(양식 1)

【 고분자학회 학회상 포상 지원서 】

[표지]

<table>
<tr><td>공모분야</td><td colspan="6">TCI고분자학술진보상</td></tr>
<tr><td rowspan="5">지원자
인적사항</td><td rowspan="2">성 명</td><td>한 글</td><td colspan="2">김 기 수</td><td rowspan="2">영 문</td><td rowspan="2">Ki Su Kim</td></tr>
<tr><td>한 자</td><td colspan="2">金 基 壽</td></tr>
<tr><td rowspan="3">소속기관</td><td>기관명</td><td colspan="4">부산대학교</td></tr>
<tr><td>부서명
(학과명)</td><td>유기소재시스템공학과</td><td colspan="2">직위/직급</td><td>교수</td></tr>
<tr><td>주 소</td><td colspan="4">부산광역시 금정구 부산대학로63번길 2,
유기소재시스템공학과</td></tr>
<tr><td>업적요지</td><td colspan="6">- “고분자기반 나노소재의 의생명응용”기술에 대한 다양한 연구업적 발표
- 고분자기반 광의학 소재 플랫폼 기술이 적용된 질병 진단 및 치료기술에 대한 다양한 연구를 통하여, 경피약물전달 및 광의학적 응용에 관한 우수한 연구논문 및 관련 특허를 발표하였음. (Journal of Controlled Release 2025, Advanced Science 2024, Science Advances 2022, 10-22430199 (2022) 및 PCT/KR2024/018196)
- 다양한 의료용 고분자 기반 나노소재 개발 및 광의학 응용 기술 개발을 위하여 광전달 나노입자를 개발하였으며 이를 통한 고분자기반 광/약물 전달 플랫폼 개발 연구를 수행하고 있음.
- 고분자학회 발전을 위하여, 2017년부터 정회원/종신회원으로 활동하고 있으며, 운영이사 및 2022년부터 고분자학회 평의원으로 봉사하고 있으며, 세션 초청강연 2회 등 다양한 고분자학회 활동에 참여하고 있음.
- 자세한 내용은 대표논문의 연구업적 요약서에서 기술하였음.</td></tr>
<tr><td colspan="7">상기와 같이 고분자학회 학회상 포상을 지원합니다.

2025. 8. 13

기관명 : 부산대학교
직 위 : 교수
지원자 : 김 기 수 (직인)</td></tr>
</table>

(양식 2)

1. 인적사항

가. 학력사항 (대학교 이상만 기재)

기 간	학 교 명	전공 및 학위, 지도교수
2003 ~ 2007	포항공과대학교	신소재공학 (학사)
2007 ~ 2012	포항공과대학교	신소재공학 (박사) 지도교수 : 한세광

나. 경력사항 (5개 이내 기재)

기 간	기관명(직위, 직책 등)
2012 ~ 2013	KAIST 자연과학연구소 (연수연구원)
2012 ~ 2017	Harvard Medical School (Research Fellow)
2023 ~ 2024	UC San Diego (Visiting Professor)
2017 ~ 현재	부산대학교 (조/부/정교수)

다. 수상경력 (최근 3년 이내)

일 자	수 상 내 용	시 상 기 관
2023. 9	덴티움 우수논문상	한국생체재료학회

2. 수상후보자 추천인단 명부

성 명	전 공 분 야	세부전공 분야	소 속	비고
허강무	의료용고분자	생체재료, 의료용고분자	충남대학교	25년 영문지 편집부위원장, 평이사
신흥수	의료용고분자	생체재료, 조직공학	한양대학교	23년 의료용고분자부문위원장, 24~25년 평이사
이수홍	의료용고분자	조직공학, 줄기세포	동국대학교	25년 의료용고분자 부문위원장, 평이사

3. 대표논문의 연구업적 요약서

- 김기수 지원자는 2017년부터 부산대학교에 임용되어 **고분자기반 스마트 나노바이오소재를 기반으로 한 차세대 광의학 플랫폼 개발연구를 수행**하였음. 특히, 비침습적 암 치료, 조직재생, 스마트 헬스케어 기기 개발등 임상적 파급력이 큰 주제를 중심으로 세계적 수준의 연구성과를 지속적으로 발표하였음. (2025년 8월 기준 H-index 38, Total citation 6400, Google Scholar)

1) **혁신적 암 치료 플랫폼** 제시 : 2025년 *Journal of Controlled Release*에 게재된 연구에서는 **MXene-캡슐화 나노입자**를 활용하여 화학요법과 광열치료를 병행하는 차세대 항암 전략을 개발하였음. 이 기술은 기존의 단일치료법 대비 높은 치료 효율과 종양 선택성을 확보하였으며, 향후 **정밀 맞춤형 멜라노마 치료**로 확장될 수 있는 잠재력을 보여줌.
2) **비침습적 경피 약물전달 연구**의 새로운 가능성 제시 : 2024년 *Biomaterials Research* 논문에서는 수용성 고분자 기반 유기 업컨버전 나노입자를 개발하여 **피부를 통한 광·약물 동시 전달**을 구현하였음. 이는 환자의 부담을 최소화하고, 통증 없는 치료를 가능하게 함으로써 환자 순응도를 획기적으로 높일 수 있음을 보여주었음.
3) **냉각-광역학 복합 암치료 플랫폼** 개발 : 2024년 *Advanced Science*에 발표된 연구는 **냉감-반응형 히알루론산 업컨버전 나노플랫폼**을 구축하여, 경피적으로 Cryo-PDT(cold-responsive photodynamic therapy)를 구현하였음. 이 성과는 피부암 등 얕은 조직의 암치료에 있어 **광-냉각 복합 전략이라는 새로운 패러다임**을 제시하였음.
4) **스마트 포토닉 의학 분야의 비전과 로드맵** 제시 : 2022년 *Advanced Drug Delivery Reviews*에 게재된 리뷰 논문은 업컨버전 나노소재와 약물전달 시스템을 포괄적으로 정리하고, **광의학 기반 차세대 의료기기 및 헬스케어 플랫폼**으로의 확장 가능성을 제시하였음.
5) **조직재생 및 창상치유 분야로의 확장** : 2022년 *Science Advances*에 발표된 연구는 **접착성 나노섬유막과 웨어러블 LED 패치**를 결합하여, 광생체자극(photobiomodulation)을 통한 **창상치유의 가속화**를 입증하였음.

