МОНГОЛЫН ЭМЭГТЭЙ ИНЖЕНЕР ТЕХНОЛОГИЧ ЭРДЭМТЭН МАТЕМАТИКЧДЫН НЭГДСЭН ХОЛБООНЫ 5-Р ЧУУЛГА

ЛИТИЙН ИОН БАТАРЕЙН АНОД ЭЛЕКТРОДОД ХЭРЭГЛЭГДЭХ ХОЛБОГЧ ПОЛИМЕР МАТЕРИАЛЫН СУДАЛГАА

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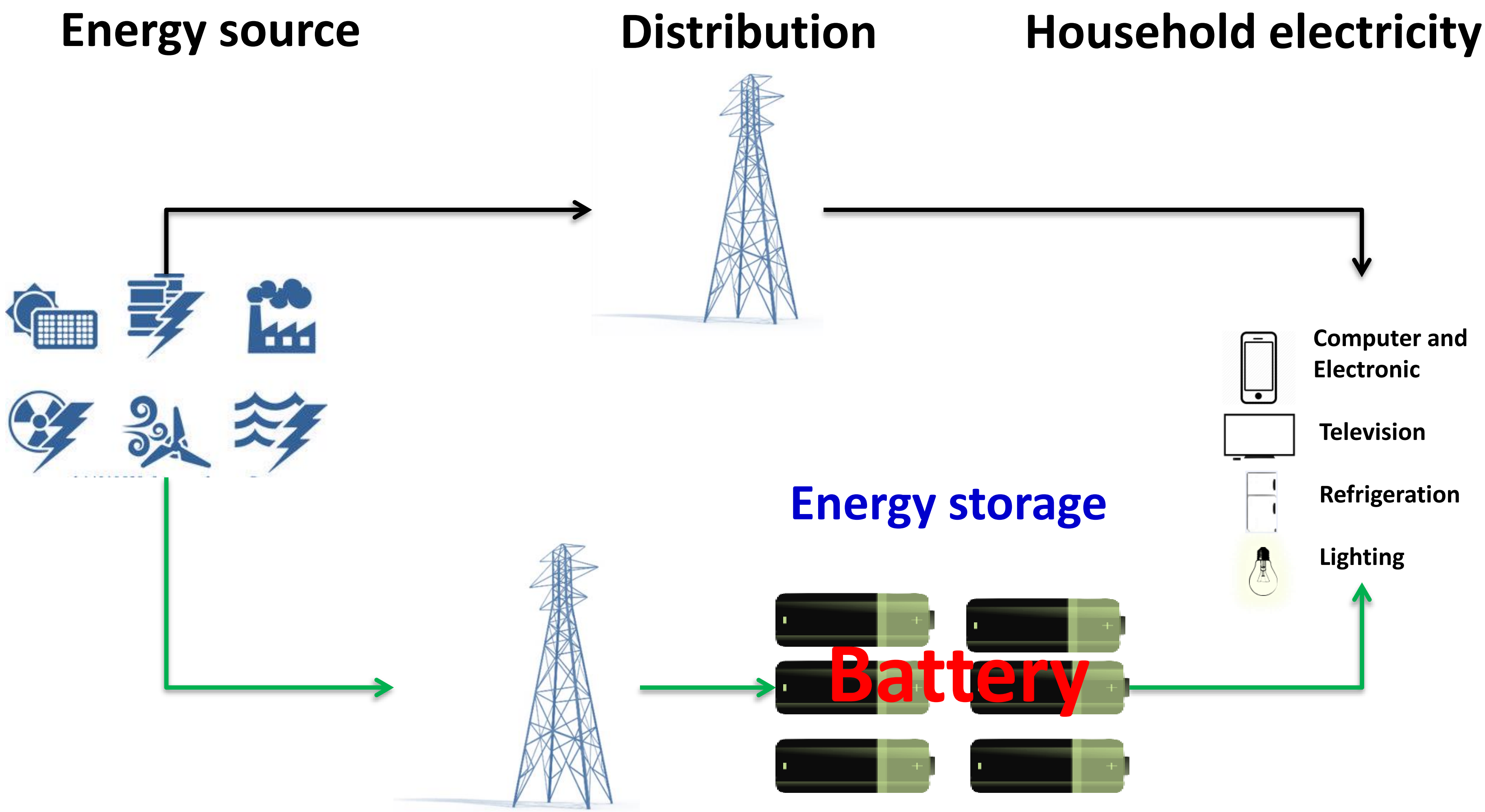
2020.10.31

Outlines

✓ **Introduction of polymer binder in LIB**

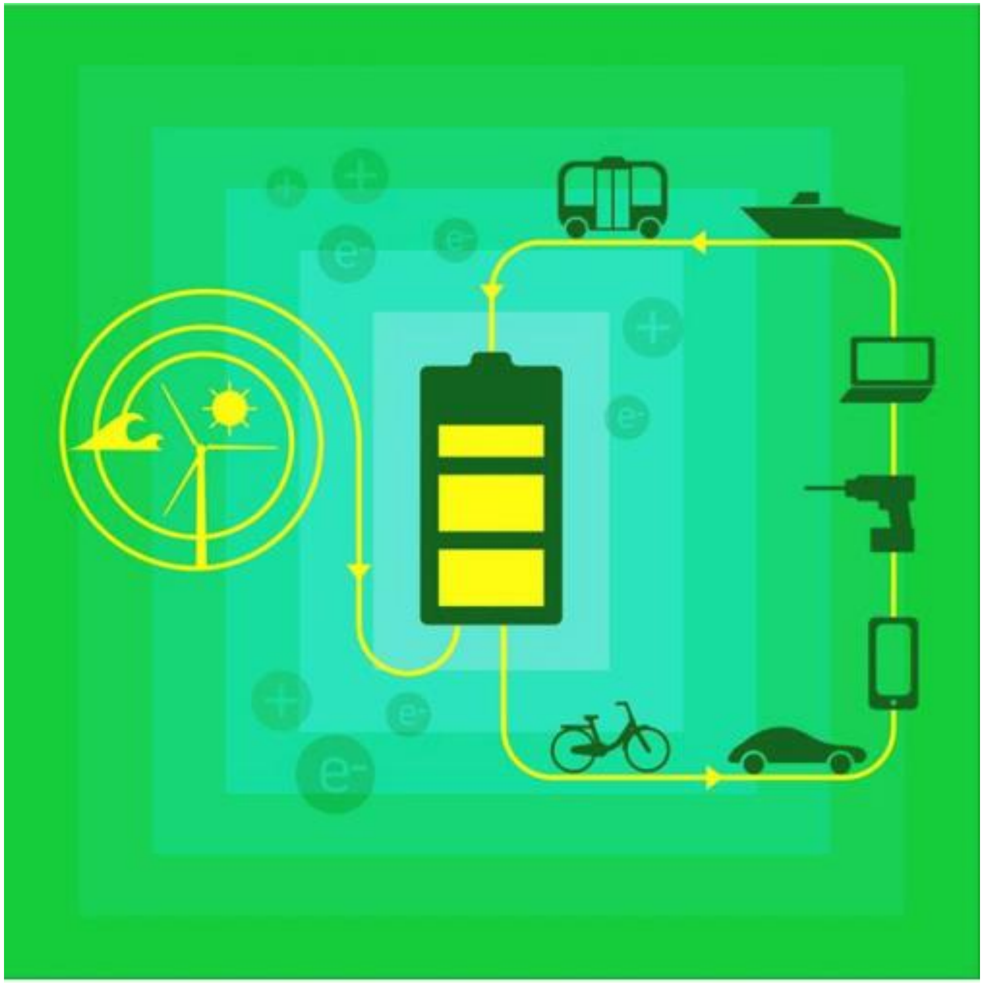
✓ **Dual-crosslinked Network binder for high-capacity Silicon based anode**

Grid system & Energy storage



A smart grid system *vs.* reachable battery

Lithium Ion Batteries (LIB)



Advantage:

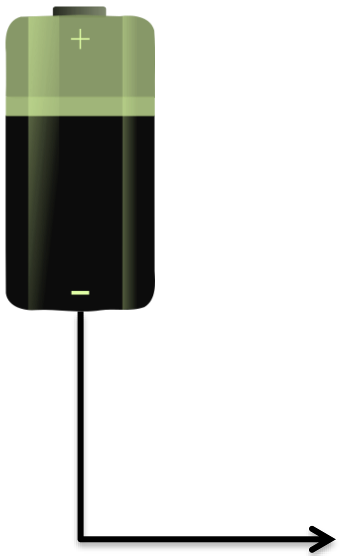
1. Various shape and size
2. No memory effect
3. Environment friendly
4. Low cost
5. High voltage
6. Large energy density
7. High cycle-life
8. Low self-discharge rate

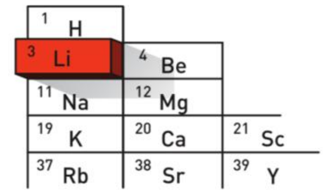
Kakao T bike

(LIB cell made by Samsung SDI Co.)

