Manufacturing Li-ion Cells

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Li-ion Battery Applications

Consumer Electronics

- Phones
- Tablets
- Laptops
- Toys
- Wearables
- Cameras

Transportation

- Cars
- Trucks
- Motorcycles
- Airplanes
- Scooters/Bikes

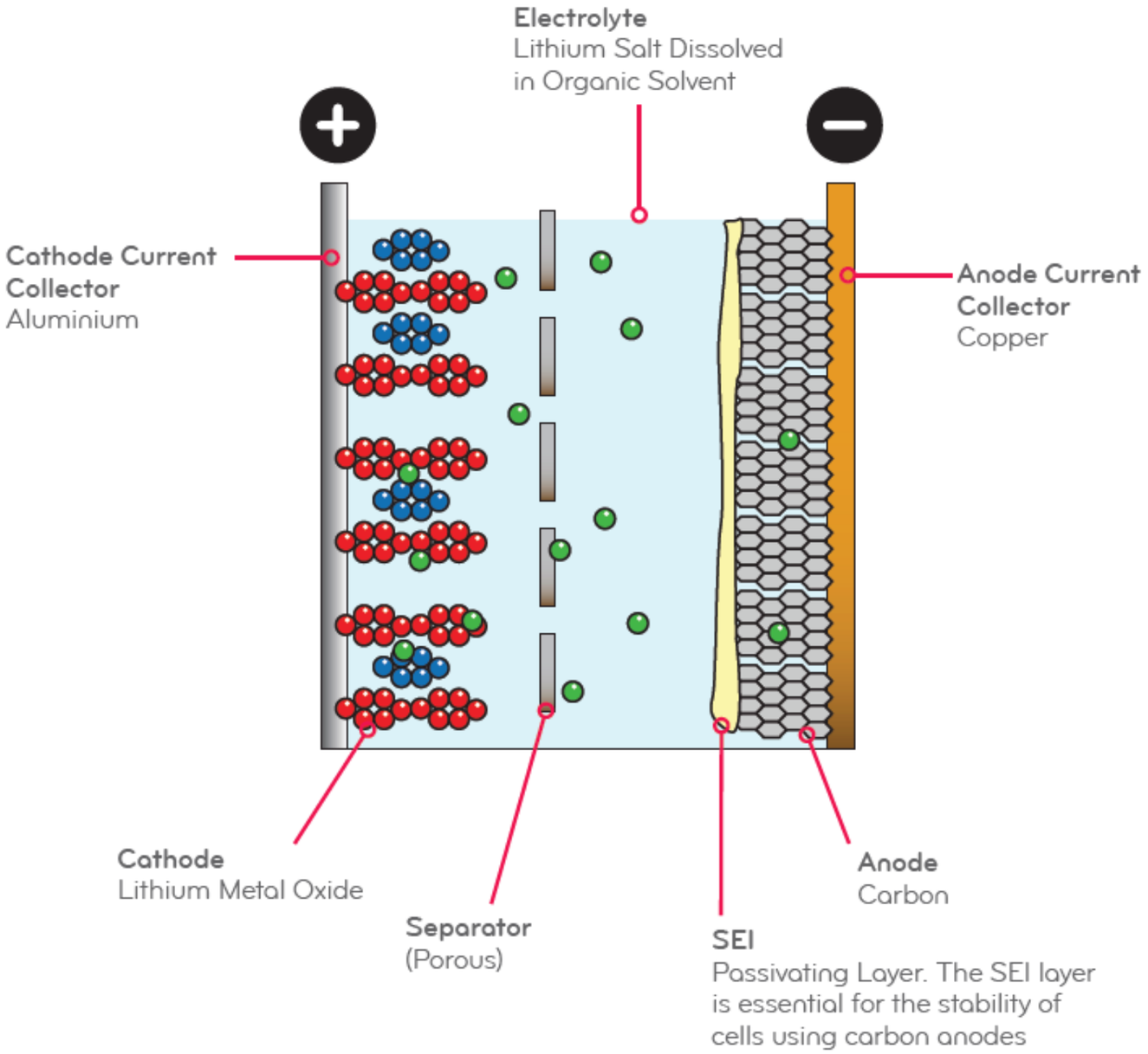
Utility Industry

- Grid Storage
- Solar Farm Storage
- Wind Farm Storage

Telecommunications

- Cell site Backup storage
- Grid Power Stabilization

Theory of Operation



Wound Polymer

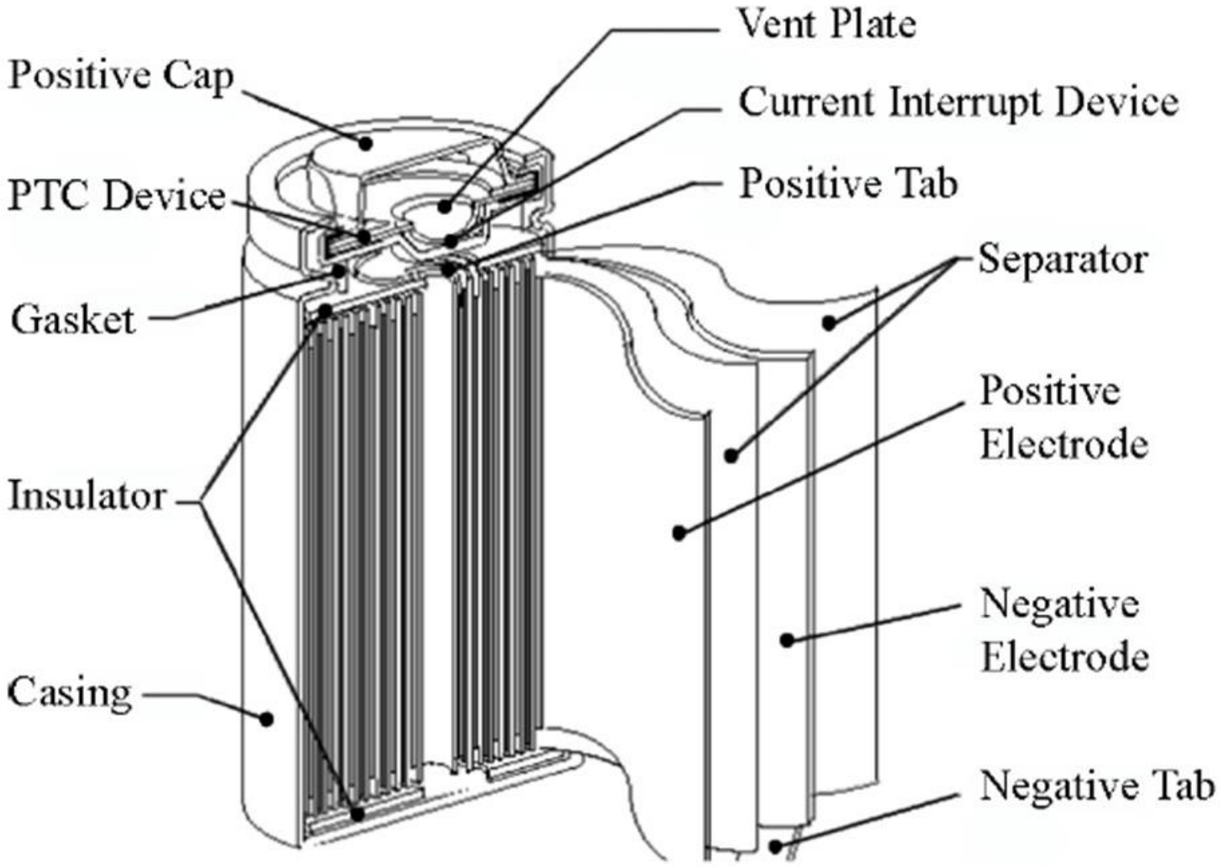
Example unrolled cell

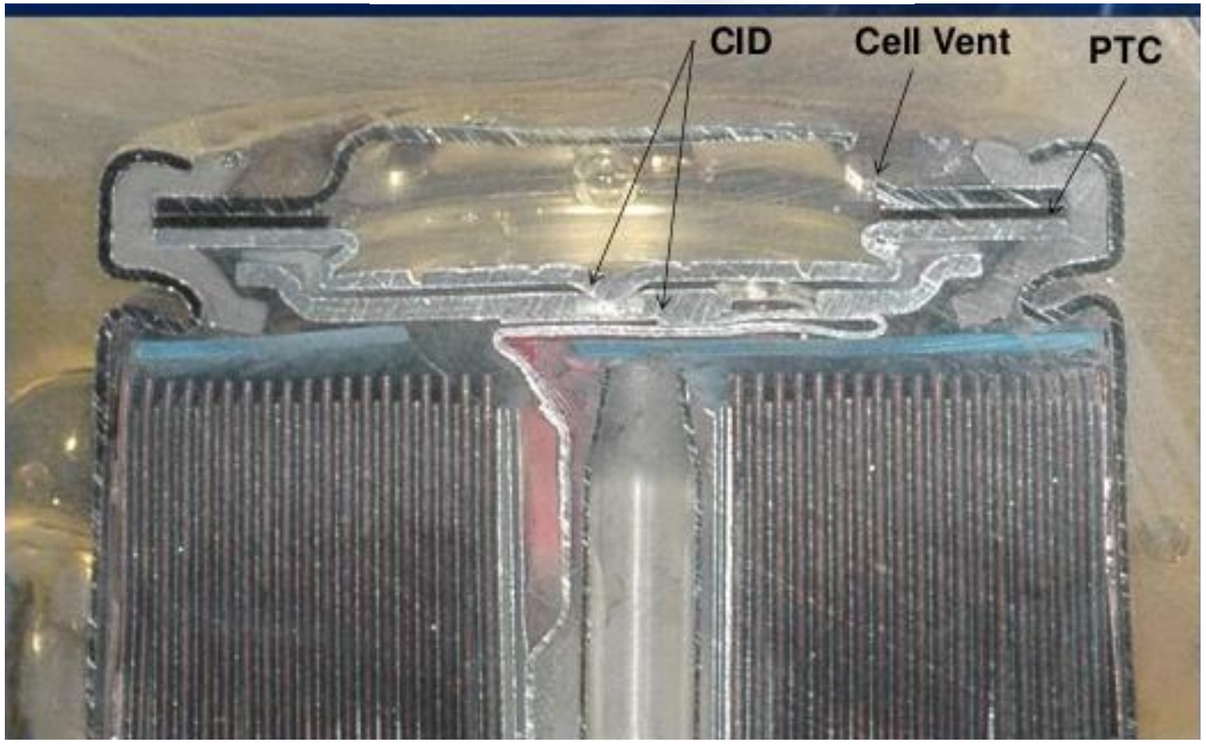
Positive Electrode

Negative Electrode

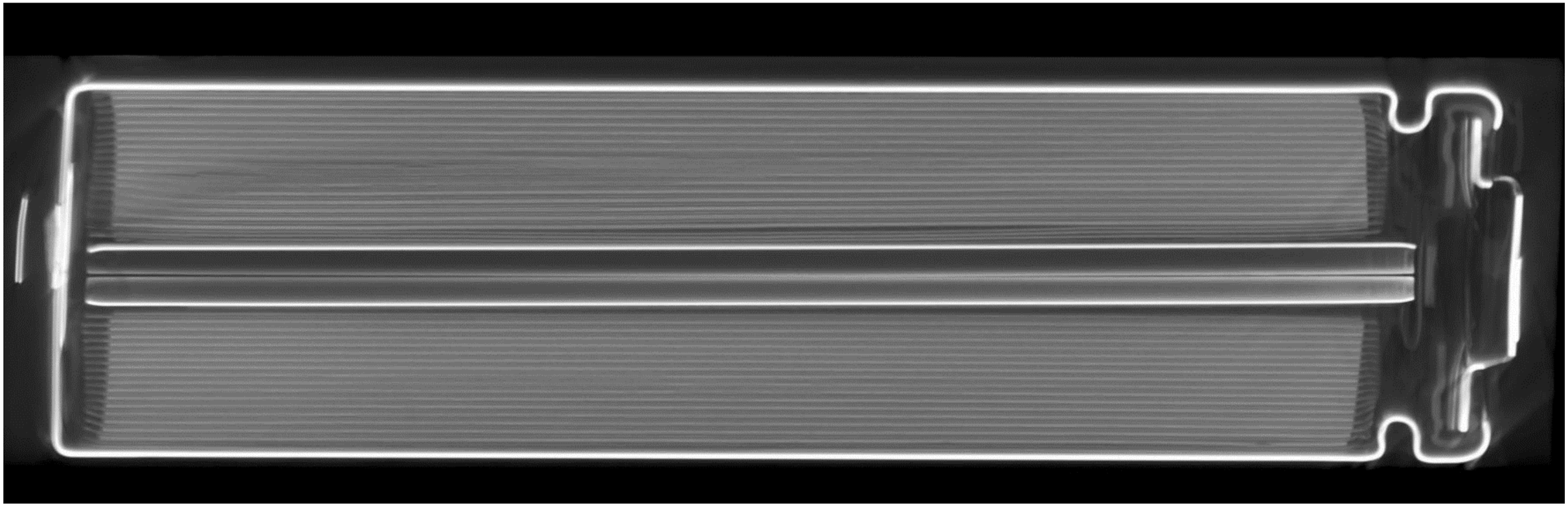
Separator

Cylindrical Cells

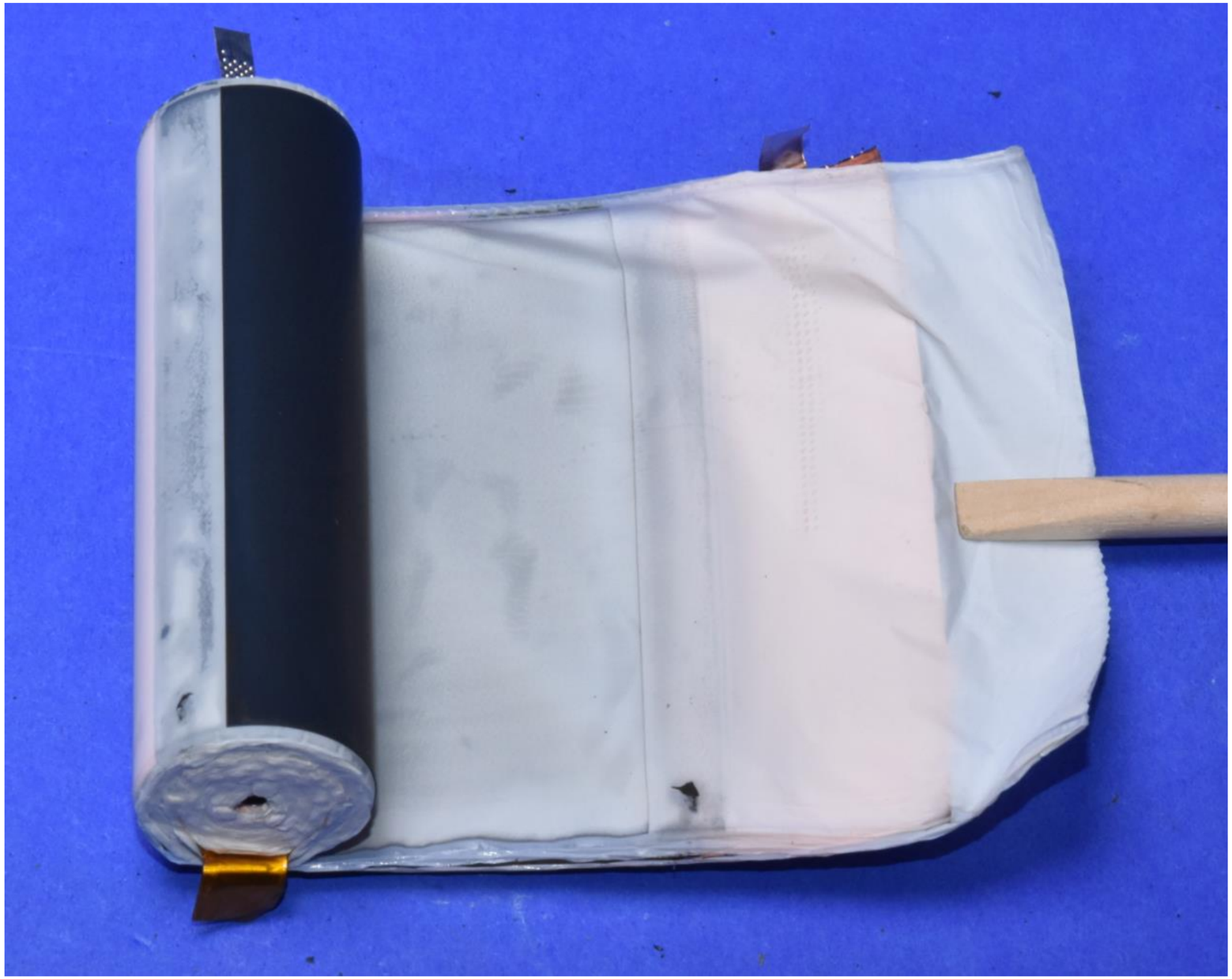




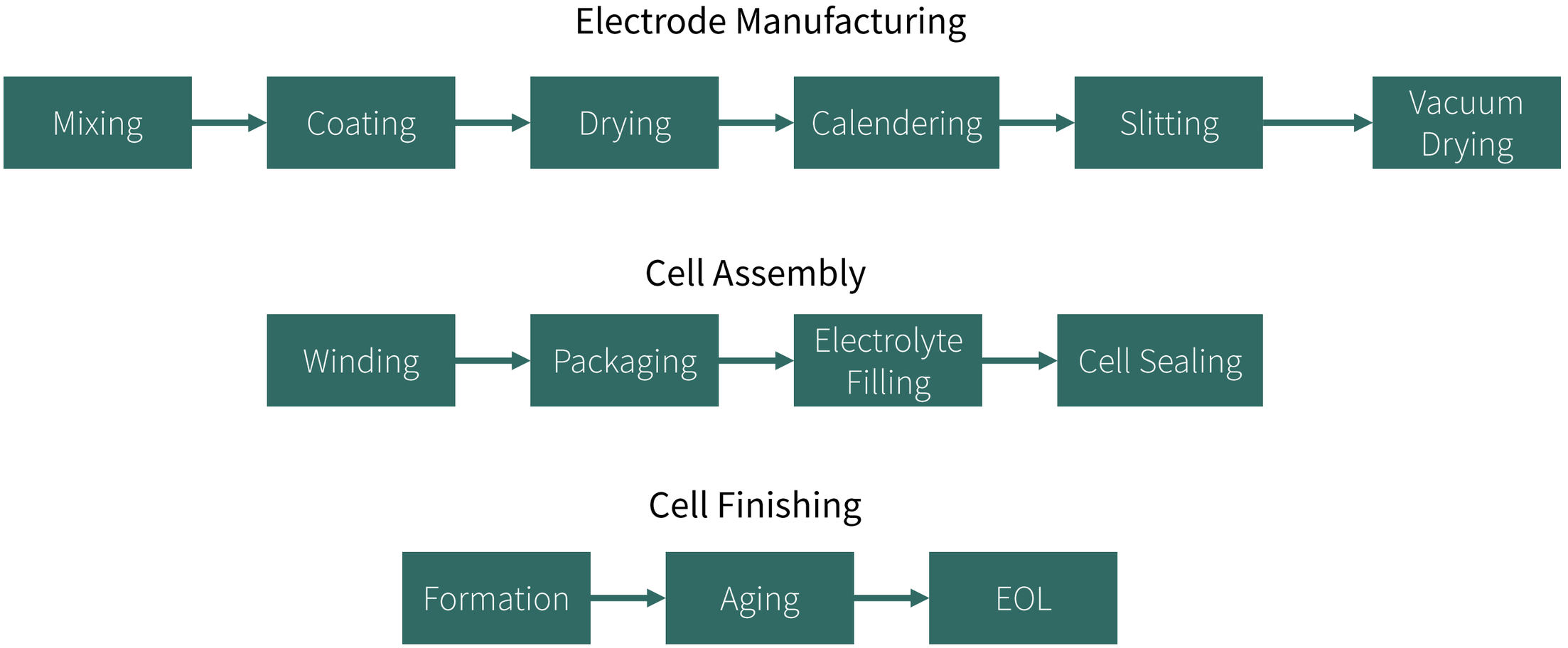
