(양식 1)

【 고분자학회 학회상 포상 지원서 】

[표지]

<table>
<tr><td>공모분야</td><td colspan="6">중견학술상</td></tr>
<tr><td rowspan="5">지원자
인적사항</td><td rowspan="2">성 명</td><td>한 글</td><td>유영재</td><td rowspan="2">영 문</td><td rowspan="2" colspan="2">YOO, YOUNGJAE</td></tr>
<tr><td>한 자</td><td>兪暎在</td></tr>
<tr><td rowspan="3">소속기관</td><td>기관명</td><td colspan="4">중앙대학교</td></tr>
<tr><td>부서명
(학과명)</td><td>첨단소재공학과</td><td>직위/직급</td><td colspan="2">부교수</td></tr>
<tr><td>주 소</td><td colspan="4">경기도 안성시 서동대로 4726</td></tr>
<tr><td>업적요지</td><td colspan="6"><u>고분자학회 업무</u>

운영이사 (조직이사(2015), 학술이사(2016)
평의원 (2016~현재)
산학협동위원 (2015, 2016, 2022)
국문지편집위원 (2014~2018)

<u>연구성과물</u>

SCI 논문 94편, Google h-index : 34
특허등록 54건 (국내 51, 국외 3)</td></tr>
<tr><td colspan="7">상기와 같이 고분자학회 학회상 포상을 지원합니다.

2025. 8. 25

기관명 : 중앙대학교
직 위 : 부교수
지원자 : 유영재 (서명)</td></tr>
</table>

(양식 2)

1. 인적사항

가. 학력사항 (대학교 이상만 기재)

기 간	학 교 명	전공 및 학위, 지도교수
2005 ~ 2010	U of Texas at Austin	화학공학, 공학박사, Donald R. Paul
1998 ~ 2000	서강대학교	화학공학, 공학석사, 이재욱
1994 ~ 1998	서강대학교	화학공학, 공학사, 이재욱

나. 경력사항 (5개 이내 기재)

기 간	기관명(직위, 직책 등)
2021 ~ 현재	중앙대학교 공과대학 첨단소재공학과 부교수
2000 ~ 2021	한국화학연구원 고기능고분자연구센터 연구원/선임/책임연구원
2013 ~ 2019	과학기술연합대학원대학교 교수
2018 ~ 2019	U of California, Irvine 방문연구원

다. 수상경력 (최근 3년 이내)

※ 정부 포상, 민간 포상 등 연구개발 업적 관련 수상경력 모두 기재

일 자	수 상 내 용	시 상 기 관
2016	창의연구상	한국화학연구원
2014	그린경영상	한국화학연구원
2013	현건섭논문상	SPE Korea

2. 수상후보자 추천인단 명부

성 명	전 공 분 야	세부전공 분야	소 속	비고
최길영	화학	고분자합성	전) 한국화학연구원	
이승우	화학공학	고분자합성	영남대학교	
이충훈	화학	고분자중합공정	LG화학	

3. 대표논문의 연구업적 요약서

본인은 **고분자 소재의 구조-물성 상관관계 규명** 연구를 통해 에너지 및 환경 문제 해결에 기여할 수 있는 **수동복사냉각소재, 열·광학 특성 제어 고분자 소재** 개발, 그리고 **건식 공정 기반 고분자 하이브리드 에너지 소재** 연구를 중점적으로 수행하였음. 이를 통해 고분자 기반 신소재의 응용 가능성을 건축, 차량, 에너지 하베스팅 시스템 등으로 확장하였음.

(대표 연구업적)

1. ACS Sustainable Chemistry & Engineering(2022): TIPS 공정을 이용하여 생분해성 PLA 기반 다공성 구조체를 제작하고, 친환경 수동복사냉각 소재를 개발하였음. 본 소재는 태양광 반사율 0.91, LWIR 방사율 0.92를 달성하였으며, 최대 117 W/m^2의 냉각 성능과 주변 온도 대비 9℃ 낮은 온도를 구현하여, 지속가능한 건축물 외장재로서의 활용 가능성을 입증하였음.
2, Chemical Engineering Journal(2023): TPU를 이용하여 신축성 있는 수동복사 냉각 필름을 개발하여 건축물 및 차량 등 복잡한 형태의 물체에 적용 가능성을 확인하였음. TPU 필름은 이중 모드 기공 구조를 통해 효율적인 태양광 산란을 유도하고, 높은 태양광 반사율 (0.93)과 LWIR 방사율 (0.90)을 나타내었음.
3. Journal of Energy Chemistry(2023): 열변색 안료와 중공 SiO_2입자를 포함한 PDMS 복합소재를 이용하여 온도 적응형 복사 냉각 필름을 구현하였음. 본 필름은 40℃ 이상에서는 냉각을 활성화하고, 40℃ 미만에서는 열 보존 기능을 수행하는 스마트 소재로 작동하였음. 또한, 열전발전 소자와 결합하여 계절에 따른 열 관리와 에너지 하베스팅을 동시에 달성할 수 있음을 증명하였음.
4. Rare Metals(2024): 질소, 인 동시 도핑된 3차원 다공성 탄소소재를 개발하여 고용량·고안정성 포타슘이온전지 음극으로 활용하였음. 본 소재는 258 $mAh.g^{-1}$의 가역용량과 800회 충·방전 후 96.1%의 용량 유지율을 나타내어 고분자·탄소 소재 에너지 저장 응용 가능성을 증명하였음.
5. Energy & Environmental Materials (2025): 용매를 사용하지 않는 건식 공정 기반 후막전극 제조 연구를 수행하였음. 전도성 첨가제의 형태 (0D Super P, 1D CNT, 2D GNP)에 따른 리튬이온 수송 경로 및 전극 내부 tortuosity를 규명하였으며, CNT 도입 시 우수한 전기화학 성능(157 $mAh.g^{-1}$, 7.16 $mAh.cm^{-2}$)을 달성하여, 친환경 건식 공정과 고성능 리튬이온전지 적용가능성을 제시하였음.

(연구의 우수성 및 의의)

- **복사냉각소재 연구**에서 PLA, TPU, PDMS 및 라즈베리형 SiO_2등 고분자·무기 하이브리드 구조를 개발하여 **생분해성·신축성·온도 적응성을 구현**하고, 다양한 응용 분야 (건축물·차량·섬유 등)에서 활용 가능성을 입증하였음.
- 옥외 실험, 모형 주택 실증, 열전발전 결합을 통해 복사냉각 소재의 **실제 에너지 절감 및 에너지 하베스팅 효과를 검증**하였음.
- 이와 병행하여 **배터리용 탄소 전극 소재 및 건식 전극 공정 연구를 수행**하여 고성능 에너지 저장 기술을 제시하였으며, 다수의 연구가 **국제 학술지 표지논문으로 선정**되어 학문적 우수성과 사회적 파급효과를 입증하였음.