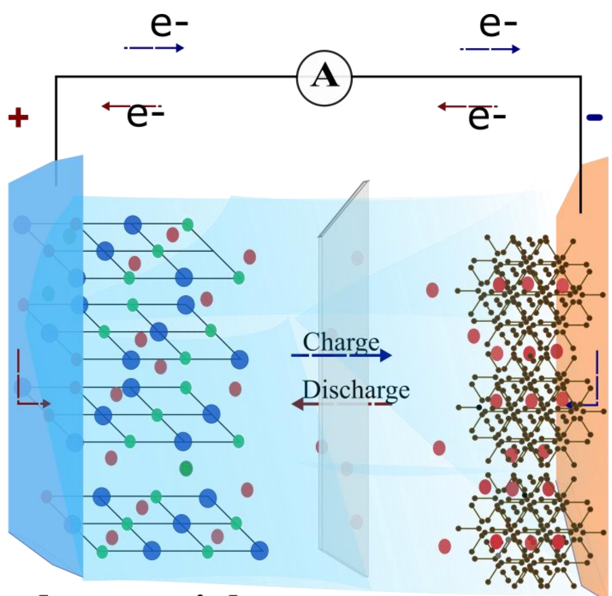
SAMSUNG SDI
삼천리자전거
alton

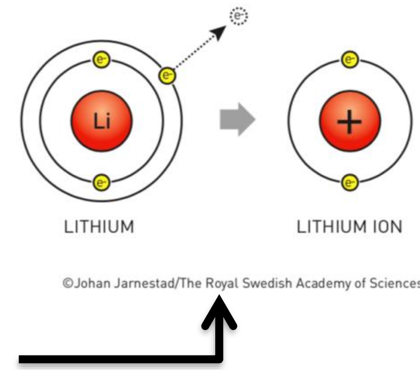
Core materials and cell reaction in LIB





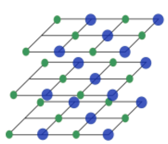
Reversible electrochemical redox reaction





Cathode material

Layered oxide



O3-type P2-type

Cathode materials:

$LiCoO_2$, $LiMn_2O_4$, $LiNiO_2$ etc.

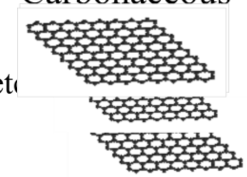
Separator

Anode materials:

