Optical spectroscopy and biosensors for investigation of biomolecules and their interactions

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Combinations of Optical Spectroscopy with other Techniques

Content

Combinations of SPR biosensors with other techniques for more complex investigations of biointerfaces, interaction analysis, and materials research:

- **Fluorescence spectroscopy (SPFS)**
- **Quartz crystal microbalance (QCM)**
- **Electrochemistry (EC-SPR)**
- **Field effect transistor (FET)**
- ~~**Mass spectrometry**~~
- ~~**SERS, TERS…**~~

Date: **May 31st**

Fluorescence

Surface Plasmon-Enhanced Fluorescence

ELSEVIER

Colloids and Surfaces
A: Physicochemical and Engineering Aspects 171 (2000) 115–130

COLLOIDS AND SURFACES A

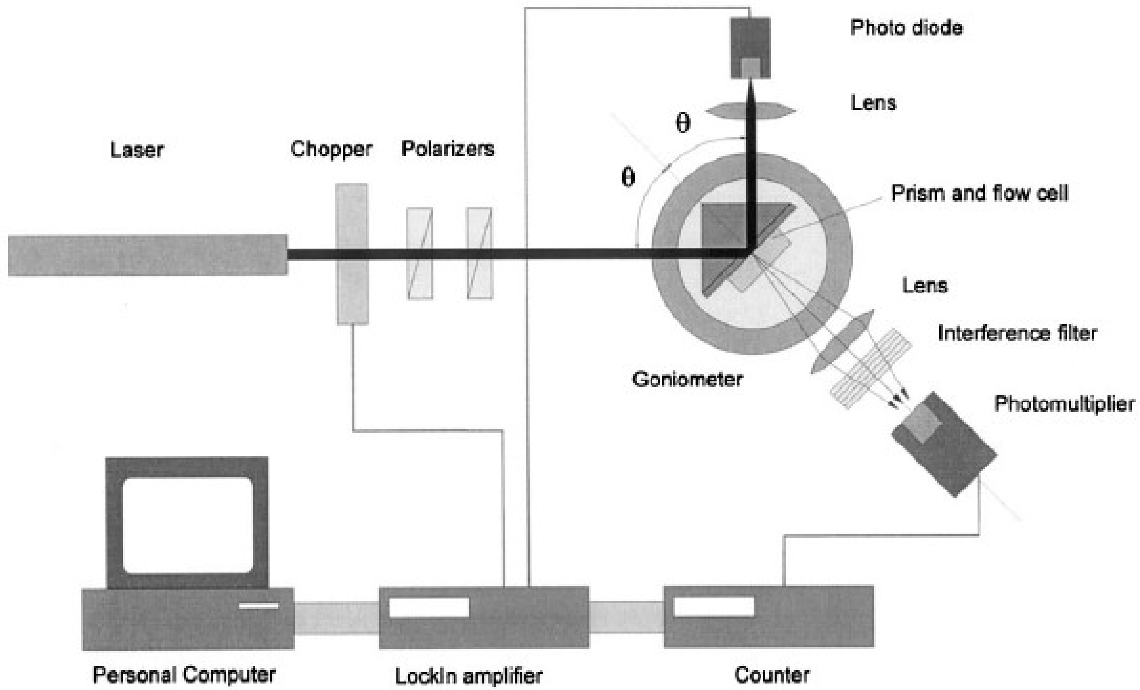
