipped in an electrolyte. The electrolyte is usually a conducting liquid but can be conducting membrane soaked with liquid. The electrode consists of a conducting material where electrochemical reaction happen on the surface; where the electrode connected to positive terminal of power supply is called anode which is where oxidation reactions happen, and the electrode connected to the negative terminal of electricity supply is called cathode which is where reduction reactions happen. While not essential for reaction to happen, a third electrode, called reference electrode, is often included to provide a reference voltage measurement.

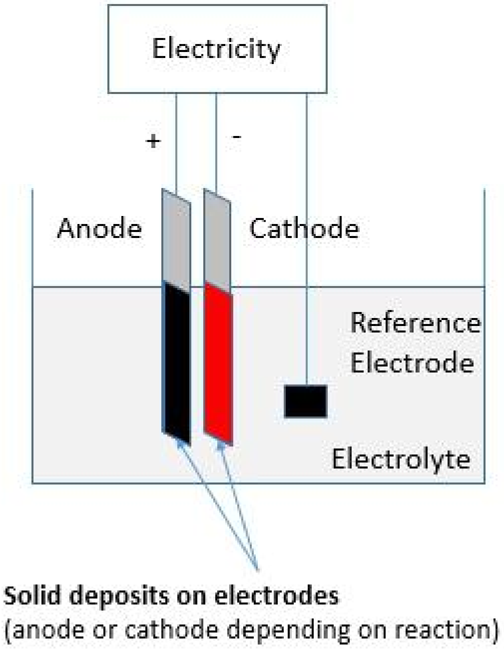


Figure 1-1 Illustration of bench-scale electrochemical polymerization, or any general electrochemical reaction where solid product is resulted

When solid products result from electrochemical reaction, it tends to stick on the surface of electrode, which often would require removal to maintain the performance of the electrochemical cell. Solid removal from electrode is of interest because it has application for electrochemical metallurgy and battery where metals of interest are formed as solid on the electrode and need to be recovered/isolated for further processing.

On the other hand, if the solid formed (on anode or cathode depending on reaction) is non-conductive, it blocks the electrode and the electrochemical reaction halts due to lack of conductivity. This warrants the need to remove the non-conductive solid deposit rapidly as it is being produced, preferably in continuous fashion.

To address this challenge, the novel device setup is designed to continuously remove the solid by relative motion between electrode and a removal device, for example, a blade to remove the solid from the electrode. The removal can happen in the top (gas/air) phase or bottom (liquid/electrolyte) phase. In the gas phase, there is substantially lower friction, and no need to filter the solid away from liquid/electrolyte. On the other hand, the relative motion between electrode and the removal device in the liquid/electrolyte phase also serves to stir the electrolyte for mixing, removing the need for stirrer in the electrolyte/liquid phase. Note also that the electrolyte tank does not have to be rectangular in shape, for instance it can be cylindrical especially when the electrodes are cylindrical in shape, to save reactor/reagent volume (and hence cost).

The devices can be multiple repeating units, in anode-anode-cathode-cathode (cluster stack), or in anode-cathode-anode-cathode (alternating stack) order, to scale up the production output.

While the arrangement can come in many forms, the major arrangements of interest are: rotating cylinder, conveyor belt, and rotating disk.

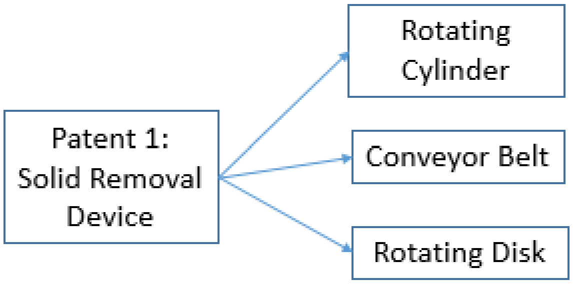


Figure 1-2 Breakdown of the variants of the novel electrochemical device design

The invention offers the following advantages:

- Shallower tank because no longer need to allow solid to settle, resulting in lower cost from lower reactor size and reagent volume
- Faster and cheaper separation: Less friction to remove the solid in air/gas phase than in the viscous electrolyte phase, while removing the need for solid to be filtered from liquid phase; or the facilitation of mixing in the liquid/electrolyte phase and the removal of a need for a stirrer.
- Continuous process removing the need to shut down the electrochemical reactor for solid recovery
- Simple design without much of the complex gear setup and mechanical arrangements which would be costly/difficult to manufacture

1. Variant 1 - Rotating Cylinder

Rotating Cylinder is the simplest variant of the design, which consists of a conductive cylinder material as the electrode. The cylinder is positioned horizontally and partially dipped into the electrolyte.

The electrochemical reaction would happen in the liquid/electrolyte phase when electricity is applied, and the rotation of the cylinder would move the deposited solid up into the gas/air phase where a removal device is used to remove the solid from the surface, for example, by friction brought about by the relative movement of the cylinder surface and the removal device.

In some embodiments, the device comprises a rigid material, for example, a plate made of the rigid material that can be slanted down to outside of the electrochemical cell. This allows the solid deposit to gradually slide down the plate to outside of the cell for downstream processing. As an alternative, the device can also be a conveyor belt with rigid sharp edges or an abrasive surface, positioned against and in contact with the surface of electrode, where the solids removed would be moved outside of the electrochemical cell in automated, continuous fashion. For example, the rigid edges may be perpendicular to the tangential surface of the electrode.

Another advantage is that the solid removed is largely dry without much liquid (though some liquid may stick on it but not much and can be washed easily), which accelerates the separation time and removes the need to filter the solid from liquid phase.

There may or may not be residual solid dropping into the tank and would be filtered out if needed. However, the solid removal device in the air/gas phase already removes the majority of the solid and thus greatly reduces the throughput needed for backup filtering. As an alternative, filter is often not needed and the solid is only recovered during maintenance.

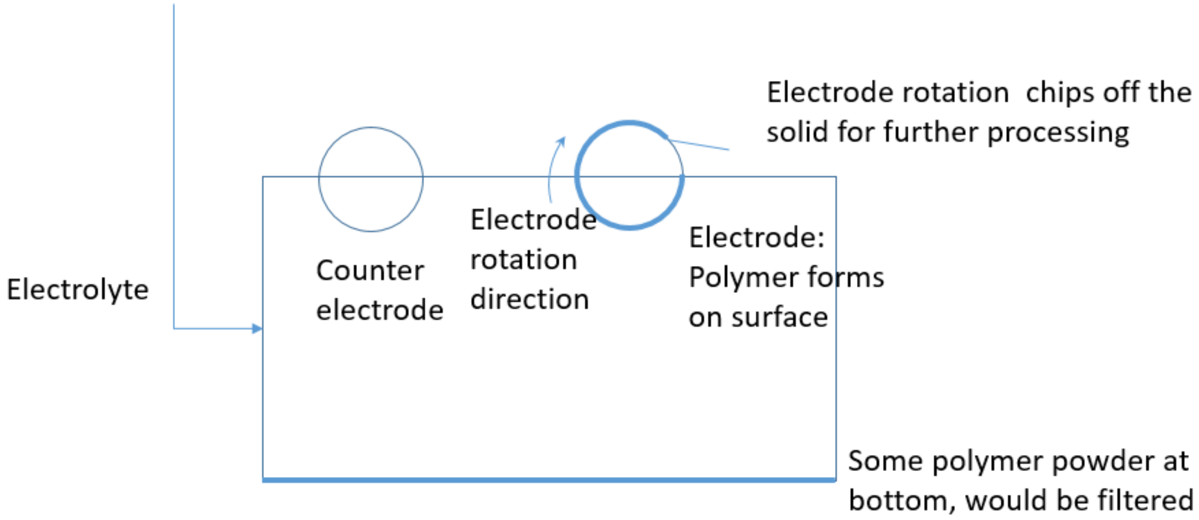


Figure 1-3 Rotating cylinder design variant of the continuous solid removal device

2. *Variant 2 - Conveyor Belt*

Conveyor belt is another variant, well-suited for industrial scale adaptation. The working principle of solid removal a cyclic movement very similar to the rotating cylinder, but it instead applies conveyor belt setup, which offers some more features:

1) Bigger area in the liquid phase, dipping well into the electrolyte to electrochemical reaction output, and allows a more compact reagent tank. For example, the lower pulley and a large portion of the conveyor belt can be submerged in the liquid/electrolyte phase.
2) Bigger area in the gas/air phase, allowing the device to be more reliable, with less worry of the liquid/electrolyte leakage to the gears and shaft for conveyor belt movement, and the electrical wiring setup of electrode.
3) Greater height in the gas/liquid phase allocates more space for more reliable design of the device for removing the deposits, such as a conveyor belt for delivery of scrubbed solid

