(양식 1)

【 고분자학회 학회상 포상 지원서 】

[표지]

<table>
<tr><td>공모분야</td><td colspan="5">권순기우수학위논문상</td></tr>
<tr><td rowspan="5">지원자
인적사항</td><td rowspan="2">성 명</td><td>한 글</td><td>박 성 현</td><td rowspan="2">영 문</td><td rowspan="2">Park, Seonghyeon</td></tr>
<tr><td>한 자</td><td>朴 星 顯</td></tr>
<tr><td rowspan="3">소속기관</td><td>기관명</td><td colspan="3">한국과학기술원</td></tr>
<tr><td>부서명
(학과명)</td><td>응용과학연구소</td><td>직위/직급</td><td>연수연구원</td></tr>
<tr><td>주 소</td><td colspan="3">대전 유성구 대학로 291, KI빌딩 C524호</td></tr>
<tr><td>업적요지</td><td colspan="5">저는 KAIST 생명화학공학과 학, 석, 박사 과정을 거쳐 현재 KAIST 응용과학연구소 박사후연구원으로 재직중이며, 고분자 박막, 조직 공학, 인간 줄기세포 배양, 장 오가노이드를 융합한 재생의학 연구를 수행하고 있습니다. 특히 개시제를 이용한 화학 기상 증착 (iCVD) 공정을 활용하여 표면의 화학, 물리적 특성을 정밀하게 제어하여 기능성 고분자 박막을 설계하고, 이를 줄기세포 및 오가노이드 배양 플랫폼에 적용하는 연구를 집중적으로 진행하고 있습니다.
연구 성과 측면에서, Nature Communications (2024)에 게재된 “Xenogeneic-free culture of human intestinal stem cells on functional polymer-coated substrates for scalable, clinical-grade stem cell therapy“ 논문뿐만 아니라, Advanced Healthcare Materials 등 고분자, 바이오 소재 분야의 권위 있는 저널에 논문을 발표하였습니다. 해당 연구들은 고분자 기반 소재 설계와 세포 배양 환경 최적화를 융합하여 임상 적용 가능성을 높이는 것을 목표로 하였으며, 특히 무이종 배양 환경 시스템 구축, 효율 향상, 대규모 생산 가능성 확보 측면에서 학문적, 기술적 진보를 이루었습니다. 이와 함께, 관련 원천기술에 대해 국내 특허 2건, PCT 국제특허 2건을 출원하여 학문적 성과를 산업 분야로 확장해 나가고 있습니다.
박사학위논문 “Development of Xenogeneic-free Polymers for Intestinal Regenerative Medicine”은 기존 장 줄기세포 배양에 필수적으로 사용되는 Matrigel, feeder cell 등 동물 유래 물질의 의존성을 완전히 배제한 세계 최초의 연구입니다. 본 연구에서는 iCVD 공정을 통해 합성된 화학적으로 규명된 기능성 고분자 박막을 합성하고, 이를 활용해 장 오가노이드 (hIO), 인간 장 줄기세포 (ISCs), 중간엽 줄기세포 (MSCs)를 무이종 환경에서 안정적으로 배양할 수 있는 플랫폼을 구축하였습니다. 개발된 고분자 표면에서 배양된 세포들을 쥐 상피 손상 모델, 염증성 장 질환 모델에 이식하여 조직 재생 효과를 입증하였으며, 기존에 해결하지 못했던 임상 등급의 장 줄기세포 대량생산, 장기보관이라는 핵심 난제를 극복한 성과입니다. 결과적으로 본 학위논문은 고분자 공학, 줄기세포 생물학, 재생의학을 융합하여 임상 등급 줄기세포 치료제 개발의 기술적 토대를 마련한 독창적 연구로써, 학문적 완성도와 사회적 파급력을 동시에 갖춘 우수한 성과입니다.</td></tr>
</table>

상기와 같이 고분자학회 학회상 포상을 지원합니다.

2025. 08. 10

기관명 : 한국과학기술원
직 위 : 연수연구원
지원자 : 박 성 현 (직인)

(양식 2)

1. 인적사항

가. 학력사항 (대학교 이상만 기재)

기 간	학 교 명	전공 및 학위, 지도교수
2021.03 ~ 2025.02	한국과학기술원	생명화학공학과 박사, 임성갑 교수님
2019.03 ~ 2021.02	한국과학기술원	생명화학공학과 석사, 임성갑 교수님
2014.03 ~ 2019.02	한국과학기술원	생명화학공학과 학사

나. 경력사항 (5개 이내 기재)

기 간	기관명(직위, 직책 등)
2025.03 ~ 현재	한국과학기술원 응용과학연구소 연수연구원

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
2024.08.30	한국줄기세포학회 2024 연례학술대회 Best Poster Award	한국줄기세포학회
2024.10.01	한국고분자학회 2024 추계 연구논문발표회 최우수논문발표상	한국고분자학회
2024.11.15	한국바이오칩학회 2024 추계학술대회 우수 구두발표상	한국바이오칩학회

4. 연구개발 실적

(3) 총괄연구업적 목록

☐ 학술지 논문 - SCIE 등재지에 한함

제 목	발표지명	Impact or factor	발표 년도	역할 (저자)	저자수 (명)	피인용 횟수
Reliable Harvest of Injectable Human Mesenchymal Stem Cell Sheets by Modulating Cell-Substrate Adhesion Strength	Advanced Healthcare Materials	9.6	2025	주저자	10	-
Long-Lasting, Transparent Antibacterial Shield: A Durable, Broad-Spectrum Anti-Bacterial, Non-Cytotoxic, Transparent Nanocoating for Extended Wear Contact Lenses	Small	12.1	2025	공동	14	2
Xenogeneic-free culture of human intestinal stem cells on functional polymer-coated substrates for scalable, clinical-grade stem cell therapy	Nature Communications	15.7	2024	주저자	23	3
Long-Term Culture of Human Pluripotent Stem Cells in Xeno-Free Condition Using Functional Polymer Films	Advanced Materials	26.8	2024	공동	12	-
Hydrophobic surface induced pro-metastatic cancer cells for in vitro extravasation models	Bioactive Materials	20.3	2024	공동	10	5
Anti-viral, anti-bacterial, but non-cytotoxic nanocoating for reusable face mask with efficient filtration, breathability, and robustness in humid environment	Chemical Engineering Journal	13.2	2023	공동	13	17
Vapor-phase synthesis of a robust polysulfide film for transparent, biocompatible, and long-term stable anti-biofilm coating	Korean Journal of Chemical Engineering	3.2	2023	주저자	8	5
Mitochondrial double-stranded RNAs as a pivotal mediator in the pathogenesis of Sjögren's syndrome	Molecular Therapy Nucleic Acids	6.1	2022	공동	16	35
Synthesis of a stretchable polyampholyte hydrophilic film with compositional gradient for long-term stable, substrate-independent fouling-resistant coating	Advanced Functional Materials	19.0	2022	공동	9	25
Engineering of Surface Energy of Cell-Culture Platform to Enhance the Growth and Differentiation of Dendritic Cells via Vapor-Phase Synthesized Functional Polymer Films	Small	12.1	2022	공동	7	5
A versatile surface modification method via vapor-phase deposited functional polymer films for biomedical device applications	Biotechnology and Bioprocess Engineering	3.0	2021	공동	6	29

