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KIT Energy News

에너지융합기술 혁신인재 양성사업단

Innovative Education & Research Center for Energy Convergence Science and Technology

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이원호 교수 공동연구팀, 고안정성 유기 태양전지 구현 성공

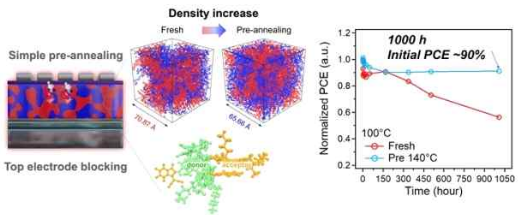
- 유기 태양전지의 안정성 확보로 상용화 기술 개발 기대
- 화학공학분야 국제 저명 SCI 학술지 'Chemical Engineering Journal' 게재

[사진 1] (좌측부터) 장용찬 학생, 이원호 교수(이하 국립금오공대), 이창연 교수(중앙대), 손현수 학생(경상국립대), 이태경 교수(경상국립대)

고분자공학과 이원호 교수 연구팀이 중앙대학교 이창연 교수 및 경상국립대학교 이태경 교수 연구팀과 공동연구를 통해 '고분자 기반 유기 태양전지의 열 안정성을 획기적으로 개선한 연구 성과'를 발표했다. 이번 연구는 고온의 가혹한 조건에서도 매우 안정적인 특성을 나타내어 '유기 태양전지의 상용화 가능성'을 크게 높였다는 평가를 받고 있다.

유기 태양전지는 유기화합물을 사용해 태양빛을 전기로 변환하는 것으로 가볍고 유연하며 저렴하지만, 온도 변화에 민감해 고온에 장기간 노출될 경우 성능이 크게 떨어지는 단점이 있다. 이에 연구팀은 아주 간단한 열처리 공정을 통해 유기 태양전지 상부 전극의 확산을 억제하여 열 안정성을 크게 개선했다고 밝혔다.

연구에 따르면, 열처리 과정이 고분자 전도층의 밀도를 증가시켜 고온의 스트레스에서도 전극 확산을 방지하고 장기적으로도 안정성이 유지되는 효과를 확인했다. 이번 연구에서는 100℃ 에서 1,000시간 동안의 열처리 과정에도 90%의 초기 효율을 유지하는 성과를 달성했다. 이는 현재까지 보고된 유사한 형태의 광활성층을 사용한 유기 태양전지 중 가장 높은 열 안정성을 유지한 기록 중 하나로 평가된다.



[사진 2] 간단한 열처리를 통해 고안정성을 구현한 유기태양전지 이미지

관련 연구의 논문 제목은 'Preventing electrode penetration and burn-in degradation in non-fullerene organic solar cells via pre-annealing: Insights from experimental and computational studies(비풀러렌 유기태양전지의 열처리를 통한 전극 침투 억제 및 안정성 향상 연구)'로 화학공학 분야의 저명 국제 학술지 Chemical Engineering Journal(JCR 상위 3.2%, IF 13.3)에 10월 28일자로 게재됐으며, 유기 태양전지의 내구성 문제를 해결할 수 있는 중요한 방법을 제안한 연구로 주목받고 있다.

공동 제1저자로 참여한 장용찬 석사과정 학생은 "이번 연구가 유기 태양전지의 상용화에 중요한 발판이 될 것이라 기대한다."며, "앞으로도 유기 전자재료의 안정성을 높일 수 있는 다양한 방법을 모색할 계획"이라고 밝혔다.

이번 연구를 주도한 이원호 교수는 "유기 태양전지의 열 안정성 개선 기술은 고효율 친환경 에너지 생산을 위한 핵심 기술"이라며, "본 연구가 차세대 태양광 발전 분야에서 큰 기여를 할 수 있을 것이라 기대한다."고 말했다.

본 연구는 BK21 프로그램, 교육부 지자체-대학 협력기반 지역혁신 사업, 중앙대 사업 지원을 받아 수행됐다.