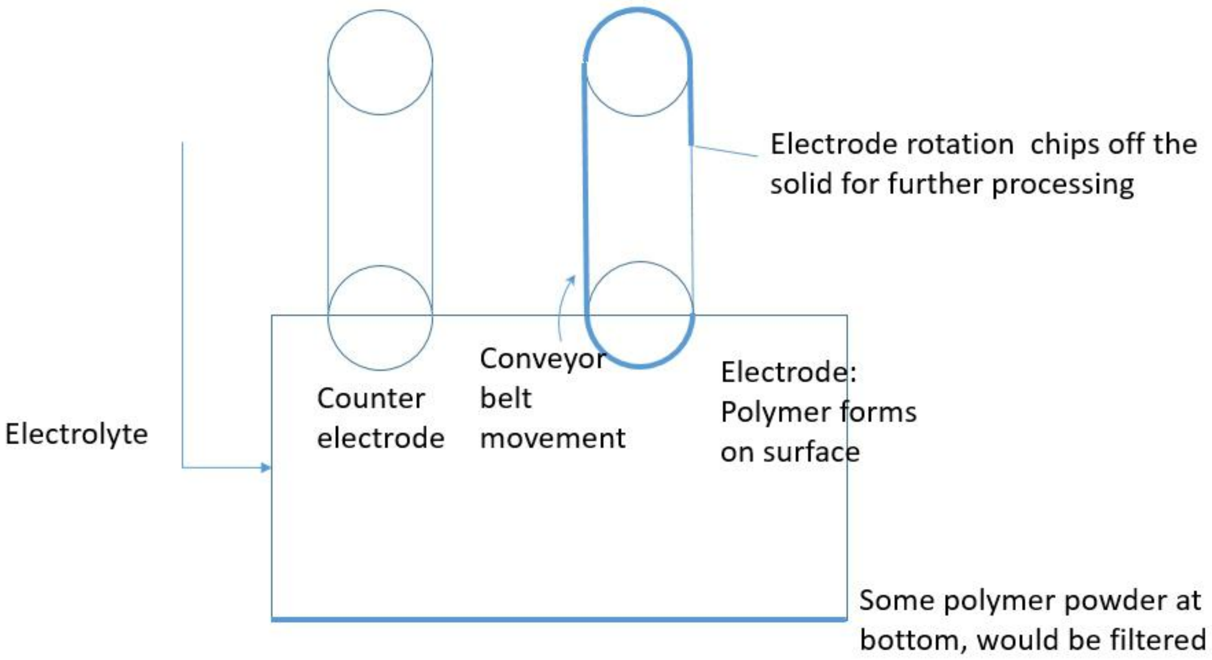


Figure 1-4 Conveyor belt variant of the continuous solid removal device

3. Variant 3 - Rotating Disk

Rotating disk is another variant of the device, where a conducting rigid disk, partially immersed in the electrolyte/liquid phase, serves as the electrode. The disk rotates by shaft action with a removal device placed against and in contact with the surface to remove solid deposited on electrode surface.

It offers the following features:

1) Large surface area
2) Easy to construct and manufacture
3) Compact design

Again, note that the tank can be cylindrical to reduce the reactor space. The rotating disk can also be made spiral instead of parallel disk as alternative that allows the products to be screwed to outside of electrochemical reactor continuously.

Note that in any cases, even though it is a good idea to have the same shape of counter electrode with electrode for easy manufacturing and setup. For the device to work the conductivity just has to be established, and the counterelectrode does not have to be the same shape as the electrode.

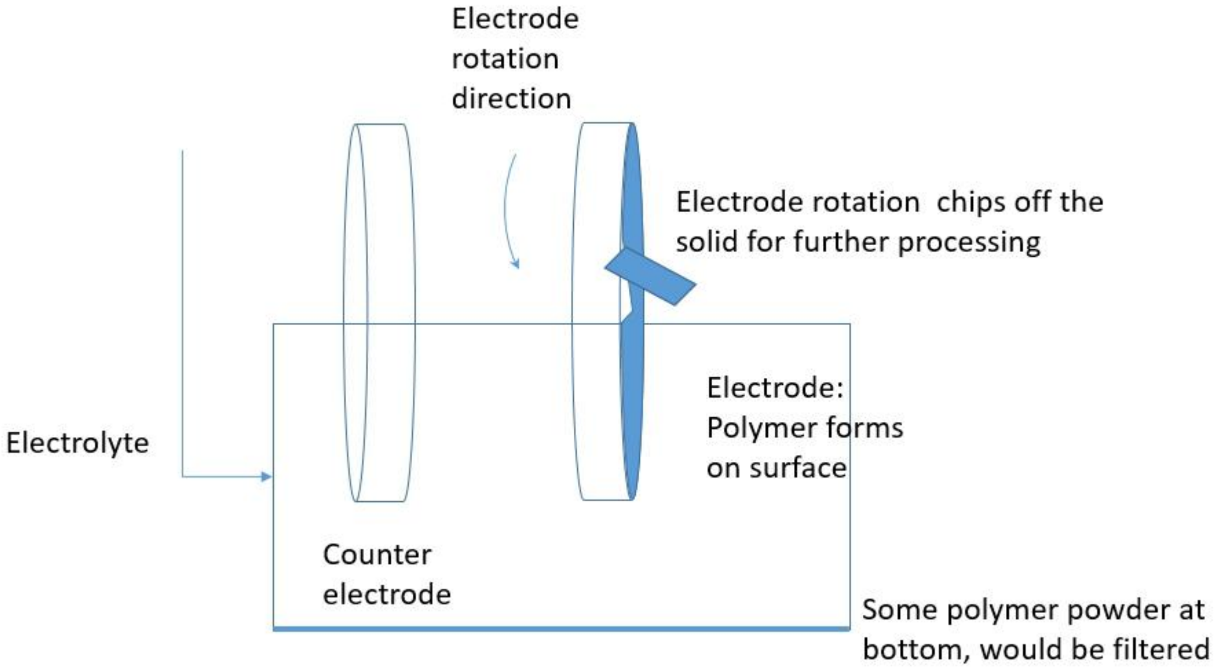


Figure 1-5 Rotating disk variant of the continuous solid removal device

2. Electrochemical Production of Addition Polymer

Addition polymer is a class of polymer formed by addition reaction, in which no by-product is produced. Some exemplary addition polymers comprise carbon backbone without heteroatoms, such as:

- Polyvinyl: Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), Polyvinyl Chloride (PVC), etc
- Polyalkanes in general, such as polybutadiene (rubber)

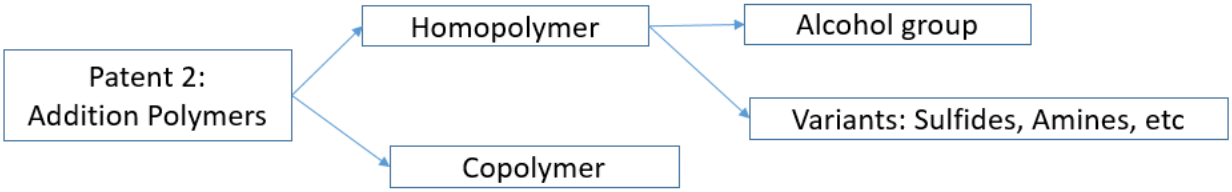


Figure 2-1 Breakdown of the electrochemical production of addition polymer

The electrochemical production of addition polymer can be classified into homopolymer and copolymer. In some embodiments, homopolymer results from elimination-addition polymerization from starting alcohol groups, or other variants such as sulfides and amines.

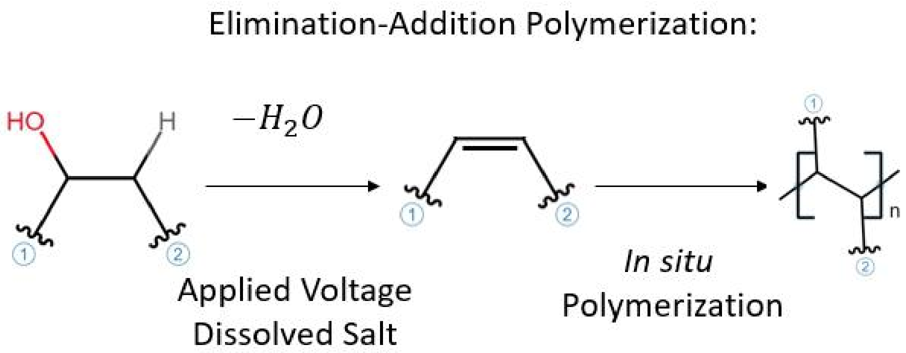


Figure 2-2 Representation of the electrochemical elimination-addition polymerization

Note that the polymerization can also be initiated from the second step, if unsaturated compounds, which includes unsaturated hydrocarbons such as alkenes or alkynes are used as the starting materials.