- 이상의 성과들은 단순한 학문적 기여에 그치지 않고, **암 치료, 피부재생, 광유전학, 항균치료 등 다양한 의생명 응용 분야로 확장 가능한 원천기술**을 제공하고 있음. 지속적인 관련연구 성과 확보를 위하여 **한국연구재단 중견연구자 지원 사업의 연구책임자**로 2025년부터 상향변환 나노입자를 활용한 광의학적 응용 관련 연구를 수행하고 있으며, **글로벌 기초연구실 공동연구진**으로, 1형 당뇨병 치료를 위한 베타세포의 광성숙 연구를 진행중에 있음.

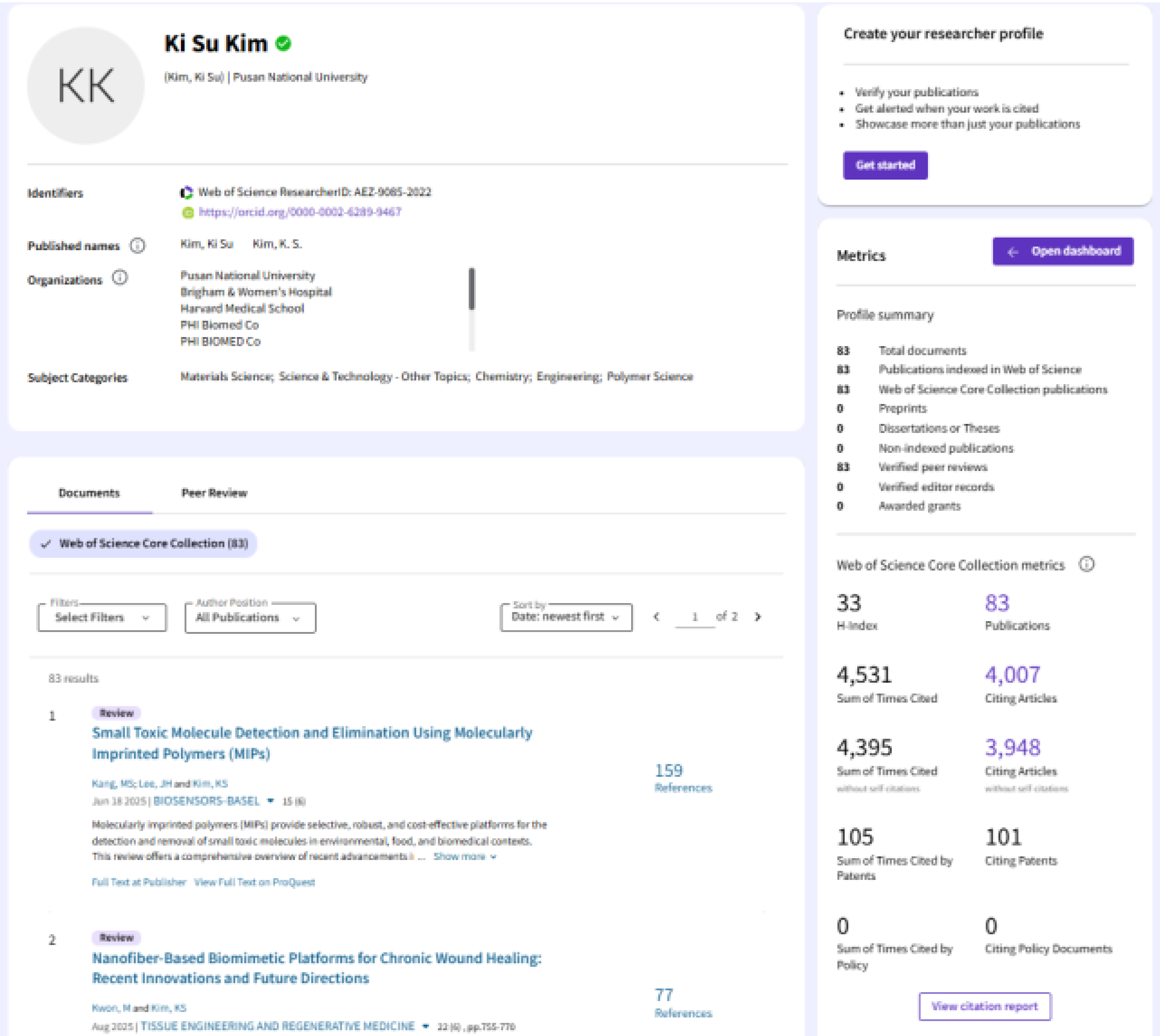
- 고분자학회 발전을 위하여, **2017년부터 정회원/종신회원으로 활동**하고 있으며, **2020/21 운영이사, 2021/22 고분자과학과 기술 (기술지) 편집위원, 2023 학회발전위원회 위원, 2024/25 PSK50 조직위원회 위원, 2025 Macromolecular Research (영문지) 편집위원, 학술교육위원회 위원 및 2022년부터 고분자학회 평의원**으로 봉사하고 있으며, **세션 초청강연 2회** 등 다양한 고분자학회 활동에 참여하고 있음.