□ **등록**된 국내외 특허

제 목	등록번호	등록년도	등록처	역할
-	-	-	-	-

논문실적 1

RESEARCH ARTICLE

ADVANCED HEALTHCARE MATERIALS
www.advhealthmat.de

Reliable Harvest of Injectable Human Mesenchymal Stem Cell Sheets by Modulating Cell-Substrate Adhesion Strength

Jemin Yeun, Seonghyeon Park, Younseong Song, Sung Hyun Yoon, Sang Yu Sun, Booseok Jeong, Minkyung Kim, Kyoung G. Lee, Sung Gap Im,* and Jieung Baek**

Cell sheet engineering has emerged as a promising scaffold-free strategy in cell-based therapeutics, preserving essential cell-cell and cell-extracellular matrix (ECM) interactions. To enable minimally invasive delivery, a key challenge relies on making the cell sheets compatible with injection-based administration without subjecting sensitive cells to physical or thermal stresses. This study addresses a reliable method for controlling cell sheet dimensions by combining differential cell adhesion-guided micropatterning along with an isothermal detachment method. The surface composition of a copolymer, poly(ethylene glycol dimethacrylate-co-hydroxyethyl methacrylate) is delicately controlled via initiated chemical vapor deposition to ensure intact cell adhesion and rapid cell detachment under isothermal condition. The optimized surface further allows hydrophobic microcontact printing for creating micron-sized sheets. Human mesenchymal stem cell sheets harvested with this method show preserved ECM without compromising cell viability after both detachment and injection. Moreover, the injected cell sheets substantially enhance the angiogenic potential of human umbilical vein endothelial cells, demonstrating the sustained therapeutic activity of the cell sheet after injection. It is believed that this approach has great potential to broaden the scope of cell sheet engineering, serving as a robust platform for regenerative medicine.

1. Introduction

Cell sheet engineering is a scaffold-free method that allows the direct transplantation of cell sheets into impaired tissues without the need for additional structural support materials,[1] aiming to restore damaged or defective tissues and organs. This cutting-edge approach is applicable to a broad spectrum of tissue types, such as bones,[2] skin,[3] and periodontal tissues.[4] Various kinds of cell sheet harvest methods have been reported, including the use of thermo-responsive surfaces,[5] and recent studied continued research on fibrin-coating,[6] oil-infusion,[7] and ion-deficiency detachment.[8] pH-responsive polymers,[9] infrared-responsive polymers,[10] and magnetic nanoparticle-based cell sheet fabrication methods.[11] These methods have demonstrated their capability to form cell sheets while preserving essential extracellular matrix (ECM) proteins and intercellular connections. In particular, thermo-responsive polymer surfaces, primarily constituting of poly(*N*-isopropylacrylmide) (pNIPAm), stand as one of the most broadly explored systems in the field of cell sheet engineering.[12] The unique temperature-dependent phase transition behavior of pNIPAm surfaces in an aqueous environment induces the detachment of cell sheet monolayers when the surface is exposed to temperatures below 20 °C.[13] Furthermore, we have recently demonstrated an isothermal cell sheet detachment by precisely adjusting the surface energy of the substrates for cell culture.[12,14] This approach induces spontaneous cell detachment simply by depleting multivalent ions in the culture medium, without requiring a change in temperature, which could be harmful to sensitive cells.

While this significant progress has been made in developing efficient cell sheet detachment methods, practical challenges remain in transferring these sheets to target tissues in a minimally

J. Yeun, S. Park, Y. Song, S. H. Yoon, S. Yu Sun, B. Jeong, M. Kim
Department of Chemical and Biomolecular Engineering
Korea Advanced Institute of Science and Technology (KAIST)
291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea
K. G. Lee
Division of Nano-Bio Sensors/Chips Development
National NanoFab Center (NNFC)
291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea
E-mail: kglee@nnfc.re.kr

The ORCID identification number(s) for the author(s) of this article can be found under https://doi.org/10.1002/adhm.202500135

S. G. Im
Department of Chemical and Biomolecular Engineering and Graduate School of Stem cell & Regenerative Biology
Korea Advanced Institute of Science and Technology (KAIST)
291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea
E-mail: sgim@kaist.ac.kr

J. Baek
Department of Mechanical and Biomedical Engineering and Graduate Program in System Health Science and Engineering
Ewha Woman's University
52 Ewhayeodae-gil, Seodaemun-gu, Seoul 03760, Republic of Korea
E-mail: jieungbaek@ewha.ac.kr

DOI: 10.1002/adhm.202500135

논문실적 2

RESEARCH ARTICLE

NANO · MICRO small
www.small-journal.com

Long-Lasting, Transparent Antibacterial Shield: A Durable, Broad-Spectrum Anti-Bacterial, Non-Cytotoxic, Transparent Nanocoating for Extended Wear Contact Lenses

Nahyun Park, Chae-Eun Moon, Younseong Song, Sang Yu Sun, Ji-Min Kwon, Sunghyun Yoon, Seonghyeon Park, Booseok Jeong, Jemin Yeun, Joseph Michael Hardie, Jun-ki Lee, Kyoung G. Lee, Yong Woo Ji,* and Sung Gap Im**

The increasing incidence of serious bacterial keratitis, a sight-threatening condition often exacerbated by inadequate contact lens (CLs) care, highlights the need for innovative protective technology. This study introduces a long-lasting antibacterial, non-cytotoxic, transparent nanocoating for CLs via a solvent-free polymer deposition method, aiming to prevent bacterial keratitis. The nanocoating comprises stacked polymer films, with poly(dimethylaminomethyl styrene-*co*-ethylene glycol dimethacrylate) (pDE) as a biocompatible, antibacterial layer atop poly(2,4,6,8-tetramethyl-2,4,6,8-tetravinylcyclotetrasiloxane) (pV4D4) as an adhesion-promoting layer. The pD6E1-*grafted* (*g*)-pV4D4 film shows non-cytotoxicity toward two human cell lines and antibacterial activity of >99% against four bacteria, including methicillin-resistant *Staphylococcus aureus* (MRSA), an antibiotic-resistant bacteria and *Pseudomonas aeruginosa*, which causes ocular diseases. Additionally, the film demonstrates long-lasting antibacterial activity greater than 96% against MRSA for 9 weeks in phosphate-buffered saline. To the best knowledge, this duration represents the longest reported long-term stability with less than 5% decay of antibacterial performance among contact-killing antibacterial coatings. The film exhibits exceptional mechanical durability, retaining its antibacterial activity even after 15 washing cycles. The pD6E1-*g*-pV4D4-coated CL maintains full optical transmittance compared to that of pristine CL. It is expected that the unprecedentedly prolonged antibacterial performance of the coating will significantly alleviate the risk of infection for long-term CL users.