Copolymer, on the other hand, can be produced when different starting groups are mixed together. It can be different alcohol groups, or even between functional groups such as alcohol and sulfides, when these different species are present in the same system of electrolyte during the electrochemical reaction.

1. Alcohol Group

The major variant is alcohol as starting material, which results in a case of dehydration-polymerization where water is formed as by-product.

Homopolymer

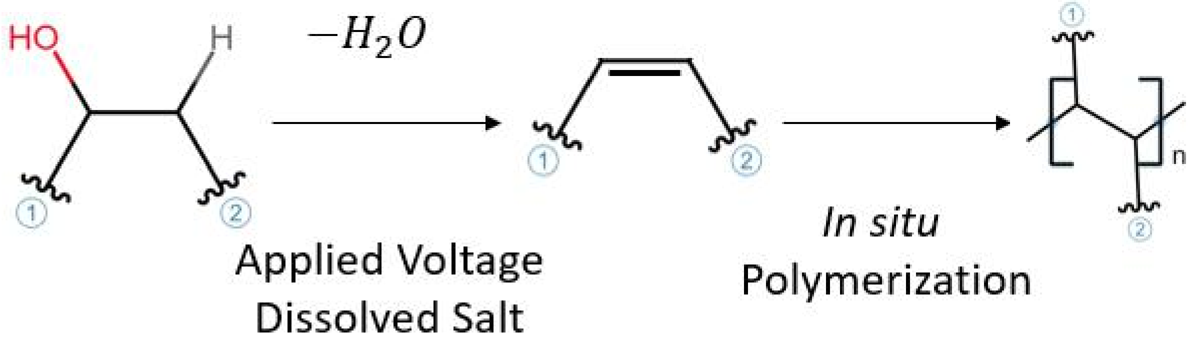


Figure 2-3 Polymer production from elimination of alcohol group

The examples include the following common polymers:

Table 1 Common examples and starting materials

1	**2**	**Products**
H	H	Polyethylene (PE)
H	CH3	Polypropylene (PP)
H	Phenyl Group	Polystyrene (PS)
H	OH	Polyvinyl Alcohol (PVOH)
H	Cl	Polyvinyl Chloride (PVC)
H	Nitrile	Polyacrylonitrile (PAN)
H	COOH	Polyacrylate (PAK)
H	Vinyl	Polybutadiene (synthetic rubber

Variants: Sulfides

Similar to alcohol group reaction, sulfides can also react electrochemically to form addition polymer, but with the formation of hydrogen sulfide as by-product:

Homopolymer

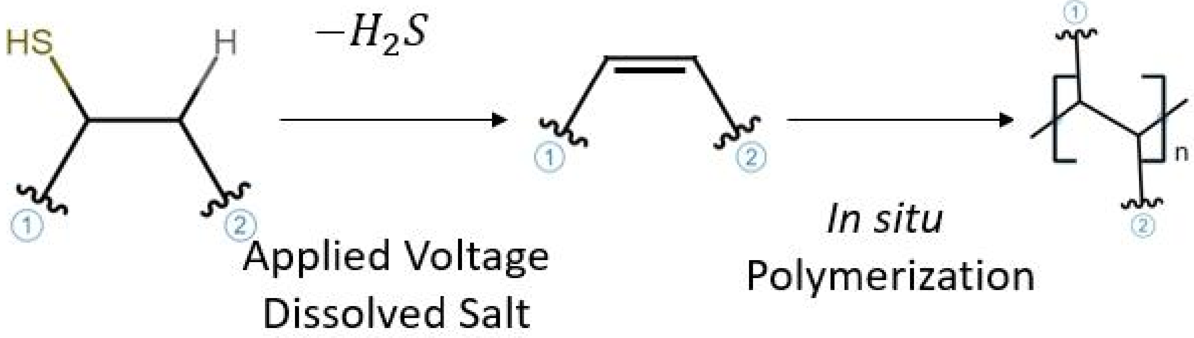


Figure 2-4 Polymer production from elimination of sulfide group

Copolymer

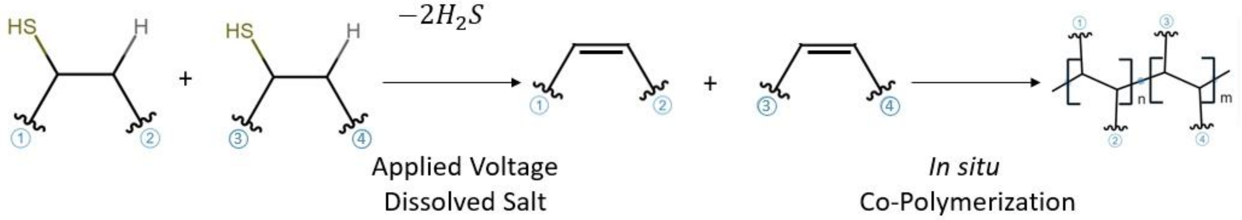


Figure 2-5 Copolymer production when different types of sulfides are present in the system

2. Variants: Amines

Similar to alcohol and sulfide reaction, amines can also react electrochemically to form addition polymer, with the formation of amines as by-product:

Homopolymer

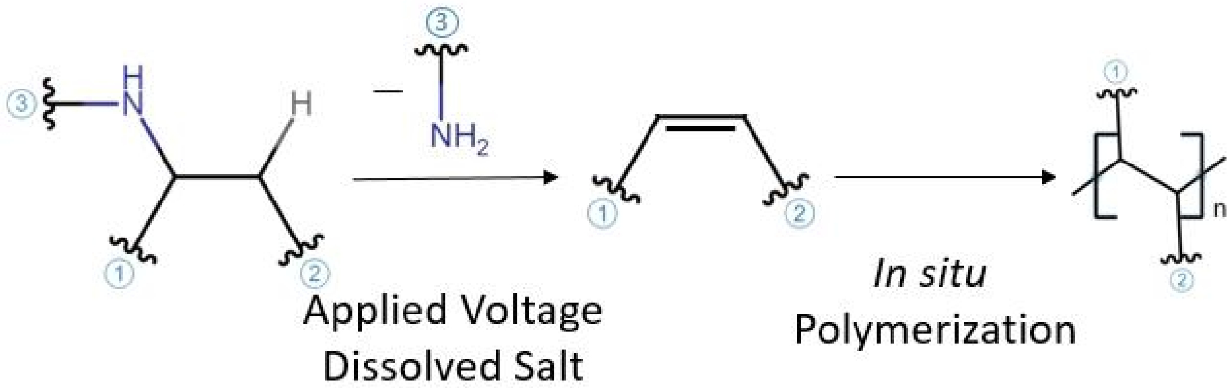


Figure 2-6 Polymer production from elimination of amine group

Note that if the substitute group 3 above is a hydrogen atom, ammonia instead of amine would be formed.

Copolymer

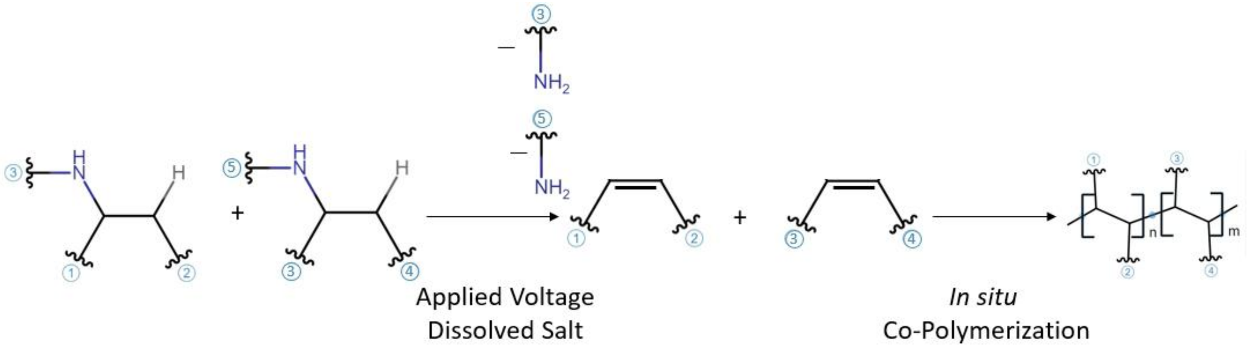


Figure 2-7 Copolymer production when different types of amines are present in the system

3. Copolymer

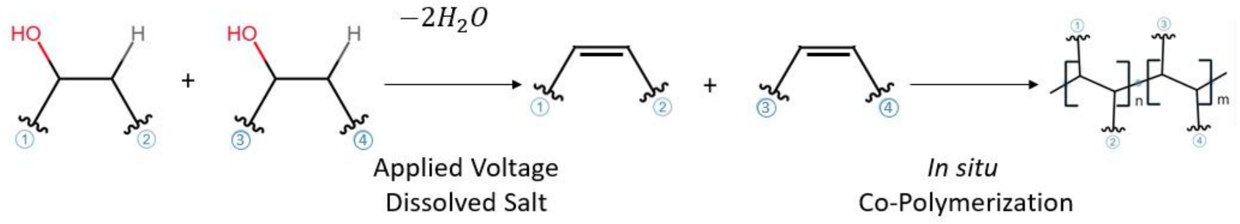


Figure 2-8 Coplymer production when different types of alcohols are present in the system

On the other hand, copolymer can be formed if different types of starting alcohols are present in the electrolyte system. Different types of starting group, such as alcohol with sulfide or amine, would also result in similar copolymer end-product.

