BTech
Project

Supervisor:
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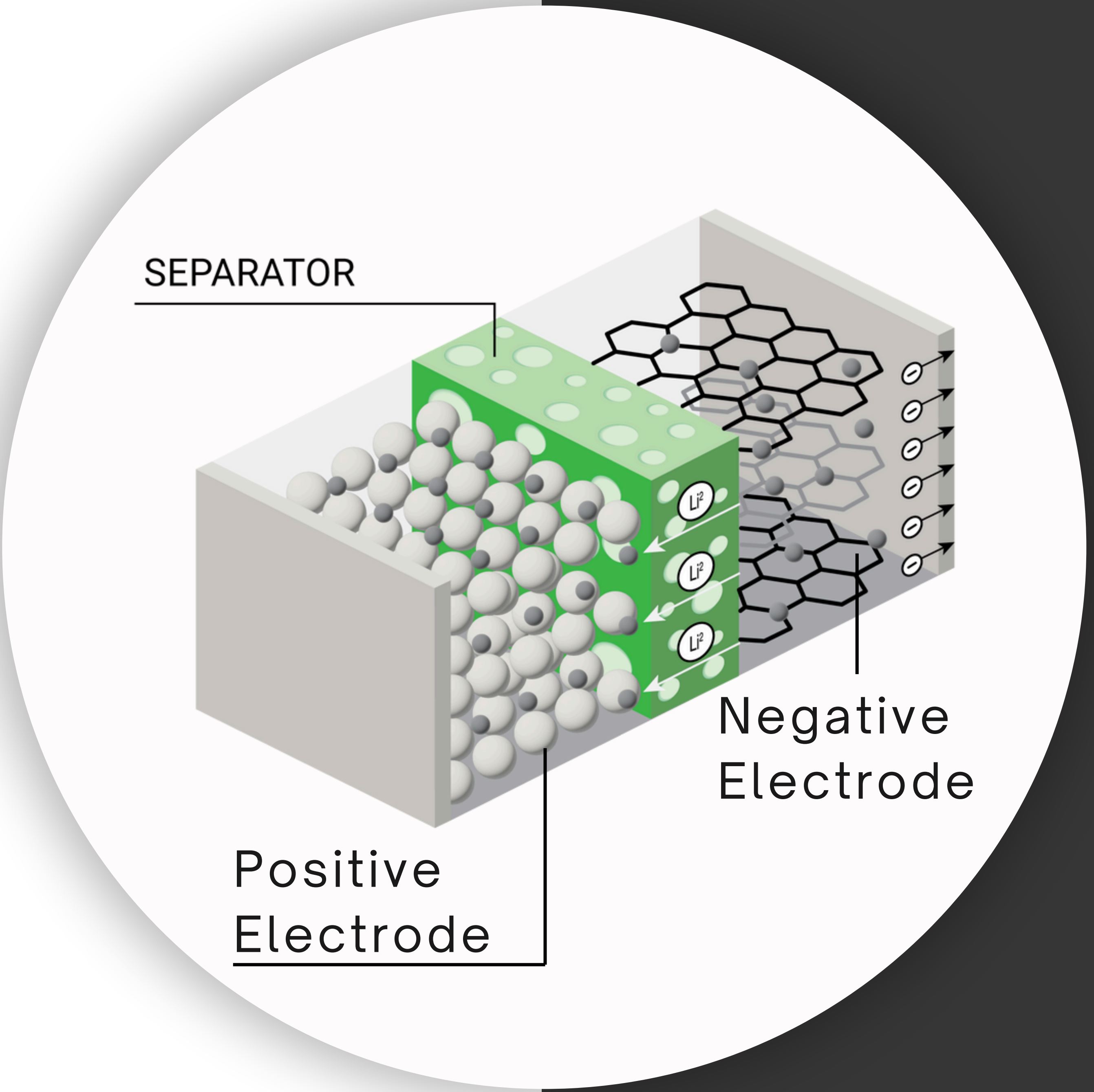
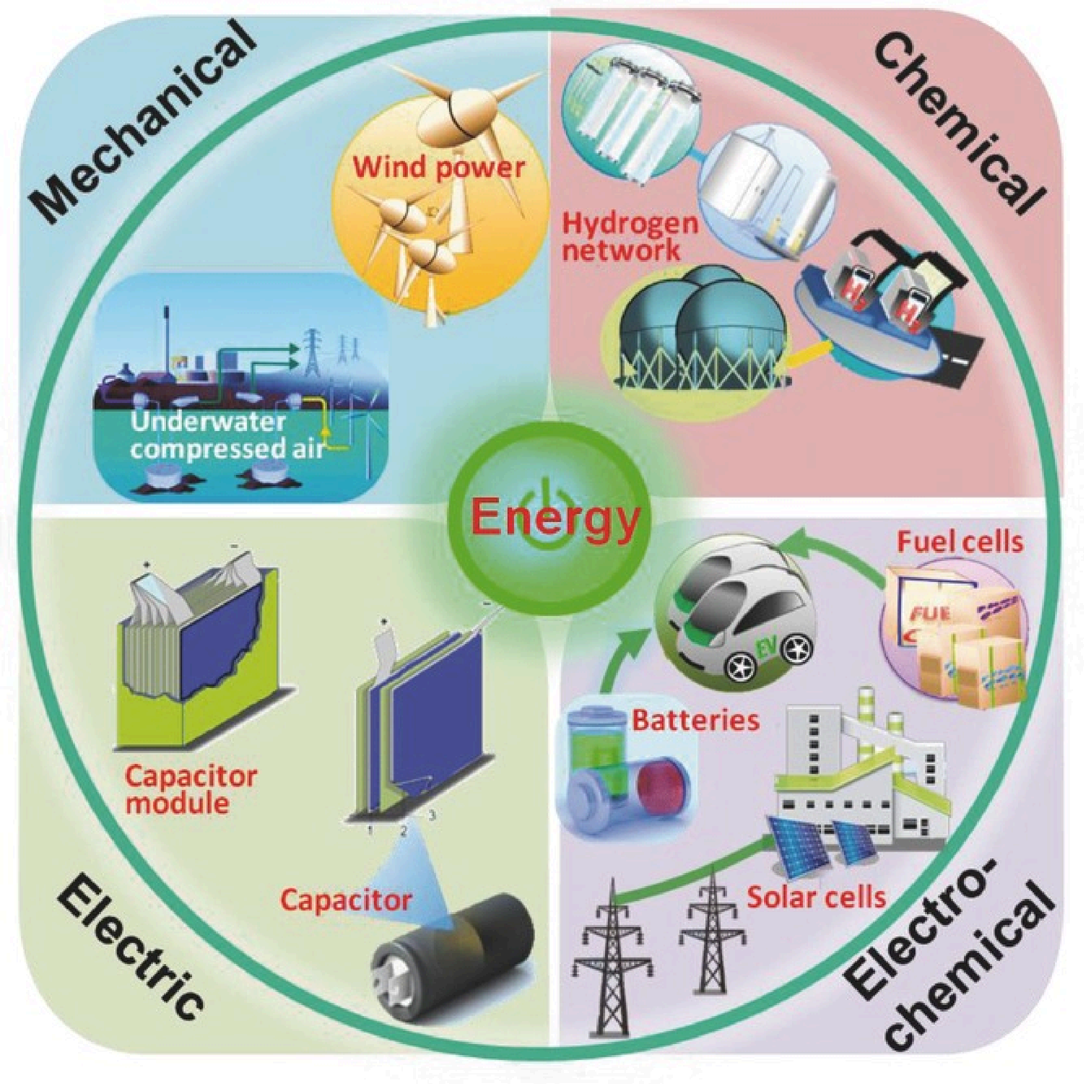