www.elsevier.nl/locate/colsurfa

Surface-plasmon field-enhanced fluorescence spectroscopy

Thorsten Liebermann *, Wolfgang Knoll

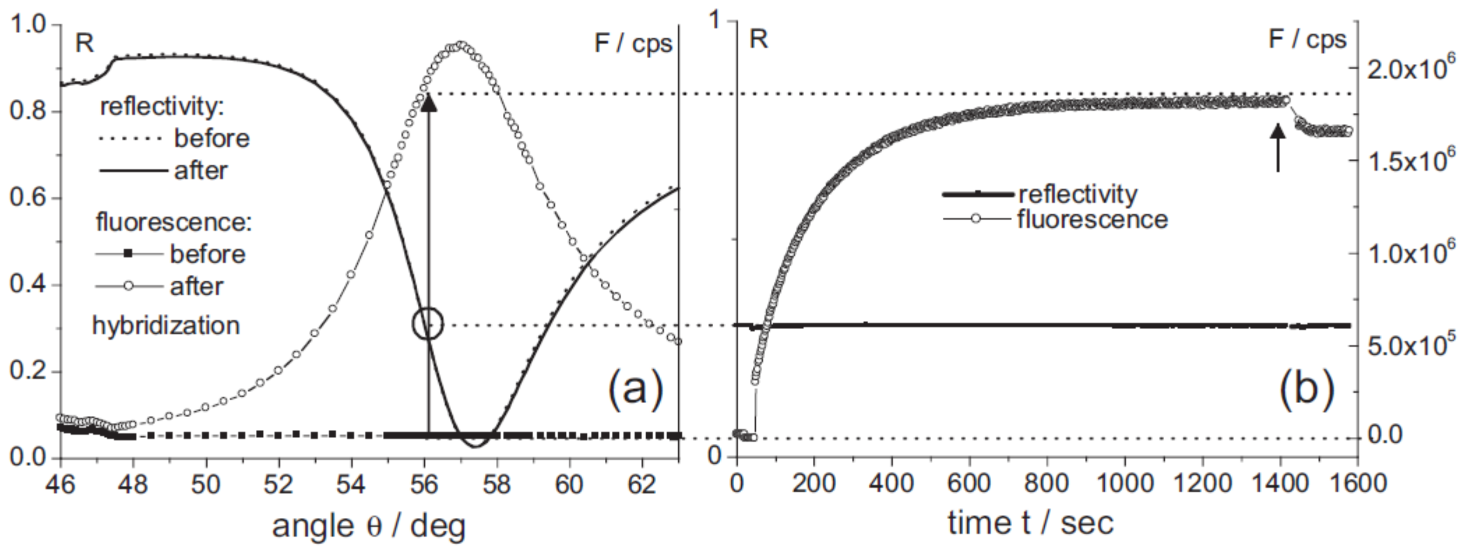
Max-Planck-Institut für Polymerforschung, Ackermannweg 10, D-55128 Mainz, Germany

Surface Plasmon-Enhanced Fluorescence (λ_{ex})



- Combination of surface plasmon resonance (SPR) and surface plasmon field enhanced fluorescence excitation (SPFS).

Surface Plasmon-Enhanced Fluorescence (λ_{ex})



- Comparison of SPR and SPFS for investigation of short oligonucleotide hybridization. Sensitivity motivation for low molecular weight analytes.

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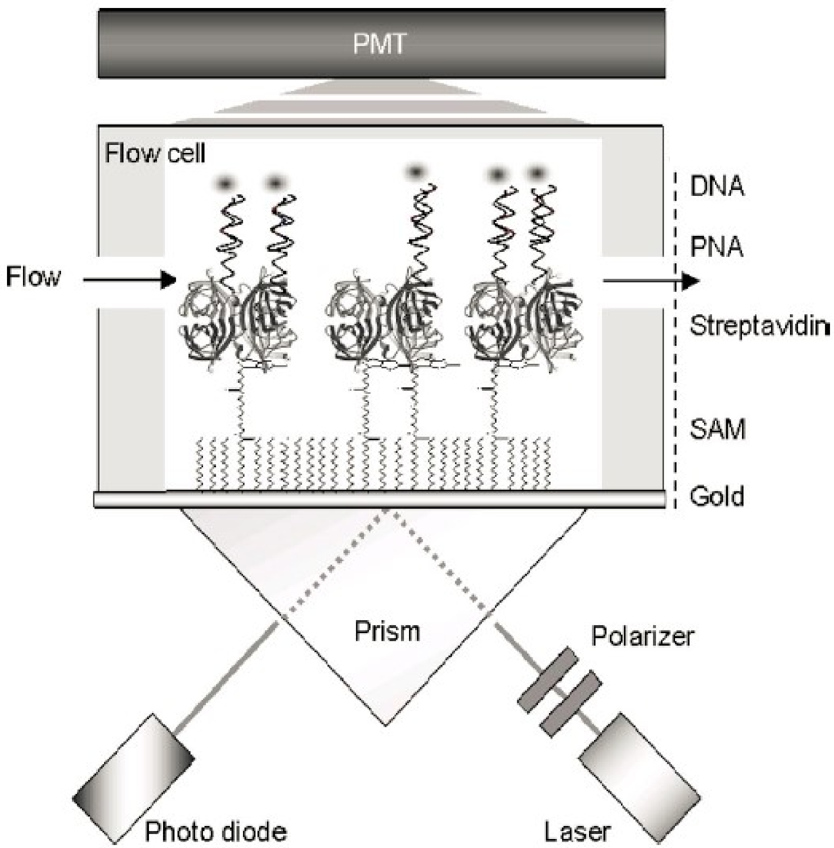
Surface Plasmon Resonance (SPR) and Surface Plasmon-Enhanced Fluorescence (SPFS)

