Korea-EU Horizon Europe Researchers Networking Forum

on Energy & Advanced Mobility

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KITECH

Energy Devices (ASSBs, PEMFCs)

KERC Korea-EU Research Centre

NRF National Research Foundation of Korea

Ministry of Science and ICT

KIST Korea Institute of Science and Technology Europe

Contents

I. Introduction

Mission

Contributing to national industrial development through **the development and commercialization of fundamental industrial technologies in the manufacturing sector, as well as by supporting small and medium-sized enterprises (SMEs) and mid-sized companies and promoting the dissemination of technological achievements.**

Univ. | Research Institute | Industrial field

KITECH
한국생산기술연구원

Basic | Fundamental Industrial | Industrial Technology | Applied Research | Commercialization

- 산업핵심 선도기술개발
- 기업 공통 수요 기술개발
- 중소·중견기업 기술지원 및 기술이전
- 기술/인재/인프라 활용 기술서비스

Ⅰ. Introduction

Focusing on R&D three key areas and commercialization, as well as developing SMEs though technical support

Mission	Main function	Core Research Area
Fundamental Industrial Technology Development	Casting, Metal Forming, Heat treatment, Surface engineering Fundamental Technology	Fundamental Technology
	Production system integration & manufacture automation Advanced clean system Tech.	Clean Production System Technology
	Support New market Creation Convergent Manufacturing Tech.	Convergent Manufacturing Technology
SMEs Company Technology Support	• Technology support though Local support sysyem • Technology support though knowledge based	Technical Support

I. Introduction

Electric Vehicles(EVs) Necessity

자료: 연합뉴스

- CO_2 emission of EV about 1/3 the average CO2 equivalent of Internal Combustion Engine (ICE) Vehicles.
- Reducing CO_2 by **2 tons** per EV/year

I. Introduction

Lithium Ion Batteries Issues

Low energy density

LIBs Energy density limit
: 250 ~ 300 Wh/kg

Source: Samsung SDI.

Low safety

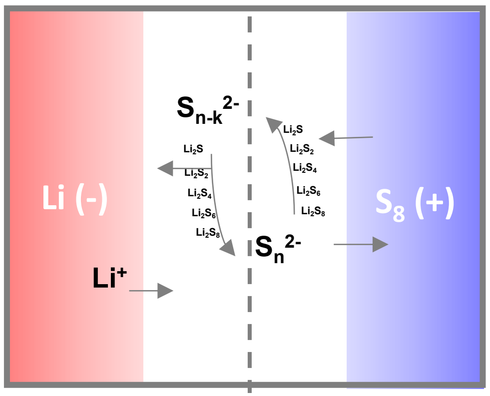
Risk of ignition
and explosion

Source: Tesla Model S.

**New high-performance secondary batteries
that surpass LIBs are needed**

I. Introduction

Next generation batteries

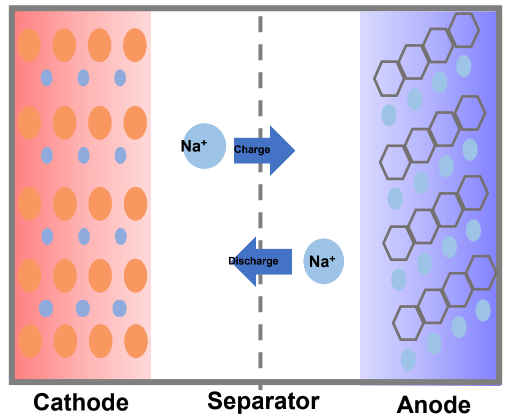


$S_8 \leftrightarrow Li_2S_8 \leftrightarrow Li_2S_6 \leftrightarrow Li_2S_5 \leftrightarrow Li_2S_4 \leftrightarrow Li_2S_2 \leftrightarrow Li_2S$

Lithium-Sulfur (Li-S) battery

Pros
- High capacity
- Low manufacturing costs

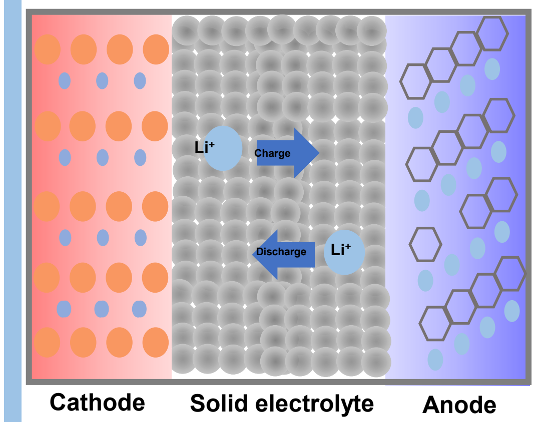
Cons
- H_2S gas generation
- Low battery life



Sodium-Ion (Na-Ion) battery

Pros
- High capacity
- Low manufacturing costs

Cons
- H_2S gas generation
- Low battery life



All-Solid-State battery

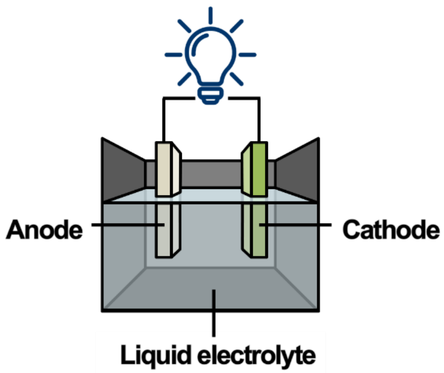
Pros
- High stability
- High energy density

Cons
- Low ionic conductivity
- Interfacial resistance

I. Introduction

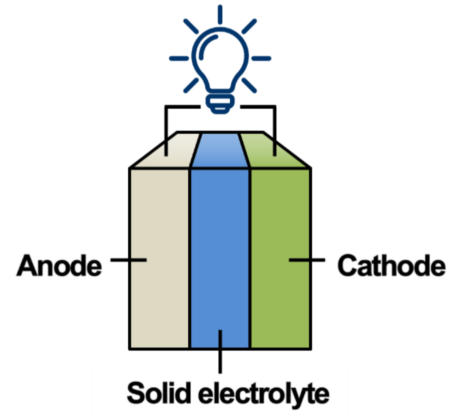
All-Solid-State Batteries(ASSBs) Necessity

LIB



Paradigm shift

ASSB



- ❖ **Liquid electrolyte**
  - ✓ Leakage
  - ✓ Narrow range of operation temperature
  - ✓ Deformation, expansion, and explosion upon heating

- ❖ **Non-explosive**
  - ✓ Good safety
- ❖ **Smaller and more lightweight**
  - ✓ High energy density
- ❖ **Problems**
  - ✓ Low ionic conductivity

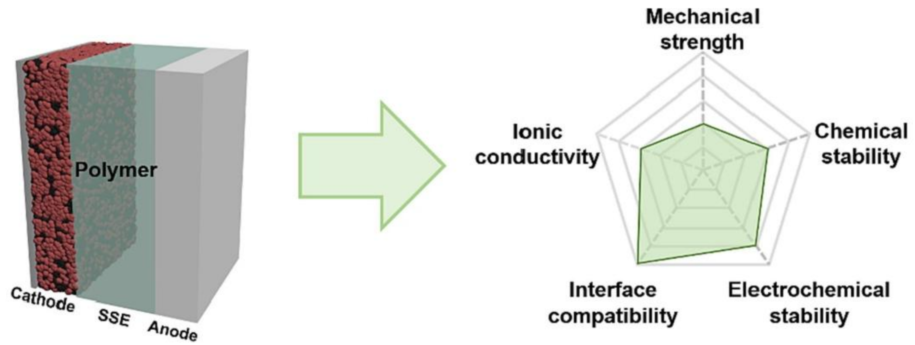
Dramatically improved safety and energy density

Research is needed to improve ionic conductivity

Liang, Xin, et al. *Journal of Energy Chemistry* 73 (2022): 370-386.

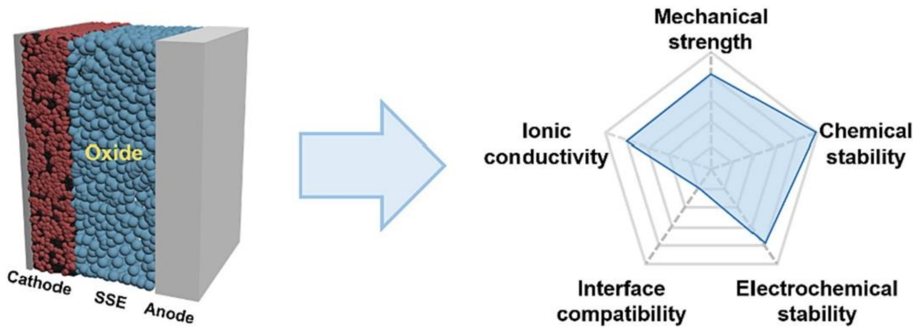
I. Introduction

Performance of Different Solid Electrolyte (SE) Materials



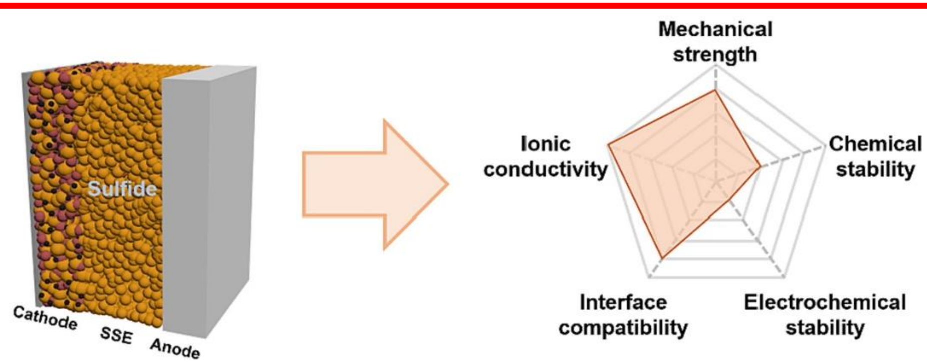
Polymer SEs

- ✓ Good interfacial stability
- ✓ High electrochemical stability
- ✓ Low mechanical strength
- ✓ Low ion conductivity



