



Programmable Nanopatterned Platforms for Autonomous Stem Cell Differentiation



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Abstract

During early development, stem cells interpret a sequence of precisely timed biochemical cues that drive lineage specification. Reproducing such temporal regulation in vitro remains challenging, as conventional differentiation protocols depend heavily on repeated factor dosing and manual control of timing. Here, we introduce a programmable hybrid nanopatterned platform that autonomously initiates neural differentiation of stem cells through stimulus-responsive release of instructive molecules. The system integrates nanostructured arrays with functional nanoparticles to generate spatially confined, temporally tunable microenvironments at the cell-material interface. Upon external activation, these microenvironments undergo dynamic modulation, resulting in stepwise engagement of neurogenic signalling pathways. This built-in spatiotemporal control yields highly reproducible differentiation outcomes without the need for repeated media exchanges or additional biochemical supplements. The resulting neural stem-like cells display uniform morphology and characteristic lineage markers, demonstrating the feasibility of on-demand, autonomously guided differentiation. Overall, this material-driven strategy streamlines stem-cell culture workflows and offers a versatile platform for probing neural development and advancing organoid-based model construction.

Biography

Dr. Tae-Hyung Kim is a Professor in the Department of Biomedical Engineering at Sungkyunkwan University (SKKU) in Korea. He received both his B.S. and Ph.D. degrees in Chemical and Biomolecular Engineering from Sogang University, and completed his postdoctoral training at Rutgers University in the United States. He began his independent career at Chung-Ang University, where he served as Assistant and Associate Professor in the School of Integrative Engineering from 2015 to 2024, before joining SKKU in 2024. Professor Kim's research focuses on nanobio-hybrid platforms integrating nanoporous materials, and electrochemical biosensing platforms for real-time monitoring of cellular metabolism and stem-cell differentiation. He has published over 130 SCI-indexed papers in leading journals such as Nature Communications, Science Advances, Advanced Materials and Advanced Functional Materials, with more than 5,200 citations and an h-index 43. Recognized among the world's top 2% scientists by Stanford University and Elsevier in 2024, he also serves as Managing Editor of Nano Convergence and actively collaborates with global leaders in bioelectronics, nanomaterials, and regenerative medicine.

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