Cylindrical (18650) Cell



Cylindrical Cell Construction



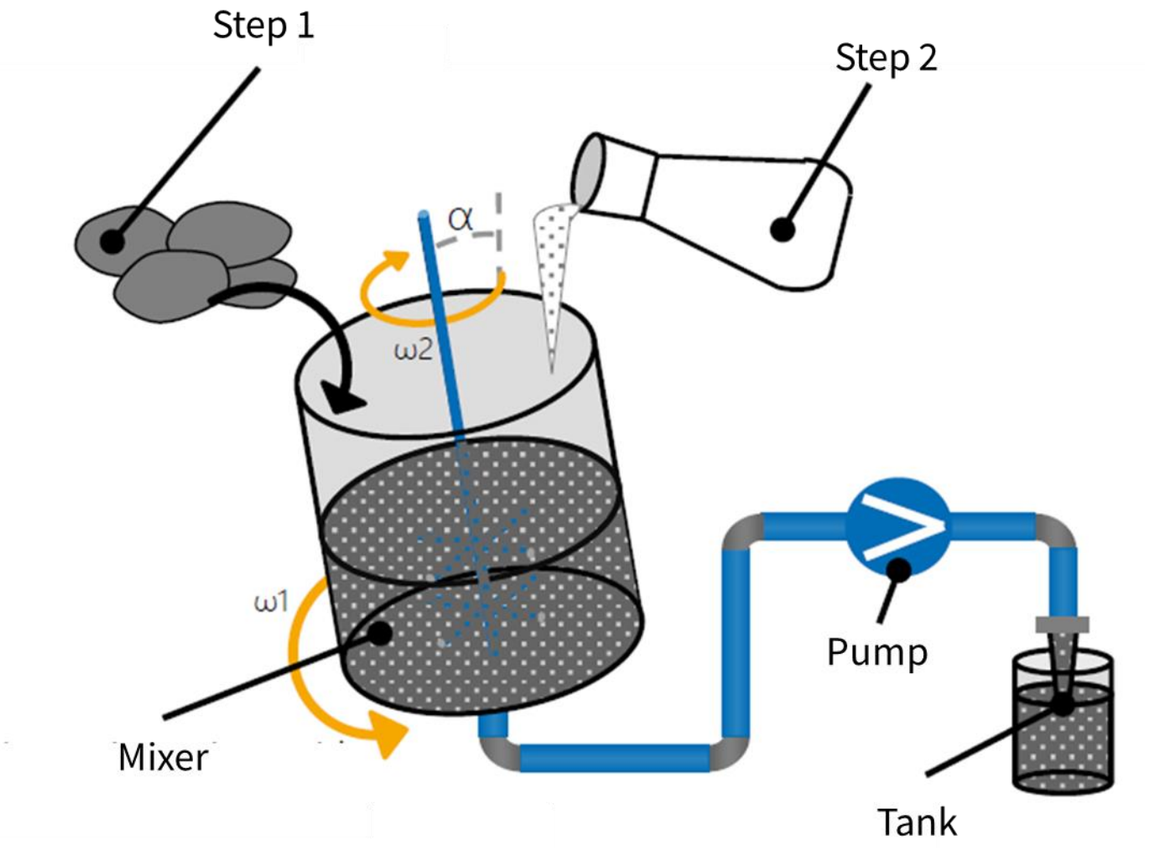
Cell Manufacturing Process



Electrode Manufacturing

Mixing → Coating → Drying → Calendering → Slitting → Vacuum Drying

Ref [1]



- Step 1
  - Mixing (dry) – active material, additives and binder are mixed dry
- Step 2
  - Dispersing (wet) – solvent added, dispersed and homogenized

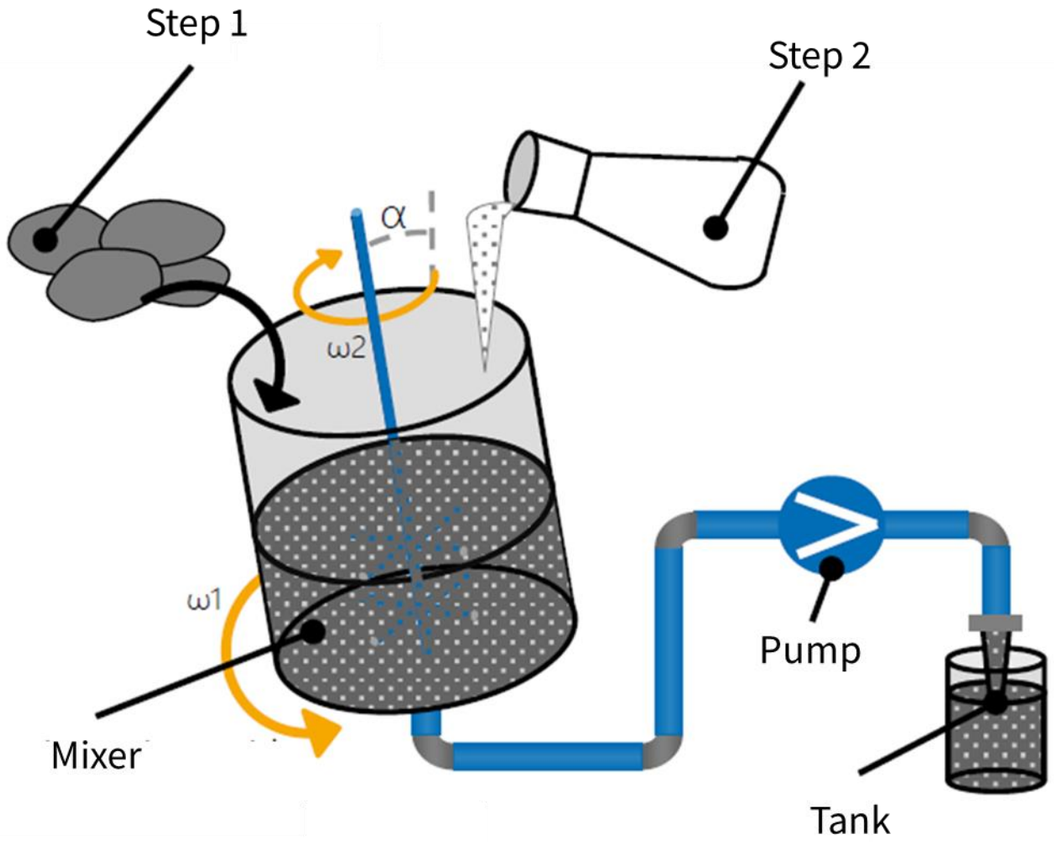
Anode

- Active Material: Graphite
- Additives: Conductive Carbon
- Solvent: Deionized water
- Binder: Carboxymethyl cellulose (CMC)
- Additive: Styrene-Butadiene (SBR)

Cathode

- Active Material: Layered transitional metal oxide
- Additives: Carbon black
- Solvent: N-Methyl-2-Pyrrolidone (NMP)
- Binder: Polyvinylidene fluoride (PVDF)