Oxide SEs

- ✓ Good chemical stability
- ✓ High electrochemical stability
- ✓ High contact resistance

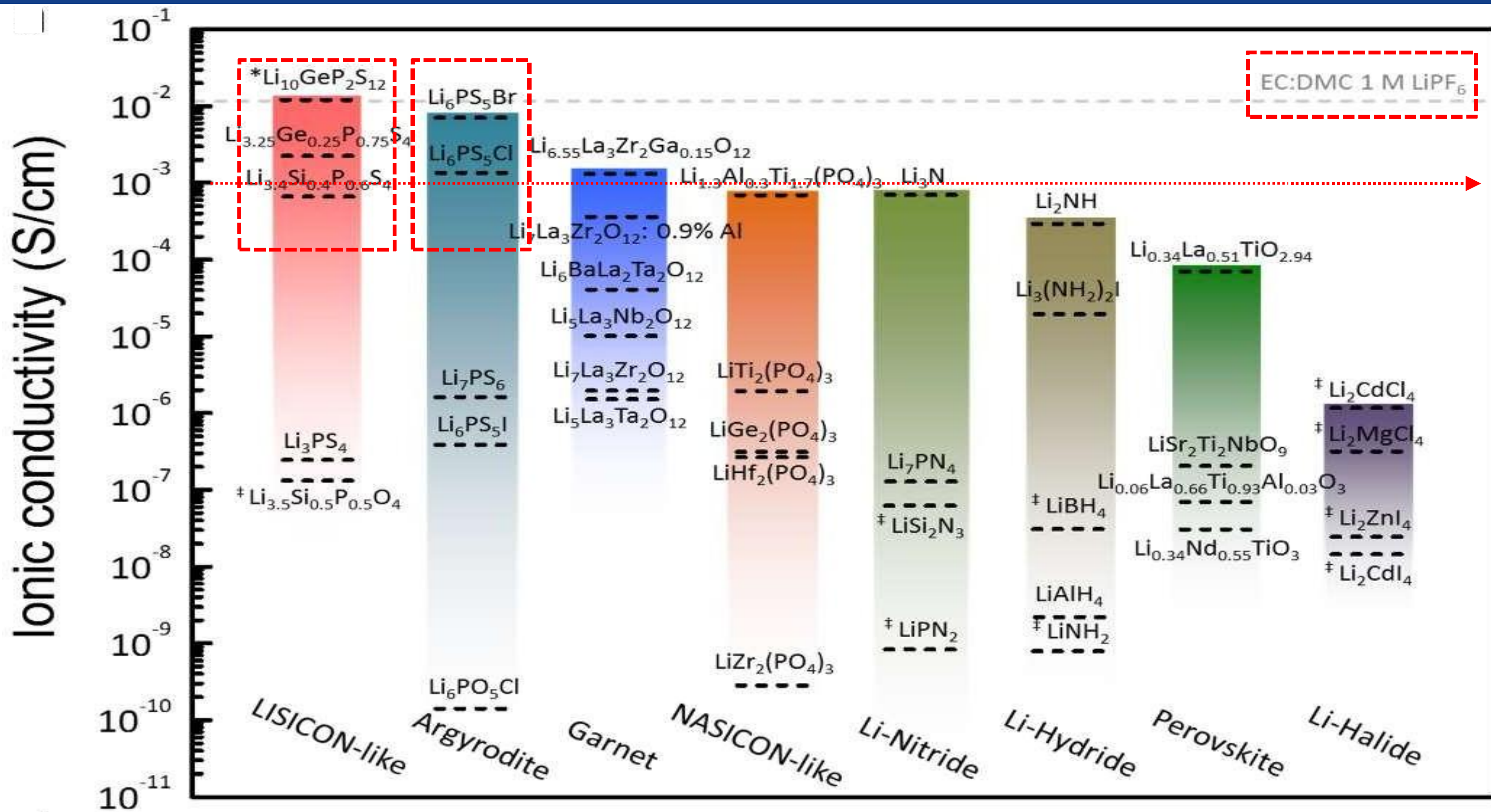


Sulfide SEs

- ✓ Good ion conductivity
- ✓ High mechanical strength
- ✓ Poor air stability
- ✓ Li-dendrites growth

I. Introduction

Ion conductivity



(1) <u>Ion conductivity of solid electrolyte in RT.</u>
LISICON-like (LISICON, thio-LISICON and **$Li_{10}GeP_2S_{12}$**), **Argyrodite (LPSCl),** Garnet, NASICON-like, Li-nitride, Li-hydride, Perovskite and Li-halide.

(2) <u>Liquid Electrolyte</u> <u>(EC:DMC 1 M $LiPF_6$)</u> ~ 10^{-2} S/cm

(3) LiGPS & LiPSX higher ionic conductivity (> ~ 10^{-3} S/cm)

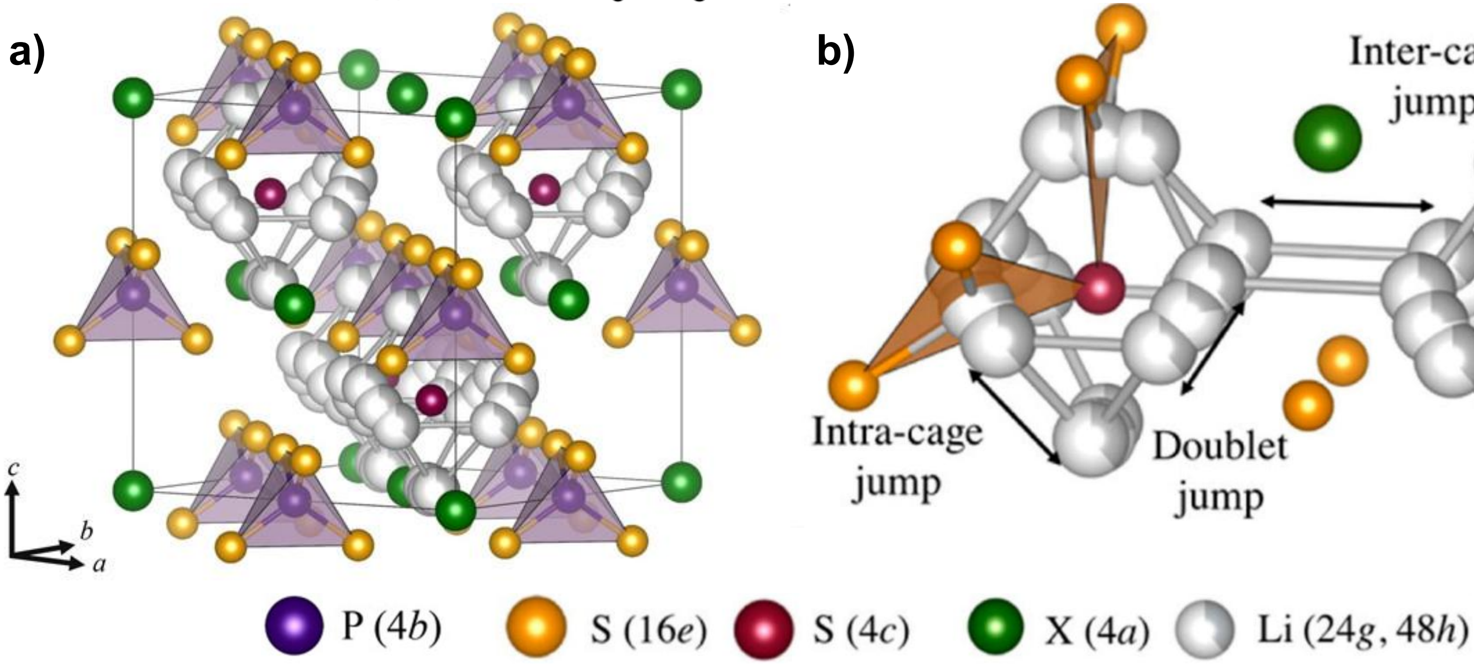
Ⅱ. Theme I_Al-Cl Doping

Motivation of Al-Cl Doping

(a) Kraft, Marvin A., et al. *Journal of the American Chemical Society* 140.47 (2018): 16330-16339.

(b) Park, Jae-Sang, Chang-Heum Jo, and Seung-Taek Myung. *Energy Storage Materials* (2023): 102869.

