IMM
Dept. of Napoli

PON Ricerca e Competitività 2007-2013

Nanostructured transducers as sensing platforms for biomedical applications

Jane Politi, Alessandro Caliò, Monica Terracciano, Mario Iodice, Ilaria Rea, Principia Dardano, Mariano Gioffrè and Luca De Stefano

Roma, 14 Novembre 2014-Workshop INBB "Biosensori per l'ambiente e la salute"

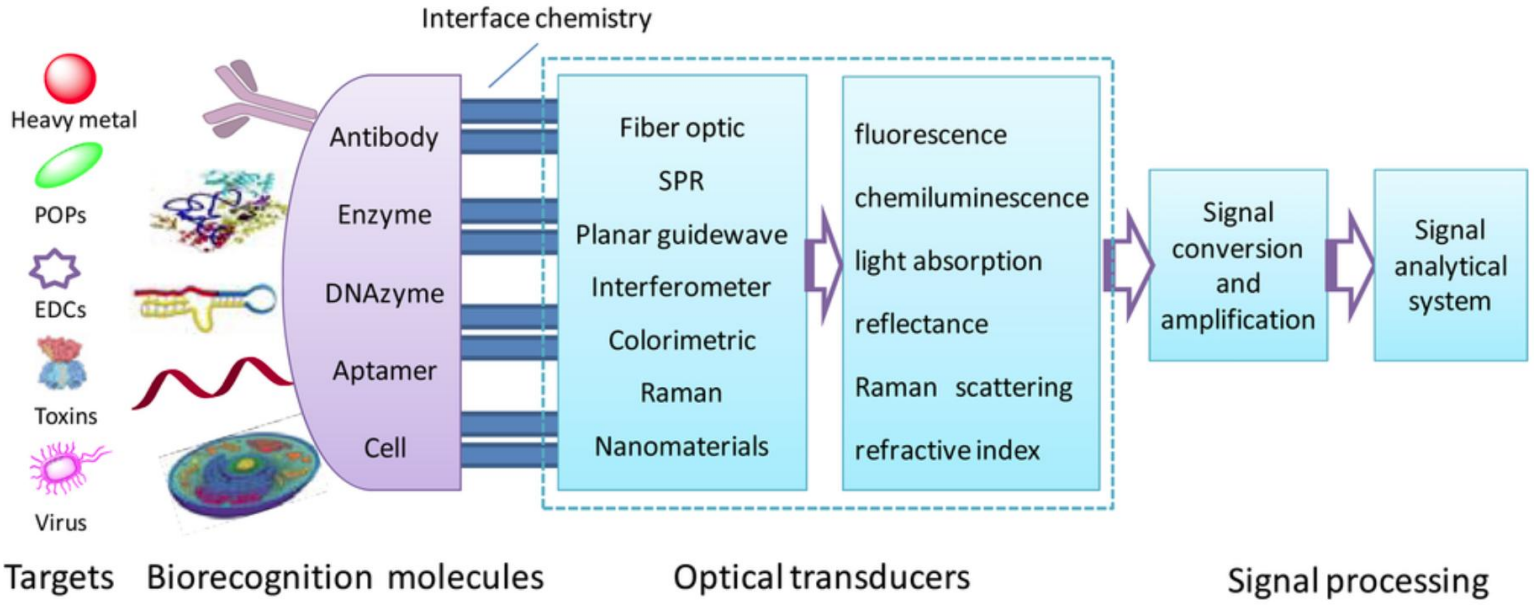
Outline

- **Motivations**
- **Silicon based and Gold based nanostructured materials**
- **Applications**
- **Coclusions**

Motivations

Biosensors are nowadays technological hot topics due to the possible applications in **social interest fields** such as medical diagnostic and health care, monitoring of environmental pollutants, home and defense security.

Optical Biosensors, Eds. F.S. Ligler and C.A. Rowe Taitt, Elsevier, Amsterdam, The Netherlands, **2004**



Why use nanostructured materials?

•…new properties of novel material (reflectivity, photoluminescence, electrical conductivity, optical waveguiding...);