Some examples of copolymer include:

Table 2 Common copolymer examples and starting materials

1	2	3	4	Products
H	H	H	Cl	vinyl chloride-ethylene plastic (VCE)
H	H	H	COOH	Ethylene-acrylic acid plastic (EAA)
H	Cl	H	OC=OCH3	Polyvinyl chloride acetate (PVCA/VCVAC)
H	H	H	OH	Ethylene-vinyl alcohol plastic (EVOH)

Note also that the copolymer can form if there are 3 or more types of starting chemicals, for instance the common Acrylonitrile butadiene styrene (ABS) resin, a type of valuable and widely used engineering plastic:

Table 3 Sample starting material for complex copolymer of ABS resin

1	2	3	4	5	6	Products
H	Phenyl	H	H	H	Nitrile	Acrylonitrile butadiene styrene (ABS)

Note that the copolymer order of each unit can be arbitrary.

3. Patent 3: Electrochemical Production of Condensation Polymers

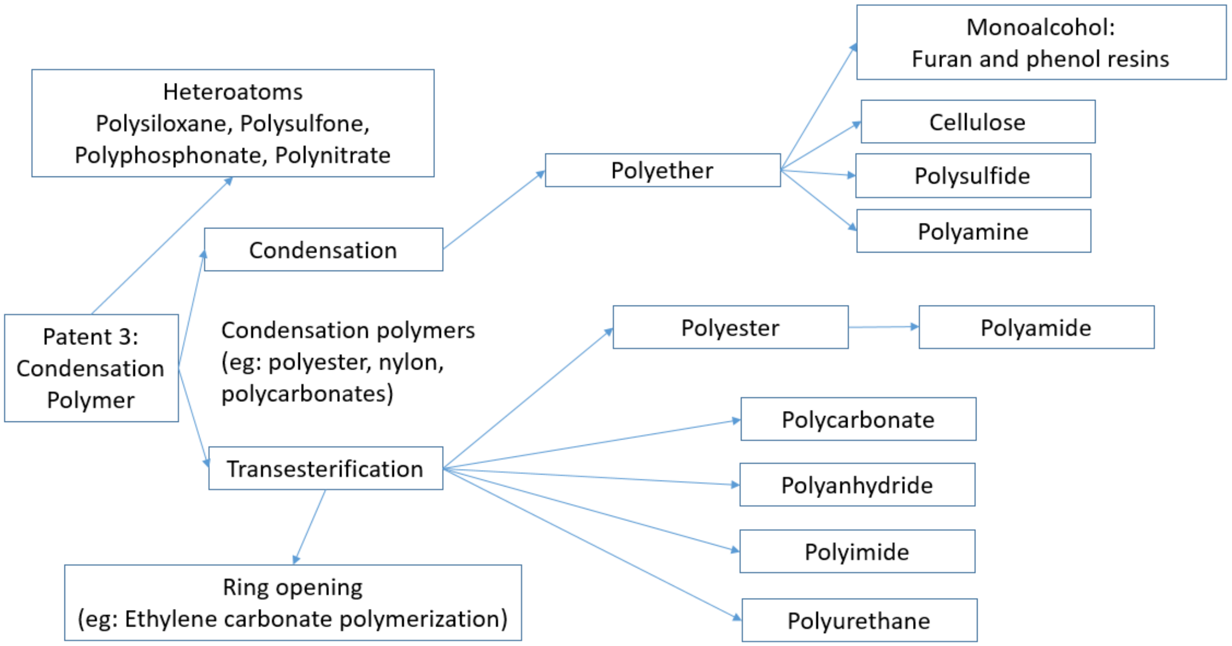


Figure 3-1 Breakdown of the major possibilities of electrochemical production of condensation polymers

Condensation polymer is a class of polymer formed through condensation polymerization. It includes but is not limited to:

- Polyether (including cellulose, furan, phenolic and related resins)
- Polysulfide
- Polyamine
- Polyester
- Polyamide
- Polycarbonate
- Polyanhydride
- Polyimide
- Polyurethane
- Heteroatom esters such as polysiloxanes, polysulfone, polyphosphonate and polynitrate

The electrochemical production of condensation polymers comprises condensation and transesterification. Condensation involves intermolecular elimination of active groups to join molecules together, while transesterification involves more complex elimination often with carbonyl groups.

1. *Condensation: Polyether*

The simplest reaction is the electrochemical condensation of diol to form polyether, with water formation as by-product:

Homopolymer

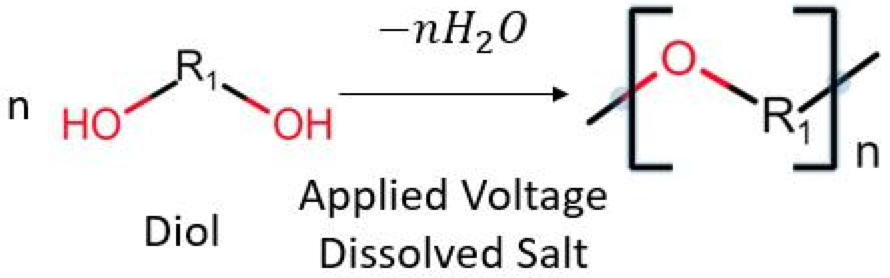


Figure 3-2 Polyether production from diols condensation

Similar to addition polymer production, copolymerization between different types of diols are possible if present in same system:

Copolymer

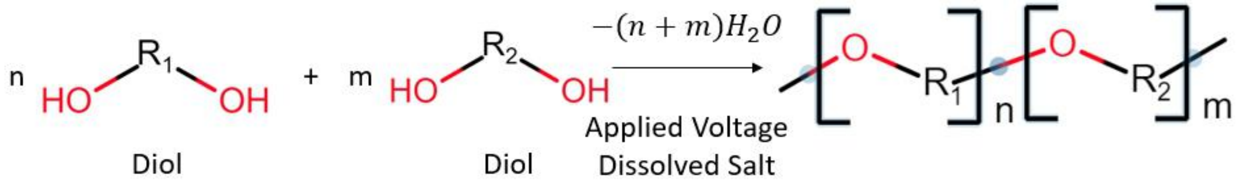


Figure 3-3 Polyether copolymer production when different types of diols are present in the system

Note that the copolymer order of each unit can be arbitrary.

2. Condensation: Monoalcohol: Furan and phenolic resin

When the carbon backbone is certain cyclic aromatic compounds, such as furan and phenol, condensation can still happen with single alcohol group. The end product is either polyether or polyalkane groups.

Furan resin

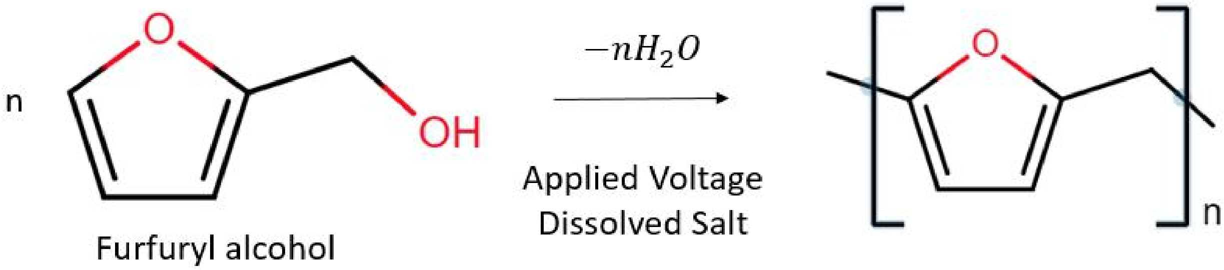


Figure 3-4 Furan resin production from furfuryl alcohols

Phenolic resin

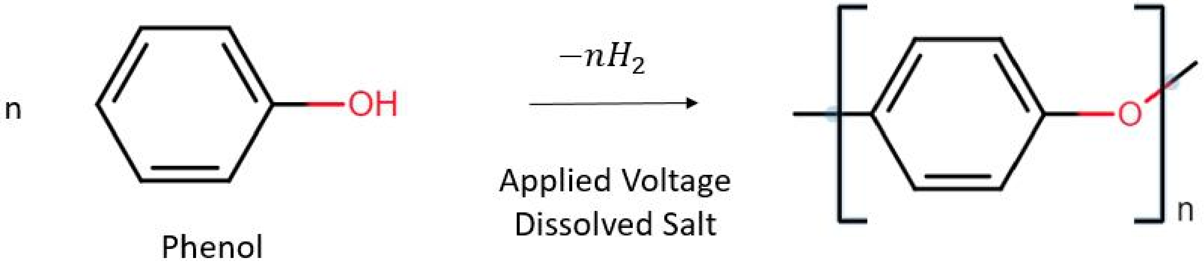


Figure 3-5 Phenolic polymer production from phenol

Note that for the above cases, there is no adjacent hydrogen atom for intramolecular dehydration/elimination, so the intermolecular reaction is the only reaction available.