CONTENT

Energy Storage

Renewable energy resources are intermittent in nature. To store the renewable energy, we need energy storage systems.

Batteries play a crucial role in energy storage due to their ability to store electrical energy chemically and releasing it as needed in place of unavailability.



Why Sodium Ion Battery ?

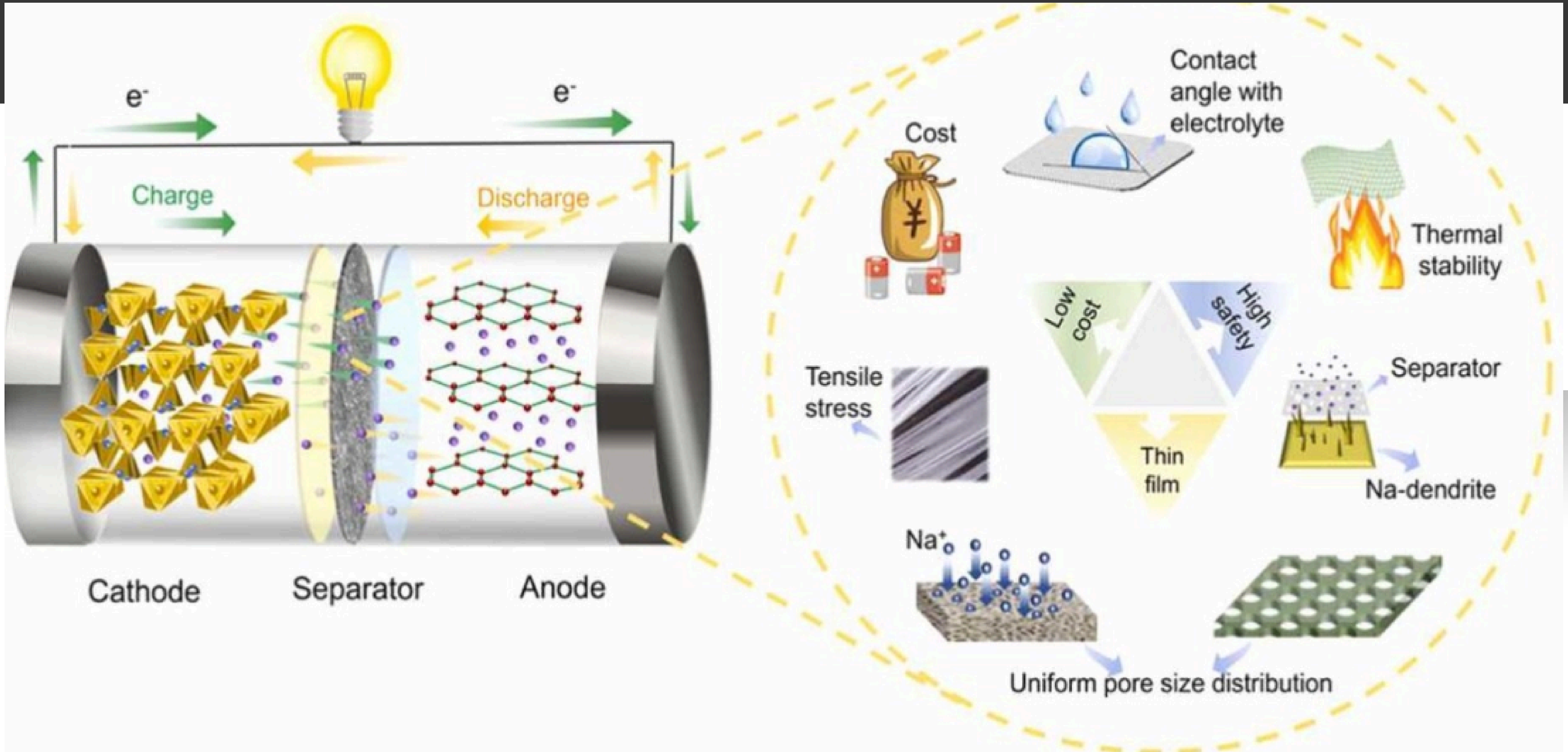
$$NaTMO_2 \underset{Discharge}{\overset{Charge}{\rightleftharpoons}} Na_{1-x}TMO_2 + xNa^+ + xe^-$$