4. 연구개발 실적

(1) 업적 총괄 (단위:건)

논문	SCIE 등재 학술지				h-index		
	제1저자	공동저자	교신저자	소계	Web of Science	Google Scholar	SCOPUS
	16	29	39	84	33	38	35
특허	국내		국외		기술이전	연구 보고서	저서
	등록		등록				
	6		3				1

(1-1) Web of Science의 h-index 증빙



(1-2) Google scholar의 h-index 증빙

Ki Su Kim

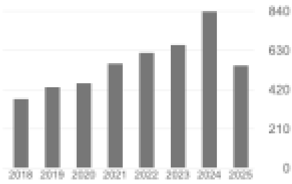
Associate Professor, School of Chemical Engineering, Pusan National University (PNU)
pusan.ac.kr의 이메일 확인됨 - 홈페이지

Biomaterials Biomedical Application Photomedicine Non-invasive Drug Delivery Tissue Engineering

제목	인용	연도
Target specific and long-acting delivery of protein, peptide, and nucleotide therapeutics using hyaluronic acid derivatives EJ Oh, K Park, KS Kim, J Kim, JA Yang, JH Kong, MY Lee, AS Hoffman, ... Journal of Controlled Release 141 (1), 2-12	682	2010
Recent advances in transdermal drug delivery systems: A review WY Jeong, M Kwon, HE Choi, KS Kim Biomaterials research 25 (1), 24	538	2021
Glucose-Sensitive Hydrogel Optical Fibers Functionalized with Phenylboronic Acid AK Yetisen, N Jiang, A Fallahi, Y Montelongo, GU Ruiz-Esparza, ... Advanced Materials 29 (15), 1606380	294	2017
Nanographene Oxide–Hyaluronic Acid Conjugate for Photothermal Ablation Therapy of Skin Cancer HS Jung, WH Kong, DK Sung, MY Lee, SE Beack, DH Keum, KS Kim, ... ACS nano 8 (1), 260-268	251	2014
Bioabsorbable polymer optical waveguides for deep-tissue photomedicine S Nizamoglu, MC Gather, M Humar, M Choi, S Kim, KS Kim, SK Hahn, ... Nature Communications 7, 10374	250	2016

인용 모두 보기

	전체	2020년 이후
서지정보	6400	3687
h-index	38	31
i10-index	61	53



공개 액세스 모두 보기

자료 0개 자료 8개

비공개 공개

재정 지원 요구사항 기준

(1-3) SCOPUS의 h-index 증빙

This author profile is generated by Scopus

Kim, Ki Su

Pusan National University, Busan, South Korea • Scopus ID: 7409322172 • Connect to ORCID

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5,127	88	35
Citations by 4,560 documents	Documents	h-index

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Review
Nanofiber-Based Biomimetic Platforms for Chronic Wound Healing: Recent Innovations and Future Directions
Kwon, M., Kim, K.S.
Tissue Engineering and Regenerative Medicine, 2025, 22(6), pp. 755–770
0 Citations
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Article
Synergistic chemo-photothermal treatment via MXene-encapsulated nanoparticles for targeted melanoma therapy
Lee, S.B., Park, J.M., Park, R., ... Hong, S.W., Kim, K.S.
Journal of Controlled Release, 2025, 382, 113729
1 Citations
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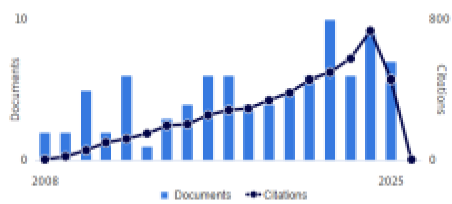

Citation overview Analyze author output

(2) 대표논문 목록

제　목	발표지명	Impactor factor	발표 년도	역할(저자)	저자수 (명)	피인용 횟수
Synergistic chemo-photothermal treatment via MXene-encapsulated nanoparticles for targeted melanoma therapy	Journal of Controlled Release	11.4	2025	주저자(교신)	6	2
Water-Dispersible and Biocompatible Polymer-Based Organic Upconversion Nanoparticles for Transdermal Delivery	Biomaterials Research	9.6	2024	주저자(교신)	6	2
Cold-Responsive Hyaluronated Upconversion Nanoplatform for Transdermal Cryo-Photodynamic Cancer Therapy	Advanced Science	15.1	2024	주저자(교신)	10	21
Upconversion nanomaterials and delivery systems for smart photonic medicines and healthcare devices	Advanced Drug Delivery Reviews	16.1	2022	주저자(교신)	9	31
Combinatorial wound healing therapy using adhesive nanofibrous membrane equipped with wearable LED patches for photobiomodulation	Science advances	13.6	2022	주저자(교신)	9	68

(3) 총괄연구업적 목록

□ 학술지 논문 - SCIE 등재지에 한함

제　목	발표지명	Impactor factor	발표 년도	역할(저자)	저자수 (명)	피인용 횟수
Highly solubilized and skin-permeable finasteride formulation using HPCD-incorporated chitosan nanocapsules to promote hair regeneration	Journal of Industrial and Engineering Chemistry	6.0	2025	주저자(교신)	9	
Small Toxic Molecule Detection and Elimination Using Molecularly Imprinted Polymers (MIPs)	Biosensors	5.6	2025	주저자(교신)	3	1
Nanofiber-Based Biomimetic Platforms for Chronic Wound Healing: Recent Innovations and Future Directions	Tissue Engineering and Regenerative Medicine	4.4	2025	주저자(교신)	2	
Synergistic chemo-photothermal treatment via MXene-encapsulated nanoparticles for targeted melanoma therapy	Journal of Controlled Release	10.5	2025	주저자(교신)	6	2
Recent research trends in gradient hydrogels for various biomedical applications	Macromolecular Research	2.8	2025	주저자(교신)	3	
Biomimetic gradient hydrogel with fibroblast spheroids for full-thickness skin regeneration	Biomaterials Advances	5.5	2025	주저자(교신)	3	
Plasmonic Biosensors in Cancer-Associated miRNA Detection	Biosensors	4.9	2025	주저자(교신)	5	2
Harnessing the Intradermal Delivery of Hair Follicle Dermal Papilla Cell Spheroids for Hair Follicle Regeneration in Nude Mice	Biomaterials Research	9.6	2025	주저자(교신)	9	1
Machine learning-assisted label-free colorectal cancer diagnosis using plasmonic needle-endoscopy system	Biosensors & Bioelectronics	10.5	2024	공동	12	7
Water-Dispersible and Biocompatible Polymer-Based Organic Upconversion Nanoparticles for Transdermal Delivery	Biomaterials Research	9.6	2024	주저자(교신)	6	2
Nitric oxide-releasing albumin/chondroitin sulfate bioadhesive dressing for the treatment of MRSA-infected wounds	Journal of Pharmaceutical Investigation	5.1	2024	공동	7	1
Ionic Liquid-Based Extraction of Fulvic-like Substances from Wood Sawdust: Reproducing Unique Biological Activities of Fulvic Acids Using Renewable Natural Sources	Journal of Agricultural and Food Chemistry	5.7	2024	주저자(교신)	10	2
Transdermal Delivery of Polymeric Nanoparticles Containing Aconite Root for	Advanced NanoBiomed	4.0	2024	주저자(교신)	3	2