1. Introduction

Contact lenses (CLs) that undergo continuous use inevitably accrue mechanical damage on their surfaces, which may act as a favorable environment for bacterial keratitis (BK). This phenomenon poses a significant public ocular health issue, accounting for approximately up to 2 million cases of visual impairment annually.[1] In severe cases, BK results in vision impairment and even total blindness, necessitating the use of antibiotics as a counteracting agent.[2] However, due to the need for multiple periodic doses, the antibiotic treatment entails potential risks including cytotoxicity, tissue damage, and promotion of antibiotic-resistant bacterial strains.[3] To date, BK is primarily attributed to various bacteria including *P. aeruginosa*,[4] *S. aureus*,[5] and methicillin-resistant *Staphylococcus aureus* (MRSA).[5] Therefore, it is imperative to develop a long-lasting antibacterial surface coating method with chemical stability and mechanical durability to prevent BK.[1b]

The rise of reusable CLs, with extended periods ranging from 2 weeks to 2 years, presents an increased risk of bacterial infection due to improper maintenance,

N. Park, Y. Song, S. Yu Sun, S. Yoon, S. Park, B. Jeong, J. Yeun, S. G. Im
Department of Chemical and Biomolecular Engineering
Korea Advanced Institute of Science and Technology
291 Daehak-ro, Daejeo, Yuseong-gu 34141, Republic of Korea
E-mail: sgim@kaist.ac.kr

C.-E. Moon, J.-M. Kwon, J.-ki Lee, Y.W. Ji
Institute of Vision Research
Department of Ophthalmology
Yonsei University College of Medicine
Seoul 03722, Republic of Korea
E-mail: lusita30@yuhs.ac

The ORCID identification number(s) for the author(s) of this article can be found under https://doi.org/10.1002/smll.202405635

DOI: 10.1002/smll.202405635

Y. Song, J. M. Hardie
Division of Engineering in Medicine
Department of Medicine
Brigham and Women's Hospital and
Harvard Medical School
Boston, Massachusetts 02139, USA

K. G. Lee
Division of Nano-Bio Sensors/Chips Development
National NanoFab Center (NNFC)
291 Daehak-ro, Daejeon, Yuseong-gu 34141, Republic of Korea
E-mail: kglee@nnfc.re.kr

Y.W. Ji
Department of Ophthalmology
Yongin Severance Hospital
Yonsei University College of Medicine
Yongin-si 16995, Republic of Korea

논문실적 3

nature communications

Article

https://doi.org/10.1038/s41467-024-54653-9

Xenogeneic-free culture of human intestinal stem cells on functional polymer-coated substrates for scalable, clinical-grade stem cell therapy

Received: 6 March 2024

Accepted: 18 November 2024

Published online: 02 December 2024

Check for updates

Seonghyeon Park[1,13], Ohman Kwon[2,12,13], Hana Lee[2,13], Younghak Cho[1], Jemin Yeun[1], Sung Hyun Yoon[1], Sang Yu Sun[1], Yubin Huh[2,3], Won Dong Yu[2,3], Sohee Park[2,3], Naeun Son[2,3], Sojeong Jeon[2,3], Sugi Lee[4], Dae-Soo Kim[3,4], Sun Young Lee[5], Jin Gyeong Son[5], Kyung Jin Lee[6], Yong Il Kim[6], Jin Hong Lim[7], Jongman Yoo[6,8,9], Tae Geol Lee[5], Mi-Young Son[2,3,8,10] & Sung Gap Im[1,11]

The need for basement membrane extract (BME) with undefined constituents, such as Matrigel, for intestinal stem cell (ISC) culture in traditional systems poses a significant barrier that must be overcome for the development of clinical-grade, scalable, ready-to-use ISCs. Here, we propose a functional polymer-based xenogeneic-free dish for the culture of intestinal stem cells (XF-DISC), ensuring substantially prolonged maintenance of ISCs derived from 3-dimensional human intestinal organoids ($ISCs^{3D\text{-}hIO}$). XF-DISC enables remarkable expandability, exhibiting a 24-fold increase in cell numbers within 30 days, with long-term maintenance of $ISCs^{3D\text{-}hIO}$ for more than 30 consecutive passages (>210 days). In addition, XF-DISC is fully compatible with a cell banking system. Notably, human pluripotent stem cell-derived $ISCs^{3D\text{-}hIO}$ cultured on XF-DISC are successfully transplanted into intestinal injury and inflammation mouse models, leading to engraftment and regeneration of damaged mouse intestinal epithelium. As a reliable and scalable xenogeneic-free $ISC^{3D\text{-}hIO}$ culture method, XF-DISC is highly promising for the development of regenerative ISC therapy for human intestinal diseases.

Inflammatory bowel disease (IBD) affects many individuals, causing significant pain and suffering because of the lack of a complete cure. According to a 2016 Centers for Disease Control and Prevention (CDC) report, 1.3% of U.S. adults were diagnosed with IBD in 2015, highlighting its prevalence and impact on quality of life and health care costs. Additionally, the World Health Organization (WHO) reported a death rate of greater than 75 per 100,000 due to IBD, with older adults, especially women, being more affected. Current treatments, such as anti-TNF-α drugs, offer symptomatic relief but do not address the underlying causes, whereas MSC-based cell therapy provides indirect benefits. Therefore, developing innovative cell therapies is crucial for effective regeneration and advancing treatments for gastrointestinal diseases[1–4].

Intestinal stem cells (ISCs) are self-organizing stem cells capable of forming organoids that resemble their native organ[5–10]. ISCs have garnered considerable interest in the last decade as promising sources for stem cell therapy in regenerative transplantation to treat intestinal diseases[11–15]. Recently, human intestinal organoid (hIO) culture has

A full list of affiliations appears at the end of the paper. e-mail: myson@kribb.re.kr; sgim@kaist.ac.kr

논문실적 4

RESEARCH ARTICLE

ADVANCED MATERIALS
www.advmat.de

Long-Term Culture of Human Pluripotent Stem Cells in Xeno-Free Condition Using Functional Polymer Films

Younghak Cho, Hana Lee, Wonji Jeong, Kwang Bo Jung, Sun Young Lee, Seonghyeon Park, Jemin Yeun, Ohman Kwon, Jin Gyeong Son, Tae Geol Lee, Mi-Young Son, and Sung Gap Im**

Human pluripotent stem cells (hPSCs), encompassing human embryonic stem cells (hESCs) and human induced pluripotent stem cells (hiPSCs), hold immense potential in regenerative medicine, offering new opportunities for personalized cell therapies. However, their clinical translation is hindered by the inevitable reliance on xenogeneic components in culture environments. This study addresses this challenge by engineering a fully synthetic, xeno-free culture substrate, whose surface composition is tailored systematically for xeno-free culture of hPSCs. A functional polymer surface, pGC2 (poly(glycidyl methacrylate-grafting-guanidine-*co*-carboxylic acrylate)), offers excellent cell-adhesive properties as well as non-cytotoxicity, enabling robust hESCs and hiPSCs growth while presenting cost-competitiveness and scalability over Matrigel. This investigation includes comprehensive evaluations of pGC2 across diverse experimental conditions, demonstrating its wide adaptability with various pluripotent stem cell lines, culture media, and substrates. Crucially, pGC2 supports long-term hESCs and hiPSCs expansion, up to ten passages without compromising their stemness and pluripotency. Notably, this study is the first to confirm an identical proteomic profile after ten passages of xeno-free cultivation of hiPSCs on a polymeric substrate compared to Matrigel. The innovative substrate bridges the gap between laboratory research and clinical translation, offering a new promising avenue for advancing stem cell-based therapies.