$$C + xNa^+ + xe^- \underset{Discharge}{\overset{Charge}{\rightleftharpoons}} Na_xC$$

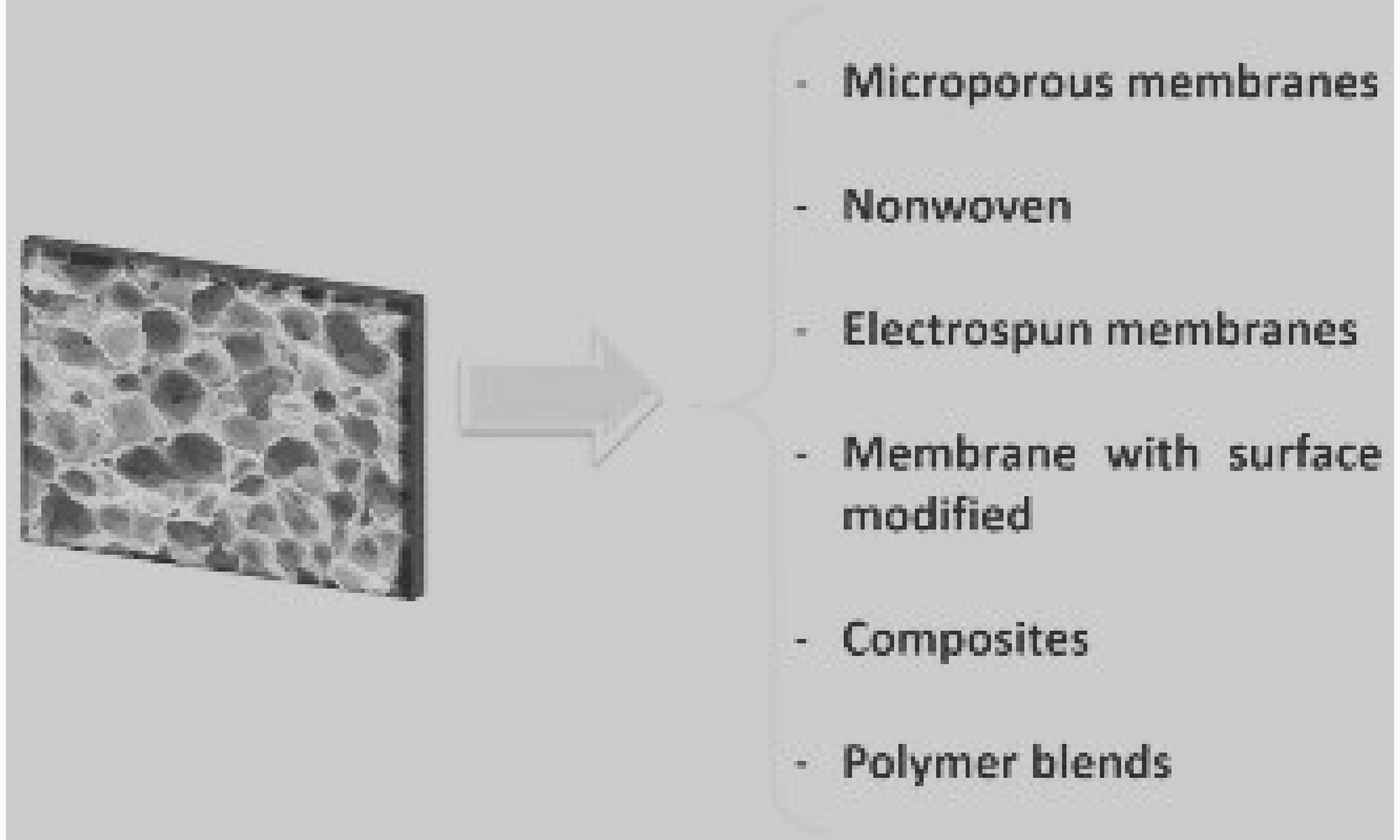
TM=Transition metal

$$NaTMO_2 + C \underset{Discharge}{\overset{Charge}{\rightleftharpoons}} Na_xC + Na_{1-x}TMO_2$$

Sodium-ion batteries are a strong alternative to lithium-ion batteries due to the abundance of sodium, making them more sustainable and potentially cheaper option for large scale industries.
They also offer better thermal stability, reducing the risk of overheating and fires.



Seperator



A separator is a porous membrane placed between electrodes of opposite polarity, permeable to ionic flow but preventing electric contact of the electrodes.

It allows ion transport through the electrolyte, which is essential for the battery's charging and discharging processes.