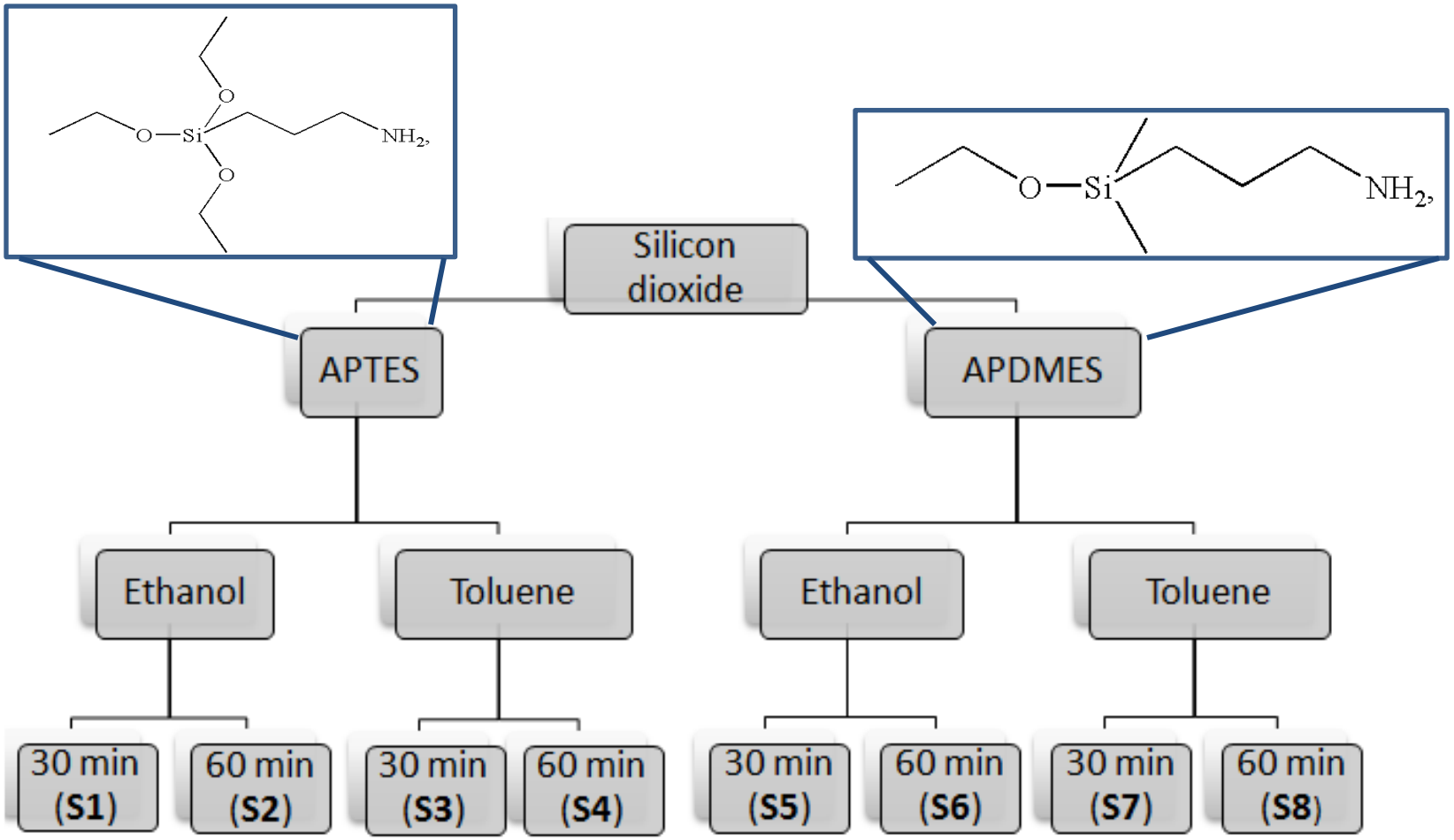
•…high surface area, useful for efficient biomodification and interaction monitoring;

•…high selectivity and specificity in interaction with chemical species;

•…Applicability in bio-medicine (as therapeutics, diagnonostic, etc…) or in environment monitoring (as new tools for pollutant detection, etc…).

Silicon and Porous Silicon

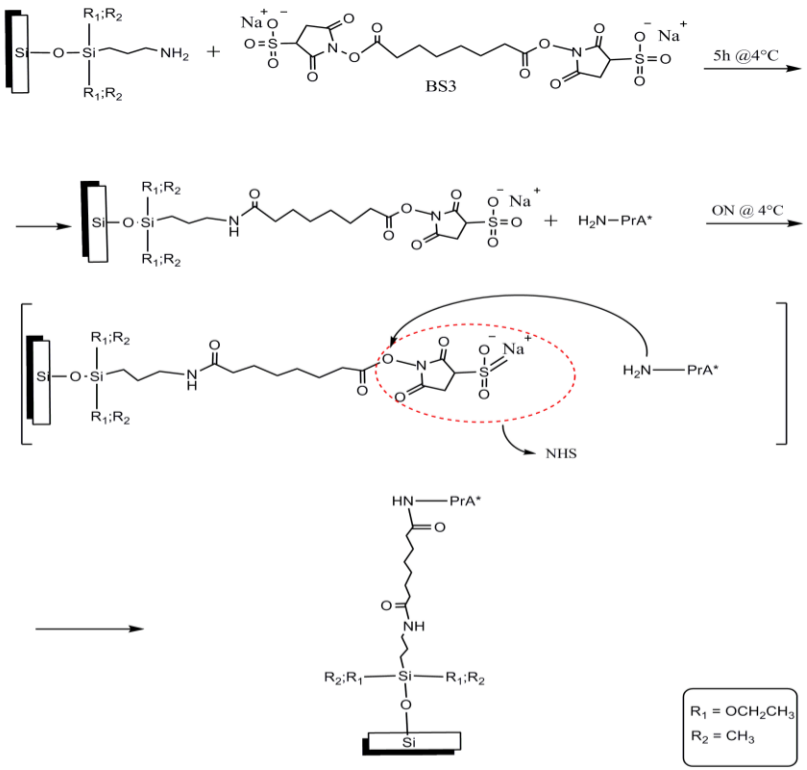
Covalent Biomodification



M.Terracciano, I.Rea, J.Politi, L.De Stefano
J. Europ. Opt. Soc. 8, 13075, 2013

Silicon and Porous Silicon

Covalent Biomodification



Spectroscopic Ellypsometric data

Sample	BS3 thickness (Armstrong)	PrA* thickness (Armstrong)
S1	7.5±0.3	14.5±0.4
S2	22.9±0.3	9.4±0.4
S3	9.3±0.3	22.3±0.5
S4	18.9±0.8	7.9±0.8
S5	5.6±0.3	10.2±0.3
S6	13.1±0.3	8.5±0.4
S7	10.0±0.3	10.1±0.4
S8	5.7±0.3	11.1±0.4

Thicker layer of protein A is obtained in case of 30 minutes silanized chip in toluene by APTES