Mixing → Coating → Drying → Calendering → Slitting → Vacuum Drying



Issues to Consider

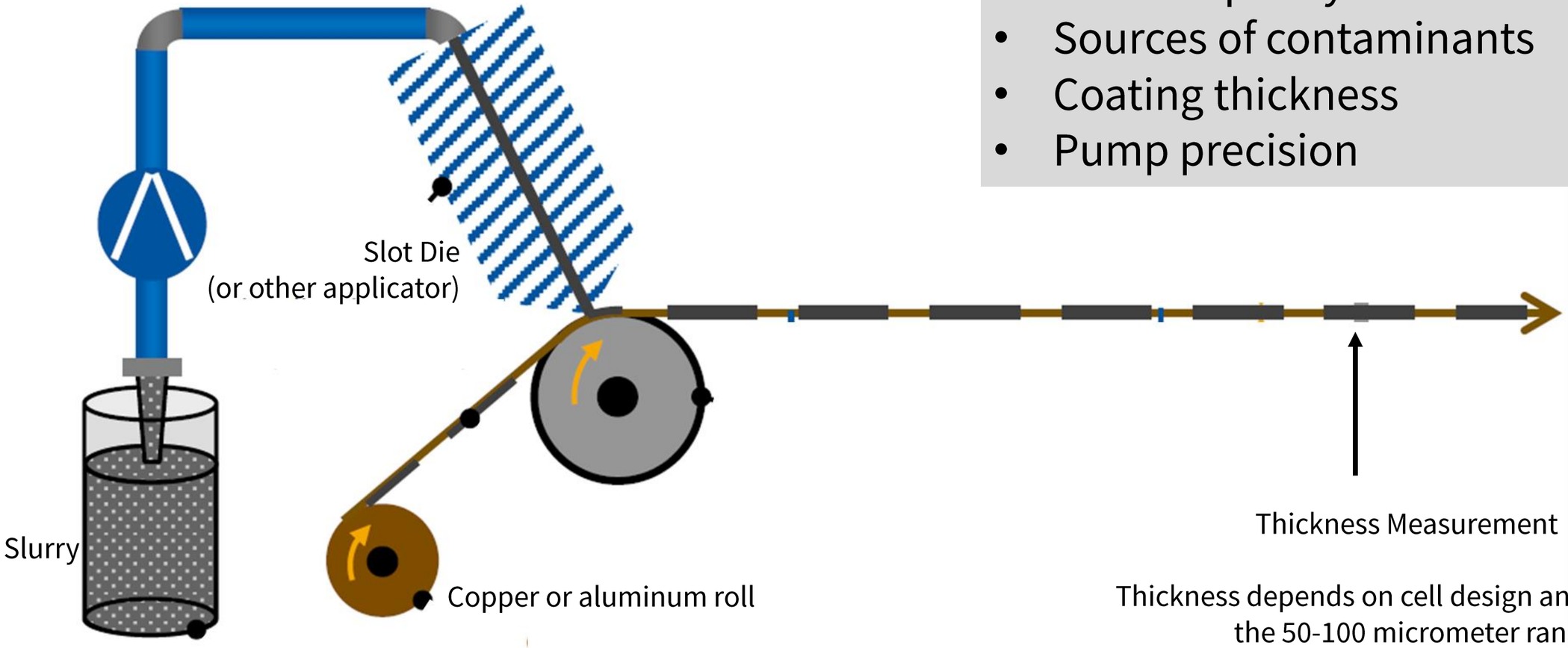
- Slurry homogeneity
- Particle size, purity and viscosity
- Mixing temperatures
- Filter system
- Sources of contaminants

Mixing → Coating → Drying → Calendering → Slitting → Vacuum Drying

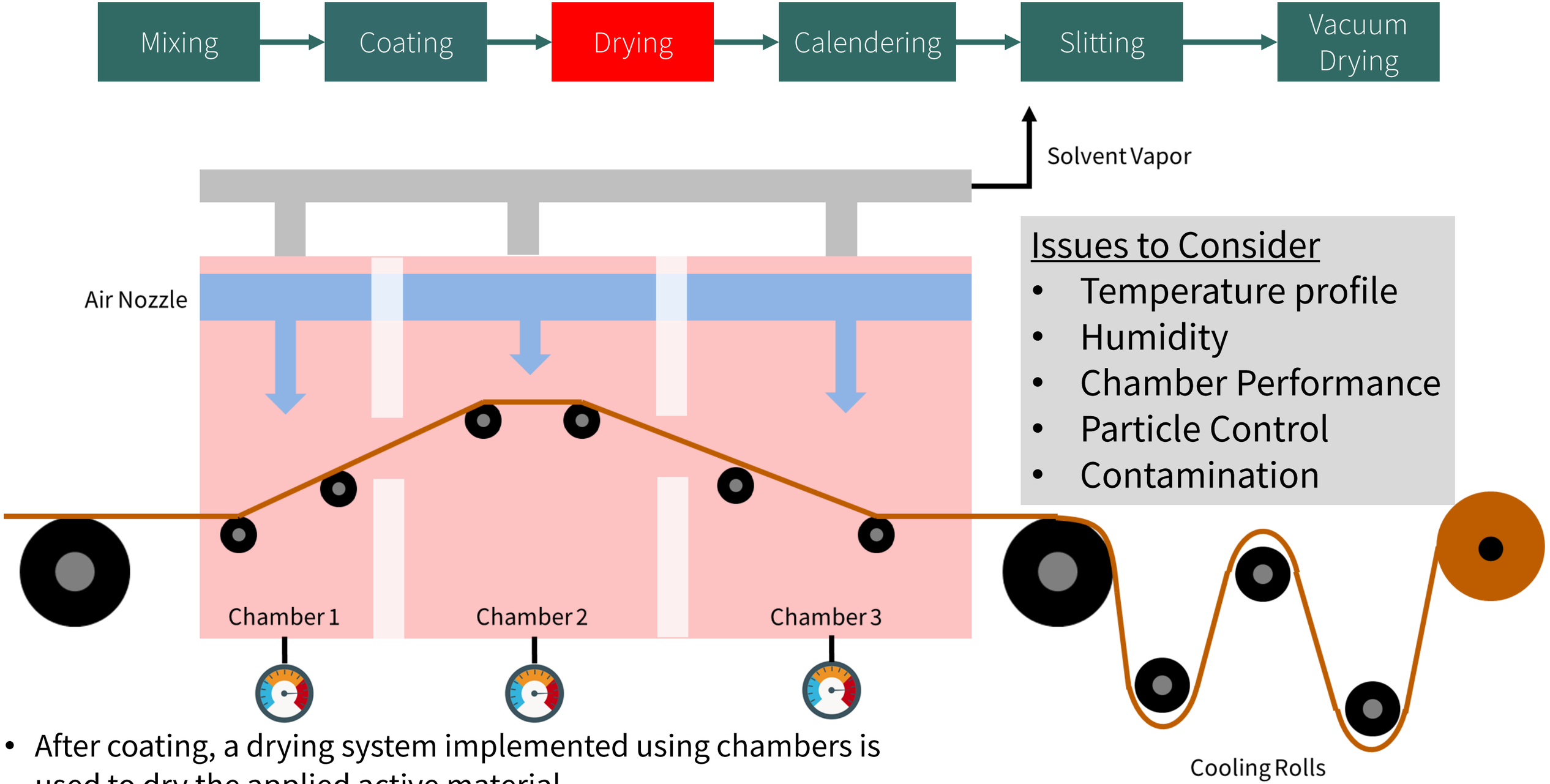
- Aluminum/copper foil is coated using applicator tool
- Coating can be continuous or intermittent
- Top and bo ially

Issues to Consider

- Surface quality
- Sources of contaminants
- Coating thickness
- Pump precision



Thickness depends on cell design and is often in the 50-100 micrometer range



Issues to Consider

- Temperature profile
- Humidity
- Chamber Performance
- Particle Control
- Contamination

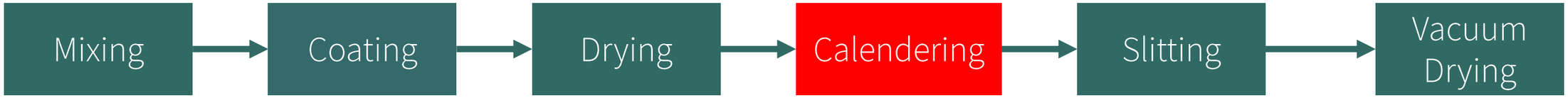
- After coating, a drying system implemented using chambers is used to dry the applied active material.
- After drying, the foil is cooled down and then can be coated on the second side or rewound.

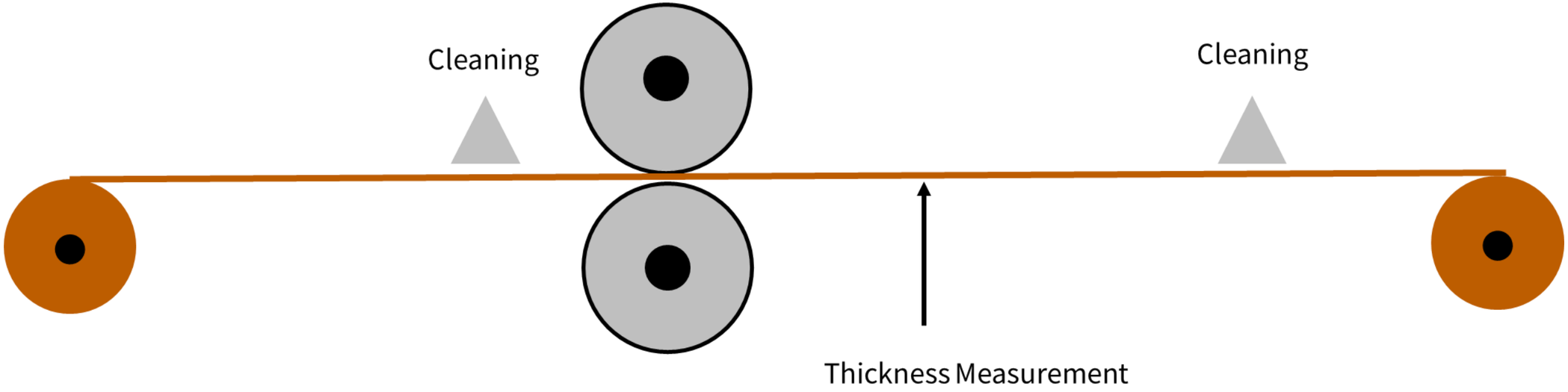
Mixing → Coating → Drying → Calendering → Slitting → Vacuum Drying

Slot die coating
with backing roll

Simultaneous 2-sided coating systems

Ref [7]



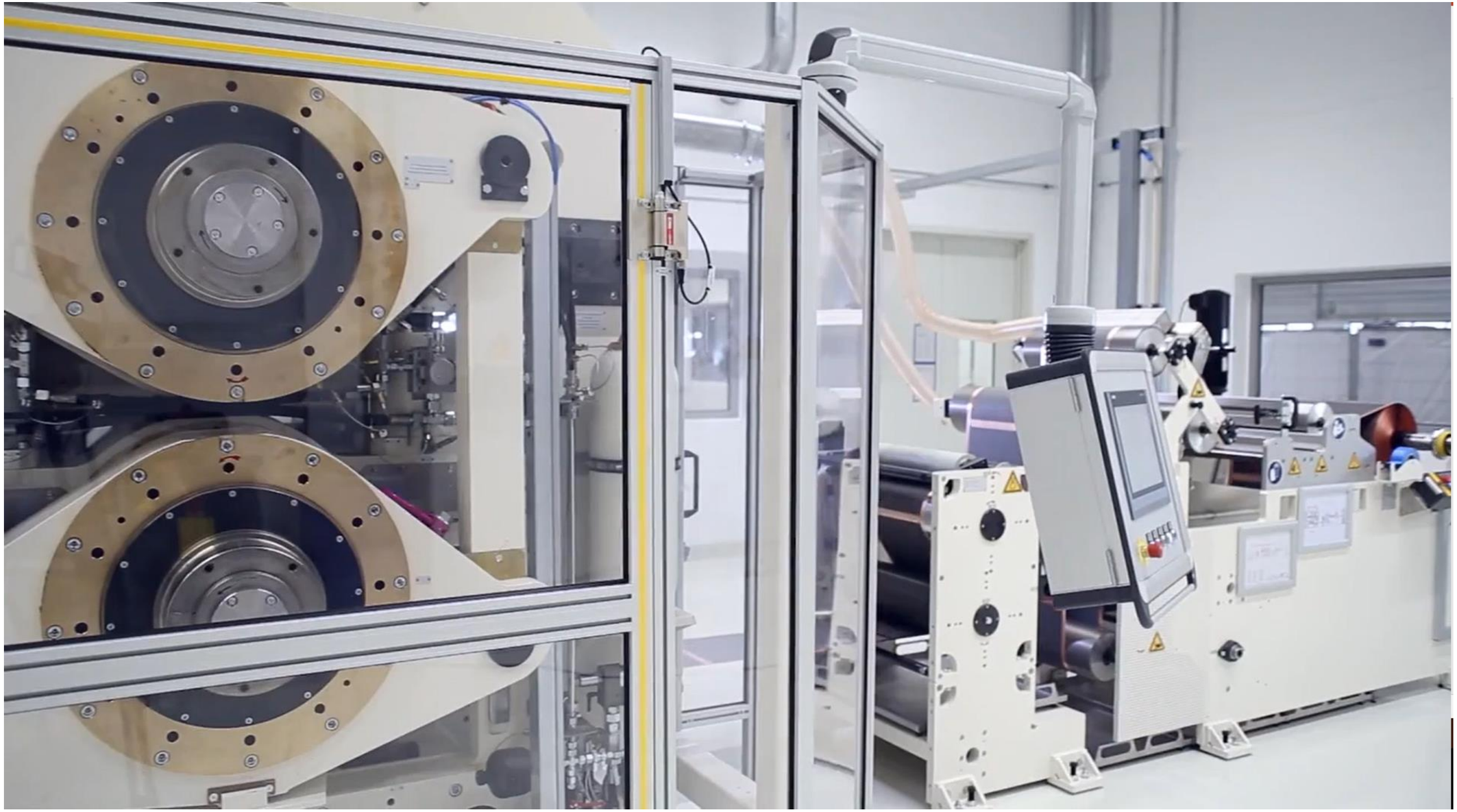


- Rotating pairs of rollers used to compress the coated foils
- Brushes/air flow often used to clean the electrodes before and after the compression
- Electrode foil rolled up again after calendering