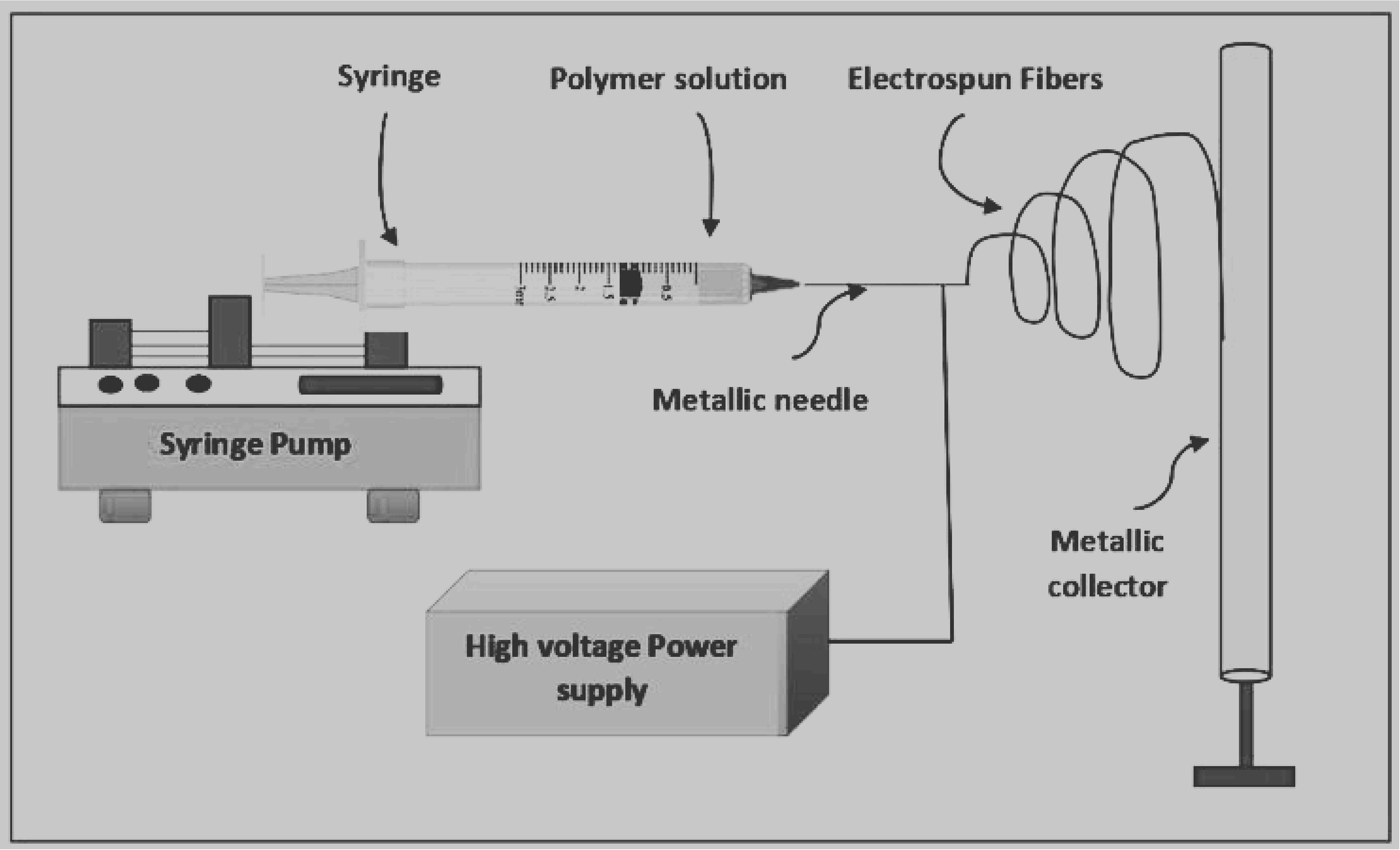
Battery separators are produced using methods such as casting, extrusion, electrospinning, and phase inversion.

Seperator Requirement

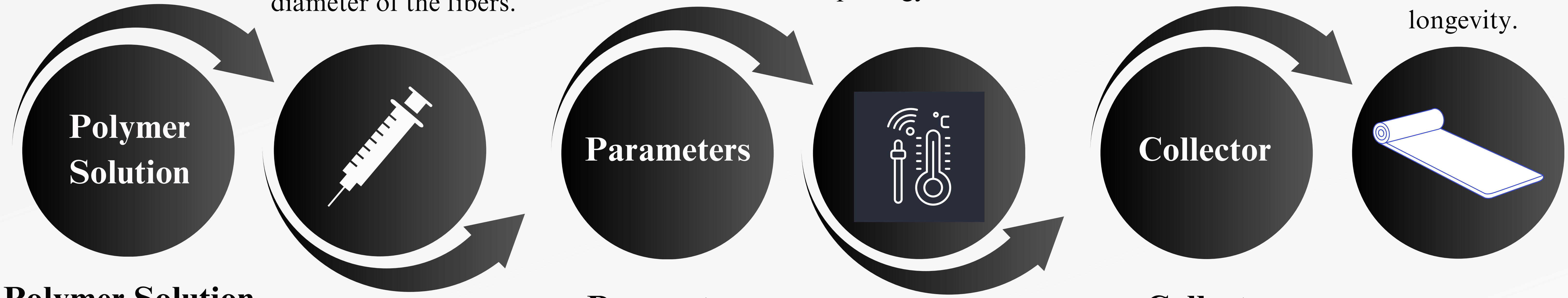
1	Chemical/electrochemical stability	Long-term stability in batteries
2	Wettability and uptake	Become wet fast and absorb adequate electrolyte
3	Ionic conductivity	10-3-10-1 S cm-1
4	Mechanical strength	>98.06 MPa
5	Thickness [μm]	<25
6	Porosity	>40%
7	Pore size [μm]	<1
8	Thermal stability (Thermal shrinkage)	<5 % after 1 hour heat treatment at 90 oC

Electrospinning

Electrospinning process is a method for producing ultra-thin fibers, ranging from nanometers to micrometers in diameter, using various materials. It works by applying a high-voltage electric field to a polymer solution, which causes the solution to be drawn into fine fibers through electrostatic forces.