(향후 연구 계획)

- **복사냉각소재의 내구성·경제성 향상 및 대면적화**를 통해 건축물·차량·섬유 등 다양한 산업 현장에 적용 가능한 실용화 기반을 마련할 계획임.
- **배터리 전극 및 건식 공정 기술**을 고도화하여 차세대 고에너지밀도·친환경 에너지 저장 시스템 개발을 추진할 예정임.
- 복사냉각과 배터리 연구를 **각각 특화된 연구축으로 심화**하여, 에너지 절감과 저장이라는 **상호 보완적 기술 발전**을 달성하고자함.

4. 연구개발 실적

(1) 업적 총괄 (단위:건)

<table>
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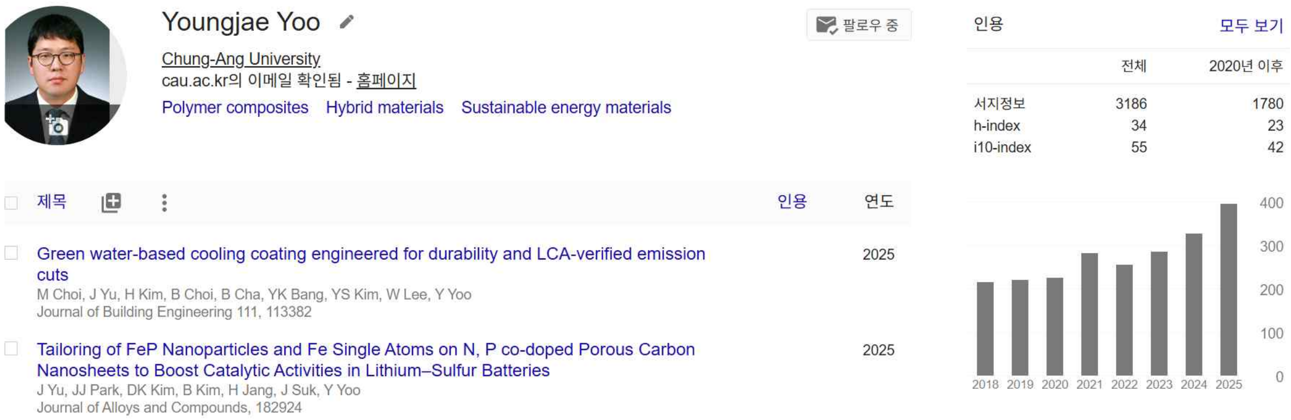
<tr><td>12</td><td>38</td><td>44</td><td>94</td><td></td><td>34</td><td></td></tr>
<tr><td rowspan="3">특허</td><td colspan="2">국내</td><td colspan="2">국외</td><td rowspan="2">기술이전</td><td rowspan="2">연구 보고서</td><td rowspan="2">저서</td></tr>
<tr><td colspan="2">등록</td><td colspan="2">등록</td></tr>
<tr><td colspan="2">51</td><td colspan="2">3</td><td>3</td><td>24</td><td></td></tr>
</table>

*h-index 증빙자료(화면캡처본) 제출.



(2) 대표논문 목록 (5편), 신진학술상의 경우 3편

제 목	발표지명	Impactor factor	발표년도	역할(저자)	저자수(명)	피인용 횟수
Conductive Agent-Controlled Tortuosity in Solvent-Free Thick-Film Electrodes for High-Energy Lithium-Ion Batteries	Energy & Environmental Materials	14.1	2025	교신저자	4	0
N, P co-doped 3D porous carbon with self-assembled morphological control via template-free method for potassium-ion battery anodes	Rare Metals	11.0	2024	교신저자	5	6
Efficient thermal management and all-season energy harvesting using adaptive radiative cooling and a thermoelectric power generator	Journal of Energy Chemistry	14.9	2023	교신저자	7	65
Hybrid emitters with raspberry-like hollow SiO2 spheres for passive daytime radiative cooling	Chemical Engineering Journal	13.2	2023	교신저자	6	79
Fully Organic and Flexible Biodegradable Emitter for Global Energy-Free Cooling Applications	ACS Sustainable Chemistry & Engineering	7.3	2022	교신저자	6	75

*제목 및 저자를 확인할 수 있는 증빙자료 제출.

RESEARCH ARTICLE

Energy & Environmental Materials WILEY

Solvent-Free Electrode Process

Conductive Agent-Controlled Tortuosity in Solvent-Free Thick-Film Electrodes for High-Energy Lithium-Ion Batteries

*Byeongjin Kim, Dae Kyom Kim, Jeehoon Yu, and Youngjae Yoo**

Rapid developments in lithium-ion battery (LIB) technology have been fueled by the expanding market for electric vehicles and increased demands for energy storage. Recently, thick electrode fabrication by solvent-free methods has emerged as a promising strategy for enhancing the energy density of LIBs. However, as electrode thickness increases, the tortuosity of lithium-ion transport also increases, resulting in severe polarization and poor electrochemical performance. Here, we investigate the effect of conductive agent morphology on the structural and electrochemical properties of 250 μm thick lithium iron phosphate (LFP)/conductive agent/polytetrafluoroethylene (PTFE)-based electrodes. Three commercially available conductive additives, namely 0D Super P, 1D multi-walled carbon nanotubes (MWCNTs), and 2D graphene nanoplatelets (GNPs), were incorporated into LFP-based electrodes. The MWCNT-incorporated electrode with a high loading mass (42 mg cm^{-2}) exhibited a high porosity ($\varepsilon = 51\%$) and low tortuosity ($\tau = 4.02$) owing to its highly interconnected fibrous network of MWCNTs. Due to the fast lithium-ion transport kinetics in the MWCNT-incorporated electrode, the electrochemical performances exhibited a high specific capacity of 157 mAh g^{-1} at 0.1 C and an areal capacity of 7.16 mAh cm$_{-2}$ at 0.1 C with a high-rate capability and excellent cycling stability over 300 cycles at 0.1 C. This study provides a guidance for utilizing conductive agents to apply in the low tortuous thick electrode fabricated by a solvent-free process. Additionally, this work paves the way to achieve scalable and sustainable dry processing techniques for developing next-generation energy storage technologies.