M.Terracciano, I.Rea, J.Politi, L.De Stefano
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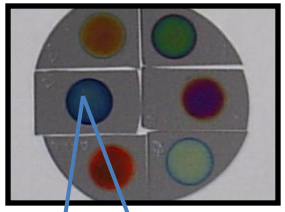
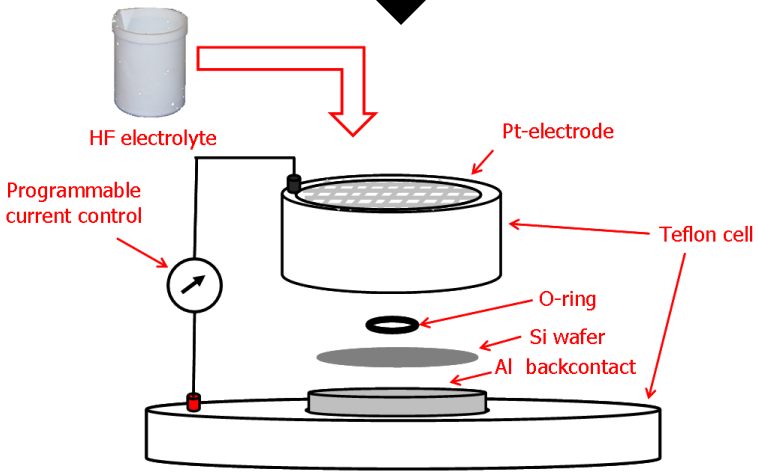
Silicon and Porous Silicon

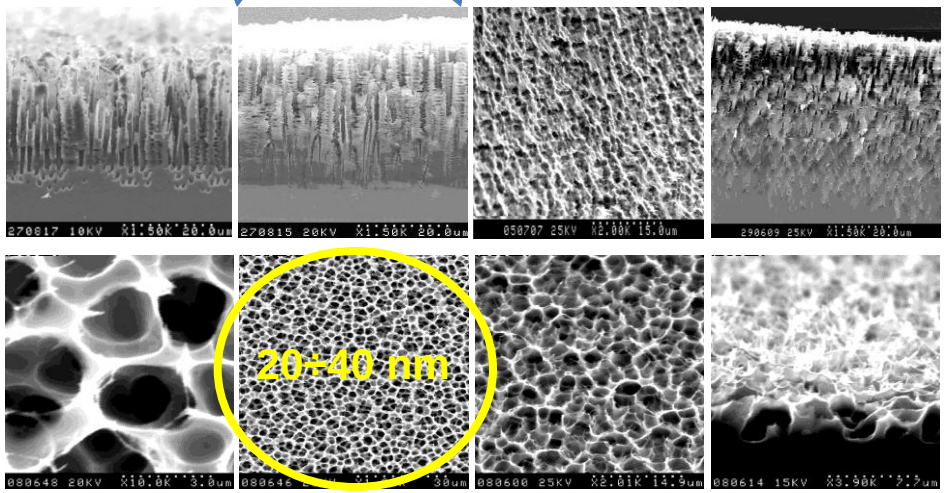
Fabbrication process

Cristalline Silicon (Csi)



Porous Silicon (PSi)



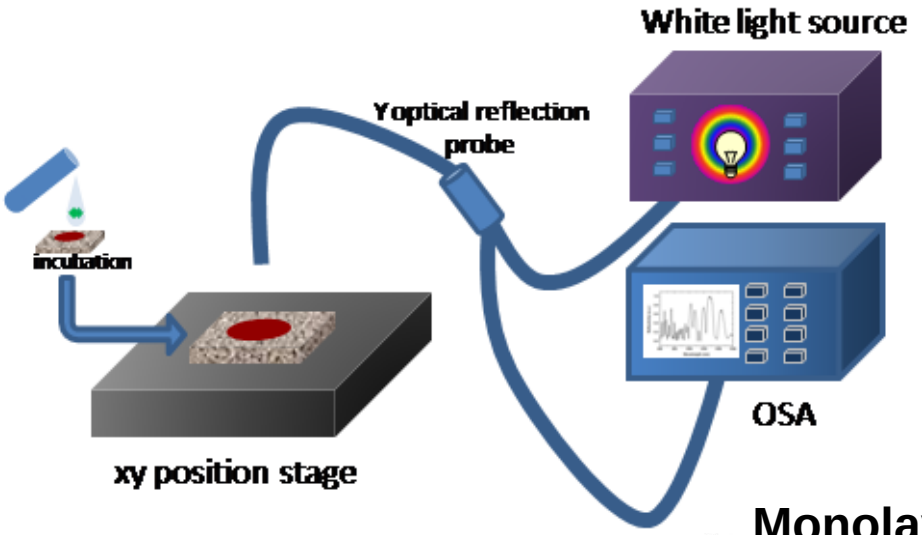


Cathode: $2H^+ + 2e^- \longrightarrow H_2$

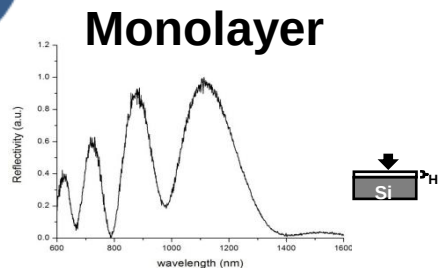
Anode: $Si + 6F^- + 2H^+ + 2h^+ \longrightarrow SiF_6^{2-} + H_2$