Structure of argyrodite Li_6PS_5X



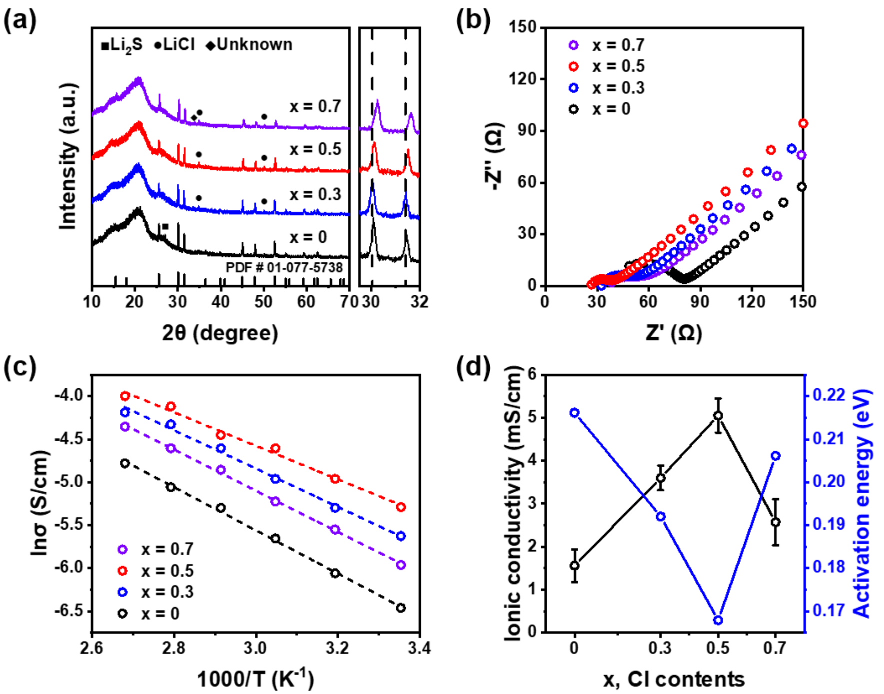
- ✓ Li ions migrate in three possible jump processes
  1) Inter-cage jump
  2) Intra-cage jump
  3) Doublet jump

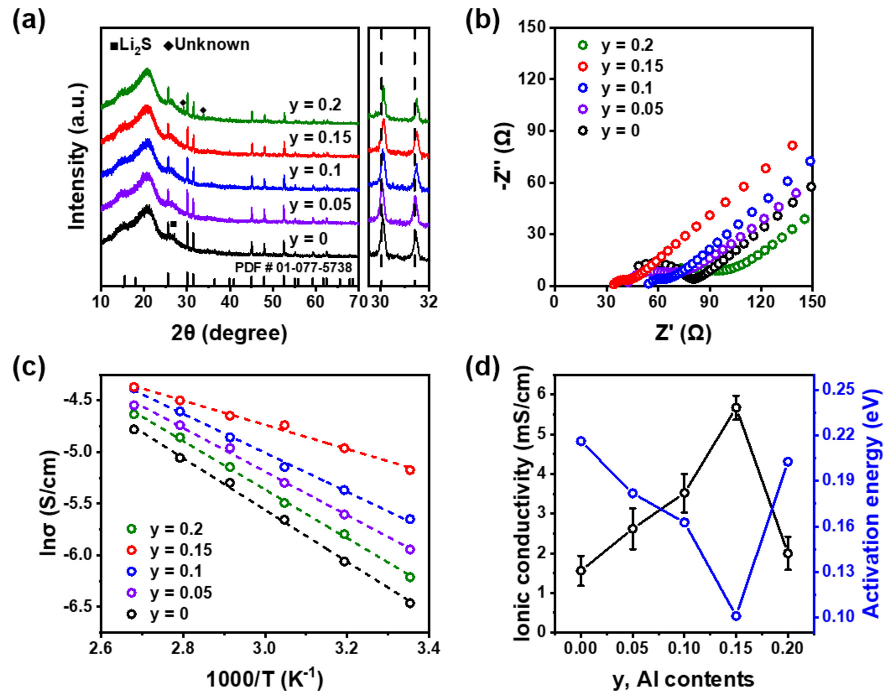
- ✓ Aliovalent doping of the Li^+ site with Al^{3+}
  → generates Li^+ vacancies
- ✓ Cl^- substitution at mixed S^{2-}/Cl^- sites
  → induces vacancies on the Li sites

Ⅱ. Theme I_Al-Cl Doping

Cl and Al Doped Solid Electrolytes

Kim et al. *Nanomaterials* 12.24 (2022): 4355.

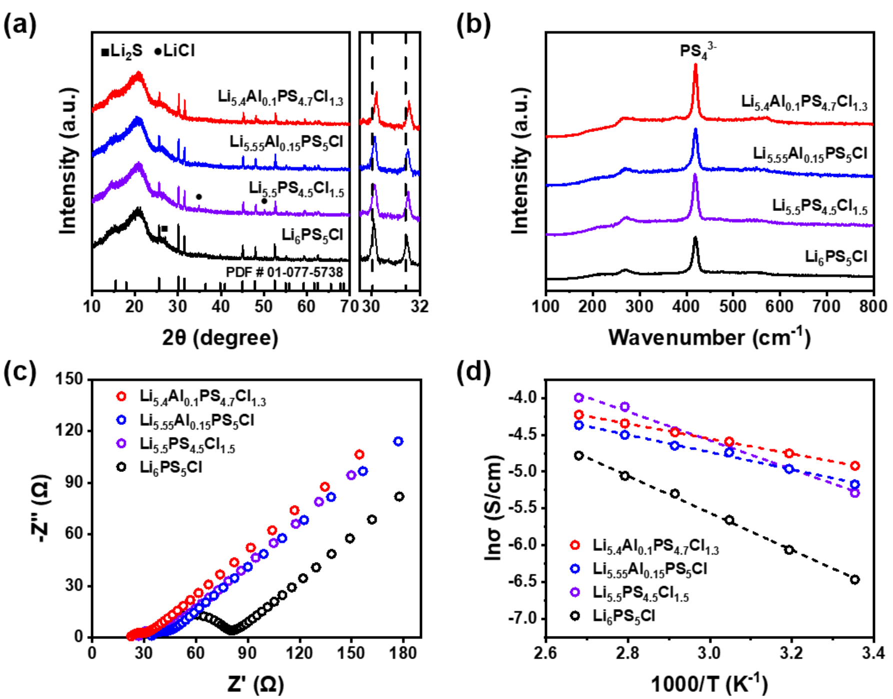


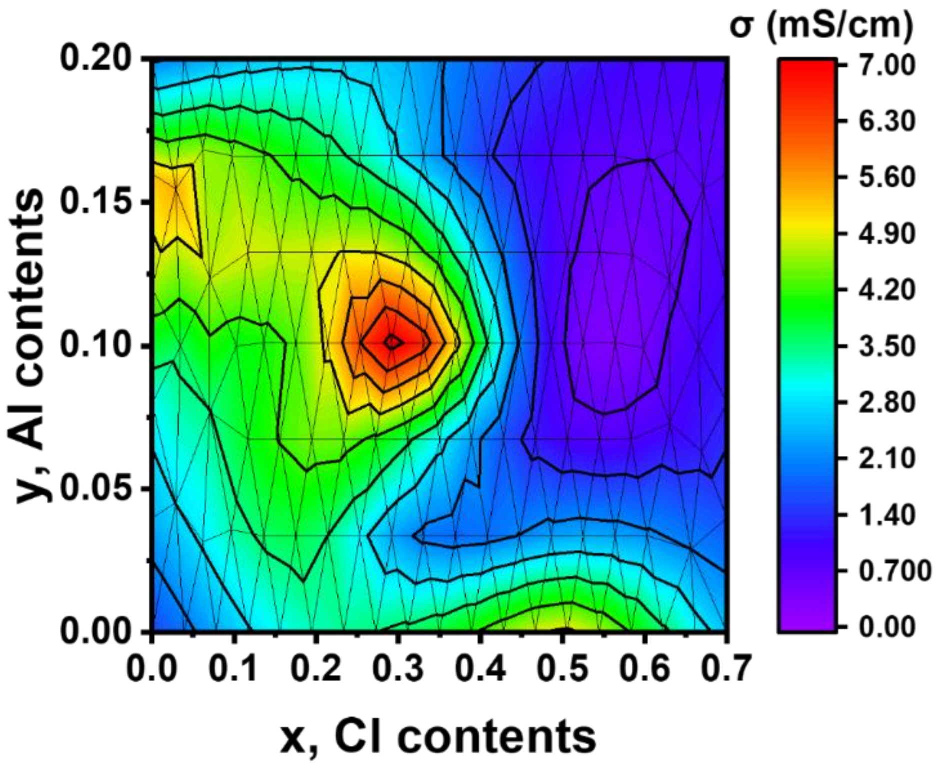


- ✓ Cl doping causes the disorder of the Cl^-/S^{2-} site, and the ionic conductivity can be improved by forming a vacancy site in Li due to the increase in the disorder of the Cl^-/S^{2-} site.
- ✓ The vacancy of Li^+ sites is increased by substituting a cation with a radius similar to that of Li^+ ions. This means that the ionic conductivity was improved by forming a diffusion pathway.

