Multi-Modal Nanofabrication of Bioactive Interfaces for Spatial and Magnetomechanical Control of Cell Fate

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Advanced in-vitro models require nanofabrication tools capable of mimicking the complex nanoscale features of the cellular microenvironment.[1] In this contribution, we present two complementary methods for controlling cellular behavior through physical and mechanical cues.

This work presents a hybrid nanofabrication strategy that integrates Two-Photon Lithography (TPL) with Scanning Probe Lithography (SPL) to create ad-hoc microenvironments with nanoscale biochemical precision (Figure 1a). Using this platform, we demonstrate the selective anchoring of fibroblasts onto functionalized 3D microscaffolds, providing a robust method for programming cellular fate through precise spatial organization.[2]

Parallel to topographic control, we investigate cellular modulation via remote mechanosensation. We developed a magnetostrictive substrate by combining the self-assembly of polystyrene nanoparticles with Physical Vapour Deposition (PVD) of Terfenol-D. This allows for the remote induction of nanoscale mechanical vibrations in human astrocytes via an external alternating magnetic field (Figure 1b). Our results indicate that remote magnetomechanical actuation significantly enhances cell confluence and network formation.[3]

Together, these dual fabrication approaches offer a sophisticated toolkit for studying fundamental biological questions and engineering robust, functional cellular architectures.

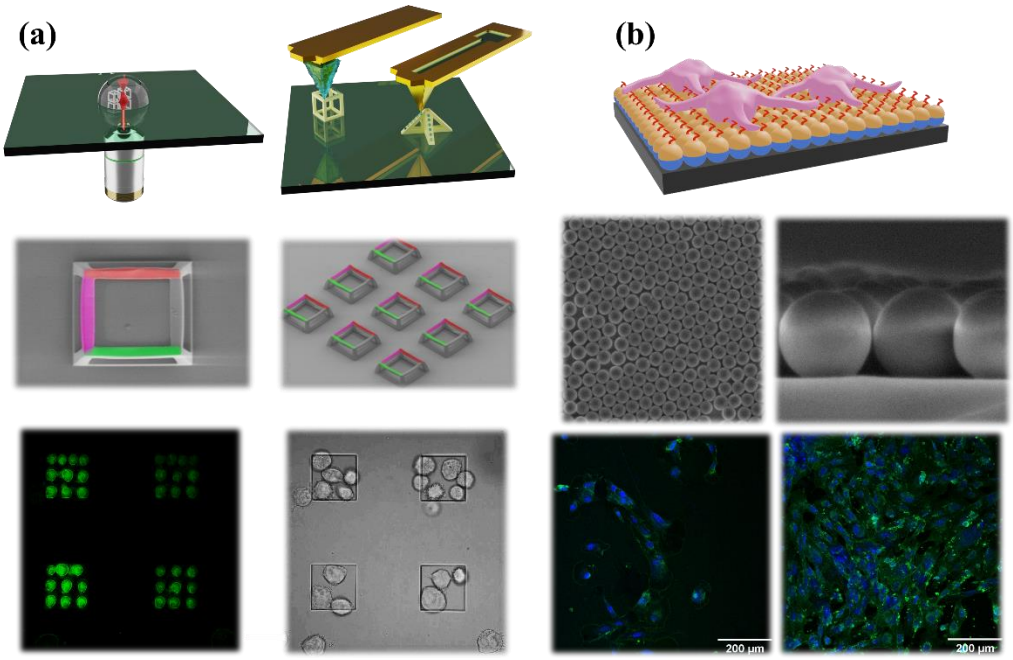

Figure 1. (a) Integration of Two-Photon and Scanning Probe Lithography for 3D scaffold functionalization. Polymeric microstructures are selectively coated with distinct lipid inks. Fibronectin micropatterns on square scaffolds facilitating site-specific fibroblast anchoring. (b) Schematic of the magnetostrictive nanoparticle interface for remote cell stimulation. Scanning Electron Microscopy (SEM) reveals the nanoparticle morphology, while fluorescence micrographs demonstrate increased astrocyte confluence following magnetomechanical actuation.

[1] J. L. Young, A. W. Holle, and J. P. Spatz, Exp. Cell Res. **343**, 3 (2016).

[2] G. Mathew, E. D. Lemma, D. Fontana, C. Zhong, A. Rainer, S. Sekula-Neuner, J. Aghassi-Hagmann, M. Hirtz, and E. Berganza, Small **20**, 2307223 (2024).

[3] J. A. L. Solaiman, A. Cruz, C. Tavares, L. Martinez, A., Y. Huttle, Asenjo, and E. Berganza (2025), (in preparation).