금오공과대학교 KIT People(2024.11.12.) https://www.kumoh.ac.kr/ko/sub01_05_02.do?mode=view&articleNo=501720

◈ 관련 기사 ◈

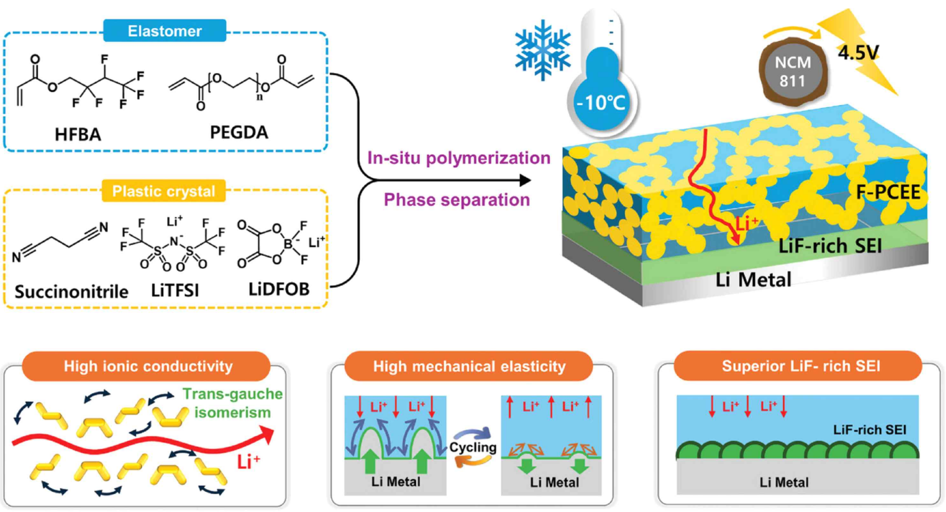
뉴데일리	금오공대 이원호 교수팀, 고안정성 유기 태양전지 구현 성공	https://tk.newdaily.co.kr/site/data/html/2024/11/12/2024111200081.html
교수신문	국립금오공대 이원호 교수 연구팀, 고안정성 유기 태양전지 구현 성공	http://www.kyosu.net/news/articleView.html?idxno=127247
전자신문	금오공대, 고안정성 고분자 기반 유기 태양전지 구현 성공	https://www.etnews.com/20241112000082
베리타스알파	국립금오공대 이원호 교수 연구팀, 고안정성 유기 태양전지 구현 성공	http://www.veritas-a.com/news/articleView.html?idxno=528855
대구신문	국립금오공대 이원호 교수 연구팀, 고안정성 유기 태양전지 구현 성공	https://www.idaegu.co.kr/news/articleView.html?idxno=481112
중앙이코노미뉴스	국립금오공대 이원호 교수 연구팀, 고안정성 유기 태양전지 구현 성공	https://www.foodneconomy.com/news/articleView.html?idxno=400289
세계일보	고안정성 유기 태양전지 구현 성공…상용화 개발 기대	https://www.segye.com/newsView/20241112509721

에너지저장

Advanced Materials
Volume 36, Jul. 2024, 2403191 (Impact Factor : 29.4)

Design of Fluorinated Elastomeric Electrolyte for Solid-State Lithium Metal Batteries Operating at Low Temperature and High Voltage

Jinseok Park, Hyeonseok Seong, Chanho Yuk, Dongkyu Lee, Youyoung Byun, Eunji Lee, **Wonho Lee**, Bumjoon J. Kim*