Issues to Consider

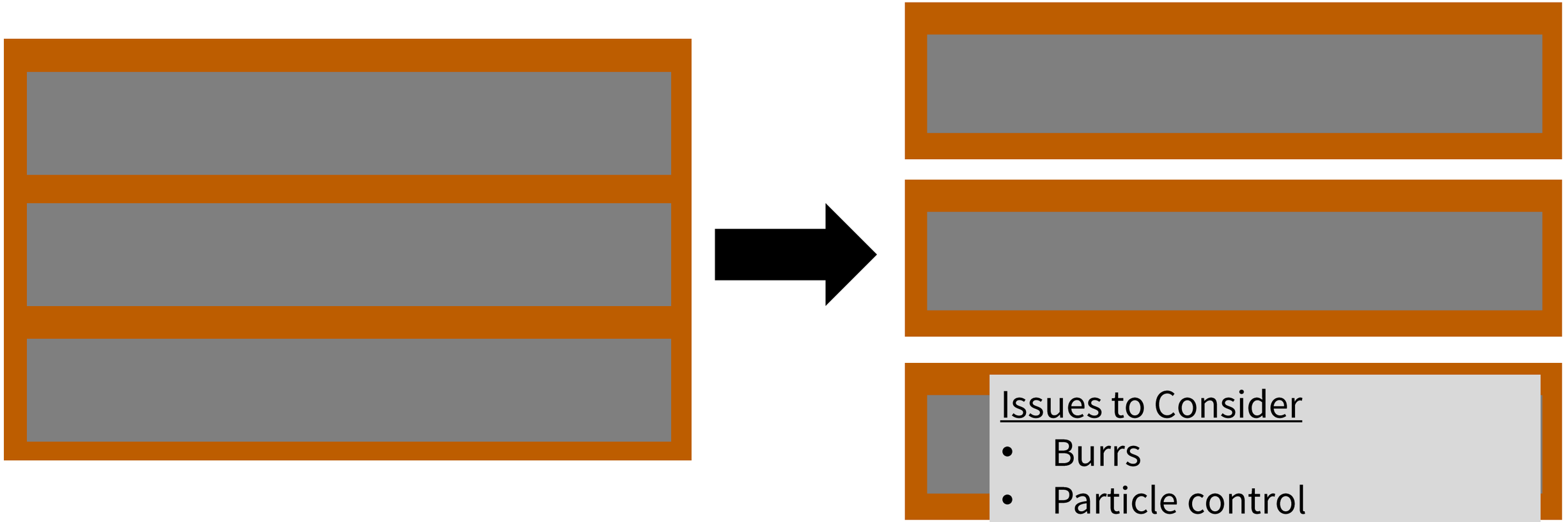
- Roller material/diameter
- Pressure/temperature
- Roller concentricity
- Surface texture
- Particle control

Mixing → Coating → Drying → **Calendering** → Slitting → Vacuum Drying



Ref [8]

Mixing → Coating → Drying → Calendering → Slitting → Vacuum Drying

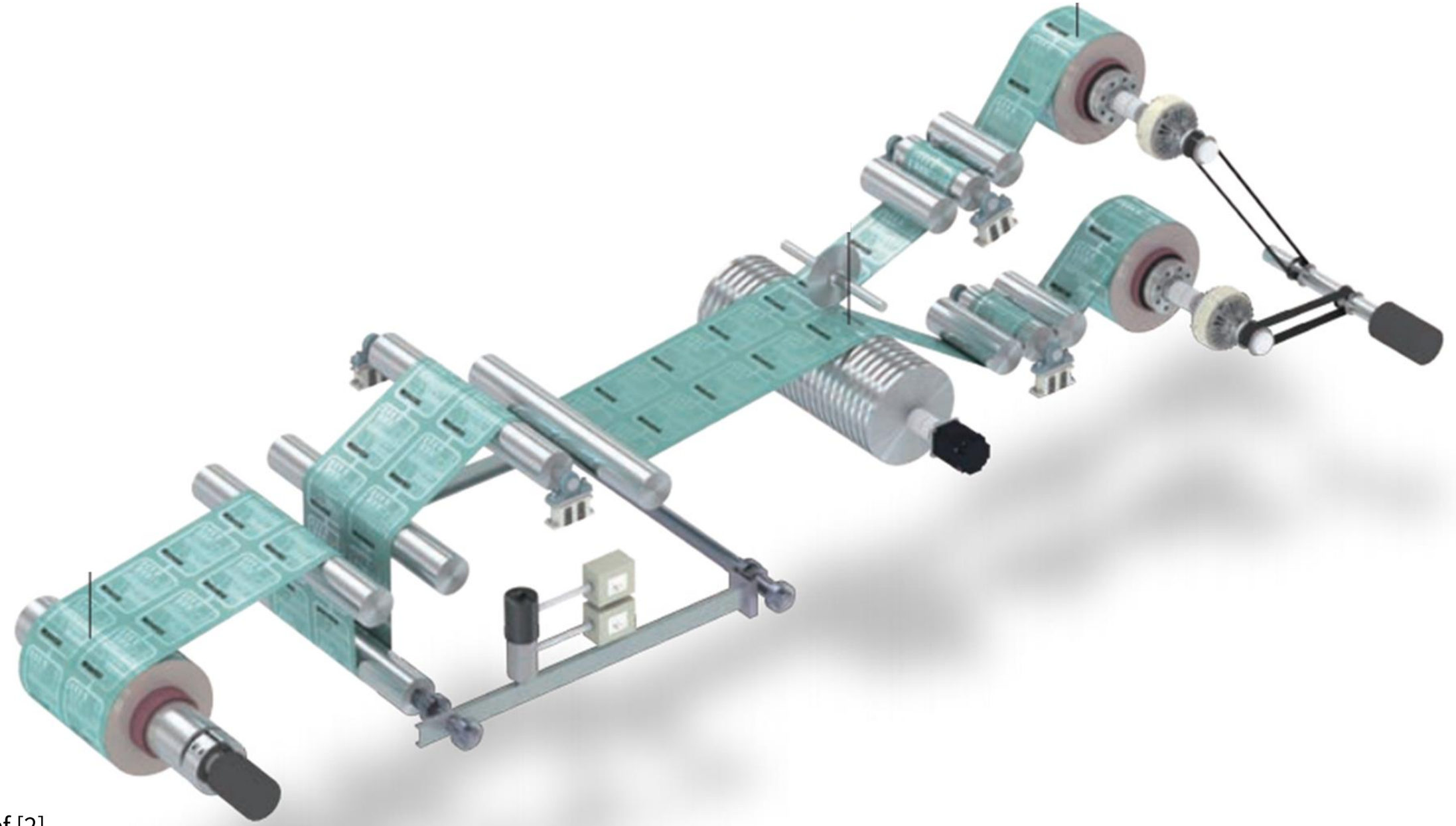


Slitting involves cutting a wider calendered electrode roll into several smaller electrode rolls that are then rewound after the cutting process.

Issues to Consider

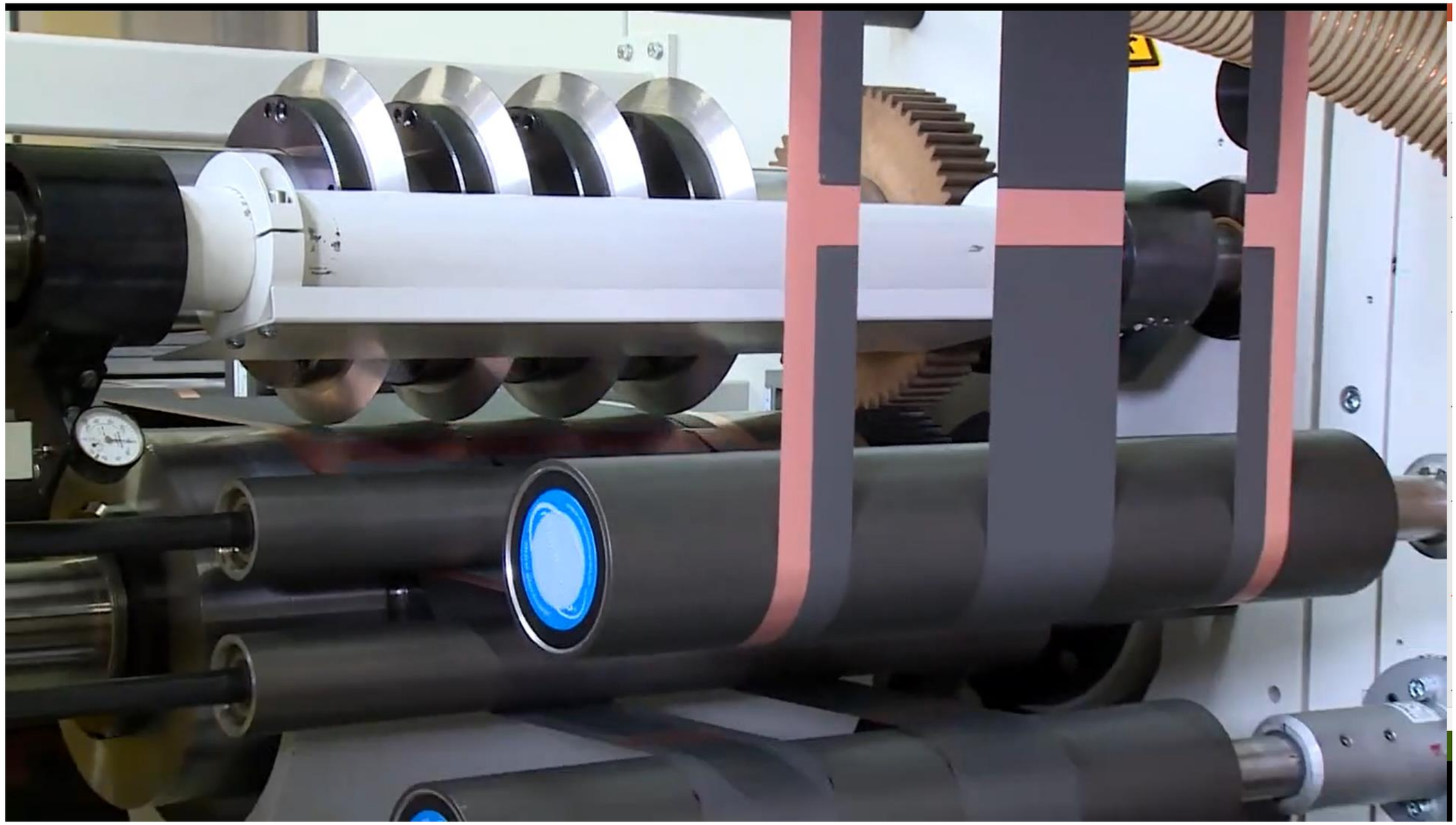
- Burrs
- Particle control
- Cutting blades
- Extraction of waste/particles
- Mechanical stresses

Mixing → Coating → Drying → Calendering → Slitting → Vacuum Drying



Source: Ref [2]

Mixing → Coating → Drying → Calendering → Slitting → Vacuum Drying



Ref [8]

- Coated and slit electrode rolls stored in vacuum ovens to remove residual moisture and solvents
- Coils transferred to dry room or dry packed under vacuum once vacuum drying process is complete.
- Drying time is often between 12 and 30 hours

Issues to Consider

- Particle control
- Moisture control
- Vacuum stability

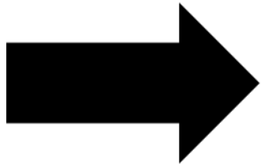
Cell Assembly

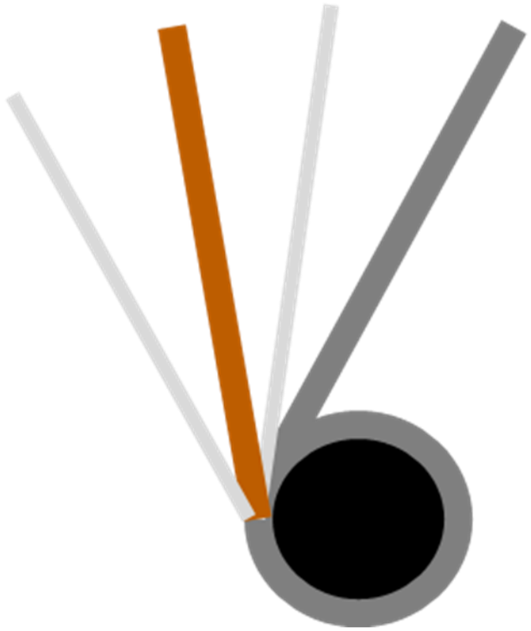
Winding → Packaging → Electrolyte Filling → Cell Sealing

Anode

Separator

Cathode



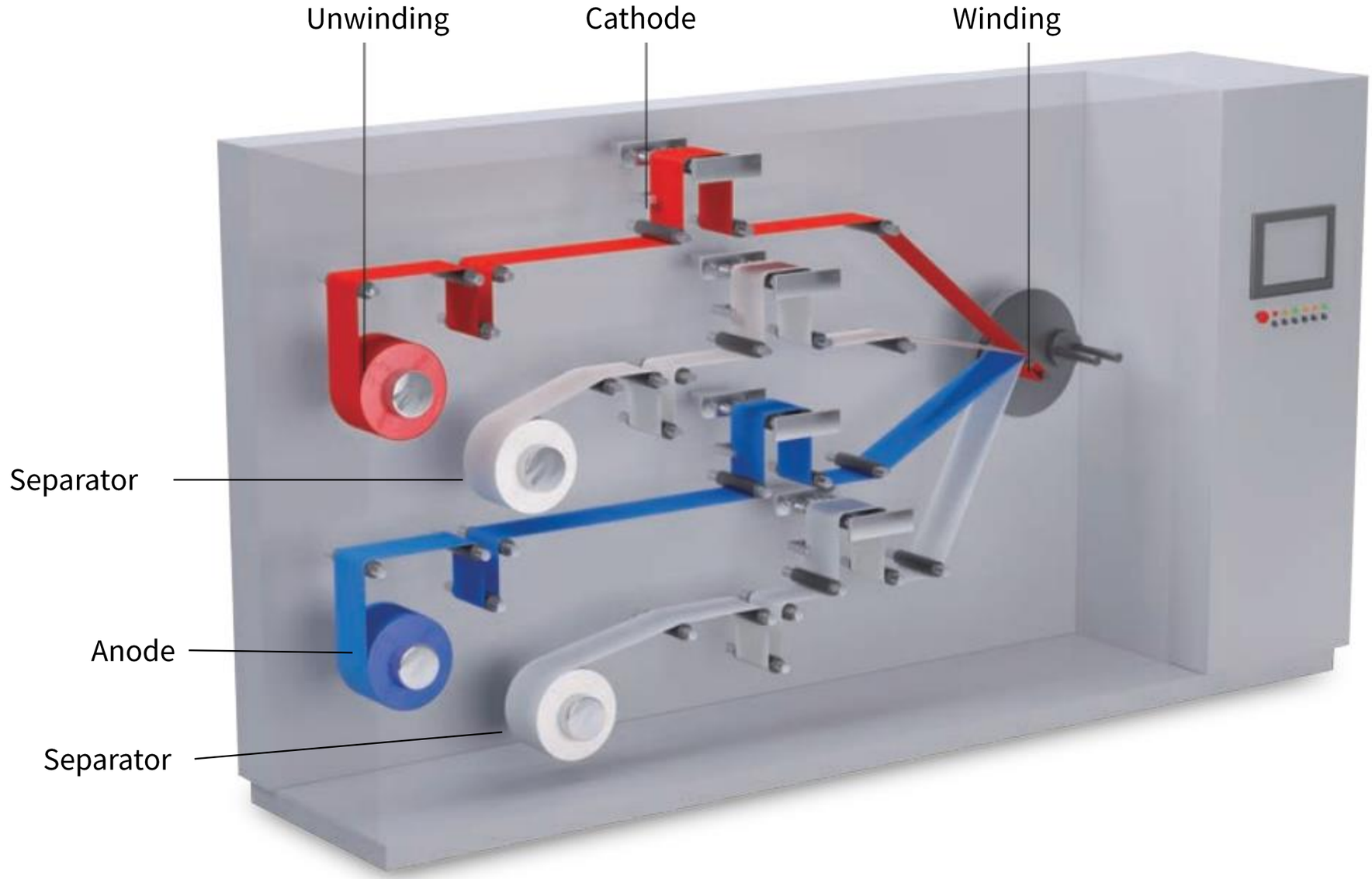


Electrode foils and two separator foils are typically wound around a center pin to create what is called a jelly roll