Ⅱ. Theme I_Al-Cl Doping

Cl-Al Doped Solid Electrolytes

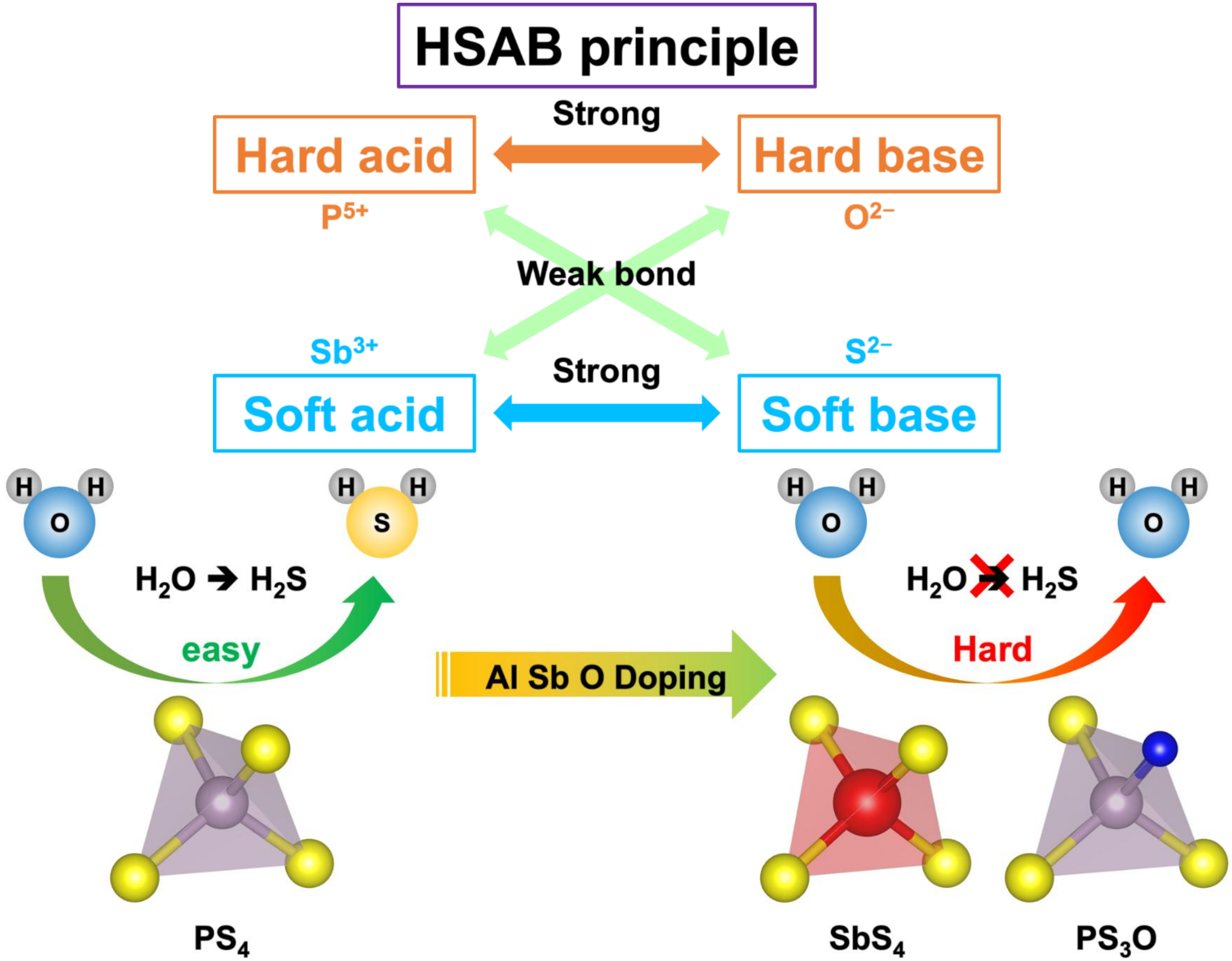




✓ The two effects work together to lower the Ea and increase the ionic conductivity and Li diffusion, provided that the solubility limit of the lattice for either dopant is not exceeded.

Ⅱ. Theme I_Al-Sb-O-Cl Doping

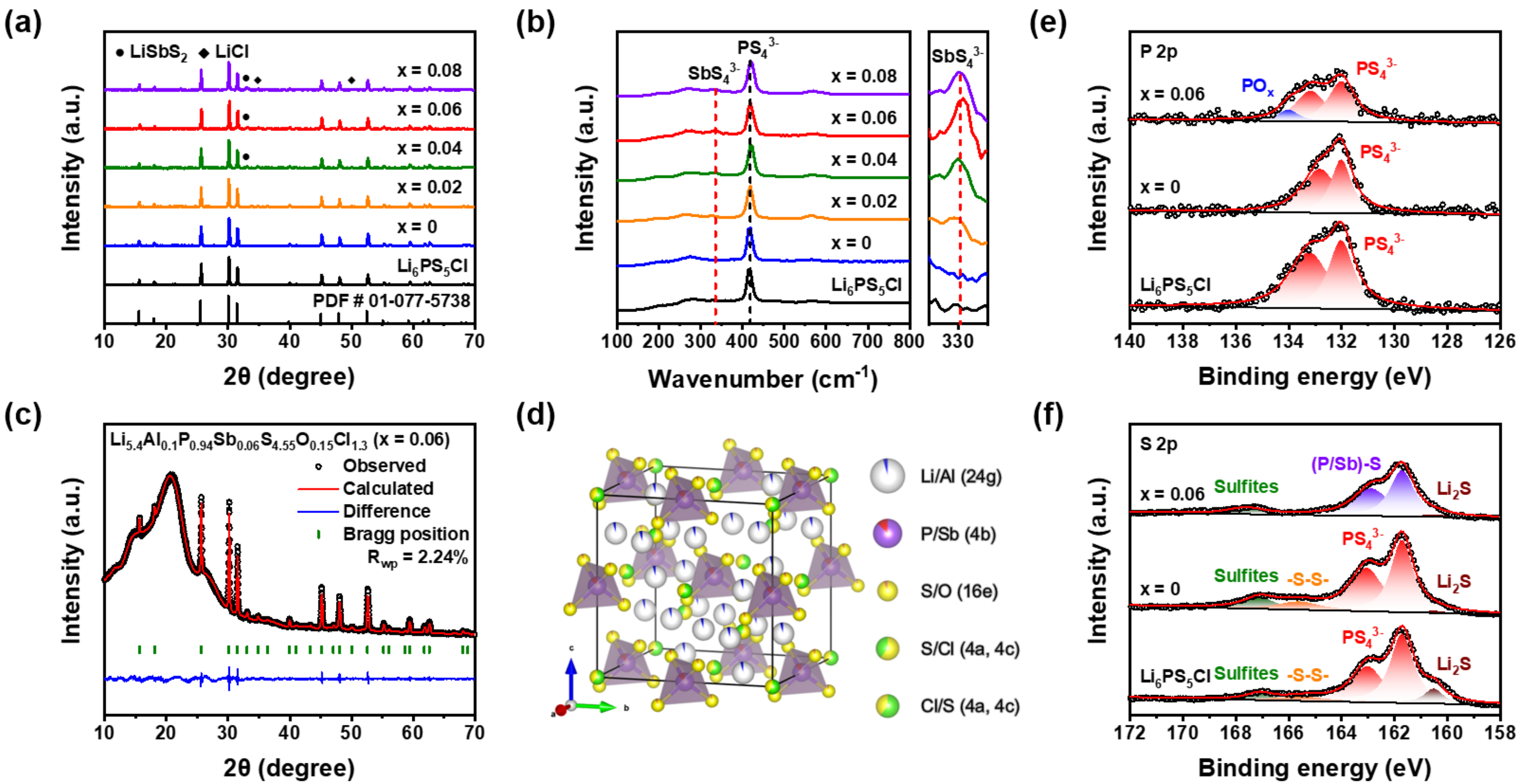
Motivation of Sb-O Doping



Ⅱ. Theme I_Al-Sb-O-Cl Doping

Structural Analysis of Sb-O Doped Solid Electrolytes

Kim et al, *Chemical Engineering Journal*, 497, (2024) 154426.

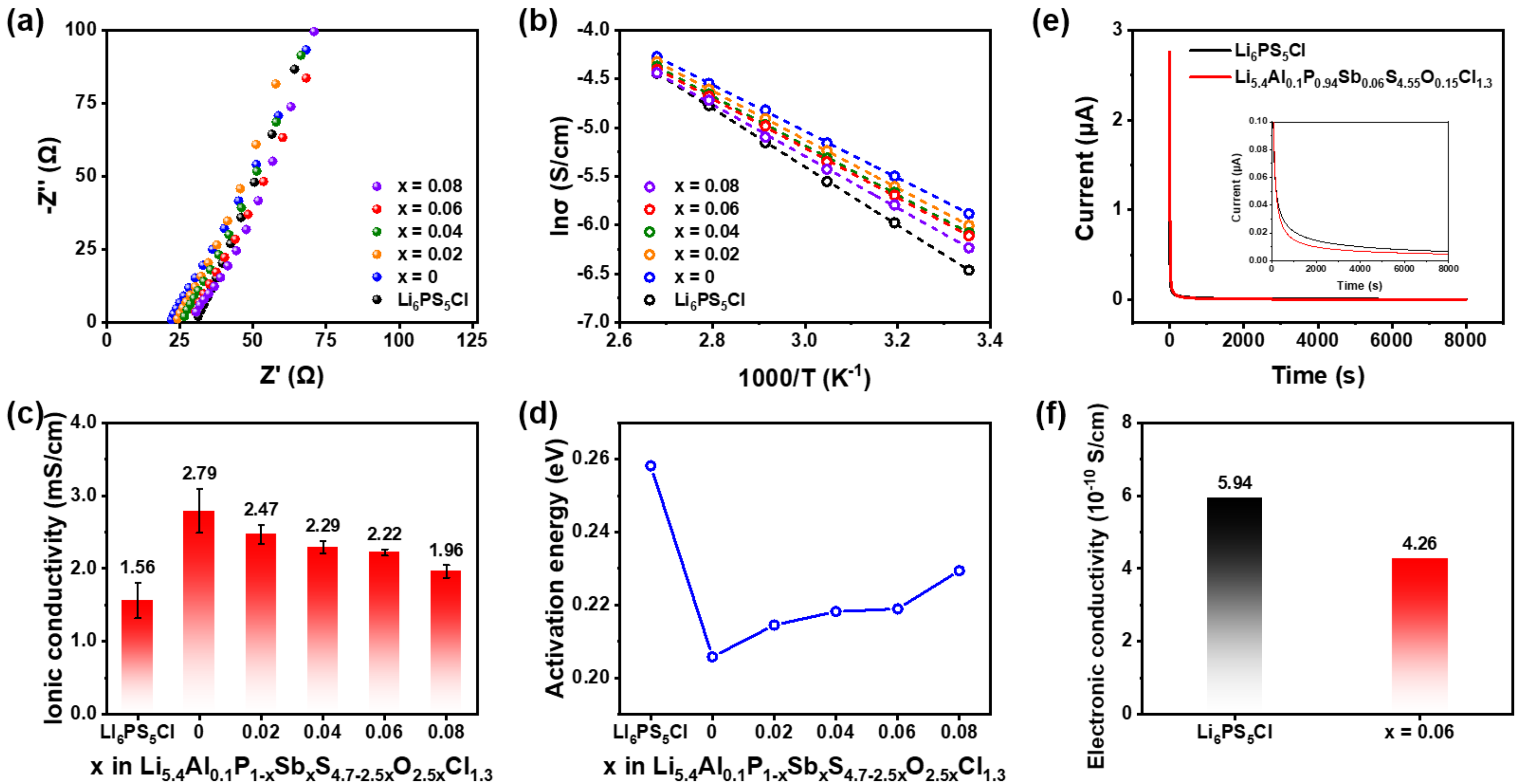


✓ Structural analyses revealed successful Al-Sb-O-Cl multiple-doping in Li_6PS_5Cl electrolyte.

