

PG2A : 에너지 환경 세라믹스

PG2A-1 | 고체 산화물 전해질 필름용 boracite계 glass-ceramics 연구

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전기 자동차 및 고성능 전자기기의 수요가 늘어남에 따라서 높은 에너지 밀도를 가지는 전지의 필요성이 대두되고 있습니다. Multi-layer all solid state battery는 리튬 이차전지보다 액체 전해질의 유출로 인한 화재 및 폭발 위험성이 적고, 적층을 통하여 높은 전압과 향상된 에너지 밀도를 구현 할 수 있습니다. 이에 따라서 Multi-layer all solid state battery에 적용 가능한 고체 전해질에 대한 관심이 집중되고 있습니다. 다양한 전해질 중 산화물계 고체전해질은 제조방법이 간단하며 화학적 안정성과 온도 안정성이 우수하지만 전해질 표면의 계면 접촉 저항의 증가 등의 문제로 인하여 glass ceramics계의 소재가 각광받고 있습니다. 최근 보고된 boracite 구조를 가지는 LiBOCl glass ceramics는 다른 Lithium boron 계 glass-ceramic에 비하여 간단한 조성으로 높은 이온전도도를 가집니다. 본 연구에서는 높은 이온전도도를 가지는 LiBOCl glass ceramics의 조성을 제어하고 후막 형태로 제작하여 구조 및 전기적 특성을 보고하고, Multi-layer all solid state battery 시스템에 적용 가능성을 논하고자 한다. Acknowledgement: This work was supported by the National Research Foundation of Korea (NRF) Grant funded by the Korean Government (Ministry of Education) [NRF-2019R111A3A01058105] and [NRF-2018R1A6A1A03025761], and the Technology Innovation Program (or Industrial Strategic Technology Development Program-Material Components Technology Development Program) (20024235, Development of Technology for Manufacturing Lithium High Corrosion Resistance Ceramic Parts for Cathode Materials of Li-ion battery) funded By the Ministry of Trade, Industry & Energy (MOTIE, Korea). This work was also supported in part by the International Science & Business Belt support program, through the Korea Innovation Foundation funded by the Ministry of Science and ICT.

PG2A-2 | 붕소 농도에 따른 Boron Doped Diamond 전극의 전기화학적 특성 연구

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하·폐수를 처리하기 위해 전극을 이용한 전기화학적 수처리 방법에 많이 사용되고 있다. 기존 IrO₂ 전극은 낮은 내구성과 좁은 전위창을 가지기 때문에 산화제 형성 효율이 낮다. 하지만, Boron Doped Diamond (BDD) 전극의 경우 넓은 전위창을 가지기 때문에 산화제 형성 효율이 높을 뿐만 아니라, 다이아몬드의 고유 특성(높은 경도, 우수한 내식성 등)을 바탕으로 내구성이 우수해 전기화학적 특성 저하가 거의 없다. BDD 전극 형성에 영향을 미치는 주요 인자로 필라멘트 온도, 공정압력, CH₄ 농도,

붕소 농도 등이 있으며 이 중 전기화학적 특성에 영향을 미치는 주요 인자는 붕소 농도이다. P-type 반도체인 BDD의 형성은 다이아몬드를 이루고 있는 탄소 자리에 붕소가 치환되면서 정공을 형성하기 때문에 전기화학적 특성이 향상된다. 하지만, 붕소 농도는 표면 형상 및 탄소 결합 구조에도 영향을 미치기 때문에 붕소 농도와 전기화학적 특성의 관계는 단순하지 않다. 따라서, Hot-Filament Chemical Vapor Deposition (HFCVD) 방법을 사용하고 선행된 연구를 바탕으로 붕소 농도를 조절하여 균일한 BDD 전극을 제작하고 전기화학 및 관련 특성 평가 결과를 발표하고자 한다.

PG2A-3 | 광원된 Pt3Ni 나노합금 입자가 담지된 레이저-유도 그래핀 제작 및 수소 생산 반응에의 응용

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Water electrolysis is one of the most promising technologies for hydrogen production because of its carbon-neutral nature, however its efficiency still requires improvement compared to other techniques. Therefore, the development of efficient electrocatalysts for water splitting is essential. In this study, we focused on the fabrication of Pt₃Ni nanoalloys on laser-induced graphene (Pt₃Ni-LIG) by the photothermal reduction using commercial CO₂ laser which irradiated on the surface of polyimide (PI) film. The laser ablation process resulted in the formation of porous and interconnected graphene sheets within only two minutes, while uniform nanoparticles with an average size of around 4.5 nm were decorated on their surface by the photothermal effect. Structural analyses confirmed that PI film was successfully transformed into graphene structure and the bimetallic nanoparticles were formed as an alloy by Raman spectroscopy and XPS, respectively. Electrochemical measurements for hydrogen evolution reaction discovered that the Pt₃Ni-LIG showed superior catalytic performance which required an overpotential of only 96 mV to achieve a current density of 10 mA cm⁻². It exhibited superior catalytic activity compared to LIG (740 mV), Pt-LIG (204 mV), and PtNi-LIG (205 mV), as well as other previously reported catalysts at the same current density. Based on these results, the Pt₃Ni-LIG was employed for hydrogen gas collection and detection. The generated bubbles were accumulated separately, and their composition with evolution rate was confirmed to be hydrogen using a commercial H₂ sensor.

PG2A-4 | Tailoring linear organic carbonates for thermally stable LIB using Ni-rich layered oxide cathode

Poster Presentations

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Thermal hazards represent a major challenge to adopting lithium-ion batteries (LIBs) widely in electric vehicles and energy storage systems. Although reducing the flammability of linear organic carbonate electrolytes in LIBs is a key solution to the fire and explosion issue, it inevitably accompanies battery performance degradation and high cost. Herein, we address this issue by combining alkyl-chain extension and alkoxy substitution, which simultaneously decreases solvent volatility and increases solvation ability, to achieve thermally stable high-performance batteries. Although the tailored molecule bis(2-methoxyethyl) carbonate (BMEC) shows an increased flash point which is 90 °C higher than that of conventional electrolytes, this electrolyte enables long-lasting cycling of the flagship electrode combination of Ni-rich layered oxide and graphite over 500 cycles in practical pouch cells. Furthermore, in contrast to commercial electrolytes, we demonstrate that the BMEC electrolyte effectively alleviates heat and reactive-gas release under thermal/mechanical/electrical abuse conditions in the presence of charged Ni-rich cathodes, thereby preventing the thermal explosion of a 4 A h pouch cell upon nail penetration.

PG2A-5 | von-Alpen형 NASICON 세라믹 전해질의 이온 전도도 향상을 위한 이중 원소인 마그네슘 이온(Mg²⁺) 도핑.

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액체 전해질을 고체 전해질로 대체하는 것은 이차 전지 분야에서 도전적인 연구 분야로 떠오르고 있습니다. 화학식 Na_{1+x}Zr₂Si_xP_{3-x}O₁₂(0 ≤ x ≤ 3)를 가진 화합물은 NASICON 재료로 일반적으로 알려져 있으며, 약 10⁻⁴ S cm⁻¹ 정도의 Na⁺ 이온 전도도를 나타내며, 대기 중 뿐만 아니라 해수에서도 화학적 안정성을 보입니다. 이러한 특성들로 인해 나트륨 이온 전지의 고체 상태 전해질(SSEs)로서 매우 유망한 후보입니다. 본 연구에서는 이중 원소인 Mg²⁺를 도입하여 von-Alpen 타입 NASICON(vA-NASICON)의 전해질 특성을 향상시키는 것을 조사했습니다. Mg 도핑에 의해 유발되는 물리화학적 변화를 체계적으로 분석하고 이온 전도도 분석을 통해 최적의 Mg 도핑 농도를 결정했습니다. 합성 과정에서 최적의 Mg 도핑된

vA-NASICON은 도핑되지 않은 vA-NASICON에 비해 약 80% 더 높은 이온 전도도와 96.6%의 상대 밀도를 나타냈습니다. 그러나 과도한 Mg²⁺ 도핑은 나트륨 마그네슘 인산염 (Na_xMg_yPO₄)과 같은 이차 상의 형성을 유발하여 이온 전도도가 감소하였습니다. 이 연구 결과는 산화물 기반 고전도 고체 상태 전해질의 개발에 효과적으로 활용될 것으로 기대됩니다.

PG2A-6 | Reversible magnesium metal cycling in additive-free simple salt electrolytes through the chemical activation

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Rechargeable magnesium batteries (RMBs) are one of the promising “beyond Li” technologies for having higher volumetric energy densities and being safer than the Li-based counterpart. However, a major challenge in developing viable RMBs is the passivation of the Mg surface in conventional electrolytes, which degrades the reversibility and kinetics of the Mg deposition/stripping. Herein, we address this issue by chemically activating the Mg metal to facilitate Mg deposition/stripping in Mg(TFSI)₂/diglyme. Combined surface analyses proved the formation of an artificial interphase comprised of ether-complexed alkyl magnesium halides, accompanied by spontaneous surface nanostructuring upon the chemical activation. The resulting activated Mg anode exhibits unparalleled performances in terms of Coulombic efficiency (>99.5%) and polarization (6S₈, sulfur and AQDS(anthraquinone-1,5-disulfonic acid sodium salt) cathodes).

PG2A-7 | A full oxide-based solid-state lithium battery and its unexpected cathode degradation mechanism

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Oxide all-solid-state battery (ASSB) is a promising contender for the post Lithium ion battery due to its superior safety. In particular, garnet-type oxide solid electrolyte, Li_{6.4}La₃Zr_{1.4}Ta_{0.6}O₁₂(LLZTO), stands out for not just superior safety but high energy density when paired with Lithium metal anode. However, it is still suffering from difficulty in reliable fabrication of physically dense and chemically intact LLZTO-based ASSB since the sintering temperature of LLZTO is too high for conventional cathode active materials (CAM) to maintain its phase unchanged. Subsequently,

interfacial issues, like mechanical or electrochemical degradation, on CAMs and oxide solid electrolyte interface has been barely addressed owing to the absence of the reliable oxide ASSB. Herein, we rationally design sintering techniques for achieving physically dense and chemically intact oxide ASSB by employing residual lithium and O₂ atmosphere to boost densification while extremely reducing sintering time to a few seconds scale with a homemade fast sintering system. By taking rationally designed sintering process, we successfully fabricated LLZTO based oxide ASSBs by exploiting LiCoO₂ (LCO) and LiNi_{1/3}Co_{1/3}Mn_{1/3}O₂ (NCM111) as CAMs in composite cathode with LLZTO solid electrolyte and they delivered 104 mAhg⁻¹ and 126 mAhg⁻¹ respectively. Surprisingly, we observe that unprecedented mechanical failure in composite cathodes after galvanostatic cycle test which is expressed as capacity fading. It is also unraveled via residual stress measurement that the volume change of CAM in (de)lithiation is resisted by rigid LLZTO framework and it accumulates residual stress over repeated cycle in composite cathode which leads to mechanical failure. Thereby, we clarify that electrochemo-mechanical degradation mechanism is an origin of capacity fading of LLZTO-based ASSB.

PG2A-8 | Ca²⁺도핑 된 산화물계 고체 전해질 Na_{0.5-x}La_{0.5-x}Ca_{2x}ZrO₃ (NLCZ)의 이온전도도 향상에 대한 고찰

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본 연구는 oxide 계열 중 perovskite 구조를 가지는 Li_{3x}La_{(2-x)/3}TiO₃ (LLTO)에서 Li 원소를 Na으로 치환한 물질을 다룬다. Na⁺ path 면적을 확장하기 위해 Ti⁴⁺을 Zr⁴⁺으로 치환하였다. 이에 Ca²⁺ doping 하여 Na 이온전도성을 높였기에 Ca²⁺의 역할을 규명하려 한다. Oxide 물질은 고온 열처리 과정 시 Na₂O가 휘발되어 La₂Zr₂O₇ 혹은 ZrO₂와 같은 불순물이 생성되는데 이러한 물질들이 이온전도성을 저하시킨다. X-ray diffraction (XRD) 분석 결과 Ca doping으로 LZO 불순물 peak가 감소하는 경향성을 확인할 수 있다. 이에 따라 Electrochemical Impedance Spectroscopy (EIS) 측정 결과 이온전도도가 향상된 것을 관찰할 수 있었다. 이처럼 Ca²⁺을 doping 하여 bare 샘플보다 약 10배의 이온전도도를 증가시켰다. La³⁺과 같은 A-site에 위치한 Ca²⁺이 첨가되면서 LZO 형성이 억제된다는 것을 발견하였다. 이에 더하여 Ca²⁺을 첨가할 때, Na⁺이 위치하는 면 형성에 기여하여서 Na⁺이동에 필요한 에너지를 낮춰 이온전도도를 향상시킨다.

PG2A-9 | 가넷계 산화물 고체 전해질의 고전류 구동을 위한 내부 미세구조 설계

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All-solid-state-battery (ASSB) system is gaining a great attention as a next generation battery technology due to its nonflammable property which is a feature that distinguish itself from other battery systems. Among the various types of solid electrolytes such as sulfide or halide-based, oxide based solid electrolyte such as garnet-type(Li_{6.4}La₃Zr_{1.4}Ta_{0.6}O₁₂, LLZO) has been recently gaining attention thanks to its ease of handling and exceptional electrochemical stability when operated under higher voltage range. However, during lithium stripping and plating process of LLZO, a phenomena known as lithium dendrite penetration occurs, eventually short-circuiting the solid electrolyte system. In this work, we present a LLZO solid electrolyte that is incorporated with lithium fluoride within its internal structures. Previous reports show that fluorine can readily substitute oxygen site of LLZO during the densification of the solid electrolyte, which generally requires exposure to high temperature for a prolonged time (more than 5 hours). In our work, through using eutectic mixtures of lithium hydroxide and lithium fluoride, we were able to obtain F-LLZO with high relative density (>95%), while minimizing the duration of high temperature sintering process (less than 10 minutes). The shortened sintering time prevented of La₂Zr₂O₇ impurity formation, which is commonly occurring phenomena when fluorine ion is doped into the bulk of LLZO structure. The F-LLZO obtained showed unique morphology where majority of lithium fluoride resided at the internal pore areas of solid electrolyte. The fluorine incorporated LLZO (F-LLZO) shows very low electronic conductivity and shows resistive to lithium dendrite penetration, allowing high current density operation.

PG2A-10 | 이리듐 도핑된 루테튬 인화물 수소 발생 촉매의 수소발생 반응

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현재, 화석연료 고갈과 지구온난화 문제로 인해 수전해 기술을 활용한 수소에너지가 재생 가능한 에너지원으로 큰 관심을 받고 있다. 이 과정에서 주로 사용되는 수전해 촉매는 백금으로, 가격 측면에서 상용화의 한계점을 가지고 있다. 이에 비해 루테튬은 백금촉매의 4분의1 가격으로 루테튬 인화물을 활용한 수소 발생 촉매가 많은 연구가 진행되고 있다. 그러나 루테튬 인화물의 수소 중간체에 대한 강한 흡착 에너지는 수소발생 반응에 어려움

을 초래한다. 따라서 이를 개선하고자 이리듐 원소 도핑을 적용하였으며, 그 결과 수소 발생 효율이 향상되었으며, 수소 중간체와의 흡착 에너지가 적절하게 조절되었다. 개발된 촉매는 루테튬 인화물 기반 촉매 중에서 우수한 수소 발생 과전압을 나타내었으며, 염기성 전해질에서 7 mV와 32 mV dec⁻¹의 Tafel 기울기를 확인하였다. 또한 DFT 계산을 통해 이리듐 원소 도핑이 루테튬 인화물의 전자 구조를 변화시켜 적절한 수소 흡착 에너지를 형성함과 이리듐이 active site로서 작용하였음을 확인하였다. 따라서 루테튬 인화물 기반 촉매의 이리듐 도핑은 수소 발생 성능을 향상하기 위한 새로운 전략이었음을 제안한다.

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education (2020R1A6A1A03045059).

PG2A-11 | Non-monotonic first-cycle irreversible capacity governed by delithiation depth in Li-rich layered cathodes

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Li-rich layered oxides are high-energy-density cathodes for lithium-ion batteries. However, their first-cycle irreversible capacity hinders its ultimate energy density. We report a non-monotonic irreversible capacity depends on the first-cycle delithiation depth in Li_{1.2}Ni_{0.13}Co_{0.13}Mn_{0.54}O₂. Contrary to the previous belief that the irreversibility increases with the depth of charging in Li-rich cathode materials, the irreversible capacity reaches a maximum, excluding the unrecoverable capacity via O₂ loss, when the delithiation depth corresponds to half of Li₂MnO₃ delithiation. We demonstrate that it relates to the discharge capacity limited by kinetics at low voltages and with a metastable phase transition to an overlithiated Li₂MO₂ 1T structure. Through scanning transmission X-ray microscopy combined with O K-edge X-ray absorption spectroscopy, the degree of oxygen loss according to delithiation depth is revealed. These results provide guidance for mitigating the energy efficiency of Li-rich layered cathodes.

PG2A-12 | 바나듐 도핑을 적용한 Na-rich P2 type 소듐이온전지 양극활물질 합성 및 전기화학 성능평가

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높은 에너지 밀도를 가지는 리튬이온 배터리는 현재 가장 널리 사용되고 있는 배터리이다. 그러나 원재료의 지속적인 원가 상승으로 인한 가격 불안정성이 문제가 되고 있고 이를 해결하기 위해 차세대 배터리에 대한 연구가 활발히 진행되고 있다. 그 중 소듐 이온 배터리는 매장량이 많은 소듐을 주 원료로 사용하여

저렴하고 리튬이온 배터리와 유사한 전기화학 반응을 활용할 수 있기 때문에 리튬이온 배터리 대체할 잠재력이 크다. 그럼에도 불구하고 고유의 낮은 이론 용량은 상용화에 걸림돌이 되고 있는 현실이다. 다양한 양극활물질 중 2차원 이온확산경로를 가진 층상형계 전이금속 산화물은 이온 거동이 빠르고, 단위 질량당 높은 이론 용량이 장점이다. 특히, P2 구조는 O3 구조에 비해 높은 이온전도도와 뛰어난 구조적 안정성을 가진다. 그러나 고용량을 위해 고전압 충전 시 비가역적인 반응을 보이는 문제점을 가지고 있으며 이를 해결하기 위한 방법 중 하나로 금속 이종무기 원소를 doping하는 방법이 시도되고 있다. 본 연구에서는 고탍량의 소듐을 가지는 P2구조 형성과 고전압 반응 안정성을 개선하기 위해 high valence state를 가지는 Vanadium 도핑을 시도하였다. one-pot sol-gel 합성을 진행하였고 X-ray diffraction (XRD) 및 Scanning Electron Microscope (SEM) 분석을 통하여 바나듐 doping된 고탍량 소듐을 갖는 P2 구조의 양극활물질이 합성된 것을 확인하였다. 또한, 충방전 측정을 통해 4.2 V 이상의 고전압 영역에서 발생한 비가역적인 산소 산화환원 반응이 억제된 것을 확인하고 추가적인 전기화학 테스트를 실시하였다.

PG2A-13 | 대면적 프로톤 세라믹 전기화학전지 최적 구조 구현을 위한 공정 개발

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기후변화를 멈추기 위해 온실가스의 배출 감소, 특히 탄소 배출이 없는 청정 에너지 순환으로의 전환이 절실히 요구되고 있다. 그 대안으로 연소 및 전기화학 반응 생성물로 물을 생성하는 수소가 주목을 받고 있으며, 이러한 수소 생산을 위해 태양력, 풍력 등의 재생에너지로부터 생성된 전력을 활용하여 수전해를 통해 청정수소를 생산하는 기술 개발이 활발히 이루어지고 있다. 수소 연료전지 중 고체산화물전지는 지속 가능한 고효율 전기화학 에너지 변환 소자로 큰 주목을 받고 있다. 하지만 고체산화물전지의 높은 구동온도(750 °C)로 인해 열적 내구성이 우수한 고가의 소재 사용이 필수불가결하며 장기 구동 시 심각한 열화 현상이 발생하는 문제가 존재한다. 프로톤 전도성 세라믹 전해질 기반의 전지는 우수한 이온전도 특성으로 작동 온도를 낮추는 동시에 고성능을 유지할 수 있다. 그러나 현재 전세계적으로 연구 초기단계로, 대면적화 기술 확보는 아직 요원하다. 본 연구에서는 세라믹 대면적화 공정의 어려움, 물질 특성에 의한 대면적화 어려움을 극복하기 위한 전략으로 테일 캐스팅과 롤 캘린더링 기술을 채택, 구조최적화를 위해 롤 캘린더의 롤 간격, 소결 온도 등의 주요 공정변수에 따른 미세구조 변화, 구조에 따른 전기화학적 특성과의 상관관계에 대하여 논의하고자 한다.

PG2A-14 | 표면 처리된 LLZO 기반의 복합체 고체 전해질의 리튬이온전도 거동 연구

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고분자 기반의 Li₇La₃Zr₂O₁₂ (LLZO) - Polyethylene oxide (PEO) 복합체는 셀에서의 낮은 계면 저항, 높은 유연성으로 리튬

전고체전지용 고체 전해질로 관심을 받고 있지만, 대표적 고체 전해질인 아지로다이트 및 가넷 대비 낮은 이온전도도, 낮은 열적 안정성 등이 여전히 문제점으로 보고되고 있다. 특히, 중요한 전기적 물성인 이온전도도가 낮아지는 이유로 LLZO 입자 표면에 형성된 Li_2CO_3 와 LLZO 간의 입자 응집등으로 인하여, LLZO-PEO 간 형성된 계면의 빠른 이온전도를 막는 것으로 알려져 있다. 따라서 본 연구에서는 LLZO-PEO 간 계면 확대를 위하여 표면처리한 LLZO를 적용하여 가연성, 열적 안정성이 확보된 세라믹 과량 복합체를 제조하고자 하였다. 고밀도 복합체 제조를 위해 테일 캐스팅법과 핫 프레스(Hot-pressing) 공정을 도입하여 $100\ \mu\text{m}$ 이하의 후막 고체전해질을 제조하였다. 고체 전해질의 이온전도도는 2-probe ac 임피던스법을 이용하여 분석하였다. 본 발표에서 표면을 처리하여 기존 LLZO 기반의 복합체보다 더 높은 이온전도도를 가지는 고체전해질에 대한 연구결과를 상세히 다루고자 한다. * 이 성과는 정부(과학기술정보통신부)의 재원으로 한국연구재단의 지원을 받아 수행된 연구임(No. RS-2023-00236572, NRF-2020R1A2C2009821).

PG2A-15 | 고성능 Se-Ni₃S₂ 촉매와 유기 반도체를 활용한 고효율 무전해 태양광 수소 생산

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An efficient bias-free solar hydrogen-generating device is introduced. First, a Se-doped Ni_3S_2 ($\text{Se-Ni}_3\text{S}_2$) nanorod was synthesized by facile 1-step hydrothermal method. $\text{Se-Ni}_3\text{S}_2$ exhibits high activity toward hydrogen evolution reaction in alkaline media, which is attributed to the increased electrochemical active site as Se was introduced. A self-supported $\text{Se-Ni}_3\text{S}_2$ nanorod also demonstrated perfect durability, allowing excellent stability for 65 h. Next, an integrated photoelectrochemical photocathode was fabricated by combining organic photovoltaics (OPV) with $\text{Se-Ni}_3\text{S}_2$. A decoupled geometry is adopted to enable the protection of the organic semiconductor from the electrolyte. Photovoltage and photocurrent of the OPV were optimized for the water-splitting reaction allowing integrated photocathode to demonstrate a high onset potential of $1.8\ \text{V}_{\text{RHE}}$. An unbiased water-splitting reaction was exhibited without external bias as an integrated photocathode was connected to an efficient NiFe-OH anode, which led to generating H_2 with 10% solar to hydrogen conversion efficiency.

PG2A-16 | 마이크로파 반응기를 이용한 전고체전지용 Li-argyrodite계 황화물 고체전해질 습식 합성법 개발

황석호¹, 서승덕¹, *김동원¹

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급격한 전기자동차의 성장과 대규모 에너지 저장장치에 대한

수요가 증가함에 따라 고에너지밀도와 안전한 배터리 개발에 대한 수요가 증가하고 있다. 따라서, 최근 액체전해질의 사용으로 발화의 위험이 있고 제한된 에너지밀도를 가지는 기존의 리튬이온 배터리를 대체하기 위해, 고체전해질을 사용함으로써 높은 에너지 밀도와 안정성을 구현할 수 있는 전고체배터리가 차세대 배터리로서 각광받고 있다. 대표적으로 황화물 고체전해질은 셀을 가공하기 위한 적절한 기계적 특성과 액체전해질 수준의 우수한 Li^+ 이온 전도 특성을 가지고 있지만, 대부분 고상 합성법 및 기계적 밀링법을 통해 만들어지고 있어 긴 합성시간과 대량생산이 어렵다는 문제를 가지고 있다. 이를 극복하기 위해, 최근 액상기반의 합성법들이 보고되고 있지만 여전히 긴 합성시간을 가지고, 친핵성의 용매사용으로 열처리시 전구체 내의 잔여용매의 탄화로 인해 순도저하 및 전자 전도를 발생시키게 된다. 따라서, 본 연구에서는 마이크로파 반응기를 도입하여, 단 시간내에 기존 액상기반 합성법들의 문제점들을 극복한 고순도의 Li-argyrodite계 고체 전해질을 합성하였다. 또한, 기존 액상법 대비 높은 anion disorder를 가지고 있었고, 이를 다양한 in/ex-situ 물성분석을 통하여 증명하였다. 이를 전고체배터리에 적용하여 우수한 이온 전도도와 사이클 특성을 전기화학분석을 통해 증명하였다. This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2022R1A2C3003319).