ELECTROSPINNING



Polymer Solution

Material to be electrospun, typically a polymer, is dissolved in a suitable solvent to create a homogeneous solution.

Syringe and Needle

Polymer solution is to be loaded into a syringe fitted with a needle, whose inner diameter influences the final diameter of the fibers.

Parameters

Set the parameters—flow rate, voltage, polymer concentration, and tip-to-collector distance—based on the requirements for optimization.

Environmental Factors

Temperature and humidity can influence solvent evaporation rates and affect the morphology of the fibers.

Collector

Fibers are collected on a grounded surface, which may include a rotating drum or a patterned collector, depending on the desired alignment and morphology of the fibers.

Membrane

We produce an optimized membrane or mat that functions as a battery separator, improving battery performance by enhancing both efficiency and longevity.

PARAMETERS

01

Flow Rate

Flow rate of the polymer solution needs to be optimized to ensure a stable jet. High flow rates can result in thicker fibers and the formation of beads.

02

Voltage

Optimal voltage is essential for both initiating and maintaining a stable jet. Insufficient voltage may prevent jet formation, whereas excessive voltage can lead to instability.

03

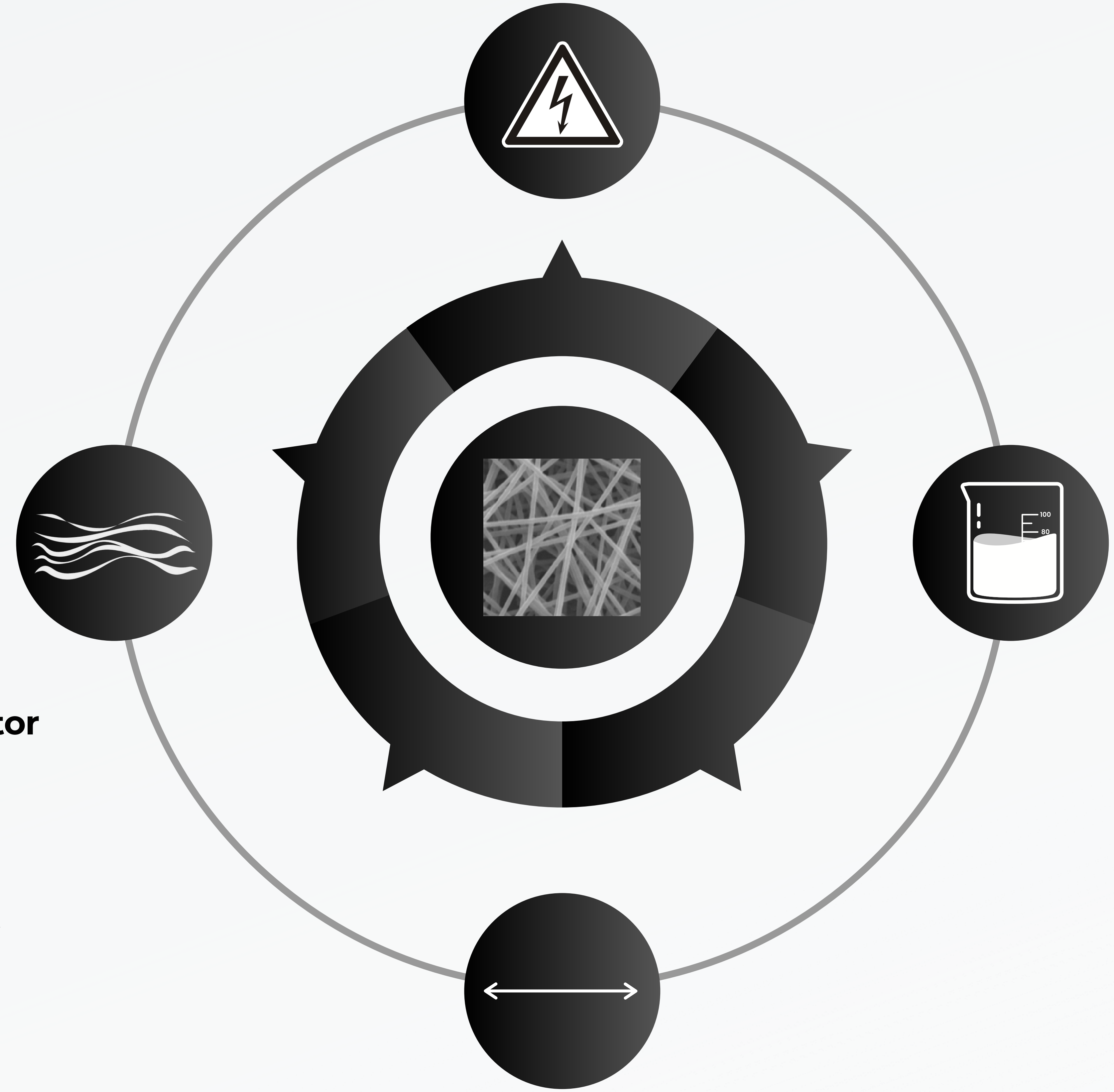
Solution Concentration