1. Introduction

The growing electric vehicle (EV) market and rising energy storage demands have driven rapid advancements in lithium-ion battery (LIB) technology. The high energy densities, long cycle lives, and cost-effectiveness of LIBs make them essential for modern applications.[1,2]

To achieve higher energy density, the exploration of advanced electrode material chemistry involved in the cathode, anode, and electrolyte is needed to increase the operating voltage range and specific capacity.[3–8] Another approach is the adoption of thick electrode configurations, which increase active material loading and overall energy density.[9–13]

Thick electrodes significantly boost energy density per unit volume, benefiting EV efficiency and driving range. Traditional wet electrode fabrication techniques present limitations when applied to thick electrodes, such as poor additive dispersion, non-uniform coatings, and structural defects during drying. Moreover, the use of toxic solvents like N-methyl-2-pyrrolidone (NMP) also necessitates complex recovery processes, adding to environmental impact. These limitations highlight the need for alternative processing methods for thick electrodes in LIBs. Ryu et al.[14] demonstrated the dry press-coating process using the combination of multiwalled carbon nanotubes (MWNTs) and polyvinylidene fluoride (PVDF) as a dry powder composite and etched Al foil as a current collector. As-prepared $LiNi_{0.7}Co_{0.1}Mn_{0.2}O_2$ (NCM712) electrodes exhibited a high loading mass (100 mg cm^{-2}) with impressive specific energy and volumetric energy density of 360 Wh kg^{-1} and 701 Wh L^{-1}, respectively. Liang et al.[15] reported a new electrode manufacturing method via the cold plasma process (CPC) without solvents, polymer binders, carbon additives, drying processes, and calendaring processes. The fabricated LFP cathode sheets have 220 μm thickness with a mass loading above 42 mg cm^{-2}, which delivered highly reversible cycling performance with a retention of 81.6% after 500 cycles. Kim et al.[16] demonstrated a hot press process with a thermoplastic phenoxy resin as a binder without solvents, which generates a uniform network structure connected with the active materials. The obtained thick $LiNi_{0.8}Co_{0.1}Mn_{0.1}O_2$ (NCM811) electrodes showed a high loading mass of 40 mg cm^{-2} with a stable cyclability. However, these approaches require either the use of a press machine, a special coating tool, or a high-temperature process. Recently, polytetrafluoroethylene (PTFE) as a deformable binder has emerged as a potential polymer binder for fabricating thick electrodes without using any solvent.[17–21] PTFE particles were formed into adhesive fibrils under shear forces during the mixing process, which make network structures and closely bind both conductive carbon and active materials.[22] Compared to previous methods, the PTFE binders have

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[Correction added on 15 May 2025, after first online publication: the capacity values have been corrected.]

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RARE METALS

ORIGINAL ARTICLE

N, P co-doped 3D porous carbon with self-assembled morphological control via template-free method for potassium-ion battery anodes

Jeehoon Yu, Dae Kyom Kim, Hong Geun Oh, Seung-Keun Park, Youngjae Yoo*

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Abstract The larger ionic radius of potassium ions than that of lithium ions significantly limits the accomplishment of rapid diffusion kinetics in graphite electrodes for potassium-ion batteries (PIBs), resulting in comparatively poor rate performance and cycle stability. Herein, we report a high-rate performance and cycling stability amorphous carbon electrode achieved through nitrogen and phosphorous co-doping. The as-prepared N, P co-doped carbon electrodes have distinct 3D structures with large surface areas, hierarchical pore architectures, and increased interlayer spaces resulting from the direct pyrolysis of supramolecular self-assembled aggregates without templates. The obtained electrode N3P1 exhibits a reversible specific capacity of 258 $mAh{\cdot}g^{-1}$ at a current density of 0.1 $A{\cdot}g^{-1}$ and a good long-term cycle performance (96.1% capacity retention after 800 cycles at 0.5 $A{\cdot}g^{-1}$). Kinetic investigations show that the N3P1 electrode with the well-developed porous structure and large number of surface defects exhibits capacitive-driven behavior at all scan rates, which may be attributed by N and P co-doping. Ex-situ transmission electron microscopy analyses in the fully discharged and charged states demonstrate structural stability and reversibility owing to the expanded interlayer space. The suggested synthesis approach is simple and effective for producing heteroatom-doped carbon materials for PIBs and other advanced electrochemical energy storage materials.

Keywords Amorphous carbons; 3D porous structures; Nitrogen and phosphorous co-doping; Potassium-ion batteries

Jeehoon Yu, Dae Kyom Kim and Youngjae Yoo have contributed equally to this work.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s12598-024-02724-7.

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1 Introduction

Lithium-ion batteries (LIBs) are commonly used in many portable electronic devices and electric vehicles due to their high energy and power densities [1–3]. However, expanding worldwide usage of lithium has resulted in scarcity and rising cost of lithium sources, making challenges in the growing demand for LIBs [4–6]. From this perspective, the development of LIB alternatives, such as sodium-ion batteries, magnesium-ion batteries, and potassium-ion batteries (PIBs), has received considerable attention [7]. PIBs are of considerable interest owing to the availability of resources, cheap cost, and long-term viability of potassium (K) [8, 9]. Additionally, the very similar redox potential of K^+/K (− 2.93 V vs. standard hydrogen electrode, SHE) and Li^+/Li (− 3.04 V vs. SHE) produce a higher energy density and a wider potential window [10]. However, since K^+ has a larger radius (0.138 nm) than Li^+ (0.076 nm), the diffusion kinetics of K^+ during the processes of intercalating and de-intercalating between graphite layers is sluggish, resulting in poor rate capability and stabled cycle performance, which is the main bottle neck for the development of PIBs [11–13].

Well-designed anode materials have been proposed to address these critical issues [14–16]. Disordered amorphous carbon materials, including hard and soft carbons, have attracted a lot of interest in comparison to graphite with

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http://www.journals.elsevier.com/journal-of-energy-chemistry/

Efficient thermal management and all-season energy harvesting using adaptive radiative cooling and a thermoelectric power generator

Chanil Park [a,1], Woohwa Lee [a,1], Choyeon Park [a], Sungmin Park [a], Jaeho Lee [b], Yong Seok Kim [a,*], Youngjae Yoo [c,*]

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[b] Department of Mechanical and Aerospace Engineering, University of California, Irvine, CA 92617, United States
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Temperature-adaptive film
Thermoelectric device
Energy harvesting

ABSTRACT

Passive daytime radiative cooling (PDRC) is useful for thermal management because it allows an object to emit terrestrial heat into space without the use of additional energy. To produce sub-ambient temperatures under direct sunlight, PDRC materials are designed to reduce their absorption of solar energy and to enhance their long-wavelength infrared (LWIR) emissivity. In recent years, many photonic structures and polymer composites have been studied to improve the cooling system of buildings. However, in cold weather (i.e., during winter in cold climates), buildings need to be kept warm rather than cooled due to heat loss. To overcome this limitation, temperature-responsive radiative cooling is a promising alternative. In the present study, adaptive radiative cooling (ARC) film fabricated from a polydimethylsiloxane/hollow SiO_2 microsphere/thermochromic pigment composite was investigated. We found that the ARC film absorbed solar radiation under cold conditions while exhibiting radiative cooling at ambient temperatures above 40 °C. Thus, in outdoor experiments, the ARC film achieved sub-ambient temperatures and had a theoretical cooling power of 63.2 W/m^2 in hot weather. We also demonstrated that radiative cooling with an energy harvesting system could be used to improve the energy management of buildings, with the thermoelectric module continuously generating output power using the ARC film. Therefore, we believe that our proposed ARC film can be employed for efficient thermal management of buildings and all-season energy harvesting in the near future.