PG2A-17 | Cu(TCNQ) 나노 와이어를 이용한 리튬-산소 배터리 양극용 Cu₃P 나노 와이어

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Lithium-oxygen batteries, which have the highest theoretical capacity (up to $5238\ \text{W h/kg}$), are prospective rechargeable battery systems that are based on the reaction of lithium and oxygen at the cathode. Despite the apparent advantage of high capacity, there are still critical challenges that block commercialization. Transition metals (TMs) phosphides are expected to reduce electrochemical overpotential because of phosphide's synergetic effect with TMs. Herein, Cu_3P nanowires with N-doped carbon are successfully synthesized using Cu(TCNQ) . Tetracyanoquinodimethane (TCNQ)-induced materials are reported as high-quality N-doped carbon sources. We controlled the heating rate to maintain wire shapes of Cu(TCNQ) to optimize the morphology and phases of Cu_3P nanowires denoted as $\text{Cu}_3\text{P@CC}$. The $\text{CuP}_2\text{-Cu}_3\text{P@CC}$ synthesized at the higher heating rate ($30\ ^\circ\text{C/min.}$) cannot maintain wire structures. The EDLC test indicated that $\text{Cu}_3\text{P@CC}$ provides active sites. The maintenance of the morphology of Cu_3P in the SEM images after cycles pointed out the sample effectively maintaining their

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active sites. The $\text{Cu}_3\text{P@CC}$ samples showed a low overpotential of less than 2 V in the final potential gap between the oxygen evolution reaction/oxygen reduction reaction. The cyclability of $\text{Cu}_3\text{P@CC}$ was higher than $\text{CuP}_2\text{-Cu}_3\text{P@CC}$. Additionally, Raman analysis suggested that lithium peroxide composition and decomposition on $\text{Cu}_3\text{P@CC}$.

ACKNOWLEDGEMENTS This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2022R1A2C3003319).

PG2A-18 | Enhancing active sites and intrinsic activity of layered perovskite LaSrCrO_4 nanofibers for Li- O_2 Batteries

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Li- O_2 batteries, characterized by high energy densities ($> 3500 \text{ W h kg}^{-1}$), operate through the reversible oxygen reduction reaction (ORR) and oxygen evolution reaction (OER) processes (i.e., $2\text{Li} + \text{O}_2 + 2\text{e}^- \leftrightarrow \text{Li}_2\text{O}_2$, $E^0 = 2.96 \text{ V}$ versus Li/Li^+) occurring at the cathode surface. However, due to the sluggish kinetics associated with ORR and OER, efficient electrocatalysts are imperative for practical applications. Layered-perovskite oxides have recently garnered attention due to their distinctive oxygen transport mechanisms involving interstitial migration in the rock-salt layers and vacancy migration in the perovskite planes (A_2BO_4). Their favorable ion transport properties are associated with low charge transfer resistance and excellent electrocatalytic performance. In this study, we focused on tailoring the active sites and intrinsic activity of Cr-based layered perovskite LaSrCrO_4 nanofibers, aiming to augment the electrocatalytic efficiency for Li- O_2 batteries. XPS and EDLC analyzes revealed the role of Cr ions in promoting the formation of abundant oxygen vacancies and active sites, ultimately improving the electrochemical performance of the catalyst. Utilizing the elevated concentration of oxygen active sites, the LaSrCrO_4 nanofibers efficiently formed and decomposed the Li_2O_2 products during the cycle. Moreover, LiO_2 intermediates were formed on the surface based on the enhanced absorption of oxygen species on the active sites. The high reversibility of LaSrCrO_4 nanofibers in a Li- O_2 battery system was carefully detailed by in-situ Raman.

PG2A-19 | 전고체 전지 양극재용 $\text{Li}_{1.3}\text{Al}_{0.3}\text{Ti}_{1.7}(\text{PO}_4)_3$ 보호 코팅층 제조 및 특성

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현재 전기자동차(EV) 및 에너지저장장치(ESS)에 사용되는 고용량 배터리의 수요가 증가하고 있다. 전고체 전지(All-solid-state Battery)는 기존 유기 액체 전해질이 갖는 폭발 및 화재의 위험성을 해결하고 높은 에너지 밀도로 많은 관심을 받고 있다. 전고체 전지의 구조는 복합양극과 고체전해질, 음극, 집전체로 구성되어 있다. 고체전해질의 사용으로 위에 언급한 장점들도 있지만, 단점도 갖고 있다.

전고체 전지 안에는 수많은 고체 계면들이 존재하는데 그 중, 양극과 고체전해질 간의 계면 저항과 부반응으로 인해 양극의 전기화학적 성능이 크게 저하되는 문제가 있다. 이와 같은 문제를 해결하기 위해서 여러 접근이 있었으며, 대표적인 방법으로 표면 개질법이 있다. 표면 개질법 중 양극 표면 위에 이온전도체와 같은 코팅 기술이 현재 많이 연구되고 있다. 하지만 기존 코팅 기술과 코팅 물질의 한계로 인하여 새로운 코팅 기술과 물질을 찾아야 했다. 따라서 상온에서 높은 이온전도도를 가지면서도 전기화학적, 화학적 안정성이 높은 LATP를 새로운 코팅 물질로 결정하였으며, 습식 공정에 위험한 유기용매 사용 대신 수계 용매를 사용하여 균일하면서도 안전한 코팅 기술을 행하였다.

PG2A-20 | Fabrication of lithium borosilicate glasses for multi-layer ceramic batteries

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Lithium-ion batteries are frequently utilized in electric energy storage systems due to their high capacity and long cycle lifetime. However, conventional lithium-ion batteries with liquid or polymer electrolytes have low thermal stability, and the resulting flammable property has a risk of safety issues. However, conventional lithium-ion batteries with liquid or polymer electrolytes have flammable property because of their low thermal stability. Because the problem causes a safety risk, many studies have aimed to substitute conventional electrolytes with solid-state electrolytes. Silica-based lithium-ion conducting glasses are promising materials for this purpose due to their outstanding chemical and thermal stability. In this study, lithium borosilicate ($\text{Li}_2\text{O-B}_2\text{O}_3\text{-SiO}_2$) glass was fabricated through the melting and quenching method. The temperature dependance of ionic conductivity was assessed using electrochemical impedance spectroscopy (EIS). In glass compositions with a high Li_2O content, the impact of the B_2O_3 and SiO_2 ratio on activation energy was also confirmed.

PG2A-21 | Reconfiguring Sodium Intercalation Process of TiS_2 electrode for a Highly-stable and Fast-charging Sodium-ion Battery by Solvent Co-intercalation

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Titanium disulfide (TiS_2), which is a well-known first-generation cathode in lithium batteries, has also long attracted a broad interest as a potential electrode candidate for sodium-ion batteries (SIBs) due to favorable sodium intercalation kinetics and semi-metallic nature. However, the reversibility of sodium de/intercalation is far inferior to that of lithium, which has been often attributed to the unfavorable intermediate phase formation upon sodiation, leading to a poor electrochemical cycle life. Herein, we demonstrate that reconfiguring sodium intercalation process via partial solvent co-intercalation can induce a significant change in the phase-transition paths for the entire sodium intercalation reactions of Na_xTiS_2 ($0 < x < 1$), successfully detouring the formation of the unfavorable intermediates. And, it unexpectedly results in a remarkable enhancement of sodium intercalation reversibility, thereby boosting the cycle stability of sodium cell along with high power capability. Our comparative investigations reveal that the sodium intercalation in Diethylene glycol dimethyl ether (DEGDME)-based electrolyte involves a partial pre-intercalation of solvent molecules and subsequently undergoes distinct phase evolutions dissimilar to the bare sodium ion intercalation in conventional electrolytes. The new altered intercalation route allows the $Na-TiS_2$ cell to deliver a reversible capacity of 93 mAh g^{-1} over 1,000 cycles with 62 % of capacity retention at as high as 10 C rate. This re-discovery of intercalation behavior of TiS_2 offers a new insight in tailoring the reversibility and kinetics of intercalation process of commonly known electrodes for rechargeable batteries.

PG2A-22 | A new reliable evaluation method for magnetocaloric materials

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Magnetocaloric materials (MCMs) exhibit a characteristic in which the temperature of the material changes as an external magnetic field is applied. Utilizing this characteristic, MCM can be used as a coolant for eco-friendly magnetic cooling devices with high energy efficiency. This presentation suggests a system for evaluating whether the MCMs possess desirable

characteristics as coolants. Adiabatic temperature change (ΔT_{ad}), which is the temperature change that occurs in the material as the magnetic field changes, is directly related to the cooling efficiency of the device. While computational methods exist for assessing ΔT_{ad} , this presentation focuses on a direct measurement approach to evaluate the temperature changes within the material. Especially in the magnetic cooling devices, where the coolant undergoes repetitive magnetic field changes, it's crucial for the coolant to maintain its characteristic throughout these rapidly changing magnetic field cycles. Hence, we have developed a measurement system that meets this requirement and are presently assessing the cycle ΔT_{ad} characteristic of our research materials. More details regarding the system will be discussed in this presentation.

PG2A-23 | 직접암모니아 고체산화물연료전지 적용을 위한 용출형 전극소재 개발

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Ammonia (NH_3) is regarded as an innovative hydrogen (H_2) carrier with its great storage characteristics and zero carbon emission. The highly active and durable catalytic material for NH_3 decomposition is attracting attentions for direct utilization of NH_3 fuel to solid oxide fuel cells (SOFCs). In this study, we introduce nano structured catalytic materials for NH_3 decomposition reaction, which prepared on the surface perovskite electrode scaffold via in-situ exsolution method. The transition metal cations ($M = Ni, Co, Fe$) are doped inside the perovskite ($La_{0.43}Ca_{0.37}M_{0.12}Ti_{0.88}O_{3-d}$) lattice structure, and exsolved on its surface as single or alloy nanometal catalysts. The chemical composition of surface exsolved nano catalysts were tailored to improve the NH_3 decomposition process under direct NH_3 SOFCs operating condition. The conversion characteristics of prepared exsolution catalyst are evaluated by using gas chromatography (GC) system and electrochemical button cell test. The result indicate that the Ni and Co based exsolution electrode materials shows 4-times higher power density compared with that of conventional Ni-YSZ cermet based SOFCs. The exsolved nano metal catalyst also showed great stability against surface nitriding or agglomeration more than 150h NH_3 conversion operation. The results obtained in this study is believed to improve the performance of diverse energy storage and conversion systems using NH_3 fuel, specifically for direct ammonia used SOFCs systems.

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PG2A-24 | Slab gliding, a hidden factor that induces irreversibility and redox asymmetry of lithium-rich layered oxide cathodes

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Lithium-rich layered oxides are regarded as a promising class of next-generation cathodes with extraordinarily high energy density because they can harness the capacity from the anionic-redox activity in addition to that from the conventional cationic redox reaction. However, the use of the oxygen redox in lithium-rich layered oxides has been limited by intrinsic shortcomings with respect to stability, as these materials display a large voltage suppression/hysteresis and capacity loss as cycling progresses. Although this deterioration is believed to primarily result from structural disordering, our understanding of how it is triggered and/or occurs remains incomplete, awaiting a complete portrayal of the complex phase transition mechanism and its interplay with the anionic redox activity. Transition metal (TM) displacement in the lithium-rich layered structure has been highlighted as a representative type of structural disordering observed during the oxygen redox. It has been reported that a significant extent of out-of-plane TM migration occurs from the very first charge of lithium-rich layered oxide electrodes. In addition, these TM migrations are only partially reversible during the subsequent discharge, with this irreversibility gradually increasing over subsequent cycles. Nevertheless, it also infers that the local TM migrations are indeed sensitively affected by the global structural framework such as stacking sequences in the layered structure. Considering that most electrode materials with layered structures undergo slab gliding during the de-/lithiation process, it implies that the control of the reversibility of the local TM migrations may not be sufficient in securing the overall structural reversibility and oxygen activity. Of great significance is that depending on the combinations of lateral slab gliding and out-of-plane/in-plane TM migration, various cation migration pathways may exist, complicating the possible restoration of the original cation arrangements during oxygen redox (i.e., structural reversibility). Despite these implications, the dynamic relationships between slab gliding and TM migration, and their effects on structural and electrochemical reversibility, have not yet been elucidated and remain elusive. Herein, we propose a theoretical picture that clarifies the irreversible transformation and corresponding redox asymmetry of lithium-rich layered

oxides by introducing a series of global and local dynamic structural evolution involving the combination of slab gliding and out-of-plane/in-plane TM migration that co-exist in the redox process. We show that the slab gliding plays a key role in triggering/initiating the structural disordering and consequent degradation of the anionic redox reaction. We identify a number of asymmetric lithiation/de-lithiation pathways, where even a reversible local structural change causes a globally irreversible structural degradation due to the slab gliding. We further reveal that this 'concerted disordering mechanism' of slab gliding and TM migration produces irreversible/asymmetric pathways of lithiation and de-lithiation in an energetically spontaneous way, causing an irreversible deterioration of the layered structure and the asymmetry of the anionic redox reaction. Our findings not only suggest a comprehensive model for the complex structural evolution of lithium-rich layered oxides but also unveil that the control of slab gliding in layered structures may be an unexplored yet important route toward achieving a reversible oxygen redox reaction.

PG2A-25 | Surplus Li incorporation을 이용한 Co-free 레이어드 옥사이드 물질의 전기화학 성능 개선

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Due to several Co-related issues, Co-free layered oxide is being investigated as the most suitable material to replace the currently utilized NCM layered cathode. However, due to the low discharge capacity and rate capability caused by cation disorder, which is an inherent disadvantage of Co-free materials, commercialization is difficult to achieve promptly. Here, we employ surplus Li incorporation as a way to improve the performance of Co-free material, $\text{LiNi}_{0.75}\text{Mn}_{0.25}\text{O}_2$. Surplus Li doping increased capacity retention as well as discharge capacity and rate capability by reducing cation disorder. The cause of these surprising findings was investigated utilizing several multi-length-scale measurements, and it was discovered that excess Li influences the whole synthesis process, not only lowering cation disorder. As the quantity of Surplus Li grows, so does the contact area of the transition metal precursor with the Li source, promoting topotactic lithiation and the formation of a more flawless layered structure. Furthermore, we created a Co-free material with enhanced performance by using a technique that promotes topotactic lithiation throughout the synthesis process.

PG2A-26 | Synthesis and intermolecular interaction engineering of the 2D siloxene anode for lithium-ion batteries

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Two-dimensional oxidized silicon nanosheets, namely siloxene, exhibit minimal volume expansion during cycling due to their distinct geometries and chemical compositions. Despite its properties, reports of the relationship between siloxene and binder are not commonly found. This study focuses on intermolecular interaction engineering to enhance lithium-ion storage in siloxene anode. The production of siloxene involves a topochemical reaction. Through HCl treatment, CaSi₂ powders undergo deintercalation of Ca²⁺ through topochemical reaction. This process leads to the formation of loosely laminated two-dimensional siloxene nanosheets. The intermolecular interaction between siloxene and four representative binders (alginate, carboxymethylcellulose, polyacrylic acid, and α -polyvinylidene fluoride) was investigated to improve electrochemical performance from FT-IR spectra. Binders are selected using two criteria: polarity and functional groups and exhibit different intermolecular interactions with siloxene. In particular, alginate forms the strongest intermolecular bonds, due to dipole-dipole attraction between the H atom of siloxene and the OH group of alginate. The trend of intermolecular binding strength of the binder is consistent with the trend of cycling stability and rate performances. In summary, alginate-based siloxene electrodes exhibit an excellent charge capacity retention rate of 66% after 500 cycles at 200 mA g⁻¹. This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2022R1A2C3003319).

PG2A-27 | Effect of cell pressure on the electrochemical performance of all-solid-state lithium batteries with zero-excess Li metal anode

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All-solid-state cells (ASSCs) typically operate at a specific pressure to ensure good contact between the solid electrolyte and the electrode-active materials. However, establishing the ideal cell pressure is challenging because of the various cell structures, the mechanical characteristics of solid electrolytes, and the extent to which the volume of the electrodes changes during

cycling. In this study, we propose a specially designed cell assembly that adjusts to the changes in volume that occur during cycling while maintaining a constant cell pressure. The evaluations indicate that the spring in the cell assembly effectively reduces the stress incurred from the volume expansion that occurs in the electrode during charging (lithiation) and the volume contraction that occurs during discharging (delithiation) while maintaining the prescribed cell pressure. The capacity fading as a function of the cycle number decreases when operating ASSCs comprising a cell assembly that include a spring, compared with those that exclude a spring. Focused ion beam-scanning electron microscope reveals no cracks and delamination in the LiNi_{0.8}Co_{0.1}Mn_{0.1}O₂ (NCM811) composite cathode of the ASSCs, operated at 25 MPa, with a spring-equipped assembly. The Ag nanolayer that deposits on the Cu foil is an effective collector metal, forming a dense lithium plating layer on the Ag/Cu foil anode.

PG2A-28 | Synthesis of Li₂MoO₄ anode material via environmentally friendly water vapor-assisted solid-state reaction

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Conventional techniques for synthesizing active materials, such as solid-state and hydrothermal reactions, often entail high energy consumption, uncontrolled morphology, and environmental risks due to the use of organic solvents. To address these challenges, this study introduces an innovative, eco-friendly, and cost-effective approach based on a facile solid-state reaction enhanced by water vapor. This novel methodology substantially reduces reaction energy and time, while allowing for the synthesis of smaller, uniformly shaped materials featuring expansive surface areas. Utilizing this approach, we successfully prepared Li₂MoO₄ anode materials under various conditions. The optimized sample demonstrated exceptional electrochemical performance, achieving capacities of 243.12 and 216.83 mAh g⁻¹ after 100 and 500 cycles at current densities of 100 mA g⁻¹, markedly surpassing the performance of materials synthesized via traditional solid-state reactions (SSR). The optimized sample also exhibited excellent stability, with a capacity of 344.08 mAh g⁻¹ at elevated current densities of 800 mA g⁻¹—a 58% improvement over the lower current density of 100 mA g⁻¹. For comparative purposes, the SSR based sample yielded only a 37% capacity retention

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at the high current density. Additionally, Electrochemical Impedance Spectroscopy (EIS) and Galvanostatic Intermittent Titration Technique (GITT) analyses were employed to quantify the ionic conductivity and diffusivity of the optimized samples. Our innovative green synthesis method opens new ways for enhancing the performance and efficient production of active materials.

PG2A-29 | Ga doping effect on LLCZNO ($\text{Li}_7\text{La}_{2.75}\text{Ca}_{0.25}\text{Zn}_{1.75}\text{Nb}_{0.25}\text{O}_{12}$) of solid electrolyte for all-solid-state batteries

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The demand for high capacity, performance, and safe energy storage make people focused on all-solid-state batteries. Garnet-based solid electrolytes, especially $\text{Li}_7\text{La}_3\text{Zr}_2\text{O}_{12}$ (LLZO) have been considered a promising material due to their stability with lithium (Li) and wide electrochemical window. However, the low ionic conductivity of LLZO has hindered its commercialization. To address this, we doped gallium (Ga) to Li sites, enhancing ionic conductivity and structural stability. Experiment was conducted various proportions and we called each sample ($\text{Li}_{7-6x}\text{Ga}_x\text{La}_{2.75}\text{Ca}_{0.25}\text{Zn}_{1.75}\text{Nb}_{0.25}\text{O}_{12}$) as "x Ga-LLCZNO". The optimal result was achieved at $x=0.15$, come with the highest ionic conductivity (4.42×10^{-4} S/cm) and the lowest activation energy (0.27 eV). Structural analysis using synchrotron XRD visualized that Ga ions occupy the Li sites, causing expansion in the Li transport channel. And unexpectedly, it revealed excessive expansion lead to reduced Li mobility. This study offers insights into understanding Li mobility and the impact of metal ion doping.

PG2A-30 | Surface modification of Halloysite (Hal) with PPy-derived carbon to enhance the conductivity properties for energy storage application

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Halloysite, a natural clay mineral with a layered aluminosilicate composition $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4 \cdot n\text{H}_2\text{O}$ and a unique nanotubular structure, presents a substantial surface area and exceptional ion transport properties, rendering it an appealing candidate for diverse energy storage applications. Nonetheless, its inherent insulating characteristics pose challenges regarding its

conductivity and stability, limiting its direct use in batteries. To address this limitation, in our study, we demonstrate the successful coating of halloysite with carbon and characterize the resulting composite through microscopy and spectroscopy techniques. To enhance the halloysite's conductivity, we synthesized conductive halloysite by enveloping it with carbon derived from Polypyrrole (PPy). Initially, PPy was conformally coated onto halloysite surfaces through chemical oxidative polymerization. Subsequently, this polymer was transformed into PPy-derived carbon via pyrolysis in a tube furnace set at 800°C within an Argon atmosphere. The resulting composite properties were thoroughly analyzed by SEM, FT-IR, RAMAN, XPS, and powder resistivity measurements to assess its conductivity. This study reveals the promising potential of halloysite-carbon coated as a versatile and eco-friendly solution for enhancing battery performance and sustainability, contributing valuable insights to the expanding knowledge base in materials science and ceramics. Keywords: Halloysite, Clay, Battery, Conductive clay, Polypyrrole, carbon

PG2A-31 | FTIR을 활용한 Detection of ppm level NO_x during direct-ammonia SOFC operation

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Direct ammonia-SOFC are promising energy conversion devices for clean energy production in the hydrogen economy. However, some research suggests that the generation of NO_x compounds may increase under specific operational conditions of direct-ammonia SOFC. Particularly, nitrogen dioxide and nitric oxide in the atmosphere can contribute to air pollution, leading to global warming. Therefore, in this study, Fourier Transform Infrared (FT-IR) is used to analyze the spectra of NO_x produced by direct-ammonia SOFC under various operating conditions, including temperature, flow rate, and ammonia dilution. FT-IR analysis quantifies the amounts of generated NO_x compounds, enabling the identification of correlations between the operating conditions and the quantity of NO_x . This study aims to comprehend factors influencing NO_x production during direct ammonia-SOFC operation, thereby proposing improvements in operating conditions and system design.

PG2A-32 | BT Coating on LCO (LCO@BT) for Improving an electrode/electrolyte interface resistance

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The current batteries' electrolyte is a liquid. Nonetheless, the use of liquid electrolyte can result in leakage and ignition, which may cause stability issues in secondary batteries. To resolve these problems, a solid secondary battery with a solid electrolyte was suggested. Compared to liquid electrolytes, solid electrolytes present a lower risk of leakage and reactivity, leading to less heat accumulation and a lower ignition potential. Nevertheless, solid electrolytes face significant grain boundary resistance, making it challenging to establish an electrode/electrolyte interface. To tackle this issue, we address coating barium titanium oxide(BT), a ferroelectric material, on the lithium cobalt oxide(LCO). The dielectric serves as an artificial solid electrolyte interface (SEI) layer, enhancing concentration at the three-phase interface (TPI) of BT-electrolyte-LCO. This is expected to reduce interfacial resistance and secure a lithium ion movement path. To create a composite cathode, two approaches were employed for coating BT onto LCO: ball milling and ultrasonic dispersion. After confirming basic physical properties through XRD and SEM, we evaluated electrochemical properties such as cycle testing to identify a more effective composite cathode.

PG2A-33 | High-Performance Lithium-Sulfur Batteries With Optimally Arranged TiO₂@MoS₂ Heterostructures Inducing Effective Built-in Electric Field

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Lithium-sulfur (Li-S) batteries have received considerable attention as one of the promising next-generation energy storage systems owing to their high theoretical specific capacity, energy density as well as environmental benignity of sulfur. However, the practical application of Li-S batteries is still hindered by a few technological obstacles, such as sluggish sulfur redox kinetics and detrimental shuttle effect. To overcome these issues, we successfully fabricated optimally arranged TiO₂ and MoS₂-based heterostructures (TiO₂@MoS₂) via a facile atomic layer deposition process of TiO₂ layer followed by a simple hydrothermal synthesis of MoS₂ nanosheets. The TiO₂@MoS₂ composites acted as a multifunctional interlayer, which could efficiently capture lithium

polysulfides and accelerate their conversion reaction. Owing to the synergistic effects between TiO₂ and MoS₂ and uniform heterointerface distribution inducing the ideally oriented built-in electric field, Li-S batteries with TiO₂@MoS₂ interlayers exhibit high rate capability (601 mA h g⁻¹ at 5 C) and satisfactory cycling stability (capacity fade rate of 0.067% per cycle over 500 cycles at 2 C). Compared to the reversely arranged composites (i.e., MoS₂@TiO₂), the superior electrocatalytic activities of the TiO₂@MoS₂ interlayer demonstrate the importance of optimizing the built-in electric field of heterostructures to produce high-performance Li-S batteries.

PG2A-34 | 백운석을 이용한 친환경제설제 제조에 활용하기 위한 아세트산 생산 공정 개발

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최근 국내 미활용 무기 자원의 활용성 극대화를 위해 고순도화 및 응용제품 생산에 대한 연구가 활발히 진행 중이다. 이중 백운석은 강원도와 충청북도를 중심으로 많은 양이 매장되어 있고 정제 기술을 통한 고순도 마그네슘 생산 기술 및 칼슘마그네슘아세테이트와 같은 응용제품 개발이 가능하다. 칼슘마그네슘아세테이트는 마그네슘과 칼슘이 혼재하는 백운석에 아세트산을 반응시켜 생산되는데 아세트산의 높은 원가가 상용화시 제한사항이 되고 있어 백운석의 활용도 한계를 가진다. 본 연구팀은 백운석을 활용한 칼슘마그네슘아세테이트 제조에 필요한 아세트산을 폐기물을 이용하여 생산함으로써 전체 공정의 경제성을 향상시키고자 담배 공장조의 열분해 및 정제 기술을 적용하였다. 담배 공장조의 열분해 결과, 폐담배필터 무게의 최소 30 % 이상이 아세트산으로 전환됨을 확인하였고 분별증류를 이용한 정제 후 최소 90 % 이상의 순도를 가진 아세트산을 회수할 수 있었다. 또한 열분해 후 회수된 아세트산을 백운석과 반응시킨 결과 친환경제설제로 활용될 수 있는 칼슘마그네슘아세테이트를 생산할 수 있었다. 이 연구는 정부(과학기술정보통신부)의 재원으로 한국연구재단((No.NRF-2022R1C1C1005976)과 2021년도 산업통상자원부 및 산업기술평가관리원(KEIT) 연구비(20016810) 지원을 받아 수행된 연구임.