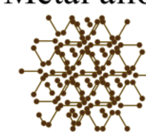
Graphite, LTO, Si, Sn, etc

Anode material

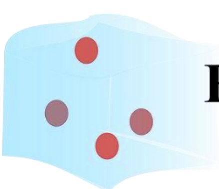
Carbonaceous



Metal alloy



Metal oxide

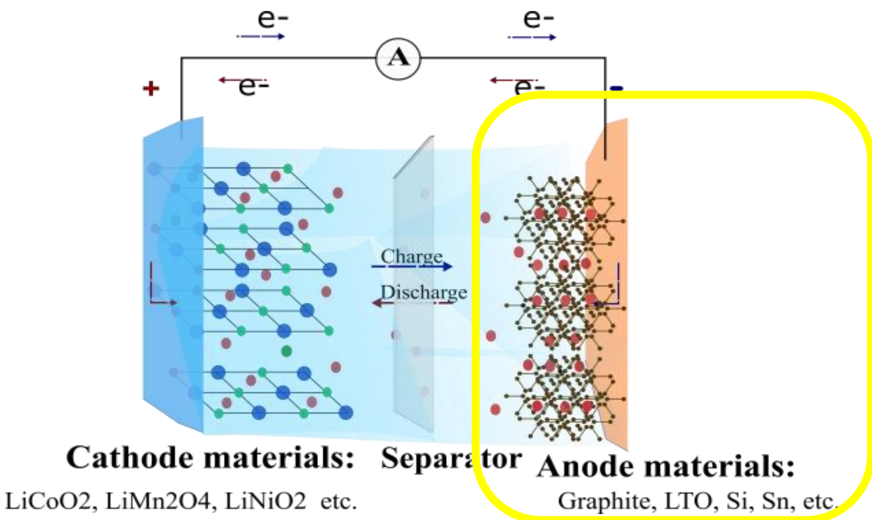


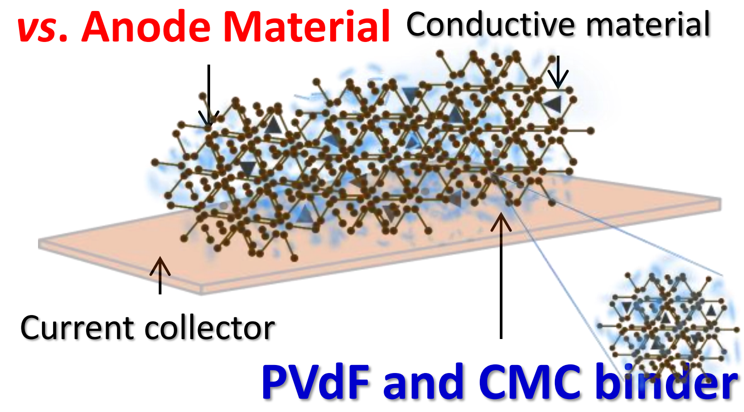
Electrolyte

Conductive material

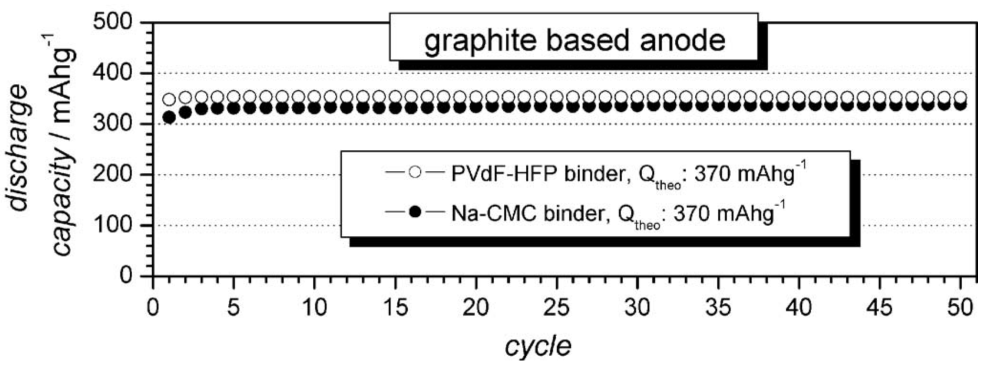
Binder

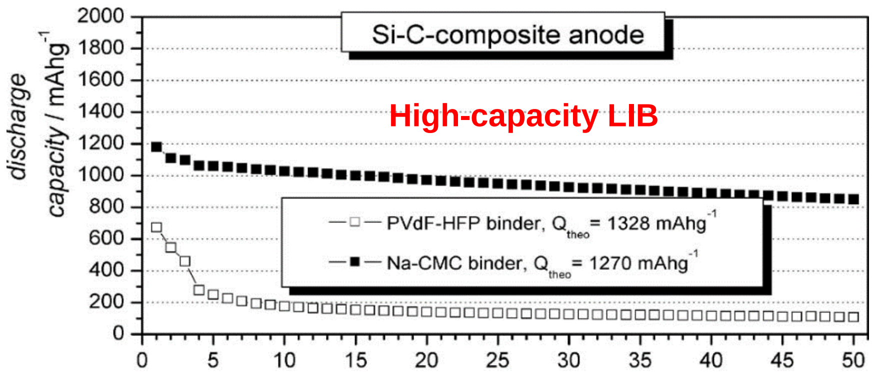
Influence of Binder Chemistry



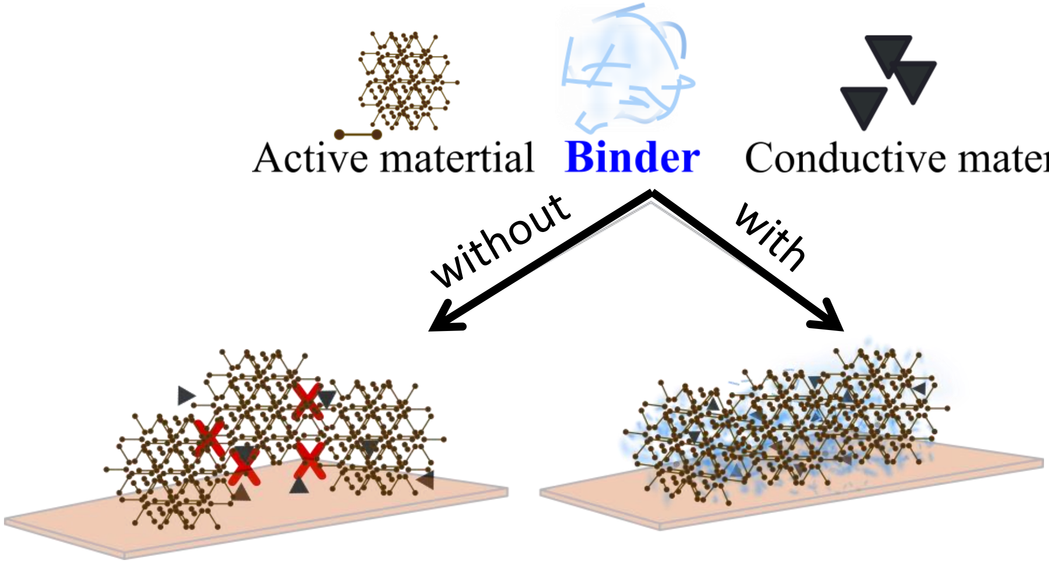


Hochgatterer et al., *Electrochem. Solid-state Lett.* 11, A76 (2008)





Role of Binder



- The **binder** is used to **glue** active materials and conductive agent **together** with the current collector.
- 2-5 wt% for LIB
- Electrochemical inactivity

Battery Binder Criteria:

➤ **Adhesion strength**
- Between AM
- Between AM and current collector

➤ Stability
- Chemical
- Electrochemical
- Thermal

➤ Processability
- Binder solution
- Electrode paste

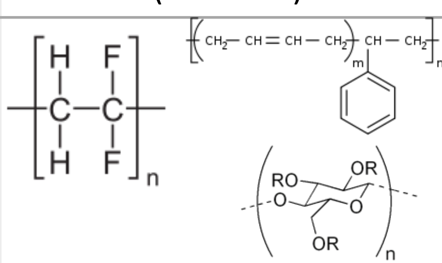
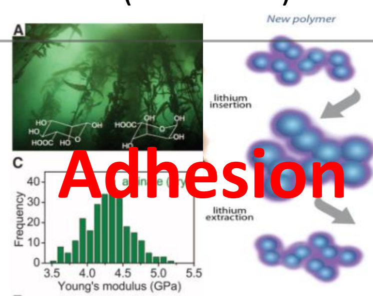
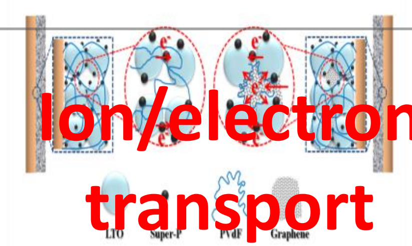
➤ Mechanical strength
- Tensile strength
- Elongation

➤ **Electronic/Ionic conductivity**

Polymer binder for high-cap. Si/C anodes

- **Dual-Crosslinked Network Binder**

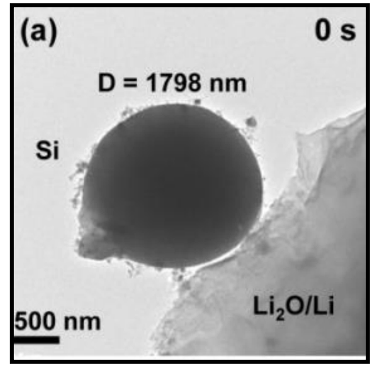
Anode active material and Binder

	Graphite	Silicon (High-capacity)	$Li_4Ti_5O_{12}$ (High-power)
Redox reaction	$C_6 + Li^+ + e^- \leftrightarrow LiC_6$	$Si + 4.4Li^+ + 4.4e^- \leftrightarrow Li_{4.4}Si$	$Li_4Ti_5O_{12} + 3Li^+ + 3e^- \leftrightarrow Li_7Ti_5O_{12}$
Capacity	372 mAh g^{-1}	4200 mAh g^{-1}	175 mAh g^{-1}
Characteristics	✓ Volume change ~10 % ✓ High reversibility & stable capacity	✓High capacity	✓ no structural change (zero-strain) ✓ High insertion potential ~1.55 V
Drawbacks	✓ Low capacity ✓ Safety issue for dendrite	✓Significant volume change ~ 310% ✓ Pulverization & electrical disconnection ✓ Rapid capacity fade	✓Electronic insulator ✓Poor ionic diffusion ✓ High residual water
Polymer Binder	PVdF, SBR/CMC (< 3 wt%)	No polymer available (> 10 wt%)	Not chosen (~5 wt%)
Research trend			

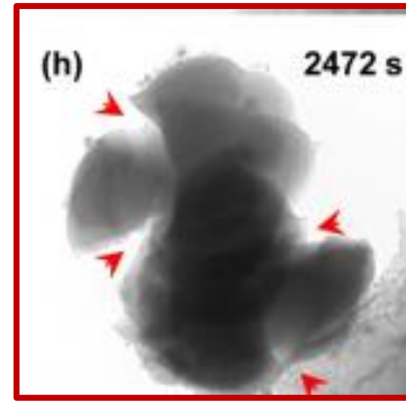
High-capacity Silicon anode

Silicon :

- ✓ High capacity (4200 mAh/g)
- ✓ Significant volume change during charge/discharge (310%)

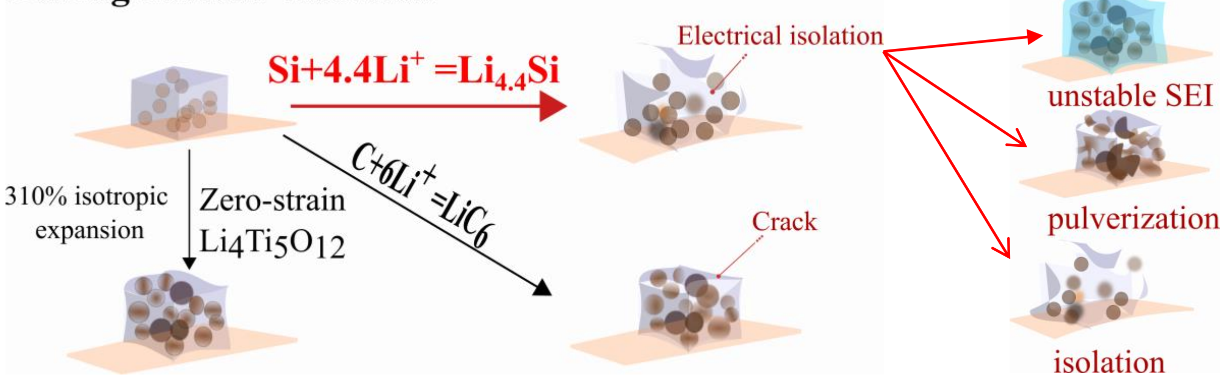


Liu et al., JACS Nano 6(2), 1522 (2012)