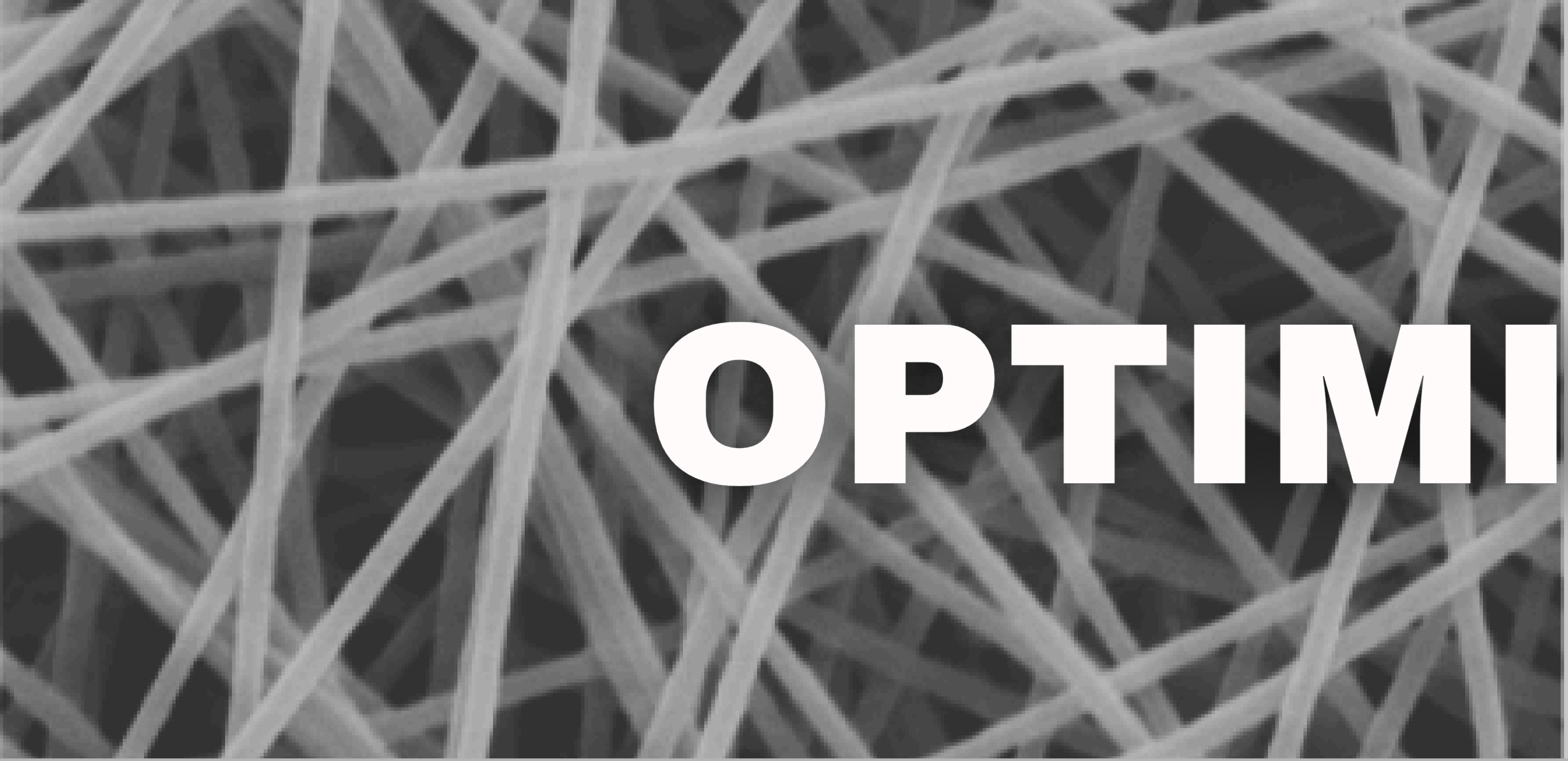
Polymer solution concentration affects viscosity and fiber properties. Optimal concentration ensures stable jet formation and correct fiber diameter, while extremes can cause weak fibers or clogging.

04

Needle Tip to Collector Distance

Distance impacts the jet's flight time and, consequently, the solvent evaporation rate. A greater distance may produce thinner fibers, but an excessively large distance can lead to fiber breakup.





OPTIMIZATION

- Optimization is the process of finding the combination of parameters that will result in the best possible outcome under a given set of constraints and conditions.
- Optimization of the electrospinning process requires precise tuning of key parameters to achieve desired fiber diameter, morphology, and material characteristics.
- Some common optimization methods used in electrospinning to improve these parameters.

01

Trial and error

02

Taguchi Method

03

Response Surface Methodology (RSM)

TAGUCHI METHOD

Taguchi method is a statistical approach to optimize process parameters with a minimal number of experiments. It uses orthogonal arrays to study the interactions with fewer trials, making it cost-effective, and reducing time wastage.

01 Identify the critical parameters (Factors & Levels) , such as solution concentration, voltage, flow rate, and tip-to-collector distance with specific values.