1. Introduction

Stem cells, well-recognized for their remarkable regenerative potential, hold the promise toward personalized medicine owing to their unique advantageous capacity for self-renewal and pluripotency.[1] While mesenchymal stem cells have historically been foundational in stem cell therapies,[2] their limited differentiation potential and finite proliferation render them inadequate for personalized cell therapies across diverse tissues.[3] Consequently, there has been extensive exploration into human pluripotent stem cells (hPSCs), including human embryonic stem cells (hESCs) and human induced pluripotent stem cells (hiPSCs), for clinical trials in stem cell therapy because of the remarkable capability for self-renewal and differentiation into diverse cell types.[1b,4] The cultivation of hPSCs forms the cornerstone of regenerative medicine, offering unprecedented prospect for both biomedical research and clinical applications,[5] such as disease modeling, drug discovery, and cell-based therapies.[4,6] However, one of the primary concerns

Y. Cho
Brain Science Institute
Korea Institute of Science and Technology (KIST)
5, Hwarang-ro 14-gil, Seongbuk-gu, Seoul 02792, Republic of Korea
Y. Cho, W. Jeong, S. Park, J. Yeun, S. G. Im
Functional Thin Film Laboratory
Department of Chemical and Biomolecular Engineering
Korea Advanced Institute of Science and Technology (KAIST)
291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea
E-mail: sgim@kaist.ac.kr

The ORCID identification number(s) for the author(s) of this article can be found under https://doi.org/10.1002/adma.202403952

DOI: 10.1002/adma.202403952

H. Lee, K. B. Jung, O. Kwon, M.-Y. Son
Korea Research Institute of Bioscience and Biotechnology (KRIBB)
Daejeon 34141, Republic of Korea
E-mail: myson@kribb.re.kr
S. Y. Lee, J. G. Son, T. G. Lee
Korea Research Institute of Standards and Science (KRISS)
Daejeon 34141, Republic of Korea
M.-Y. Son
KRIBB School of Bioscience
Korea University of Science and Technology (UST)
Daejeon 34113, Republic of Korea
M.-Y. Son
Department of Biological Science
Sungkyunkwan University
Suwon 16419, Republic of Korea

논문실적 5

Bioactive Materials 34 (2024) 401–413

Contents lists available at ScienceDirect

Bioactive Materials

journal homepage: www.keaipublishing.com/en/journals/bioactive-materials

Hydrophobic surface induced pro-metastatic cancer cells for *in vitro* extravasation models

Minseok Lee [a,1], Seunggyu Kim [b,1], Sun Young Lee [c], Jin Gyeong Son [c], Joonha Park [b], Seonghyeon Park [a], Jemin Yeun [a], Tae Geol Lee [c,**], Sung Gap Im [a,d,***], Jessie S. Jeon [b,*]

[a] Department of Chemical and Biomolecular Engineering, Korea Advanced Institute of Science and Technology, Daehak-ro 291, Yuseong-gu, Daejeon, 34141, Republic of Korea
[b] Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology, Daehak-ro 291, Yuseong-gu, Daejeon, 34141, Republic of Korea
[c] Bioimaging Team, Safety Measurement Institute, Korea Research Institute of Standards and Science (KRISS), Gajeong-ro 267, Yuseong-gu, Daejeon, 34113, Republic of Korea
[d] KAIST Institute for the NanoCentury (KINC), Korea Advanced Institute of Science and Technology, Daehak-ro 291, Yuseong-gu, Daejeon, 34141, Republic of Korea

ARTICLE INFO

Keywords:
Initiated chemical vapor deposition
Cancer spheroid
Cancer extravasation
Organ-on-a-chip
In vitro disease model

ABSTRACT

In vitro vascularized cancer models utilizing microfluidics have emerged as a promising tool for mechanism study and drug screening. However, the lack of consideration and preparation methods for cancer cellular sources that are capable of adequately replicating the metastatic features of circulating tumor cells contributed to low relevancy with *in vivo* experimental results. Here, we show that the properties of cancer cellular sources have a considerable impact on the validity of the *in vitro* metastasis model. Notably, with a hydrophobic surface, we can create highly metastatic spheroids equipped with aggressive invasion, endothelium adhesion capabilities, and activated metabolic features. Combining these metastatic spheroids with the well-constructed microfluidic-based extravasation model, we validate that these metastatic spheroids exhibited a distinct extravasation response to epidermal growth factor (EGF) and normal human lung fibroblasts compared to the 2D cultured cancer cells, which is consistent with the previously reported results of *in vivo* experiments. Furthermore, the applicability of the developed model as a therapeutic screening platform for cancer extravasation is validated through profiling and inhibition of cytokines. We believe this model incorporating hydrophobic surface-cultured 3D cancer cells provides reliable experimental data in a clear and concise manner, bridging the gap between the conventional *in vitro* models and *in vivo* experiments.

1. Introduction

Metastasis, the spread of cancer cells from primary site to another organ, is estimated to be a leading cause of cancer-related death due to a poor patient prognosis [1,2]. Hence, one of the most effective methods to raise the cure rate of cancer patients is early diagnosis and prevention of metastasis. The metastatic cascade refers to the complex multistep process; separation of aggressive cancer cells from the primary tumor by losing their cell-cell junctions, invasion to stromal and endothelial barrier into the bloodstream, termed as intravasation, circulation inside of bloodstream, breaking and crossing the endothelial barrier into the metastatic sites, termed as extravasation, and finally, metastatic colonization for the formation of new tumors [3,4]. Epithelial-to-mesenchymal transition (EMT) is closely associated to the intrinsic characteristics of cancer cells during metastasis progression [5]. Cancer cells undergo EMT, lose the epithelial characteristics and acquire mesenchymal and invasive properties to shed from the primary tumor and intravasate into the peripheral blood circulating system as

Peer review under responsibility of KeAi Communications Co., Ltd.
* Corresponding author. Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology, Daehak-ro 291, Yuseong-gu, Daejeon, 34141, Republic of Korea.
** Corresponding author.
*** Corresponding author.
E-mail addresses: tglee@kriss.re.kr (T.G. Lee), sgim@kaist.ac.kr (S.G. Im), jsjeon@kaist.ac.kr (J.S. Jeon).
[1] These authors contributed equally.

