Non equilibrium plasma processes for biomedical applications and nanotechnology

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Ravello, December 5-7, 2002
kick off meeting
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On a grant
G. Iacoviello, V. Bonasia,
R. Di Mundo, L. Iacobelli

5 undg students

Secretariat
Grazia RETTO
Roberta GIORDANO
OUR GROUP
Biomedical applications of plasmas

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Dr. Marco Morra (NobilBio Ricerche) consultant for NANOBIO Firb
PLASMA PROCESSES

PE-CVD deposition of thin films
organic-inorganic

TREATMENTS grafting of groups, crosslinking

DRY ETCHING ablation of materials

PARALLEL PLATE PLASMA REACTOR

RF generator 13.56 MHz
optical window (spectroscopy)
gas inlet
pressure gauge 50 - 1000 mTorr
pump
Understanding relationships between
plasma chemistry (emission spectroscopy)
surface chemistry (surface analysis)
and surface properties
for industrial applications
REACTORS AVAILABLE IN MANY CONFIGURATIONS

parallel plate, triode, roll to roll, powders, small tubes, ...

REACTOR ENGINEERING
OES

Plasma treatments inside small caliber tubes (catheters, VGs, ... )
NOBIL BIO RICERCHE
Dr. Marco Morra, Dr. Clara Cassinelli

SURFACE MODIFICATION
AND SURFACE CHARACTERIZATION
OF BIOMEDICAL MATERIALS AND DEVICES

NOBIL BIO RICERCHE is an independent company that provides contract services for the surface characterization and modification of biomedical devices and materials.

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e-mail: info@nobilbio.it

www.nobilbio.it
Nobil Bio Ricerche  

founded in 1993

A small, privately-owned company, operates in the field of biomedical devices and materials. The expertise includes study, characterization and modification of surface properties of medical devices and materials, and their chemico-physical and biological characterization. Nobil Bio Ricerche operates on a contract-service basis for a number of biomedical companies. Contract activities include:

- studies aimed to improve surface properties of existing devices or to develop new surface modification treatments.
- characterization of composition/properties of medical devices and materials
- custom surface treatments.

Typical works include surface modification of IOLs, prevention of post-surgical adhesion to surgical meshes, surface modification of blood filters, immunologic plates, coronary catheters and stents. The facilities include a chemico-physical lab equipped with SEM, AFM, different spectroscopies, and two plasma reactors ((micro-wave and radio-frequency) in a class 10,000 clean room. Biological tests are performed in a microbiological lab, that allows growth culture of mammalian and bacterial cells, and the study of their interactions with medical materials and devices.
“PRODUCTS” from UNIBA for the biomedical field

PE-CVD, Treatment, Etching processes
Continuous and modulated processes
Plasma and surface diagnostics
Plasma treatments of powders
Roll-to roll reactor
Plasma-reactor design

Hydrophilic-hydrophobic surfaces
Immobilization of biomolecules
Cell-adhesive surfaces
Cell-repulsive (non fouling) surfaces
Micro-patterning of polymers
Bacterial-resistant coatings
Nano-rough functional surfaces
Conformal thin coatings on nano-structures

Permanently wettable teflon
Plasma treatments inside small caliber tubes
Super-hydrophobic surfaces
Gas barrier coatings
Improving metal adhesion on polymers
Control of the hydrophobic recovery in plasma-treated polymers

Pre-treatments (e.g., H₂, Ar, …) may be utilized to cross-link the surface of the polymer before the grafting.
IMMOBILIZED HEPARINE FOR BLOOD-COMPATIBLE SURFACES

SAME APPROACH FOR PEPTIDES, ENZYMES, ANTIBODIES, …
PE-CVD - COOH functional coatings
PLASMA TREATMENT N-grafted polymer surfaces

cell growth covalent binding of molecules

KEY ISSUES
retention of monomer structure
low power, modulated discharges
process control
density of groups
adhesion to substrate
stability in water

NH₃

CH₂=CH-COOH
FINE CONTROL OF COMPOSITION
plasma deposited Acrylic Acid (pdAA) coatings
FROM MODULATED PLASMAS

Available also for monomers with –NH₂ and other groups

C3 component of pdAA films deposited at different Duty Cicles (3% ●; 5% □; 10% ♦; 20% △; 30% ×; 50% ▲; non modulated ○)
### TUNING CELL-ADHESION/SPREADING WITH -COOH (C3) SURFACE DENSITY OF pdAA COATINGS

(NCTC 2544 keratinocytes, 24 h of culture)

AA 3 sscm; Ar 20 sscm; 230 mtorr; 20 W

<table>
<thead>
<tr>
<th>C3%</th>
<th>Adhered cells on 0.8 mm²</th>
<th>Spread cells %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DC 3%</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3= 26±3%</td>
<td>43.0±5.5</td>
<td>60±2.2</td>
</tr>
<tr>
<td><strong>DC 20%</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3= 18±3%</td>
<td>33.0±7.5</td>
<td>39±5.7</td>
</tr>
<tr>
<td><strong>continuous plasma</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C3= 13±3%</td>
<td>32.0±5.8</td>
<td>9.6±0.8</td>
</tr>
</tbody>
</table>
PEO-like COATINGS
non fouling, hydrophilic, cell-repulsive

Feed glycols, crown ethers

$\text{CH}_3\text{O(}\text{CH}_2\text{CH}_2\text{O})_n\text{CH}_3$

Key Parameter
retention of the PEO structure in the coating

Process control
OES monitoring of CO emission

CELL REPULSIVE (non fouling) SURFACES

PEO $-(\text{CH}_2\text{CH}_2\text{O})_n-$

PEO-like
The images show the effect of different power levels (5W, 10W, 15W) on the binding energy (eV) and the percentage of adhered cells (C1). The data indicates that as the power increases from 5W to 15W, the percentage of adhered cells decreases from 81% to 41%. The binding energy distribution is also affected by the power, with the 15W condition showing a lower binding energy peak compared to the 5W and 10W conditions.

The images also illustrate the spread of cells at different magnifications (70µm) for each power level, showing the repulsive nature of the interaction as the power increases.
MICRO-PATTERNING OF POLYMERS

35 µm

G50P
holes=416µ
bar=84µm

G100P
holes=208µ
bar=42µm

ALLIGNED 3T3 FIBROBLASTS (pdAA/PEO-like)

70 µm
G50P
holes= 416µm
bar= 84µm

NCTC2544 human keratinocytes onto microstructured PS

PS/PEO-like

N-groups/PEO-like

DEGDME/Ar

NH₃

DEGDME/Ar

holes= 416µm
bar= 84µm
3T3 murine fibroblasts on pdAA/PEO-like μ-structured PS

The tracks, in effect, are more like CHANNELS

The cells can “feel” the chemistry of the channels, but also their BORDERS
Nanocomposite Ag/PEO-like coatings

PEO-like network -(CH₂CH₂O)n-

NON FOULING

substrate

Ag clusters

BACTERIOSTATIC

BACTERIAL RESISTANT COATINGS
super hydrophobic
nano-structured
fluorocarbon coatings

5 µm
Nano roughness of two different PS dwells (2 different manufacturers)
PE-CVD of ultrathin hydrophilic conformal coatings on hydrophobic nanostructured (35 nm height) polymers for tissue engineering

without pre-treatment

with pre-treatment
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