02 Use an orthogonal array to design experiments with the help of **MINITAB** software.

03 Analyze the results using signal-to-noise ratios to determine the optimal conditions.

Orthogonal Array	No. Runs	Max. Factors	Max. of columns at these levels			
			2-level	3-level	4-level	5-level
L4	4	3	3			
L8	8	7	7			
L9	9	4		4		
L12	12	11	11			
L16	16	15	15			
L'16	16	5			5	
L18	18	8	1	7		
L25	25	6				6
L27	27	13		13		
L32	32	31	31			
L'32	32	10	1		9	
L36	36	23	11	12		
L'36	36	16	3	13		
L50	50	12	1			11
L54	54	26	1	25		
L64	64	63	63			
L'64	64	21			21	
L81	81	40		40		

RESPONSE SURFACE METHODOLOGY (RSM)

Response Surface Methodology (RSM) includes various experimental design types, each customized to different optimization needs.

Design-Expert is an advanced software tool used for designing and analyzing experiments employing a variety of Response Surface Methodology (RSM) techniques.

Central Composite Design (CCD)

Box-Behnken Design (BBD)

POLYMER

Polymer is a long chains or networks of smaller molecules called monomers.

Typical Polymers Used in Electrospinning

Natural polymers

Gelatin

collagen

Synthetic polymers

polycaprolactone

nylon 6,6

Semi-synthetic polymers

cellulose acetate

Cellulose nitrate

POLYMERS

01 PVDF

- Good mechanical properties
- High chemical resistance
- High polarity
- Interaction with lithium ions

02 PAN

- Good Processability
- Wettability
- Thermal Stability

03 PET

- Excellent electronic insulation
- Good mechanical
- Thermal properties

04 PI

- High thermal stability
- Mechanical properties
- Chemical resistance
- Good wettability

Polyacrylonitrile(PAN)

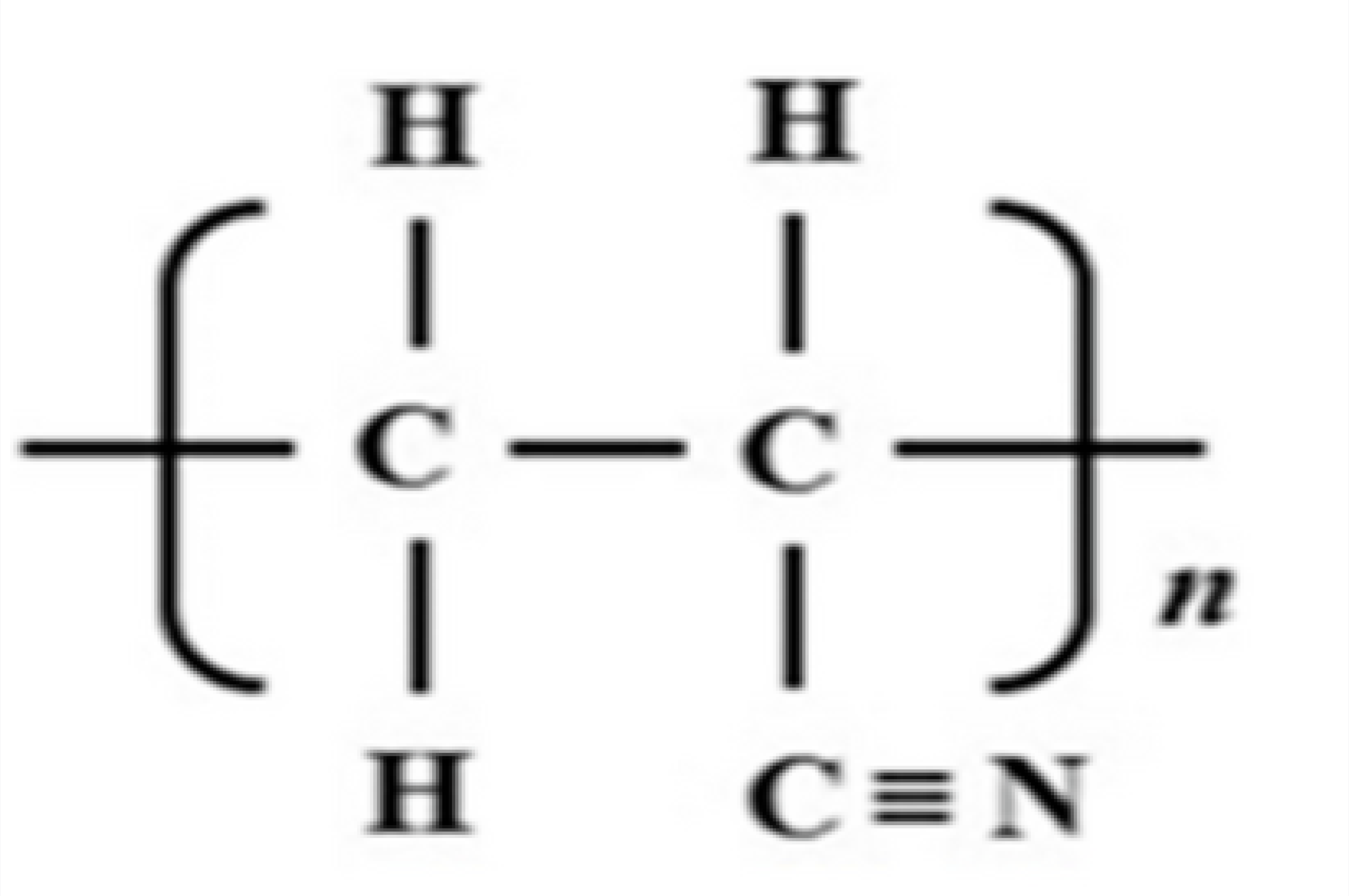
• **Thermal stability**	PAN's thermal stability makes it a good choice for batteries, as it helps ensure their safety.
• **Mechanical strength**	PAN fibers exhibit good tensile strength and flexibility, essential for battery components like separators
• **Wettability**	PAN separators have good wettability with liquid electrolytes
• **Electrolyte compatibility**	PAN's compatibility with electrolytes makes it a good choice for separators
• **Low interface resistance**	PAN separators have low interface resistance.
• **Porosity**	PAN-derived CNFs possess large surface area and interconnected pore structure, enhancing ion diffusion and electrochemical reactions.