During lithium insersion

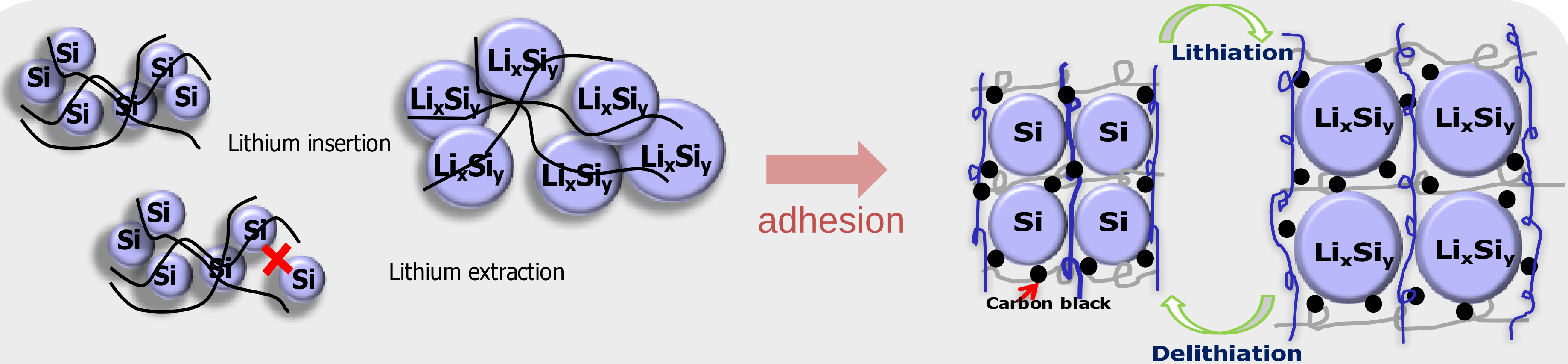
Main Problem of Si



Solution:

- ➢ Nanostructured design: Si NP, Si/C composite, Si alloy
- ➢ **New polymeric binder**

Dual-crosslinked Network binder

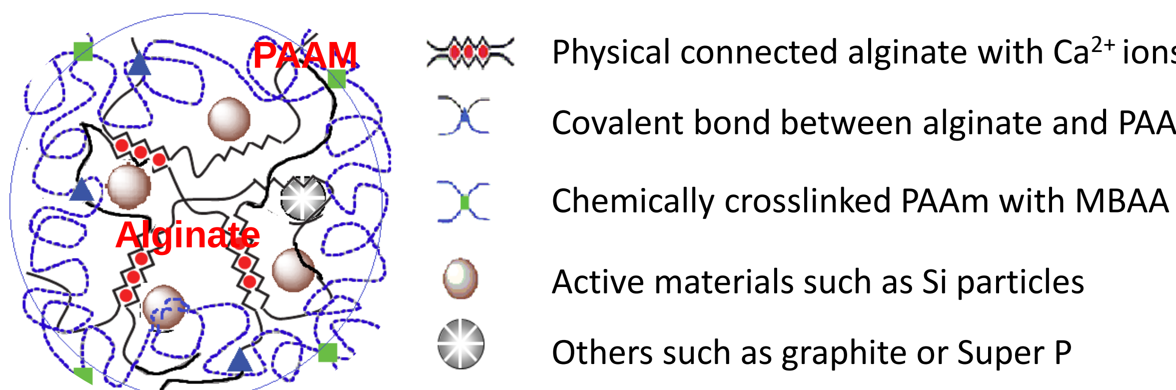


Conventional structure with linear chain polymers

Network structure with a dual-crosslinked polymer

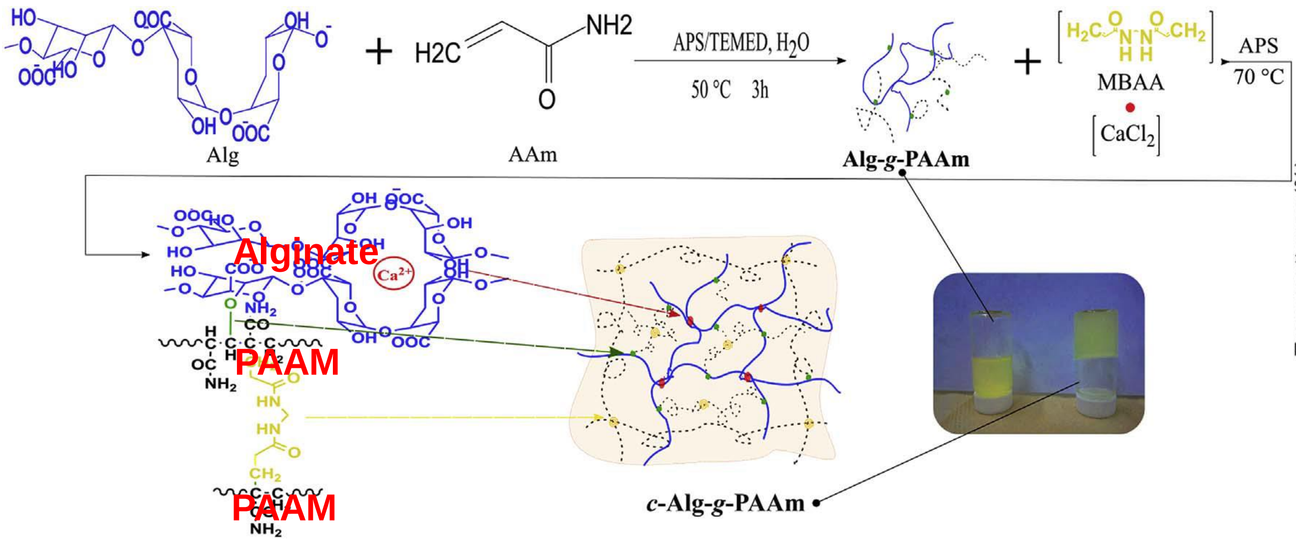
❖ **Dual-crosslinking between Alginate-Polyacrylamide**

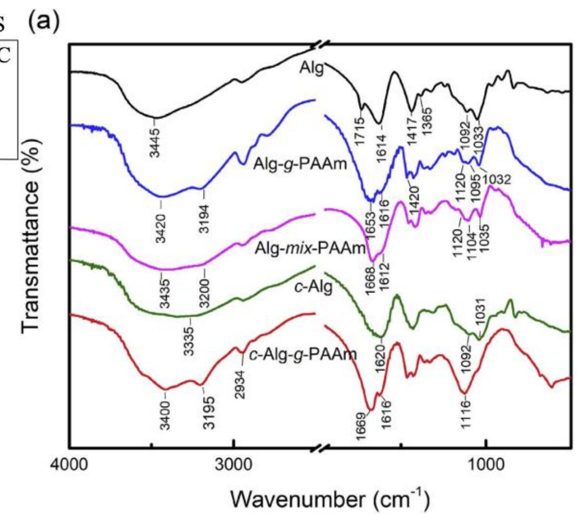
- ✓ Ionic (physical) crosslink: Alginate
- ✓ Chemical crosslink: Polyacrylamide