PG2A-35 | 양성자 전도성 산화물 전해질에서 반응 소결을 통해 향상된 소결성

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고체산화물 전해질 중에서 양성자 전도성 전해질은 최근에 큰 관심을 받고 있는데, 이는 중·저온 (600 ~ 300°C)에서도 가장 높은 이온 전도도를 가지기 때문입니다. 그러나, 이러한 전해질은 재료의 고유한 물성으로 인해 화학적으로 안정하며 동시에 물리적으로도 밀도가 높은 전해질을 제조하는 것이 상당히 어렵습니

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다. 따라서 본 연구에서는 소결 온도를 효과적으로 낮출 수 있는 반응 소결과 관련된 새로운 접근 방식을 제안합니다. 이 방법은 단 한번의 열처리 과정 동안 전해질의 치밀화와 함께 2상 (fast-sintering and slow-sintering phases)의 혼합물을 완벽한 단일 상 (single phase) 고용체 화합물로 합성하는 것입니다. 반응 소결 과정 동안 빠른 소결 특성을 지닌 상의 입자들은 우수한 소결성으로 인해 빠른 성장이 진행됩니다. 또한 이러한 빠른 성장은 Ostwald ripening 현상으로 인해 더 작고 느린 소결 상의 입자들이 도움을 주게 됩니다. 결국, 프로톤 전도성 전해질의 소결 온도를 기존에 비해 (~ 100°C) 낮춤으로써 전해질의 의도된 초기 화학양론이 잘 보존될 수 있었습니다. 그리고 기존에 고온에서 제작된 프로톤 전도성 연료전지의 전기화학 성능에 비해서 ~ 2배 높은 성능을 얻을 수 있었습니다. 이러한 연구 결과는 고온 소결이 필요한 고체산화물 전기화학 소자의 제조 과정을 단순화하면서도 고유한 물성을 보존하는 방법입니다.

PG2A-36 | 고효율 직접 암모니아 고체 산화물 연료전지를 위한 베이직안 최적화 기반 연료 주입 제어

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Direct-Ammonia solid oxide fuel cell (DA-SOFC)는 최근 수소를 대체할 수 있는 친환경 연료인 암모니아를 직접 주입하여 작동할 수 있는 연료전지이다. 암모니아를 통한 수소의 생산 반응인 암모니아 크래킹 ($\text{NH}_3 \rightarrow \text{N}_2 + 3\text{H}_2$)은 750 °C 이상에서 100%에 가까운 분해율을 보인다. 하지만, 흡열반응인 암모니아 크래킹 반응이 전기화학 반응에 필요한 수소의 양 보다 과하게 진행될 경우 SOFC의 온도가 감소해 오히려 성능 및 효율이 감소하게 되는 영향을 준다. 또한, 공기 및 암모니아의 과도한 주입은 연료 이용률을 감소시켜 연료 주입 조건, 유량 그리고 분압 등의 최적화는 필수적이다. 하지만 이는 많은 양의 실험, 시간 및 큰 인력의 소모를 동반한다. 본 연구에서는 DA-SOFC 운전 조건 중 공기 및 암모니아 주입 유량, 그리고 암모니아 농도 등 최적화가 필요한 약 수십만 번 이상의 실험 경우의 수를 베이직안 최적화 기법 기반 Gaussian Process Regression (GPR), Random Search (RS) 등의 불확실성 예측 모델 끼리의 예측 성능을 비교하고, 이를 적용하여 최고의 성능 및 효율을 보이는 작동 조건을 약 수십 번의 계산으로 최적화 한다.

PG2A-37 | Dissolution and Exsolution of Ni in SrTiO_{3-δ} using ab-initio thermodynamics

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This study explores the dissolution and exsolution of Ni within a SrTiO_{3-δ} supercell using ab-initio thermodynamics. Many researchers have aimed to induce exsolution of transition metals from perovskite oxide to create nanoparticles, which are used as catalysts of SOFCs. H. Han et al. found the exsolution of Ni from LaSrNiTiO₃

perovskite oxide. They have shown that anti-phase boundary holds the excess Ni within LaSrTiO₃, providing a swift diffusion pathway, resulting in nanoparticle formation by exsolution through transmission electron microscope. Furthermore, they also have calculated the energy barriers required for Ni migration at the anti-phase boundary and in the bulk by density functional theory [1]. However, they did not elicit the phase stability between Ni and doped SrTiO₃, so we study the thermodynamic stability of Ni-doped SrTiO₃ by using Gibbs free energy of formation. Within SrTiO₃, Ni is stable when it dissolves into SrTi_{0.875}Ni_{0.125}O_{2.96} at an oxidizing atmosphere of 0.21 atm and precipitates into Ni+SrTiO_{3-δ} at a reducing atmosphere of 10⁻²⁰ atm, respectively. Lattice vibration is considered for accurate calculations [2].

References [1] H. Han et al., Nature Communications, 13, 6682 (2022). [2] V. Wang et al., Computer Physics Communications, 267, 108033 (2021).

PG2A-38 | Simple synthesis of hierarchical porous carbon derived from agricultural wastes by self-template method for supercapacitors

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¹Korea Institute of Ceramic Engineering and Technology Pore-tailoring of electrode materials is important for organic ion storage and accessibility. Herein, we report a pruned fruit tree branch derived activated carbon that has a hierarchical micropore structure suitable for non-aqueous supercapacitors. Pruned peach and apple tree branches are used as the biomass base in which two different pore-tailoring strategies are performed through an alkali activation and a self-template using naturally occurring compounds in the biomass. In tailoring, the amount of KOH was regulated to increase the specific surface area and micropore volume, for the creation of energy storage related pores. Furthermore, CaCO₃ particles (< 2 nm) in carbonized pruned fruit tree branches were additionally adopt to create interconnecting micropores. The obtained activated carbons show high surface area (up to 3090 m² g⁻¹) and pore volume (up to 1.39 cm³ g⁻¹) with connected pore structure. The largest specific capacitance of 41.7 F g⁻¹ was obtained when the pruned apple tree branch based electrode was used with an organic electrolyte. The maximum energy and power densities achieved were 42.1 Wh kg⁻¹ and 7.1 kW kg⁻¹, respectively. The results of this study present an environment friendly method to control the porosity in biomass-derived activated carbon for sustainable energy storage applications.

PG2A-39 | Manufacturing of Mn-doped Co_3O_4 Nanofibers using Electrospinning and Performance Evaluation of Cathode Materials for Lithium-Ion Batteries

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As carbon neutrality has become a hot topic, interest in the development of electric vehicles (EVs) and energy storage systems (ESSs) has been receiving considerable attention, and accordingly, efforts have been steadily made to find new electrode materials with larger capacity. A variety of materials have been studied, of which Co_3O_4 is known as a promising anode material. Although it has high lithium storage capacity, structural instability due to high volume changes and low electrical conductivity during the cycle hinders its widespread use as a cathode material. To resolve this problem, nanostructure and doping with heterogeneous atoms were introduced, and this research synthesized Co_3O_4 doped with Mn by electrospinning, and when Mn is doped, a particle size decreases and volume expansion is alleviated. The structure of Mn-doped Co_3O_4 was characterized by scanning electron microscope (SEM), transmission electron microscope (TEM), and X-ray diffraction (XRD) analysis. X-ray photoelectron spectroscopy (XPS) analysis was also performed to determine the change in binding energy according to the amount of doped Mn, and constant current (CC), constant voltage (CV), and electrochemical impedance spectroscopy (EIS) analysis were also performed to evaluate cycle performance and reversibility. BET, BJH were performed to confirm particle change by Mn doping. PL, UV-vis were performed for band-gap.

PG2A-40 | Enhancing Stable Spin-Dependent Oxygen Evolution Reaction through Chiral Fluorinated Structural Isomer Cations in 2D Perovskites

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Chiral 2D organic-inorganic hybrid perovskite (OIHP) has attracted great attention in the field of spin-dependent electrochemistry due to its impressive spin-selectivity. Leveraging the advantage of the spin-selective property, the spin-polarized carriers that

transport through the chiral 2D OIHP can reduce the overpotential of the oxygen evolution reaction (OER) by mitigating the sluggish kinetics from the spin-dependent reaction. However, there are intrinsic obstacles to chiral 2D OIHP for OER devices. For example, 2D OIHP structures exhibit poor out-of-plane conductivity and are vulnerable to water. To solve this problem, we introduced chiral structural isomer cations to the OIHPs. Strikingly, the ortho-fluorinated methyl benzylamine cations endowed hydrophobicity and promoted conductivity to the OIHP system via strong halogen-halogen interaction and reduced dielectric confinement effect. Finally, the OER device was fabricated by depositing chiral OIHP spin filters on BiVO_4 photoanode and the ortho-fluorinated cation-incorporated OIHPs dramatically enhanced both the operational stability and OER performance.

PG2A-41 | 전이금속이 도핑된 나노 세리아의 광학적 특성

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에너지 밴드갭을 지닌 세리아(CeO_2)는 자외선 차단제, 광촉매 및 삼원촉매로 사용되고 있을 뿐만 아니라, 최근 연료전지 등 전기화학전지의 산화환원 촉매로 크게 주목받고 있다. 본 연구에서는 다양한 응용을 위해 액상 기반 침전법으로 5nm 크기 이하의 초나노 크기를 갖는 세리아 입자를 합성하였다. 에너지 밴드갭 제어를 위해 전이금속(Co, Ni, Fe)이 도핑된 세리아도 합성하였다. 이렇게 합성된 세리아의 광학적 물성을 자외선-가시광선 분광법을 이용하여 분석하였다. 전이금속 종류 및 농도에 따라 변화된 세리아의 광학적 물성과 나아가 변화된 에너지 밴드 구조를 보고하고자 한다. 이 성과는 정부(과학기술정보통신부)의 재원으로 한국연구재단의 지원을 받아 수행된 연구임(No. RS-2023-00236572, NRF-2020R1A2C2009821).

PG2A-42 | Fuel Electrode Tuning for CO_2 Electrolysis in SOEC via Catalyst Engineering

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With the continued rise in atmospheric CO_2 levels and the increasing accessibility of competitively priced renewable electricity, there's a growing need to comprehend the electrochemical conversion of CO_2 into valuable chemicals. Solid oxide cells are becoming a preferred method for CO_2 electrolysis at high temperatures because of their high efficiency, strong affinity for CO production, and considerable current density. Using fuel electrodes for CO_2 electrolysis

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presents more obstacles than for H₂O, mainly due to the high polarization resistance and risks of coke deposits. Hence, improving the conventional Ni/YSZ cermet fuel electrode is crucial for CO₂ electrolysis. Meanwhile, manufacturing an entirely new electrode comes with substantial challenges associated with ceramic processing of solid oxide cells. Therefore, introducing an additional catalyst to enhance the performance and stability of conventional fuel electrodes is gaining attention as a method in catalyst engineering. To deepen our understanding of the electrochemical reduction of CO₂ in SOEC, various Ni-Alloy/YSZ electrodes were investigated using symmetrical half cells. The effects of different catalysts, including pure nickel and its alloys with other metals, were examined.

PG2A-43 | Revolutionizing hydrogen production with LSGM-based Solid Oxide Electrolysis Cells: An innovative approach to green energy generation

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Solid Oxide Electrolysis Cells (SOECs) are considered promising systems for generating green hydrogen, an alternative new energy source. Instead of the most common electrolyte YSZ (yttria-stabilized zirconia), La_{1-x}Sr_xGa_{1-y}Mg_yO_{3-δ} (LSGM) has emerged as a substitute due to its superior ionic conductivity. Therefore, SOECs supported by LSGM are expected to exhibit high performance and efficiency. The sonic spray is a new approach of a cell manufacturing process. Compared to the current screenprinting method, its non-contact property makes it possible to utilize wider range of substrates. Moreover, it enhances the microstructure of the layer, which leads to a higher performance. This one, too, would be able to give satisfactory amount of hydrogen. In this study, an LSGM-supported solid oxide electrolysis cell fabricated by the sonic spray was tested, and the hydrogen production efficiency was also calculated with the electrochemical analysis of the process and performance. As a results, this SOEC achieved as high as 1.15 A/cm² at 800°C, and the hydrogen production efficiency reached almost 80%. The practical application of the LSGM electrolyte and the sonic spray was examined, and it indicated that these could be the useful ways of fabricating successful solid oxide fuel cells.

PG2A-44 | Synergistic Effects of Amorphous TiO₂/amorphous MoS₂ Heterostructure for High- Performance Lithium-Sulfur Batteries

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With the increasing demands of electric vehicles and grid-scale energy storage systems, lithium-sulfur (Li-S) batteries have attracted significant research interest as one of the promising next-generation battery technologies due to their high theoretical energy density of 2600 Wh kg⁻¹. However, the practical application of Li-S batteries is still impeded by the shuttle effect, which is caused by the dissolution of soluble lithium polysulfides (LiPSs) in organic electrolytes. In addition, the poor conductivity of sulfur cathodes and the following sluggish Li-S redox kinetics further induce rapid capacity loss during cycling. To overcome these serious drawbacks, various polar materials have been investigated as effective additives that can efficiently trap the dissolved LiPSs and accelerate their conversion reactions to the final products. Among them, TiO₂ nanomaterials have been frequently employed to enhance the LiPS adsorption ability due to their highly polar surfaces. MoS₂, which has decent binding energy and high electrical conductivity, has also been extensively studied to highly accelerate the conversion kinetics of LiPSs. Due to these outstanding properties, it is reported that building TiO₂ and MoS₂-based heterostructures could considerably alleviate the shuttle effect owing to the synergistic effects between TiO₂ and MoS₂ and increased active sites at heterointerfaces. However, further improvements must be needed because the ordered crystalline planes of the host materials allow the LiPSs to interact only with limited atoms on exposed plane surfaces. Recently, many efforts have been made to apply amorphous materials as efficient catalysts in electrochemical reactions. Compared with crystalline hosts, amorphous structures exhibit more effective LiPS anchoring ability originating from abundant dangling bonds and loosely packed structures which can easily accommodate volume change during repeated cycle processes. However, the complicated fabrication of amorphous nanomaterials has blocked further development to amorphous/amorphous heterostructures. Herein, we fabricated an amorphous TiO₂/amorphous MoS₂ heterostructure on a conductive carbon cloth as a multifunctional sulfur host via simple hydrothermal synthesis and atomic layer deposition. Amorphous

TiO₂/amorphous MoS₂ synthesized on activated carbon cloth (a-TiO₂/a-MoS₂@C) revealed superior electrochemical performances to crystalline/crystalline heterostructures due to synergistic effects of amorphous phases and heterostructures. Therefore, by introducing amorphous TiO₂/amorphous MoS₂ heterostructure as the sulfur host for the first time, this work provides a new route to develop high-performance Li-S batteries.

PG2A-45 | Enhancement of cathode performance by Sm_{0.5}Sr_{0.5}CoO_{3-δ} infiltration with co-spraying.

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The Solid Oxide Fuel Cell (SOFC) is getting attention from next-generation electrochemical energy conversion devices with high efficiency and low pollutant emission. In SOFCs, the cathode performs a critical role, especially in the occurrence of the Oxygen Reduction Reaction (ORR). To increase ORR activity, many studies have been reported on utilization of infiltration methods. However, this method has been limited due to the multi-step process and instability of long-term operation. In this study, we suggest a new process that combines the infiltration and spray method with co-spray to diminish the multi-step. We fabricated a cathode in which the LSM and Sm_{0.5}Sr_{0.5}CoO_{3-δ} infiltration solvent coated simultaneously by the spray process and co-sintered. And we measured the cell performance and stability. Consequently, when applied as electrolyte-supported cells at 1073K, performance is measured by exhibiting a maximum power density of 0.986W cm⁻² in fuel cell mode and electrolysis performance of 0.878A cm⁻² at 1.3V. The result of this study was 0.724W higher than that of the bare LSM electrode.

PG2A-46 | SOFC 연결재용 460FC 에 전기영동법을 활용한 Zn doped MnCo-spinel 코팅층 증착 연구

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Solid oxide fuel cell (SOFC)는 연료와 산화제의 전기화학적 반응을 통해 전기를 생성한다. Cell 사이 연료와 산화제의 혼입을 막아주는 interconnect 역할이 필수적이다. 작동 온도가 1000 °C 에서 600 - 800 °C로 감소함에 따라 세라믹 소재에서 금속 소재로 대체되었다. 금속 소재 중 ferrite 계열은 고온에 노출될 경우 Cr₂O₃를 먼저 형성해 SiO₂나 Al₂O₃ 같은 절연층의 형성을 막는다는 점이 우수하지만 장시간이 지날 경우 Cr₂O₃의 Cr이 휘발해 anode, cathode를 오염시키는 Cr 피독 현상이 관찰되었다. 이러한 Cr 피독 현상은 cell performance를 악화 시키는

단점이 있다. 따라서 금속 interconnect의 고온 산화분위기에서 장시간 안정성을 확보와 동시에 Cr의 activity를 낮춰 증발을 예방하기 위해 coating층의 필요성이 제시되었다. Coating 소재로서는 Mn-Co spinel 계열이 고온에서도 높은 전도성을 보이고, 기관에서 확산되는 Cr과 반응을 통해 reaction layer를 형성해 코팅층 외부로 확산을 억제한다는 연구들이 보고되고있다. 그 중에서 Zn를 도핑을 통해 (MnCo) spinel의 전기 전도성을 향상 시킨 선행 연구를 통해 코팅 물질로 선정하여 EPD 방법을 통해 증착 하였다. 본 실험은 zeta potential을 기준으로 에탄올에 아이오딘을 분산하여 suspension을 제작하였다. EPD는 coating 층의 두께와 형상을 조절하며 최적의 조건으로 증착했고, 증착이 끝난 시편들은 치밀한 막을 얻기 위해 5 % H₂ - 95 % N₂ 분위기에서 800 °C 2시간 동안 환원했다. 환원이 끝난 시편은 800 °C, 1000 h 동안 재산화 과정을 통해 area-specific resistance (ASR) 과 산화에 따른 무게 변화를 측정했다. ASR이 끝난 sample 들은 electron probe micro-analyzer (EPMA)를 통해 Cr의 확산 정도와 line 분석을 통해 Cr, Mn 그리고 Co의 영역을 확인하여 reaction layer를 관찰하였다.

PG2A-47 | 세라믹 기반 분리막을 이용한 리튬 선택적 추출 시스템 개발 및 인가 전압에 따른 추출 효율 분석

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In recent times, numerous studies have focused on the extraction of lithium ions from seawater utilizing membranes. The prospect of directly extracting lithium ions from seawater presents an appealing opportunity to establish an efficient means of securing a lithium supply. Nonetheless, extracting lithium from seawater remains a significant challenge due to its low concentration and the presence of abundant interfering ions. To achieve selective separation of lithium ions, the use of a nano-channel-equipped separator becomes imperative, facilitating the passage of only lithium ions. This research encompasses a three-module system for lithium ion extraction, employing an anion exchange membrane (AEM) and a perovskite-structured Li_{0.33}La_{0.56}TiO₃ (LLTO) membrane. The system's configuration involves an aqueous solution of saturated NaCl in the left module, a lithium-containing aqueous solution in the central module, and an aqueous solution of phosphoric acid in the right module. A platinum (Pt) plate electrode serves to draw out lithium ions. A continuous extraction system, facilitated by a peristaltic pump, enables the continuous extraction of a high-concentration lithium aqueous solution. A voltage of 3.7 V applied over 20 hours yielded a current of

approximately 1 mA, resulting in an extracted solution with a lithium concentration of at least 250 ppm. It also analyzes lithium extraction performance and efficiency, achieved by applying varying voltages (1.7, 2.7, 3.7, and 4.7 V) to the system modules. This work is fundamental to the extraction of lithium ions from seawater and contributes to research comparing ion extraction efficiency as a function of applied voltage in aqueous systems.

PG2A-48 | Effect of Al₂O₃ layer deposited using atomic layer deposition on electrochromic characteristics of amorphous WO₃ thin films

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Electrochromic devices (ECDs) are a subject of extensive research due to their potential applications in energy-efficient technologies such as smart windows. ECDs can change their optical properties in the visible spectrum via charge insertion or extraction. WO₃ is a commonly used inorganic material in ECDs due to its excellent memory effect and coloration efficiency. The degradation mechanism of ECDs manifests as a decrease in transmittance variation (ΔT), which can be attributed to two primary factors. Firstly, during the bleaching process, the intercalated lithium ions within the electrochromic electrodes may exhibit irreversible de-intercalation. Secondly, the repeated intercalation and deintercalation of lithium ions can induce volumetric changes, leading to peeling or dissolution of the electrode materials. This study involved the fabrication of an electrochromic electrode made of a thin film of WO₃. The fabrication process included electrophoretic deposition (EPD) followed by atomic layer deposition (ALD) of Al₂O₃ to minimize degradation. The change in transmittance of the electrode was evaluated in-situ using a He-Ne laser and a potentiostat. Additionally, the surface morphology of the WO₃ thin film was examined using high-resolution scanning electron microscopy (HR-SEM) after conducting electrochemical measurements.

PG2A-49 | 고성능 대칭 고체 산화물 전지를 위한 Sr₂Fe_{1.5-x}Co_xMo_{0.5}O_{6-δ} 이중 페로브스카이트 시스템의 상전이 특성 최적화

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Double perovskite oxides have garnered considerable attention as electrode materials of symmetrical solid

oxide cells (SSOCs), owing to their good electrochemical activity and robust redox-stability under various fuel conditions. In this work, we present an approach to modulate the phase transformation of Sr₂Fe_{1.5-x}Co_xMo_{0.5}O_{6-δ} (CSFM, x= 0, 0.1, 0.3, 0.5) double perovskite system through precise control of B-site Co doping. The resulting 3CSFM (Sr₂Fe_{1.2}Co_{0.3}Mo_{0.5}O_{6-δ}) exhibits enhanced CoFe nanoparticle exsolution properties with great phase transformation stability under redox cycle condition. The SSOC button cell with 3CSFM demonstrate outstanding electrochemical performance compared to undoped Sr₂Fe_{1.5}Mo_{0.5}O_{6-δ} (OCSFM), achieving excellent peak power density of 1.27 W cm⁻² (in H₂ fuel cell mode at 850 °C) and great performance of 2.33 A•cm⁻² at 1.6 V (in H₂O electrolysis mode at 800 °C). These results highlight the substantial effect of B-site doping in nano-structuring double perovskite materials, offering promising prospects for the development of high performance catalysts across a wide range of energy conversion applications.

PG2A-50 | Thermal stability and insulation property improvement of Y₂O₃-doped Silica aerogel

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To enhance the thermal properties of silica aerogels, it is crucial to mitigate radiative heat transfer. Incorporating Y₂O₃ into the silica sol to obscure the infrared radiation of silica aerogels has exhibited enhanced stability under high temperatures. The impact of introducing Y₂O₃ on the aerogels' insulation at elevated temperatures and the specific extinction coefficient of the produced aerogels were probed. Y₂O₃ nanoparticles contribute to diminishing the portion of macropores, consequently leading to a reduction in their thermal conductivity. The augmentation of Y₂O₃ concentration correlates with an observable increase in the thermal resilience of the silica aerogels. The inclusion of Y₂O₃ in the silica aerogels elevates the specific extinction coefficient, thereby resulting in a noticeable attenuation of radiative heat transfer for Y₂O₃-opacified silica aerogels. Microscopic images distinctly illustrate spherical granular structures, wherein the average particle size escalates with higher Y₂O₃ content due to Y₂O₃ powder aggregation within the silica network.

Acknowledgement: This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government (MSIT) (No. 2020

R1A5A1019131).

PG2A-51 | Research about Surface Modification Effect of Trimethylethoxysilane for Silica Aerogels

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Silica aerogels have specific properties such as high specific surface area (>350 m²/g), high porosity (80~99.8%) and low density (~0.003 g/cm³). Based on these excellent physical properties, it has been applied for industrial and research field. Silica aerogels can be synthesized by sol-gel method and ambient pressure drying that is most cheap method synthesizing silica aerogels compared to other drying methods. In this work, the effect of trimethylethoxysilane (TMES) as an alternative silylating agent was investigated. TMES is a kind of alkoxysilanes which can increase the degree of hydrophobicity and other physical properties for silica aerogels when it can be used as a co-precursor. It can be suggested that TMES can act as an alternative silylating agent similar with trimethylchlorosilane (TMCS). Aerogels which are synthesized by different surface modification conditions with TMES, TMCS, and mixture of TMCS and TMES with various ratio.

Acknowledgement: This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. 2020R1A5A1019131).

PG2A-52 | NiO/RuO₂ Composite Nanofiber Catalyst for High-Performance Li-CO₂ Batteries

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Li-CO₂ batteries present high potential due to their environmentally friendly utilization of CO₂ during the charging and discharging, and theoretically achieving the very high energy density (~1,876Wh/kg). However, the most significant drawback of these Li-CO₂ batteries is the formation of hard-to-dissociate substances like Li₂CO₃ as discharge, leading to increased overpotential and reduced energy efficiency, thereby degrading battery performance. Consequently, the utilization of catalysts that can assist in the decomposition of these discharge products is essential for Li-CO₂ systems. Herein, this study reports the utilization of the NiO/RuO₂ composite catalytic nanofiber (NRO) are employed in Li-CO₂ batteries to achieve low overpotential and high

energy efficiency. NRO shows high advantages as a catalyst for Li-CO₂ batteries; depending on the orbital structure and energetic characteristics. Additionally, it is manufactured in the form of nanofibers through electrospinning, which has a high specific surface area that enhances reactivity as a catalyst. As a result, NRO is an efficient way to decrease overpotential and increase energy efficiency as a catalyst for Li-CO₂ batteries.