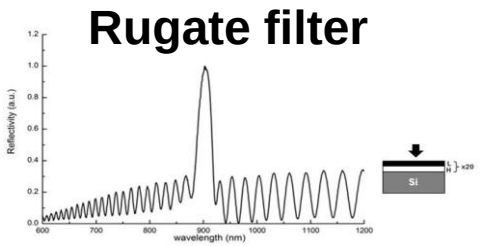
Silicon and Porous Silicon

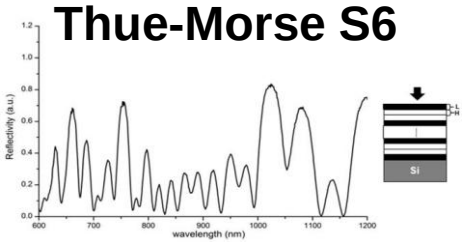
Spectroscopic Reflectometry

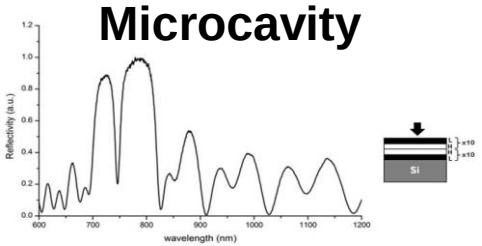


Optical structures









Silicon and Porous Silicon

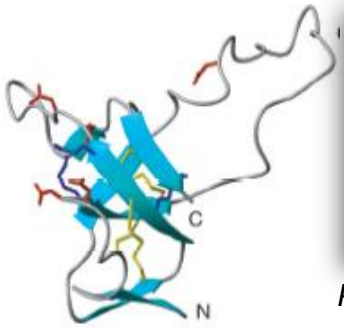
Non-covalent Biomodification

Small amphiphilic fungal proteins (about 100 aminoacids; 10 kDa):

- **self-assembling into thin amphipatic film at air-liquid, liquid-liquid or solid-liquid interfaces;**
- **high active surface.**

Class I

Forming highly insoluble biofilm

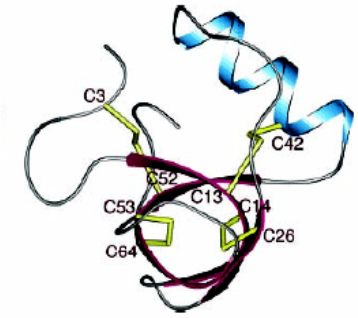


Pleurotus ostreatus

Kwan A.H.Y. et al. (2006) PNAS

Class II

Forming readly dissolving aggregates

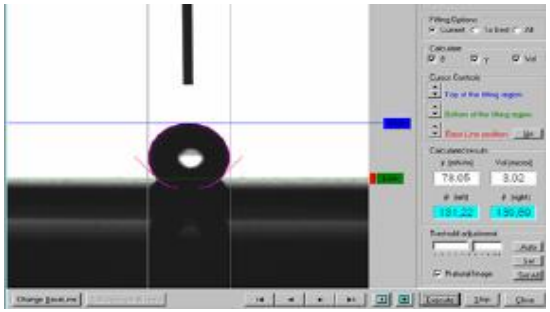


J. Hakanpaa et al. (2003) Am. Soc. Biochem. Molec. Biol.

Silicon and Porous Silicon

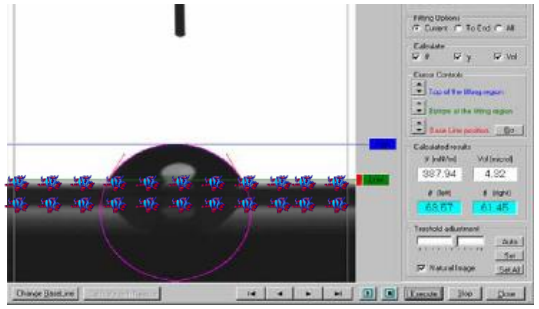
Non-covalent Biomodification

PSi as etched



HFB

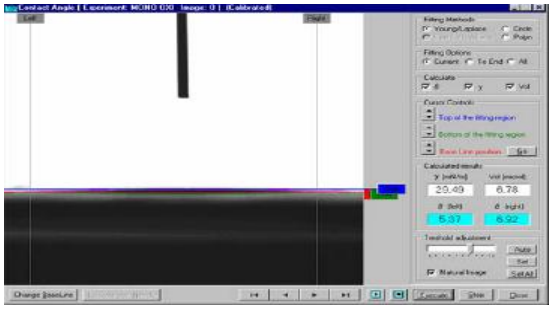
PSi post HFB



WCA=131° - Hydrophobic

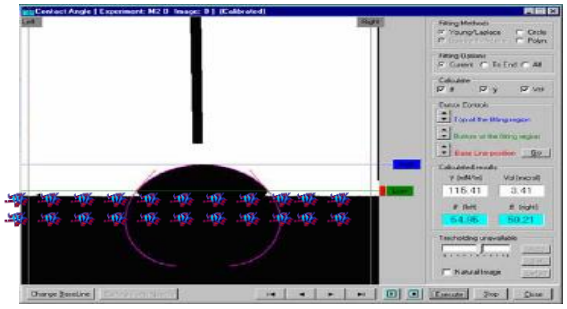
WCA=62° - Hydrophilic

$PSiO_2$ pre-infiltration



HFB

$PSiO_2$ post HFB



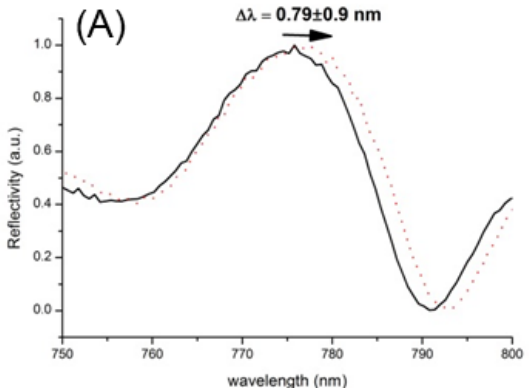
WCA=6° - Hydrophilic

WCA=57° - Less hydrophilic

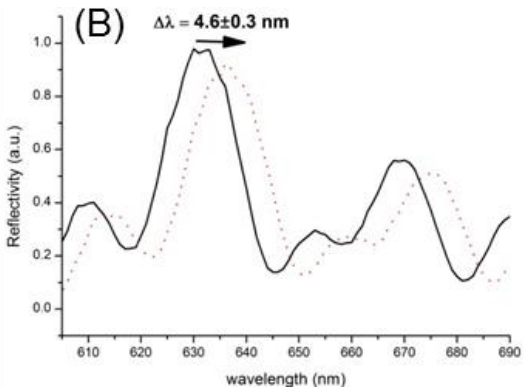
A.Caliò, I.Rea, J.Politi, S. Longobardi, P. Giardina, L.De Stefano, J. Appl. Phys. 114, 134904 (2013)