1. Introduction

There has been a steady global shift away from fossil-based energy sources to renewable alternatives such as solar, wind, and geothermal heat. Currently, about 20% of all energy consumed comes from renewable sources, and this is expected to increase in the future. However, effective energy management remains important for the conversation of energy. Recently, passive daytime radiative cooling (PDRC) has been widely investigated for use in various applications, such as the thermal management of buildings, solar cells, and thermoelectric generators, due to its zero-energy cooling abilities based on the transfer of natural heat to outer space using the clear sky as a heat sink. Raman et al. were the first to propose a thermal emitter with multilayers of HfO_2 and SiO_2 that could be cooled below ambient air temperatures under direct sunlight [1]. Since then, many researchers have investigated various photonic crystals [2–5], porous polymers [6,7], polymers embedded with nano- or microparticles [8–10], and polymeric fabrics to improve PDRC performance [11–13]. Although radiative cooling demonstrates significant potential as a zero-energy cooling approach in year-round hot climates, adaptive radiative cooling (ARC) has also been investigated because radiative cooling is not required all year in colder climates, especially during winter when buildings need to be kept warm. As such, the development of switchable radiative cooling would allow for efficient, all-season energy management of buildings.

ARC can be achieved by controlling the long-wavelength infrared (LWIR) emissivity [14–17] or solar reflectivity [18,19] of materials, Liu et al. proposed a polydimethylsiloxane (PDMS) grating and nanoparticle-embedded PDMS film that achieved ARC through

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Hybrid emitters with raspberry-like hollow SiO_2 spheres for passive daytime radiative cooling

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ABSTRACT

Passive daytime radiative cooling (PDRC) has been vigorously investigated in recent years because it does not require electrical energy, reducing greenhouse gas emissions for a more sustainable society. Representative approaches to improve radiative cooling performance are the design of metamaterials with a long-wave infrared (LWIR) emissivity and porous polymer structures with a high-solar reflectivity. Furthermore, coating materials for a simple process should be researched to improve the applicability of radiative cooling. In this study, we investigate a daytime radiative cooling coating using raspberry-like hollow SiO_2 spheres (RHSs) to achieve effective radiative cooling performance and a simple coating process. The raspberry-like morphologies of the synthesized hollow SiO_2 spheres contribute to multiple scattering of sunlight, resulting in enhanced performance of the radiative cooling coating. Moreover, the results of an outdoor experiment and energy-saving demonstration suggest that the RHS coating is suitable for effective heat management of the buildings. The RHS coating achieves a cooling temperature of 9.7 °C under solar irradiance of 800 W m^{-2}. The inner temperature of a house coated with PDRC is 6.6 °C lower than that of a bare house under direct sunlight.

1. Introduction

The Earth absorbs solar energy as radiation and emits heat to outer space through the atmosphere. Therefore, the temperature balance in the Earth is maintained by emitting absorbed heat through a wavelength range of 8–13 μm (so-called "atmospheric window"). Passive daytime radiative cooling (PDRC) is defined by radiative emissions that form electromagnetic waves under direct sunlight. A PDRC material prevents heating the targeted space and object without using electrical energy. Unlike air conditioning systems, a building coated with the PDRC material does not require electrical energy to cool indoor air. Therefore, PDRC technology has been developed for effective heat management in buildings, vehicles, and solar cells [1–4].

Several critical parameters should be considered to improve daytime radiative cooling performance. First, a high LWIR emissivity causes efficient thermal radiation through an atmospheric window. The atmospheric window is defined as a wavelength region from 8 to 13 μm, in which Earth's atmospheric transmittance is close to 100 % caused by the low absorption bands of molecules (e.g., H_2O, CO_2, and O_2) in the atmosphere. Kirchhoff's law of thermal radiation declares that the thermal radiative emissions of an object is equal to its absorptivity in thermodynamic equilibrium [5]. Therefore, the high electromagnetic emissions in the infrared atmospheric window should be achieved by materials with high absorptivity in the LWIR region.

Second, a high reflection in visible and near-infrared (NIR) wavelength regions can reduce the heating surface of the object by sunlight. For decades, many researchers have focused on achieving high LWIR emissivity using metamaterials such as photonic crystals and dielectrics [1,2]. The photonic structures composed of polar dielectrics such as silicon carbide (SiC) cause an increase in heat emissions within the atmospheric window by optically active resonances. Moreover, a silver (Ag) layer was used at the bottom of the metamaterial structure to achieve high-solar reflection. Yao Zhai et al. reported that the resonant polar dielectric microspheres with a silver coating result in an infrared emissivity of 0.93 and radiative cooling power of 93 W m^{-2} [6]. Silicon dioxide (SiO_2) microspheres randomly distributed in a polymeric matrix were investigated to achieve suitable PDRC coatings [7].

Furthermore, hollow spheres in a polymer matrix are an attractive radiative cooling material because of high-solar reflectivity [8–10]. When sunlight is incident on the material with hollow spheres,

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Fully Organic and Flexible Biodegradable Emitter for Global Energy-Free Cooling Applications

Chanil Park,[‖] Choyeon Park,[‖] Xiao Nie,[‖] Jaeho Lee,* Yong Seok Kim,* and Youngjae Yoo*

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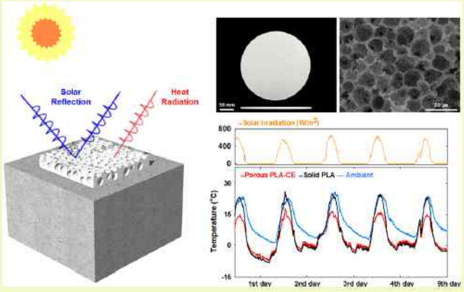
ABSTRACT: In recent years, many researchers believe that global energy consumption can be significantly reduced by passive daytime radiative cooling (PDRC) without any electricity input. Over a decade, PDRC has been developed to enhance solar reflectivity and emissivity in the long-wavelength infrared (LWIR) region; however, sustainable materials for radiative cooling have not been sufficiently investigated. In the present study, the preparation of an eco-friendly polymer structure for effective radiative cooling via thermally induced phase separation is described. The as-fabricated radiative cooler exhibits reasonable durability for application to buildings, and furthermore, biodegradable polylactic acid (PLA) is environmentally benign with respect to end-of-life disposal. Moreover, the hierarchically porous PLA exhibits a solar reflectivity of 0.91 and an LWIR emissivity of 0.92, thus realizing high-performance passive radiative cooling without a silver coating for solar reflection. In addition, a radiative cooling power of 117 W m^{-2} is achieved under direct sunlight, and the porous PLA cooled as much as 9 °C below the ambient temperature. This cooling effect is the highest among all organic-based passive radiation cooling emitters reported so far. The present work provides an ideal passive radiative cooling strategy for creating environmentally friendly buildings with reduced energy consumption.