the Treatment of Chemotherapy-Induced Peripheral Neuropathy	**Research**					
Cold-Responsive Hyaluronated Upconversion Nanoplatform for Transdermal Cryo-Photodynamic Cancer Therapy	**Advanced Science**	15.1	2024	주저자(교신)	10	21
Biomedical Applications of CNT-Based Fibers	**Biosensors**	5.4	2024	주저자(교신)	5	4
Nano/Micro Biosensors for Biomedical Applications	**Biosensors**	5.4	2024	주저자(교신)	2	4
Recent Trends in Macromolecule-Based Approaches for Hair Loss Treatment	**Macromolecular Bioscience**	5.8	2023	주저자(교신)	8	3
Microfluidic Fabrication of Highly Efficient Hydrogel Optical Fibers for In Vivo Fiber-Optic Applications	**Advanced Optical Materials**	10	2023	주저자(교신)	9	8
Molecularly imprinted polymers (MIPs): emerging biomaterials for cancer theragnostic applications	**Biomaterials Research**	9.6	2023	주저자(교신)	6	56
Plasmon Modulated Upconversion Biosensors	**Biosensors**	5.7	2023	주저자(교신)	5	5
Activated carbon nanofiber nanoparticles incorporated electrospun polycaprolactone scaffolds to promote fibroblast behaviors for application to skin tissue engineering	**Advanced Composites and Hybrid Materials**	11.8	2023	공동	9	43
Terbium-doped carbon dots (Tb-CDs) as a novel contrast agent for efficient X-ray attenuation	**RSC advances**	4.0	2023	공동	9	9
Biosafety of inorganic nanomaterials for theranostic applications	**Emergent Materials**	4.4	2022	주저자(교신)	6	18
Terbium and barium codoped mesoporous silica nanoparticles with enhanced optical properties	**Materials Letters**	3.1	2022	주저자(교신)	9	7
3D Printing of Skin Equivalents with Hair Follicle Structures and Epidermal-Papillary-Dermal Layers Using Gelatin/Hyaluronic Acid Hydrogels	**Chemistry–An Asian Journal**	4.1	2022	주저자(교신)	10	47
Upconversion nanomaterials and delivery systems for smart photonic medicines and healthcare devices	**Advanced Drug Delivery Reviews**	16.1	2022	주저자(교신)	9	31
Designing inorganic nanoparticles into computed tomography and magnetic resonance (CT/MR) imaging-guidable photomedicines	**Materials Today Nano**	10.3	2022	주저자(교신)	6	22
In Situ Crosslinkable Collagen-Based Hydrogels for 3D Printing of Dermis-Mimetic Constructs	**ECS Journal of Solid State Science and Technology**	2.2	2022	주저자(교신)	8	13
Combinatorial wound healing therapy using adhesive nanofibrous membrane equipped with wearable LED patches for photobiomodulation	**Science advances**	13.6	2022	주저자(교신)	9	68
Recent advances in transdermal drug delivery systems: A review	**Biomaterials research**	15.8	2021	주저자(교신)	4	528
Recent advances in hollow gold nanostructures for biomedical applications	**Frontiers in Chemistry**	15.8	2021	주저자(교신)	4	31
Recent trends in photoacoustic imaging techniques for 2D nanomaterial-based phototherapy	**Biomedicines**	4.7	2021	주저자(교신)	6	31
Non-Invasive Topical Drug-Delivery System Using Hyaluronate Nanogels Crosslinked via Click Chemistry	**Materials**	3.7	2021	주저자(교신)	4	15
State of the Art Biocompatible Gold Nanoparticles for Cancer Theranosis	**Pharmaceutics**	6.5	2020	주저자(교신)	4	141
Two-dimensional theranostic nanomaterials in cancer treatment: State of the art and perspectives	**Cancers**	6.5	2020	주저자(교신)	5	33
Hyaluronic Acid-Based Theranostic Nanomedicines for Targeted Cancer Therapy	**Cancers**	6.5	2020	주저자(교신)	4	134
Degradable Nanomotors Using Platinum Deposited Complex of Calcium Carbonate and Hyaluronate Nanogels for Targeted Drug Delivery	**Particle & Particle Systems Characterization**	3.4	2020	공동	5	27
Transdermal delivery of Minoxidil using HA-PLGA nanoparticles for the treatment in alopecia	**Biomaterials Research**	9.6	2019	주저자(교신)	7	59

