Microelectrophoresis of Semiconductive Quantum Dots

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Abstract

Semiconductive quantum dots (QDs) with superior optical properties, have been used as unique fluorescent probes in biological sensing and labelling. The effective intracellular delivery of QDs is critical to those biological applications. Microelectrophoresis is a promising technique to precisely deliver monodispersed nanoparticles into target cells with negligible cell membrane damage and cell distortion. In addition, it can record the intracellular electrical activities of target cells at the same time. This thesis aims to achieve for the first time the intracellular delivery of QDs via microelectrophoresis technique.

Microelectrophoresis technique has been well established to eject charged substances from fine-tipped glass micropipettes into tissue and cells via electrical currents. However, few studies have paid any attention to exploring standard experimental protocols for the intracellular microelectrophoretic ejection of biocompatible nanoparticles. The success of microelectrophoresis is largely limited by the aggregation of nanoparticles and subsequent blockages in the tip of micropipettes during ejection, which is caused by the colloidal instability of nanoparticles when the attractive van der Waals forces between them prevail over the repulsive electrostatic forces. Thus, successful microelectrophoresis requires optimized suspensions with monodispersed nanoparticles within micropipettes to avoid blockage. To improve the delivery, the tip size, current magnitude and ejection duration should be screened in parallel for the optimal parameters.

To address the above-mentioned requirements, Chapter 2 provides an effective experimental protocol for the preparation of QDs suspensions for filling

micropipettes, which has balanced the stability of QDs against the electrolytic conductivity of suspensions. In Chapter 3, micropipettes have been designed and manufactured with suitable tip inner diameters (IDs) for the size distribution of QDs suspensions, which has been demonstrated in Chapter 4 via microinjection technique. Finally, in Chapter 5, QDs have been successfully ejected out of micropipettes via microelectrophoresis and observed under a fluorescence microscope. The success of microelectrophoresis technique in ejecting semiconductive QDs described in this thesis has paved the way for managing a variety of other biocompatible nanoparticles with proper surface functional groups in either intracellular or extracellular delivery for various biological research.

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Abbreviations and Symbols for Units

Ω	Ohm
µL	Microliter
µM	Micromole per litre
°C	Celsius degree
µm	Micrometre
0D	Zero dimensional
1D	One dimensional
2D	Two dimensional
3D	Three dimensional
A/D	Analog-to-digital
Ag	Silver
Ag^+	Silver ion
AgCl	Silver chloride
AR	Analytical reagent
AU/a.u.	Arbitrary units
CdSe	Cadmium selenide
Cl^-	Chloride ion
cm	Centimeter
Conc.	Concentration
cP	Centipoise
DLS	Dynamic light scattering
DNA	Deoxyribonucleic acid
DOS	Electronic density of the states
e^-	Electron
EDTA	Ethylenediaminetetraacetic acid
eV	Electronvolt

FESEM	Field emission scanning electron microscope
H^+	Hydrogen ion
HCl	Hydrochloric acid
Hz	Hertz
ID	Inner diameter
IS	Ionic strength
K^+	Potassium ion
KCl	Potassium chloride
kHz	Kilohertz
LCD	Liquid crystal display
M	Mole per liter
MΩ	Megaohm
mL	Millilitre
mm	Millimeter
mM	Millimole per litre
ms	Millisecond
mV	Millivolt
mW	Milliwatt
nA	Nanoampere
Na^+	Sodium ion
NaCl	Sodium chloride
NaOH	Sodium hydroxide
NCs	Nanocrystals
nm	Nanometer
nM	Nanomole per litre
OD	Outer diameter
OH^-	Hydroxide ion
PCS	Photon correlation spectroscopy
PEG	Polyethylene glycol

pH	Potential of hydrogen
pKa	Acid dissociation constant
PL	Photoluminescence
QDs	Quantum dots
rad	Radian
RDB	Rhodamine b
rpm	Revolutions per minute
S	Sulfur
s	Second
SD	Standard deviation
SEM	Scanning electron microscope
STMD	Small target motion detector
TAE	Tris-acetate-EDTA
TEM	Transmission electron microscope
TiO_2	Titanium dioxide
UV	Ultraviolet
V	Volt
W	Watt
ZnS	Zinc sulfide