3. Condensation: Cellulose

It is notable that the carbon backbone can comprise a sugar or its derivative, for which case the end product of polyether formation is actually a cellulose resin, often of useful application as biodegradable polymer. For instance, the starting material can be glucose:

Homopolymer

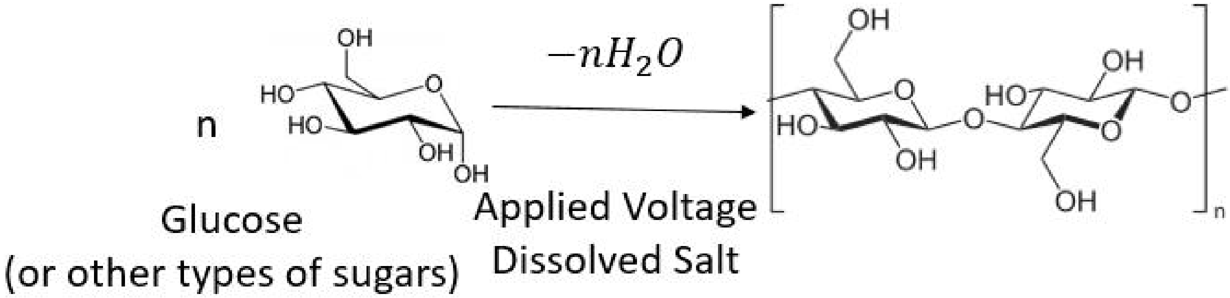


Figure 3-6 Cellulose polymer (subset of polyether) production from simpler forms of sugars such as glucose

Similar reaction applies for derivatives of sugars such as glucose with some –OH group esterified with acetate group:

Derivatives: such as cellulose acetate

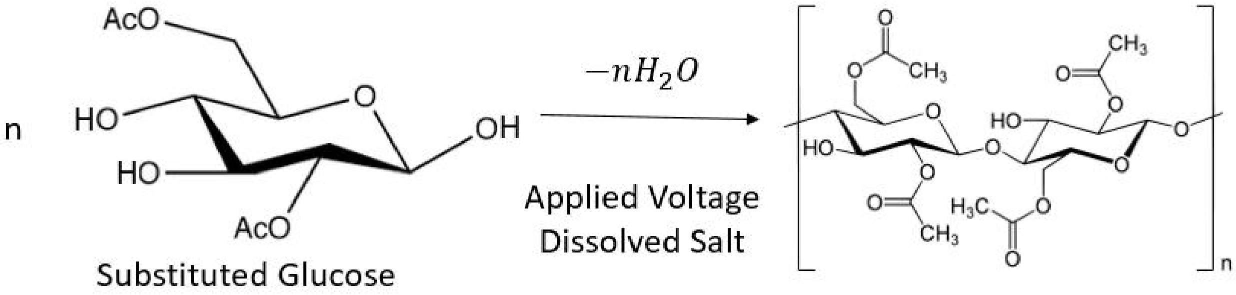


Figure 3-7 Cellulose resins derivative production example where some parts of sugars have been substituted with derivative groups

Cellulose copolymers are also possible if different sugars are mixed in the same system during the reaction.

4. Condensation: Polysulfides

Similar to polyether, polysulfides can be produced electrochemically from disulfide:

Homopolymer

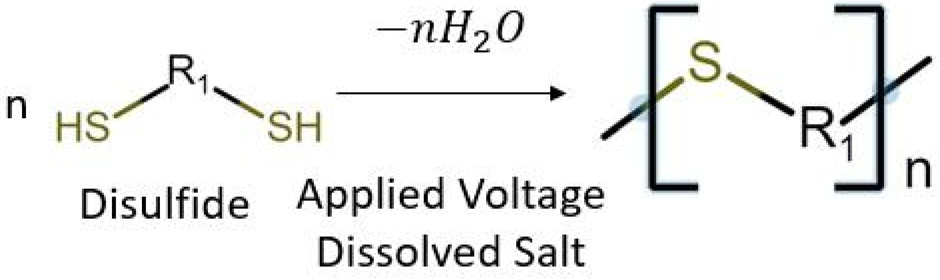


Figure 3-8 Polysulfide production from disulfides

Copolymers are also possible when different disulfides are mixed together in the same system:

Copolymer

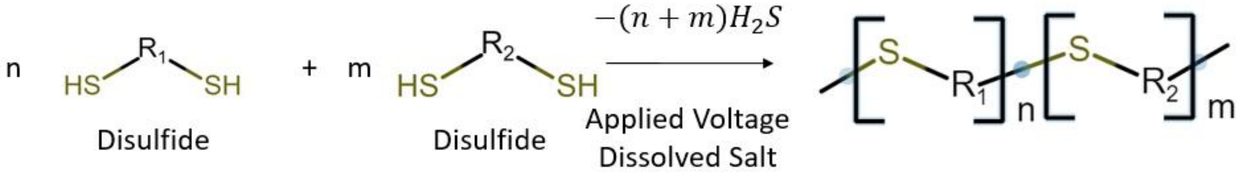


Figure 3-9 Polysulfide copolymer production when different types of sulfides are present in the system

5. *Condensation: Polyamines*

Similar to polyether and polysulfides, polyamines can be produced electrochemically from diamine:

Homopolymer

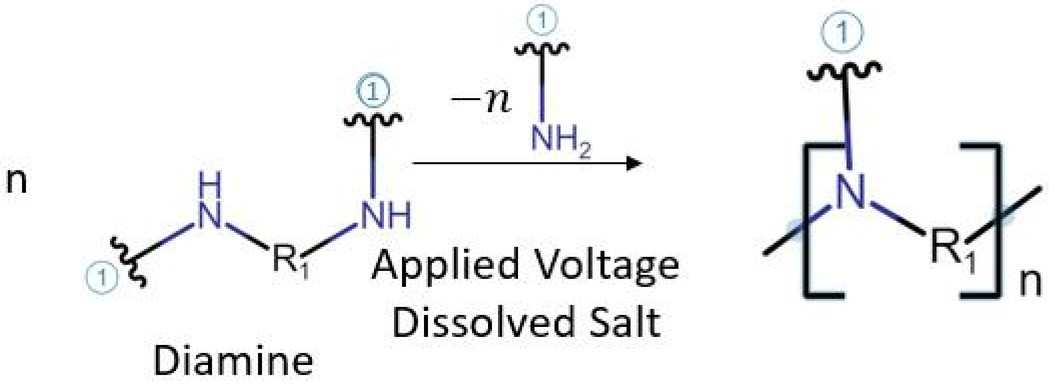


Figure 3-10 Polyamine production from diamine condensation

Copolymers can be produced when different types of diamines are mixed in the same system.