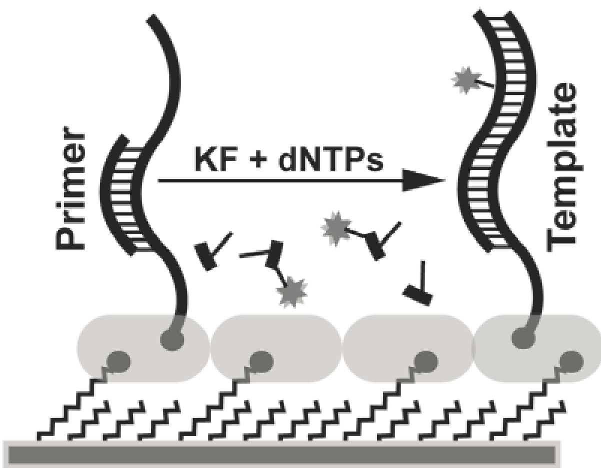


Example: investigation of peptide nucleic acid (PNA) probes for the detection of single nucleotide polymorphism (SNP).

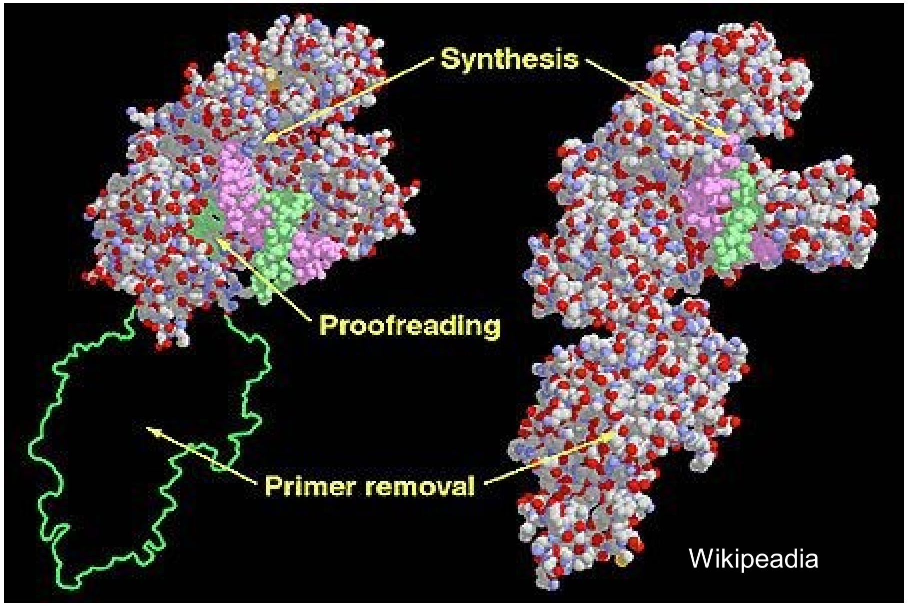
- Relevant to e.g. diagnosis of genetic diseases such as thalassemia.
- Instrumentation: combined SPR and surface plasmon-enhanced fluorescence spectroscopy (SPFS).