Porous Silicon for Glucose detection

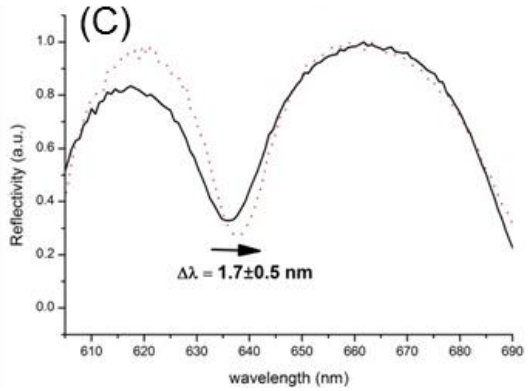
Rugate filter



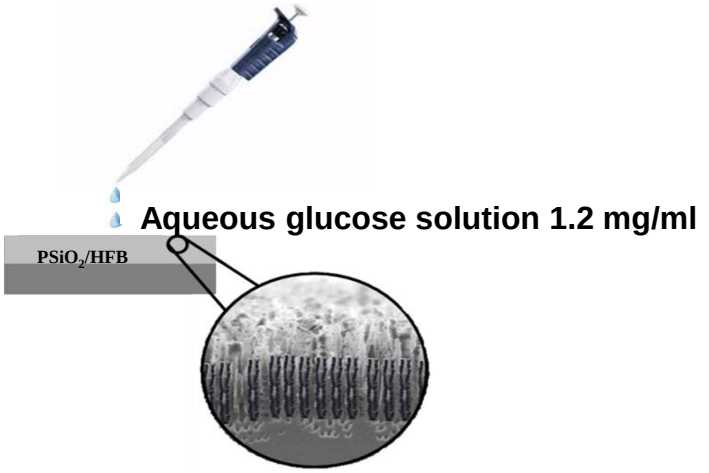
Thue-Morse S6



Microcavity



Glucose deposition in optical transducers



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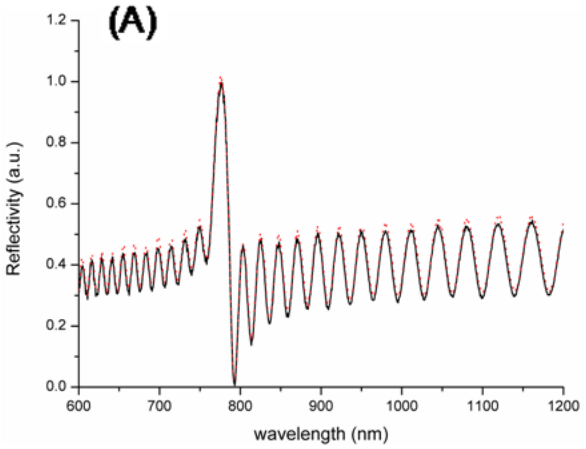
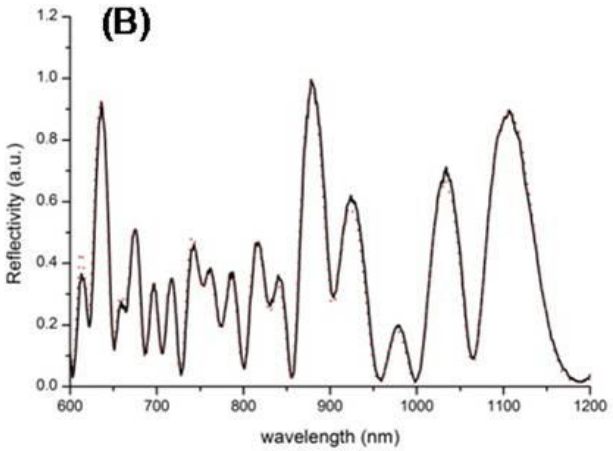
Porous Silicon for Glucose detection

Spectroscopic reflectometry

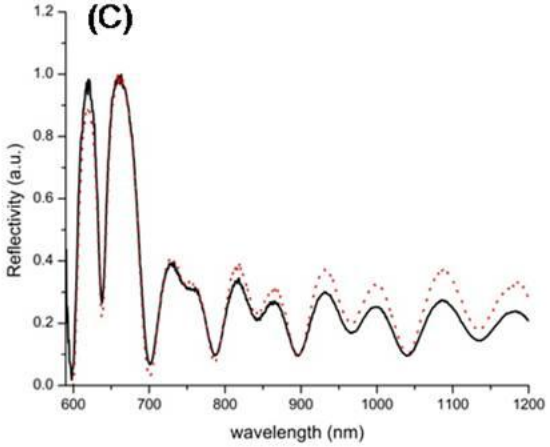
Rugate filter



Thue-Morse S6



Microcavity



$\Delta\lambda \leq 1$ nm ☹

Possible motivations:

- **sugar molecules are too small: 180 Da (glucose) vs 10 kDa (HFB);**
- **few glucose molecules bind HFB biofilm.**

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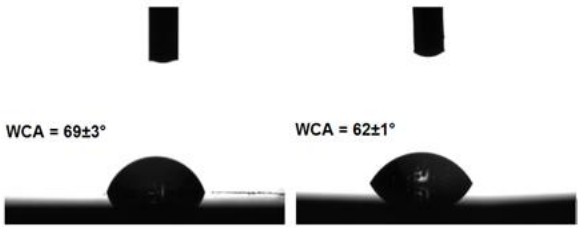
Porous Silicon for Glucose detection

Sessile drop

Rugate filter

(A)