Keywords: nickel oxide, ruthenium oxide, catalyst, nanofiber, electro spinning, Li-CO₂ batteries

PG2A-53 | Electrospun Al-LLZO Ceramic Nanofiber/PVDF-HFP Composite Electrolytes for Flexible Solid State Lithium Batteries

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The use of solid electrolytes in lithium metal batteries offers the advantage of accommodating a lithium metal anode, which in turn provides higher capacity and energy density. However, achieving stable operation of lithium metal batteries is challenging due to the compromised ionic conductivity of solid electrolytes and the limited compatibility between the electrolyte and electrode interfaces. In this work, we have tried to improve the above problems by developing a composite electrolyte using a combination of polyvinylidene fluoride-co-hexafluoropropylene (PVDF-HFP) and 1D electrospun nanofibers of aluminum-doped garnet structure Li_{6.28}La₃Zr₂Al_{0.24}O₁₂ (Al-LLZO). These Al-LLZO nanofibers were integrated into the PVDF-HFP polymer matrix as a filler. Furthermore, the incorporation of succinonitrile as an additive enhances lithium-ion mobility by creating continuous pathways for Li-ion transport, thereby contributing to improved ionic conductivity. As a result, the composite solid electrolyte demonstrated a significantly high ionic conductivity, and a symmetric Li||Li cell with this composite electrolyte maintained a consistently flat and stable voltage potential and exhibited an extended cyclic life, exceeding 1000 hours of operation.

PG2A-54 | The influence of fluorine doping on tin oxide aerogel in conjunction with Pt nanocomposite for the purpose of electrocatalytic metal oxide support

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The electrocatalytic water-splitting process plays a

critical role in the creation of hydrogen, which is essential for attaining objectives such as zero carbon emissions, renewable energy generation, and large-scale manufacturing capabilities. Nevertheless, it has been shown that Pt/C, which has been marketed, has notable activity in the hydrogen evolution process. However, it has faced criticism due to the occurrence of metallic Pt corrosion when used in acidic electrolytes. There is a pressing need for the development of electrocatalysts that exhibits chemically robust reaction kinetics. The catalytic efficiency and long-term corrosion resistance of a novel hybrid catalyst, which is extensively disseminated inside a three-dimensional aerogel matrix of F-doped SnO₂, have been shown over a span of 10,000 cyclic voltammetry cycles. The use of an F-SnO₂ support structure has been shown to effectively mitigate metallic corrosion and provide enhanced electrochemical characteristics compared to Pt/C.

Acknowledgement: This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. 2020R1A5A1019131).

PG2A-55 | 인가된 전류밀도 차이에 따른 IT-SOFC 공기극의 미세구조 특성 변화 연구

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일반적으로 중저온형 고체산화물 연료전지(IT-SOFC)의 성능은 IT-SOFC 공기극의 미세구조에 의해 영향을 받을 수 있다. 따라서 높은 성능을 얻기 위해서는 IT-SOFC 공기극의 미세구조 특성을 연구하는 것이 중요하다. 이러한 관점에서 본 연구팀은 층상 페로브스카이트 구조의 공기극 SmBa_{0.5}Sr_{0.5}Co₂O_{5+d} (SBSCO)를 제작하고, SBSCO 공기극의 미세구조적 특성과 그에 따른 전기적 특성을 연구하였다. 그 결과로 치밀한 미세구조와 다공성 미세구조를 가지는 동일한 조성의 SBSCO 공기극에서 높은 전류밀도를 인가하였을 때, nanoneedle과 nanoflower 등 특이한 형상의 미세구조가 관찰되었다. 특히 nanoneedle은 공기극 표면 전체에 형성되었으며, nanoneedle이 존재하는 공기극이 일반 공기극에 비해 우수한 전기적 특성을 나타낸 것을 확인하였다.

PG2A-56 | 리튬 메탈의 수지상 성장 억제를 위한 플루오린화 리튬(LiF)이 풍부한 코팅층의 영향

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리튬 메탈은 -3.04V (vs SHE)의 낮은 환원전위와 3860 mAh g⁻¹의 높은 비용량을 가지고 있어 고에너지 밀도를 충족시킬 수 있는 음극 재료로 주목받고 있다. 그러나, 리튬 메탈 표면의 산화물과 수산화물로 구성된 절연층의 존재는 불균일한 Li

plating/stripping을 유발하여 리튬 메탈의 수지상 성장을 야기하며, 이는 전지의 성능 저하 및 안전 문제의 원인이 된다. 본 연구에서는 리튬 메탈의 수지상 성장을 억제하기 위해, 리튬 메탈의 전처리 공정 없이 Fluoroalkylsilane (FAS)을 기화시키는 과정만으로 리튬 수산화물의 수산화 이온과 FAS 말단기 사이 치환 반응을 통해 플루오린화 리튬 (LiF)이 풍부한 코팅층을 형성하였다. 이 코팅층은 기계적/화학적으로 안정한 특성을 보일 뿐만 아니라, 국부적인 리튬의 증착을 억제하여 리튬 메탈의 수지상 성장을 효과적으로 완화하였다. 전기화학적 특성 분석 결과, FAS 코팅된 리튬 메탈을 사용한 symmetric cell은 1mA cm⁻²에서 190mV의 과전위를 보이며, 200시간 이상 사이클링이 가능하였다. 본 연구는 FAS의 SAM (self-assembled monolayer) 코팅법으로 균일한 Li plating/stripping을 가능하게 하는 방법을 제시하였다.

PG2A-57 | 고에너지 기계적 밀링을 이용한 고성능 리튬이온전지 음극재 MoP₂/P와 MoP₂/P@CNT의 합성

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휴대폰과 같은 소형 모바일 IT 기기의 전원으로 사용되고 있는 리튬 이온 전지는 전자자동차와 에너지 저장 시스템(ESS)의 수요가 급증함에 따라 그 활용도가 넓어지면서 대용량의 에너지를 저장할 수 있는 배터리에 관한 연구가 활발히 이루어지고 있다. 현재 상용화 되어있는 음극 소재인 흑연은 용량이 매우 낮다는 단점이 있어 이를 대체할 새로운 음극 소재의 개발이 필요한 상황이다. 인은 리튬 이온과의 전환 반응을 통한 높은 이론 용량을 나타내면서 반응 전위가 낮다는 장점이 있다. 하지만 충/방전 시 부피 변화가 크고 전기전도도가 낮아 전지 수명 특성이 좋지 않다는 단점이 있다. 금속 인화물은 인의 장점을 유지하면서 인의 부피 변화를 감소시키고 전기전도도를 높여 수명 특성을 향상시킬 수 있어 배터리 음극 소재로서 각광받고 있다. 특히 몰리브데넘 이인화물(MoP₂)은 band gap이 없어 준금속의 성질을 나타내어 다른 금속 인화물에 비해 전기전도도가 높다는 장점이 있다. 따라서 본 연구에서는 MoP₂와 인의 복합체 형성을 통해 고성능 음극 소재를 개발하였다. 또한 CNT 코팅을 통해 높은 전류 밀도에서도 용량을 일정하게 유지할 수 있는 소재를 개발하였다. 본 연구에서는 고에너지 기계적 밀링법(HEMM)을 이용하여 수백 나노미터의 크기를 가지는 몰리브데넘 이인화물/인 복합체(MoP₂/P) 합성에 성공하였으며, 리튬 이온 배터리 음극 소재로서의 특성을 분석하였다. 100 mA g⁻¹의 전류 밀도에서 약 850 mAh g⁻¹의 초기 용량이 구현되었으며, 50 cycle에서 약 616 mAh g⁻¹의 고용량이 유지되었다. 또한, 1000 mA g⁻¹의 고전류 밀도에서도 150 cycle에서 약 393 mAh g⁻¹의 용량이 구현되었다. 또한 합성된 MoP₂/P와 CNT와의 추가적인 HEMM을 통해 3~5 nm 두께의 균일한 CNT 코팅(MoP₂/P@CNT)에 성공하였으며, 1000 mA g⁻¹의 고전류 밀도에서 200 cycle까지 약 586 mAh g⁻¹의 고용량이 일정하게 유지되어 안정적인 가역 용량 구현에 성공하였다. MoP₂/P@CNT의 rate 특성도 MoP₂/P에 비해 매우 향상되어 2000 mA g⁻¹의 고전류 밀도까지도 안정적인 용량을 유지함을 확인하였다.

PG2A-58 | Enhanced the textural properties of phenyltrimethoxysilane modified hydrophobic silica aerogels prepared by supercritical alcohol drying

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Phenyltrimethoxysilane (PTMS) and tetraethoxysilane (TEOS) were employed as co-precursors in varying molar ratios to produce silica aerogels via the sol-gel process and supercritical alcohol drying method was used. Hydrolysis and polycondensation procedures utilized oxalic acid and ammonium hydroxide as catalysts to form silica aerogels. The molar ratios of TEOS, methanol, oxalic acid (0.01 M), and NH₄OH (1 M) were maintained at 1: 30.2: 2, respectively, resulting in the formation of silica sol. Tuning the aerogel's characteristics involved adjusting the PTMS molar ratio from 0 to 1. The composite silica aerogels (PTMS/TEOS) were examined for chemical bonding, surface morphology, hydrophobicity, and textural features. Fourier transform infrared analysis confirmed chemical linkages and possible functional groups in hydrophobic silica aerogels. BET analysis revealed increased specific surface area (398 m²/g to 739 m²/g), and contact angle measurements indicated improved hydrophobicity (76°-149°). These physico-chemical properties make these hydrophobic silica aerogels suitable for thermal insulation applications.

Acknowledgement: This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. 2020R1A5A1019131).

PG2A-59 | High-performance perovskite-kesterite monolithic tandem solar cells enabled by the roughness control strategy

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In spite of the high potential economic feasibility of the tandem solar cells consisting of the halide perovskite and the kesterite Cu₂ZnSn(S,Se)₄ (CZTSSe), they have rarely been demonstrated due to the difficulty in implementing solution-processed perovskite top cell on the rough surface of the bottom cells. Here, we firstly demonstrate an efficient monolithic 2-terminal perovskite/CZTSSe tandem solar cell by significantly reducing the surface roughness of the electrochemically deposited CZTSSe bottom cell. The surface roughness (R_{rms}) of the CZTSSe thin film could be reduced from

424 nm to 86 nm by using the potentiostatic mode rather than using the conventional galvanostatic mode, which can be further reduced to 22 nm after the subsequent ion-milling process. The perovskite top cell with a bandgap of 1.65 eV could be prepared using a solution process on the flattened CZTSSe bottom cell, resulting in efficient perovskite/CZTSSe tandem solar cells. After the current matching between two subcells involving the thickness control of the perovskite layer, the best-performing tandem device exhibited a high conversion efficiency of 17.5% without the hysteresis effect.

PG2A-60 | 대칭 전극을 사용한 고체 산화물 전지 기반 암모니아 합성 연구

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암모니아는 수소에너지에 대한 에너지 저장 밀도가 높아 수소 캐리어로 용이하게 사용될 수 있다. 또한, 기존 비료 공급망 및 운송 라인과의 활용도가 높고 비용 측면에서도 이점을 지닌다. 현재 암모니아는 주로 하버-보슈법을 통해 생산되고 있다. 하지만, 하버-보슈법은 고온과 고압에서 작동하기 때문에 에너지 효율이 낮고 많은 에너지를 소비한다. 또한 수소를 생산하는 과정에서 전세계 이산화 탄소 배출량의 약 1.8%가 배출이 되는 문제가 있으며 이를 해결하기 위해 그린 암모니아 생산 기술에 대한 필요성이 증대하고 있다. 그 중 고체 전해질을 이용한 전기화학적 암모니아 합성 기술은 생산된 암모니아에 대해 추가적인 분리 공정이 필요하지 않을 뿐만 아니라 저온 암모니아 합성 기술에 비해 열역학적으로 물 분해 반응에 필요한 에너지 감소로 저온 암모니아 합성보다 구동 전압 장점이 있다. 현재 고온 암모니아 전기화학적 전지 연구는 캐소드 전극 지지체 셀(Ni Cermet)을 이용한 연구가 중점적으로 이루어지고 있으나, Ni Cermet 경우 전극의 산화를 막기 위해 수소 분위기에서 구동 해야 하나, 본 연구에서는 순수한 물과 질소로부터 전기화학적 합성이 가능한 대칭 전극형 고체 산화물 전지를 설계했다. 또한 증저온에서 높은 산소 이온전도성을 가지며 SOEC 구동조건에서 적합성을 가지는 La_{0.9}Sr_{0.1}Ga_{0.8}Mn_{0.2}O_{3-δ}(LSGM)을 사용하여 암모니아 합성속도(10⁻¹⁰~10⁻⁹ mol NH₃/cm²·sec)를 증진과 그린 암모니아 합성 전지에 대한 접근법을 제시하고자 한다.

PG2A-61 | Fabrication of anatase TiO_{2-x} nanofibers as an anode by the Intense Pulsed Light method

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TiO₂, also known as white TiO₂, has been proposed as a promising anode material for lithium-ion batteries (LIBs). It offers advantages such as low cost and

nontoxicity. And compared to graphite anode materials, TiO_2 exhibits better structural stability, enabling more stable operation during the lithiation/delithiation process. However, its electrochemical performance is hindered by low electrical conductivity due to a large energy bandgap of 3.0–3.2 eV. To replace white TiO_2 , TiO_{2-x} , called black TiO_2 , has been employed due to its good reactivity with lithium ion and improved electrical conductivity. Several methods involving heat treatment in a reducing atmosphere have been utilized for its preparation. TiO_{2-x} demonstrates significantly improved electrical conductivity compared to white TiO_2 . However, conventional methods – using high-temperature ($>300^\circ\text{C}$) electric furnace – for producing TiO_{2-x} are less productive as they require high thermal energy and long processing times (>1 hours). In this study, we introduce a novel approach for the fabrication of TiO_{2-x} using the Intense Pulsed Light (IPL) method. The IPL method enables rapid heat treatment within 7.5ms at room temperature and atmospheric pressure, leading to a significant increase in productivity compared to conventional methods. The reduction of TiO_2 nanofibers by IPL was observed to be more effective compared to TiO_2 nanoparticles, and its performance as anode was evaluated through battery tests.

PG2A-62 | 하소 온도가 전고체 전지 전해질의 이온전도도에 미치는 영향

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가넷 구조는 다른 구조의 산화물계 고체 전해질과 비교해 상대적으로 높은 이온전도도를 가지고 Li 금속과 고온에서도 높은 화학적 안정성의 특성상 전고체 전지의 전해질로서 주로 사용된다. 특히 가넷 구조를 갖는 LLZO의 경우 10^{-4} S/cm 의 비교적 높은 이온전도도를 가지고 Li 금속 대비 우수한 안정성을 가지고 있다. 이러한 장점으로 인해 최근 상온에서도 우수한 이온전도도를 가질 수 있는 가넷 형 고체 전해질에 대한 연구가 진행되고 있다. 본 연구에서는 가넷 구조의 전고체 전지 전해질의 이온전도도를 결정하는 다양한 조건 중 하소 온도에 따른 이온전도도의 전기화학적 특성을 알아보려고 한다. 하소 시간은 10시간으로 동일하게 설정하였고 하소 온도는 $600^\circ\text{C} \sim 900^\circ\text{C}$ 로 설정해 LLZTO 파우더를 제조하고, 파우더의 특성을 확인하였다. 각 하소 온도에 따라 이온전도도의 값이 다른 것을 확인하면서 하소 온도가 전고체 전지의 이온전도도 특성에 큰 영향을 미치는 것을 알 수 있었다. 그 중 $700^\circ\text{C}_{10\text{h}}$ 의 하소 조건과 $1100^\circ\text{C}_{8\text{h}}$ 의 소결 조건에서 소결을 진행한 LLZTO는 상온에서 4.89×10^{-4} S/cm의 이온전도도를 보이며 소결 밀도가 높고 이온전도도를 향상시킬 수 있는 최적의 열처리 조건으로 판단되었다.

PG2A-63 | Surface-Engineered BaNiO_3 Perovskite as a Promising Electrocatalyst for Oxygen Evolution Reaction

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The Oxygen Evolution Reaction (OER) is a crucial chemical process for generating oxygen in various practical applications such as water electrolyzers and metal-air batteries. However, the low efficiency of OER has hindered the advancement of these applications. To address this issue, we propose a cost-effective and sustainable solution by introducing surface-engineered BaNiO_3 (BNO) with a hexagonal perovskite structure as a promising electrocatalyst. Our study modulated the surface of BNO crystals by controlling the cooling rate at 5, 10, 30, and 60 $^\circ\text{C}/\text{h}$. We found that the surface of BNO crystals was covered with a Ni-rich layer that become more obvious with slower cooling rates. Despite this, all compositions displayed a single-phase perovskite structure as revealed by X-ray diffraction profiles and microstructure images. Our results showed that BNO crystals displayed exceptional OER performance, with the electrochemical kinetics of BNO60 being far superior to that of the commercial electrocatalyst IrO_2 : the potential at 10 mA/cm^2 was 1.69 V and the Tafel slope was 244 mV/dec . The OER activity was highest in specimens with a less obvious Ni-layer, which was prepared at a cooling rate of 60 $^\circ\text{C}/\text{h}$, as the Ni layer inhibited the OOH^* transformation. Our findings provide a general framework for developing perovskite-structured electrochemical catalysts by modulating their morphology.

PG2A-64 | 다성분계 세공 충전 복합 이온교환막 제조를 위한 무기 나노입자 분산액 함침 공정

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이온교환막은 고분자 주사슬에 이온을 전달할 수 있는 관능기가 수식되어 선택적으로 양이온, 음이온을 투과시킬 수 있는 전기화학적 분리막이다. 이온교환막 특성 개선을 위하여 이온교환막 내에 무기 나노입자를 첨가하는 복합 이온교환막에 대한 연구가 활발히 진행되고 있다. 본 연구에서는 세공 충전 이온교환막에 1가지 나노 입자 (SiO_2) 또는 2가지 나노 입자 ($\text{SiO}_2/\text{ZrO}_2$)를 첨가할 수 있는 간단한 함침 공정을 제안한다. 다공성 분리막에 나노입자 분산액을 함침한 뒤, 건조를 수행하면 나노입자가 포함된 다공성 분리막 (복합 다공성 분리막)을 얻을 수 있다. 이 후, 양이온 또는 음이온 모노머 전해질을 복합 다공성 분리막에 함침/광중합을 수행해 세공충전 복합 이온교환막을 얻을 수 있다. 2가지 나노입자가 포함되는 세공충전 복합 이온교환막의 경우,

다공성 분리막을 2가지 분산액의 2번 합침 공정에 의해 얻을 수 있다. 제조된 단성분계/다성분계 세공 충전 복합 이온교환막은 이온교환막 내 낮은 전해질 고분자 함량으로 인해 낮은 이온교환 용량 및 높은 저항을 지니고 있었지만, 나노 입자에 의한 전해질 고분자 내 관능기의 재배열 현상으로 인해 높은 선택도를 지니고 있었다. 키워드 : 복합 이온교환막, 세공 충전, 분산액, 무기 나노입자, 합침

PG2A-65 | Enhancement of Capacity Retention in Ni-rich $\text{LiNi}_{0.92}\text{Co}_{0.04}\text{Mn}_{0.04}\text{O}_2$ through dual modification of B Doping and Al_2O_3 coating as a Cathode for Lithium-ion Batteries

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Lithium-ion batteries (LIBs) are employed as an efficient portable energy source. The growing use of LIBs in electric vehicles has led to a demand for high practical specific capacity exceeding 200 mA h g^{-1} in cathode materials. Ni-rich layered $\text{LiNi}_x\text{Co}_y\text{Mn}_{1-x-y}\text{O}_2$ (Ni-rich NCM, $x \geq 0.8$) cathodes address this demand due to the lower energy band of Ni but suffer from limited capacity retention due to instability during cycling, including microcrack propagation and side reactions with electrolyte. The enhancement of capacity retention can be achieved through bulk doping and particle coating methods. Notably, B doping induces a plate-like morphology in the primary particles of Ni-rich NCM, alleviating internal stress and enhancing cycle performance. Additionally, Al_2O_3 coating mitigates the side reaction with the electrolyte, further improving the cycle performance. By combining B doping and Al_2O_3 coating, a dual modification approach for Ni-rich NCM is expected to yield substantial improvements in cycle performance through distinct mechanisms. In this study, we enhanced the capacity retention of the Ni-rich layered NCM cathode $\text{LiNi}_{0.92}\text{Co}_{0.04}\text{Mn}_{0.04}\text{O}_2$ (NCM9244) by employing dual modifications of B doping and Al_2O_3 coating. We synthesized B, Al_2O_3 dual-modified NCM9244 by incorporating B_2O_3 during the synthesis of NCM9244, followed by post-annealing for Al_2O_3 coating. Both modifications led to the electrochemical improvement. B doping resulted in plate-like primary particle morphology, which was retained after the formation of the Al_2O_3 coating layer during post-annealing. After 100 cycles at 0.5C-rate, the B, Al_2O_3 dual-modified NCM9244 exhibited a specific capacity of $164.54 \text{ mA h g}^{-1}$, representing 85.58% of the initial capacity. In comparison, B-doped NCM9244 and pristine NCM9244 showed specific capacities of

150.97 and $131.76 \text{ mA h g}^{-1}$, with capacity retentions of 82.97% and 70.23%, respectively. Furthermore, the B, Al_2O_3 dual-modified NCM9244 demonstrated superior rate capability, delivering a specific capacity of $163.10 \text{ mA h g}^{-1}$ compared to $149.38 \text{ mA h g}^{-1}$ of pristine NCM9244 at a high rate of 2C.

PG2A-66 | Synergy of liquid metal and in-situ polymerization for anode-free batteries

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Anode-free battery (AFB) using no excess Li-metal anode is a promising candidate for replacing conventional Li-ion batteries. However, there are major challenges including fast Li dendrite growth, low Coulombic efficiency, safety issue, and thickness problem, which hinder the practical application of AFBs using liquid electrolytes (LEs) and solid electrolytes (SEs). Herein, we report potential AFBs using polymer electrolyte (PE) and Li metal-free anode. The current collector surface is modified by coating nanocomposite layer comprising C and different liquid metal nanoparticles. The synergetic effects of PE and liquid metals (LMs) are carefully investigated. Besides, the in-situ polymerization and Li-LMs alloying are also clarified in this study. We observe that the polymerization depends on the solvent composition and the concentration of Li salt, and the cells containing polymerized electrolyte show better performance compared to other conventional LEs. LMs play a role as materials that rapidly become alloys with Li, resulting in the reduction of nucleation energy barrier for uniform deposited Li formation. Furthermore, the AFB with Ag-C composite on current collector is also fabricated and compared with our concept using LMs-C composite to examine the differences in the cell performance and working mechanism.

PG2A-67 | Regulating crystallization for efficient perovskite solar cells using metal - chelating agent

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Since various environmental issues such as abnormal climates due to global warming have emerged, humanity has been conducting research on various alternative energies to replace fossil fuels over the past few decades. Among them, perovskite solar cells (PSCs) have attracted enormous interest as promising next-generation photovoltaic devices, thanks to their excellent

optoelectronic properties and low-cost fabrication process. However, the efficiency and stability of PSCs are limited due to many defects that lead to nonradiative recombination loss and material degradation. To overcome these problems, attention must be paid to controlling morphology, grain boundary, grain size, and density of defect states in perovskite film. Additive engineering is one of the most efficient strategies for regulating the crystallization process, leading to reduce defects and large grain size. Herein, we used a chelating agent to facilitate the formation of high-quality target perovskite film with larger grains, reduced trap densities, and smoother film surfaces, compared to the control. By using a metal chelator as an additive in the perovskite precursor solution, the ligand forms chelate compounds with Pb^{2+} , which can form colloids in precursor ink and reduce Gibbs free energy during the crystallization process, resulting in perovskite film with larger grains. Moreover, anchoring between the chelator and exposed metal cations of the perovskite surface is beneficial to improve energy level alignment, leading to improved carrier extraction and transfer. This study demonstrates that metal-chelating polymers can improve the power conversion efficiency (PCE) and stability of PSCs by controlling the perovskite crystallization process.

PG2A-68 | GeO_2 Incorporated $Li_{1.5}Al_{0.5}Ti_{1.5}(PO_4)_3$ Ceramics for High Performance Solid Electrolyte

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In response to the safety concerns associated with liquid electrolytes, extensive researches are being conducted to explore solid electrolytes as alternatives for liquid electrolytes. This study focuses on the development of a NASICON-based solid electrolyte, $Li_{1.5}Al_{0.5}Ti_{1.5}(PO_4)_3$ (LATP), which is particularly promising due to its favorable attributes of high ionic conductivity and ease of handling among oxide-based solid electrolytes. By introducing GeO_2 into LATP, a notable advancement is achieved. During the sintering process, the combination of GeO_2 and LATP leads to the formation of a liquid phase at the interface with $LiTiPO_4$ secondary phase. This innovative configuration results in a remarkable 5 times increase in ionic conductivity when compared to the pure LATP phase. Moreover, the integration of GeO_2 along the liquid phase at the grain boundary serves to amplify the transport of lithium ions, further enhancing battery performance. Consequently,

these findings give the potential of incorporating GeO_2 to realize the next generation solid state batteries.