✓ Sb and O replaced P and S without damaging the argyrodite structure.

Ⅱ. Theme I_Al-Sb-O-Cl Doping

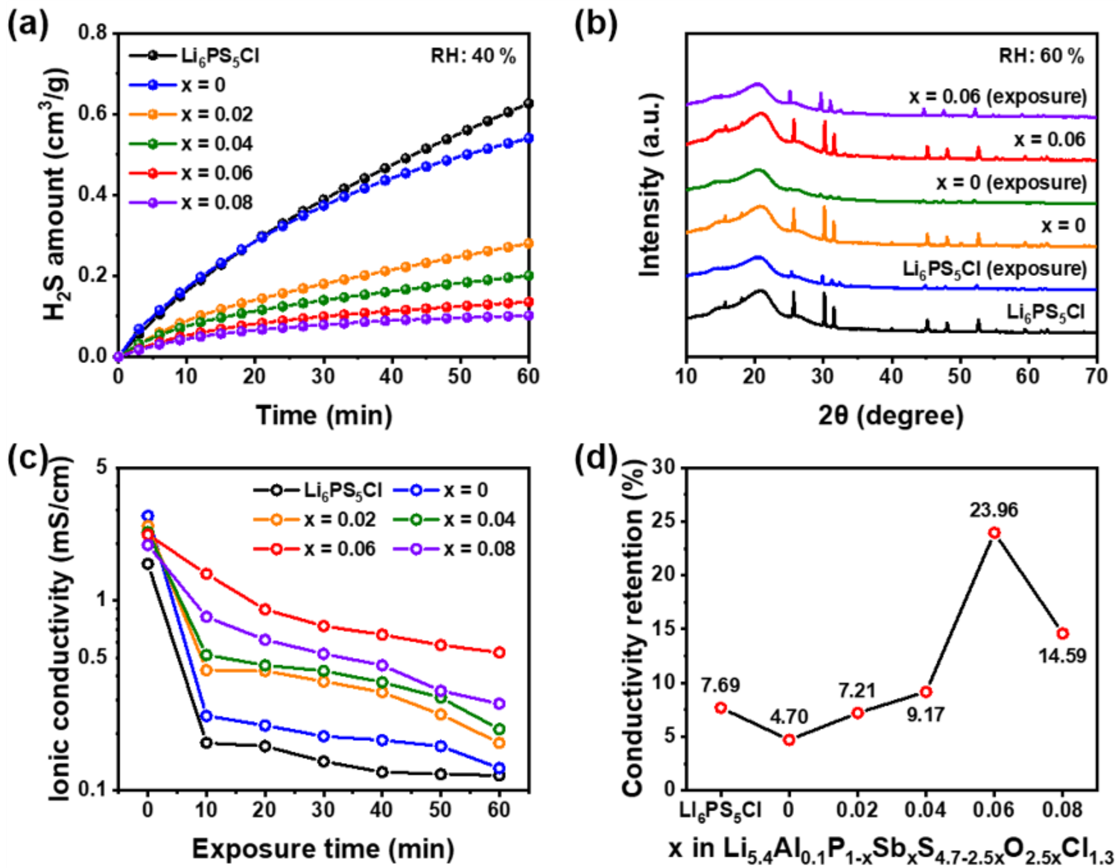
Electrochemical Properties of Sb-O Doped Solid Electrolytes

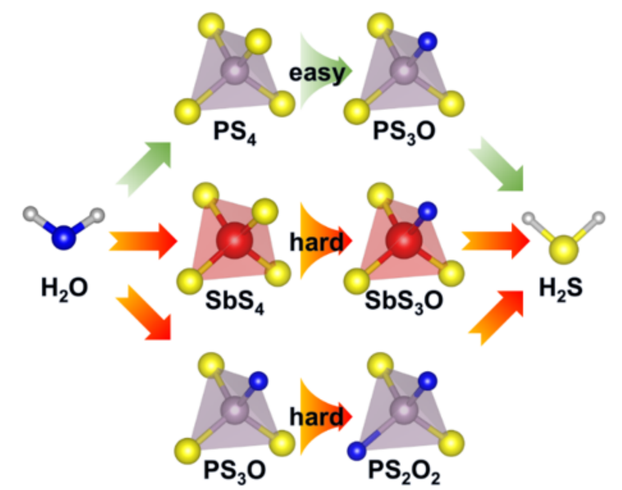


✓ Elevated levels of Sb_2O_5 doping may impede the ionic conduction pathway in the electrolyte, as the introduction of oxygen into the structure tends to decrease conductivity.

Ⅱ. Theme I_Al-Sb-O-Cl Doping

Air-Stability of Sb-O Doped Solid Electrolytes

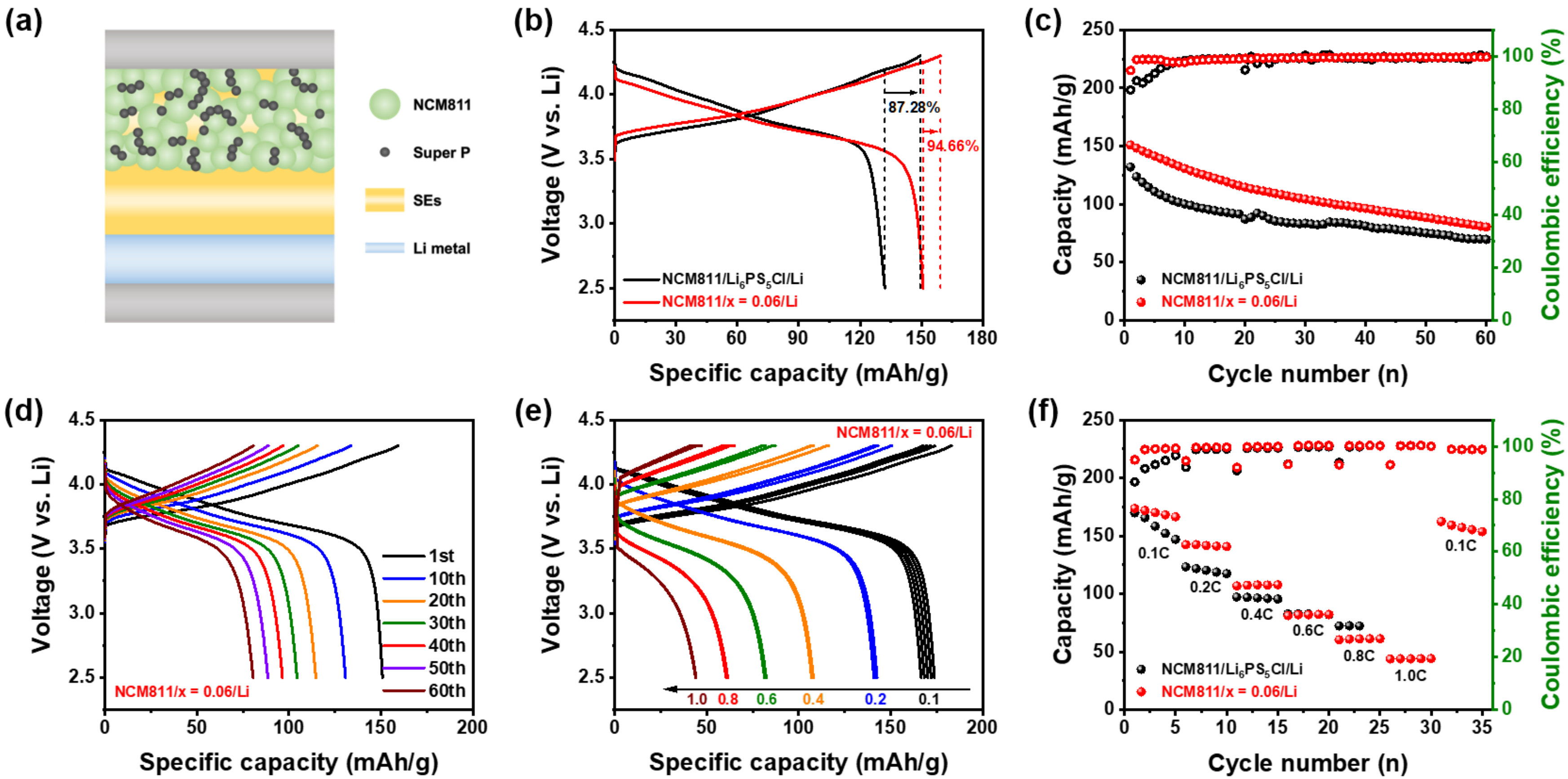




- ✓ This suggests that the release of H_2S experiences rapid suppression with increasing Sb_2O_5 content.
  - ✓ Air-stability is significantly improved when Sb and O are introduced into the structure.