ΔWCA ~ -7°

Thue-Morse S6

(B)

ΔWCA ~ -8°

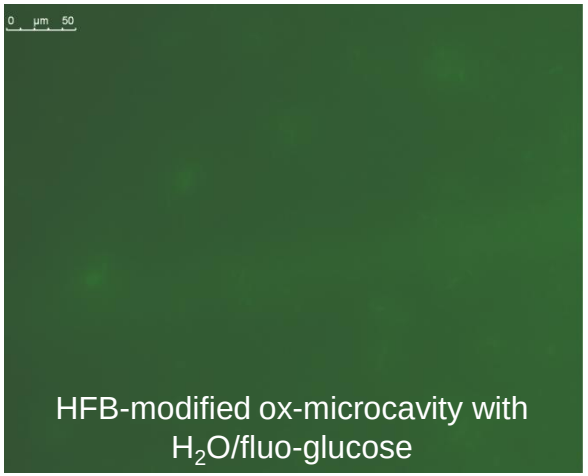
Microcavity

(C)

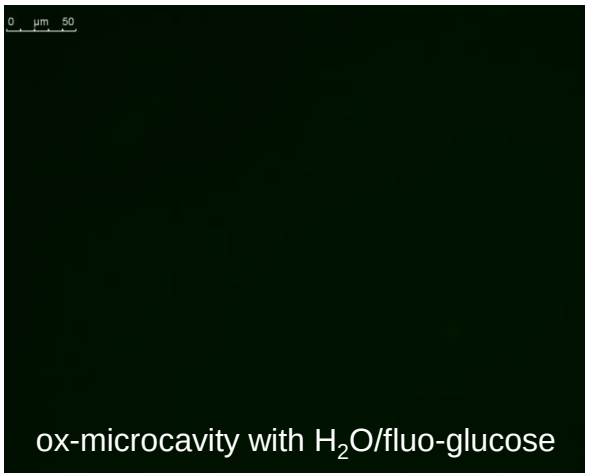
ΔWCA ~ -10°

Fluorescence

(A)



(B)



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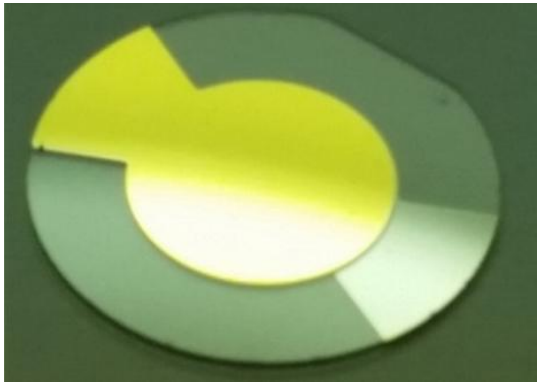
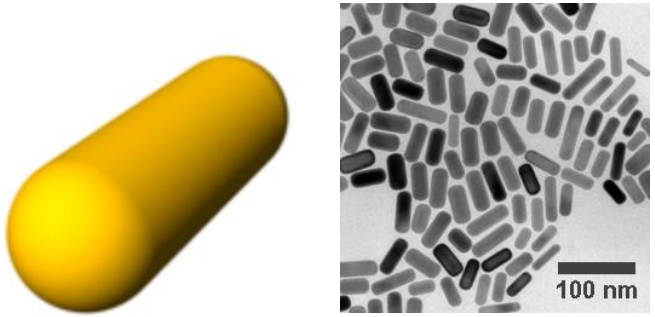
Gold and gold nanoparticles

Gold substrates (Au)

Gold Nanoparticles (AuNPs)



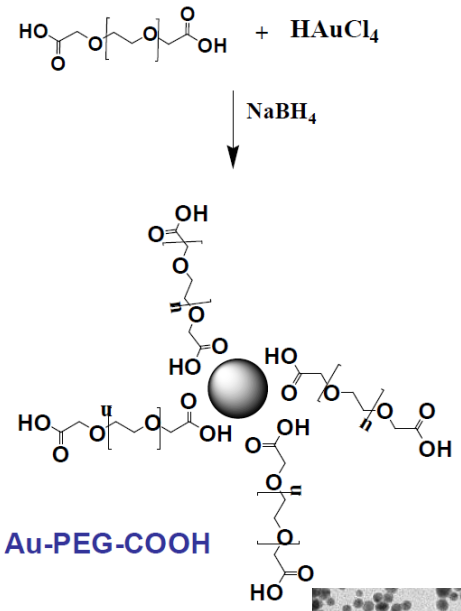
Quartz Resonators coated by gold layer (QR)



Gold Nanorods (AuNRs)