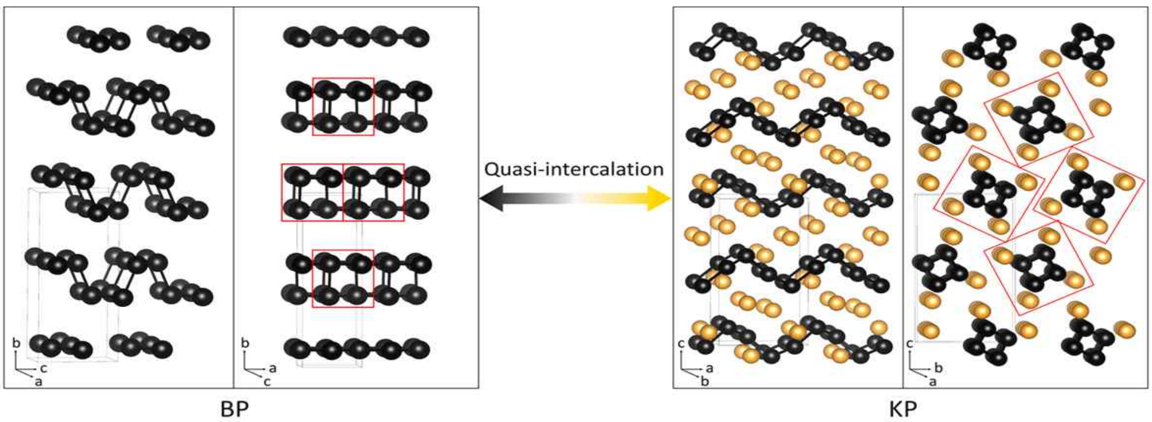
This work demonstrates the low-temperature operation of solid-state lithium metal batteries (LMBs) through the development of a fluorinated and plastic-crystal-embedded elastomeric electrolyte (F-PCEE). The F-PCEE is formed via polymerization-induced phase separation between the polymer matrix and plastic crystal phase, offering a high mechanical strain (≈300%) and ionic conductivity (≈0.23 mS cm^{-1}) at −10 ˚C. Notably, strong phase separation between two phases leads to the selective distribution of lithium (Li) salts within the plastic crystal phase, enabling superior elasticity and high ionic conductivity at low temperatures. The F-PCEE in a Li/$LiNi_{0.8}Co_{0.1}Mn_{0.1}O_2$ full cell maintains 74.4% and 42.5% of discharge capacity at −10 ˚C and −20 ˚C, respectively, compared to that at 25 ˚C. Furthermore, the full cell exhibits 85.3% capacity retention after 150 cycles at −10 ˚C and a high cut-off voltage of 4.5 V, representing one of the highest cycling performances among the reported solid polymer electrolytes for low-temperature LMBs. This work attributes the prolonged cycling lifetime of F-PCEE at −10 ˚C to the great mechanical robustness to suppress the Li-dendrite growth and ability to form superior LiF-rich interphases. This study establishes the design strategies of elastomeric electrolytes for developing solid-state LMBs operating at low temperatures and high voltages.

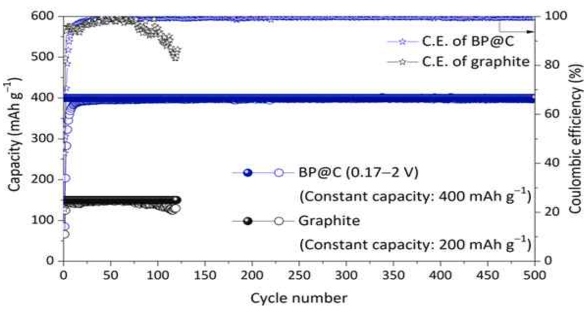
에너지저장

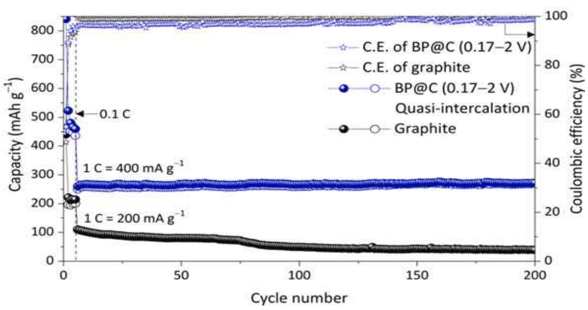
Journal of Power Sources
Volume 629, February 2025, p236129 (Impact Factor : 8.1)

K quasi-intercalation in black P nanocomposite as a high-performance anode for K-ion batteries

Do-Hyeon Kim, Young-Han Lee, Je-Hyeon Han, Jeong-Myeong Yoon, Sun-Hwa Yeon, Jeong-Hee Choi*, and Cheol-Min Park*