H. Park, A. Germini, S. Sforza, R. Corradini, R. Marchelli, and Knoll W. ,BioInterphases **1, 113 2006.**

DNA Hybridization: Primer Extension



dNTP – deoxynucleotide
KF – Klenow fragment

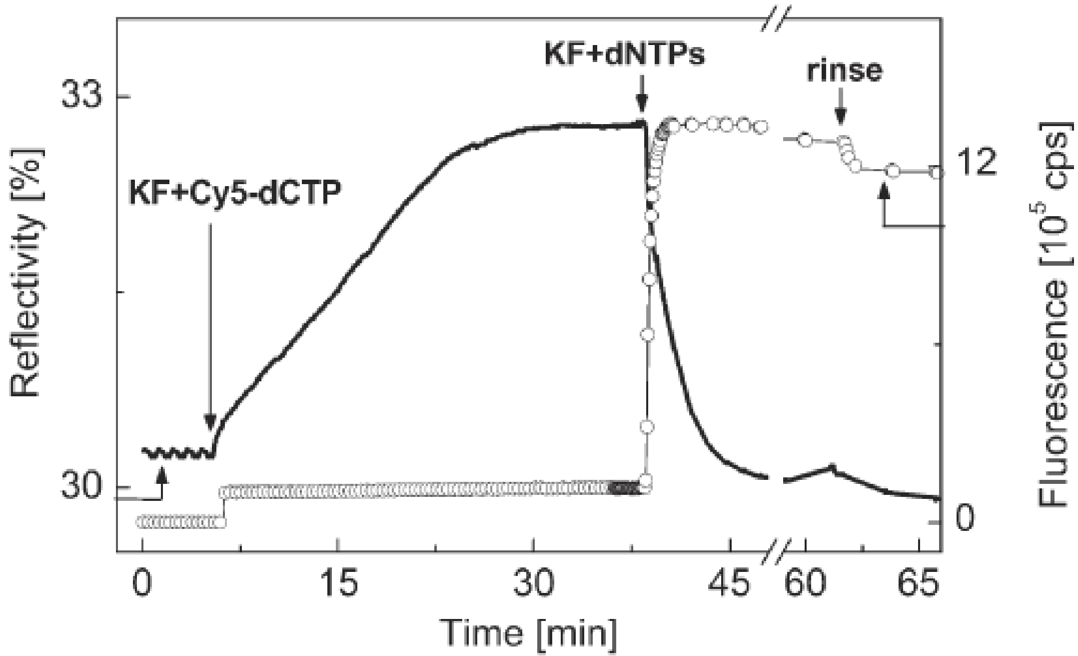


DNA polymerase

- Besides sensitivity, combined SPR and SPFS offers means to probe more parameters at the same time: applied for primer extension studies.

G. Stengel and W. Knoll, Nucleic Acids Res. **33, 69 2005**

DNA Hybridization: Primer Extension



Complementary information obtained:

- **SPR:** Mostly sensitive to binding of large KF to DNA probes.
- **Fluorescence: "**Zipping up" the duplex DNA strand (low molecular weight).

G. Stengel and W. Knoll, Nucleic Acids Res. **33, 69 2005**

Ultrasensitive Detection – Relating Fluorescence Signal with Number of Molecules

J|A|C|S
COMMUNICATIONS

Published on Web 07/01/2004

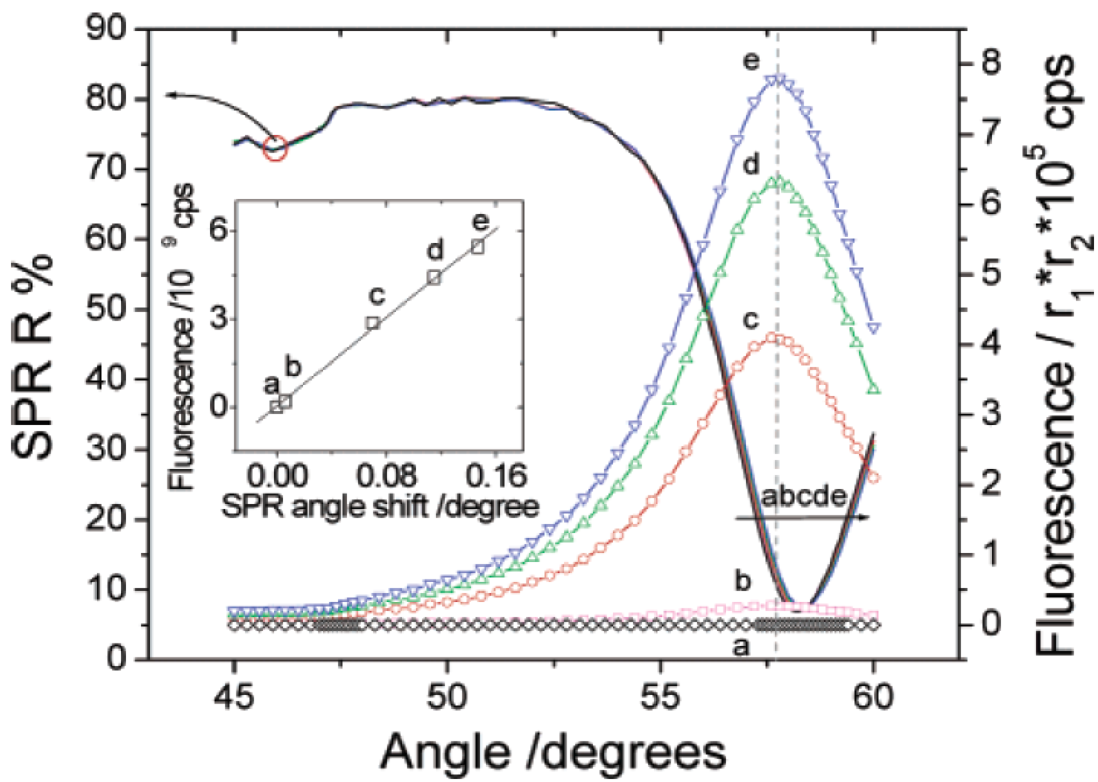
Attomolar Sensitivity in Bioassays Based on Surface Plasmon Fluorescence Spectroscopy