KEYWORDS: *passive radiative cooling, thermal emitter, energy saving, biodegradable polymer, hierarchically porous structure*

■ INTRODUCTION

Solar energy enters the atmosphere as short wavelength (visible) light and ultraviolet energy. However, since the earth/atmosphere energy balance is achieved via energy radiation, the earth's surface maintains a stable temperature. In other words, the earth releases almost the same amount of energy that it absorbs from the sun into the outer space. Theoretically, all objects with temperature emit radiant energy, as described by Planck's law; the earth emits most of its energy in the form of infrared rays.[1] The long-wave infrared (LWIR) region of 8−13 μm is called the atmospheric window. Radiative cooling is defined by the emission of electromagnetic radiation within this atmospheric window. Recently, as the need for energy saving and effective energy consumption in buildings has attracted attention globally, passive daytime radiative cooling (PDRC) under direct sunlight is being vigorously developed.[2−5] Improving the radiative cooling performance in external daytime environments requires technology for controlling the radiant properties within each selective wavelength band.[6,7] In daytime environments, since the transmittance of the atmosphere is close to 1 in the wavelength range 8−13 μm (i.e., the atmospheric window), the radiant heat emitted into space can be maximized by implementing high emissivity within this region.

In recent years, several experiments have been reported to realize PDRC for the control of solar reflection and heat emission. In particular, to increase the emissivity in the LWIR region, approaches such as the stacking of dielectric materials or the use of photonic structures have been adopted.[8−10] The use of a dielectric such as silicon carbide (SiC), which has optically active resonances, results in selective emissivity peaks, and the structure consisting of a dielectric film on a metallic substrate leads to strong absorption.[11,12] Rephaeli et al. proposed a daytime radiative cooling structure consisting of two photonic crystal layers composed of SiC, quartz, and a wide solar reflector.[13] Thermal simulation studies showed that a net cooling power > 100 W m^{-2} could be achieved. Since then, Raman et al. have demonstrated passive radiative cooling to 5 °C below the ambient temperature under direct sunlight using a planar light emitter composed of seven layers of alternating hafnium dioxide (HfO_2) and silicon dioxide (SiO_2) on a solar reflector.[14] However, there are limitations due to the

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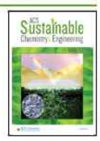

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(3) 총괄연구업적 목록

☐ 학술지 논문 - SCIE 등재지에 한함

	제 목	발표지명	Impactor factor	발표년도	역할(저자)	저자수(명)	피인용횟수
1	Tailoring of FeP Nanoparticles and Single Fe–N Atoms on N, P co-doped Porous Carbon Nanosheets to Boost Catalytic Activities in Lithium–Sulfur Batteries	Journal of Alloys and Compounds	6.3	2025	교신저자	7	0
2	Reconfigurable Binary and Ternary Logic Devices Enabling Logic State Modulation	Nature Communications	15.7	2025	공동저자	6	0
3	Biodegradable PLA-Bleached Pulp Composites for Sustainable Building Cooling Applications	Advanced Sustainable Systems	6.1	2025	교신저자	2	0
4	Structurally stable and high-performance potassium ion battery anodes enabled by spray-dried porous MXene/N-doped carbon–CoSe2 microspheres	Applied Surface Science	6.9	2025	공동저자	6	0
5	Green Water-Based Cooling Coating Engineered for Durability and LCA-Verified Emission Cuts	Journal of Building Engineering	7.4	2025	교신저자	9	0
6	Colored and Paintable Polyurethane Dispersion Coatings for Sustainable Building Applications	Energy	9.4	2025	교신저자	6	4
7	Conductive Agent-Controlled Tortuosity in Solvent-Free Thick-Film Electrodes for High-Energy Lithium-Ion Batteries	Energy & Environmental Materials	14.1	2025	교신저자	4	0
8	Dry-Electrode Manufacturing for High-Energy Lithium-Ion Batteries: Principles, Advances, and Challenges	Elastomers and Composites	1.0	2025	교신저자	2	1
9	Enhancing Passive Radiative Cooling Films with Hollow Yttrium-Oxide Spheres Insights from FDTD Simulation	Macromolecular Rapid Communications	4.3	2025	교신저자	8	11
10	Turning Discarded Oyster Shells into Sustainable Passive Radiative Cooling Films	Polymers	4.9	2025	교신저자	6	1
11	Taming the Flow with Hyperbranched Polyamides as Melt Modifiers in Polyamide Composites	Macromolecular Rapid Communications	4.3	2025	교신저자	5	0
12	Self-defined dual charge percolation networks for solution-processed multithreshold transistors	npj Flexible Electronics	15.5	2024	공동저자	12	0
13	Sulfur-doped pomegranate-like carbon microclusters designed via facile spray-drying process: A novel anode material for potassium-ion batteries	Applied Surface Science	6.9	2024	공동저자	7	2
14	In-situ doped and activated N, S co-doped porous carbon derived from organic salt for application in high-performance potassium-ion batteries	Journal of Energy Storage	9.8	2024	교신저자	5	7
15	Electrospun MOF-derived N-doped mesoporous carbon fibers embedded with ultrafine vanadium oxide as an ultralong cycling stability for potassium ion storage	Journal of Alloys and Compounds	6.3	2024	공동저자	6	3
16	Impeding polysulfide diffusion strategies in lithium-sulfur batteries using 3D porous carbon nanosheets integrated by cathode and functional separator	Applied Surface Science	6.9	2024	교신저자	5	4
17	Scalable and efficient radiative cooling coatings using uniform-hollow silica spheres	Applied Thermal Engineering	6.9	2024	교신저자	7	36
18	Flow enhanced high-filled polyamide composites without the strength-flowability trade-off	Polymer Bulletin	4.0	2024	교신저자	3	1