Ⅱ. Theme I_Al-Sb-O-Cl Doping

Full Battery Performance

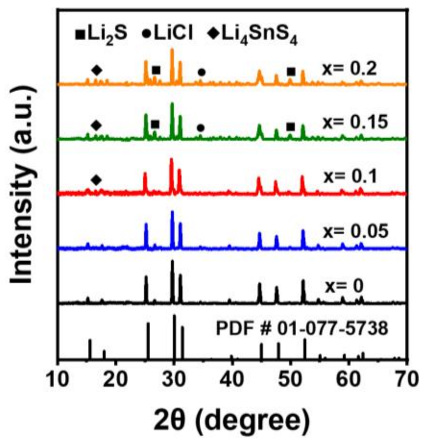


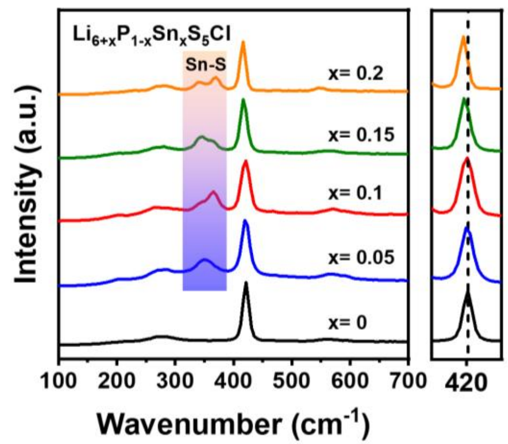
- ✓ The superior battery performance is attributed to the better bare Li metal compatibility with x = 0.06.
  - ✓ The existence of Sb can mitigate the growth of Li dendrite and promote Li diffusion.

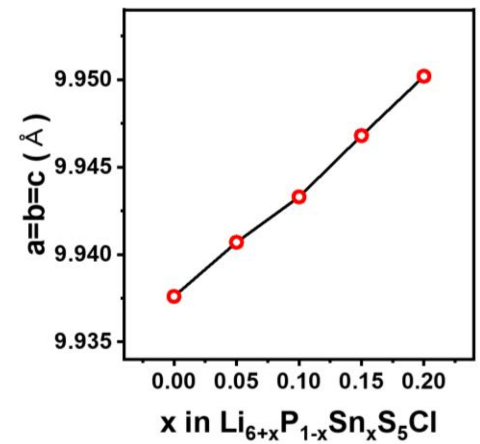
Ⅲ. Theme II_Sn Doping

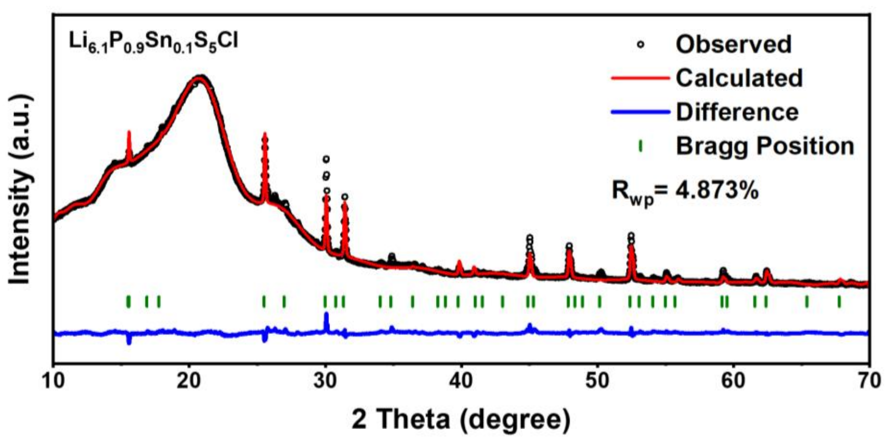
Structural Analysis of Sn Doped Solid Electrolytes

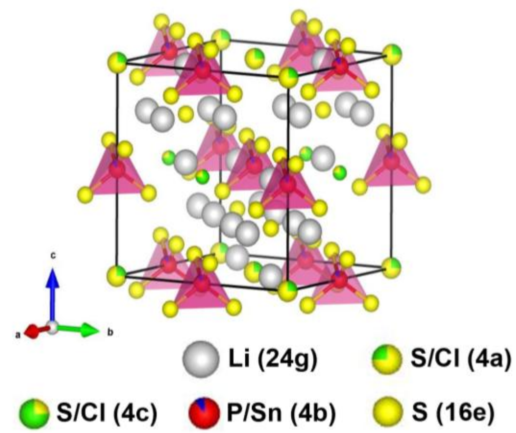
Kim et al, *ACS Applied Energy Materials*, 7 (2024), 9451-9459







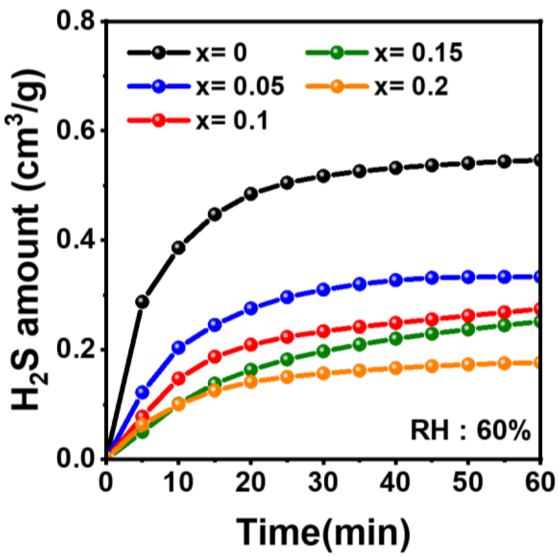


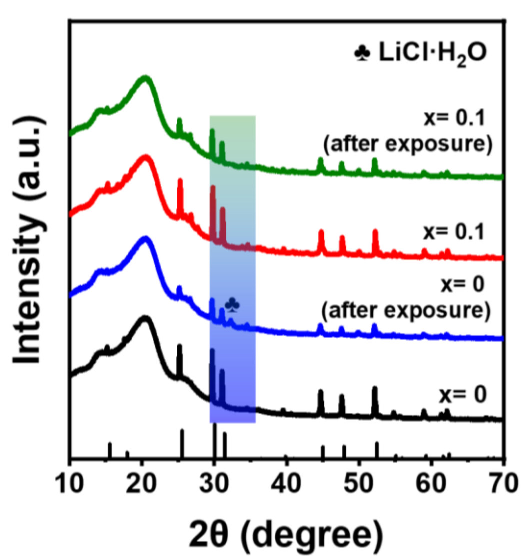


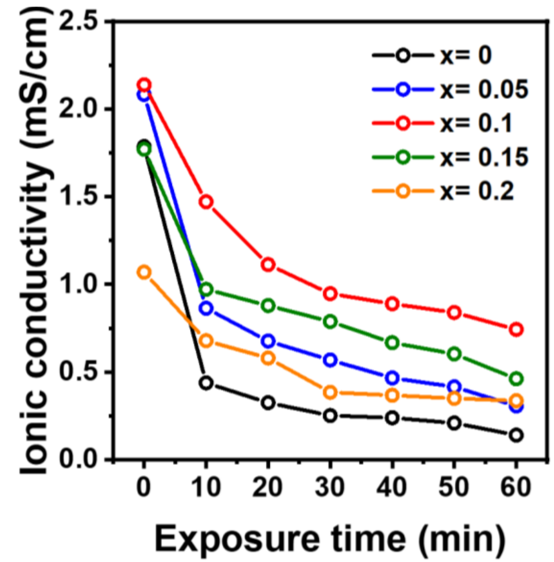
- ✓ Structural analyses revealed successful Sn-doping in Li_6PS_5Cl electrolyte.
  - ✓ Sn replaced P without damaging the argyrodite structure.