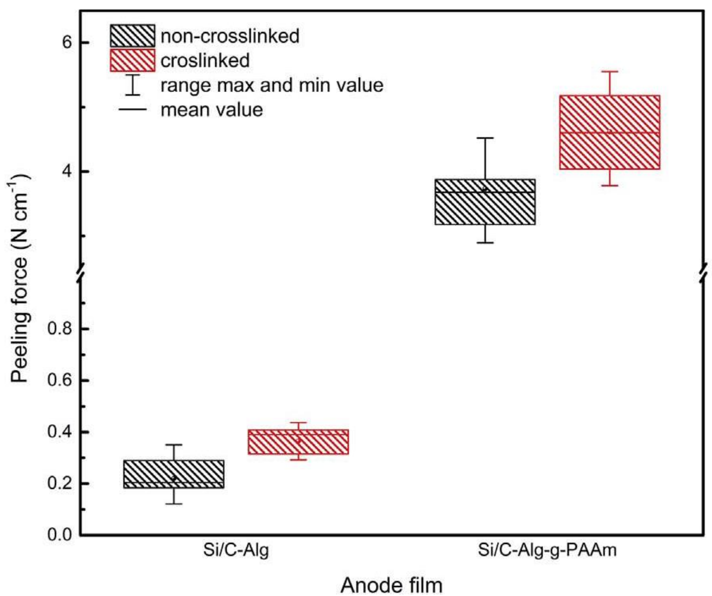


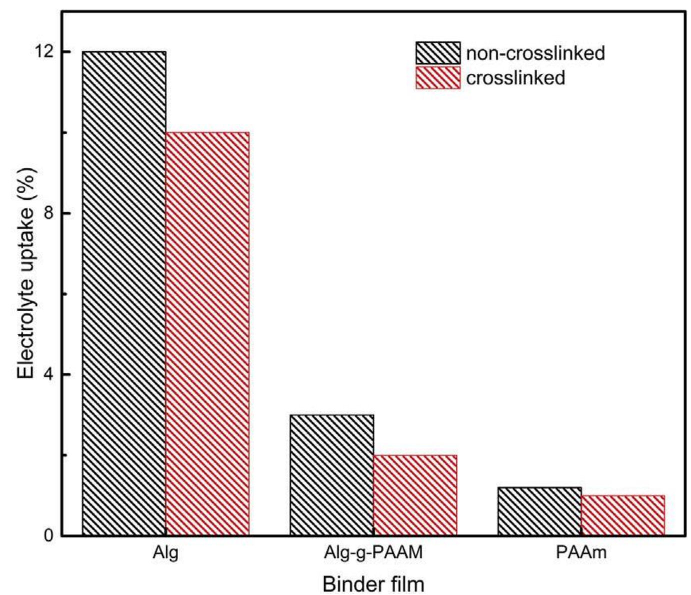
B. Gendensuren and E.-S. Oh, *J. Power Sources* 384, 379 (2018)

Dual-crosslinked binder



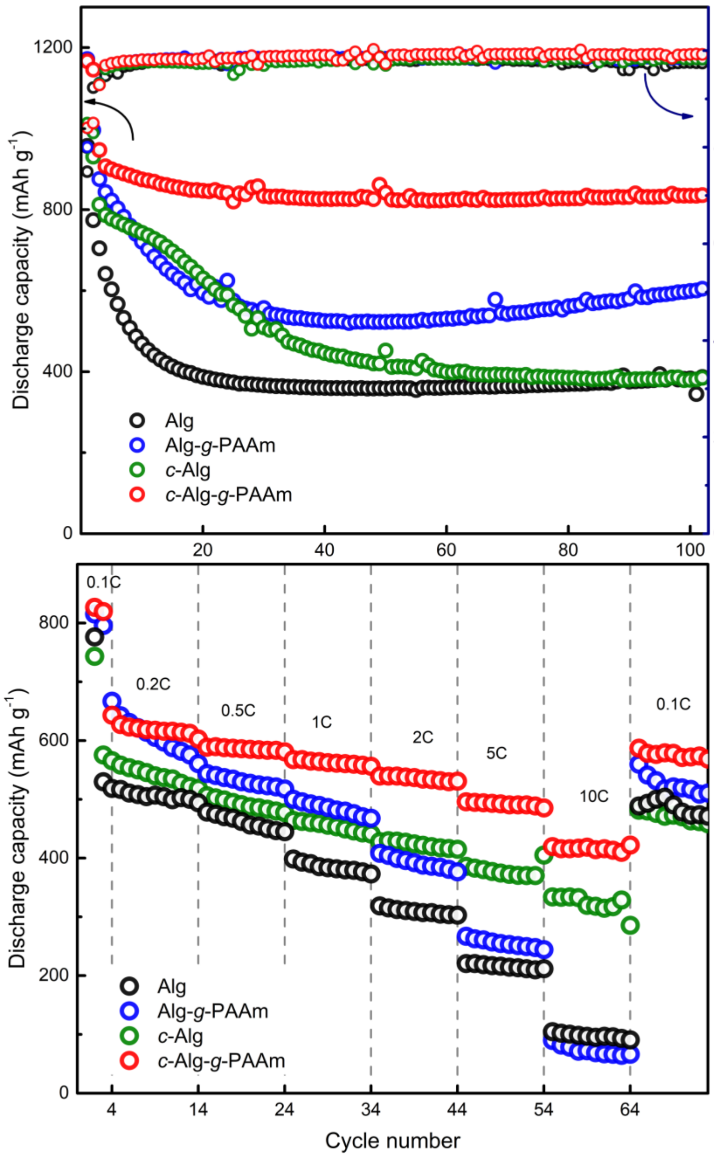




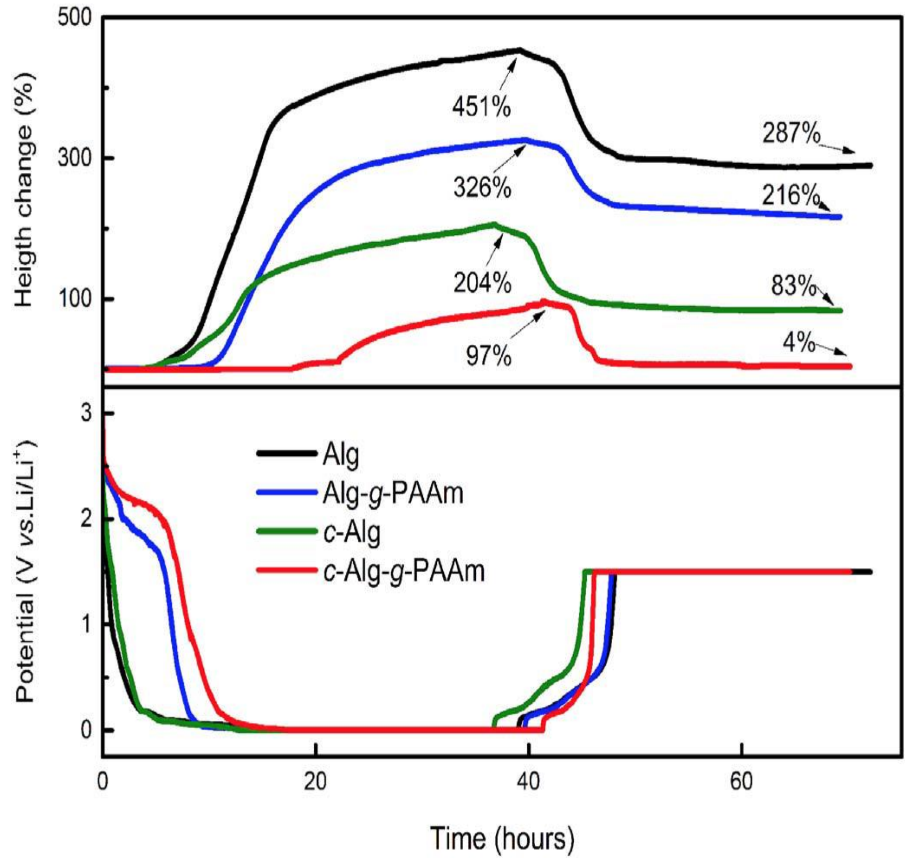


B. Gendensuren and E.-S. Oh, *J. Power Sources* 384, 379 (2018)

Dual-crosslinked binder

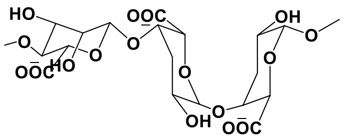


Theoretical volume expansion = 85% (Si:C=1:3)