19	Stabilizing Analog Signal Processing of Artificial Synapse Under Heat Fluctuations Through Light-Temperature Antagonistic Operation	Advanced Functional Materials	19.0	2024	공동저자	9	4
20	Assembly of Hollow Yttrium Oxide Spheres from Nano-Sized Yttrium Oxide for Advanced Passive Radiative Cooling Materials	Polymers	4.9	2024	교신저자	4	3
21	N, P co-doped 3D porous carbon with self-assembled morphological control via template-free method for potassium-ion battery anodes	Rare Metals	11.0	2024	교신저자	5	6
22	Recent Advances in Passive Radiative Cooling: Material Design Approaches	Elastomers and Composites	1.0	2024	교신저자	2	1
23	Soybean oil derived-process oil prepared via recyclable organocatalysis for eco-friendly styrene–butadiene rubber composites	Green Chemistry	9.2	2024	교신저자	1	3
24	Fabrication of Yttrium Oxide Hollow Films for Efficient Passive Radiative Cooling	Materials	3.2	2023	교신저자	2	1
25	Efficient thermal management and all-season energy harvesting using adaptive radiative cooling and a thermoelectric power generator	Journal of Energy Chemistry	14.9	2023	교신저자	7	65
26	Miscibility and related rheological, physical, and optical properties of polycarbonate/poly(methyl methacrylate-co-phenyl methacrylate) blends: Effect of varying phenyl methacrylate composition	Polymer Testing	6.0	2023	교신저자	6	2
27	Ultrafine Co-Mo oxide nanocrystals embedded in hierarchical N-doped carbon microflowers for high-performance lithium-ion batteries	Journal of Alloys and Compounds	6.3	2023	교신저자	3	7
28	Electrospinning-assisted radiative cooling composite films	Solar Energy Materials and Solar Cells	6.3	2023	교신저자	5	16
29	Polypropylene/polyolefin elastomer composites with enhanced impact strength: The effect of rubber domain size on toughness	Journal of Polymer Research	2.8	2023	교신저자	7	7
30	Hybrid emitters with raspberry-like hollow SiO2 spheres for passive daytime radiative cooling	Chemical Engineering Journal	13.2	2023	교신저자	6	79
31	Effective flow modifiers for high-filled poly (phenylene sulfide) composites based on chemical structure similarity	Composites Science and Technology	9.8	2022	교신저자	6	8
32	Passive Daytime Radiative Cooling by Thermoplastic Polyurethane Wrapping Films with Controlled Hierarchical Porous Structures	ChemSusChem	6.6	2022	교신저자	7	64
33	Enhanced Thermal Diffusion in the Vertical Direction of Flexible Polyimide Composite Films with Magnetically Alignable h-BN Platelets via Ferrofluids Hybridization	Journal of Materials Research and Technology	6.6	2022	교신저자	6	8
34	Fully Organic and Flexible Biodegradable Emitter for Global Energy-Free Cooling Applications	ACS Sustainable Chemistry & Engineering	7.3	2022	교신저자	6	75
35	Recent progress in passive radiative cooling for sustainable energy source	Elastomers and Composites	1.0	2022	교신저자	3	4
36	A concise review of high performance PPS composites using various fillers	Elastomers and Composites	1.0	2022	교신저자	5	3
37	Facile preparation and immediate effect of novel flow modifiers for engineering the flowability of high-filled composites	Journal of Materials Research and Technology	6.6	2021	교신저자	6	11

38	Simultaneous effects of silver-decorated graphite nanoplatelets and anisotropic alignments on improving thermal conductivity of stretchable poly (vinyl alcohol) composite films	Composites Part A: Applied Science and Manufacturin	8.9	2020	교신저자	7	15
39	Cool White polymer coatings based on Glass Bubbles for Buildings	Scientific Reports	3.9	2020	교신저자	6	76
40	Spatiotemporally Controlled Plasticity and Elasticity in 3D Multi-Shape Memory Structures Enabled by Elemental Sulfur-Derived Polysulfide Networks with Intrinsic NIR Responsiveness	Macromolecular rapid communications	4.3	2020	공동저자	8	23
41	Synthesis of Poly(phenylene polysulfide) Networks from Elemental Sulfur and p-Diiodobenzene for Stretchable, Healable, and Reprocessable Infrared Optical Applications	ACS Macro Letters	5.2	2020	공동저자	8	55
42	Flexible and free-standing thermoelectric devices prepared from poly(vinylidene fluoride-co-hexafluoropropylene)/graphite nanoplatelet/single-walled carbon nanotube composite films	Materials Science and Engineering B	4.6	2019	교신저자	7	9
43	Synergistic effects of various ceramic fillers on thermally conductive polyimide composite films and their model predictions	Polymers	4.9	2019	교신저자	6	27
44	Tailoring biomimetic polymer networks towards an unprecedented combination of versatile mechanical characteristics	RSC advances	4.6	2019	공동저자	8	10
45	Anisotropy-driven high thermal conductivity in stretchable poly (vinyl alcohol)/hexagonal boron nitride nanohybrid films	ACS applied materials & interfaces	8.2	2018	교신저자	9	94
46	A facile preparation route of n-type carbon buckypaper and its enhanced thermoelectric performance	Composites Science and Technology	9.8	2017	교신저자	6	12
47	Simultaneous flow enhancement of high-filled polyamide 66/glass fiber composites	Journal of Alloys and Compounds	6.3	2017	교신저자	11	14
48	Highly Carboxylate-Functionalized Polymers of Intrinsic Microporosity for CO2-Selective Polymer Membranes	Macromolecules	5.2	2017	공동저자	7	109
49	Amide-based oligomers for low-viscosity composites of polyamide 66	Macromolecular Research	3.4	2017	공동저자	8	18
50	Synthesis and Analysis of Flow Modifiers for PPS Flowability Enhancement	Polymer-Korea	0.4	2017	공동저자	8	3
51	Large-Area CVD-Grown Sub-2 V ReS2 Transistors and Logic Gates	Nano letters	9.6	2017	공동저자	7	83
52	Photoresponse of Physically Oxidized Graphene Sensitized by an Organic Dye	Journal of Physical Chemistry C	3.3	2017	공동저자	9	1
53	Properties of Reactive Silicone Rubber Modified Epoxy Resins: Cure Kinetics and Chemorheology	Polymer-Korea	0.6	2017	공동저자	4	6
54	Recycling of metal sludge wastes for thermal conductive filler via sintering and surface modification	Journal of Alloys and Compounds	6.3	2017	공동저자	4	5
55	Electrically conductive graphene/polyacrylamide hydrogels produced by mild chemical reduction for enhanced myoblast growth and differentiation	Acta biomaterialia	9.6	2017	공동저자	9	192
56	Highly anisotropic thermal conductivity of discotic nematic liquid crystalline films with homeotropic alignment	Chemical Communications	4.2	2017	공동저자	9	29
57	A carbonaceous membrane based on a polymer of intrinsic microporosity (PIM-1) for water treatment	Scientific Reports	3.9	2017	공동저자	8	57