Multifunctional Nanodroplets Encapsulating Naphthalocyanine and Perfluorohexane for Bimodal Image-Guided Therapy	Biomacromolecules	6.9	2019	공동	9	32
Electroceutical Residue-Free Graphene Device for Dopamine Monitoring and Neural Stimulation	ACS Biomaterials Science & Engineering	5.4	2019	공동	8	7
Cancer Theranosis: Multimodal Cancer Theranosis Using Hyaluronate-Conjugated Molybdenum Disulfide	Advanced Healthcare Materials	9	2019	주저자(교신)	9	1
Multimodal Cancer Theranosis Using Hyaluronate-Conjugated Molybdenum Disulfide	Advanced healthcare materials	9	2019	주저자(교신)	9	47
Light-Guided Nanomotor Systems for Autonomous Photothermal Cancer Therapy	ACS applied materials & interfaces	10.3	2018	주저자(교신)	4	82
Supramolecular hydrogels encapsulating bioengineered mesenchymal stem cells for ischemic therapy	RSC Advances	4.0	2018	공동	9	12
Multi-functional Photonic Nanomaterials for Diagnostic, Therapeutic, and Theranostic Applications	Advanced Materials	32	2017	공동	9	207
Hyaluronate – parathyroid hormone peptide conjugate for transdermal treatment of osteoporosis	Journal of Biomaterials Science, Polymer Edition	3.6	2017	주저자(교신)	4	16
Bioimaging of botulinum toxin and hyaluronate hydrogels using zwitterionic near-infrared fluorophores	Biomaterials Research	9.6	2017	주저자(제1)	6	9
Targeted Hyaluronate−Hollow Gold Nanosphere Conjugate for Anti-Obesity Photothermal Lipolysis	ACS Biomaterials Science and Engineering	5.4	2017	주저자(교신)	8	46
Upconversion Nanoparticles/Hyaluronate−Rose Bengal Conjugate Complex for Noninvasive Photochemical Tissue Bonding	ACS nano	18	2017	주저자(교신)	8	101
Glucose-Sensitive Hydrogel Optical Fibers Functionalized with Phenylboronic Acid	Advanced Materials	32	2017	공동	10	292
Optical lens-microneedle array for percutaneous light delivery	Biomedical Optics Express	3.2	2016	주저자(제1)	7	67
Vaccines: Noninvasive Transdermal Vaccination Using Hyaluronan Nanocarriers and Laser Adjuvant (Adv. Funct. Mater. 15/2016)	Advanced Functional Materials	19	2016	주저자(제1)	8	1
Self-adjuvanted hyaluronate – antigenic peptide conjugate for transdermal treatment of muscular dystrophy	Biomaterials	12.4	2016	공동	9	28
Noninvasive Transdermal Vaccination Using Hyaluronan Nanocarriers and Laser Adjuvant	Advanced Functional Materials	19	2016	주저자(제1)	8	71
Bioabsorbable polymer optical waveguides for deep-tissue photomedicine	Nature Communications	14.7	2016	공동	8	247
Biodegradable Photonic Melanoidin for Theranostic Applications	ACS Nano	18	2016	공동	7	88
Photonic Hydrogel Sensors	Biotechnology Advances	12.5	2016	공동	10	200
Photodynamic therapy of melanoma skin cancer using carbon dot−chlorin e6−hyaluronate conjugate	Acta biomaterialia	9.7	2015	공동	8	145
Bioimaging of Hyaluronate-Interferon α Conjugate Using Non-Interfering Zwitter Ionic Fluorophore	Biomacromolecules	5.5	2015	주저자(제1)	8	20
A Simple Approach to Biological Single-Cell Lasers Via Intracellular Dyes	Advanced Optical Materials	7.2	2015	공동	8	39
Hyaluronate−Flt1 peptide conjugate/epirubicin micelles for theranostic applications to liver cancers	RSC Advances	4.6	2015	주저자(제1)	8	7
Nanographene Oxide−Hyaluronic Acid Conjugate for Photothermal Ablation Therapy of Skin Cancer	ACS nano	18	2014	공동	8	250
Enhancing the Transdermal Penetration of Nanoconstructs : Could Hyaluronic Acid be the Key?	Nanomedicine	4.7	2014	공동	4	38
Hyaluronate - Gold Nanoparticle / Tocilizumab Complex for the Treatment of Rheumatoid Arthritis	ACS Nano	18	2014	공동	8	237
Bioimaging and pulmonary applications of self-assembled Flt1 peptide−hyaluronic acid	Biomaterials	12.4	2013	공동	8	41

conjugate nanoparticles						
Self-assembled complex of probe peptide–E. Coli RNA I conjugate and nano graphene oxide for apoptosis diagnosis	**Biomaterials**	12.4	2012	공동	8	23
Facile Surface Modification and Application of Temperature Responsive Poly(N-isopropylacrylamide-co-dopamine methacrylamide)	**Macromolecular Chemistry and Physics**	2.7	2012	주저자(제1)	4	1
Bioimaging of hyaluronic acid derivatives using nanosized carbon dots	**Biomacromolecules**	6.0	2012	주저자(제1)	8	194
Gold half-shell coated hyaluronic acid-doxorubicin conjugate micelles for theranostic applications	**Macromolecular Research**	3.4	2012	주저자(제1)	5	30
Flt1 peptide-hyaluronate conjugate micelle-like nanoparticles encapsulating genistein for the treatment of ocular neovascularization.	**Acta Biomater.**	8.8	2012	공동	6	62
In vivo real-time confocal microscopy for target-specific delivery of hyaluronic acid-quantum dot conjugates	**Nanomedicine: Nanotechnology, Biology, and Medicine**	4.8	2012	주저자(제1)	6	32
Facile Surface Modification and Application of Temperature Responsive Poly(N-isopropylacrylamide-co-dopamine methacrylamide)	**Macromol. Chem. Phys.**	2.5	2012	주저자(제1)	4	22
Target-specific gene silencing of layer-by-layer assembled gold–cysteamine/siRNA/PEI/HA nanocomplex	**ACS nano**	18	2011	공동	6	176
Injectable hyaluronic acid–tyramine hydrogels for the treatment of rheumatoid arthritis	**Acta biomaterialia**	9.7	2011	주저자(제1)	7	178
Target specific tumor treatment by VEGF siRNA complexed with reducible polyethyleneimine–hyaluronic acid conjugate	**Biomaterials**	12.4	2010	공동	4	166
Bioimaging for targeted delivery of hyaluronic acid derivatives to the livers in cirrhotic mice using quantum dots	**ACS nano**	18	2010	주저자(제1)	8	152
Target specific and long-acting delivery of protein, peptide, and nucleotide therapeutics using hyaluronic acid derivatives	**Journal of Controlled Release**	11.4	2010	공동	10	681
Real-time, step-wise, electrical detection of protein molecules using dielectrophoretically aligned SWNT-film FET aptasensors	**Lab on a Chip**	6.1	2010	공동	4	64
The fabrication, characterization and application of aptamer-functionalized Si-nanowire FET biosensors	**Nanotechnology**	2.8	2009	주저자(제1)	4	117
Electrical detection of VEGFs for cancer diagnoses using anti-vascular endotherial growth factor aptamer-modified Si nanowire FETs	**Biosensors and Bioelectronics**	10.6	2009	주저자(제1)	4	167
Target specific intracellular delivery of siRNA/PEI— HA complex by receptor mediated endocytosis	**Molecular pharmaceutics**	5.3	2009	공동	4	210
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Hyaluronic acid–polyethyleneimine conjugate for target specific intracellular delivery of siRNA	**Biopolymers: Original Research on Biomolecules**	3.2	2008	공동	9	239
Characterization of PEGylated Anti-VEGF Aptamers Using Surface Plasmon Resonance	**Macromolecular Research**	2.4	2008	주저자(제1)	4	8