Ⅲ. Theme II_Sn Doping

Air-Stability of Sn Doped Solid Electrolytes



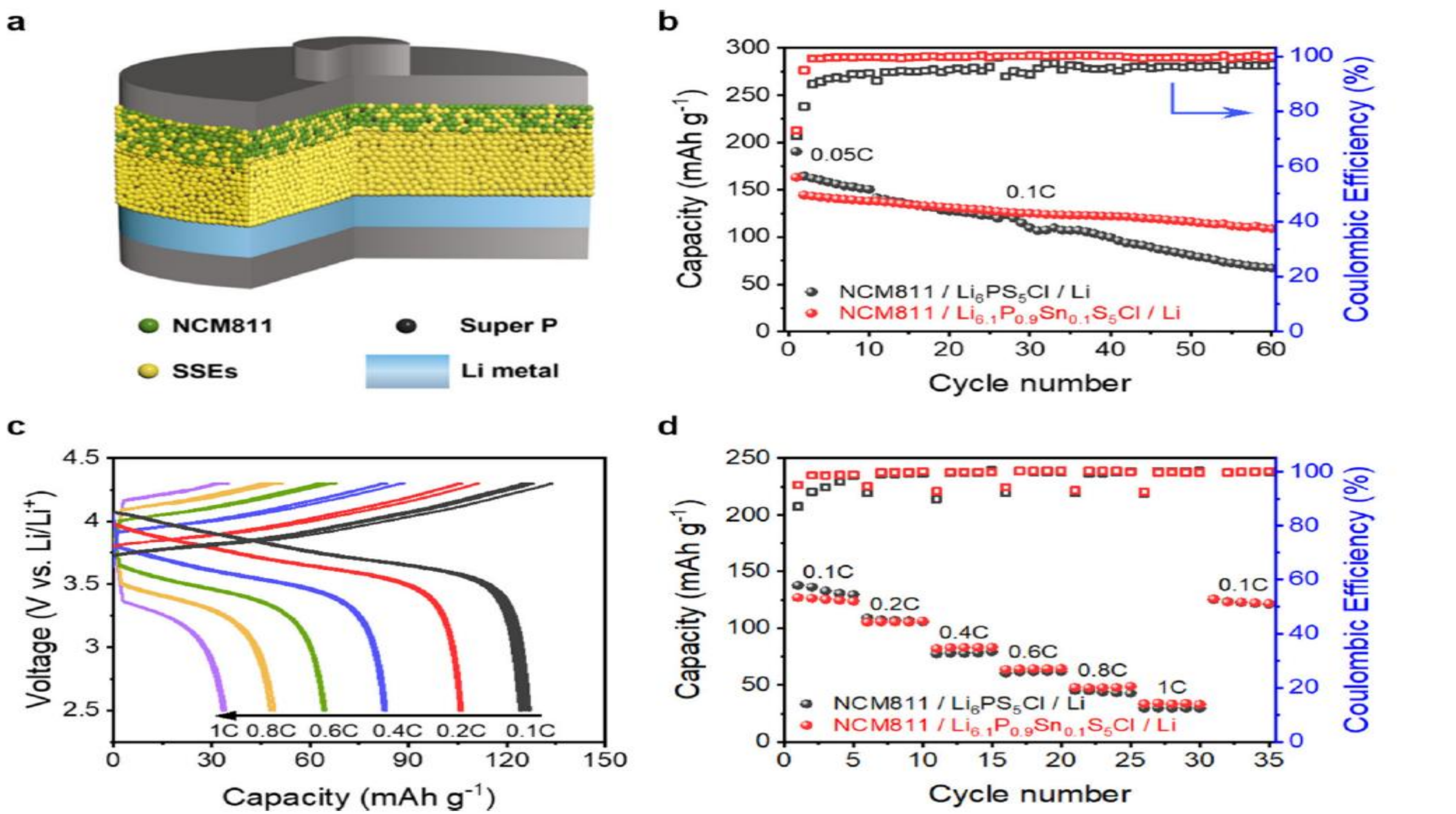




- ✓ This suggests that the release of H_2S experiences rapid suppression with increasing SnS_4 content.
  - ✓ Air-stability is significantly improved when Sn is introduced into the structure.

Ⅲ. Theme II_Sn Doping

Full Battery Performance



- ✓ The superior battery performance is attributed to the better bare Li metal compatibility with $Li_{6.1}P_{0.9}Sn_{0.1}S_5Cl$.
  - ✓ The existence of Sn can mitigate the growth of Li dendrite and promote Li diffusion.

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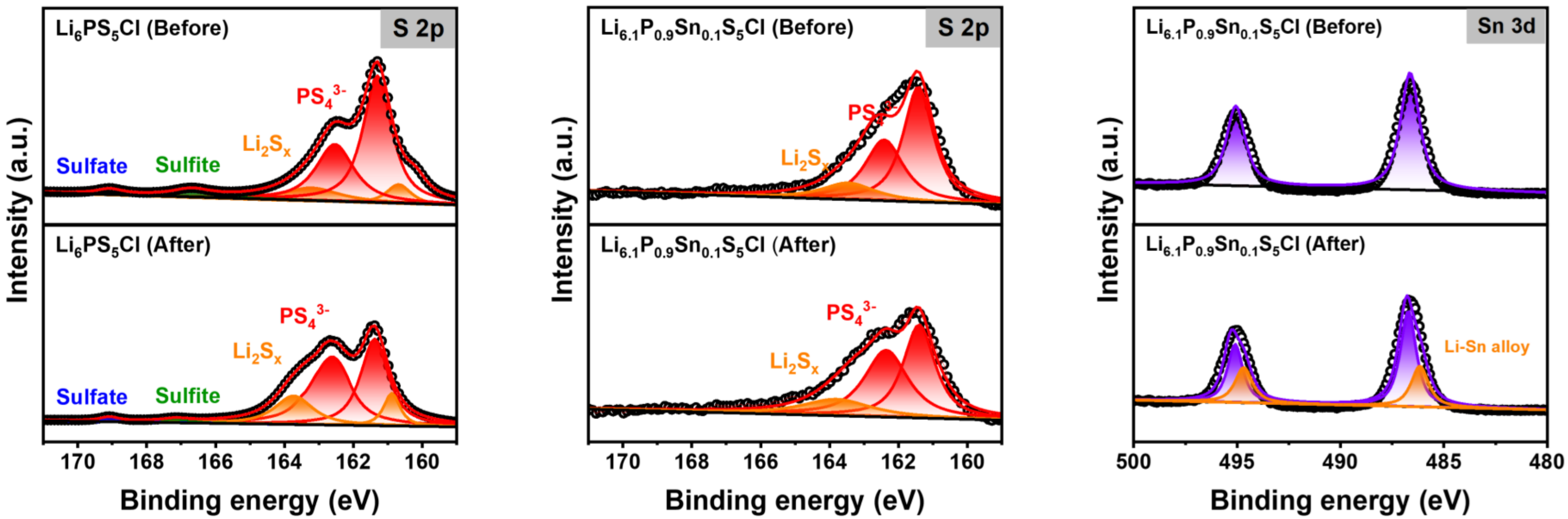
Green Renewable Environment Energy & Nanomaterials Laboratory GREEN

Ⅲ. Theme II_Sn Doping

XPS spectra of Sn Doped Solid Electrolytes

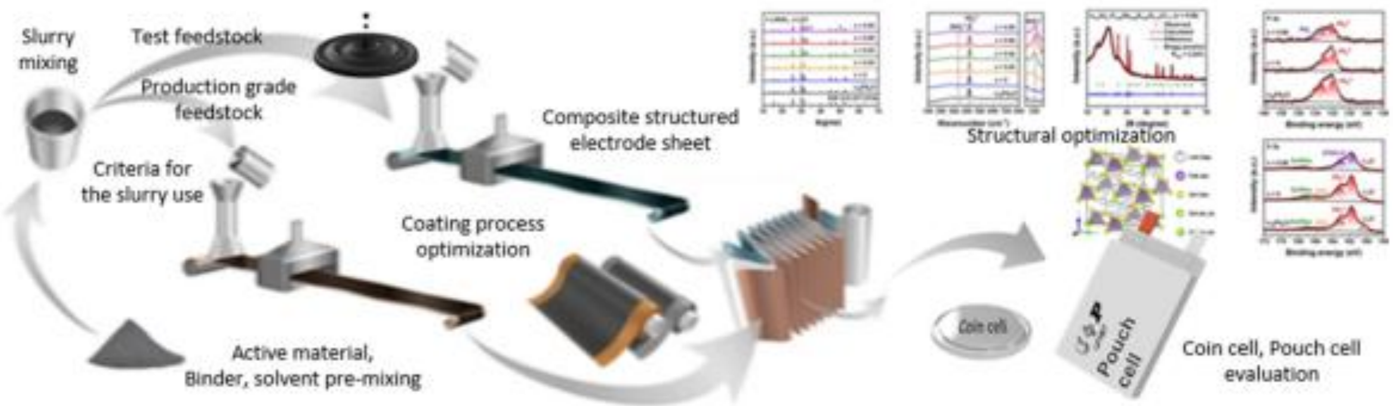


✓ Li-Sn alloy can promote the even deposition of Li and ensure a consistent Li^+ flow at the interface.

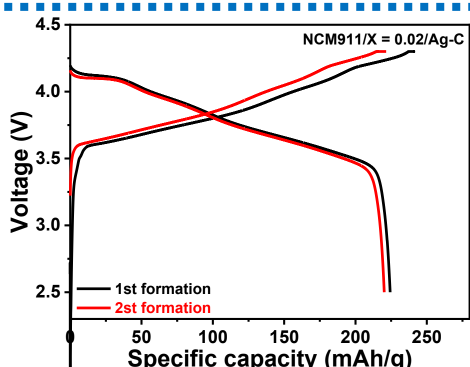
Ⅳ. Research Plan

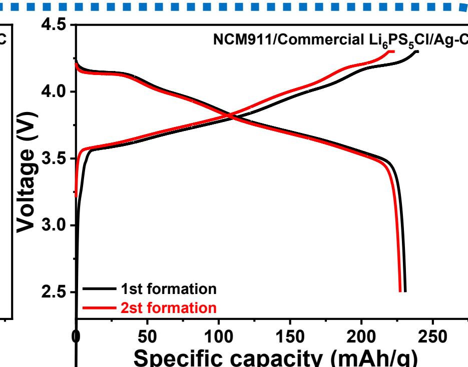
Automation ASSB electrode production

"Development of a hyper-connected Ai-driven autonomous manufacturing system with integrated operation for next-generation (Thio-) ASSB electrode production."



Pouch Cell test





Green Lab.

