Electrochemical Redox Modulation on Conductive Nanocomposites for Rapid and Enzyme-Free Release of Adherent Cells

Wang Hee Lee
Massachusetts Institute of Technology, Cambridge, Massachusetts

Kripa K. Varanasi
Massachusetts Institute of Technology, Cambridge, Massachusetts

Abstract

Efficient harvesting of anchorage-dependent cells is essential for biomedical production, yet conventional methods relying on enzymatic digestion or mechanical scraping can compromise cell integrity, induce stress responses, and limit scalability. We present a non-enzymatic, electrically driven approach for controlled cell release using alternating electrochemical redox modulation on a conductive polymer–based nanocomposite surface. This method leverages periodic redox transitions to generate transient ionic fluxes that weaken cell–substrate adhesion, enabling detachment without damaging viability. Using MG63 osteoblast-like cells as a model, optimal cycling at low frequency achieved >90% cell release within minutes while preserving proliferation capacity. These results demonstrate a sustainable and automation-compatible alternative to conventional dissociation techniques, with potential to streamline regenerative medicine and large-scale cell manufacturing.

Keywords

Electrochemical modulation, non-enzymatic cell release, conductive nanocomposites, automated bioprocessing, cell harvesting technology