Copolymer

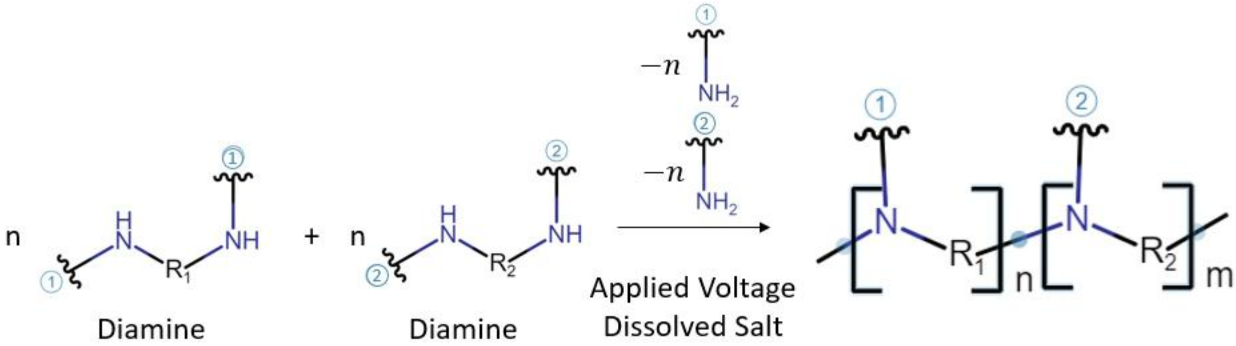


Figure 3-11 Polyamine copolymer production when different types of diamines are present in the system

6. Transesterification: Polyester

Polyester can be produced from transesterification, which is in some sense very similar to condensation. The simplest variant is the reaction between alcohol and carboxylic acid group in the same molecule of hydroxyl acid:

Homopolymer:

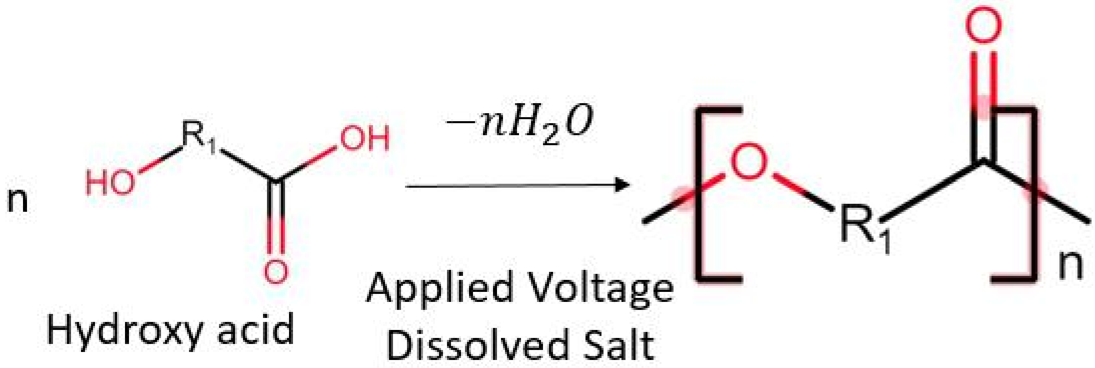


Figure 3-12 ***Polyester production from Hydroxy acid condensation***

Note that the hydroxyl acid reaction to form polyester is very useful for many biodegradable polymer production such as polylactic acid from lactic acid, and polyacrylate from acrylic acid.

The next variant is the reaction between alcohol and carboxylic acid groups in different molecules, such as between diol and diacid:

Regular Esterification:

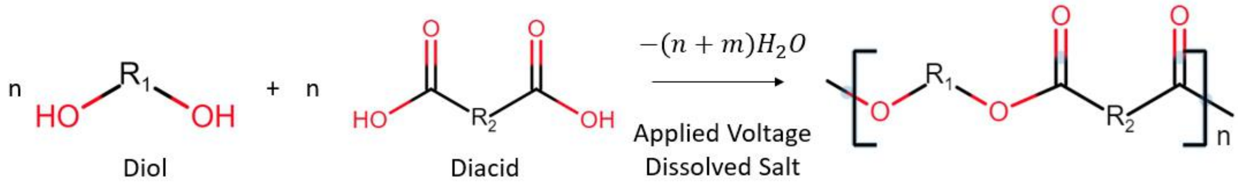


Figure 3-13 Polyester production from diol and diacid

7. Transesterification: Polyamide

Polyamide is a class of useful polymer materials, it includes biological proteins and materials such as nylon and Kevlar. In very similar pattern as polyester, it involves reaction between amine and carboxylic acid groups to be produced. The simplest variant is the amino acid polymerization where amine and carboxylic acid groups are in the same molecule:

Homopolymer:

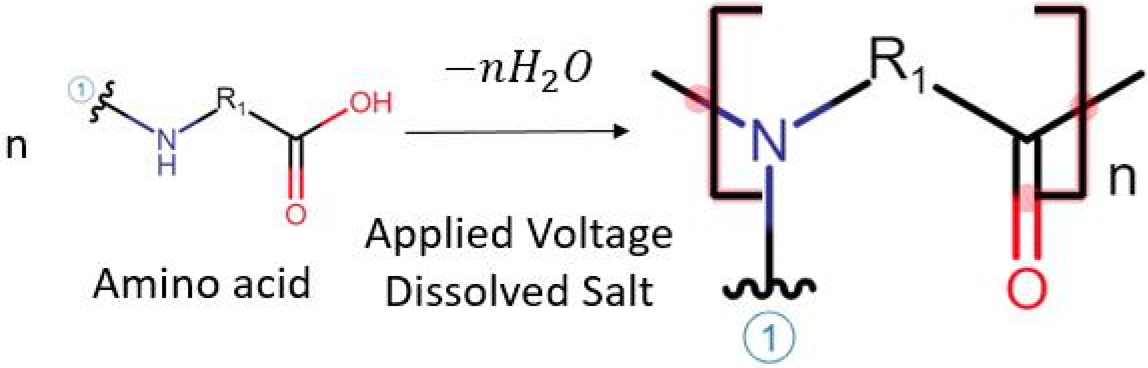


Figure 3-14 Polyamide production from amino acid condensation

Another variant is the esterification of amine and carboxylic acid groups in different molecules, between diamine and diacid:

Regular Condensation:

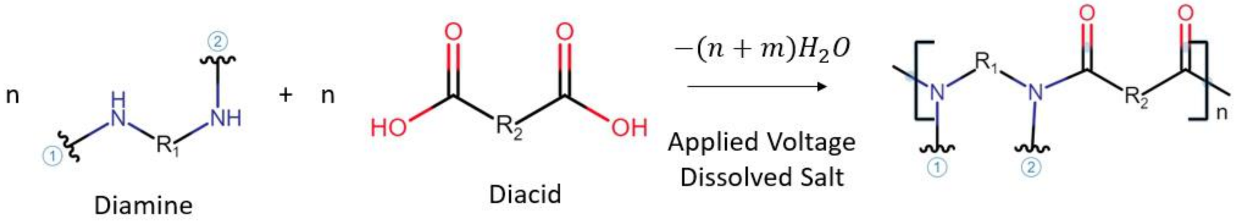


Figure 3-15 Polyamide production from diamine and diacid

8. Transesterification: Polycarbonates

Polycarbonates can also be produced electrochemically by reaction between diol and carbonyl compounds. This is a very useful reaction because the carbonyl compounds can include (but not limited to) urea which is abundantly cheap, yet not super toxic, carbonic acid from carbon dioxide sequestration, and dimethyl carbonates from industry as chemical feedstock. It also produces alcohols as by-products which is often recovered as useful fuels or valuable chemical product.

Homopolymer

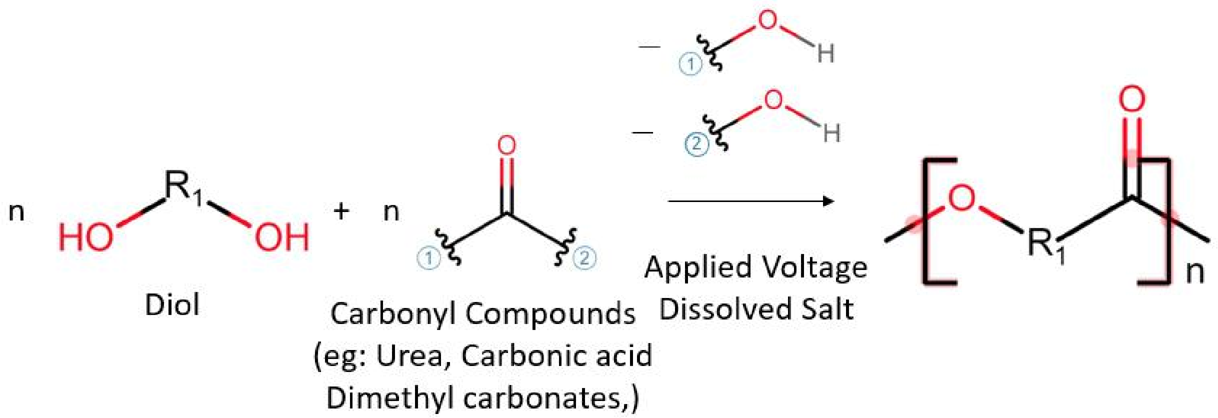


Figure 3-16 Polycarbonate production from diols and carbonyl compounds

When different diols are present, copolymeric carbonates can be produced:

Copolymer

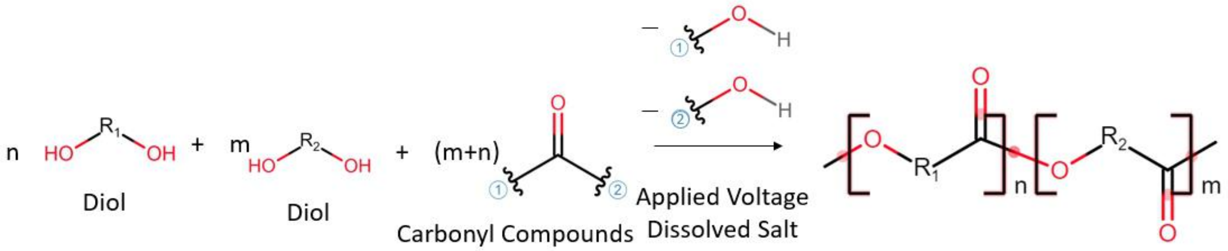


Figure 3-17 Copolymer production of polycarbonates, when different diols are present in the system

9. Transesterification: Polyanhydride

Polyanhydride can be produced electrochemically from diacid and acid anhydride. The products are carboxylic acid or its derivatives.