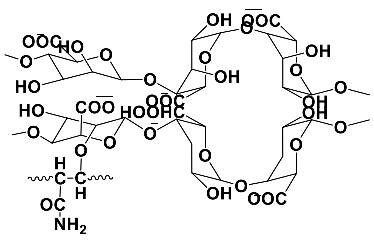


B. Gendensuren and E.-S. Oh, *J. Power Sources* 384, 379 (2018)

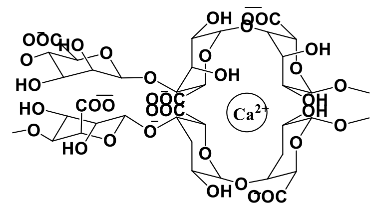
Conclusion



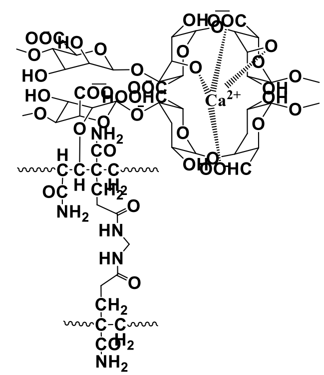
Alginate
(Alg)



Alginate-g-Polyacrylamide
(Alg-g-PAAm)



crosslinked Alginate
(*c*-Alg)

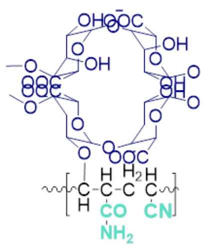


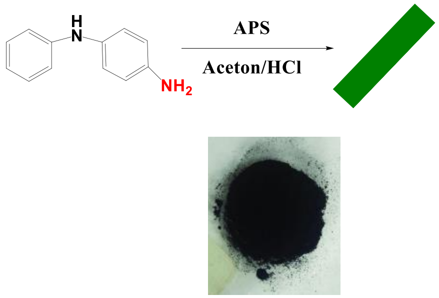
dual-crosslinked Alg-*g*-PAAm
(*c*-Alg-g-PAAm)

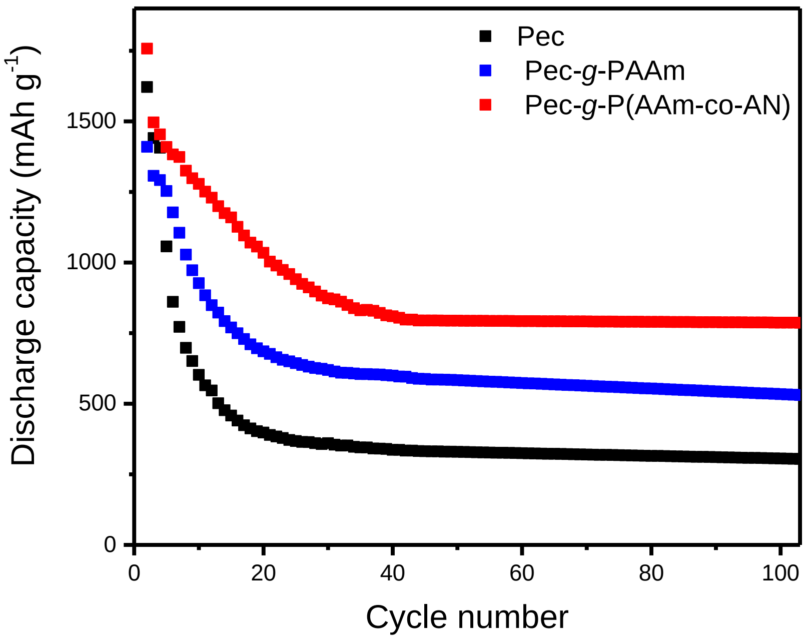
- ✓ Successful synthesis of graft copolymer and establishment of dual-crosslinked network in linear alginate
- ✓ Enhanced adhesion with current collector
- ✓ Improving the electrochemical performance of Si/C anode with *c*-Alg-*g*-PAAm

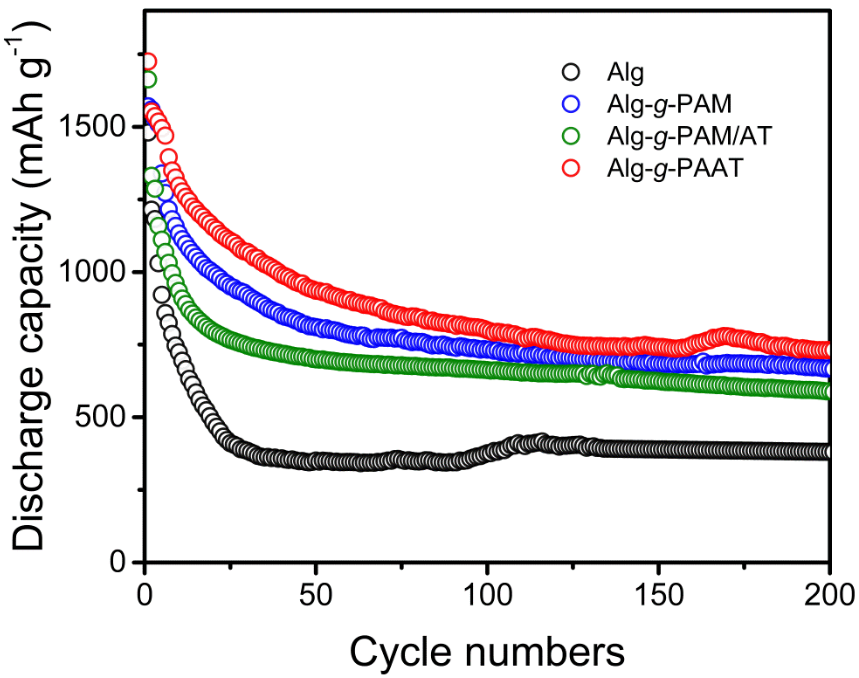
Future work

➢ **Water-treated conductive self-healing polysaccharide based binders for high capacity anode**