□ **등록**된 국내외 특허

제 목	등록번호	등록년도	등록처	역할
목질계 바이오매스로부터 풀빅산 유사체를 추출하는 방법 및 이에 의해 추출된 풀빅산 유사체	10-2703227	2024	대한미국	공동발명
히알루론산-콜라겐기반 3D 바이오잉크 조성물	10-2634670	2024	대한민국	공동발명
경피전달이 가능한 히알루론산-고분자 나노입자 및 이의 응용	10-22430199	2022	대한민국	공동발명
Compositions for Nucleic Acid Delivery Using Metal Nanoparticles and Prparing Method Thereof	US Patent 8,747,903	2014	미국	공동발명
Drug Delivery System Using Hyaluronic Acid-Peptide Conjugate Micelle	US Patent 8,895,069	2014	미국	공동발명
Drug Delivery System Using Hyaluronic Acid-Peptide Conjugate Micelle	10-1296329	2013	대한민국	공동발명
Composition for Nucleic Acid Delivery Using Metal Nanoparticles and Preparing Method Threof	10-1255149	2013	대한민국	공동발명
Nucleic acid delivery system comprising conjugates of PEI and hyaluronic acid	US Patent 8,318,856	2012	미국	공동발명
Fabrication of Aptmer-Based Nanowire Biosensor for Detection of VEGF and Cancer Diagnoses	10-1009938	2011	대한민국	공동발명

별첨	대표논문 증빙자료 01

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Synergistic chemo-photothermal treatment via MXene-encapsulated nanoparticles for targeted melanoma therapy[☆]

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ABSTRACT

Owing to its high photothermal conversion efficiency, MXene has garnered strong interest in biomedical applications. MXene has demonstrated significant promise particularly in chemo-photothermal cancer therapy. However, MXene's inherent instability in aqueous environments poses challenges for advanced biological applications. Here, we address this limitation by encapsulating MXene nanoparticles (NPs) within an amphiphilic polymer matrix of hyaluronic acid and poly(lactide-co-glycolide) (HA-PLGA/MX NPs), enhancing photothermal stability and functionality in physiological conditions. Moreover, to achieve targeted chemo-photothermal therapy, we co-loaded the anticancer agent paclitaxel (PTX) with HA-PLGA/MX (HA-PLGA/MXP NPs), facilitating simultaneous delivery of heat and drug to tumor sites. The HA-PLGA/MXP NPs were synthesized using a straightforward water-oil-water emulsion method and extensively characterized for drug release assays to confirm their suitability as dual-functional nanocarriers. Both in vitro and in vivo studies demonstrated that HA-PLGA/MXP NPs, under laser irradiation, achieved obviously enhanced therapeutic efficacy, with an ~81.9 % cell death rate and a ~95.7 % tumor inhibition rate, outperforming the effects of chemotherapy or photothermal therapy alone. Integrating MXene in HA-PLGA encapsulation introduces a potent platform for melanoma treatment, offering synergistic therapeutic potential by combining photothermal activity with sustained drug release, highlighting a promising approach to targeted cancer therapy, and advancing the field of NP-based chemo-photothermal therapeutics.

1. Introduction

Given the growing interest in personalized medicine and the development of nanotechnology for targeted cancer therapies, this technology stands at the intersection of several cutting-edge research areas [1–3]. In particular, melanoma is the most aggressive form of skin cancer, raising significant concerns due to its high metastatic potential and the majority of deaths from skin cancer, highlighting its severity [4]. By enhancing the therapeutic window and minimizing systemic side effects, current treatment modalities include surgical resection, immunotherapy, radiation therapy, and chemotherapy with cytotoxic drugs to target rapidly dividing cancer cells [5,6]. However, these therapeutic approaches still face considerable challenges, including high toxicity, incomplete elimination, recurrence, and metastasis [7]. Therefore, photomedicine has rapidly emerged as a powerful tool for non-invasive cancer treatment [8]. In this context, as an interdisciplinary field combining medicine and photonics, photomedicine has gained great attention for its potential in cancer therapy [9,10]. Two notable photomedicine techniques are categorized in photodynamic therapy (PDT) and photothermal therapy (PTT). PDT involves the administration of a photosensitizer followed by light activation at a specific wavelength, generating reactive oxygen species (ROS) that induce localized oxidative damage and cell death [11,12]. While PDT selectively targets cancer cells and is minimally invasive, its efficacy is limited by light penetration depth, restricting its use to superficial or accessible tumors [13,14]. In contrast, PTT utilizes light-absorbing agents such as nanoparticles (NPs)

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RESEARCH ARTICLE

Water-Dispersible and Biocompatible Polymer-Based Organic Upconversion Nanoparticles for Transdermal Delivery