PG2A-69 | 고성능 흐름전극 축전식 염분차발전을 위한 활성탄 기반 복합 활물질 합성 및 특성 평가

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흐름전극 축전식 혼합 염분차발전(F-CapMix)은 해수와 담수 사이의 염 농도차이 및 흐름전극 내 활물질의 이온 흡착/탈착을 이용해 전기를 생산하는 재생 에너지 기술 중 하나이다. 본 연구에서는 F-Capmix 성능을 개선하기 위해 멜라민 및 Ni source를 사용해 흐름전극에 사용하는 신규 활물질을 합성했다. 액체 형태의 흐름전극 내 활물질의 접촉에 의한 이온 및 전자 전달 특성을 향상시키기 위해 상용 활성탄 위에 carbon nanofiber(CNF) 성장을 유도해 복합 활물질을 제조했다. 제조된 복합 활물질의 분석 결과, 활성탄 위에 결정성 CNF가 성공적으로 성장되었음을 확인했고, 복합 활물질로 제조된 흐름전극은 F-Capmix 시스템 내에서 개선된 출력밀도 특성을 보였다. EIS (electrochemical impedance spectroscopy) 분석을 기반으로 개선된 출력밀도 특성은 활성탄 위에 성장된 CNF 사이의 효율적인 접촉에 의한 흐름전극 내에서의 활물질 사이의 개선된 이온 및 전자 전달 특성 때문으로 분석되었다.

PG2A-70 | Understanding the unique phase evolution of Prussian white cathodes by π electron transition during battery operation

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Transition metal-based Prussian whites (TM-PWs), consisting of a cyanide anion ($(-C\equiv N^-)$) and TM cations in an alternative manner, have a general chemical formula of $A_xP^{m+}R^{n+}(CN)_6$. The covalent bonding of cyanide anion form one sigma (σ) and two pi (π) bonds, which would significantly affect the phase transition behavior during battery operation; however, there have been only few studies on their associated features.

In this talk, the phase transition behavior controlled by the π electron transition during battery operations was investigated. In situ X-ray diffraction and X-ray absorption fine structure analyses reveal that the combined effect of π bonding between metal and ligand effectively controls the bond length of the TM-C \equiv N-TM unit, thus influencing the lattice volume of TM-PW cathodes during the charge/discharge process. This study presents a understanding of the structure-property relationship of the TM-PW cathodes involving π electron interactions during battery operations.

PG2A-71 | Synthesis of graphitic carbon coated nickel thiophosphate as bifunctional materials for Li-ion storage and oxygen evolution reaction

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가볍고 높은 에너지 밀도로 고용량, 고효율 구현이 가능한 리튬 이온 전지는 ESS 및 전기차에까지 그 사용처가 확대되고 있으며, 수전해 기술은 탄소 배출 없이 그린 수소 생산을 가능케 하여 현재 많이 각광받고 있다. 전원으로 사용되고 있는 리튬 이온 전지는 기술이 발달함에 따라 더 큰 저장용량을 필요로 한다. 그러나 현재 상용화 되어있는 흑연 음극재의 경우 용량이 낮다는 단점이 있으며, 수전해 기술에서 뛰어난 효율을 보이는 귀금속류 촉매 또한 상업적 이용의 불리함에 따라 대체할 물질의 개발이 필요하다. 다양한 음극 및 촉매 소재 후보군 중에서 금속 인산화물은 리튬 이온과의 전환 반응을 통해 높은 이론 용량을 나타낸다는 장점을 가지고 있다. 또한 2D 층상 구조의 넓은 표면적을 통해 촉매로 작용하는 active site를 보다 많이 제공해주며, 인접한 층 사이에 존재하는 반 데르 발스 힘에 따라 이온이 쉽게 이동할 수 있도록 낮은 에너지 장벽을 제공한다. 리튬 저장의 측면에서 인과 황의 단계적 산화 환원 반응은 전환 과정에서의 Strain을 줄여 전기화학적 특성이 우수하다. 하지만 사이클이 진행될수록 부피 팽창을 위시하여 집전체로부터의 박리, 불안정한 SEI 층 형성 등의 이유로 급격한 수명 감소가 이어진다. 또한 NiPS₃ OER 촉매로의 성능은 낮은 전도성 및 작동 전극에 도포 시 입자들의 응집 문제로 적용이 제한된다. 이를 해결하기 위해 NiPS₃의 표면에 graphitic carbon을 코팅하여 음극 및 촉매 소재가 가지는 고질적 문제인 낮은 전도성과 응집 현상 등을 완화하였다. 본 연구에서는 기상으로의 합성을 통해 NiPS₃를 합성한 뒤 고에너지 기계적 밀링법을 통해 표면에 5 nm 두께의 graphitic carbon 층을 형성하여 리튬 이온 전지 음극재와 촉매로서의 특성을 평가하였다. 순수 NiPS₃의 경우 100 mAh/g의 전류 밀도에서 초기용량 1200 mAh/g의 높은 용량이 구현되었으나, 층방전 과정에서의 비가역적인 반응 및 큰 부피 팽창으로 인해 용량이 빠르게 감소하여 50 cycle 진행 후에는 용량이 200 mAh/g 정도로 감소하는 현상이 발생하였다. 반면, graphitic carbon이 코팅 된 경우 탄소의 함유에 따라 초기용량이 1000 mAh/g 정도로 줄었지만, 100 cycle까지도 약 660 mAh/g의 용량을 유지하여 수명 특성이 크게 향상되었다. OER에서는 10 mA cm⁻²의 전류 밀도에서 296 mV의 낮은 과전압과 높은 안정성을 보였다.

PG2A-72 | Effect of Crystalline TiO₂ on V₂O₅-WO₃/TiO₂ Denitration Catalyst on Temperature

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Temperature shift V₂O₅-WO₃/TiO₂ (VW/Ti) catalysts for selective catalytic reduction of NO_x with NH₃ (NH₃-SCR) were prepared. The temperature shift performance of the catalysts was investigated using different

heat-treated TiO₂. Nearly 100 % DeNO_x efficiency was achieved and shifted from higher to lower temperatures for the high-temperature treated TiO₂ catalyst. DeNO_x efficiency of the catalyst, along with the temperature shift effect was elucidated due to various sizes of TiO₂. It was also suggested that high-temperature treated TiO₂-based catalysts weaken the DeNO_x activity. A high V₂O₅ amount in the catalyst enhanced the DeNO_x efficiency at lower temperatures. This was due to the synergetic effect between V₂O₅ content and TiO₂ crystalline size. The catalysts prepared in this work potentially meet their application to effectively decompose NO_x at low temperatures.

PG2A-73 | 박막 고체산화물 셀을 이용한 연료전지-수전해 가역 운전 연구

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고효율 전기화학반응으로 고체 산화물 셀(Solid Oxide Cells, SOCs)은 특별한 귀금속 촉매의 활용 없이도 전기에너지 생산과 화학에너지 저장이라는 기술적 요구에 양방향 대응이 가능하다. 구체적으로 SOC의 전기화학적 가역운전은 수소와 산소를 연료 및 산화제로 활용하는 연료전지 모드와 수증기를 수소와 산소로 전기 분해하는 수전해 모드를 포함하는 것이다. 그러나 기존의 연료전지-수전해 가역 운전 셀은 고온 작동 온도로 인해 소재 및 환경 선택의 제약이 있으며 장시간 작동 시 부품 열화와 같은 문제가 있는 반면 작동 온도를 낮추는 경우 성능이 감소하는 경향을 나타낸다. 이러한 한계를 극복하기 위해 최근 낮은 작동 온도에서도 고성능을 발휘하는 기술 연구가 진행되고 있으며 그 중 하나의 방법으로서 박막 공정에 기반한 고성능 셀 제작 연구가 있다. 본 연구에서는 다층 진공 증착 기술을 사용하여 제작한 박막 연료전지-수전해 가역 운전 셀을 활용해 고온 전기분해 기술을 연구하고 그 가능성을 확인하였다. 연료전지-수전해 가역 운전 셀의 성능 및 전기 화학적 특성을 전류밀도-전압 측정과 전기화학 임피던스 측정법을 통해 분석하였고 미세구조를 관찰하여 구조와 성능 간의 상관관계를 조사하였다. 셀 성능은 첫 사이클에 연료 전지 모드에서 1.8 W/cm²의 peak power density를, 수전해 모드에서는 1.9 A/cm²의 current density를 나타냈다. 추후 저온에서 장기간 안정적으로 구동하는 박막 연료전지-수전해 가역 운전 셀을 제작하고 셀의 성능을 높이기 위한 연구를 계속적으로 진행할 예정이다.

PG2A-74 | The enhancement in pore properties of sodium silicate-based aerogel behalf of the addition of acetonitrile

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The sodium silicate-based aerogel has advantages in

commercialization due to the cheap cost precursor and safe drying conditions as ambient pressure drying. However, the sodium silicate-based aerogel retains lower physical properties than silicon alkoxide-based aerogel that uses supercritical drying. In this work, the drying control chemical additive (DCCA) is introduced to enhance the pore properties of sodium silicate-based aerogel. The acetonitrile was selected due to the lower boiling point and surface tension than the other DCCAs. In this study, we confirmed the acetonitrile can suppress the agglomeration of particles by forming a steric shield with methyl groups and keeping the pore size distribution uniformly with an appropriate molar ratio of acetonitrile/ Na_2SiO_3 . As a result, the sodium silicate-based aerogel showed a high specific surface area ($577 \text{ m}^2/\text{g}$), pore volume (3.29 cc/g), and porosity (93%) that are comparable to the pore properties of silica alkoxide based silica aerogels. Acknowledgement: This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. 2020R1A5A1019131).

PG2A-75 | 리튬이온의 선택적 투과를 위한 Lithium Lanthanum Titanate계 분리막 제조 공정 개발

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The global demand for raw lithium materials is rapidly increasing, accompanied by the demand for lithium ion batteries for next-generation mobility. The batch-type method, which selectively separates and concentrates lithium from seawater rich in reserves, could be an alternative to mining, which is limited owing to low extraction rates. Therefore, research on selectively separating and concentrating lithium using an electrodialysis technique, which is reported to have a recovery rate 100 times faster than the conventional methods, is actively being conducted. In this study, a lithium ion selective membrane is prepared using lithium lanthanum titanate, an oxide-based solid electrolyte material, to extract lithium from seawater, and a large-area membrane manufacturing process is conducted to extract a large amount of lithium per unit time. Through the developed manufacturing process, a large-area membrane with a diameter of approximately 20 mm and relative density of 96% or more is manufactured. The lithium extraction behavior from seawater is predicted by measuring the ionic conductivity of the membrane through electrochemical analysis.

PG2A-76 | LSM-YSZ functional layer를 적용한 고체 산화물 연료전지의 전기 화학 특성

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LSM은 우수한 전기 전도성 및 고온 안정성을 가지며 YSZ 및 GDC 전해질과의 반응성이 적어 500~700 °C 에서 작동하는 중·저온형 IT-SOFC의 공기극 물질로 사용된다. 하지만 Co가 포함된 공기극 물질에 비해 LSM은 상대적으로 적은 TPB(Triple Phase Boundary)를 가져 산소 활성화 반응이 덜 발생한다. 이를 개선하기 위해 LSM과 YSZ를 합성한 공기극 물질이 연구되고 있다. 본 연구에서는 TPB 증가 및 YSZ 전해질과의 열팽창계수 차이 감소를 위해 LSM과 YSZ를 5(YSZ):5(LSM) 및 8(YSZ):2(LSM) 비율로 합성한 functional layer를 적용한 샘플의 전기적 특성을 비교하였다. LSM은 상용 LSM82(A)와 자체적으로 합성한 $\text{La}_{0.8}\text{Sr}_{0.2}\text{MnO}_{3\pm\sigma}(\text{B})$ 를 사용하였다. LSM-YSZ를 합성한 functional layer를 적용했을 경우 LSM만 사용했을 때 보다 ASR이 감소하고 A와 B 샘플간의 ASR 차이 또한 감소하여 전기화학적 특성이 개선됨을 확인하였다.

PG2A-77 | 이동형 전원을 위한 고체산화물연료전지의 냉간 5분 쾌속 시동 연구

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저온 영역에서 고성능 구현이 가능한 박막형 고체산화물연료전지 (Thin film solid oxide fuel cell, TF-SOFC)의 발전에 따라 TF-SOFC는 폭넓은 응용분야에서 차세대 이동형 전력원으로 주목받고 있다. 그러나 실제 사용하는 이동형 전력원은 상온에서 작동 온도까지 도달하는 시간이 매우 짧아 급격한 온도 변화를 수반하는데, 이러한 환경과 비슷한 가혹한 조건에서 TF-SOFC를 운전하고 평가할 수 있는 시스템에 대해서는 매우 제한적인 연구들만 수행되어왔다. 따라서, 본 연구에서는 상온에서 작동 온도까지 냉간 쾌속 시동이 가능한 새로운 램프 가열형 평가 시스템을 개발하고 TF-SOFC의 성능 및 사이클 평가를 진행하였다. 전기화학 특성 평가를 통해 5분이라는 냉간 쾌속 시동 조건 적용에도 불구하고 600 °C에서 TF-SOFC는 약 1.124 V의 개회로 전압과 약 1.123 mW cm^{-2} 의 최대 전력 밀도를 갖는 것을 확인하였다. 상온과 고온을 왕복하는 장기 열사이클링 후에 전압 열화율은 500와 600 °C에서 각각 약 9.01 및 약 11.045%로 확인되었다. 본 연구의 결과는 앞으로 차세대 이동형 전원 장치로써 TF-SOFC를 적용하기 위한 연구 기술 개발의 교두보가 될 것으로 기대된다.

PG2A-78 | Transparent lithium-ion batteries with fully transparent materials

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The demand for next-generation transparent energy sources is increasing as a result of the rapid development

of transparent devices such as body sensors, smart lenses, transparent displays, and windows. It is essential to go above the constraints of traditional batteries, which are primarily opaque except for the solid electrolyte and have not yet become transparent. Previous studies on transparent batteries concentrated on creating micro-patterned devices with narrow line widths to produce a transparent battery with non-transparent materials. This strategy, however, has a low energy density and necessitates a large packing system. We have created a stackable transparent battery made entirely of transparent materials to overcome these difficulties. The creation of a transparent cathode, LiFePO_4 , with a wide bandgap of 3.7 eV and great transparency of over 75%, is one notable development. This makes LiFePO_4 a promising candidate for the cathode in transparent batteries. However, up until now, the creation of full cells has been limited by the lack of a transparent anode. To solve this problem, we developed a transparent anode that does not require an anode current collector during fabrication. Our novel Zn-doped SnO_2 (ZTO)/ AgTi_xCr_y (ATC)/Zn-doped SnO_2 (ZTO) multilayer anode demonstrates exceptional characteristics, including high transmittance of 90%, low sheet resistivity of $8.8 \Omega/\text{sq}$, and a high discharge capacity of $1036.9 \mu\text{Ah}/\text{cm}^2 \cdot \mu\text{m}$. The high electrical conductivity of the anode overcomes the demand for an anode current collector, simplifying the fabrication process. In this study, we successfully fabricated an all-solid-state full cell by integrating the ITO current collector, LiFePO_4 cathode, and LiPON electrolyte with ZTO/ATC/ZTO anode using radio frequency (RF) sputtering. We produced a cell with a total thickness of $1.5 \mu\text{m}$, excluding the glass substrate. Electrochemical analysis, involving 100 charge/discharge cycles, was performed within a glove box. The transparency of the full cell was verified using UV spectroscopy at 550 nm.

PG2A-80 | 마그네슘 도핑이 $\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$ 양극재의 전기화학 적 성능에 미치는 영향

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$\text{LiNi}_{0.5}\text{Mn}_{1.5}\text{O}_4$ (LNMO)는 코발트를 배제하며 낮은 니켈함량으로 비용 효율적이면서도 상당한 에너지 밀도(650 Wh kg^{-1})를 제공하는 양극재이다. 그러나 충방전과정에서 일어나는 상전이와 Mn^{3+} 의 Jahn-Teller distortion은 LNMO의 구조적 불안정성을 유발하여 배터리의 용량 손실을 가속화한다. 본 연구에서는 용융염법을 이용하여 제조된 단결정 LNMO에 소량의 마그네슘을 도입하여 충방전시 LNMO의 구조변화에 미치는 영향을 분석하였다. XAFS 분석 결과, LNMO내 마그네슘 도입은 충방전시

발생하는 전이금속과 산소의 결합 길이 변화를 완화하여 LNMO 입자 내부의 응력을 효과적으로 줄일 수 있음을 확인하였다. 또한, in-situ XRD 분석을 통해 마그네슘 도입이 LNMO의 충방전시 발생하는 격자 상수 변화 및 상전이를 효과적으로 억제한다는 것을 확인함으로써, 장기 사이클동안에도 LNMO의 구조적 안정성을 향상시킬 수 있음을 확인하였다. 본 연구는 마그네슘 도입을 통해 LNMO의 구조적 불안정성 문제를 완화하여, 고전압 LNMO양극재의 수명 특성을 향상시킬 수 있는 가능성을 제시하였다.

PG2A-81 | Half cell 제작 방법에 따른 $\text{SmBa}_{0.5}\text{Sr}_{0.5}\text{Co}_x\text{O}_{5+d}$ layered perovskite 산화물의 전기화학 특성 연구

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최근 많은 연구 팀에서는 중저온형 고체산화물 연료전지 (IT-SOFC)의 공기극 물질로서 우수한 산소이동도와 표면 특성을 갖고 있는 $\text{A}^{1/2}\text{B}_2\text{O}_{5+d}$ 구조의 Layered perovskite 산화물을 연구하고 있다. 본 연구팀에서는 layered perovskite 산화물 $\text{SmBa}_{0.5}\text{Sr}_{0.5}\text{Co}_2\text{O}_{5+d}$ (SBSCO)를 IT-SOFC의 공기극 물질로서 적용하여 공기극의 특성을 연구하였다. 특히 SBSCO 기본 조성에서 Co 치환량을 변화시킨 비화학량론 조성을 이용하여 공기극의 전기화학특성 연구를 진행하였다. 그 중 전기화학특성이 가장 우수한 $\text{SmBa}_{0.5}\text{Sr}_{0.5}\text{Co}_{2.05}\text{O}_{5+d}$ (SBSCO-2.05)와 기본조성 SBSCO를 이용하여 half cell을 제작하였으며, 본 연구에서는 다양한 제작방식을 적용하여 그에 따른 전기화학특성의 변화를 연구하였다.

PG2A-82 | 전기방사법을 통한 1차원 구조를 갖는 Mn_5O_8 나노파이버의 전기적 & 전기화학 특성평가

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최근 고출력 에너지 저장 매체의 개발에 대한 관심이 커지면서 슈퍼커패시터가 주목 받고 있다. 전극 활물질로 망간 산화물은 자연에서 다양한 산화상태로 발생하며, 저렴하고 환경친화적인 장점으로 인해 촉매 및 전기화학 에너지 저장매체와 같은 기술적 응용분야에서 중요성을 가지고 있어 RuO_2 를 대체 가능한 물질로 주목 받고 있다. Mn_5O_8 은 수소·산소 생산, Na이온 에너지 저장 매체에 대한 연구가 진행되어왔다. 본 연구에서는 KOH 내에서 슈퍼커패시터 특성을 확인해보고자 전기방사법을 통해 제작하였다. 또한 동일 합성 공정 내 상이한 온도에서 열처리하여 Mn_3O_4 , Mn_2O_3 또한 나노파이버 합성에 성공하였다. XRD 분석결과 250, 350, 500°C에서 열처리한 샘플은 각각 Mn_3O_4 , Mn_5O_8 , Mn_2O_3 로 확인되었다. TEM 분석 결과 직경 100 ~ 200 nm의 나노파이버가 합성된 것을 확인하였다. 슈퍼커패시터의 적용을 위해 전기화학 특성평가인 삼전극법을 활용한 순환전류전압법(CV)측정, 충·방전 분석 (GCD), 전기화학 임피던스 분석 (EIS)를 진행하였다. GCD, EIS 분석 결과 Mn_5O_8 나노파이버가 343.3 F/g의 가장 높은 비정전용량과 4.3 Ω 의 가장 낮은 전하 이동 저항(Rct) 값을 보였다. 전기전도도 측정을 추가적으로 진행

하였으며, Mn_5O_8 나노파이버가 $2.44 \times 10^{-4} \Omega^{-1} \cdot cm^{-1}$ 로 가장 높은 전기전도도 값을 나타내었다. 상기 결과로부터 전도도가 미치는 정전 용량 값의 영향과 Mn_5O_8 나노파이버가 큰 비표면적과 전하이동을 제공하는 2차상이 없는 나노파이버 구조이기에 우수한 성능이 나왔음을 확인하였다. 최근 고출력 에너지 저장 매체의 개발에 대한 관심이 커지면서 슈퍼커패시터가 주목 받고 있다. 전극 활물질로 망간 산화물은 자연에서 다양한 산화상태로 발생하며, 저렴하고 환경친화적인 장점으로 인해 촉매 및 전기화학 에너지 저장매체와 같은 기술적 응용분야에서 중요성을 가지고 있어 RuO_2 를 대체 가능한 물질로 주목 받고 있다. Mn_5O_8 은 수소·산소 생산, Na이온 에너지 저장매체에 대한 연구가 진행되어왔다. 본 연구에서는 KOH 내에서 슈퍼커패시터 특성을 확인해 보고자 전기방사법을 통해 제작하였다. 또한 동일 합성 공정 내 상이한 온도에서 열처리하여 Mn_3O_4 , Mn_2O_3 또한 나노파이버 합성에 성공하였다. XRD 분석결과 250, 350, 500°C에서 열처리한 샘플은 각각 Mn_3O_4 , Mn_5O_8 , Mn_2O_3 로 확인되었다. TEM 분석 결과 직경 100 ~ 200 nm 의 나노파이버가 합성된 것을 확인하였다. 슈퍼커패시터의 적용을 위해 전기화학적 특성평가인 삼전극법을 활용한 순환전류전압법(CV)측정, 충·방전 분석(GCD), 전기화학 임피던스 분석(EIS)을 진행하였다. GCD, EIS 분석 결과 Mn_5O_8 나노파이버가 343.3 F/g의 가장 높은 비정전 용량과 4.3 Ω 의 가장 낮은 전하 이동 저항(R_{ct}) 값을 보였다. 전기전도도 측정을 추가적으로 진행하였으며, Mn_5O_8 나노파이버가 $2.44 \times 10^{-4} \Omega^{-1} \cdot cm^{-1}$ 로 가장 높은 전기전도도 값을 나타내었다. 상기 결과로부터 전도도가 미치는 정전 용량 값의 영향과 Mn_5O_8 나노파이버가 큰 비표면적과 전하이동을 제공하는 2차상이 없는 나노파이버 구조이기에 우수한 성능이 나왔음을 확인하였다.

PG2A-83 | 플루오린 도핑을 통한 표면 안정화로 리튬이온전지 양극활물질 니켈 고품량 $LiNi_{0.9}Co_{0.05}Mn_{0.05}O_2$ 의 전기화학 성능 향상

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Ni 고품량 양극활물질 $Li[Ni_xCo_yMn_{1-x-y}]O_2$ ($x>0.6$)은 높은 용량(~180 mAh/g)과 상대적으로 저렴한 가격으로 인해 많은 관심을 받고 있다. Ni 함량에 비례하여 용량이 증가함에 따라 $Li[Ni_xCo_yMn_{1-x-y}]O_2$ ($x>0.9$)에 대한 연구가 활발히 진행중이나 용량이 증가하는 대신 microcrack, side reaction, phase transition 등으로 인해 낮은 수명특성을 보인다. 이러한 문제점을 개선하기 위해 Zr, Ti, Mg, B 등 다양한 원소에 대한 도핑 연구가 진행되고 있다. 여러 도핑 원소 중 F의 경우 리튬이온의 확산속도를 향상시킬 수 있으며, 전해질과의 부반응을 억제함으로써 더욱 우수한 수명특성을 보인다. 따라서, 본 연구에서는 F로 도핑된 $Li[Ni_{0.9}Co_{0.05}Mn_{0.05}O_2]$ (NCM9055)의 전기화학적 특성을 분석하여 F의 NCM9055에 대한 도핑 효과를 고찰하고자 하였다. NCM9055에 NH_4F (ammonium fluoride)를 첨가한 뒤 450°C에서 12시간 열처리하여 합성하였다. XRD (X-ray diffraction) 분석 결과 도핑에 따른 결정구조의 변화는 없었으며

TEM (transmission electron microscopy)을 통해 입자표면에 amorphous layer가 형성된 것을 확인할 수 있었다. 0.5 C rate, 2.5-4.4 V 조건에서의 100 cycle에 대한 전기화학적 특성평가를 진행하였다. undoped NCM9055의 경우는 143.3 mAh/g 용량으로 72.4%의 낮은 수명특성을 보였다. 반면 F doped NCM9055의 경우 86.0%의 우수한 수명 특성을 보이며 165.5 mAh/g 이상의 용량을 유지했다.