58	Influence of carbon nanotubes localization and transfer on electrical conductivity in PA66/(PS/PPE)/CNTs nanocomposites	Polymer	4.5	2016	공동저자	10	39
59	Synthesis and characterization of polyethersulfone with intrinsic microporosity	RSC advances	4.6	2016	공동저자	8	5
60	Thermally conductive polyamide 6/carbon filler composites based on a hybrid filler system	Science and technology of advanced materials	6.9	2015	교신저자	9	32
61	Reduction of graphene oxide/alginate composite hydrogels for enhanced adsorption of hydrophobic compounds	Nanotechnology	2.8	2015	공동저자	5	36
62	Enhanced thermoelectric performance of bar-coated SWCNT/P3HT thin films	ACS applied materials & interfaces	8.2	2015	공동저자	8	95
63	Effective doping by spin-coating and enhanced thermoelectric power factors in SWCNT/P3HT hybrid films	Journal of Materials Chemistry A	9.5	2015	공동저자	7	131
64	Effect of film thickness and crystallinity on the thermoelectric properties of doped P3HT films	RSC advances	4.6	2015	공동저자	6	47
65	Synthesis of microsphere silicon carbide/nanoneedle manganese oxide composites and their electrochemical properties as supercapacitors	Journal of Power Sources	7.9	2014	교신저자	3	38
66	The addition of functionalized graphene oxide to polyetherimide to improve its thermal conductivity and mechanical properties	Polymers for Advanced Technologies	3.4	2014	공동저자	4	34
67	Characterization of morphologies of compatibilized polypropylene/polystyrene blends with nanoparticles via nonlinear rheological properties from FT-rheology	Macromolecules	5.2	2014	공동저자	4	112
68	Capacitance behavior of composites for supercapacitor applications prepared with different durations of graphene/nanoneedle MnO2 reduction	Microelectronics Reliability	1.9	2014	공동저자	4	17
69	Thermal conductivity improvement of surface-enhanced polyetherimide (PEI) composites using polyimide-coated h-BN particles	Physical Chemistry Chemical Physics	2.9	2014	교신저자	9	70
70	Effect of graphite and carbon fiber contents on the morphology and properties of thermally conductive composites based on polyamide 6	Polymer International	3.6	2014	교신저자	6	96
71	Thermal conductivity of graphite filled liquid crystal polymer composites and theoretical predictions	Composites Science and Technology	9.8	2013	교신저자	10	77
72	Extending the Limit of Low Energy Photocatalysis: Dye Reduction with PbSe/CdSe/CdS Core/Shell/Shell Nanocrystals of Varying Morphologies under Infrared Irradiation	Journal of Physical Chemistry C	3.2	2012	공동저자	6	56
73	Surface Viscoelasticity of an Organic Interlayer Affects the Crystalline Nanostructure of an Organic Semiconductor and Its Electrical Performance	Journal of Physical Chemistry C	3.2	2012	공동저자	10	7
74	Environmentally stable NIR-absorbing window	Pigment & Resin Technology	1.5	2012	공동저자	7	2
75	Reactive extrusion of polypropylene/polystyrene blends with supercritical carbon dioxide	Macromolecular Research	3.4	2012	공동저자	5	24
76	Properties of polycarbonate/acrylonitrile-butadiene-styrene/talc composites	Journal of Applied Polymer Science	2.8	2012	공동저자	6	32

77	Electrical conductivity, phase behavior, and rheology of polypropylene/polystyrene blends with multi-walled carbon nanotube	Rheologica acta	3.0	2012	교신저자	3	40
78	Preparation and properties of ethylene propylene diene rubber/multi walled carbon nanotube composites for strain sensitive materials	Composites Part A: Applied Science and Manufacturin	8.9	2011	공동저자	6	97
79	Synthesis of poly (ε-caprolactone)/clay nanocomposites using polyhedral oligomeric silsesquioxane surfactants as organic modifier and initiator	Journal of Applied Polymer Science	2.8	2011	공동저자	3	8
80	Morphology and mechanical properties of glass fiber reinforced Nylon 6 nanocomposites	Polymer	4.5	2011	주저자	3	127
81	Effect of organoclay structure and mixing protocol on the toughening of amorphous polyamide/elastomer blends	Polymer	4.5	2010	주저자	4	38
82	Morphology and properties of nanocomposites based on HDPE/HDPE-g-MA blends	Polymer	4.5	2010	공동저자	4	134
83	Morphology and mechanical properties of rubber toughened amorphous polyamide/MMT nanocomposites	Macromolecules	5.2	2010	주저자	4	95
84	Polyamide-and polycarbonate-based nanocomposites prepared from thermally stable imidazolium organoclay	Polymer	4.5	2009	공동저자	6	32
85	Preparation of acrylic copolymers and crosslinking agents and properties as a film	Journal of Applied Polymer Science	2.8	2009	주저자	7	27
86	Effect of organoclay structure on morphology and properties of nanocomposites based on an amorphous polyamide	Polymer	4.5	2008	주저자	2	79
87	Sonocrystallization of polycarbonate melts	Polymers for Advanced Technologies	3.4	2007	주저자	6	6
88	Fracture behavior of nanocomposites based on poly (ethylene-co-methacrylic acid) ionomers	Polymer	4.5	2007	주저자	3	33
89	Microwave-Irradiated Copolymerization of Styrene and Butyl Acrylate	Macromolecular Symposia	0.9	2007	공동저자	4	13
90	Influence of addition of organoclays on morphologies in nylon 6/LLDPE blends	Macromolecular Chemistry and Physics	2.7	2005	주저자	6	88
91	Enhancement of the thermal stability, mechanical properties and morphologies of recycled PVC/clay nanocomposites	Polymer Bulletin	4.0	2004	주저자	5	58
92	Polycarbonate/Montmorillonite Nanocomposites Prepared by Microwave-Aided Solid State Polymerization	Macromolecular Chemistry and Physics	2.7	2004	주저자	3	42
93	Morphology and Mechanical Properties of Recycled PVC Blends (III) - Morphologies and Mechanical Properties of Recycled PVC/PE Blends with Different Kinds of Compatibilizers and Mixing Conditions	Polymer-Korea	0.4	2004	주저자	5	1
94	Morphology and Mechanical Properties of Waste PVC Blends (II) - The Relationship between Rheology and Morphology of Waste PVC/PE Blends	Polymer-Korea	0.4	2004	주저자	5	0

□ 등록된 국내외 특허

제 목	등록번호	등록년도	등록처	역할
Compound having bis phenylene group substituted with alkylamide, composition for controlling polyphenylene polymer flowability and method of polyphenylene polymer flowability control using the same	US 10,927,237	2021	미국	공동발명자