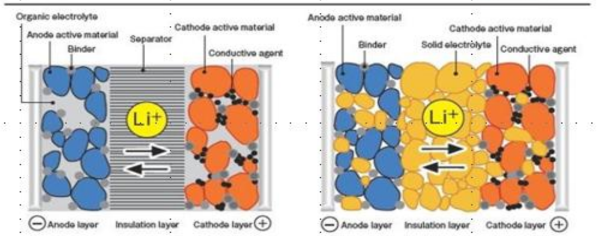
Secondary lithium ion battery

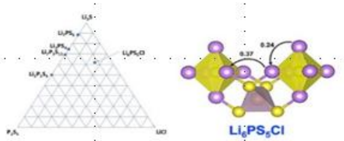
기술내용

All-Solid-State Battery

<Comparison between lithium-ion battery and all-solid-state battery>

Liquid Lithium-Ion Battery | All-Solid-State Batteriy

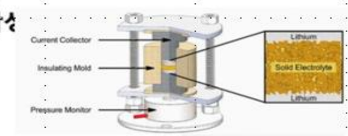




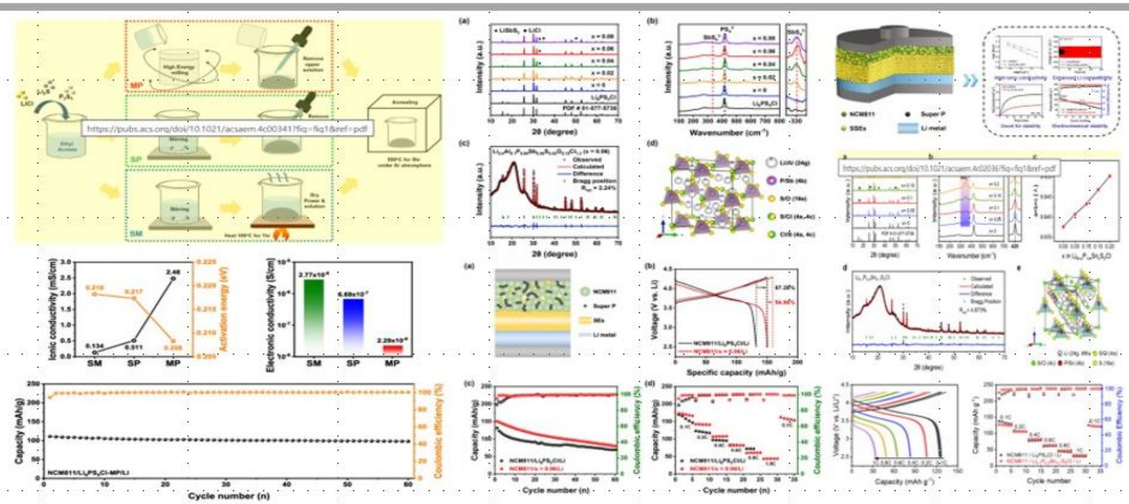
- What are the advantages of solid electrolyte batteries?
  - High energy density
    - Storing up to three or even five times more energy
    - Smaller and more lightweight
  - Reduced charging times
    - Much shorter charging times
    - Reduced by up to six times
  - Greater safety
    - Eliminating the possibility of explosion and fire

수행 연구내용

- 전고체전지용 전해질 설계 및 합성
  : 황화물계 고체전해질 설계 및 합성
  : 대기안정형 고체전해질 합성
  : 고안정성 고체전해질 제조
- 전고체전지 셀 제작
- 리튬이차전지 평가
  : 고체전해질 이온전도도 측정
  : 전고체전지 셀 특성 분석



연구성과 **대기 안정형 황화물계 전해질 제조 기술 개발**



ACS Appl. Energy Mater. 2024, 7, 4421–4428

Chemical Engineering Journal 497 (2024) 154426

ACS Appl. Energy Mater. 2024, 7, 9451–9459

연구실적

주요수행과제

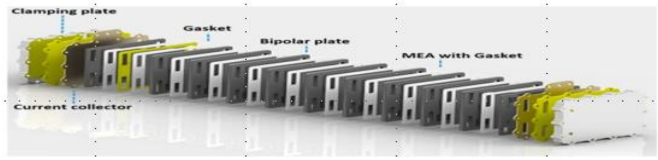
- *50G 이상 고에너지를 적용한 저가 고이온 전도성 다성분계 설파이드 공정기술개발*
- *친환경 합성법을 통한 전기차용 고체 이온*
- *전도 물질 제조 및 공정기술 개발*

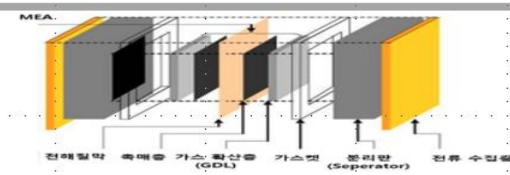
연구실적 (SCI(우수)논문 3편, 특허 등록&출원 6건)

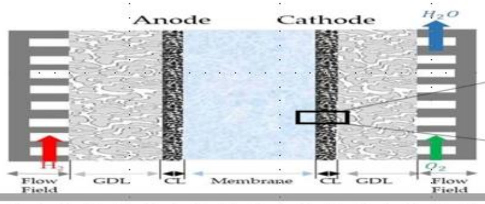
Green Lab.

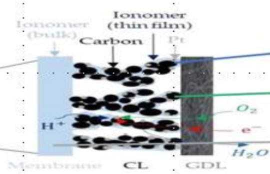
Hydrogen Energy

기술내용

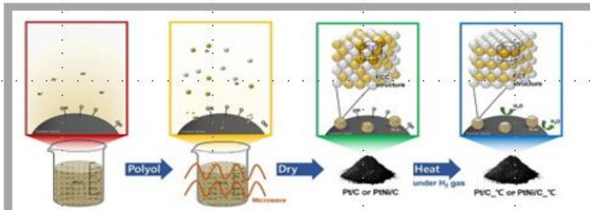


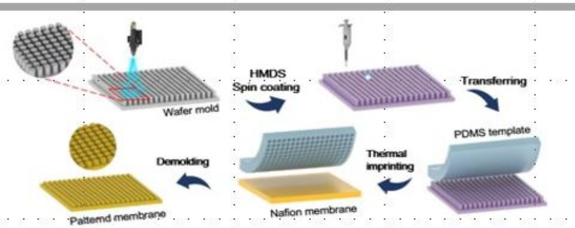


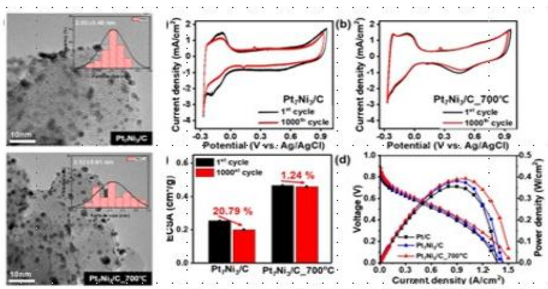


1. Pt catalyst → Expensive
2. Carbon support → Poor durability
3. Membrane → Poor property in lower humidity

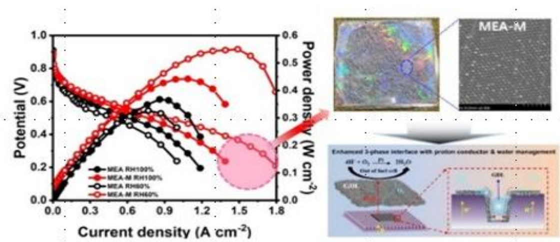
연구성과 고출력 고내구성 MEA 핵심 소재 기술 개발







T. Kim et al, Applied Surface Science, 656, (2024) 159620



T. Kim et al, *ACS Applied Materials & Interfaces* 2024, 16, 67567–67576

연구실적

주요수행과제

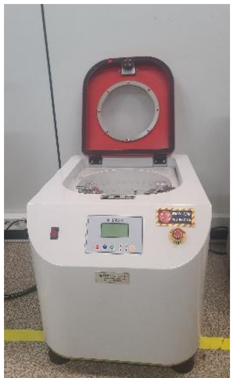
- *수소 생태계 확립을 위한 원스탑 플랫폼 사업*
- *수소 산업 기업지원 혁신기반구축 조성사업*
- *고분자 전해질 연료전지용 고내구성 복합 소재 분리판 제조 기술 개발*

연구실적 (SCI(우수)논문 3편, 특허 등록&출원 3건)

V. Green Lab.

Facilities

▪ ASSBs



Milling machine

Tube furnace

Globe box for electrolyte synthesis

Globe box for cell fabrication

Cell test systems

▪ PEMFCs

Clean room

Ultrasonic spray coater

Hot Press for MEA

Hot Press for bipolar plate

PEMFCs single cell test systems


Thank
You
Vinaka
köszönöm
Kiitos
Maake
Asante
Shukria
Dhanyavadagalu
Manana
Dankon
감사합니다
Dankscheen
спасибо
Kam Sah Hammida
Mauruuru
Biyan
Diolch i Chi
Terima Kasih
Matondo
Taiku
Dank Je
Blagodaram
Ngiyabonga
Dziekuje
Chokrane
Tack
Arigato
Grazie
Juspaxar
Mochchakkeram
Gracias
Tingki
நன்றி
Bedankt
Dakujem
धन्यवाद
Grazas
cảm ơn bạn
Paldies
Gratias Tibi
Ua Tsaug Rau Koj
Obrigado
Děkuji
Nuwun
Nirringrazzjak
Di Ou Mèsi
Kia Ora
Khap Khun Kop
ありがとう
Suksama
Hvala
Rahmat
Matur Nuwun
谢谢
хвала
Welalin
Djiere Dieuf
Misaotra
Danke
Merci
Go Raibh Maith Agat
Eskerrik Asko
Tuke
Salamat
ขอบคุณ
Najis Tuke

Thank You !