PG2A-84 | 자외선 조사에 따른 $SrTiO_3$ 나노파이버가 분산된 유무기 하이브리드 필터의 공기 정화 특성 향상

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광촉매 물질 중 페로브스카이트 구조를 가진 $SrTiO_3$ 는 물 분해 촉매, 전자기기 및 유기 오염 물질의 광촉매 분해에 두각을 드러낸다. 또한 $SrTiO_3$ 는 TiO_2 와 에너지 밴드갭이 3.2eV로 유사하지만 단순 이원 산화물과 비교하여 $SrTiO_3$ 는 다중 양이온 산화물로서 조성을 변경하여 화학적, 물리적 특성을 조절할 수도 있다. 첫번째 단계로 전기방사법을 활용하여 균일한 직경을 갖는 $SrTiO_3$ 나노파이버를 전기방사법으로 합성에 성공하였다. 이후 $SrTiO_3$ 나노파이버를 400°C, 600°C, 800°C에서 소결하여 파우더를 습득하고 XRD 및 SEM 분석을 진행하였다. XRD 분석 결과 제작한 파우더의 피크가 $SrTiO_3$ 페로브스카이트 결정구조의 피크와 일치하였다. SEM 분석 결과 $SrTiO_3$ 나노파이버의 평균 직경은 각각 320, 174, 165nm, 평균 결정립 크기는 각각 16, 26, 35nm였으며 이는 XRD 분석 이후 Scherrer eq. 을 통해 계산한 결정립 크기인 15.43, 24.08, 34.76nm와 유사함을 확인할 수 있었다. 볼밀링 공정을 통하여 $SrTiO_3$ 나노파이버를 균질하게 분쇄한 후 일정량을 유기물인 PAN과 혼합하여 2차 전기방사를 통하여 유무기 하이브리드 필터를 제작하였다. 필터 성능향상을 위하여 $SrTiO_3$ 나노파이버 양을 0.15~0.35g의 범위에서 조절하였고 PAN과 혼합한 후 전기 방사를 1~10분 방사를 수행하였다. 필터 테스트 결과 $SrTiO_3$ 나노파이버의 분산량을 0.35g으로 조절하여 전기방사를 2분간 진행한 필터의 품질계수(QF)가 가장 높았으며 이는 적절한 축적 밀도에 의한 차압의 영향으로 판단된다. 자외선 조사에 따른 품질계수값의 변화를 확인하기 위하여 자외선을 조사하지 않고 테스트를 진행한 것과 자외선을 조사하여 테스트를 진행한 것으로 나뉘었다. 전기방사를 2분간 진행한 필터의 자외선 조사 전후의 품질계수 차이는 각각 6.91, 9.08, 7.48%로 자외선을 조사한 필터의 품질계수가 높아짐을 확인할 수 있었다.

PG2A-85 | 고전압 작동을 위한 스피넬 $LiNi_{0.5}Mn_{1.5}O_4$ 양극재의 표면 개질

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LNMO($LiNi_{0.5}Mn_{1.5}O_4$) 양극재는 3차원 리튬 확산 경로를 갖는 스피넬 구조로 인해 우수한 율속 특성을 보이고, 코발트를 포함하고 있지 않아 가격 경쟁력이 높다. 또한 146.7 mAhg⁻¹의 가역 용량과 4.7V의 높은 작동전압으로 인해, 높은 에너지 밀도를 충족시킬 수 있는 양극재로 주목받고 있다. 그러나, LIB에서

사용하는 탄산염 기반의 유기 전해질은 4.5V 이상의 고전압에서 작동 시 산화 분해가 발생하는 문제점이 있다. 전해질 산화 분해의 산물인 HF는 양극재의 표면을 손상시키고 전이금속이 용출되는 문제를 야기하여 성능 저하의 원인이 된다. 본 연구에서는 표면에서 발생하는 전이금속의 용출 문제를 완화하기 위해, AlPO_4 와 Al_2O_3 를 코팅층으로써 적용하여 표면 분석 및 전기화학적 특성 평가를 진행하였다. Raman 분석을 통해 AlPO_4 와 Al_2O_3 가 코팅층으로 적용했을 때 Ni-O 결합에 해당하는 피크 강도의 차이를 관찰함으로써, 표면층을 구성하는 재료의 선택이 양극재 표면 구조를 변화시킬 수 있음을 확인하였으며, 이러한 양극재 표면의 물리 화학적 구조 변화가 계면에서 발생하는 리튬이온전도에 미치는 영향을 분석하였다.

PG2A-86 | Core-Shell Heterostructured Perovskite Quantum Dots Enabled Room-Temperature Spin Light-Emitting Diodes with High Selectivity

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Circularly polarized light (CPL) is a promising light source with wide potential applications. In this study, we propose core-shell heterostructured perovskite quantum dots (QDs) for room-temperature spin-polarized light-emitting diodes (spin-LEDs). Specifically, a 2D chiral perovskite shell based on (R)- and (S)-1-(2-(naphthyl)ethylamine) (R-/S-NEA) chiral cations with strong chiroptical properties is deposited onto the achiral 3D inorganic perovskite (CsPbBr_3) core. Owing to the chiral-induced spin selectivity effect, the spin state of the injected charge carriers is biased when they are transmitted through the 2D chiral shell. Systematic defect analyses also confirmed that R-/S-NEA successfully passivated halide vacancies of the CsPbBr_3 QDs, enabling high photoluminescence quantum yield of core-shell QDs. The resulting spin-LEDs delivered a maximum external quantum efficiency of 5.47% and circularly polarized electroluminescence with a polarization degree of 12%. Finally, various patterns fabricated by inkjet printing the core-shell QDs emitted strong CPL, highlighting their potential for next-generation displays.

PG2A-87 | High Efficiency middle-bandgap solar cells for Si/perovskite/perovskite triple junction tandem solar cells

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Halide perovskite materials have attracted a tremendous

attention as next-generation solar cell materials due to their superior optoelectronic properties and low-cost deposition processing. They are also suitable for use in multi-junction tandem solar cell because of their bandgap tunability, which is a promising approach to overcome the Shockley-Queisser limit of single-junction solar cells. While perovskite double-junction tandem solar cells have been extensively studied, there are only a few studies on triple-junction tandem solar cells. Although triple-junction tandems could theoretically achieve higher efficiency, the perovskite/Si double-junction tandem currently holds the highest record with a power conversion efficiency (PCE) of 33.7%. In comparison, the perovskite/perovskite/Si triple-junction tandem has achieved a PCE of 24.3%. To fabricate highly efficient tandem device, achieving current matching is crucial. However, in our triple-junction tandem cells, the middle-bandgap solar cell limits the current due to current mismatching. Therefore, it is necessary to enhance the current of the middle-bandgap cell. In this study, we controlled the cesium ratio in the perovskite composition to enhance the current of the middle-bandgap cells. As a result, we successfully reduced the bandgap from 1.57eV to 1.54eV, leading to an average short-circuit current (J_{sc}) improvement from about 22 mA/cm² to about 23 mA/cm². Furthermore, we focused on controlling the carrier transfer layers (CTLs) to further enhance the performance of the middle-bandgap cells. With the improved middle-bandgap cells, the J_{sc} of the triple-junction tandem cells increased from 9.74 mA/cm² to 10.33 mA/cm², resulting in a high PCE of 22.23% - the highest among perovskite/perovskite/Si tandem cells. Further research on the hole transfer layer (HTL) of the middle-bandgap cell could potentially further enhance the J_{sc} and overall efficiency of perovskite/perovskite/Si triple-junction tandem solar cells.

PG2A-88 | 고체전해질 환경에서 계면 환경에 의해 유발되는 배터리 양극 소재(NMC) 내 리튬의 불균일성 실시간 관측 및 규명

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고체 전해질을 사용한 전고체 전지는 높은 에너지 밀도로 주목받고 있으나, 기존의 액체 전해질과 비교해 전극 내 반응 불균일성이 더 크다고 알려져 있음. 그러나 이러한 불균일성이 증폭되는 정확한 원인은 아직 밝혀지지 않았음. 기존 분석은 전극 전체의 ensemble effect를 보기 때문에 그 원인을 분리하기 어려웠음. 이에 본 연구에서는 방사광가속기 기반의 플랫폼을 개발하여 단일 입자 단위로 전극을 관측했음. NMC표면에 LiNbO_3 코팅을

한 것과 그렇지 않은 것에 대하여 실시간 리튬이온 거동을 비교분석함. 이를 통해 계면 안정성이 입자 내 화학전위 변화에 미치는 영향과, 나아가 전지 수명에 주는 영향을 규명함. 코팅된 입자는 리튬이 매우 균일하게 확산되었음. 반대로 코팅되지 않은 입자는 충방전 모두에서 리튬 이온 거동이 불균일하였음. 이는 확산 계수가 빠르기 때문에 계면 부반응이 있더라도 리튬이 고르게 분포할 것이라는 기존 이론과 대치됨. 이 현상은 계면 부반응에 의하여 표면의 저항이 증가하고, 입자 내 불균일한 격자 변화가 생겨 입자 내 국부적으로 화학전위를 변화시킨 것으로 해석할 수 있음. 이러한 국부적인 화학전위 변화는 입자 내에 응력/변형을 필드에 변화를 일으키고, 불균일한 수축-팽창을 반복하게 하여 입자의 열화를 가속화함. 본 연구결과는 전극 내 전류 불균일도 및 응력 발생에 대한 근원적인 원리를 규명하였음. 이를 통해 전고체전지 계면 안정성 향상을 위한 계면 공정 기술 확보에 기여함.

PG2A-89 | Fabrication of Polyimide-Ceramic composite Separator Using Electrospinning Technique for Lithium-Ion Batteries

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The excessive use of fossil fuels has triggered an energy crisis and caused severe environmental problems. As a result, many researchers have been actively participating in the development of energy storage devices for secondary batteries. The Separators used in lithium-ion batteries(LIB) require characteristics such as high density, and excellent mechanical strength. Polyimide(PI) polymer separators have outstanding thermostability and do not deteriorate in performance even at high temperatures. The ceramic composite separators coated with silica or alumina particles have been used in power batteries due to their better electrolyte wettability.

In this work, we fabricated PI-ceramic composite separators for lithium-ion batteries using a electrospinning technique. The morphologies of the obtained separators were analyzed using scanning electron microscopy (SEM), Fourier transform infrared(FTIR) and X-ray photoelectron spectroscopy(XPS). Coin cells(2032) were fabricated using the developed separators, Ni-rich cathode and Li metal counter electrode. Their electrochemical characteristics were compared through performance evaluation.

PG2A-90 | 고성능과 안정적인 리튬 금속 전지를 위한 이중 염 고분자 전해질의 저장 및 사이클 성능 분석

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Lithium-metal batteries have garnered attention for high-energy. Plastic crystals combined with polymer electrolytes (PPEs) stand out as one of the promising candidates because of fast ion-conducting characteristics and exceptional processability. However, PPEs remain susceptible to lithium metal due to their inadequate (electro)chemical stability. As a result, most of the efforts have been dedicated to developing electrochemically stable polymer electrolytes by introducing additives, and dual salts. Among these strategies, the use of dual salts has gained significant traction within organic electrolytes. Through the introduction of small amounts of the salt mixture, the electrochemical performance experiences a significant boost. Despite numerous attempts to elucidate the role of dual salts, a comprehensive understanding of storage and cycling performance remains lacking. In this study, we employed different borate salts and FEC that have been individually investigated. These were comparatively investigated to characterize the structure and chemistry of the interphases. Through detailed electrochemical analyses, we explored the pivotal role each salt plays in influencing the SEI layer, the dendritic morphological evolution of lithium, and the alterations in interfacial resistance. Based on these observations, we would fulfill the strong demand for demonstrating further stable polymer electrolytes in terms of choosing dual salts.

PG2A-91 | Anode engineering using Ceria and Ruthenium deposited by ALD for direct ammonia-fueled SOFC

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Solid oxide fuel cells (SOFCs) are highly efficient and eco-friendly energy conversion devices using various fuels, including hydrogen, alcohol, and ammonia. Among them, ammonia is a carbon-free hydrogen carrier, can be used directly in SOFCs, is easier to transport and store than hydrogen, and has a high volumetric energy density. Therefore, this study aims to develop an effective catalyst for ammonia conversion and apply it to the anode side (Ni-YSZ anode support layer and Ni foam used as a current collector) of direct ammonia SOFC. Ruthenium is one of the most effective substances for ammonia conversion. Therefore, this study deposited Ru and Ceria together using atomic layer

deposition (ALD) on the anode side, improving the ammonia conversion rate. In addition, we attempted to determine the effect on ammonia decomposition by changing the thickness and particle size of Ru through ALD cycle control.

PG2A-92 | Cl계 용융염 원자로 구조재료의 고온 부식 후 Cr, Fe의 산화거동 및 분포

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4세대 원자로인 용융염 원자로(Molten Salt Reactor, MSR)는 안전성, 경제성, 소형화 측면에서 장점을 갖고 있다. MSR의 연화물염은 악티늄족 핵연료인 우라늄과 플루토늄에 대한 용해도가 높아 기존 불화물염에 비해 연료 효율이 향상되고 수소 생산에 이점이 있다. 그러나 고온 연화물염에 의한 구조재의 부식으로 인해 원자로의 재료적, 기계적 특성이 저하될 수 있어 방지 연구가 필수적으로 선행되어야 한다. 본 연구에서는 MSR의 구조재료 Fe계 기반의 Stainless Steel 316L, Ni계 기반의 Hastelloy C-276, Hastelloy N10003을 선정하고 NaCl-KCl-MgCl₂ 혼합염에서 800도, 48시간 동안 부식 침지 테스트를 수행하였다. 그 결과, Fe계 합금은 SEM(Scanning Electron Microscope)을 통해 약 400μm에 해당하는 Pitting 및 Grain boundary 부식 형상이 확인되었다. 또한 합금 성분 중 Cr, Fe의 높은 확산계수와 반응성으로 표면 Oxide layer 형성에 기인한 합금의 세라믹화 현상이 EPMA(Electron Probe Micro Analyzer), XPS(X-ray Photoelectron Spectroscopy)를 통해 확인되었다. 반면에 Ni계 합금은 느린 부식속도, 얇은 부식 영향층을 보이며 고온 용융염 환경에 가장 견전함을 보였다. 따라서 Ni계 저 Cr 함량의 Hastelloy N10003을 고온 용융염 부식에 가장 우수한 저항성을 갖춘 MSR의 후보 구조 재료로 제안함과 동시에 표면 개질에 대한 필요성을 제안한다.

PG2A-93 | Effects of surface modification for oxide-based solid electrolytes of all-solid-state batteries

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 Solid-state electrolytes have attracted much attention for their potential to improve the safety of Li-ion batteries. Li₇La₃Zr₂O₁₂ is a promising oxide-based solid electrolyte due to highly chemical stability with Li. However, there is highly interfacial resistance with Li because of the presence of Li₂CO₃ layer on its surface. In this study, an acid treatment as simple process was conducted to remove Li₂CO₃ layer and form a lithophilic layer and then optimize the process conditions by using electrochemical test. The lithophilic layer on the surface of solid electrolyte inhibited the formation of Li dendrites by blocking interfacial electron transport. The results

can offer an efficient solution of the issues faced on all-solid-state batteries.

PG2A-94 | Suppressing Sn ion oxidation using reducing agent for stable Sn-Pb mixed perovskite solar cells

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Perovskite solar cells have attracted as next-generation solar cells due to their high absorption coefficient, easy bandgap tuning, and advantage of low-temperature solution processing. To achieve higher efficiency compared to single-junction solar cells, all-perovskite tandem solar cells are actively studied which combine two perovskite subcells with different bandgaps. In particular, Sn-Pb mixed perovskites are commonly used as bottom cell of all-perovskite tandem solar cells. However, there is an issue that Sn²⁺ is easily oxidized to Sn⁴⁺, which generates Sn vacancies in perovskite lattice. Sn vacancies can act as trap sites and shorten carrier diffusion length, which degenerates Power Conversion Efficiency (PCE) and stability of solar cell. To prevent the degradation caused by Sn ion oxidation, a strong reducing agent is needed. In this study, we used Ni metal as a reducing agent. As a result, oxidized Sn ions on perovskite film surface were reduced when Ni metal was used. Moreover, we achieved 22.26% PCE of single junction Sn-Pb mixed perovskite solar cell and 90% of initial efficiency was maintained after 1250 hours when kept in air. The results are expected to contribute improving efficiency and stability of all-perovskite tandem solar cells.

PG2A-95 | 전기화학적 CO₂ 환원을 위한 고체 직접 분사 스프레이를 통해 페로브스카이트 기반 전극에서 Ce(Mn, Fe)O₂의 촉매 활성 강화

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Solid oxide electrolysis cells (SOECs) have tremendous potential to be highly efficient devices for high-temperature CO₂ electrolysis. In general, the commonly used Ni-based cathodes suffer from inherent redox instability during direct CO/CO₂ conditions. Therefore, the robust perovskite oxide La(Sr)Cr(Mn)O₃ (LSCM) is suggested as an alternative due to its excellent coking resistance. However, the LSCM cathodes are limited due to their poor catalytic activity on CO₂ reduction. [1] To alleviate this problem, the Ce(Mn, Fe)O₂

(CMF) was added as a catalyst owing to the surface oxygen vacancy of CMF, which accelerates the chemical adsorption of CO₂. [2] In this study, the solid direct injection process by ultrasonic spraying (SDI-USSP) is employed to fabricate the nano-decorated embedded CMF on LSCM surface as enhancing catalytic activity. The highly decorated electrode surface with CMF nano catalyst was embodied by an advanced one-step SDI-USSP without any complicated pretreatment and infiltration. We also analyzed the uptake of the catalytic activity and the ratio of CMF nanocatalysts through comparison with conventional composite electrodes. Consequently, when applied as a cathode for electrolyte-supported cells, the performances are measured at 1123 K, exhibiting a maximum power density of 1.35 W cm⁻² in fuel cell mode (H₂) and electrolysis performance of 2.76 A cm⁻² at 1.5 V in CO₂ reduction with high faradaic efficiency of nearly 94 %.

PG2A-96 | Investigation of Abnormal Grain Growth in LATP solid electrolyte

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Li_(1+x)Al_xTi_(2-x)(PO₄)₃ has been extensively researched as a potential solid electrolyte material for Li-ion batteries and all-solid-state batteries due to its high safety and high ionic conductivity. However, abnormal grain growth occurs within the LATP electrolyte during the sintering process, which leads to bimodal grain size distribution and the formation of microcracks. Therefore, research has been conducted on the effects of abnormal grain growth through pressure and temperature control during hot pressure sintering. In this study, the changes in the ionic conductivity and microcracks due to abnormal grain growth within the LATP03(x=0.3) electrolyte were examined.

PG2A-97 | 변형된 공침법을 이용한 나노크기의 Ga 도핑 Li-La-Zr-O 분말 합성

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리튬이차전지의 안정성 이슈로 최근 고체전해질을 이용하여 전고체전지에 대한 관심이 커지고 있다. 특히 Li₇La₃Zr₂O₁₂ (LLZO)는 높은 리튬이온전도도($> 10^{-4}$ S/cm), 넓은 전기화학 전위창, 및 리튬금속과의 안정성으로 많은 관심을 받고 있다. 하지만 분말 합성 시 조대화가 진행되어 마이크로 미터 이하의 크기를 갖는 입자 합성도 쉽지 않은 것으로 알려져 있다. 본 연구에서는 마이크로 미터 이하의 크기를 갖는 분말을 합성하기 위해 공침법과 고상합성법의 조합인 변형된 공침법을 이용하였다. 이 방법을

이용하여 나노크기의 Ga이 도핑된 LLZO 분말을 합성하는데 성공하였다. 결정구조 분석결과 입방정(cubic crystal structure)을 갖는 것으로 확인되었다. 이 성과는 정부(과학기술정보통신부)의 재원으로 한국연구재단의 지원을 받아 수행된 연구임(No. RS-2023-00236572, NRF-2020R1A2C2009821).

PG2A-98 | 2차원구조 티타늄산화물 나노시트를 이용한 무음극 전극에서의 리튬 수지상 억제

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고밀도 전지로 주목받고 있는 무음극 전지 및 리튬금속전지(Lithium Metal Battery, LMB)에서 리튬 수지상 성장이 큰 이슈로 제기되고 있다. 이를 해결하기 위해 전해질 조성 제어, 리튬 표면 개질, 지지체 미세구조 제어 및 금속-리튬 합금화 연구전략이 사용되었다. 상응하여 충방전 특성이 개선된 결과가 보고되고 있다. 하지만 리튬 수지상 형성 및 성장은 장기 사이클 특성에서 여전히 중요한 문제이다. 본 연구에서는 2차원 티타늄산화물 나노시트 기능층을 이용하여 리튬 수지상 성장을 억제하였다. 나노시트를 적층하여 제조한 기능층은 다양한 두께 (0.25 μ m ~ 1.2 μ m)로 제조되었으며, 두께에 따라 무음극 전지의 충방전 특성이 연구되었다. 기능층은 티타늄산화물 서스펜션을 이용하여 구리 기판 위에 전기영동법으로 제조되었다. 무음극 전지 셀에 기능층 도입으로 리튬 수지상 성장이 억제됨을 확인할 수 있었다. 이 성과는 정부(과학기술정보통신부)의 재원으로 한국연구재단의 지원을 받아 수행된 연구임(No. RS-2023-00236572, NRF-2022M3H4A1A01010836).

PG2A-99 | Synthesis of black TiO_{2-x} particles having a high concentration of oxygen vacancies with excellent photothermal conversion efficiency through ultrasonic spray pyrolysis

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The photothermal effect is a phenomenon that converts absorbed photon energy into heat. Noble metal and carbon-based materials do not satisfy high photo-to-thermal conversion efficiency, physicochemical stability, and cost-effectiveness all at once. However, semiconductor materials with good stability and economic feasibility can lead to excellent photothermal performance by inducing high concentrations of oxygen vacancies. A partial reduction process that has limitations in increasing the concentration of oxygen vacancies has been conducted for synthesizing oxygen-deficient black metal oxide. In this study, black TiO_{2-x} particles were synthesized by ultrasonic spray pyrolysis process which is an incomplete oxidation synthesis route capable of introducing high concentrations

of oxygen vacancies. This was achieved through the control of the carrier gas and the design of the precursor solution. To identify the effect of high concentrations of oxygen vacancies on photothermal performance, the presence of oxygen vacancies and photothermal properties of black TiO_{2-x} particles were investigated.

PG2A-100 | 무음극 배터리 계면 안정성 향상을 위한 구리 전극의 플라즈마 표면개질 연구

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최근 전기자동차 시장의 확대에 따라 기존 리튬이온전지 대비 고용량, 고출력 성능을 유지할 수 있는 배터리 개발에 대한 연구가 활발히 진행되고 있다. 특히 리튬 금속은 높은 이론 용량 (3,680 mAh/g), 낮은 밀도 (0.534 g/cm^3) 특성 때문에 리튬황전지, 리튬공기전지 등 차세대 이차전지용 음극재로 주목받고 있다. 하지만, 리튬 수지상 결정 (dendritic) 성장으로 인한 배터리의 안정성 및 성능 저하 등의 문제가 대두되면서 음극 자체에 리튬을 제거하거나 극소량의 리튬만 적용하는 기술에 대한 관심이 급증하고 있다. 무음극 배터리는 제조가 용이하고, 높은 에너지 밀도 제공이 가능하며, 안전성 및 경제적 측면에서 상당한 장점을 지니고 있으나, 불안정한 구리 음극 표면으로부터 기인하는 급격한 용량 감소 현상이 발생하고 있어 이를 개선할 수 있는 기술 개발이 요구되고 있다. 본 연구에서는 구리 음극 표면의 플라즈마 표면개질 (산화 및 질화) 공정 최적화를 통해 인위적인 SEI (Solid Electrolyte Interface) 층을 형성하였다. 또한, SEM, XRD를 통해 플라즈마 공정 변수에 따른 표면 구조 및 화학적 조성 변화를 관찰하였으며 이에 따른 리튬친화도 (Lithiophilicity)의 차이점을 분석하였다.

PG2A-101 | Enhancing circularly polarized light sensitivity through halogen substitution of chiral 2D double perovskites

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Chiral 2D perovskites exhibit outstanding chirality and optoelectronic properties. However, conventional perovskites contain toxic Pb and thereby developing lead-free perovskites is in high demand. Double perovskites can exhibit non-toxicity by combining non-toxic monovalent cation and trivalent cation. One of the impediments to using double perovskites is phase instability causing random distortion of the inorganic layers. To stabilize the double perovskites phase, substituting the halogen functional group of the chiral spacer alleviate inorganic random distortion by

organic-organic interaction. Among various halogen functional groups tested, notably enhanced g-factor were obtained with Br-substituted cations which arose from the interaction of bromine with the π electrons of the benzene rings. Such halogen interaction can change spacer packing to relax inorganic layer distortion, intensifying asymmetry hydrogen bonding by their stronger penetration into inorganic layers. The resulting double perovskites were implemented as an absorber for a circularly polarized luminescence detector, exhibiting an enhanced anisotropy factor through increased chirality transfer driven by asymmetry hydrogen bonding.

PG2A-102 | Tuning the catalytic activity of Pt-alloy electrocatalyst for the oxygen reduction reaction by regulating ligand pair

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A variety of techniques for synthesizing nano-sized electrocatalysts have resulted in notable enhancements in their ability to facilitate the oxygen reduction reaction (ORR), both in terms of mass activity and specific activity. Among the most effective strategies for achieving nano-structuring is the bottom-up chemical synthesis method. In this approach, surface ligands play a pivotal role in essential regulating the size, shape, and composition of the nanostructures. Therefore, in this work, we investigate various types of Pt-alloy nanoparticles synthesized by a hot-injection method where the ligand pair of oleic acid (OAc) and oleylamine (OAm) is varied to determine its effect on the size, shape, and composition. By simply adjusting the ratio of OAm to OAc, we effectively manage to manipulate the size of the nanoparticles within the range of 1 to 10 nm. By conducting a comprehensive assessment of ORR performance, we determine the optimal ratio of OAm to OAc that facilitates Pt reduction and demonstrates outstanding ORR characteristics.

Acknowledgements: This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2020R1A6A1A03045059).

PG2A-103 | Evaluation of Catalytic and Cell Performance for Direct Ammonia Decomposition in SOFCs

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Many studies alternative energy have been conducted

Poster Presentations

as greenhouse gas emissions regulations strengthen in various countries. Additionally, ammonia is carbon-free fuel, and much research is being conducted as a way to respond to strengthened carbon emission regulations. Ammonia is an energy carrier that carries hydrogen and has a large density per unit volume, so it is possible to store large capacity. For the effective production of hydrogen or syngas, the role of reforming catalysts becomes more significant. In this study, the Ni/MgO catalyst was prepared by co-precipitation method and under various conditions to obtain nano-sized nickel particles more effectively. The ammonia reforming reaction of the catalyst thus prepared was measured by gas chromatography. The long-term output performance of the fabricated electrolyte support cell was evaluated and measured. Besides, to evaluate long-term stability, nitrating and microstructure were analyzed for each sample. Electrochemical characteristics were measured using impedance spectroscopy while flowing ammonia through the anode.