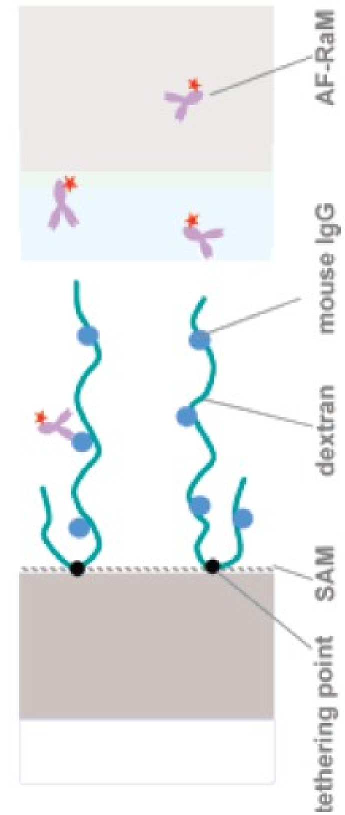
Fang Yu,† Björn Persson,‡ Stefan Löfås,‡ and Wolfgang Knoll*,†

Max-Planck-Institute for Polymer Research, Ackermannweg 10, D-55128 Mainz, Germany, and Biacore AB, Rapsgatan 7, SE-754 50 Uppsala, Sweden

Received March 11, 2004; E-mail: knoll@mpip-mainz.mpg.de

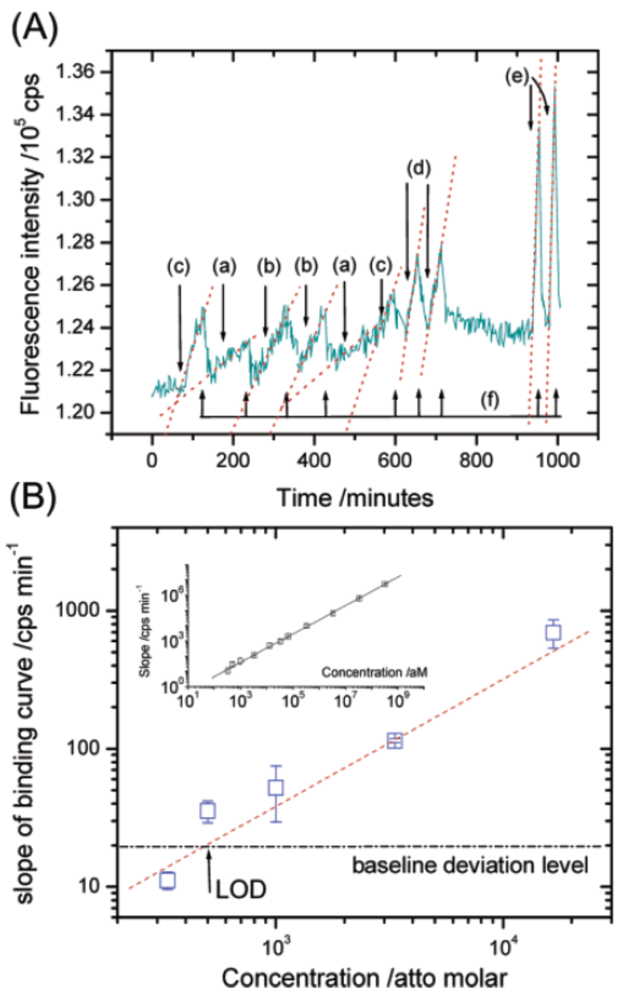
Calibration of Fluorescence Signal by SPR / SPFS





- Calibration: SPR allows for determining the captured molecules surface density (for high analyte concentrations), relate that to the fluorescence signal, and extrapolate (also for concentration much lower where SPR is blind)

Calibration of Fluorescence Signal by SPR / SPFS



- Achieved 0.5 fM limit of detection (SPFS with very high excitation power and long incubation time of 60 min)
- By SPFS related to SPR, there was determined that one can detect 600 molecules / mm^2.
- Taking advantage of time kinetics and processing all data measured over long time (corresponding to averaging).