https://doi.org/10.1016/j.bioactmat.2023.12.021
Received 17 July 2023; Received in revised form 8 December 2023; Accepted 23 December 2023
Available online 8 January 2024

논문실적 6

Chemical Engineering Journal 470 (2023) 144224

Contents lists available at ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Anti-viral, anti-bacterial, but non-cytotoxic nanocoating for reusable face mask with efficient filtration, breathability, and robustness in humid environment

Younseong Song [a,1], Yong-ki Lee [a,1], Yujin Lee [a,1], Won-Tae Hwang [b], Jiyoung Lee [b], Seonghyeon Park [a], Nahyun Park [a], Hyunsub Song [b], Hogi Kim [a], Kyoung G. Lee [c], Il-Doo Kim [b,d,*], Yoosik Kim [a,*], Sung Gap Im [a,d,*]

[a] Department of Chemical and Biomolecular Engineering, Korea Advanced Institute of Science and Technology (KAIST), 291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea
[b] Department of Materials Science and Engineering, KAIST, 291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea
[c] Division of Nano-Bio Sensors/Chips Development, National NanoFab Center (NNFC), 291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea
[d] KAIST Institute for NanoCentury, KAIST, 291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea

ARTICLE INFO

Keywords:
Human beta-coronavirus
Influenza virus
Anti-bacterial
Anti-viral
Initiated chemical vapor deposition
Face mask

ABSTRACT

We fabricated a multi-use face mask with anti-bacterial and anti-viral, but non-cytotoxic properties by adding a functional nanocoating on an electrospun nanofiber filter. The nanocoating consists of a copolymer synthesized from dimethyaminomethyl styrene (DMAMS) monomer containing anti-microbial tertiary amine moiety, and a biocompatible crosslinker, ethylene glycol dimethylacrylate (EGDMA). Initiated chemical vapor deposition process is utilized to deposit the nanocoating in order to impart desired functionalities conformally onto the nanofiber filter without deforming its highly porous structure. The synthesized non-cytotoxic copolymer of p(DMAMS-co-EGDMA), or pDE film showed excellent biocidal efficacy of > 99.995% and > 99.985% against *Escherichia coli* O157: H7 (*E. coli* O157: H7) and *Staphylococcus aureus*, respectively. The pDE-coated nanofiber filter shows a filtration efficiency of 91% with extremely low air resistance of ~ 50 Pa. In highly humid conditions, the pDE-coated nanofiber filter shows long-term anti-microbial efficacy of 99.89% for *E. coli* O157: H7 up to 168 h, 99.21%, and 99.23% for human influenza virus (H1N1) strain A/Puerto Rico/8/1934 and human beta-coronavirus strain *OC43* up to 100 h, without sacrificing breathability, and filtration performance. Furthermore, the surface-modified filter can easily eliminate dead pathogens with a simple water rinse, which enabled the full retention of the filtration efficiency even in six washing cycles, proving excellent reusability. We envision the highly breathable, antimicrobial, multi-use face mask will serve as an environmentally free platform for personal protective equipment against future viral threats.

1. Introduction

Acute respiratory infections caused by airborne pathogens have seriously threatened global health and economic growth [1–3]. In particular, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is highly transmissible with a broad tissue tropism, leading to the current pandemic [4–6]. Along with the emergence of various variants including Delta and Omicron, the persistent SARS-CoV-2 pandemic has resulted in over 655 million infections and more than six million deaths, as of January 5th, 2023 [7]. This pathogen is known to be transmitted to humans through several routes, including aerosol, surface contamination, and potential fecal-oral transmission [8–10]. Among them, there is growing evidence that aerosol is the most pronounced mode of transmission reported during the pandemic. Virus-laden aerosols, released by infected people into the air *via* breathing, speaking, coughing, or sneezing, can function as a key viral transmitter, notably from

* Corresponding authors at: Department of Materials Science and Engineering, Korea Advanced Institute of Science and Technology (KAIST), 291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea (Il-Doo Kim). Department of Chemical and Biomolecular Engineering, KAIST, 291 Daehak-ro, Yuseong-gu, Daejeon 34141, Republic of Korea (Yoosik Kim and Sung Gap Im).
E-mail addresses: idkim@kaist.ac.kr (I.-D. Kim), yyyoosik@kaist.ac.kr (Y. Kim), sgim@kaist.ac.kr (S.G. Im).
[1] These authors contributed equally.

https://doi.org/10.1016/j.cej.2023.144224
Received 11 April 2023; Received in revised form 3 June 2023; Accepted 17 June 2023
Available online 19 June 2023
1385-8947/

논문실적 7

Korean J. Chem. Eng., 40(2), 412-418 (2023)
DOI: 10.1007/s11814-022-1275-0

pISSN: 0256-1115
eISSN: 1975-7220

Vapor-phase synthesis of a robust polysulfide film for transparent, biocompatible, and long-term stable anti-biofilm coating

Hogi Kim*,†, Seonghyeon Park*,†, Younseong Song*, Wontae Jang*, Keonwoo Choi*, Kyoung G. Lee, Eunjung Lee*,†, and Sung Gap Im*,***,†**

*Department of Chemical and Biomolecular Engineering, KAIST, Daejeon 34141, Korea
**Nano-bio Application Team, National Nanofab Center (NNFC), Daejeon 34141, Korea
***KAIST Institute for the NanoCentury (KINC), Korea Advanced Institute of Science and Technology, Daejeon 34141, Korea
(*Received 27 July 2022 • Revised 23 August 2022 • Accepted 28 August 2022*)

Abstract–Biofilm formation caused by the fouling of microorganisms is one of the major problems in biomedical devices, food industry, and marine transportation. Since the removal of adherent biofilm is not a trivial task, it is of paramount importance to contain the formation of the anti-biofilm film. Herein, a polysulfide-based anti-biofilm coating (PAC) equipped with full transparency, non-toxicity, and environmental stability was developed via a simple vapor-phase synthesis. The polymer coating consists of polysulfide chain grafted onto poly (1,3,5,7-tetramethyl-1,3,5,7-tetravinyl cyclotetrasiloxane) (pV4D4) layer via thiol-ene click reaction, which was accomplished via a sequential deposition of each polymer followed by UV irradiation. The pV4D4 served as an adhesion promoter layer that substantially enhanced the interfacial adhesion between polysulfide layer and various substrate materials. The polysulfide layer exhibits a long-lasting anti-biofilm performance against pathogenic bacteria, such as *Escherichia coli: O157* and *Staphylococcus aureus*. The excellent anti-biofilm property is attributed to slippery surface derived from the non-adherent, dynamic characteristics of the polysulfide (-S-S-) chain. The anti-biofilm coating indeed shows outstanding durability and robustness when exposed to extreme pH, organic solvents, and mechanical stresses. The fully transparent, robust coating developed in this study is a promising candidate material for a broad range of anti-biofilm applications.