PG2A-104 | Modified Separators Using RuO₂@CeO₂-CNT Nanocomposites as Dual-Mode Li-Polysulfide adsorption for High-Performance Lithium-Sulfur Batteries

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리튬-황 전지는 이론 에너지 밀도가 2,600 Wh/kg으로 현재 리튬-이온 전지(~570 Wh/kg) 대비 4배 이상의 에너지 밀도를 구현할 수 있는 유망한 차세대 전지이다. 리튬-황 전지의 높은 에너지 밀도뿐만 아니라, 양극 소재로 사용되는 황은 풍부한 자원과 높은 경제성으로 전지의 제조단가 또한 획기적으로 낮출 수 있다. 하지만, 황 및 그 방전 생성물(폴리 설퍼이드)의 절연 특성과 유기 전해질에서 폴리 설퍼이드의 셔틀 효과는 리튬-황 전지의 상용화에 걸림돌이 되고 있다. 본 연구에서는 리튬-황 전지의 분리막에 진공 여과 과정을 통해 극성 물질인 루테늄 산화물 (RuO₂), 세륨 산화물(CeO₂)과 전도성 탄소나노튜브 (CNT)로 구성된 복합체를 적용하여 고질적인 문제를 완화했다. 수열반응법으로 합성된 나노 크기의 RuO₂@CeO₂는 뛰어난 폴리 설퍼이드 화학 흡착 능력을 가지고 전환 매개체로서 작용하며, CNT는 폴리 설퍼이드의 물리적 흡착과 효과적인 전자 이동을 위한 전자 네트워크를 형성한다. 세 물질의 시너지 효과를 갖는 개발된 분리막은 높은 Li-ion transference number와 이온 전도도를 나타낸다. 따라서, 다기능성 복합 분리막을 적용한 리튬-황 전지는 고율속에서 높은 용량과 장사이클 안정성을 달성하였다. Acknowledgements: This work is supported by the National Research Foundation of Korea (NRF) Grant funded by the Ministry of Science, ICT, and Future Planning (Grant No. 2016R1A2B2012728).

PG2A-105 | Tailoring intrinsic and extrinsic properties of CoFeP nanoframe via Ru doping and size regulation for efficient hydrogen evolution reaction

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The development highly active and stable hydrogen evolution reaction (HER) catalyst is essential to replace Pt-based catalysts in the alkaline electrolyte. In this study, we develop heteroatom Ru-doped cobalt-iron bimetallic phosphide nanoframes (Ru-CoFeP/NF) showing superior HER performance. Only a small amount of Ru dopant sufficiently modifies the electronic structure of the cobalt-iron bimetal phosphide (CoFeP), resulting in excellent intrinsic HER activity. X-ray photoelectron spectroscopy (XPS) analysis was performed to visualize the electron transfer due to Ru doping which caused a significant transition in the valence state. In addition, the size tuning of the nanoframe structure increases the surface area of the catalyst, thereby successfully improving the extrinsic activity of the catalyst. To optimize the size tuning, the surface area of the catalyst was analyzed by Brunauer-Emmett-Teller (BET) surface area and electrochemical surface area (ECSA). The synthesized catalyst exhibits remarkable HER performance, especially at high current densities, due to the synergistic effects of improved intrinsic and extrinsic activity attributed to Ru doping and morphological regulation. Ru-CoFeP/NF shows a low overpotential of 191 mV and superb stability for 100 h at 100 mA cm⁻². This study proposes key elements for improving the HER activity of transition metal phosphide as a catalyst.

Acknowledgements: This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2020R1A6A1A03045059).

PG2A-106 | Design of dual metal Cu-Co electrocatalysts with doping strategy to improve performance of nitrate reduction to ammonia

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Ammonia (NH₃) is one of the most important materials for human beings due to its various uses such as fertilizers, pharmaceuticals, and carbon-free energy fuel. NH₃ is produced via the Haber-Bosch process which requires high energy demand and CO₂ emission. Therefore, electrochemical NH₃ synthesis is rising as an alternative to conventional methods. Recently,

electrochemical nitrate reduction reaction (NitRR) has been studied due to its efficiencies like as the low energy barrier, the high solubility of nitrogen source in electrolyte, and high activity. However, the complex pathways of NitRR make a variety of byproducts and cause low selectivity. To improve the activity and selectivity of NitRR, we designed dual metal Cu-Co electrocatalysts and evaluated the doping strategy. In this work, Cu-Co dual metal catalysts show more than 2039 $\mu\text{g}/\text{h cm}^2$ of yield rate and 87% of faradaic efficiency at -0.4 V (vs. RHE) in KOH 1M and KNO_3 0.1M solution. We expect that this research contribute to not only efficient production of ammonia under ambient condition but also discovery of doping strategy NitRR pathway. Acknowledgements: This research was supported by the Outsourced R&D Project of Korea Electric Power Corporation (KEPCO) (Grant number: R23XO04).

PG2A-107 | 강유전체의 분극 방향이 ORR/OER 성능에 끼치는 영향

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It is known that the rate determining step (RDS) for Oxygen Evolution Reaction (OER) & Oxygen Reduction Reaction (ORR) is affected by the surface adsorption of intermediate species. The ferroelectric material can be a fascinating strategy for electrochemical catalysts owing to its unique property, switchable spontaneous polarization which could control the adsorption energy. Among them, Sodium bismuth titanate, $(\text{Na}_{1/2}\text{Bi}_{1/2})\text{TiO}_3$ (BNT) is a promising candidate for ferroelectric perovskite with excellent oxygen ion conductivity. We prepare BNT samples by poling in different directions to maximize the effect of polarization on catalytic activity. It is observed that Down-poling BNT exhibit lowest onset potential (0.757 V) and smallest Tafel slope (94 mV/dec.) in ORR performance. Consequently, the OER performance of Down-Poling BNT is better than other samples. This work demonstrates that utilizing ferroelectric polarization can be a useful strategy to accelerate the electrocatalytic performance.

PG2A-108 | Cubic stabilized Barium Cobaltite through Fluorine Doping: A highly active air electrode for Protonic Ceramic Fuel Cells

ROH Seungwoo¹, AHN Sejong¹, KIM Hyunseung¹, *JUNG WooChul¹

¹Korea Advanced Institute of Science and Technology Solid oxide fuel cells (SOFCs) with elevated efficiency

and operation reversibility have attracted considerable interests, but concerns relating to cost and durability due to high temperature ($800^\circ\text{C}\sim 1000^\circ\text{C}$) operation has spurred the development of low-to-mid temperature ($450^\circ\text{C}\sim 650^\circ\text{C}$) protonic ceramic fuel cells (PCFCs) with low ion conduction activation energy. The hindrance posed by the sluggish air electrode reaction has been identified as a pivotal impediment to commercialization. Recent investigations have spotlighted cubic stabilized $\text{BaCoO}_{3-\delta}$ perovskite as a highly active and durable air electrode material. Here we present an innovative anion doping strategy as an alternative to conventional cation doping techniques. Utilizing the sol-gel method, we successfully synthesized fluorine doped $\text{BaCo}_{0.85}\text{Y}_{0.15}\text{O}_{2.9-\delta}\text{F}_{0.1}$ of highly crystalline cubic phase at relatively low calcination temperature of 950°C . Phase transition from hexagonal to cubic by fluorine doping was first reported in the field of PCFCs. This phenomenon is tentatively considered to be caused by reduction of cobalt due to fluorine doping, which is planned to be confirmed by XAS analysis in the future. Upon application as an electrode material, a notable reduction in electrode resistance and activation energy was confirmed in symmetrical cells, which partially owes to increased ion diffusivity. Further investigation of bulk diffusion and surface exchange property is in progress with ECR analysis, and the quantitative analysis on electrode sinterability is also planned to be probed.

PG2A-109 | 고체 산화물 수전해 안정성 향상을 위한 Sr-free 공기극 개발

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고체 산화물 수전해(Solid Oxide Electrolysis Cell, SOEC)는 고온 수증기를 전기분해하여 그린수소를 생산하는 기술로 주목받고 있다. $700 - 850^\circ\text{C}$ 의 고온 환경에서 작동하기 때문에 높은 에너지 효율을 나타내는 장점을 지니고 있다. 하지만 장기간 운영 시 발생하는 열화 현상은 이 기술을 상용화 하는데 있어서 걸림돌이 되고 있다. 다양한 열화 현상 중에서도 공기극의 Sr(Strontium) segregation이 큰 문제로 인식되고 있으나, 아직까지 근본적인 원인과 해결방안은 명확하게 제시되고 있지 못하다. 따라서 본 연구에서는 Sr이 포함되지 않은 물질, LNC($\text{La}_{0.95}\text{Ni}_{0.60}\text{Co}_{0.40}$)를 공기극 소재로 사용하여 전극 성능 및 안정성 평가를 진행하였다. 1.3V 일정 전압 조건에서 장기 평가를 진행한 후 구성 원소의 segregation 현상 유무를 확인 하였다. 더 나아가 전극의 성능을 향상시키기 위해 동일한 소재를 나노촉매로 사용하여 구조분석 및 전기화학 평가를 진행하였다.

PG2A-110 | Effects to improve the biofuel characteristics of bagasse by acid treatment

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Biomass contains a significant amount of alkali metal elements (i.e. Na, K, Ca etc). Herbaceous biomass usually has higher contents of K and Cl when compared to woody biomass. During combustion, the alkali elements react with chloride in biomass to form the compounds of KCl(g) or NaCl(g). These compounds produced sticky ash particles during combustion. It adhered and formed fouling on the surface of a furnace when the temperature on the surface dropped down. In addition, alkali metal elements cause agglomeration and slagging in the bottom of the furnace. To address these issues, this study used the weak acid treatments to remove alkali metal elements in bagasse using three acid solutions, acetic acid, oxalic acid and citric acid. The weak acid treatments were performed in different reaction times and concentrations. The removal efficiency of alkali elements and recovery of solid contents were measured depending on acid solutions. Using acetic acid showed higher efficiencies in both alkali element removal and solid content recovery with 91.32 and 85%, respectively among three acid solutions. The initial deformation temperature of bagasse treated with acetic acid increased upto 32.74% compared to a raw material. Based on the results, predictive indices were analyzed to predict the possibility of troubles in the furnace. The applicability of predictive indices was shown to be poor in fouling, slagging, slagging viscosity, agglomeration when the raw bagasse used. However, the index values of acid treated bagasse showed lower possibility than the raw bagasse. Therefore, it was found that the acid treatments used in this study could reduce alkali metal elements and improve the quality of bagasse as a biofuel.

PG2A-111 | LAMP-based All-Solid-state Batteries Featuring Li-In Alloy Anode

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NASICON-type $\text{Li}_{1.3}\text{Al}_{0.3}\text{Ti}_{1.7}(\text{PO}_4)_3$ (LAMP) solid electrolyte is supposed to be one of the most promising solid electrolytes for high energy solid state batteries. However, LAMP solid electrolyte has interfacial problems, such as restricted contact area. Moreover, Li/LAMP interface is deteriorated by structural collapse due to its reduction products. Herein, we employed PEO based protecting layer (PL) and Li-In alloy anode to

modify the electrode interface. PEO based protecting layer (PL) was applied to prevent the Li/LAMP interface side reactions and minimize the LiFePO_4 (LFP) /LAMP interfacial resistance. We applied two kinds of PLs, solid polymer electrolyte (SPE) and composite polymer electrolyte (CPE). A CPE was prepared using a ceramic filler of LLZTO to enhance the ionic conductivity and the long-term cycling stability of PL. As an anode material Li foil and $\text{In}_{1.5}\text{Li}$ foil were utilized. The symmetric and full cells were prepared with a PL coated on both sides of the electrolyte. The symmetric cell and full cell with CPE exhibited stable cycling performance, compared to that with SPE. The symmetric cell utilizing $\text{In}_{1.5}\text{Li}$ foil showed higher overpotential during the initial cycles, but it showed improved cycling stability, compared to that with Li metal foil. XRD and TOF-SIMS results indicate that there were no structural and chemical changes in the LAMP coated with PL. Therefore, the modifications of CPE protecting layer and Li-In alloy anode are effective for enhancing cycling performance in all-solid-state batteries.

PG2A-112 | Behaviors of alkali metal ingredients in bagasse during the combustion simultaneously with additives

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Bagasse is an abundant agricultural waste in southeast Asia. It can be used as a carbon neutral energy source that can replace fossil fuels. During combustion, the alkali elements react with chloride in biomass to form the compounds of KCl(g) or NaCl(g). These compounds produced sticky ash particles during combustion. It adhered and formed fouling on the surface of a furnace when the temperature on the surface dropped down. In addition, alkali metal elements causes agglomeration and slagging in the bottom of the furnace. Therefore, in this study, a fuel additive that mainly composed of alumina and silica was used to reduce the possibility of trouble in the furnace. The compounds produced in ash were analyzed using X-ray diffraction to identify and quantify the products after combustion. During the co-combustion, alkali elements in bagasse reacted with Al and Si in the fuel additive and formed ash-fusion compounds such as kalsilite (KAlSiO_4), microline (KAlSiO_8), and lomonosovite ($\text{Na}_{10}\text{Ti}_4(\text{Si}_2\text{O}_7)_2(\text{PO}_4)_2\text{O}_4$). These ash-fusion compounds has high melting temperature. Originally, alkali elements flied out as an exhaust gas but the ash-fusion compounds kept alkali elements in ash as a solid phase. It reduced the possibility

of furnace corrosion. In this study, potassium sulfate in the ash decreased 20% after co-combustion with the additive but the ash-fusion compounds increased about 80%. Because of increased the ash-fusion compound, the initial deformation temperature increased 38.9% when compared to the ash produced from the raw bagasse. Based on the results, predictive indices were analyzed to predict the possibility of troubles in furnace. When used a raw bagasse, the applicability of predictive indices was shown to be poor in fouling, slagging, slagging viscosity, agglomeration. However, the index values of ash produced from co-combustion with additives showed lower possibility than the raw bagasse. Therefore, it was found that using the fuel additive prevents alkali components from being attached to the furnace.

PG2A-113 | Ni-doped layered perovskite oxide as a promising air electrode for high performance reversible protonic ceramic cells

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Reversible protonic ceramic cells (R-PCCs) are a promising technology that converts energy between electricity and hydrogen using a proton-conducting electrolyte at intermediate temperatures (400-600 °C). However, their electrochemical performance has currently lagged behind predictions based on their high ionic conductivity due to insufficient catalytic activity on the air electrode side, such as oxygen reduction reactions (ORR) and oxygen evolution reaction (OER) in both fuel cell and electrolysis modes. These issues significantly reduced the commercialization potential of R-PCCs. Thus, the development of suitable air electrodes for R-PCCs to satisfy various requirements such as high triple ($H^+/O^{2-}/e^-$) conductivities, superior catalytic activities for ORR/OER, and chemically stable compatibility with other components is greatly imperative. Herein, the effects of Ni substitution on the Co site in $PrBa_{0.5}Sr_{0.5}Co_{2-x}Ni_xO_{5+\delta}$ ($x = 0, 0.1, \text{ and } 0.2$) are systematically studied with regard to structural characteristics, hydration properties, and electrochemical performance as R-PCCs air electrode material.

PG2A-114 | Effect on hydration properties and electrochemical performances with Ln cation (Ln=Pr, Nd, and Gd) size in layered perovskite cathodes for protonic ceramic fuel cells

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Recently, the layered perovskite $PrBa_{0.5}Sr_{0.5}Co_{1.5}Fe_{0.5}O_{5+d}$ (PrBSCF) material has been reported as the triple ionic and electronic conductor for protonic ceramic fuel cells (PCFCs), ensuring the extension of the electrochemically active sites over the whole surface of the cathode due to their superior proton uptake abilities. This layered perovskite structure enhances the oxygen ion diffusivity because of disorder-free channels in LnO plane, and thus previous research has focused primarily on the Ln effect on electrical properties, oxygen ion diffusion, and surface exchange kinetics. However, the Ln effect on hydration properties, a crucial factor for high-performance PCFC systems, remains unanswered. Herein, to discover the detailed studies on correlation between hydration properties with Ln^{3+} cation size ($Pr^{3+} > Nd^{3+} > Gd^{3+}$), we systematically analyze the $LnBa_{0.5}Sr_{0.5}Co_{1.5}Fe_{0.5}O_{5+d}$ (LnBSCF, Ln = Pr, Nd, and Gd) cathode in terms of proton uptake behavior, thermodynamic parameters for the hydration reaction, and electrochemical performances.

PG2A-115 | Metal Nanoparticle Infiltration for a Fuel Electrode in Proton Ceramic Electrolysis Cells

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Proton ceramic cells (PCCs) is preferred for next-generation electrochemical energy conversion and storage equipment due to its high ion conductivity at intermediate and low temperature. Several studies have been conducted on electrolytes and air electrodes to improve the cell performance. In this study, various metallic nanoparticles (such as Ni, Pd and Pt) were infiltrated to modify the microstructure of air electrodes and increase the three-phase boundary (TPB, electrode-electrolyte-gas phase). The fabricated fuel electrode supported PCC consisted of Ni-BaCe_{0.7}Zr_{0.1}Y_{0.1}Yb_{0.1}O_{3-δ} cermet fuel electrode, BaCe_{0.7}Zr_{0.1}Y_{0.1}Yb_{0.1}O_{3-δ} (BCZYYb) electrolyte, and BCZYYb-La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-δ} composite air electrode. SEM analysis results revealed that metallic nanoparticles can be infiltrated up to the fuel electrode functional layer and their distribution was uniform through the layer. The PCC with metal nanoparticle infiltrated fuel electrode exhibited higher power density and lower polarization resistance than that with bare fuel electrode. This study shows the electrochemical performance of fuel electrode supported PCCs can be further improved by the facile infiltration method.

Poster Presentations

PG2A-116 | Effect of Li Ion Diffusivity on the Chemo-mechanical Stability of Li-Si Alloy Anodes in Sulfide-based All-solid-state-batteries

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Silicon (Si) is a promising anode material for all-solid-state-batteries (ASSBs) because of its high theoretical capacity (~3580mAh/g). Pre-lithiation is a strategy to mitigate the relative volume changes of Si anode due to pre-volume expansion [1]. In this study, we investigate the electrochemical performance of metastable Li_xSi ($x = 4.4, 3.25, 2.33, 1.71, \text{ and } 1.0$) phases in Sulfide-based ASSBs. The ASSBs were fabricated by consisting of Li-Si alloy anode, sulfide electrolytes and sulfur composite cathode. Phase changes in Li-Si alloy were studied using XRD (X-ray diffraction) as a function of Li concentration. A half-cell was fabricated using Indium foil as a counter electrode to determine Li-ion diffusion coefficient of Li-Si alloy working electrode using the Galvanostatic Intermittent Titration Technique (GITT). During charge-discharge cycles, changes in polarization resistance in the anode was individually monitored using a three-electrode system of an embedded Indium reference electrode in ASSBs. Using Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS), distribution of Li was investigated to illustrate alloying and de-alloying in Li-Si anodes. The optimal Li composition in Li-Si alloy anode was determined based on chemo-mechanical stability.

References: [1] Domi, Y., Usui, H., Iwanari, D., & Sakaguchi, H. Effect of mechanical pre-lithiation on electrochemical performance of silicon negative electrode for lithium-ion batteries. Journal of The Electrochemical Society, 164(7), A1651. (2017).

PG2A-117 | Fabrication of anode-supported SOFCs with single-step sintering and infiltration

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Currently, one of obstacles for commercial use of solid oxide fuel cell (SOFC) is its complicated manufacturing system especially in the sintering process. The yttria-stabilized zirconia (YSZ) electrolyte and gadolinium doped cerium oxide (GDC) buffer layers are sintered at 1300~1500 °C, NiO-YSZ anode support layer is sintered at 800~1000 °C, and the cathode layer is sintered again at 1000~1100 °C to form a SOFC. While

trying to simplify the sintering process, there is an issue that the different sintering temperature of each layer is difficult to be integrated. In this study, tape-casting and laminating process is adapted to reduce fabricating time with single-step sintering. Anode, YSZ, and GDC layers were tape-casted and laminated to make a cell. The combined layers were sintered together once at 1300~1400°C. Finally, GDC was screen-printed to the anode supported cell and lanthanum strontium cobalt ferrite (LSCF) solution was infiltrated to form LSCF-GDC. With this infiltration, GDC surface is coated with LSCF particle and this makes inner microstructure minutely to increase the stability of the cell. During the infiltration, vacuuming step removes the air pores to decrease the polarization resistance. Microstructures of fabricated cells were investigated by scanning electron microscope (SEM). The cell performance is evaluated with electrochemical impedance spectroscopy (EIS) and PVI curve.

PG2A-118 | Production Method and Property Evaluation of Activated Carbon Using Low-Molecular-Weight Lignin

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Global warming continues to advance due to the rising concentration of carbon dioxide in the atmosphere, a consequence of increased fossil fuel consumption. In response to this concern, environmental regulations are undergoing strengthening, leading to a growing demand for materials that are environmentally friendly. Among these, porous adsorbents play a crucial role in carbon dioxide control technology, with activated carbon being a prime example owing to its extensive specific surface area and porous structure. This makes it highly effective for carbon dioxide and heavy metal adsorption, as well as catalyst support and various other applications. The present study focuses on the utilization of low-molecular-weight lignin as a precursor to manufacture activated carbon. The resulting characteristics of the manufactured activated carbon were comprehensively evaluated to determine optimal conditions. Through chemical activation of low-molecular-weight lignin, considering parameters such as activation temperature (500~700°C) and duration (1~4 hours), the impact of these process conditions on the properties of the activated carbon was investigated using techniques

including BET, FE-SEM, XRD, and XPS analyses. Notably, the activated carbon synthesized under the conditions of maintaining a temperature of 700°C for 2 hours demonstrated the most favorable outcomes, displaying a BET specific surface area and pore volume of 2119.2 m²/g and 1.44 cm³/g, respectively.

PG2A-119 | 전기 전도성 및 열 안정성 향상 : 열전지 성능 확보를 위한 FeF₃ @Ni/MWCNT 복합 음극 재료

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¹가천대학교

열전지는 장기간 보관 가능하며 군용 및 비상전원 용도로 사용되는 1차 전지입니다. 이러한 전지는 용융염 전해질로 구성되어 있어 상온에서는 고체 상태이지만, 전원이 필요한 경우 열원을 통해 약 500°C 이상의 열을 공급하여 상변이가 발생하고 전지가 활성화되어 방전됩니다. 국방 및 항공우주 기술의 발전으로, 전원이 필요한 재래식 무기도 전력 요구량이 높아지고 첨단화되는 추세입니다. 이로 인해 전원 소형화와 고출력 성능이 필요로 합니다. 현재, 열전지는 일반적으로 저렴한 황철석(FeS₂)을 양극 재료 사용하고 있지만, 낮은 개방회로전압(OCV)인 2.0V 이하와 작동 온도에서의 낮은 열 안정성으로 인해 열전지의 활용이 제한되고 있습니다. 이러한 문제점을 돌파할 수 있는 키는 열적 안정성과 고출력 성능을 이끄는 세라믹 재료의 개발이 중요한 키입니다. 본 연구에서는 이론용량이 높고, 비용이 저렴한 고전압 양극활물질로 제시되어왔으나 높은 밴드갭에 의한 낮은 전도도를 나타내는 FeF₃를 양극활물질로 사용하기 위해 MWCNT와의 복합화하였으며, MWCNT의 열적 안정성을 높이고자 표면에 Ni를 코팅한 Ni/MWCNT를 복합화 하였습니다. 복합화된 FeF₃@Ni/MWCNT는 Scanning Electron Microscope (SEM)을 통해 전도성 네트워크 채널을 형성한 것을 확인했으며, 해당 파우더를 펠렛화하여 4 point probe, 2단자 직류저항측정기 (Multimeter)를 통해 FeS₂ 대비 우수한 전기전도성을 확보한 것을 확인하였습니다. 그 결과, FeF₃@Ni/MWCNT 복합 물질은 FeS₂의 전기전도도를 뛰어넘고 기본 MWCNT 보다 높은 열적 안정성을 갖는 것을 확인하였습니다. 본 연구의 양극활물질을 활용하여 전지 적용을 위한 코인셀 분석에서는 상온 방전 특성을 확인하였을 때, 3.1~3.4V의 개방회로 전압을 확인함을 물론 용량은 기존 FeS₂ 대비 1.5배 향상된 특성을 확인하였습니다. 결과적으로 FeF₃@MWCNT 대비 FeF₃@Ni/MWCNT의 복합 물질은 전기전도성을 확보하고, 열적 안정성까지 뛰어나 열전지용 양극활물질의 적용 가능성이 높은 후보로 제시할 수 있습니다.

PG2A-120 | 전고체전지용 아지로드ایت 황화물 고체전해질의 Sn 치환 효과에 관한 연구

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Currently, liquid electrolyte-based LIBs experience challenges due to low energy density and leakage of flammable liquid electrolytes. In order to solve these

problems, an argyrodite-based sulfide electrolyte has shown attractive attention. However, sulfide solid electrolytes still suffer from low ionic conductivity, unstable interface with Li-metal and poor air stability. One of the methods to improve these problems of sulfide electrolyte is via elemental substitution (Sn). However, due to the large atomic size of Sn, the Sn substitution is limited. Therefore, in this study, an optimized synthesis method for aliovalent Sn⁴⁺ substituted Li₆PS₅Cl_{0.5}Br_{0.5} was investigated. In addition, the correlation between appropriate aliovalent element (Sn) substitution and ionic conductivity was inspected. When P is substituted with Sn, the ionic conductivity can be improved by reducing the charge density of S²⁻. The effect on the crystal structure and ionic conductivity by substitution was confirmed using X-ray diffraction (XRD) and electrochemical impedance spectroscopy (EIS) analyses. Also, the interfacial stability with Li-metal anode and electrochemical performances were evaluated by symmetric cell test.