Issues to Consider

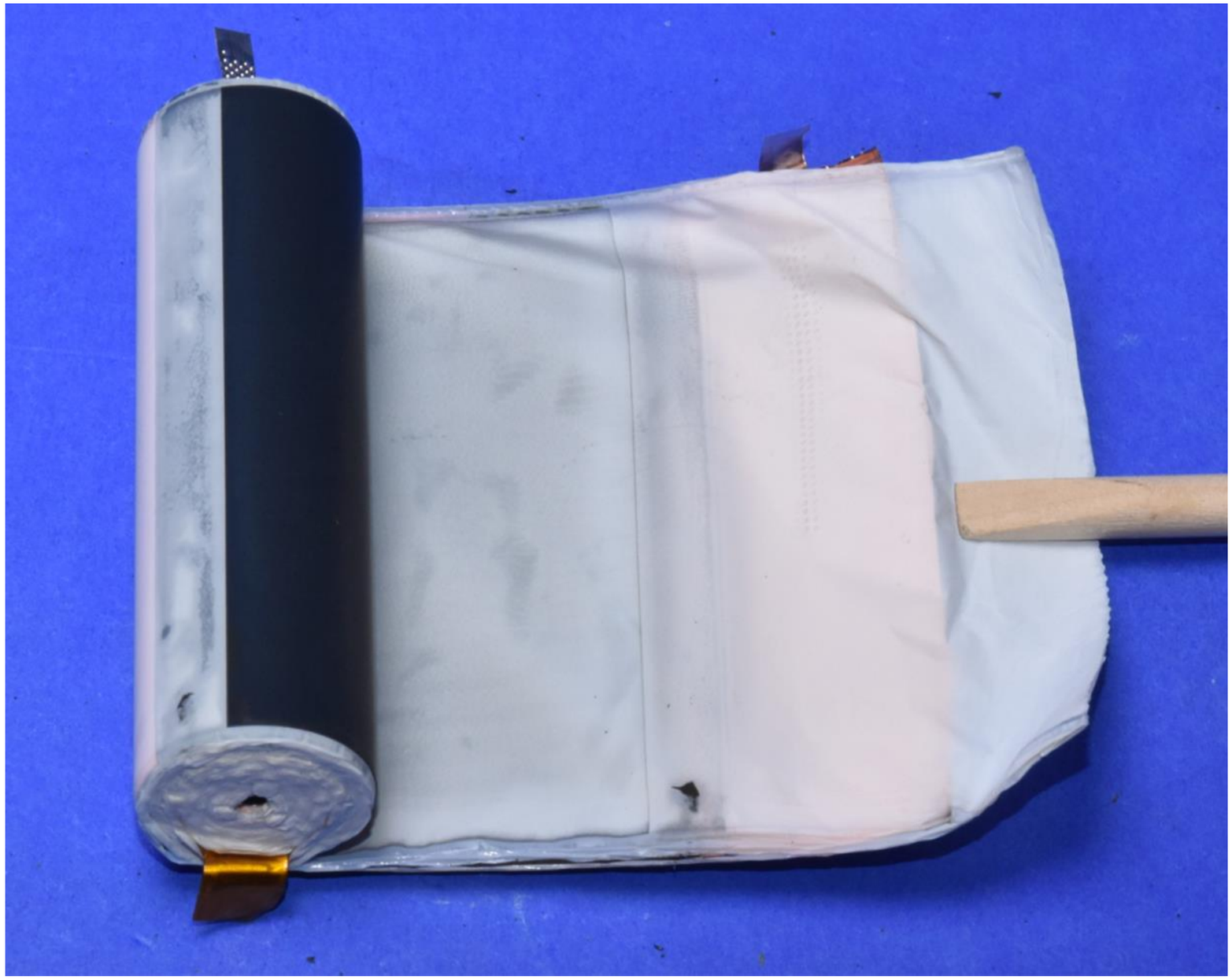
- Winding alignment
- Damage to electrode surface/separator
- Winding speed and tension

Winding → Packaging → Electrolyte Filling → Cell Sealing

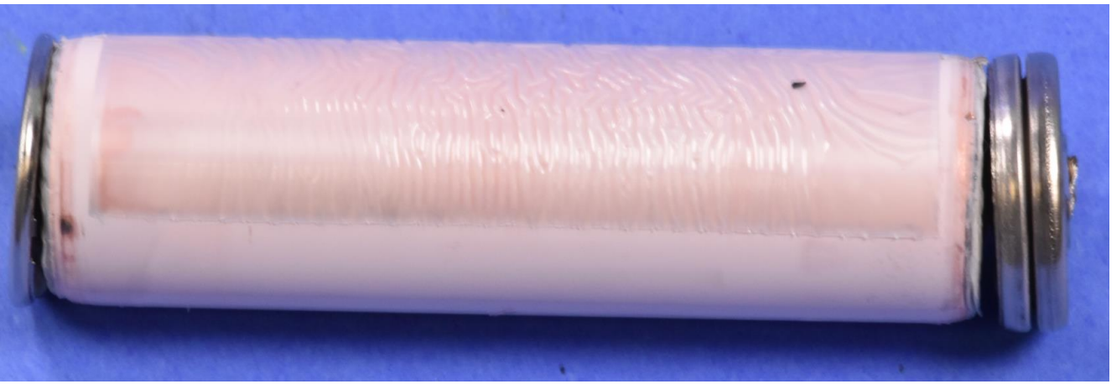


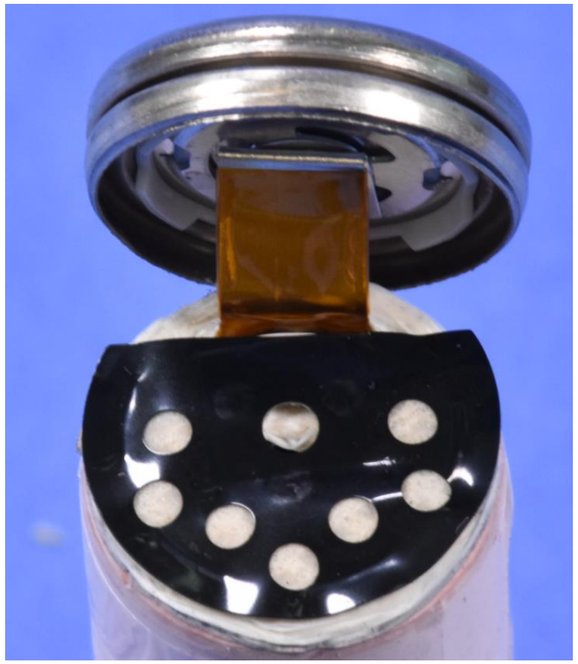
Source: Ref [2]

Winding → Packaging → Electrolyte Filling → Cell Sealing



Winding → Packaging → Electrolyte Filling → Cell Sealing

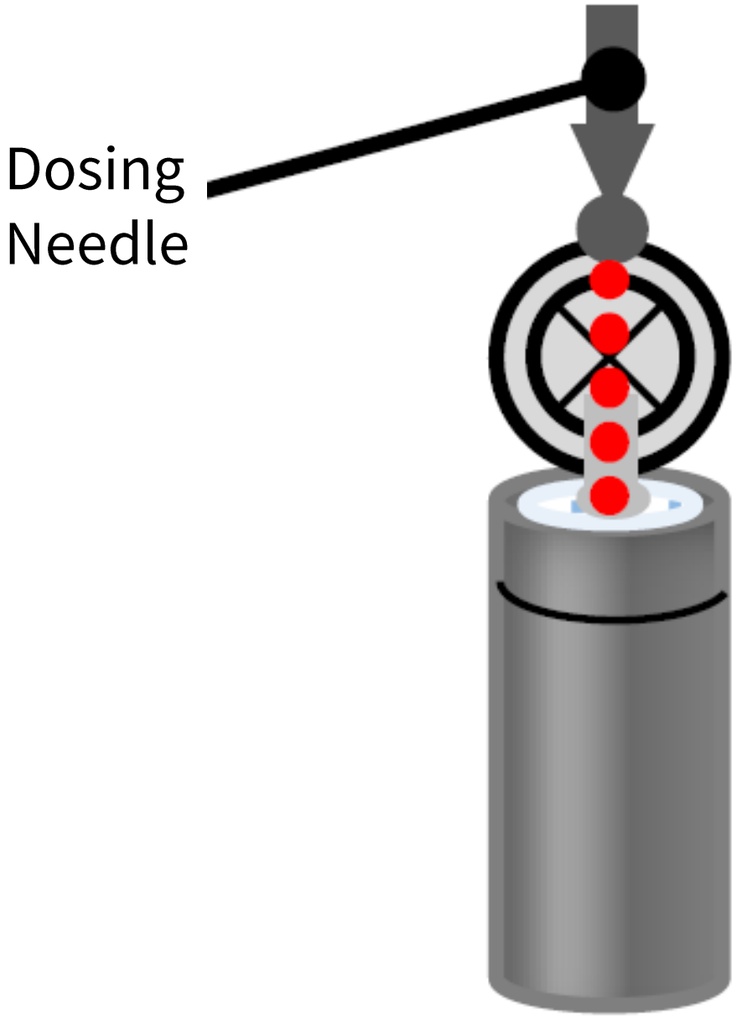




- Jelly roll inserted into a metal container
- Current collector of anode is typically welded to the bottom of the container and the current collector of the cathode is welded to the lid
- Insulation ring used both at the top and bottom of the jelly roll to insulate jelly roll from container

Issues to Consider

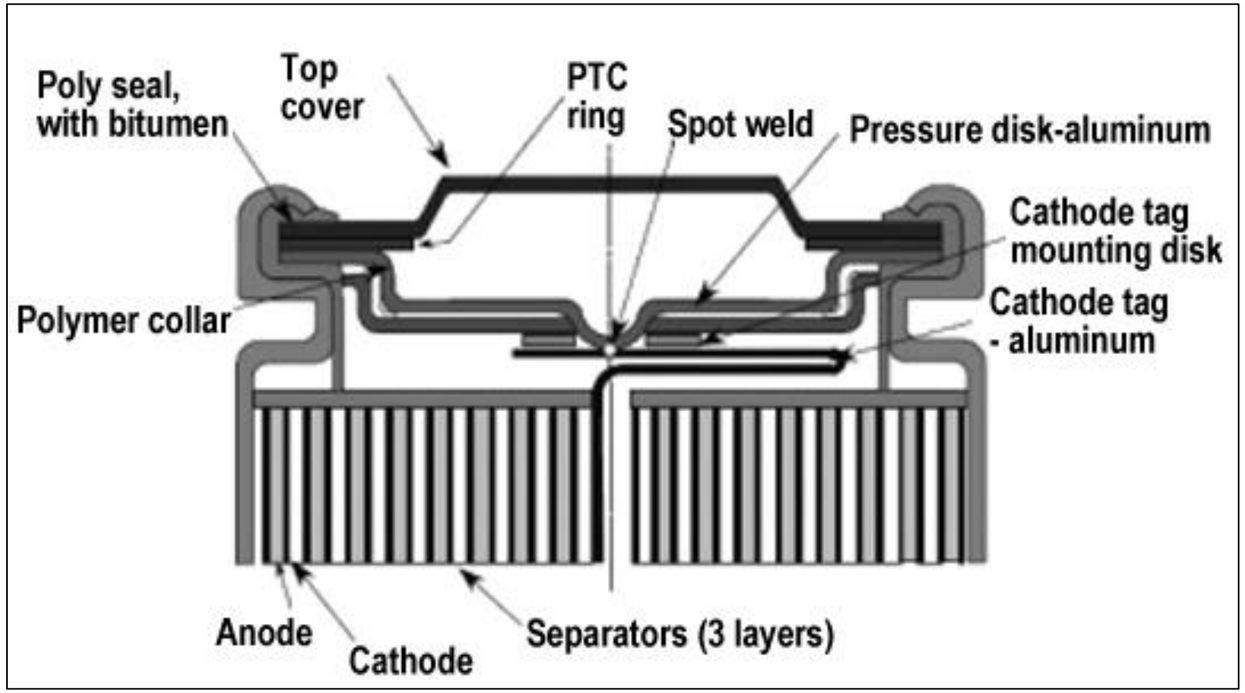
- Contact resistance during welding
- Insulation application
- Contaminant control
- Damage during welding process



- Electrolyte (e.g. LiPF6) is added after jelly roll has been inserted into enclosure
- A high precision dosing needle is used to add electrolyte into the cell under vacuum
- By applying a pressure profile to the cell (supply of inert gas and/or generation of a vacuum in alternating operation), the capillary effect in the cell is activated (wetting). Evacuation and partial filling may be repeated several times depending upon cell type [1]

Issues to Consider

- Amount of electrolyte added
- Electrolyte transportation system
- Contaminant control



- Once the electrolyte has been added to the cell, the cell is sealed (e.g. crimped)
- The cell's cap assembly contains additional protection features (e.g. PTC, CID etc.)