- **Good Ionic conductivity**

Carbonized PAN fibers offer reasonable electrical conductivity, facilitating electron transport within battery components

- **Chemical stability**

PAN demonstrates resistance to degradation under battery operating conditions, ensuring long-term performance



FILLERS

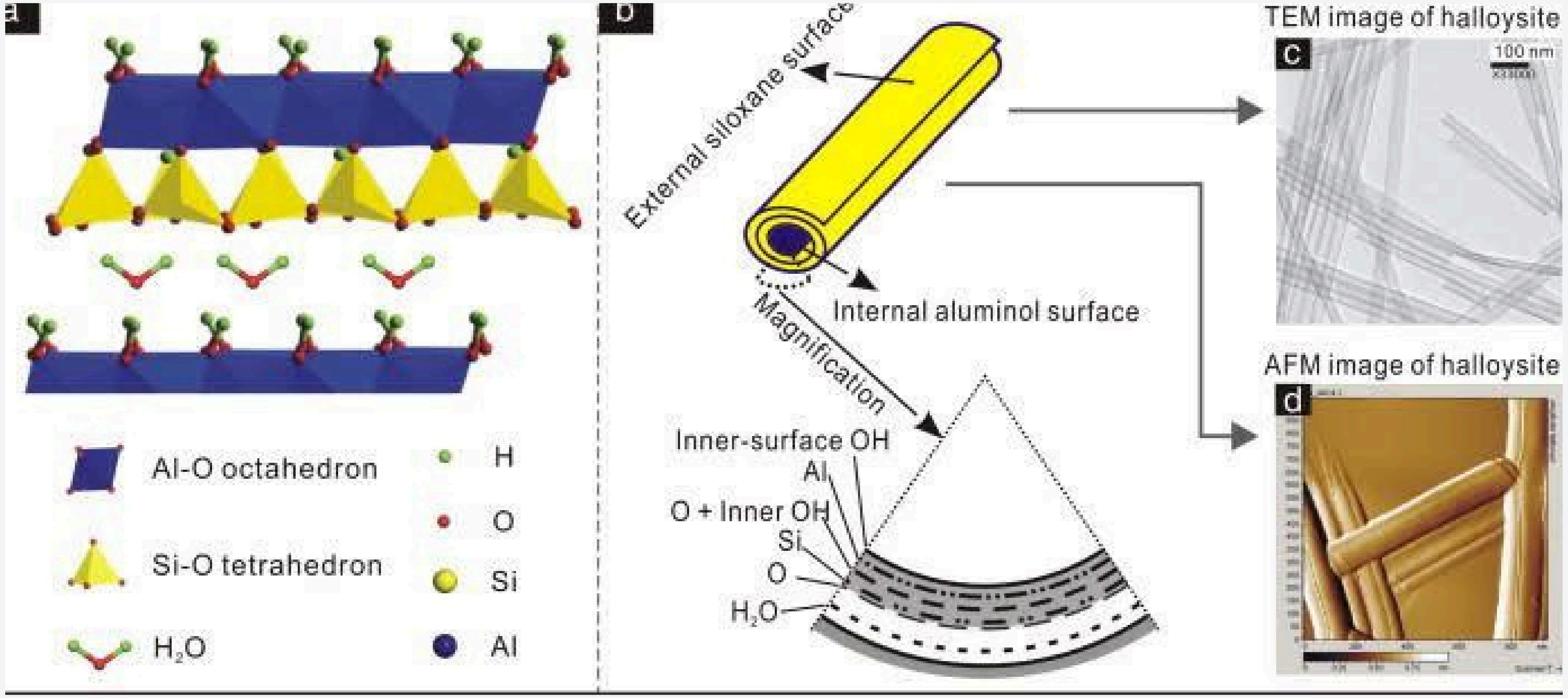
Fillers are stable compounds that can be incorporated into polymers to improve their properties or reduce their cost. For example, in plastic manufacturing, minerals like calcium carbonate, silica, clay, kaolin, and carbon are often added as fillers to polymers. These fillers can make the polymers easier to mold and shape, while also ensuring the stability of the compounds.

In electrospinning, fillers are incorporated into the polymer solution or melt to modify the properties of the resulting fibers

- Increased Strength and Toughness
- Conductivity
- Heat Resistance
- Biocompatibility
- Surface Modification

HALLOYSITE NANOTUBES (HNT)

HNTs (Al2Si2O5(OH)4*n*H2O) are naturally occurring, nontoxic, biocompatible clay minerals with a chemical composition like kaolinite, composed of aluminum, silicon, hydrogen, and oxygen.



- Halloysite nanotubes are rodlike-shaped, and the dimensions are also compatible.
- Stiffer tubular structures like HNT contribute to the mechanical stiffness and strength significantly.
- Despite the similarity of its structure to a carbon nanotube, halloysite nanotubes have distinctive advantages such as low price and perfect biocompatibility.

Incorporation of HNT into the polymer-based membrane matrix improves membrane surface

01 Wettability or hydrophilicity

02 Porosity

03 Thermal resistance

04 mechanical properties

Thank You!