PG2A-121 | High-performance protonic ceramic fuel cells with electrode-electrolyte composite cathode functional layers

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Solid oxide fuel cells (SOFCs) are gaining momentum as the power sources of the future, ideal for city gas grids in buildings and as promising replacements for gas turbine-based power plants. However, they face challenges. Their high operating temperatures (800-1000 °C) lead to increased manufacturing costs due to thermal sealing and also limit material options. Plus, the lengthy start-stop durations, associated with these high temperatures, pose barriers to their market entry. Researchers are now focusing on reducing SOFCs' operating temperatures to a more manageable 600°C or below. Protonic ceramic fuel cells (PCFCs) are considered as a good alternative to SOFCs. Using a proton-conductive oxide as an electrolyte, PCFCs are well-suited for these lower operating temperatures. Since protons are smaller than oxygen ions, they require roughly half the activation energy (0.4-0.5 eV) to conduct. But for PCFCs to truly excel, their cathodes need improvement. The ideal cathode material should promote a robust oxygen reduction reaction while maintaining sufficient ionic conductivity. Furthermore, to ensure the fuel cells' longevity, the cathode and

electrolyte need to be thermally and mechanically compatible. Recent advancements highlight the effectiveness of using composite cathodes, which combine both electrolyte and cathode materials. These composites bolster performance by increasing active reaction sites and minimizing thermal strains where the electrode meets the electrolyte. In our recent study, we explored the potential of such an electrode-electrolyte composite, using it as a cathode functional layer (CFL) below the cathode, aiming to boost PCFC efficiency. For this purpose, we chose $\text{PrBa}_{0.5}\text{Sr}_{0.5}\text{Co}_{1.5}\text{Fe}_{0.5}\text{O}_{5+\delta}$ (PBSCF) and $\text{BaZr}_x\text{Ce}_{0.8-x}\text{Y}_{0.1}\text{Yb}_{0.1}\text{O}_{3-\delta}$ (BZCYYb) as our cathode and electrolyte materials, respectively. These are currently among the top-performing materials in PCFC technology due to their impressive proton conductivity and stability. Notably, PBSCF has a thermal expansion coefficient (TEC) of $21.3 \times 10^{-6} \text{ K}^{-1}$, nearly double that of BZCYYb. By incorporating a composite CFL with these materials, we anticipated improved integration and reduced thermal stress between the layers. By evaluating fuel cell power and impedance, we found that cells equipped with CFLs showcased power densities between $0.35\text{-}1 \text{ W cm}^{-2}$ at temperatures ranging from $450\text{-}600 \text{ }^\circ\text{C}$. This marked a 20% performance improvement over cells without the CFLs. In our upcoming presentation, we'll discuss how the CFLs have contributed to this performance surge, focusing especially on their structural characteristics.

PG2A-122 | 고체산화물 연료전지의 연료극 성능 향상을 위한 세리아 기반 나노 촉매 개발

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고체산화물 연료전지(SOFC)는 고온(약 $700 \text{ }^\circ\text{C}$ 이상)에서 작동하는 연료전지로, 높은 에너지 변환 효율을 가지고 있습니다. 이 연료전지의 연료극 지지형 셀에서는 연료극이 지지체 역할을 하며, 이 연료극은 고온에서 공소결로 제작되기 때문에 기존의 Ni-YSZ(Yttria-stabilized zirconia)를 다른 소재로 대체하기 어렵습니다. 따라서 연료극에 나노촉매를 도입함으로써 셀의 성능을 향상시키는 노력이 진행되고 있습니다. 이 연구에서는 고온 공소결로 제작된 셀의 연료극에 세리아 기반의 여러 전이 금속 (Co, Fe, Ni)과 세리아 나노촉매를 주입하여 나노촉매를 합성하였습니다. 최적의 생산 공정을 찾아내고 여러 금속 촉매의 다양한 조합을 실험하여 최적의 재료와 조성을 결정하였습니다. 그 후에 연료극 지지형 셀에 최적화된 나노촉매를 도입하여 연료 전지 모드와 수전해 모드에서 성능 향상을 확인하였습니다.

PG2A-123 | Development of Ammonia Decomposition Catalyst Using Non-precious Metal Nanoparticles Supported by h-BNNT

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¹Korea Advanced Institute of Science and Technology Hydrogen energy, a clean resource, is currently being actively studied as an eco-friendly option for future societies, as it doesn't emit greenhouse gases during electricity generation. To ensure reliable hydrogen supply and transportation, researchers are developing liquefied storage methods, with ammonia emerging as a promising hydrogen carrier due to its high energy density. Ammonia, however, requires a cracking process to convert it into hydrogen and nitrogen. This process demands harsh conditions and creates a highly reducing environment, causing severe catalyst damage such as catalyst degradation, particle agglomeration, nitride poisoning, and subsequent catalyst detachment. Hence, developing a catalyst which is both active and stable for ammonia decomposition is a crucial challenge. In this study, we aim to create a highly active and stable catalyst for ammonia decomposition, employing hexagonal boron nitride nanotubes (h-BNNT). h-BNNT boasts a high melting point ($3273 \text{ }^\circ\text{C}$) due to strong covalent bonding and remarkable thermal stability, thus, does not easily agglomerate even at elevated temperatures. Additionally, it shows excellent resistance to nitride/oxide poisoning due to its inherent stability as a nitride. In this research, we synthesized porous h-BNNT nanostructures with a high specific surface area reaching $1000 \text{ m}^2\text{g}^{-1}$ through pyrolysis of melamine diborate. We successfully designed Ni-Fe alloy nanoparticles supported by h-BNNT to develop a catalyst for ammonia decomposition with both high activity and stability. Structural properties and performance of the catalyst will be discussed.

PG2A-124 | Fe/Co 비율 제어를 통한 P형 Nd-Fe-Co-Sb계 Skutterudite 소재의 열전특성 향상

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본 연구는 Fe/Co 비율 제어를 통한 P형 Nd-Fe-Co-Sb계 skutterudite 합금의 열전 특성 향상에 대해 보고한다. 유도 용해 및 급속 응고법을 통해 분말을 제작한 후 방전 플라즈마 소결법(903 K , 50 MPa , 15min)으로 $\text{Nd}_{0.9}\text{Fe}_{4-x}\text{Co}_x\text{Sb}_{12.2}$ ($x=0.5, 0.75, 1, 1.25, 1.5$)소결체를 합성하였다. 소결체의 XRD 분석을 통해 skutterudite 단일상이 형성되었으며, Fe/Co 비율 조절에 따른 주요 회절 피크의 이동을 통해 Co가 Fe 자리로

효과적으로 치환된 것을 확인하였다. Co 치환량 증가에 따른 캐리어 농도 감소로 전기전도도는 감소하고 제백계수는 증가하는 경향을 보였으며, 캐리어 농도 최적화에 따라 $x=0.75$ 샘플에서 최대출력인자($28.9 \times 10^{-4} \text{ Wm}^{-1}\text{K}^{-2}$ @ 769 K)를 얻었다. 또한, 열전도도는 Co 치환량 증가에 따른 전자 전도 기여분의 저하로 감소하는 경향을 보였다. 결과적으로 Fe/Co 비율 조절을 통해 p형 skutterudite 소재의 전기적·열적특성을 동시에 제어하여 열전성능이 향상되는 것을 확인하였으며, $\text{Nd}_{0.9}\text{Fe}_{3.25}\text{Co}_{0.75}\text{Sb}_{12.2}$ 샘플에서 1.0(769 K)의 최대 열전성능지수를 보였다.

PG2A-125 | 내관 보호된 사고저항성 피복관 제작을 위한 공정으로 축관-인발 공정의 적용 가능성

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후쿠시마 원전사고 이후, 원자로 정상 작동 범위(300~400°C) 이상의 고온에서도 구조적 안정성을유지할 수 있는 산화 저항성 피복관을 개발하기 위한 연구가 다수 진행되었다. 대부분 지르코늄 합금 피복관 외부에 물리적, 화학적 기상 증착법을 이용해 산화 저항성 코팅을 진행하는 방법을 채택했다 [1,2]. 그러나 이러한 방법들은 4 m 길이 피복관에 적용할 수 없고 내부에는 보호막을 형성하기 어렵다 [3,4]. 본 연구에서는, 기존 피복관 제작 공정에서는 응용한 적 없던 축관-인발을 이용해 2 m 길이의 지르코늄 합금 피복관 내부까지 보호막을 형성한 삼중관 구조의 피복관을 개발했다. 이 시편은 최고 1,200°C에서 열처리되었으며 동일한 조건에서 열처리된 단일 지르코늄 피복관과 비교되었다. 이후 삼중관 미세 구조, 산화 층 정량화, 산화 메커니즘은 전자 현미경 (SEM), X-선 회절 (XRD), 열중량 평가(TGA) 등에 의해 분석되어졌다. 1,200°C에서 열처리된 단일 지르코늄 피복관은 완전히 산화되어 파열되었다. 삼중관은 전체 피복관 중 15%만 산화되어 형태를 보존했다. 본 연구는 축관-인발 접근법을 통해 유일하게 2 m 길이의 지르코늄 피복관 내외부에 보호층을 형성할 수 있으며 고온에서도 구조적으로 안정할 수 있다는 가능성을 보여줬다.

PG2A-126 | 열전지 성능 향상을 위한 $\text{Li}_7\text{La}_3\text{Zr}_2\text{O}_{12}$ 세라믹 재료의 결정 구조 및 이온 전도도에 대한 LiOH 및 Li_2CO_3 전구체 효과 비교 연구

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무기체계가 고도화, 첨단화가 진행됨에 따라 열전지의 소형화 및 고출력화 위해 소재 개발이 진행 중이다. 기존 용융점 전해질은 점도가 낮아 누액을 방지하기 위한 MgO 바인더를 이용하는데, 이는 절연 특성을 가지고 있어 함량이 높을수록 전해질의 이온전도도가 낮아지는 문제점이 존재하며 전해질과 혼합과정에서 입도 제어에 영향을 미친다. 이를 개선하고자 본 연구에서는 전고체전지용 고체 전해질로 주목받고 있는 산화물계 고체전해질 $\text{Li}_7\text{La}_3\text{Zr}_2\text{O}_{12}$ (LLZO)로 대체하는 것을 목적으로 하여 열전지 환경에서의 특성을 조사하였다. 고체전해질 LLZO는 고상합성 공정을 통해 합성하였고 Li_2CO_3 및 LiOH의 리튬 전구체를 달리

하여 결정구조, 미세구조 및 이온 전도도에 미치는 영향을 분석하였다. 합성된 시료는 X-ray Diffraction (XRD)분석을 통해 결정화 및 상변화를 분석하였고 입자 형태 및 소결 효과를 Scanning Electron Microscope-Energy Dispersive X-ray Spectrometer (SEM-EDS)을 통해 특성화 하였다. 또한, 고온 환경에서의 Electrochemical Impedance Spectroscopy (EIS)와 Thermogravimetric Analysis (TGA)를 통해 열전지 작동환경에서의 이온전도도와 질량손실을 확인하였다. LiOH를 공급원으로 합성된 LLZO는 입방정계 단일 상으로 확인되었고, 1 μm 이하의 균일한 입자 크기 및 분포와 높은 상대밀도를 나타내었다. 또한 500°C에서 $10^{-2} \text{ S cm}^{-1}$ 의 이온전도도와 99.8%의 질량손실이 확인되었다. 본 연구를 통해 리튬 공급원과 합성된 고체전해질의 관계와 기존 열전지 전해질의 비교 및 분석을 통해 대체 가능성을 평가하였다.

PG2A-127 | Mapping faradaic efficiencies of protonic ceramic electrolysis cells under various conditions and cell processing

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Water electrolysis is attracting attention as a technology that can produce hydrogen in an environmentally friendly. Generally, the use of solid oxides is known to be the most efficient. However, since it operates at a high temperature of over 700°C, it is challenging to maintain durability as the material degradations. Protonic ceramic electrolytes are being studied as an alternative to solve the problems of high-temperature operation and maintain the high efficiency of high-temperature electrolysis. Protonic ceramic electrolytes have as high ionic conductivity as solid oxide electrolytes, even at low temperatures. However, since the protonic ceramic electrolyte has mixed conductivity, holes are conducted together inside the electrolyte, resulting in low faradaic efficiency. Faradaic efficiency measures how much of the applied current is used to produce hydrogen. This research sought how to operate a protonic ceramic electrolyte cell to increase its faradaic efficiency. The most favorable conditions were found by calculating the faradaic efficiency for conditions such as temperature, humidity, PH₂O, thickness, electrolyte compositions, and cell processing. The most studied BCZYYb ($\text{BaCe}_{0.8-x}\text{Zr}_x\text{Y}_{0.1}\text{Yb}_{0.1}\text{O}_3$) with different compositions was used as the protonic ceramic electrolyte. This study's results will compensate for the disadvantages of protonic ceramic electrolytes with mixed conductivity and suggest a direction to achieve a high level of faradaic efficiency at a lower temperature than solid oxide water electrolysis.

PG2A-128 | Nitrogen으로 도핑된 탄소소재를 음극재로 활용

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현재 흑연은 낮은 방전 안정기와 우수한 사이클 안정성으로 인해 LIB(Lithium-ion batteries)에서 가장 성공적인 상업용 음극 재료로 사용되고 있으나 낮은 이론적 용량과 속도 성능으로 고용량을 필요로 하는 음극재로 제작하는데 어려움을 겪고있습니다. 따라서 흑연을 대체할 새로운 탄소 기반 음극 소재를 개발하기 위해 많은 연구자들이 관심을 기울이고 있습니다. 음극에 활용되는 탄소소재에 N, P 또는 S 도핑한 결과, 많은 결함과 공극을 유발해 탄소 기반 전극의 전기전도도를 향상시킨다는 결과가 알려져 있습니다. 특히 N-도핑은 리튬 이온 흡수를 위한 추가 전자가 있는 충분한 사이트를 제공할 수 있으며, 이는 배터리 충전/방전 중에 상당한 표면 용량 기여를 제공할 수 있습니다. 본 연구에서는 다공성 탄소로 활용되는 재생에너지원인 biomass를 탄화로부터 700°C, 1시간 유지하고 24시간 ball milling을 진행해 N 도핑된 분말을 얻을 수 있었습니다. N 도핑된 biomass 분말을 통해 셀을 제작하였고 C-rate의 범위를 0.1~10C로 하여 용량 측정된 결과, 흑연 대비 약 2배 높은 용량을 가지는 것을 확인하였습니다.

PG2A-129 | MLCC 공정 활용한 LAGP 시트 특성평가

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산화물계 초소형 적층 전고체 전지는 높은 안전성을 기반으로 유망한 차세대 이차전지 중 하나다. 전고체 전지는 배터리 양극과 음극 사이에 있는 전해질을 액체에서 고체로 바꾼 전지를 말하며, 전해질이 액체가 아니기 때문에 양극과 음극 사이 분리막이 필요 없다. 전고체 전지는 현재 사용 중인 리튬이온전지와 비교하여, 배터리 발화 위험 감소와 에너지 밀도 상승을 기대할 수 있다. 산화물계 고체전해질은 일반적으로 상온에서 최대 10^{-4} - 10^{-3} S/cm의 이온전도도 값을 가지며, 고전압 영역에서 안정하고, 공기에서도 안정해 합성 및 취급이 용이한 장점들이 있다. LAGP와 같은 산화물계 NaSICON 유형 고체 전해질은 공기 및 또는 물에서 화학적 안정성을 나타내며, 비용과 독성이 낮으며, 제조가 용이하다는 장점이 있다. 산화물계 초소형 적층 전고체 전지를 만드는 공정은 적층세라믹콘덴서(MLCC) 공정과 매우 유사하다. 이에 본 연구에서는 MLCC 공정법을 사용하여, Li_{1.5}Al_{0.5}Ge_{1.5}P₃O₁₂ (LAGP) 기반의 고체전해질 세라믹시트를 제작하였고, 시트 특성평가와 이온전도도를 분석하였다. 분말을 사용해 제작된 고체전해질 시트는 소결 온도 850~950°C로 소결했을 때도 10^{-4} S/cm의 이온 전도도를 보였다.

PG2A-130 | Exsolution control to improve low temperature ammonia synthesis using high energy milling

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Exsolution is a promising method to design metal nanoparticles for electrocatalysis and renewable energy. Metal nanoparticles exsolved from perovskite oxide lattices have been utilized as catalysts in many energy fields because of their high durability and excellent electro-catalytic properties. This study aims to control the exsolution with the high-energy ball-milling process of Ru doped perovskites to control exsolution. The exsolved materials with various milling times (4h, 28h) were used to confirm the impact of high-energy milling on the exsolution. The controlled catalysts will be analyzed by HR-TEM, XRD and SEM. In the 28 hours of milling that followed the reduction at 800 °C, the peaks shrank and became narrower, leading to a crystallinity drop. Severe agglomeration in HR-TEM shows the ready for ex-particle above the surface. The observed variation in the grain surface morphology can be explained by increasing temperature in O₂ conditions, which results in an increase in surface roughness and a subsequent smoothing of the matrix grains. According to XRD analysis, the crystallinity decreased as a result of the peaks being reduced and becoming narrower during the course of 28 h following reduction at 800 °C. After reduction with milling at 200 rpm for 60 h, barium carbonate manifested. This shows the possibility of high energy milling to accelerate exsolution, resulting in ammonia synthesis at low temperature (350, 400, and 450 °C).

PG2A-131 | Hydrogen production and storage characteristics for Mg-based hydrogen storage alloys by methane pyrolysis reaction

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Most of the hydrogen currently supplied domestically is by-product hydrogen from petrochemical processes. The production of by-product hydrogen is limited, and it is difficult to utilize in the long term because it emits carbon dioxide. As an alternative, extracting hydrogen through methane and steam reforming is currently a realistic method, but since this also emits carbon dioxide, it cannot be considered as a hydrogen production technology in the long term. Hydrogen production technology through methane pyrolysis is emerging as a technology that can compensate for the shortcomings of these current technologies. Methane pyrolysis technology does not emit carbon dioxide because methane is decomposed into solid carbon and hydrogen at high temperatures, and because it is based on a chemical process, it can be scaled up. In addition,

the technology to lower the temperature of methane pyrolysis and simultaneously store the produced hydrogen using solid hydrogen storage alloy is expected to further expand the hydrogen economic value chain. In this study, a magnesium-based hydrogen storage alloy with added Ni catalyst was used. Hydrogen production and storage experiments through methane thermal decomposition reaction were performed using GC (gas chromatography) equipment and Sieverts' equipment, and hydrides were produced through combination with hydrogen, magnesium, and nickel while the reaction continued. XRD analysis was performed to confirm their formation. The microstructure of carbon produced as a by-product was confirmed through TEM images, and FT-IR and EDS analyzes were performed on the carbon composition. Key Word: Methane pyrolysis, Hydrogen production, Hydrogen Storage, Mg-based Alloy, Nickel catalyst, Cracking

PG2A-132 | Tape casting법을 이용한 PCFC 단위전지 제조

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프로톤 전도성 고체산화물 연료전지(Protonic Ceramic Fuel Cell : PCFC)는 기존 산소이온 전도성 전해질 기반 고체산화물 연료전지에 비해 중저온에서의 우수한 특성을 나타내나, 높은 제조 비용과 스케일업의 어려움으로 인해 소규모의 실험 연구에 머물러 있는 실정이다. 본 연구에서는 Tape Casting공정을 통해 연료극과 전해질을 제작, Screen Printing공정을 통해 공기극을 성막하는 대면적화 가능 공정 기반의 단위전지 제작 기술을 논의하고자 한다. 특히, Tape Casting를 이용한 다층 Tape 제작은 대면적 전지 제작은 물론 전해질 및 전극의 두께 조절이 용이하며, 치밀 전해질 구조와 다공성의 전극 구조를 동시소결로 획득하기 위한 각 층의 구조 최적화에도 장점을 가지고 있다. 본 연구에서는 전해질로 BaCe_{0.4}Zr_{0.4}Y_{0.1}Yb_{0.1}O_{3-δ} 프로톤 전도성 세라믹 소재를, 공기극으로 PrBa_{0.5}Sr_{0.5}Co_{1.5}Fe_{0.5}O_{5+δ} 삼중전도성 소재를 채택하여 단위전지 제작공정 기술을 개발하였으며, 전기화학 특성 평가를 통해 전지의 활용가능성을 평가하였다.

PG2A-133 | 리튬이온배터리용 탄소-LiCoO₂ 코어-셸 구조의 합성 및 특성 평가

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리튬이온배터리의 양극재인 LiCoO₂는 우수한 성능으로 인해 활용도가 높으며, 전지성능과 장기 안정성을 향상시키기 위해 많은 연구의 대상이 되어 왔다. 그 중 표면의 탄소 코팅은 전하 이동 킨덕턴스와 충전 속도 성능을 향상시키는 이점이 있다. 그러나 LiCoO₂의 경우 낮은 용점으로 인해 탄화 공정에서 용융되는 문제점이 있다. 이에 본 연구에서는 낮은 온도에서 탄화 될 수 있는 polypyrrole을 활용하여 탄소 코팅을 하여, 일정한

입자 크기와 높은 표면적을 갖는 탄소-LiCoO₂ 코어-셸 구조 구형 분말을 분무 건조로 과립 분말을 제조하였다. 분말의 분체 저항측정기를 통해 전기전도도를 분석하였고, FT-IR과 Raman spectroscopy를 이용하여 탄소 코팅 유무를 확인하였다. SEM을 통해 과립 분말의 형태와 미세구조를 확인하였다.

PG2A-134 | 열산화 및 steam/CO₂ 하이브리드 활성화로 제조된 석유 피치 기반 슈퍼커패시터용 활성탄

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석유 잔사로부터 추출된 피치를 물리적 활성화를 통해 활성탄을 제조하고, 슈퍼커패시터의 전극활물질로서 전기화학적 특성을 조사하였다. 피치는 열처리시 경도가 높아 통상적으로 물리적 활성화를 통한 기공 형성에 어려움이 있어 알칼리약품에 의한 활성화 연구가 주로 이루어져왔다. 본 연구에서는 열산화 공정을 통해 피치 구조에 산소 관능기를 도입하여 활성화 과정에서 피치의 구조적 재배열을 억제하는 전처리 공정을 시행하였고, 열산화된 피치에 CO₂ 및 Steam을 동시에 활용한 하이브리드 활성화 기법을 적용한 결과 최대 2312 m² g⁻¹의 비표면적과 1.19 cm³ g⁻¹의 기공적을 보여 전극활물질로서 충분한 물성을 확인하였다. 전기화학적 특성평가 결과 1 mA/cm²의 전류밀도에서 106.4 F/g의 비축전용량을 보였으며, 50 mA/cm²에서 1 mA/cm² 대비 88 %의 높은 rate 특성을 나타내었다.

PG2A-135 | Alkaline leaching: a facile surface modification strategy to boost the surface reactivity of air electrodes for solid oxide fuel cells

HONG Yeongtaek¹, KIM Hyunseung¹, JEON SungHyun¹, KIM Yong Beom¹, KIM Sangwoo¹, SUN Hainan¹, LEE Jeongah¹, NAM Seongwoo¹, *JUNG WooChul¹

¹Korea Advanced Institute of Science and Technology Solid oxide fuel cells (SOFCs) have been considered as next-generation energy conversion devices due to their high conversion efficiency. Nonetheless, high operating temperatures (> 800 °C) of SOFCs give rise to various issues such as limited material selection and high system costs. Consequently, the development of suitable air electrode materials with high reactivity at low temperatures is crucial. In this perspective, surface modification methods have been studied to enhance the surface reactivity of air electrodes. We propose the utilization of alkaline leaching as a strategy that is both more cost- and time-efficient compared to the previously reported methods such as nanocatalyst decoration, surface coating, and acid etching. When an anodic bias is applied to a perovskite oxide in an alkaline solution, alkaline earth metal cations on A-site in perovskite oxide are selectively dissolved into the alkaline medium, a phenomenon commonly referred to

Poster Presentations

as leaching. As a result, the surface of perovskite oxide differs from the pristine condition (e. g. transition-metal-rich) which is known to be advantageous for the oxygen reduction reaction occurring at the air electrode of SOFCs. In this work, $\text{PrBa}_{0.8}\text{Ca}_{0.2}\text{Co}_2\text{O}_{5+\delta}$ (PBCC) was chosen for air electrode material as the first case study of alkaline leaching, which has garnered significant attention due to its exceptional electrode performance. After the alkaline-leaching-treatment, the electrode resistance of $0.018 \Omega \cdot \text{cm}^2$, which was 5-fold enhanced activity compared to that of the bare PBCC air electrode, was recorded at 650°C . Various analyses including XRD, XPS, and TEM were conducted to reason out the enhanced activity.

PG2A-136 | A Study on Particle and Crystal Size Analysis of Lithium Lanthanum Titanate Ceramic Powder Depending on Synthesis Methods

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Lithium is a key resource for the global rapid growth of the EV industry, and continuously increasing demand and price. In order to overcome the limited reserves of major lithium sources such as rock and brine, research on seawater lithium extraction with electrodialysis and lithium ion selective membranes is being conducted. Lithium lanthanum titanate(LLTO), an oxide solid electrolyte for all-solid-state batteries, is promising as a lithium ion selective membrane, and a powder synthesis process is important to improve its performance. In this study, LLTO powder was prepared by two synthesis methods, Sol-Gel reaction (SGR) and Solid-State reaction (SSR), and the powder shape, which is an index related to membrane performance, was compared. Characterized with XRD and SEM, and analyzed for the crystallite size with FWHM of the powders prepared by the two synthetic methods. As a result, the powder synthesized by SGR was smaller and more uniform than that of SSR, and the crystal size was 0.68 times smaller. This is the basis for optimizing the powder manufacturing process for manufacturing LLTO membranes suitable for applications such as manufacturing high-performance membranes or mass production of membranes.