Surface Plasmon-Enhanced Fluorescence (Study in Early 90ties)

Sensitivity enhancement of optical immunosensors by the use of a surface plasmon resonance fluoroimmunoassay

J. W. Attridge, P. B. Daniels, J. K. Deacon, G. A. Robinson & G. P. Davidson

Serono Diagnostics Ltd., Unit 21, Woking Business Park, Albert Drive, Woking, Surrey GU21 5JY, UK

(Received 4 May 1990; revised version received 7 August 1990; accepted 9 August 1990)

Biosensors & Bioelectronics **6** (1991) 201–214

Surface Plasmon-Enhanced Fluorescence ($\lambda_{ex}, \lambda_{em}$)

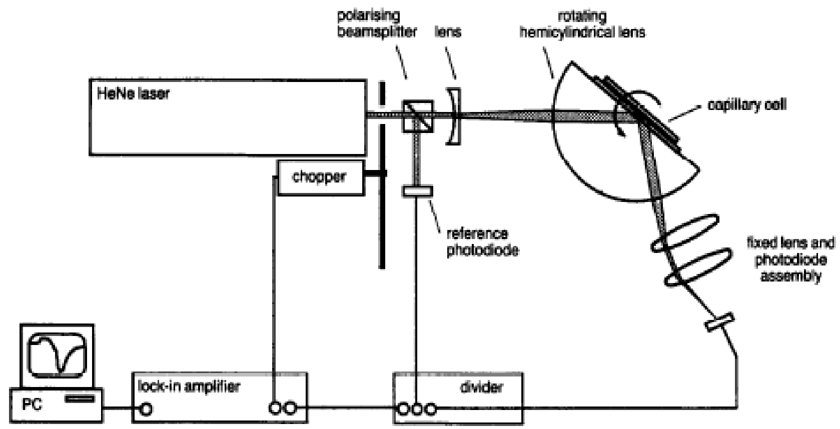
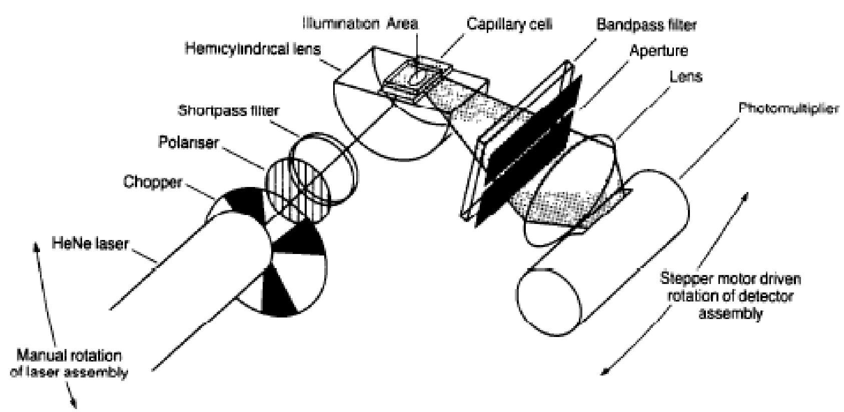


Fig. 4. Experimental apparatus used for SPR reflectance measurements.