Issues to Consider

- Damage to cell during sealing process
- Contaminant control

Source: Ref [3]

Cell Finishing

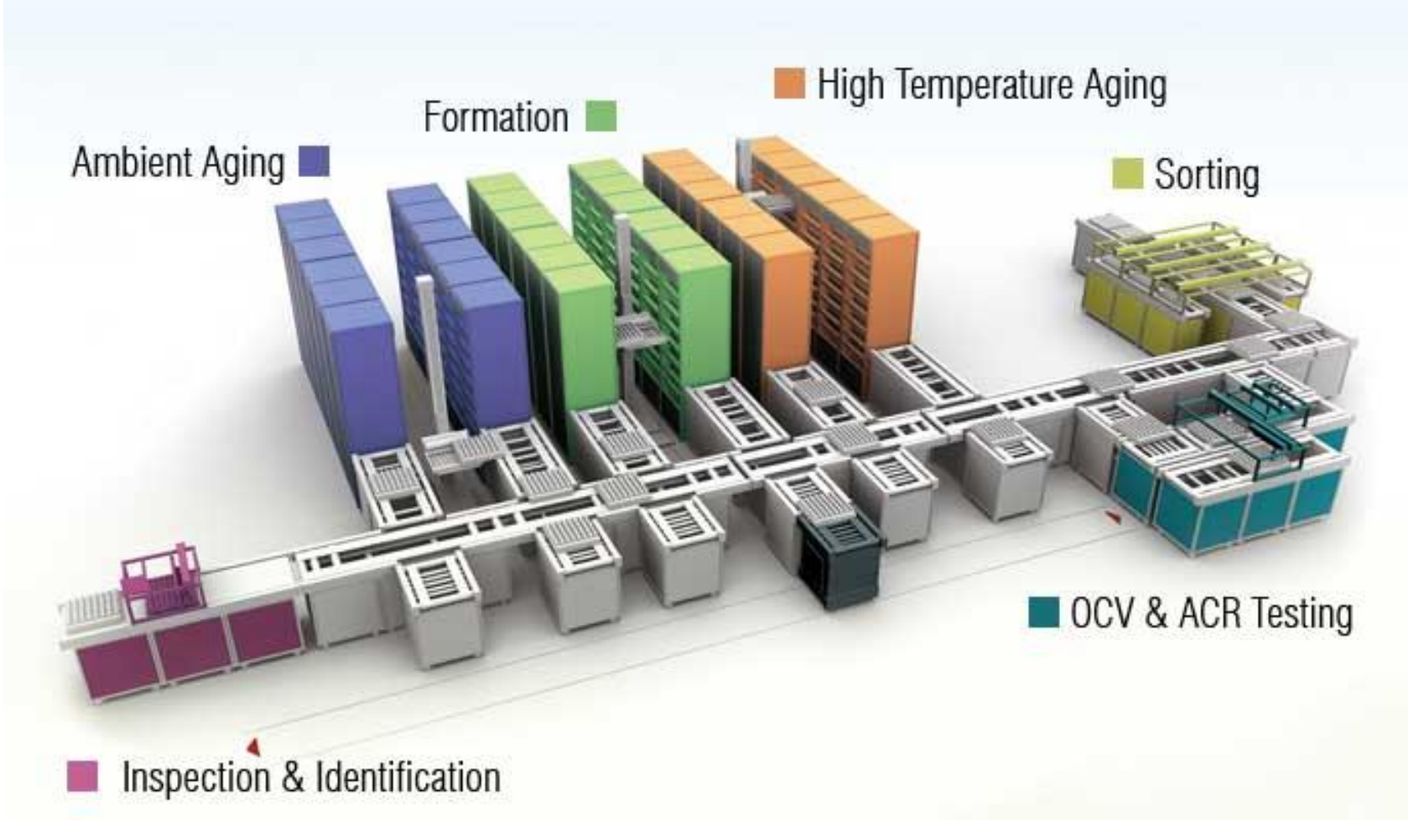
Formation → Aging → EOL

- Formation refers to the first charge/discharge cycle of the assembled cell
- Well defined current and voltage profiles are used during formation
- Formation results in the forming of the solid electrolyte interface (SEI) layer which creates an interface between the electrolyte and the anode.

Issues to Consider

- Charge/discharge profile
- Stability of SEI layer
- Cell internal resistance
- Formation temperature

Source: Ref [4]



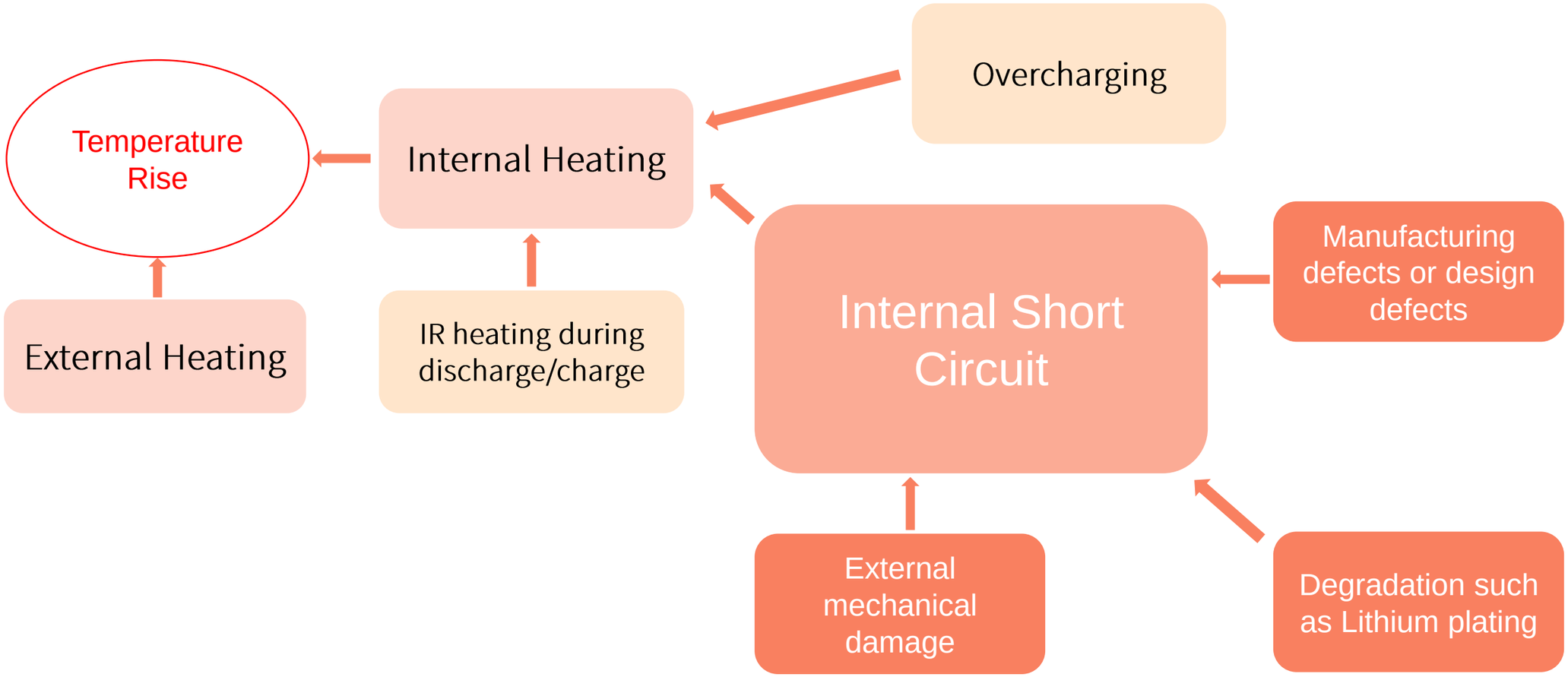
- Aging is one of the final steps and used for quality assurance.
- During aging which is performed at both high and normal temperatures, cell open-circuit voltage of the cell is measured over a period of time (can be several weeks)
- End-of-line (EOL) tests performed can include pulse tests, internal resistance measurements, visual inspections, OCV measurements etc.

Source: Ref [5]

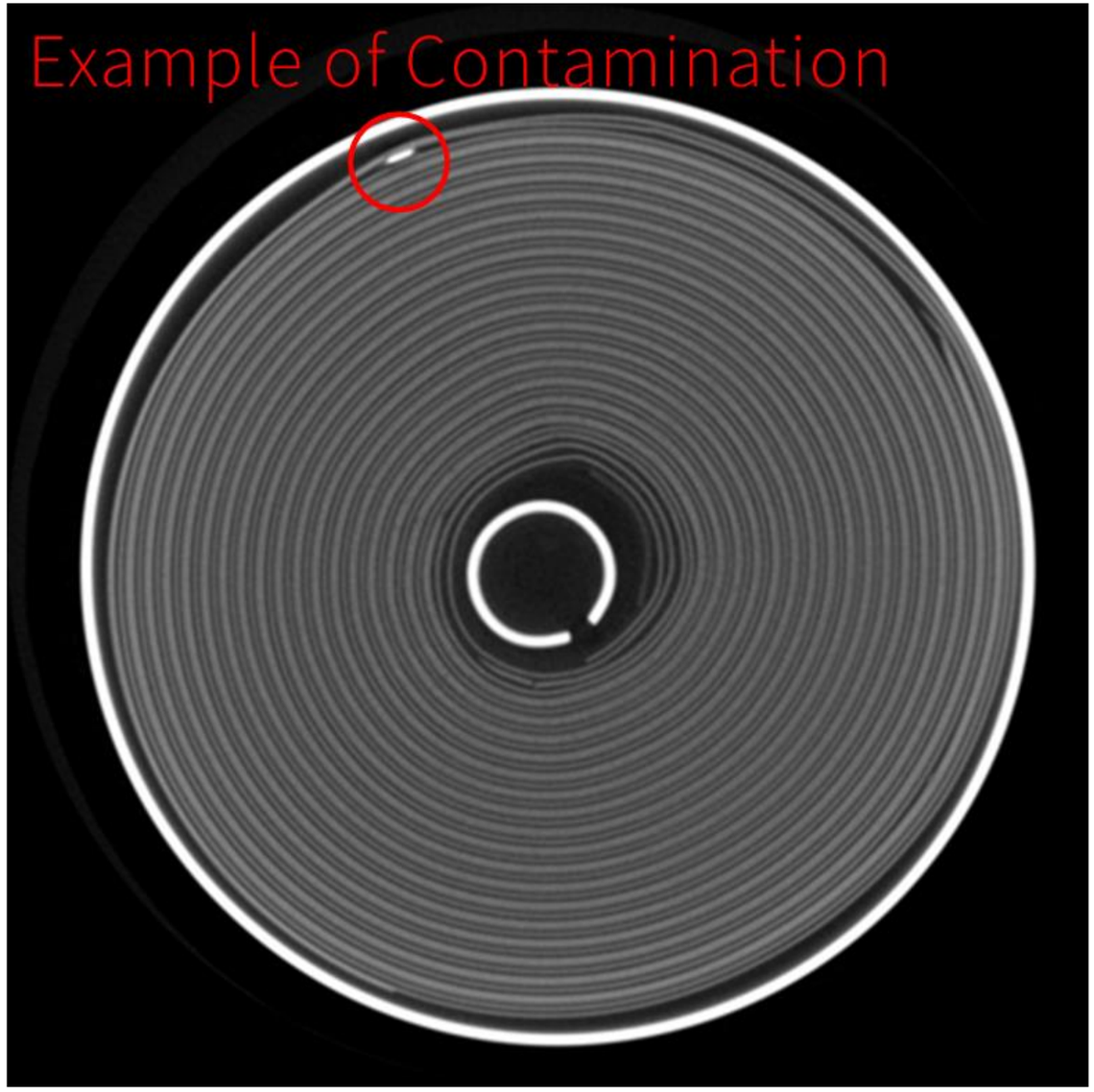
Why do we care?

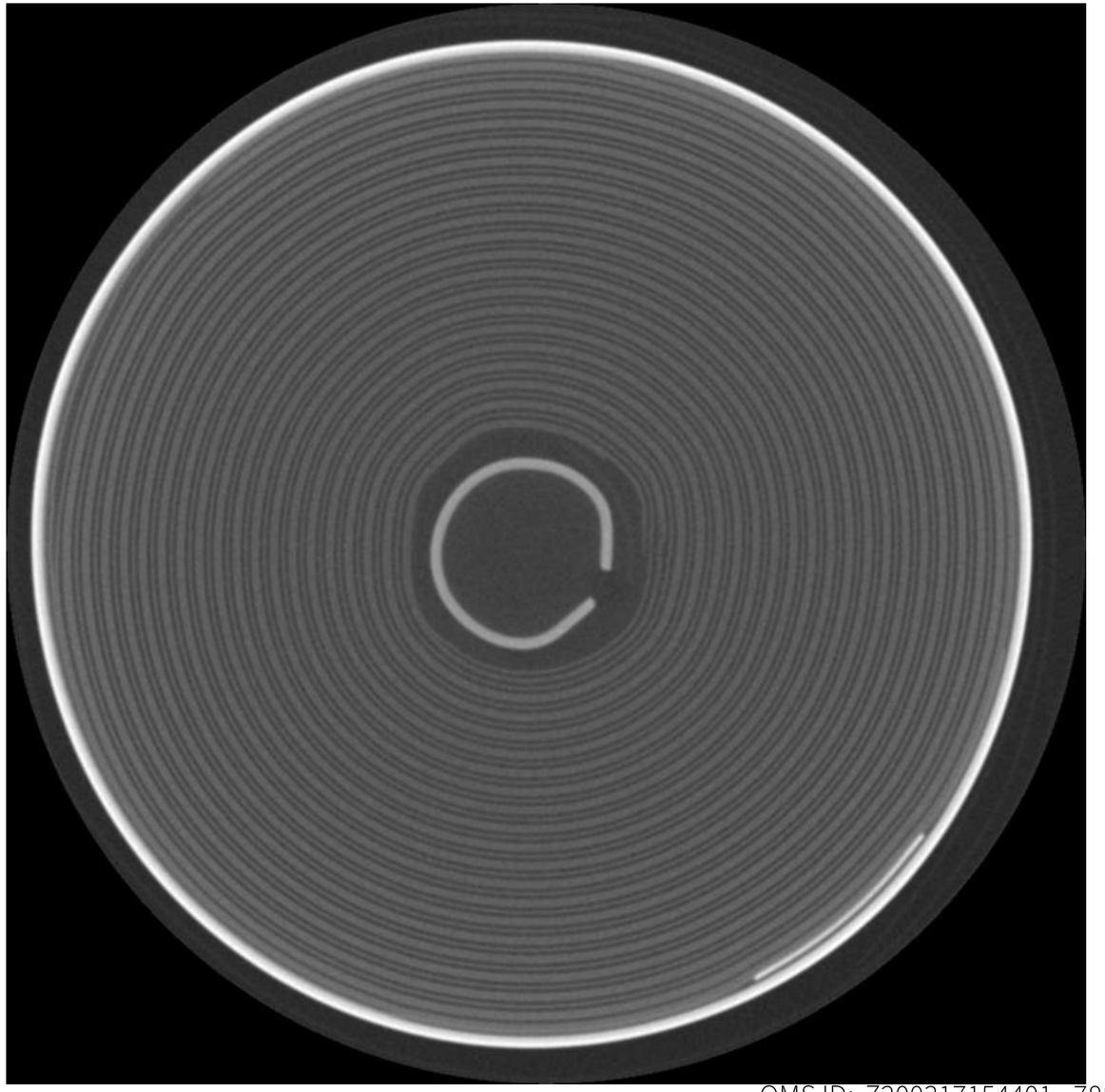
Safety of Lithium Ion Battery in a Product