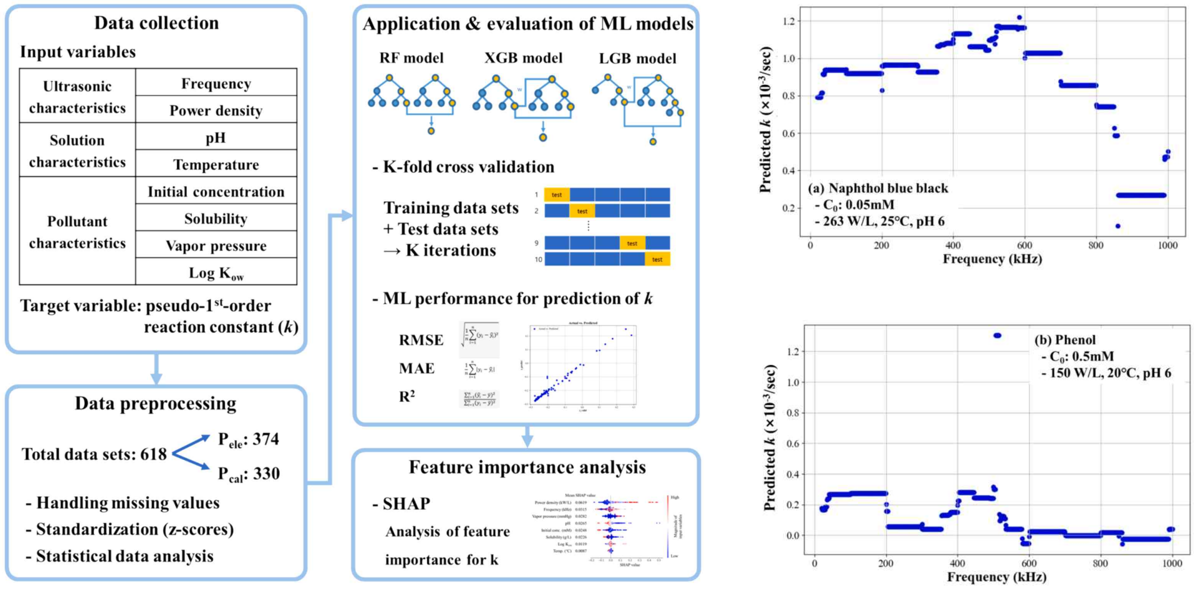
Potassium-ion batteries (PIBs) have emerged as promising alternatives to lithium-ion batteries owing to their various advantages. Among the various anode candidates for PIBs, black P (BP) has garnered attention owing to its high theoretical capacity and favorable reaction potential (vs. K^+/K). Although several studies have reported on the reaction mechanism of BP during potassiation/depotassiation, it remains controversial. Therefore, the exact reaction mechanism needs to be clarified, and further enhancements in electrochemical performance are required. To thoroughly investigate the reaction mechanism of BP, a BP nanocomposite with amorphous carbon (BP@C) is synthesized to enhance its reversibility with K ions. A thorough investigation of the reaction mechanism employs various ex situ analytical tools for the potassiation/depotassiation process. During potassiation, BP sequentially transforms into the KP and K_4P_3 phases, whereas the reaction is reversed during depotassiation. Based on the reaction mechanism, distinctive K quasi-intercalation is suggested using a similar structural relationship between the BP and KP phases. The K quasi-intercalation is applied to a BP@C anode, which consequently demonstrate a highly reversible capacity of 400 mAh g^{-1}, exceptional cycle stability over 500 cycles, and superior rate capability. Consequently, we anticipate that K quasi-intercalation in BP will provide a high-performance P-based anode for PIBs.

환경에너지

Ultrasonics Sonochemistry
110, 2024.11., 107032 (Impact Factor : 8.7)

Machine learning model to predict rate constants for sonochemical degradation of organic pollutants