Keywords: Biofilm, Anti-biofilm Coating, Polysulfide, Slippery Surface, Initiated Chemical Vapor Deposition (iCVD)

INTRODUCTION

It is well recognized that microorganisms can attach to many arbitrary surfaces to form multicellular communities, called biofilms [1]. Most synthetic surfaces are quite vulnerable to microbial adhesion and biofilm formation, which often causes serious problems, such as surgical site infection [2], food poisoning [3], and increase of marine transport cost [4]. Since the biofilm is embedded in a resilient, chemical-resistant external matrix, called extracellular polymeric substances (EPS), removal of adherent biofilm is extremely challenging and labor-intensive [5]. Thus, instead of developing a removal method of biofilm, blocking the biofilm formation in early stage, or preventing the initial adhesion of microorganism becomes critically important [6]. Initially, the release of biocidal compounds was developed to eradicate the attachment of the microorganisms to the surface by killing or degrading them [7]. However, these strategies showed only short-period effect due to limited loading capacity, and have been restricted due to the potential environmental contamination by the release of toxic compounds [8].

A recent anti-biofilm strategy is to modulate the surface properties of the target substrates, such as topography, architecture, and surface chemical functionality, especially using polymer brushes [9], due to cost-effectiveness, non-toxicity, and their ability to form a thin coating to impart new surface properties [10]. Hydrophilic polymers such as polyethylene glycol (PEG) [11], polysaccharides [12], and zwitterionic polymers [13] are known to form a tightly bound hydration layer near the polymer brushes. Since the dehydration process by adhering fouling materials is thermodynamically unfavorable on the hydrated surface, hydrophilic polymer brushes are quite repulsive to the approach of foulants [14]. However, it has several limitations relating to long-term effectiveness and mechanical/chemical stability, which hamper the practical application of hydrophilic anti-biofilm coatings [15].

In case of hydrophobic polymer brushes, adsorption energy between foulants and surfaces is generally low; thus, foulants can be released easily by external stresses [16]. For the prevention of microbial adhesion, fouling-release strategies are widely accepted in which the foulant can be washed out through external stresses. Recently, robust superhydrophobic surfaces with complex surface structure have emerged as a potential solution for anti-biofilm surfaces [17]. However, realization of materials that persistently resist bacterial adhesion is not trivial to achieve by surface chemistry or surface structuring alone, because the nonspecific adsorption of proteins and surfactants secreted by bacteria often shields the underlying chemical functionality and thus loses anti-fouling performance [18]. Additionally, any defects in the surface chemistry could serve as nucleation sites for bacterial attachment. Especially, structured super-

†To whom correspondence should be addressed.
E-mail: ejung0608@kaist.ac.kr, sgim@kaist.ac.kr
‡Co-first authors.

논문실적 8

Molecular Therapy
Nucleic Acids
Original Article

Mitochondrial double-stranded RNAs as a pivotal mediator in the pathogenesis of Sjögren's syndrome

Jimin Yoon,[1,14] Minseok Lee,[1,14] Ahsan Ausaf Ali,[1] Ye Rim Oh,[2] Yong Seok Choi,[2] Sujin Kim,[1] Namseok Lee,[1] Se Gwang Jang,[3] Seonghyeon Park,[1] Jin-Haeng Chung,[4] Seung-Ki Kwok,[5] Joon Young Hyon,[6] Seunghee Cha,[7] Yun Jong Lee,[8,9] Sung Gap Im,[1,10] and Yoosik Kim[1,11,12,13]

[1]Department of Chemical and Biomolecular Engineering, Korea Advanced Institute of Science and Technology (KAIST), Daejeon 34141, Republic of Korea; [2]Medical Science Research Institute, Seoul National University Bundang Hospital, Seongnam 13620, Republic of Korea; [3]The Rheumatism Research Center, Catholic Research Institute of Medical Science, College of Medicine, The Catholic University of Korea, Seoul 06591, Republic of Korea; [4]Department of Pathology, Seoul National University College of Medicine, Seoul 03080, Republic of Korea; [5]Division of Rheumatology, Department of Internal Medicine, Seoul St. Mary's Hospital, College of Medicine, The Catholic University of Korea, Seoul 06591, Republic of Korea; [6]Department of Ophthalmology, Seoul National University Bundang Hospital, Seongnam 13620, Republic of Korea; [7]Department of Oral and Maxillofacial Diagnostic Sciences, University of Florida College of Dentistry, Gainesville, FL 32610, USA; [8]Division of Rheumatology, Department of Internal Medicine, Seoul National University Bundang Hospital, Seongnam 13620, Republic of Korea; [9]Department of Internal Medicine, Department of Internal Medicine, Seoul National University College of Medicine, Seoul 03080, Republic of Korea; [10]KAIST Institute for NanoCentury (KINC), KAIST, Daejeon 34141, Republic of Korea; [11]KAIST Institute for Health Science and Technology (KIHST), KAIST, Daejeon 34141, Republic of Korea; [12]KAIST Institute for BioCentury (KIB), KAIST, Daejeon, 34141, Republic of Korea; [13]BioProcess Engineering Research Center and BioInformatics Research Center, KAIST, Daejeon, 34141, Republic of Korea

Sjögren's syndrome (SS) is a systemic autoimmune disease that targets the exocrine glands, resulting in impaired saliva and tear secretion. To date, type I interferons (I-IFNs) are increasingly recognized as pivotal mediators in SS, but their endogenous drivers have not been elucidated. Here, we investigate the role of mitochondrial double-stranded RNAs (mt-dsRNAs) in regulating I-IFNs and other glandular phenotypes of SS. We find that mt-dsRNAs are elevated in the saliva and tears of SS patients (n = 73 for saliva and n = 16 for tears) and in salivary glands of non-obese diabetic mice with salivary dysfunction. Using the in-house-developed 3D culture of immortalized human salivary gland cells, we show that stimulation by exogenous dsRNAs increase mt-dsRNAs, activate the innate immune system, trigger I-IFNs, and promote glandular phenotypes. These responses are mediated via the Janus kinase 1 (JAK1)/signal transducer and activator of transcription (STAT) pathway. Indeed, a small chemical inhibitor of JAK1 attenuates mtRNA elevation and immune activation. We further show that muscarinic receptor ligand acetylcholine ameliorates autoimmune characteristics by preventing mt-dsRNA-mediated immune activation. Last, direct suppression of mt-dsRNAs reverses the glandular phenotypes of SS. Altogether, our study underscores the significance of mt-dsRNA upregulation in the pathogenesis of SS and suggests mt-dsRNAs as propagators of a pseudo-viral signal in the SS target tissue.