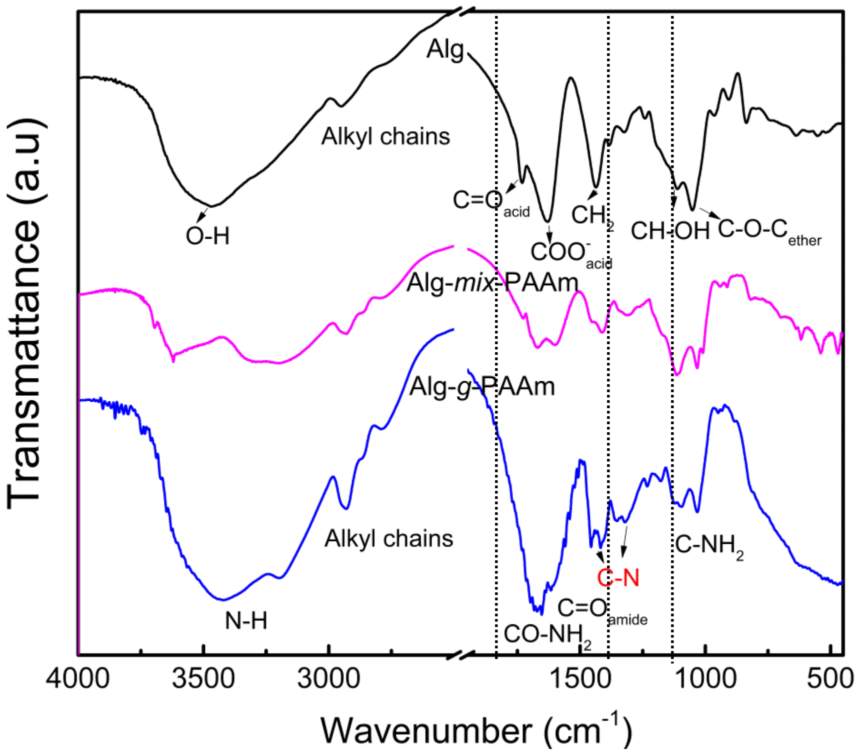




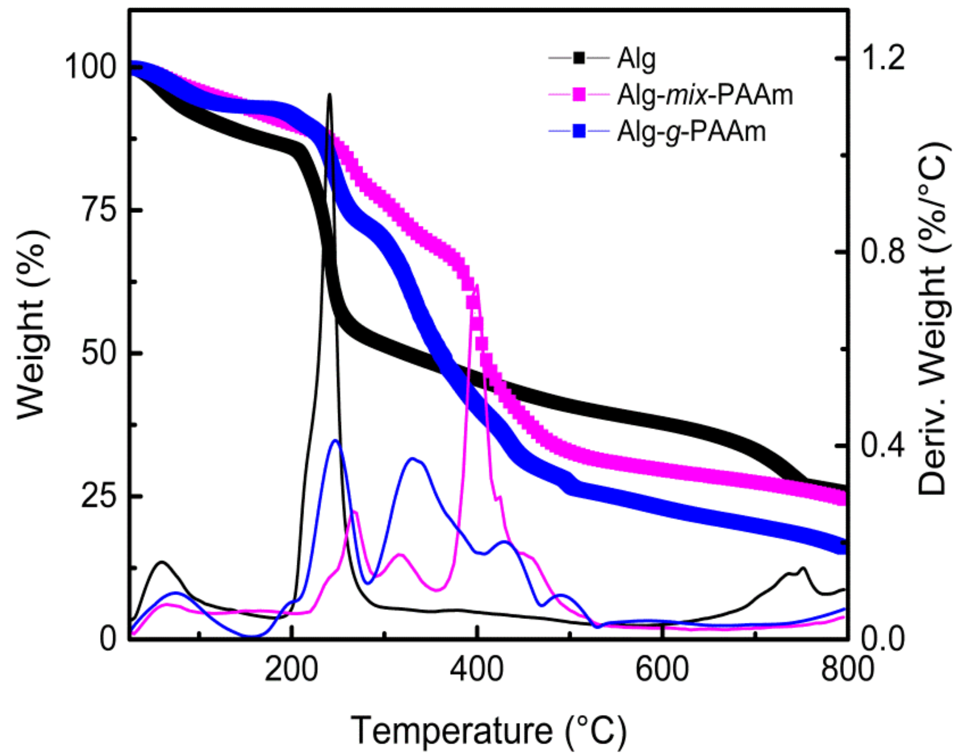
THANK YOU FOR YOUR ATTENTION

Chemical analysis of the graft copolymer

FT-IR spectra



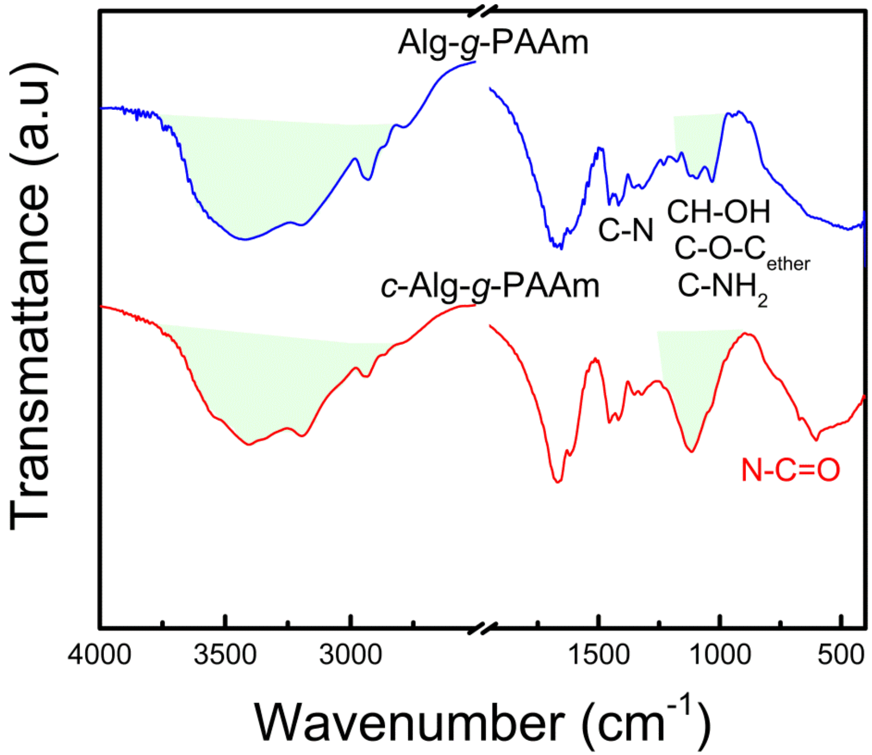
TGA curve



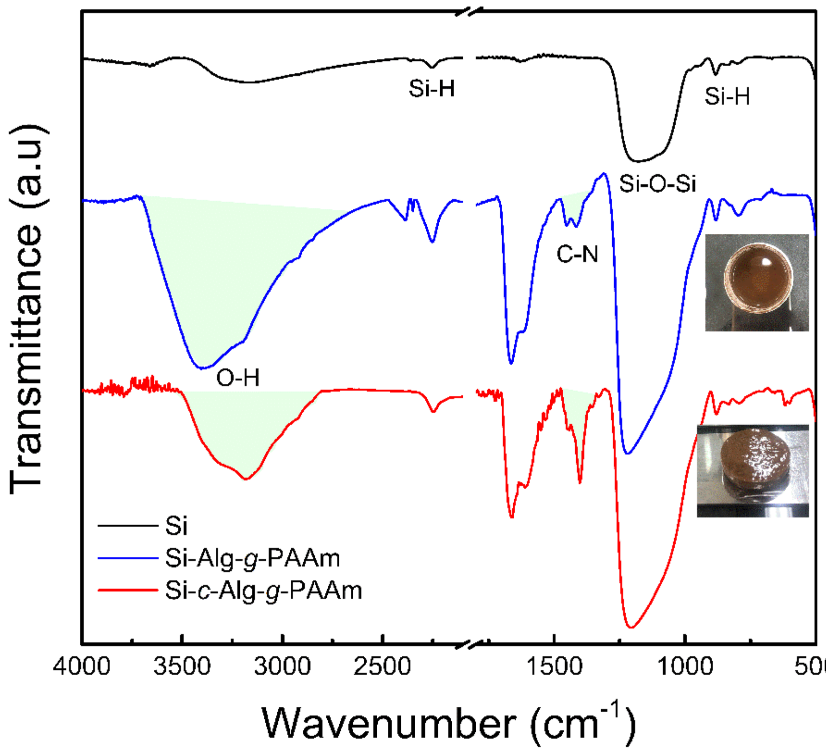
✓ **Successful grafting of PAAm onto alginate**