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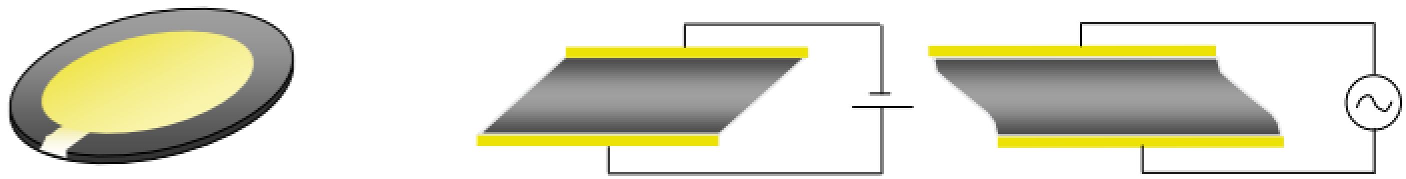
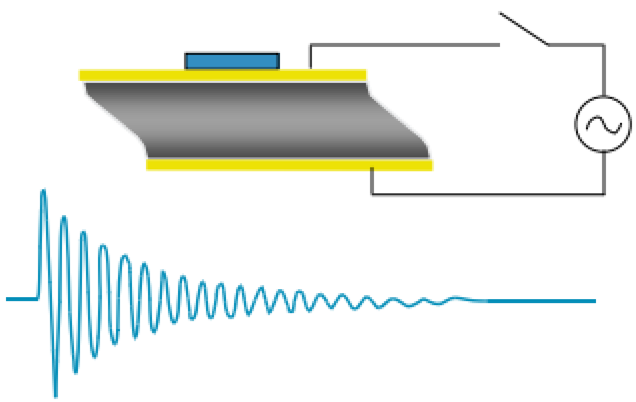
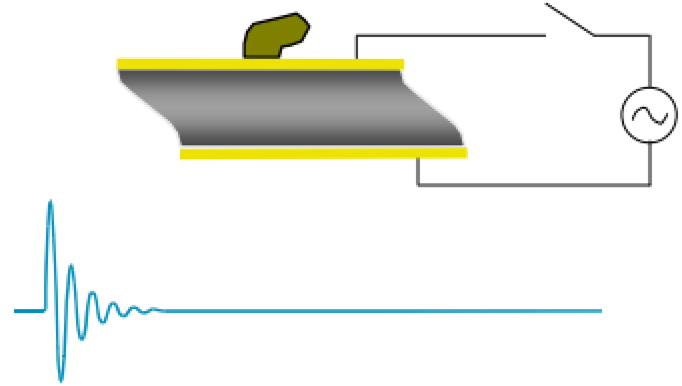
Quartz Crystal Microbalance

Quartz Crystal Microbalance (QCM)





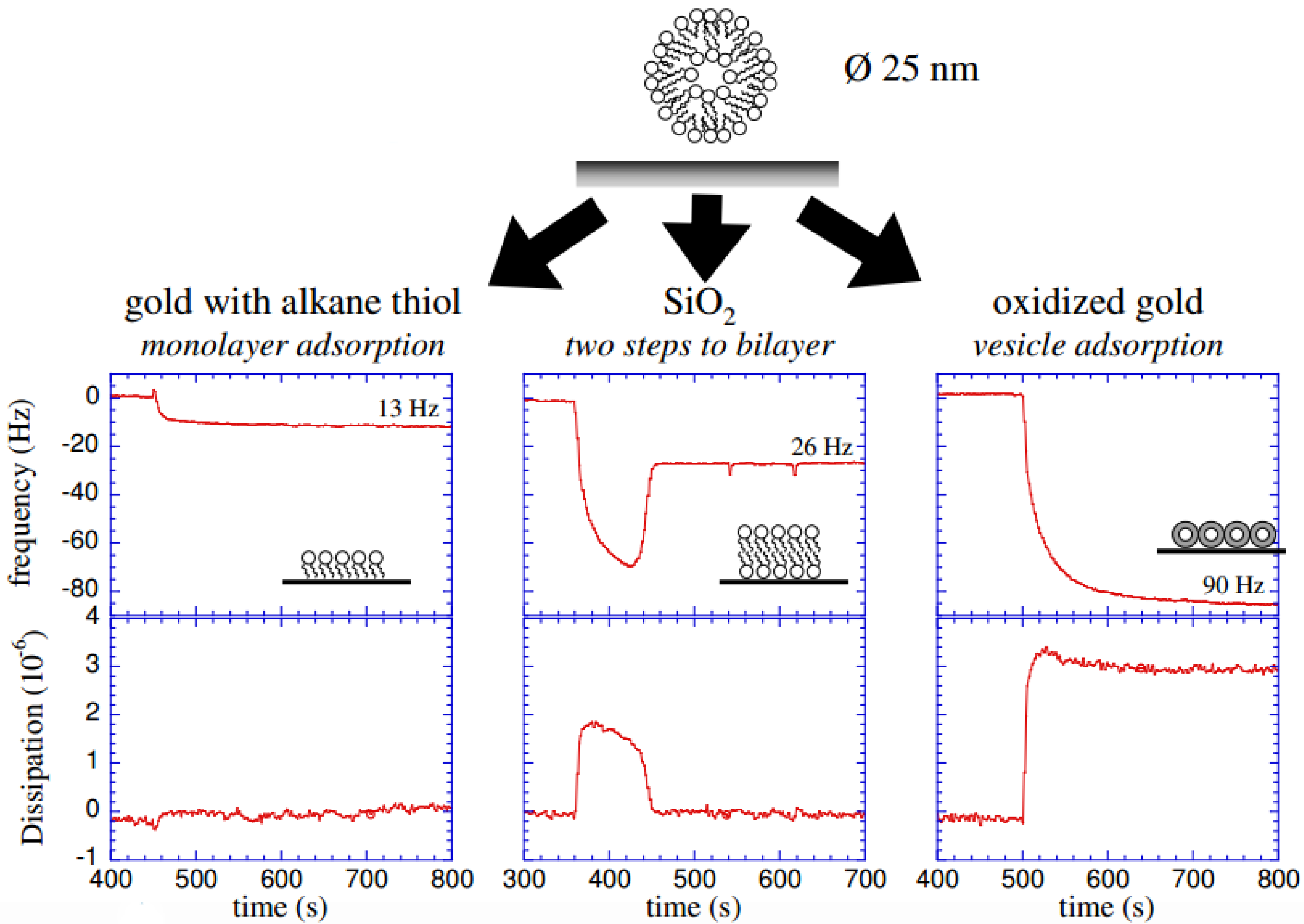
Δf is related to the mass of the attached film (Sauerbrey relation)