INTRODUCTION

Sjögren's syndrome (SS) is a chronic disorder characterized by lymphocytic infiltration in the exocrine glands and B cell hyperactivity with autoantibody production, resulting in oral and eye dryness. Similar to most autoimmune disorders, the etiology of SS is not yet fully understood. It can be challenging to diagnose patients with SS due to the heterogeneity of disease manifestations and the lack of disease-specific biomarkers for the condition.[1,2] A delay in timely diagnosis and intervention can adversely affect patients' quality of life due to severe hyposalivation, glandular B cell lymphoma, and/or extraglandular organ involvement.[3]

One of the most notable features of SS is the type I interferon (I-IFN) signature in the minor salivary gland lip biopsy specimens, CD14+ blood monocytes, plasmacytoid dendritic cells, and peripheral blood mononuclear cells.[4] I-IFNs, which are critical molecules in host defense against viral infections, can be produced in response to the stimulation of pattern recognition receptors (PRRs). In particular, toll-like receptors (TLRs), protein kinase R (PKR), and melanoma differentiation-associated gene 5 (MDA5) are known to be stimulated by double-stranded RNAs (dsRNAs) originating from the viral genome.[5]

Received 12 May 2022; accepted 23 September 2022;
https://doi.org/10.1016/j.omtn.2022.09.020.

[14]These authors contributed equally

Correspondence: Yoosik Kim, KAIST Institute for Health Science and Technology (KIHST), KAIST, Daejeon 34141, Republic of Korea.
E-mail: ysyoosik@kaist.ac.kr
Correspondence: Seunghee Cha, Department of Oral and Maxillofacial Diagnostic Sciences, University of Florida College of Dentistry, Gainesville, FL 32610, USA.
E-mail: scha@dental.ufl.edu
Correspondence: Yun Jong Lee, Division of Rheumatology, Department of Internal Medicine, Seoul National University Bundang Hospital, Seongnam 13620, Republic of Korea.
E-mail: yn35@snu.ac.kr
Correspondence: Sung Gap Im, Department of Chemical and Biomolecular Engineering, Korea Advanced Institute of Science and Technology (KAIST), Daejeon 34141, Republic of Korea.
E-mail: sgim@kaist.ac.kr

논문실적 9

RESEARCH ARTICLE

ADVANCED FUNCTIONAL MATERIALS
www.afm-journal.de

Synthesis of a Stretchable Polyampholyte Hydrophilic Film with Compositional Gradient for Long-Term Stable, Substrate-Independent Fouling-Resistant Coating

Hogi Kim, Younseong Song, Seonghyeon Park, Youson Kim, Hyeonwoo Mun, Jueun Kim, Seongeun Kim, Kyung G. Lee, and Sung Gap Im**

The prevention of nonspecific biofouling is crucial for technological development in biomaterials and medical devices. Thus, zwitterionic materials have attracted significant attention due to their effective fouling-resistance, long-term durability against oxidation, and biocompatibility. However, fabricating a substrate-independent zwitterionic surface with outstanding fouling-resistance remains a challenge. In this study, a polyampholyte coating that satisfies the aforementioned requirements is obtained using a vapor-phase method. The polyampholyte coating consists of a bilayer of poly(1,3,5,7-tetramethyl-1,3,5,7-tetravinyl cyclotetrasiloxane) (pV4D4) and polyampholyte, poly(2-carboxyethyl acrylate-co-2-(dimethylamino)ethyl acrylate) (pCD), stacked with compositional gradient, which are obtained via sequential deposition using initiated chemical vapor deposition. The heavily crosslinked pV4D4 acts as an adhesion promoter layer that may be applied conformally to various substrate materials with high interfacial adhesion. The pCD surface exhibits a long-lasting, superior fouling-resistance to proteins (20.3 ± 1.8 ng cm^{-2} for undiluted human serum) and microorganisms. The pCD-grad-pV4D4 films, coupled with the stress-dissipative gradient interface, are highly stretchable up to 50% without compromising the fouling-resistance. The fouling-resistance is maintained after 1 day of sonication, 10 days of water flushing, and 30 days of water shearing. Further, the pCD-grad-pV4D4 films are fully transparent and patternable, making them a prospective alternative for future non-fouling biomedical applications.

1. Introduction

Nonspecific adsorption of biological substances on arbitrary surfaces is a prevalent phenomenon that may cause several severe issues in biomedical device applications. For example, biomaterials can be covered by host proteins, which can result in a cascade foreign body reaction and subsequent malfunctions.[1] Medical devices and implants are also susceptible to microbial adhesion, which can result in the formation of infectious, antibiotic-resistant biofilm.[2] Thus, tremendous efforts have gone into developing effective antifouling strategies, particularly synthetic polymer-based antifouling surfaces that are nontoxic and versatile in function.[3] Particularly, surface modification with hydrophilic polymer brushes is a renowned strategy for creating fouling-resistance, where water molecules bound to the hydrophilic surface can generate steric repulsion, forming physical and energetic barriers against nonspecific adsorption.[4,5] Various synthetic surfaces with hydrophilic polymers, such as poly(ethylene glycol) (PEG),[6] poly(2-hydroxypropyl methacrylamide) (pHPMA),[7] and zwitterionic polymers (polybetains and polyampholytes),[8] have proven to significantly suppress nonspecific fouling and are widely used for fouling-resistant surfaces. Particularly, zwitterionic materials are seen as highly promising in terms of superior fouling-resistance, oxidation stability, and biocompatibility.[9] However, surface modification with zwitterionic polymers is difficult to achieve since many zwitterionic polymers are water-soluble, preventing their application in an aqueous environment.[10] Thus, achieving excellent fouling-resistance and substrate-independent durability from zwitterionic polymers is crucial. Significant efforts have been made toward imparting fouling-resistant characteristics to a target surface while maintaining environmental stability. For

H. Kim, Y. Song, S. Park, Y. Kim, H. Mun, S. Kim, S. G. Im
Department of Chemical and Biomolecular Engineering
Korea Advanced Institute of Science and Technology
Daejeon 34141, Republic of Korea
E-mail: sgim@kaist.ac.kr

The ORCID identification number(s) for the author(s) of this article can be found under https://doi.org/10.1002/adfm.202113253.

DOI: 10.1002/adfm.202113253

J. Kim, K. G. Lee
Nano-bio Application Team
National Nanofab Center (NNFC)
Daejeon 34141, Republic of Korea
E-mail: kglee@nnfc.re.kr, kglee003@gmail.com
S. G. Im
KAIST Institute for the NanoCentury (KINC)
Korea Advanced Institute of Science and Technology
Daejeon 34141, Republic of Korea

논문실적 10

RESEARCH ARTICLE

NANO · MICRO small
www.small-journal.com

Engineering of Surface Energy of Cell-Culture Platform to Enhance the Growth and Differentiation of Dendritic Cells via Vapor-Phase Synthesized Functional Polymer Films

Minseok Lee, Dongmin Chun, Seonghyeon Park, Goro Choi, Yesol Kim, Suk-Jo Kang, and Sung Gap Im**

Although the dendritic cell (DC)-based modulation of immune responses has emerged as a promising therapeutic strategy for tumors, infections, and autoimmune diseases, basic research and therapeutic applications of DCs are hampered by expensive growth factors and sophisticated culture procedures. Furthermore, the platform to drive the differentiation of a certain DC subset without any additional biochemical manipulations has not yet been developed. Here, five types of polymer films with different hydrophobicity via an initiated chemical vapor deposition (iCVD) process to modulate the interactions related to cell–substrate adhesion are introduced. Especially, poly(cyclohexyl methacrylate) (pCHMA) substantially enhances the expansion and differentiation of conventional type 1 DCs (cDC1s), the prime DC subset for antigen cross-presentation, and $CD8^+$ T cell activation, by 4.8-fold compared to the conventional protocol. The cDC1s generated from the pCHMA-coated plates retain the bona fide DC functions including the expression of co-stimulatory molecules, cytokine secretion, antigen uptake and processing, T cell activation, and induction of antitumor immune responses. To the authors' knowledge, this is the first report highlighting that the modulation of surface hydrophobicity of the culture plate can be an incisive approach to construct an advanced DC culture platform with high efficiency, which potentially facilitates basic research and the development of immunotherapy employing DCs.