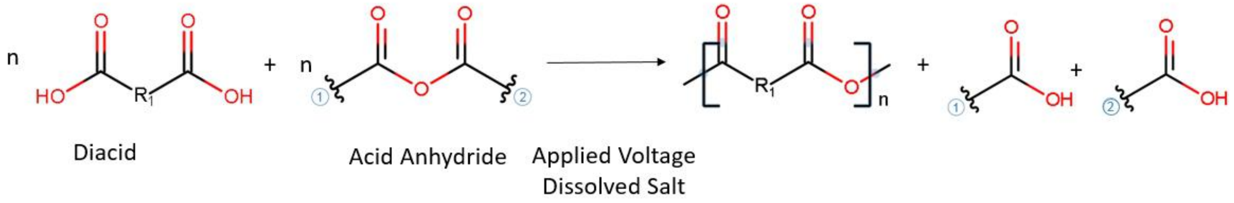


Figure 3-18 Polyanhydride production from diacid and acid anhydride

10. Transesterification: Polyurethane

Polyurethane can be produced electrochemically from reaction between diol and diisocyanate.

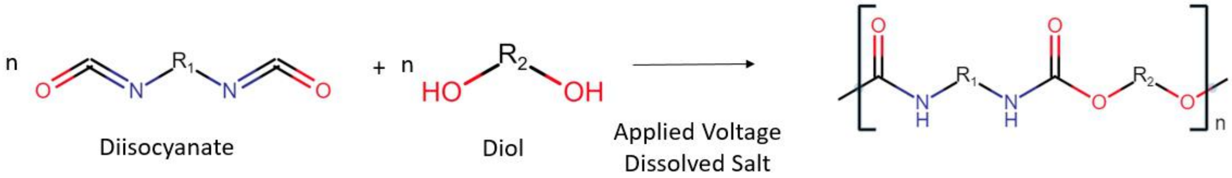


Figure 3-19 Polyurethane production by diisocyanate and diol

11. Transesterification: Polyimide

Polyimide can be produced from reaction dianhydride and diamine, or dianhydride with diisocyanate. Dianhydride-diamine reaction is more common because diamine is more abundant:

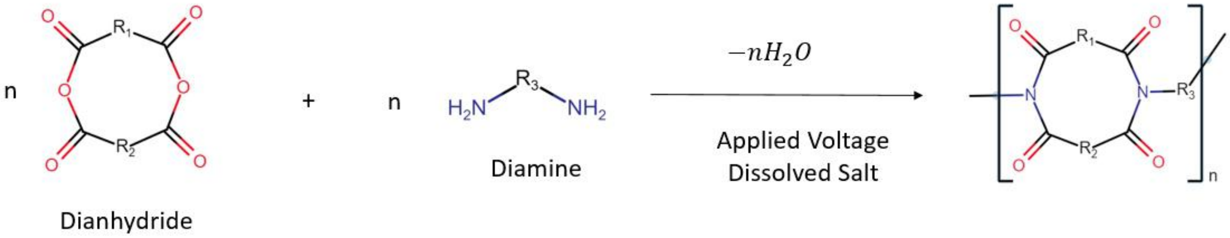


Figure 3-20 Polyimide production from dianhydride and diamine

On the other hand, the dianhydride-diisocynate reaction produces carbon dioxide which can be readily separated as gas for recovery.

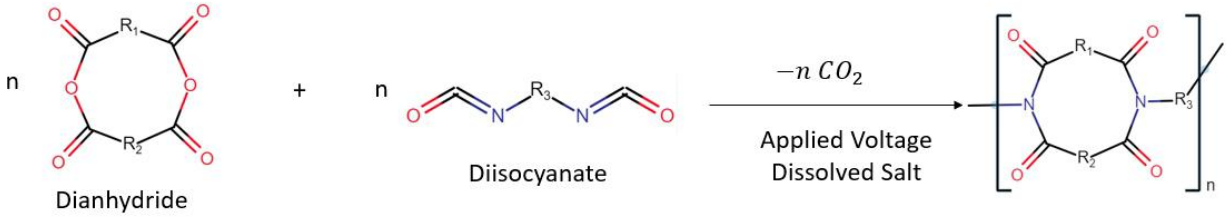


Figure 3-21 Polyimide production from dianhydride and diisocyanate

12. Transesterification: Ring opening

Ring-opening reaction is a useful way to produce polymers from cyclic compounds. The cyclic compounds are often heteroatom rings, containing groups such as carbonyl (C=O), Carbonate, Ether, Ester, amine, amide, sulfide, or other groups with atoms other than Carbon atom.

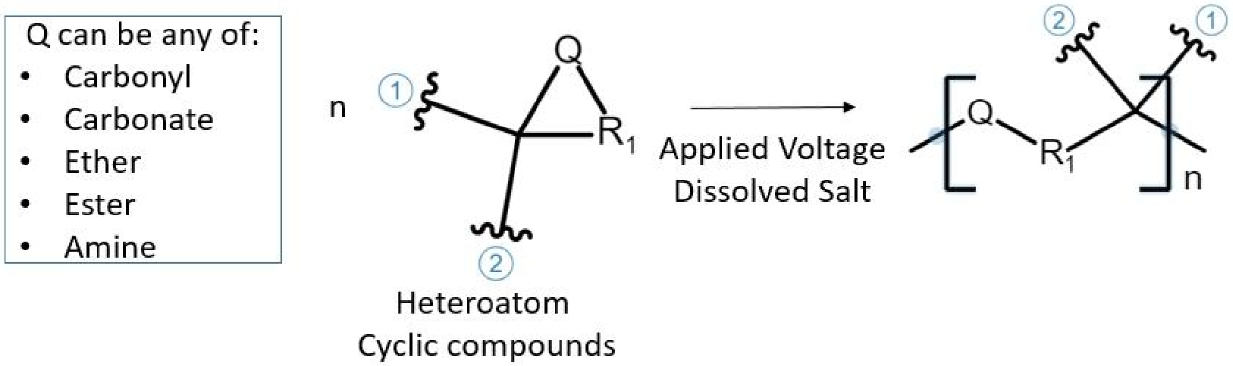


Figure 3-22 General ring opening reaction as a variant of condensation polymer production

Note that while the equation began with the shortest ring possible which is a triangle ring, the ring can be larger by using larger ring. In some embodiments, the resulting polymers comprise carbon backbones. Some notable examples include ring opening of cyclic carbonates which are staple of polycarbonate production:

Examples: Cyclic Carbonates

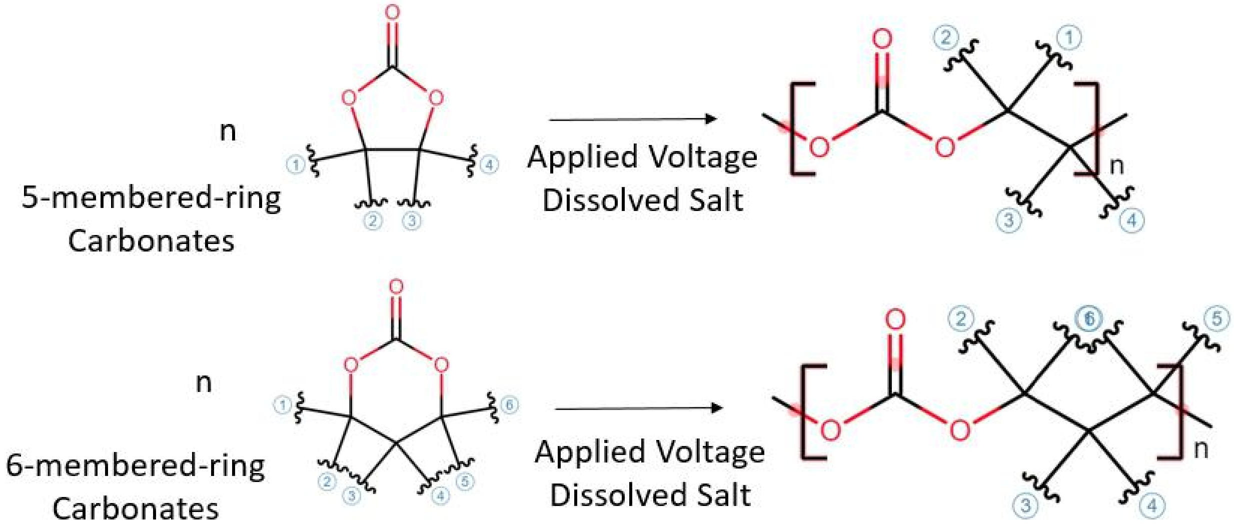


Figure 3-23 Examples of Ring opening reaction as a variant of transesterification, for this case the 5-membered and 6-membered cyclic carbonates compounds

13. Transesterification - Heteroatoms:

14. Polysiloxanes, Polysulfone, Polyphosphonate, Polynitrate

The condensation and/or transesterification also works when the adjacent atom is heteroatom instead of carbon atom. For instance, siloxanes can undergo condensation (similar to polyether) to form polysiloxanes:

Polysiloxanes

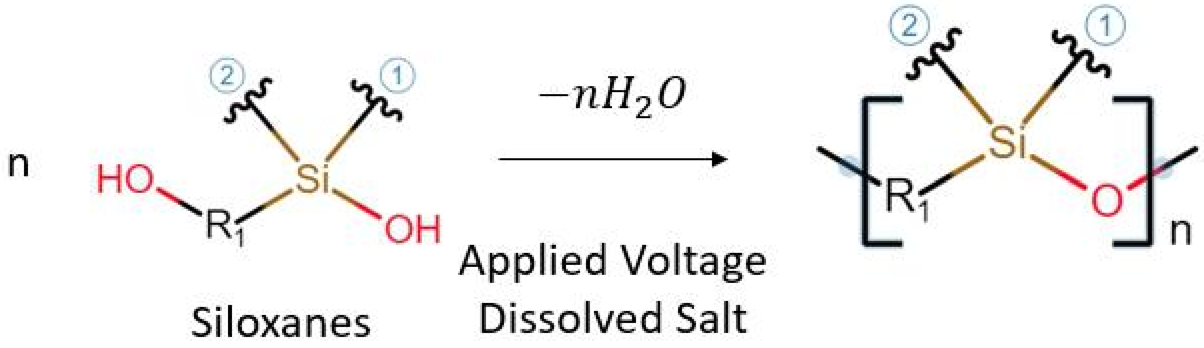


Figure 3-24 Polysiloxanes production from siloxanes

As another example, diol can undergo transesterification with sulfonyl compounds (similar to carbonyl compounds) to form polysulfones.

Polysulfones

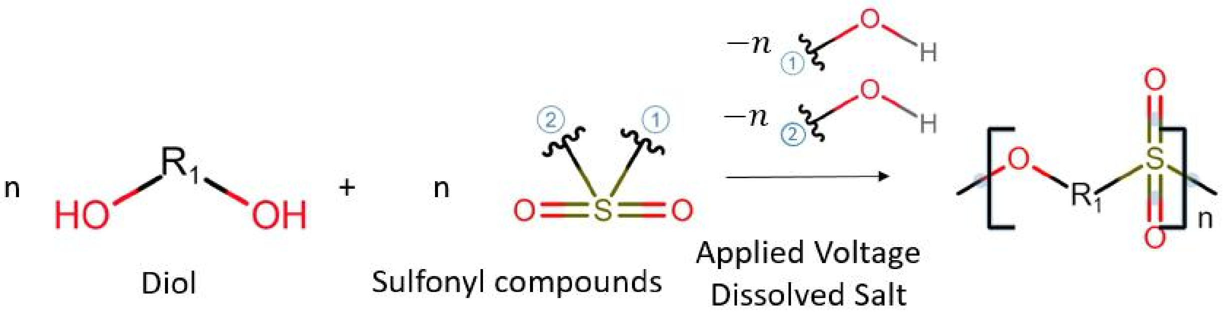


Figure 3-25 Polysulfones production from diol and sulfonyl compounds

Other possibility include Polyphosphonate, Polynitrate, among others

Claims

1. A reactor for electrochemical reaction, the reactor comprising:

a vessel for containing an electrolyte solution;

an electrode and a counter electrode, wherein the electrodes are disposed in the vessel such that

a first portion of the electrode and the counter electrode is immersed in the electrolyte solution,

a second portion of the electrode is not immersed in the electrolyte solution, and

the electrode moves such that the size of the first portion and the second portion thereof remain constant while parts of the first electrode forming the first portion and the second portion thereof changes; and

a removal device disposed in contact with the electrode for removing deposits from the electrode.

2. The reactor of claim 1, wherein
the counter electrode further comprises a second portion that is not immersed in the electrolyte solution.

3. The reactor of claim 1 or 2, wherein the movement of the electrode stirs the electrolyte solution.

4. The reactor of any one of claims 1 to 3, wherein the electrode is cylindrical and rotates about an axis of the cylinder.

5. The reactor of claim 4, wherein the rotation of the cylindrical electrode stirs the electrolyte solution

6. The reactor of any one of claims 1 to 3, wherein the electrode comprises a conductive conveyor belt that is partially immersed in the electrolyte solution.

7. The reactor of claim 6, wherein the electrode further comprises at least two pulleys, and at least one of the at least two pulleys is partially immersed in the electrolyte solution.

8. The reactor of claim 7, wherein the one of the two pulleys that is partially immersed in the electrolyte solution is not conductive.

9. The reactor of any one of claims 1 to 8, wherein the removal device is in contact with the second portion of the electrode.

10. The reactor of claim 9, wherein the removal device comprises a rigid plate for scraping the deposits off the second portion of the electrode.

11. The reactor of claim 10, wherein the rigid plate is tilted such that the deposits scraped off slide away from the second portion of the electrode on the rigid plate.

12. The reactor of any one of claims 9, wherein the removal device comprises a conveyor belt for removing the deposits off the second portion of the electrode by friction.

13. The reactor of claim 12, wherein the conveyor belt comprises an abrasive surface.

14. The reactor of any one of claims 11 to 12, wherein the conveyor belt transports the removed deposits away from the second portion of the electrode.

15. The reactor of any one of claims 1 to 8, wherein the removal device is in contact with the first portion of the electrode.

16. The reactor of claim 15, further comprising a device for collecting the removed deposits.

17. The reactor of any one of claims 1 to 16, wherein the electrode and the counter electrode are separated by a separator, a diaphragm, or a conducting membrane.

18. The reactor of any one of claims 1 to 17, wherein the electrolyte solution is stirred to maintain a substantially homogeneous concentration.

19. The reactor of any one of claims 1 to 18, further comprising a reference electrode for measuring standard electrode potential.

20. A electrochemical reaction system, comprising
a mixing unit for mixing reactants;
the reactor of any one of claims 1 to 19; and
a solid separator.

21. The electrochemical reaction system of claim 20, further comprising an electrolyte recovery unit.

22. A Process for preparing polymer products, comprising:
immersing a reaction electrode and a counter electrode in an electrolyte solution;
establishing a voltage differential between the electrode and the counter electrode;
mixing reactant in the electrolyte solution;
polymerizing the reactant, the resulting polymer depositing on the reaction electrode;
removing deposits from the reaction electrode; and
separating impurities from the deposits to obtain polymer products.

23. The process of claim 22, further comprising collecting spent electrolyte and recover electrolyte from the spent electrolyte.

24. The process of claim 23, wherein the recovered electrolyte is introduced into the reactor.

25. The process of any one of claims 22 to 24, wherein the reactant comprises ethylene glycol, propylene glycol, halohydrin, urea, glycerol, ethanol, unsaturated compounds, or a mixture of two or more thereof.

26. The process of claim 25, wherein the unsaturated compounds are unsaturated hydrocarbons.

27. The process of any one of claims 22 to 24, wherein the reactant comprises alcohol, sulphide, amine, or a mixture of two or more thereof.

28. The process of any one of claims 22 to 27, wherein a membrane is disposed in the electrolyte solution.

29. The process of claim 22, wherein the polymerization comprises condensation polymerization, addition polymerization, or transesterification polymerization.

30. The process of claim 22, wherein the polymerization comprises internal elimination followed by addition polymerization.

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