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Photomedicine, which utilizes light for therapeutic purposes, has several hurdles such as limited tissue penetration for short-wavelength light and inadequate deep tissue efficacy for long-wavelength light. Photon energy upconversion (UC) reveals promise in photomedicine because it enables the conversion of lower-energy photons into higher-energy photon. Lanthanide (Ln)-based inorganic UC system has been extensively studied but faces challenges, including high excitation laser power density, intrinsically subpar UC quantum efficiency, and potential biotoxicity. Recently, an organic-based triplet–triplet annihilation UC (TTA-UC) system has emerged as a novel UC system due to its prolonged emission lifetime upon low power laser excitation and exceptional UC quantum yield. In this study, we developed water-dispersible hyaluronic acid (HA)-conjugated polycaprolactone (PCL) nanoparticles loaded with TTA-UC chromophores (HA-PCL/UC NPs), which allow deeper tissue penetration by converting red light (635 nm) into blue light (470 nm) for noninvasive transdermal delivery. HA-PCL/UC NPs demonstrated a 1.6% high quantum yield in distilled water, improved cellular imaging in HeLa cells, and effectively penetrated the deep tissue of porcine skin, showing upconverted blue light. Our strategy holds significant potential as a next-generation noninvasive photomedicine platform for bioimaging, photo-triggered drug delivery, and photodynamic therapy, ultimately advancing targeted and effective therapeutic interventions.

Introduction

Photomedicine, an emerging therapeutic approach that utilizes light for diverse applications, offers inherent therapeutic effects and facilitates other therapeutic effects [1]. This approach harnesses the unique characteristics of light based on wavelength, leading to versatile applications. Among various wavelengths, near-infrared (NIR) light is commonly used in thermal therapy due to its heat properties and ability to induce photothermal effects [2,3]. Conversely, ultraviolet (UV) light serves as the stimulator, promoting antibacterial effects or activating other pharmacological effects owing to its high energy [4]. Despite their potential, photomedicine encounters challenges because of the properties of light. Long-wavelength light is effective for reaching and acting within deep tissue but may lack sufficient energy to activate adequate reactions. In contrast, short-wavelength light possesses higher energy and is capable of triggering chemical reactions but holds boundaries about penetration restrictions when exposed externally to the body.

In the pursuit of surmounting these constraints, photon energy upconversion nanoparticles (UC NPs) have shown great promise in various photomedicine fields. UC involves the conversion of lower-energy photons into a single photon with higher energy, possessing the advantages of a broad hypochromatic shift, sharply defined emission peaks, extended luminescence shelf-life, exceptional photostability, and improved penetration into biological tissues [5,6]. Based on these attributes, UC has been developed in photomedicine for applications such as bioimaging [7], drug delivery [8], photothermal therapy [9], photodynamic therapy [10], immunotherapy [11], neuromodulation [12], and photochemical tissue bonding [13]. In the UC landscape, particular attention has been directed toward inorganic (rare earth ion)-based UC NP system. Inorganic lanthanide (Ln)-doped UC NPs exhibit minimal photodegradation, significant anti-Stokes shifts, manageable emission spectra, ease of multifunctional integration, size manipulation, phase adjustability, and enduring photostability. However, inorganic UC NPs encounter various hurdles, including the requirement for a relatively intense excitation power density (>10^3 to 10^5 mW cm^{-2}), the intrinsic subpar UC quantum yield (<0.001%), and potential toxicity associated with Ln ions when situated at the target site [14].

RESEARCH ARTICLE

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Cold-Responsive Hyaluronated Upconversion Nanoplatform for Transdermal Cryo-Photodynamic Cancer Therapy

Anara Molkenova, Hye Eun Choi, Gibum Lee, Hayeon Baek, Mina Kwon, Su Bin Lee, Jeong-Min Park, Jae-Hyuk Kim, Dong-Wook Han, Jungwon Park, Sei Kwang Hahn, and Ki Su Kim**

Cryotherapy leverages controlled freezing temperature interventions to engender a cascade of tumor-suppressing effects. However, its bottleneck lies in the standalone ineffectiveness. A promising strategy is using nanoparticle therapeutics to augment the efficacy of cryotherapy. Here, a cold-responsive nanoplatform composed of upconversion nanoparticles coated with silica – chlorin e6 – hyaluronic acid (UCNPs@SiO_2-Ce6-HA) is designed. This nanoplatform is employed to integrate cryotherapy with photodynamic therapy (PDT) in order to improve skin cancer treatment efficacy in a synergistic manner. The cryotherapy appeared to enhance the upconversion brightness by suppressing the thermal quenching. The low-temperature treatment afforded a 2.45-fold enhancement in the luminescence of UCNPs and a 3.15-fold increase in the photodynamic efficacy of UCNPs@SiO_2-Ce6-HA nanoplatforms. Ex vivo tests with porcine skins and the subsequent validation in mouse tumor tissues revealed the effective HA-mediated transdermal delivery of designed nanoplatforms to deep tumor tissues. After transdermal delivery, in vivo photodynamic therapy using the UCNPs@SiO_2-Ce6-HA nanoplatforms resulted in the optimized efficacy of 79% in combination with cryotherapy. These findings underscore the Cryo-PDT as a truly promising integrated treatment paradigm and warrant further exploring the synergistic interplay between cryotherapy and PDT with bright upconversion to unlock their full potential in cancer therapy.

