





Hes∙so

Haute Ecole Spécialisée de Suisse occidentale

Fachhochschule Westschweiz

University of Applied Sciences and Arts Western Switzerland

Nanotechnologies used in NANOCI

Nanotechnology-based implantable and interfaceable devices

Alexandra Kämpfer-Homsy, Edith Laux, Laure Jeandupeux, Julien Brossard, Loïc Piervittori, François Feuvrier, Harry Withlow, Oksana Banakh, *Herbert Keppner*

Partnership









UPPSALA UNIVERSITET







Hes·so

Haute Ecole Spécialisée de Suisse occidentale

Fachhochschule Westschweiz

University of Applied Sciences and Arts Western Switzerland

b UNIVERSITÄT BERN

Pascal Senn









Outline

- Summary of the challenges
- Selected technologies drug dispensing: SOLID on Liquid deposition. surface conditioning: Deposition of nanoparticles by sonochemistry
 Conclusion and outlook.

Summary of the challenges



Development of a cochlear implant



Summary of the challenges



Essential elements for neuronal interfacing:

- Attraction of neuron-growth towards electrodes via selectively operating delivery of growth factors.
- Creation of a neuron-electrode junction allowing signal transmission.





Growth Factor (GF) emitting device (vision)



Solid on liquid deposition

Finding a solution: short walk in the garden:



Solid on liquid?

More and others



Natural SOLID systems seems to be either thermally, mechanically or chemically unstable



First "archaic" approach for obtaining better stability

Mercury has a high density; paint spray come from the gas phase and polymerises on the surface of a Mercury droplet.



SOLID (Solid on liquid deposition): Coating of liquids and hermetical sealing using CVD Parylene.



H. Keppner, M. Benkhaira, Patent WO/2006/06395, Dec. 2004. J. Charmet et al. Thin Solid Films 518 (2010) 5061-5065



Monolayer of Parylène







Later: mechanically stable coating



LPCVD deposition of Parylene (Poly-Chloro-Para Xylylene) :



W.F. Gorham, J. Poly, Sci., Part A-1: Polym. Chem. 4 (1966) 3027





SEM micrograph from a Butterfly wing a) uncoated, b) Parylene coated D.W. Grattan; *Can. Chem. News* **1989**, 25

Parylene layers are highly biocompatible

Why SOLID-technology may be considered as nanotechnology:





J. Charmet, H. Haquette, E. Laux, G. Gorodyska, M. Textor, G. Spinola Durante, E. Portuondo-Campa, H. Knapp, R. Bitterli, W. Noell, and H. Keppner. Liquid as template for next generation MEMS. J. Phys.: Conf. Ser., 182:012021, 2009. ¹⁴

Controlled release of growth factors (GF)* from a localized well

*e.g. such as brain-derived neurotrophic factor (BDNF)





Cases study



GF-gradient can be for a long time

GF-gradient can not be maintained

Design requirements:

The gradient of growth factors (GF) in the matrix (M) must be maintained during 4 days across 1-2 mm in order to allow oriented grow of the neuron cells toward the implant prior to be attached with the contact-pad.

After the choice of M and GF the diffusion constant $D_{GF}(M)$ and the mobility $\mu_{AGF}(M)$ of GF in M will be determined (dependence on the molecular size of GF, the pore size, and diffusion coefficient of GF in M.

Fluorescence microscope Micrograph observing the spatially resolved intensity of light emitted by the Fluorescein molecules



Results

A 25 mmol/l fluorescein in glycerol solution diffuses through a single 50 μm opening



With a diffusion constant of 1.48·10⁻⁵ mol /I·s·m and creates a gradient of concentration of 2.75 mol /I·m

Conclusion: the observed system could be potentially be used if fluorescein would be replaced by DHF



2) Deposition of nanoparticles by sonochemistry



Pioneer input from A. Gedanken / Bar ilan University



Nanoparticles in liquids are interacting with a high frequency acoustic field (20 kHz 3 kW)



principle of sonochemistry



Sound = pressure waves = periodic compression / expansion- cycles traveling through a medium possessing elastic properties (gas, liquid, solid)



Acoustic Cavitation = creation, growth, and implosive collapse of bubbles in a liquid



Distance from sonotrode

Ref. Jiri Pinkas Department of Chemistry Masaryk University Brno Czech Republic



Further considerations: Acoustic pressure



$$P_A = \sqrt{2I\rho c}$$

 P_A = driving pressure amplitude [Pa]; I = irradiation intensity [W m⁻²] (500 W system - 1.3 105 W m⁻²); ρ = liquid density [kg m⁻³] c = sound velocity in liquid [m ^{s-1}] (Water 1482 m s⁻¹) P_A = 620 700 Pa = 6.2 bar

Acoustic Cavitation

Bubbles collapse = spherically symmetrical implosion,

shear forces, adiabatic compression, life time 1-2 μs

Hot spot = end of the collapse temperature of the gas inside bubble 5000–20 000°C (for 1 ns) surrounding liquid layer 2000 °C pressure 500 –1500 bar Extreme cooling rates 10¹⁰Ks-¹







Summary: Sonochemical reactions



- Chemical changes / reactions induced by ultrasound
- No direct interaction of ultrasound fields with molecules (in contrast to photons, heat, electro-magnetic fields)
- Liquid phase reactions driven by cavitation effects, radical generation, bond- breaking
- Solid state reactions introduction of defects
- Extreme acceleration of nanoparticles in the imploding bubble (shockwave-induced nano-particle implantation)
- Isotropic implantation in complex objects form all sides; hence cylindrical objects and tissues can be homogeneously be treated.

Implantation of ZnO, MgF₂ nanoparticles using sonochemistry







24



Biofilm biomass formation resulted after 24 hours of treatment with pure glass slides, glass slides coated solely with Parylene and glass slides coated with Parylene and ZnO nanoparticles. No leaching of nanoparticles was observed at long term.

Gedanken, A. Using Sonochemistry for the Fabrication of Nanomaterials. *Ultrason. Sonochem.* 2004, 11, 47-55.

Summary and Conclusion



Solid on liquid deposition is a platform technology allowing integrating liquids as functional "layer" in microsystems

Sonochemistry is a method allowing isotropic implantation of nanoparticles into all kind of surfaces such as metals, ceramics and even textiles.

Acknowledgement

The project NANOCI is funded within the 7th EC framework programme in NMP.2011.1.4-4, Grant agreement no: 281056