Polymer-derived carbon surfaces for enhancing stem cell differentiation

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Parkinson’s disease

DOPAMINE

Corpus striatum
Frontal cortex

Normal Neuron
Neuron Affected by Parkinson’s

Normal Movement
Movement Disorders

Dopamine production or substitute the neurotransmitter

Dopamine cannot pass through the blood-brain barrier

Surgery is employed in extreme cases

Treatment
Surgical treatment

• Employed in advanced stages in patient non-responsive to medication
• FDA-approved for Parkinson’s in 2002
• The procedure blocks electric signals from target areas in the brain
• It does not stop the disease from progressing
Fabrication

Micropillars:
Φ = 1.4 µm, h = 11 µm

Nanopillars:
Φ = 200 nm, h = 650 nm
Before pyrolysis:
Diameter: 450 nm
Height: 1200 nm

Contact angle: 95° (before) and 0° after plasma treatment
Electrochemical characterisation

Redox probe: $\text{[Ru(NH}_3\text{)_6]Cl}_2 / \text{[Ru(NH}_3\text{)_6]Cl}_3$

$\Delta E_p$ also varies with $v$

Cells growing on C surfaces

Flat carbon - schematic

Pillars – schematic

SEM images of hVM1-Bcl-x(L) cells growing on carbon nanopillars
Immunostaining experiments

Cell line: hVM1-Bcl-x(L) (human ventral mesencephalic neural stem cell line 1) cultured in growth media (in the absence of differentiation factors)
Immunostaining: for tyrosine hydroxylase (TH) and nuclei
Both carbon surfaces lead to spontaneous stem cell differentiation with high yields (70-80% dopaminergic neurons)

Dopamine exocytosis

Representative current-time trace recorded during amperometric detection of dopamine upon K⁺-induced depolarization from a population of hVM1-Bcl-x(L) under growing conditions (in the absence of differentiation factors): a: surface with no cells; b: cells grown on flat carbon; c: cells grown on carbon nanopillars.
Detection of dopamine

Calculated average charge related to the amount of detected dopamine released by cells grown without (no DF) and with (+ DF) differentiating conditions on flat carbon surfaces (flat) and carbon nanopillars (nanopillar) or micropillars (micropillar). Error bars represent the standard error of mean, n = 4 for the flat carbon surfaces and n = 7 for carbon pillars.

Surface area increase: 1.9x for micropillars and 1.01x for nanopillars – the surface area increase alone does not explain the large increase in measured currents.

Conclusions

✦ Carbon surfaces induce spontaneous stem cell differentiation into dopaminergic neurons
✦ They can be also employed as electrodes to measure dopamine exocytosis
✦ Detection of dopamine on nanopillars shows much higher currents than in the case of micropillars/flat carbon
✦ Currents are slightly higher in the presence of differentiation factors due to the slightly higher number of cells on the surface
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Thank you