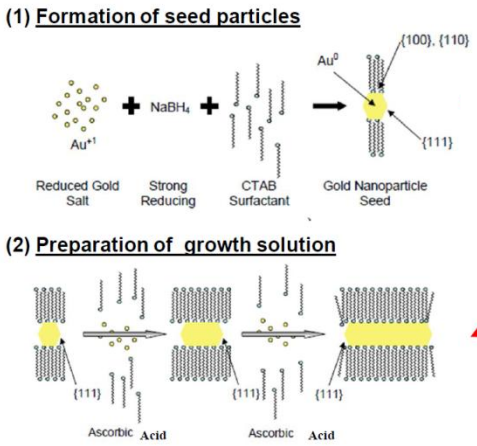
Gold and gold nanoparticles

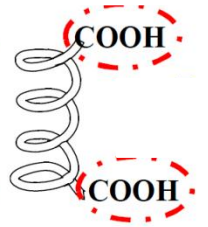
Synthesis of PEG-Gold Nanoparticles



Au-PEG-COOH

Synthesis of PEG-Gold Nanorods

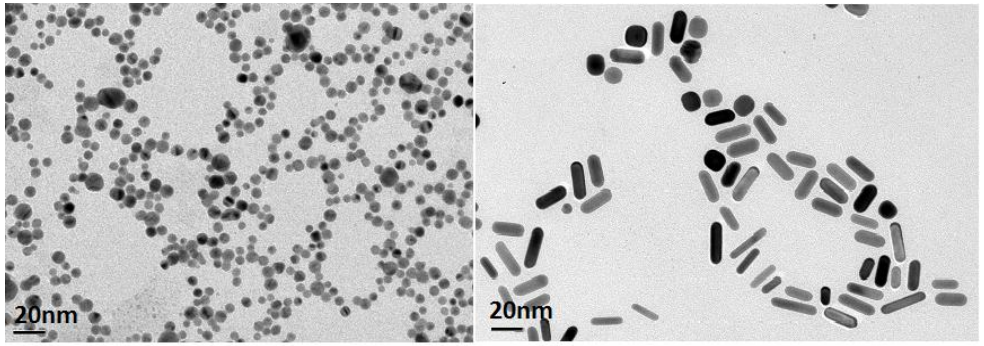




Dicarboxylic PEG

Nanorods!!!

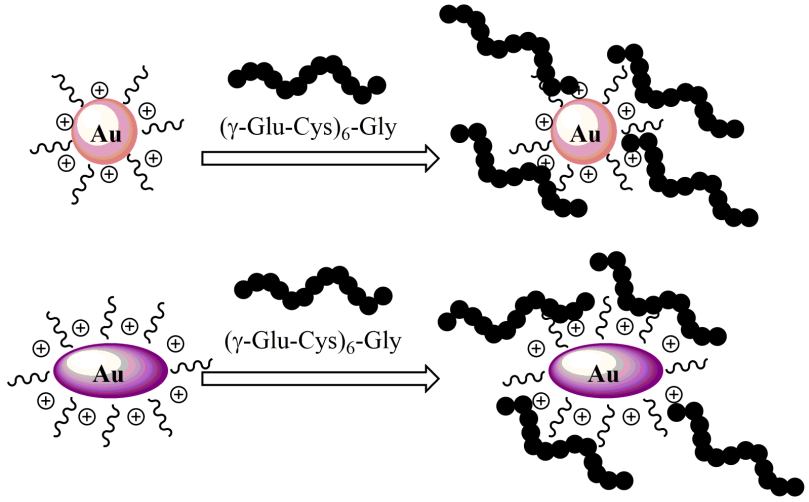
TEM images



J.Politi, J. Spadavecchia, M. Iodice, L.De Stefano, Analyst 2014, DOI 10.1039/c4an01491j

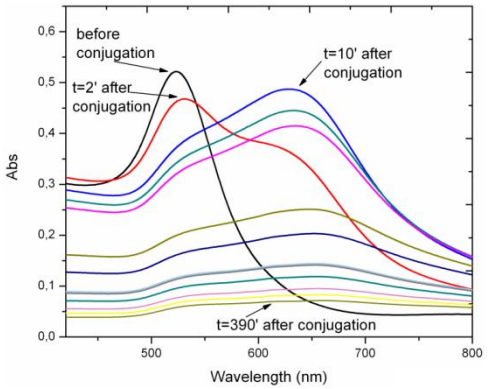
Gold Nanoparticles for heavy-metals interaction monitoring