- Many ways to potentially heat a battery in a product



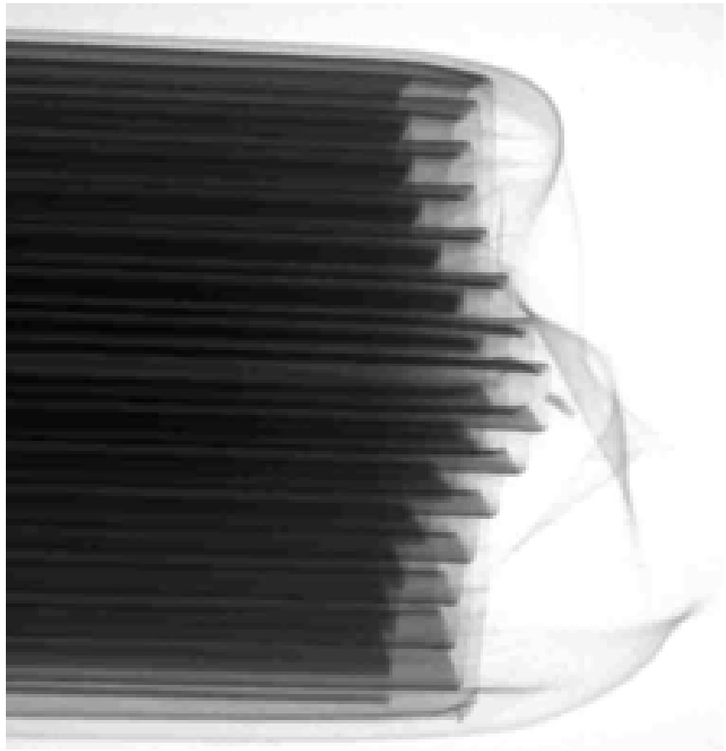
Metallic Contaminants

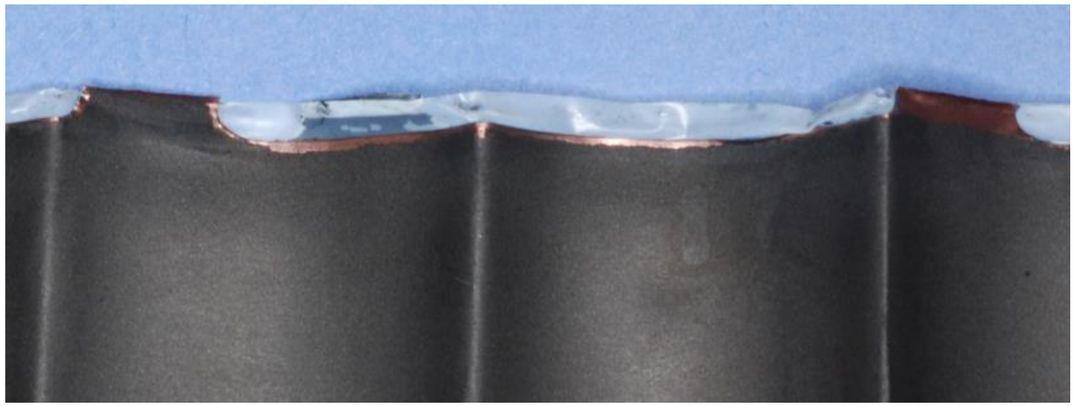




Cell Defects

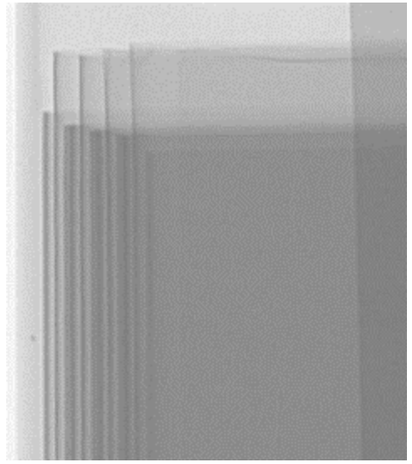
- Examples of defects during the cell manufacturing process may include:
  - Improper cell tab positioning (e.g. folding and routing of tabs, tab overhang, etc.)
  - Improper cell tab insulation
  - Winding misalignment resulting in crushing of electrodes, positive/negative electrode registry problems, etc.