1. Introduction

Cryotherapy, including cryosurgery,[1] cryoablation,[2] and cryospray,[3] is a cold-enabled curative approach to diverse human cancers with lethal repetitive freezing and thawing of cancer cells.[4,5] Despite a long history in therapeutic practices, this therapy is insufficient for a complete interception of cancer progression.[6] Recently, nanoparticles have been reported to hold great promise for augmenting the efficiency of cancer therapy.[7] For example, Wang et al. developed cold-responsive polymer nanoparticles that release drugs when cooled and generate localized heating under near-infrared (NIR) laser irradiation, demonstrating the potential for improved breast cancer treatment with cryosurgery.[8] Kwak et al. reported the incorporation of thermally conductive inorganic nanoparticles into cryotherapies, such as magnesium oxide, gold, silver, and iron oxide nanoparticles, to maximize the extent of intracellular freezing, drug delivery, and imaging guidance.[9] However, their clinical applications remain limited due

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Upconversion nanomaterials and delivery systems for smart photonic medicines and healthcare devices

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A B S T R A C T

In the past decade, upconversion (UC) nanomaterials have been extensively investigated for the applications to photomedicines with their unique features including biocompatibility, near-infrared (NIR) to visible conversion, photostability, controllable emission bands, and facile multi-functionality. These characteristics of UC nanomaterials enable versatile light delivery for deep tissue biophotonic applications. Among various stimuli-responsive delivery systems, the light-responsive delivery process has been greatly advantageous to develop spatiotemporally controllable on-demand "smart" photonic medicines. UC nanomaterials are classified largely to two groups depending on the photon UC pathway and compositions: inorganic lanthanide-doped UC nanoparticles and organic triplet–triplet annihilation UC (TTA-UC) nanomaterials. Here, we review the current-state-of-art inorganic and organic UC nanomaterials for photo-medicinal applications including photothermal therapy (PTT), photodynamic therapy (PDT), photo-triggered chemo and gene therapy, multimodal immunotherapy, NIR mediated neuromodulations, and photochemical tissue bonding (PTB). We also discuss the future research direction of this field and the challenges for further clinical development.

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별첨 대표논문 증빙자료 05

SCIENCE ADVANCES | RESEARCH ARTICLE

APPLIED SCIENCES AND ENGINEERING

Combinatorial wound healing therapy using adhesive nanofibrous membrane equipped with wearable LED patches for photobiomodulation

So Yun Lee[1]†, Sangheon Jeon[2]†, Young Woo Kwon[3], Mina Kwon[1], Moon Sung Kang[2], Keum-Yong Seong[4], Tae-Eon Park[1], Seung Yun Yang[4], Dong-Wook Han[2], Suck Won Hong[2]*, Ki Su Kim[1]*

Wound healing is the dynamic tissue regeneration process replacing devitalized and missing tissue layers. With the development of photomedicine techniques in wound healing, safe and noninvasive photobiomodulation therapy is receiving attention. Effective wound management in photobiomodulation is challenged, however, by limited control of the geometrical mismatches on the injured skin surface. Here, adhesive hyaluronic acid–based gelatin nanofibrous membranes integrated with multiple light-emitting diode (LED) arrays are developed as a skin-attachable patch. The nanofibrous wound dressing is expected to mimic the three-dimensional structure of the extracellular matrix, and its adhesiveness allows tight coupling between the wound sites and the flexible LED patch. Experimental results demonstrate that our medical device accelerates the initial wound healing process by the synergetic effects of the wound dressing and LED irradiation. Our proposed technology promises progress for wound healing management and other biomedical applications.

INTRODUCTION

Skin is the largest organ system of the human body and plays a key role as the first barrier protecting the internal organs from environmental hazards by restoring a physiologically compromised condition. Owing to the excellent regenerative properties of the skin, the injured skin tissue or surgical wound can be healed through the biological healing process in the four physiological events, including hemostasis, inflammation, proliferation, and mutation (remodeling) (*1*). Although the traditional therapies such as ointment, dressing, and derived compound are currently in practice, these strategies are insufficient for the contribution in full stages (*2–5*). Thus far, a major class of biomaterials such as hydrogels (*6*, *7*), fibrous membranes (*8*), porous structures (*9*), and drug-embedded functional electrospun nanofibers have been developed for wound treatment to support pain relief and infection prevention by covering wound sites (*10–12*). The main goal of those strategies with engineered wound dressings is to provide a favorable environment promoting the wound healing cascade in control of the tissue formation and mediate multiple cellular fate including cell survival, proliferation, and morphogenesis. Therefore, the development of materials has focused on mimicking the microenvironment of natural extracellular matrix (ECM) for wound care purposes, including collagen, gelatin, hyaluronic acid (HA), and chitosan, and consisted of a multiscale mat or electrospun nanofibers (*13–19*). In particular, layered nanofibrous structures used in the treatment of wounds represent a very similar physical structure to natural ECM to facilitate the regenerative process with their high porosity and surface-to-volume ratio. Therefore, these structural advantages allow them to protect wound beds with favorable properties of their intrinsic structures as engineered scaffolds in wound healing and hemostasis (*20–30*).

In many biomedical applications, gelatin has been considered as one of the most promising biomaterials, as a Food and Drug Administration–approved natural polymer, due to its excellent biocompatibility, hydrophilicity, and suitable degradation profile under a physiological environment (*31–34*). To date, gelatin has shown excellent performance contributing to wound repair when conformally placed to the wound sites by forming a gel state to absorb the exudate with the permeability to water and oxygen in the regular healing process under an isolated wound environment (*35–38*). In addition to this, the easy control of the fiber diameter and pore size is advantageous in the manufacturing process when produced by electrospinning technique, resulting in favorable architectures that can mimic the biocompatible nanofibrillar ECM to promote wound healing process (*39*). However, the electrospun gelatin nanofibers generally exhibit unsatisfied mechanical strength hard to maintain the morphological integrities with a lack of stiffness when it exposed in physiological moist conditions, which has restricted the further applications of intrinsic gelatin nanofibers (*40*, *41*). To overcome this limitation, many efforts have been made on cross-linking strategies in a simple manner. Among other material systems for the cross-linking approach, natural polysaccharide, HA, has been explored as a proper constituent of ECM in tissue engineering, mainly due to its advantageous physicochemical properties, demonstrating excellent nontoxic biocompatibility, appropriate biodegradability, nonimmunogenicity, and versatile bioactivities (*42*, *43*). With some specific molecular configurations, the applied HA plays an important role in cell growth and drug delivery involving a series of biological processes and contributes to the structural stability that guides tissue regeneration (*1*, *44–46*). Despite these advantages, some drawbacks still exist in the form of nanofibers, such as less-effective cell adhesion and weak mechanical stability. Thus, to improve the capability in the wound dressing

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