Iseul Na, Taeho Kim, Pengpeng Qiu, Younggyu Son



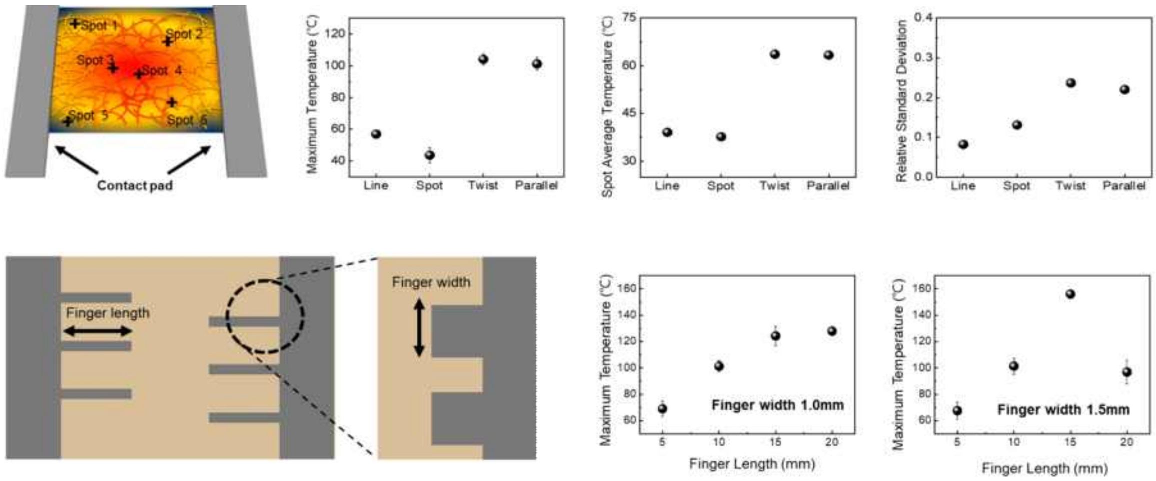
In this study, machine learning (ML) algorithms were employed to predict the pseudo-1st-order reaction rate constants for the sonochemical degradation of aqueous organic pollutants under various conditions. A total of 618 sets of data, including ultrasonic, solution, and pollutant characteristics, were collected from 89 previous studies. Considering the difference between the electrical power (Pele) and calorimetric power (Pcal), the collected data were divided into two groups: data with Pele and data with Pcal. Eight input variables, including frequency, power density, pH, temperature, initial concentration, solubility, vapor pressure, and octanol-water partition coefficient (Kow), and one target variable of the degradation rate constant, were selected for ML. Statistical analysis was conducted, and outliers were determined separately for the two groups. ML models, including random forest (RF), extreme gradient boosting (XGB), and light gradient boosting machine (LGB), were used to predict the pseudo-1st-order reaction rate constants for the removal of aqueous pollutants. The prediction performance of the ML models was evaluated using different metrics, including the root mean squared error (RMSE), mean absolute error (MAE), and R squared (R2). A significantly higher prediction performance was obtained using data without outliers and augmented data. Consequently, all the applied ML models could be used to predict the sonochemical degradation of aqueous pollutants, and the XGB model showed the highest accuracy in predicting the rate constants. In addition, the power density and frequency were the most influential factors among the eight input variables in prediction with the Shapley additive explanation (SHAP) values method. The degradation rate constants of the two pollutants over a wide frequency range (20–1,000 kHz) were predicted using the trained ML model (XGB) and the prediction results were analyzed.

태양에너지

Nanomaterials
Volume 14, October 2024, p1735 (Impact Factor : 4.4)

Optimization of Contact Pad Design for Silver Nanowire-Based Transparent Heater to Improve Heating Characteristics

Seo Bum Chu, Yoohan Ma, Jinwook Jung, Sungjin Jo, Dong Choon Hyun, Jae-Seung Roh, Jongbok Kim*, Dongwook Ko*



Transparent heaters are gaining significant attention for applications such as antifog glass, smart windows, and smart farm greenhouses. A transparent heater basically consists of transparent conducting materials that serve as a heating area and contact pad electrode to apply power. To fabricate a transparent heater, materials with excellent light transmittance and low sheet resistance are required. Among various transparent conducting materials, such as Indium Tin Oxide (ITO), carbon nanotube (CNT), graphene, and silver nanowires (AgNWs), AgNWs are particularly favored due to their good electrical, optical, and mechanical properties. However, in order to improve the heating characteristics of transparent heaters, research is essential not only on improving the properties of transparent conducting materials but also on the design of contact pad electrodes that can uniformly improve current distribution. Here, we explore various shapes of contact pad electrodes for AgNW-based transparent heaters to improve current distribution. Shapes such as line, spot, twisted, and parallel-type contact pad electrodes are designed and investigated to optimize overall heating characteristics. We analyze the heating properties of these transparent heaters with various contact pad electrodes, demonstrating how their specific shape and size affect heating characteristics and uniformity. We also investigate the optimal shape of the contact pad electrode to minimize transmission loss through UV-VIS spectroscopy. As a result, we confirm that the shape of the contact pad electrode was important for simultaneously achieving high heating characteristics of 120 ˚C, good heating uniformity, and over 80% transparency in an AgNW-based transparent heater.