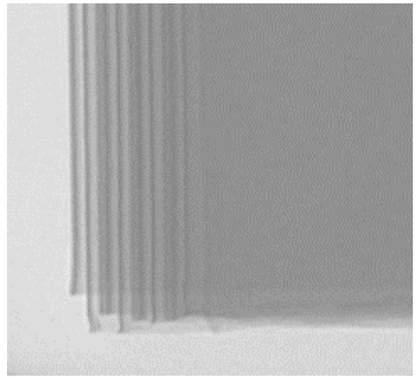




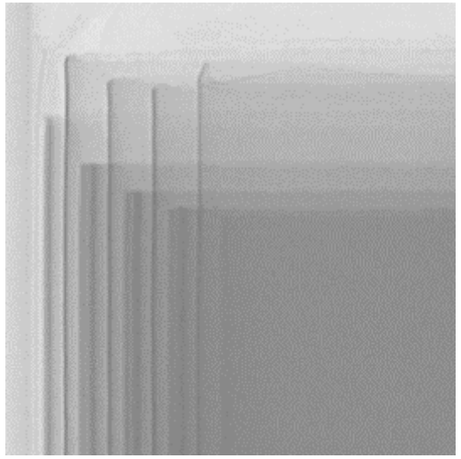
Winding Misalignments

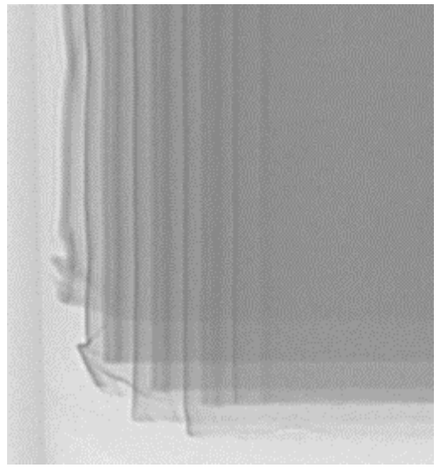
Cell 1



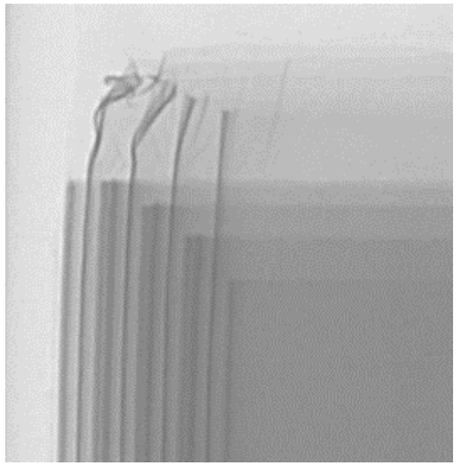


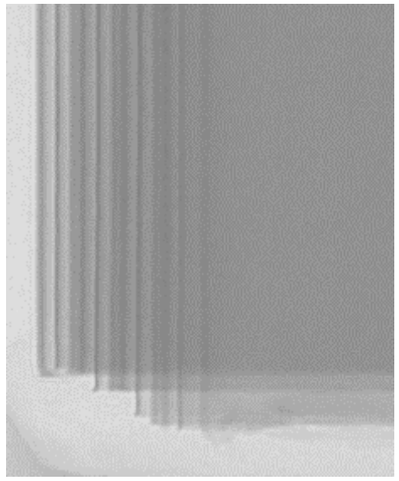
Cell 2



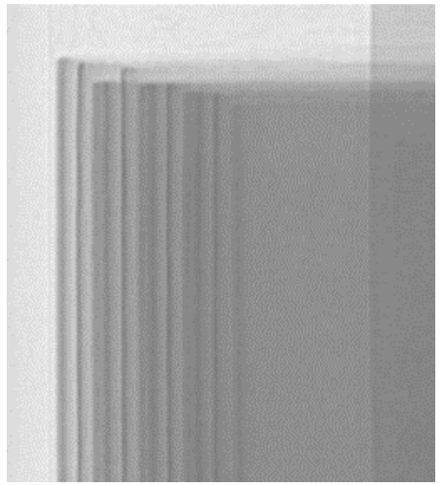


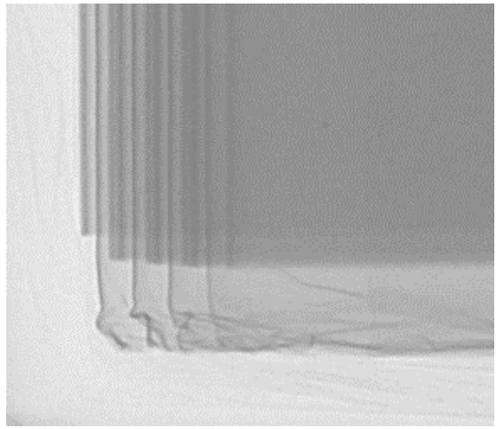
Cell 3



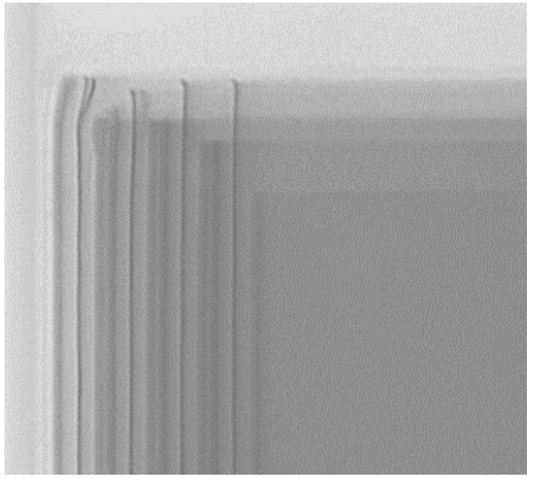


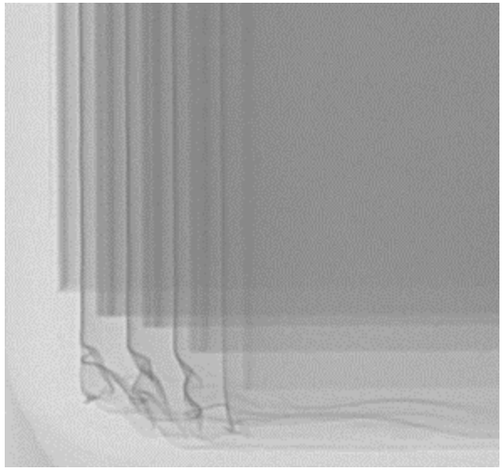
Cell 4



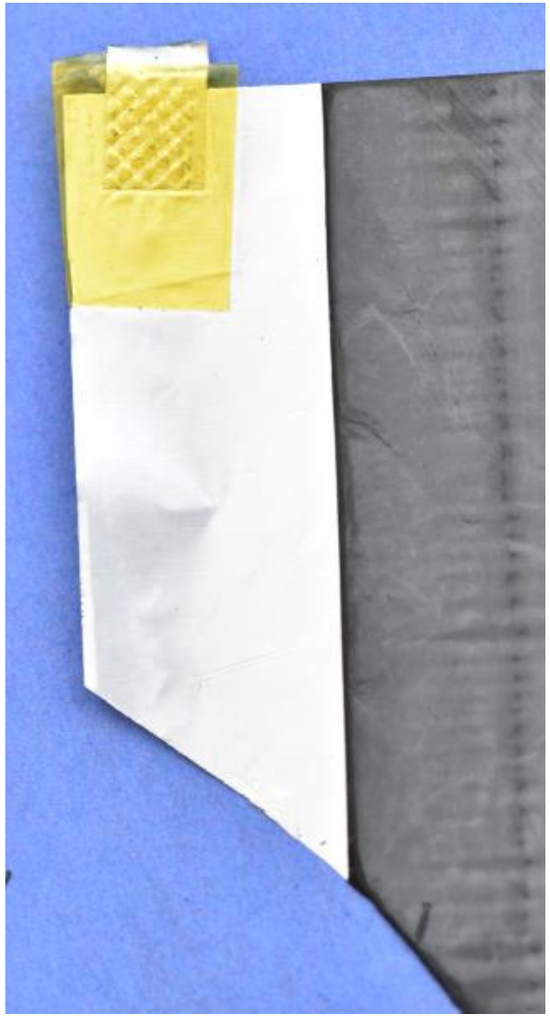


Cell 5

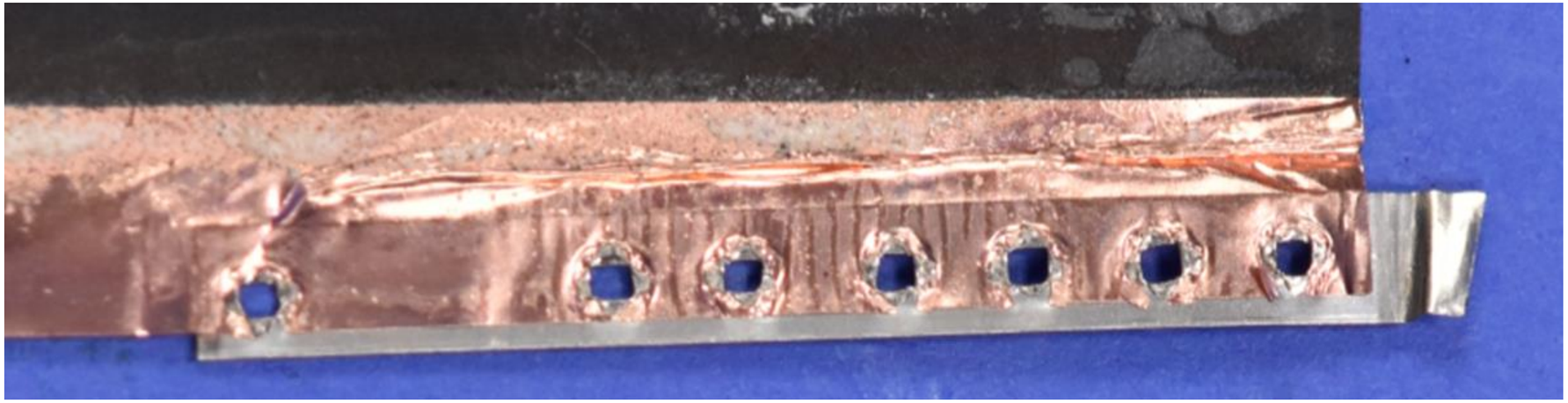


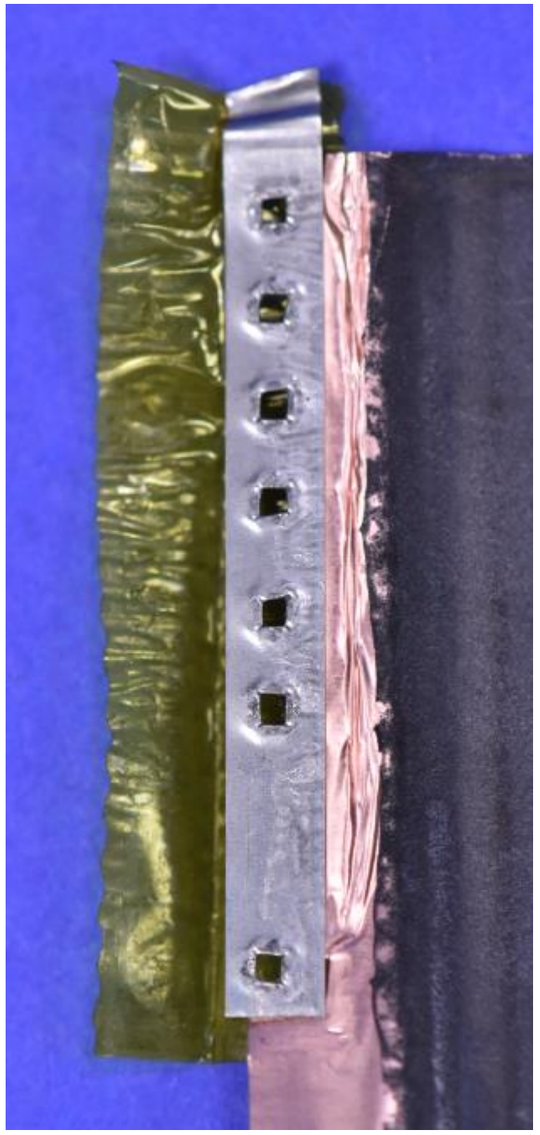


Damaged Electrodes

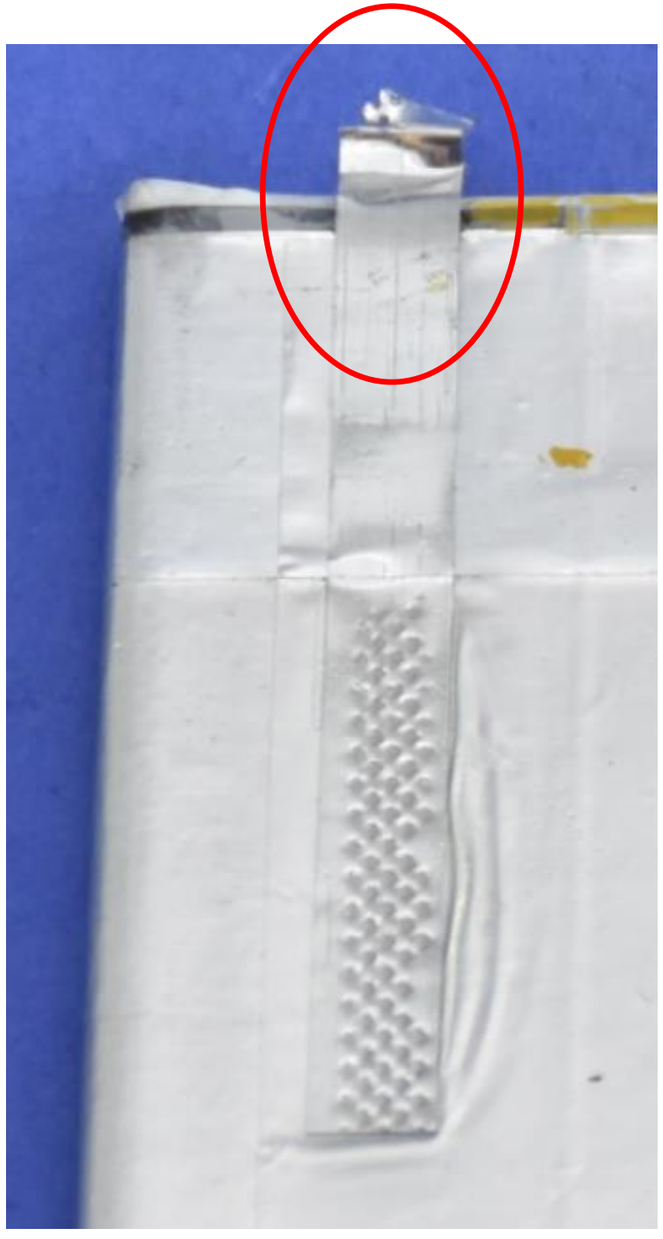


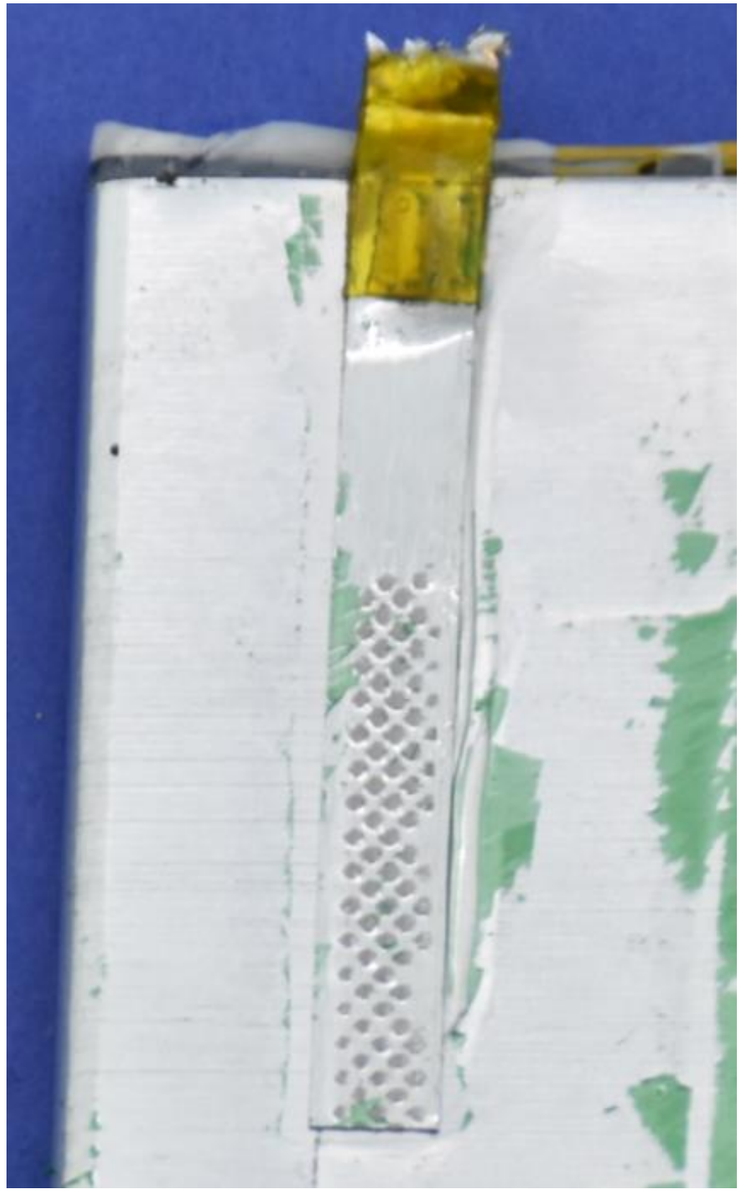
Tab Overhang



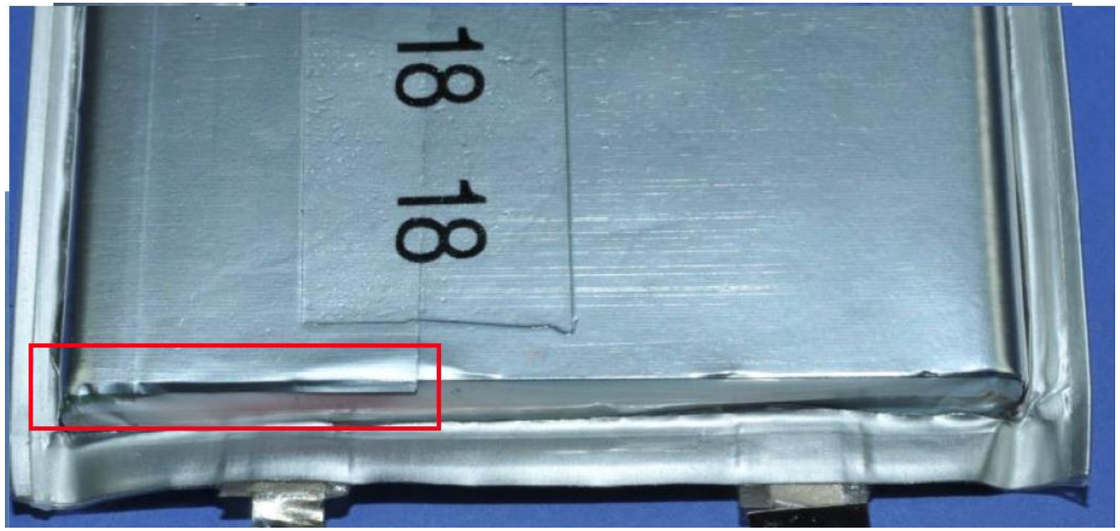


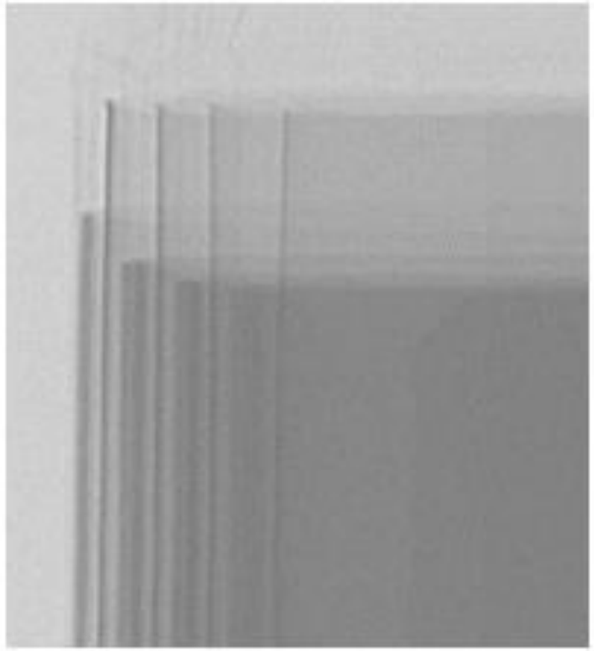
Lack of Insulation

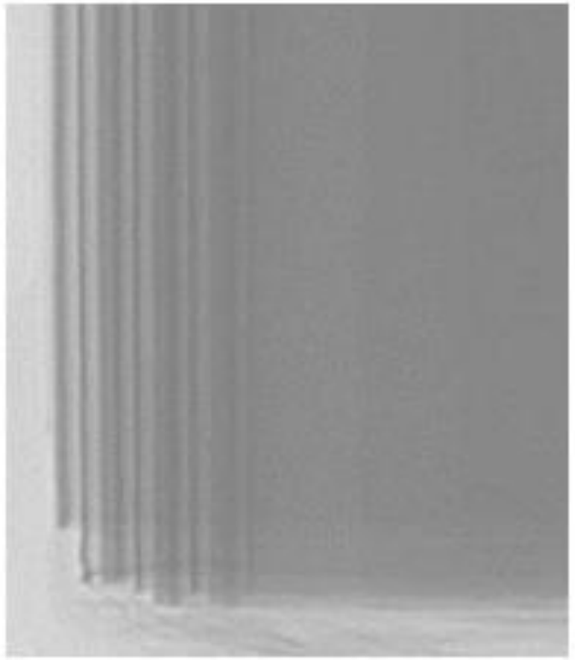




Winding Misalignments







Cell Tab Welding Issues

Lithium Plating

Causes of Lithium Plating

- Charging at low temperature
- Charging at elevated currents
- Inhomogeneous electrode coating
- Gaps between electrodes
- Mismatch in capacity between positive and negative electrodes
- Trickle charging cells at top-of-charge

Questions

References

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