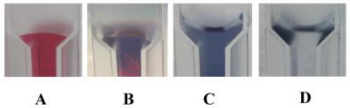
Non-covalent Biomodification



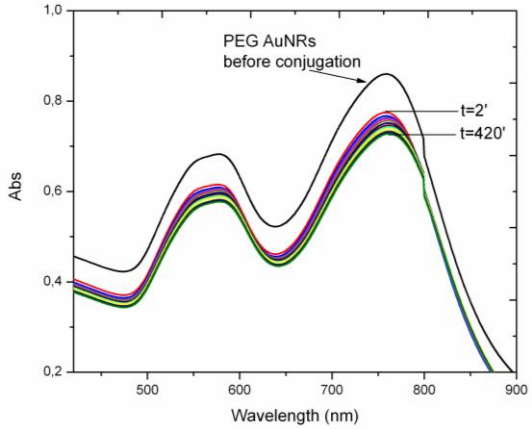
Adsorption

Hybrid PEG AuNPs





Hybrid PEG AuNRs



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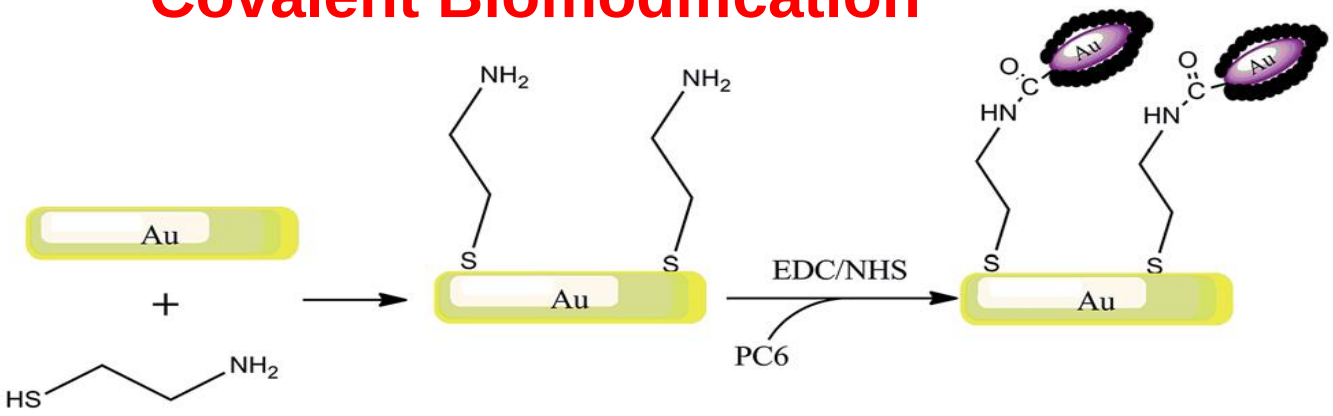
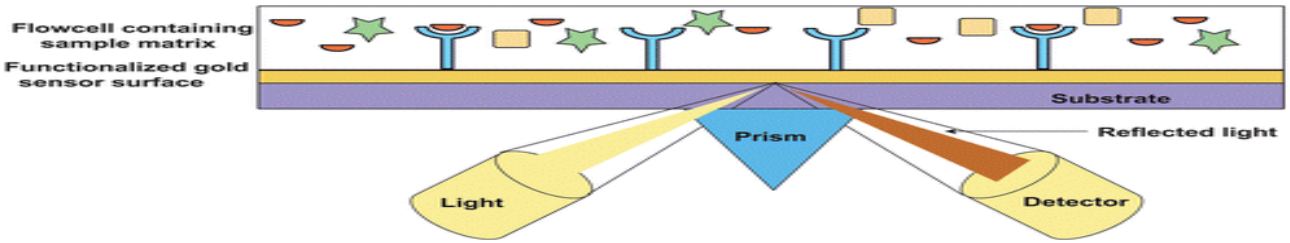
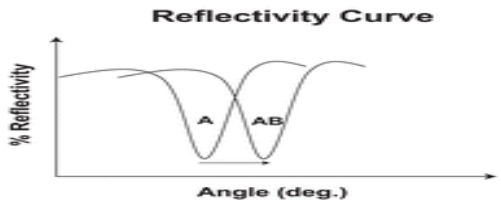
Gold Nanoparticles for heavy-metals interaction monitoring

Covalent Biomodification



FT-SPR





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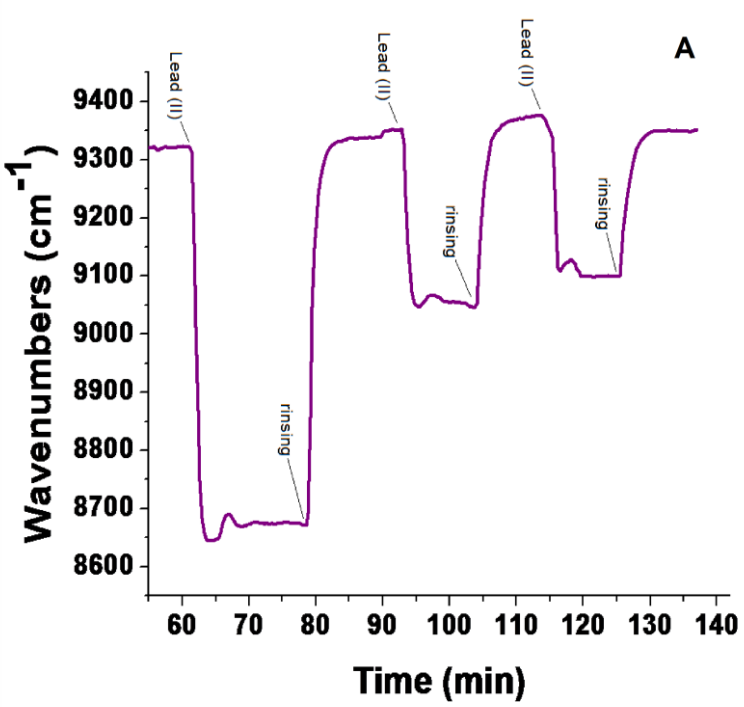
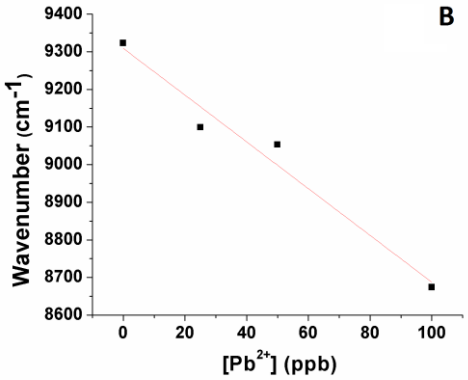
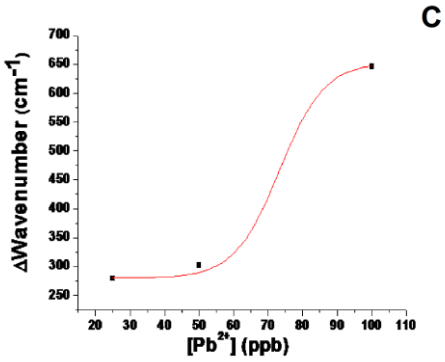
Gold Nanoparticles for heavy-metals interaction monitoring

Lead (II) interaction monitoring by FT-SPR







Interaction described by Boltzmann model:

$Y = A2 + ((A1\ \ A2)/(1 + [e]\text{^}((x-x0)/dx)))$

Where x0=inflection point
useful for affinity evaluation of biomolecular interaction

x0 value is 73.6±0.9 $cm^{-1}ppb^{-1}$ corresponding to $1.8 \times 10^{-10} \pm 2 \times 10^{-12} cm^{-1}$ mol l^{-1}.

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Conclusions

- **Silicon and Porous silicon optical structures have been succesfully biomodified;**

- **Porous silicon optical structures successfully detected glucose molecules in aqueous solution;**

- **Gold and Gold Nanoparticles were successfully biomodified;**

- **Stable PC_6-AuNr conjugates were obtained for efficient interaction monitoring of Pb(II) ions in aqueous solution.**

Thank you for your kind attention!!!

Jane Politi

Ph.D. student in Industrial and Molecular Biotechnologies

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