Chemical analysis of crosslinked polymer

FT-IR spectra of network



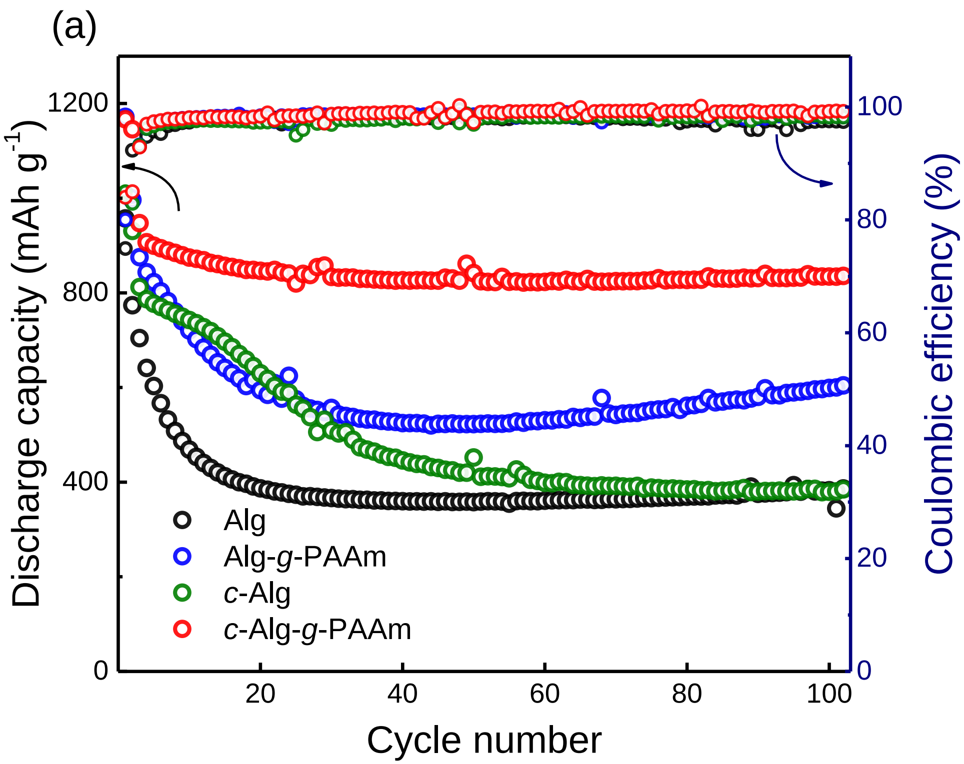
FT-IR spectra of slurry



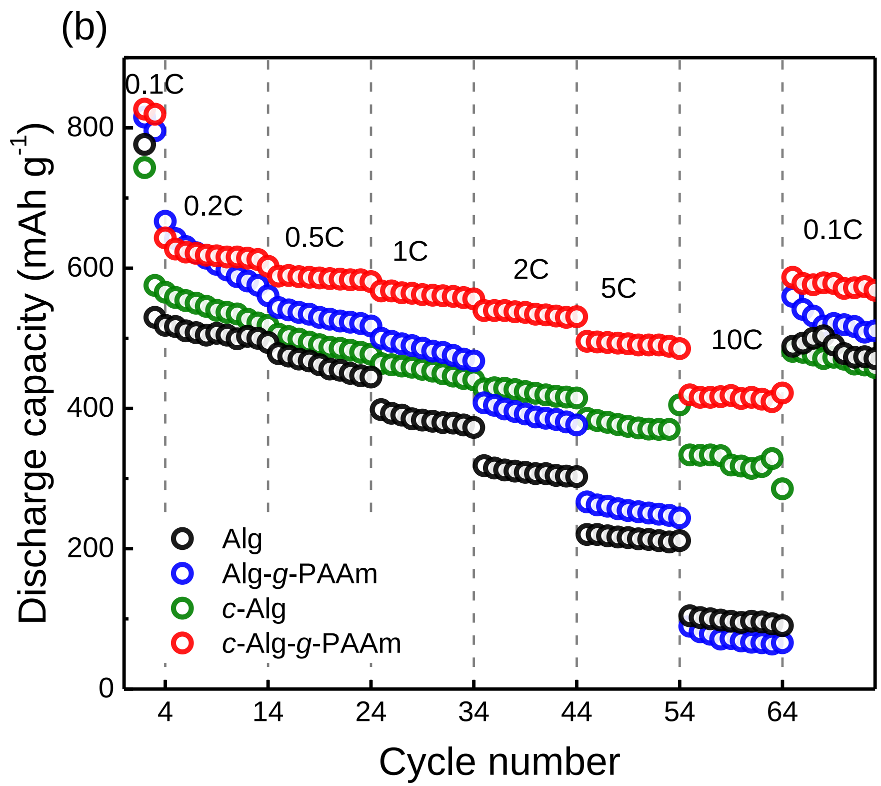
✓ **Achievement of dual-crosslinking in binder**

Galvanostatic charge-discharge test

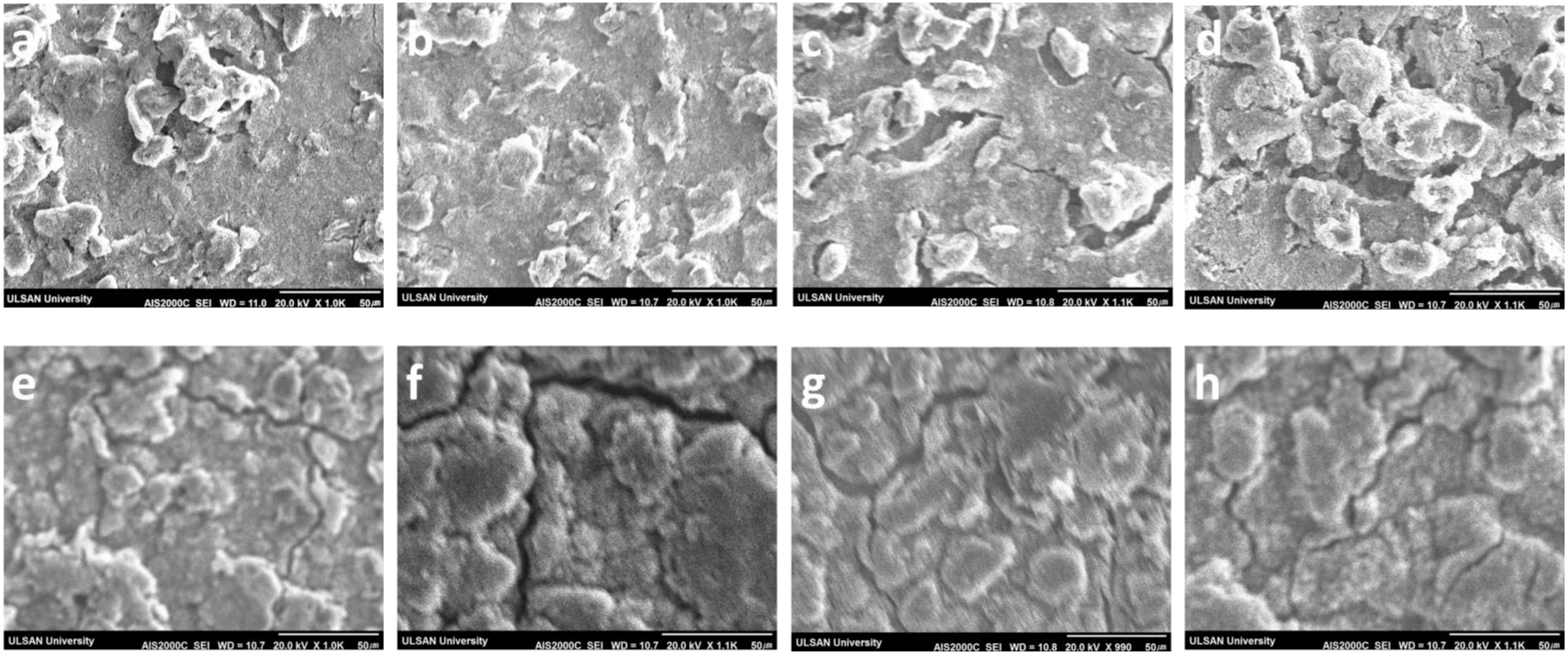
Cyclic performance



Rate capability test



Surface morphology



Low magnification SEM images of Si/C electrodes with Alg (a and e), Alg-g-PAAm (b and f), c-Alg (c and g), and c-Alg-g-PAAm (d and h) before and after 100 cycles, respectively