Polyamide based polymer compositions comprising cyclic compound and polymer based composite material using the same	US 10,100,161	2018	미국	주발명자
Methods of preparing high density aligned silicon nanowire	US 9,840,774	2017	미국	공동발명자
고분자 조성물 및 이로부터 형성되는 형상기억 고분자 및 이의 제조방법	10-2645385	2024	대한민국	공동발명자
온도감응형 복사냉각 소자를 이용한 열전발전 시스템	10-2605925	2023	대한민국	주발명자
촉매적 역가황 중합법을 이용한 황 함유 가교 고분자의 제조방법 및 이의 제조방법으로 제조된 황 함유 가교 고분자	10-2595613	2023	대한민국	공동발명자
에폭시 비트리머 고분자의 압출적층방식 3D 프린팅용 필라멘트화, 최적화 및 프린팅 방법	10-2553078	2023	대한민국	공동발명자
선형 고분자를 포함하는 유동성 개질제 및 이를 포함하여 유동성이 향상된 고분자 조성물	10-2514248	2023	대한민국	주발명자
하이퍼브랜치 고분자를 포함하는 유동성 개질제 및 이를 포함하여 유동성이 향상된 고분자 조성물	10-2514169	2023	대한민국	공동발명자
무전원냉각용 다공성 고분자 및 이의 제조방법	10-2466621	2022	대한민국	주발명자
폴리헤드랄 올리고메릭 실세스퀴옥산 실라놀, 고리형 실록산 단량체 및 염기 촉매를 포함하는 고분자 조성물, 및 이로부터 제조되는 재성형, 재가공, 자가치유 가능한 실리콘 가교 네트워크 필름	10-2443459	2022	대한민국	공동발명자
하이퍼브랜치 폴리아미드를 함유하는 유동성이 향상된 폴리아미드계 고분자 조성물 및 이의 제조방법	10-2375504	2022	대한민국	주발명자
근적외선을 이용한 폴리(페닐렌 폴리설파이드) 네트워크의 가소성 및 탄성 제어	10-2373607	2022	대한민국	공동발명자
가역적 조립과 분리 및 엑추에이션이 가능한 액정 비트리머	10-2309693	2021	대한민국	공동발명자
초음파를 이용한 상온 재가공 가능한 황 함유 가교 고분자의 제조방법	10-2306923	2021	대한민국	공동발명자
폴리(에테르-티오우레아), 에폭시 가교제 및 염기 촉매를 포함하는 고분자 조성물 및 이로부터 제조되는 재성형 및 재가공 가능 형상기억 고분자 필름	10-2271412	2021	대한민국	공동발명자
셀룰로오스 나노섬유를 포함하는 폴리비닐 알콜계 수지 조성물 및 이를 이용한 필름	10-2256125	2021	대한민국	주발명자
알킬 아마이드로 치환된 비스 페닐렌 그룹을 가지는 화합물, 이를 포함하는 폴리페닐렌계 고분자의 유동성 조절용 조성물 및 이를 이용한 폴리페닐렌계 고분자 유동성 조절 방법	10-2090166	2020	대한민국	공동발명자
기능성 첨가제, 이를 포함하는 기계적 물성이 향상된 폴리페닐렌 설파이드 수지 및 이의 제조방법	10-2087888	2020	대한민국	공동발명자
폴리(에테르-티오우레아) 및 에폭시 가교제를 포함하는 고분자 조성물 및 이로부터 제조되는 생체모방형 고분자 필름	10-2080609	2020	대한민국	공동발명자
방열필름용 조성물, 이를 사용하는 방열필름 및 이의 제조방법	10-2064826	2020	대한민국	공동발명자
폴리페닐렌 설파이드의 용액 중합법 및 이로부터 제조된 폴리페닐렌 설파이드 중합체	10-1977936	2019	대한민국	공동발명자
기계적 물성이 우수한 에폭시 수지 조성물	10-1972440	2019	대한민국	공동발명자
스피로 구조를 가지는 신규한 디아이오도 단량체, 이의 합성 및 이를 이용한 폴리페닐렌설파이드 공중합체	10-1959254	2019	대한민국	공동발명자
보론나이트라이드를 포함하는 고분자 전해질막, 이의 제조방법, 및 상기 고분자 전해질막을 포함하는 리튬 이차 전지	10-1911070	2018	대한민국	공동발명자
황을 포함하는 시트랄 기반 중합체 및 그의 제조방법	10-1900483	2018	대한민국	공동발명자
디스코틱(discotic) 액정 화합물을 포함하는 방열용 조성물, 이로부터 제조된 방열필름 및 이의 제조방법	10-1893872	2018	대한민국	공동발명자
폴리페닐렌 설파이드 공중합체의 제조방법 및 이로부터 제조된 폴리페닐렌 설파이드 공중합체	10-1887654	2018	대한민국	공동발명자
자기장을 이용하여 열전도도가 향상된 고분자 복합 필름 및 이의 제조방법	10-1854436	2018	대한민국	주발명자
웨어러블 디바이스용 열전발전 시스템	10-1843959	2018	대한민국	공동발명자

내재적 미세기공성 고분자를 이용한 다공성 탄소구조체 및 이를 포함하는 전지용 전극	10-1818757	2018	대한민국	공동발명자
폴리헤드랄 올리고머릭 실세스퀴옥산-황 중합체를 포함하는 리튬 설퍼 전지용 양극 활물질 및 그의 제조방법	10-1963863	2017	대한민국	공동발명자
전기전도성이 우수한 열전재료 조성물 및 이의 제조방법	10-1808827	2017	대한민국	공동발명자
고리형 화합물이 첨가된 폴리아미드계 고분자 조성물 및 이를 이용한 폴리아미드계 복합소재	10-1795675	2017	대한민국	주발명자
내재적 기공성 고분자로 제조된 다공성 탄소 구조체를 포함하는 수처리용 막 및 이의 제조방법	10-1789529	2017	대한민국	공동발명자
하이퍼브랜치 고분자를 함유하는 유동성이 향상된 폴리아미드계 고분자 조성물 및 이의 제조방법	10-1781509	2017	대한민국	공동발명자
열전 특성이 향상된 열전소재의 제조방법 및 이에 따라 제조되는 열전소재	10-1746682	2017	대한민국	공동발명자
유동성이 우수한 폴리아미드계 고분자 조성물 및 이를 이용하여 제조되는 폴리아미드계 복합소재	10-1740687	2017	대한민국	주발명자
전기 전도성이 우수한 고분자 열전특성 조성물 및 이를 포함하는 열전재료 필름	10-1736203	2017	대한민국	주발명자
열전재료용 고분자 조성물 및 이를 포함하는 열전재료 필름	10-1732974	2017	대한민국	주발명자
탄소 나노 튜브 및 전도성 고분자를 포함하는 열전 소재의 제조방법 및 이에 따라 제조되는 열전 소재	10-1695226	2017	대한민국	공동발명자
다가 알콜 가소제 혼합물을 포함하는 폴리비닐 알콜계 수지 조성물 및 이를 이용한 필름	10-1804524	2017	대한민국	주발명자
하이퍼브랜치 폴리아미드를 함유하는 유동성이 향상된 폴리아미드계 고분자 조성물 및 이의 제조방법	10-1815577	2016	대한민국	공동발명자
열전도성 고분자 복합체 및 이의 제조방법	10-1527164	2015	대한민국	공동발명자
신규한 폴리이미드 중합체, 이의 제조방법 및 이를 이용한 유기절연막	10-1485866	2015	대한민국	공동발명자
신규한 폴리이미드 중합체, 이의 제조방법 및 이를 이용한 유기절연막	10-1508208	2015	대한민국	공동발명자
2,6-다이아미노-9,10-다이하이드로안트라센을 고순도로 정제하는 방법	10-1511235	2015	대한민국	공동발명자
전기절연성 및 열전도성 고분자 조성물, 이의 제조방법 및 이를 포함하는 성형품	10-1478819	2014	대한민국	주발명자
분산특성이 우수한 필러를 포함하는 전기절연성 및 열전도성 고분자 조성물, 이의 제조방법및 이를 포함하는 성형품	10-1446707	2014	대한민국	주발명자
형태가 다른 2종의 열전도성 필러를 포함하는 고분자 조성물 및 이의 제조방법	10-1298739	2013	대한민국	주발명자
열전도성이 우수한 고분자 조성물 및 이의 제조방법	10-1285349	2013	대한민국	주발명자
폴리카보네이트 수지의 제조방법	10-0561745	2006	대한민국	공동발명자
초음파를 이용한 폴리카보네이트의 결정화 방법	10-0561742	2006	대한민국	공동발명자
섬유가 포함된 폐PVC레자를 이용한 재활용 쉬트	10-0510931	2005	대한민국	공동발명자