1. Introduction

In recent decades, dendritic cell (DC)-based vaccines served as a promising therapeutic approach to induce an antitumor immune response.[1] DCs act as translators between the innate and adaptive immunity by sensing infection or tissue damage, and processing and presenting antigens to generate T cell immunity.[2] They also secrete multiple cytokines to regulate immune processes such as the differentiation, expansion, and activation of T cells.[3] More than 300 clinical trials involving DCs have been conducted to evaluate its applicability as therapeutics for strengthening immunity against tumor viruses, and cytotoxic vaccines and numerous efforts to develop better DC-based vaccines are currently under progress.[4] However, DC culture is still considered quite challenging because the considerable labor force incurred during the isolation process from bone marrow, and current DC culture methods require long culture periods and particularly expensive growth factors.[1a,5] Therefore, the development of advanced protocols that can effectively and economically generate large numbers of DCs is still in high demand, and its value is expected to increase as DC-based antitumor therapeutics are developed.

Based on lineage ontology, DCs are divided into multiple subsets: two types of classical DCs (cDC1 and cDC2), plasmacytoid DCs (pDC), and monocyte-derived DCs (moDC).[6] cDCs have superior ability to present antigens and activate T cells, compared to moDCs and pDCs, and cDC1s are better equipped with the ability to cross-present exogenous antigens to $CD8^+$ T cell and produce interleukin-12 (IL-12) which is required to control the intracellular pathogens and tumor.[7] To generate DCs in vitro, bone-marrow cells or blood mononuclear cells are cultured with granulocyte-macrophage colony-stimulating factor (GM-CSF) and interleukin-4 (IL-4) or fms-like tyrosine kinase 3 ligand (Flt3L).[8] Flt3L-generated DCs are distinct from GM-CSF/IL-4-generated DCs in the types of DC

M. Lee, S. Park, G. Choi, Y. Kim, S. G. Im
Department of Chemical and Biomolecular Engineering
Korea Advanced Institute of Science and Technology
Daejeon 34141, Republic of Korea
E-mail: sgim@kaist.ac.kr
D. Chun, S.-J. Kang
Department of Biological Sciences
Korea Advanced Institute of Science and Technology
Daejeon 34141, Republic of Korea
E-mail: suk-jo.kang@kaist.ac.kr
S. G. Im
KAIST Institute For NanoCentury (KINC)
Korea Advanced Institute of Science and Technology
Daejeon 34141, Republic of Korea
The ORCID identification number(s) for the author(s) of this article can be found under https://doi.org/10.1002/smll.202106648.

DOI: 10.1002/smll.202106648

논문실적 11

Biotechnology and Bioprocess Engineering 26: 165-178 (2021)
DOI 10.1007/s12257-020-0269-1

pISSN 1226-8372
eISSN 1976-3816

INVITED REVIEW

A Versatile Surface Modification Method via Vapor-phase Deposited Functional Polymer Films for Biomedical Device Applications

Younghak Cho, Minseok Lee, Seonghyeon Park, Yesol Kim, Eunjung Lee, and Sung Gap Im

Received: 21 August 2020 / Revised: 5 October 2020 / Accepted: 8 October 2020

Abstract For last two decades, the demand for precisely engineered three-dimensional structures has increased continuously for the developments of biomaterials. With the recent advances in micro- and nano-fabrication techniques, various devices with complex surface geometries have been devised and produced in the pharmaceutical and medical fields for various biomedical applications including drug delivery and biosensors. These advanced biomaterials have been designed to mimic the natural environments of tissues more closely and to enhance the performance for their corresponding biomedical applications. One of the important aspects in the rational design of biomaterials is how to configure the surface of the biomedical devices for better control of the chemical and physical properties of the bioactive surfaces without compromising their bulk characteristics. In this viewpoint, it of critical importance to secure a versatile method to modify the surface of various biomedical devices. Recently, a vapor phase method, termed initiated chemical vapor deposition (iCVD) has emerged as damage-free method highly beneficial for the conformal deposition of various functional polymer films onto many kinds of micro- and nano-structured surfaces without restrictions on the substrate material or geometry, which is not trivial to achieve by conventional solution-based surface functionalization methods. With proper structural design, the functional polymer thin film via iCVD can impart required functionality to the biomaterial surfaces while maintaining the fine structure thereon. We believe the iCVD technique can be not only a valuable approach towards fundamental cell-material studies, but also of great importance as a platform technology to extend to other prospective biomaterial designs and material interface modifications for biomedical applications.

Keywords: initiated chemical vapor deposition (iCVD), surface modification, non-flat surfaces, biomedical applications

Younghak Cho[†], Minseok Lee[†], Seonghyeon Park, Yesol Kim, Eunjung Lee[*], Sung Gap Im[*]
Department of Chemical and Biomolecular Engineering, Korea Advanced of Institute of Science and Technology, Daejeon 34141, Korea
Tel: +82-42-350-3976; Fax: +82-42-350-3910
E-mail: ejung0608@kaist.ac.kr
Tel: +82-42-350-3936; Fax: +82-42-350-3910
E-mail: sgim@kaist.ac.kr

[†]These authors contributed equally.

1. Introduction

Great progress has been made in the field of biomedical applications with advance in novel biomaterials [1-4]. However, most conventional materials such as metals, polymers, hydrogels, carbons, and composites do not always meet the demands required for biomaterials in both their surface and bulk properties. Therefore, a myriad of surface modification methods have been applied to the materials for providing a proper chemical and physical properties such as biocompatibilities, surface functionalities, and mechanical strength in the field of tissue engineering, regenerative medicine, and biomedical devices [5-9]. Since the surface characteristics such as topographic and geometric features can regulate the cellular response, researchers in this area continuously attempted to create scaffolds with specific surface functionalities via surface modification, which can offer several advantages compared to flat surface including cell adhesion and cell fate decision [10-14]. The surface of medical devices also has been modified to provide additional functionalities such as sensing, diagnosis, or treatment [15-18].

For the recapitulation of cellular microenvironments, a