ΔD is related to the viscoelasticity

Taken from Q-Sense

Quartz Crystal Microbalance (QCM)



C.A. Keller and B. Kasemo, Biophysical J. 75 (1998) 1397.

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Langmuir **2002**, *18*, 479−489

Using Surface Plasmon Resonance and the Quartz Crystal Microbalance to Monitor in Situ the Interfacial Behavior of Thin Organic Films

Larry E. Bailey,[†] Dev Kambhampati,[‡] Kay K. Kanazawa,[†] Wolfgang Knoll,[†,§] and Curtis W. Frank*[,†]

Department of Chemical Engineering, Stanford University, Stanford, California 94305-5025, Thermo Hybaid Interactiva, Sedanstrasse 10, D-89077 Ulm, Germany, and Max Planck Institute for Polymer Research, Ackermannweg 10, 55128, Mainz, Germany

Received August 10, 2001

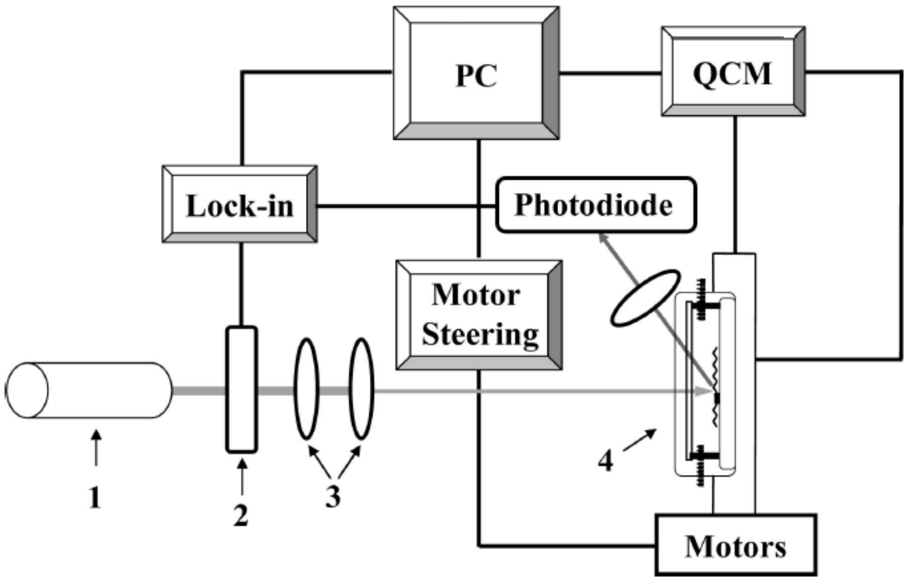
Anal. Chem. **2008**, *80*, 5246–5250

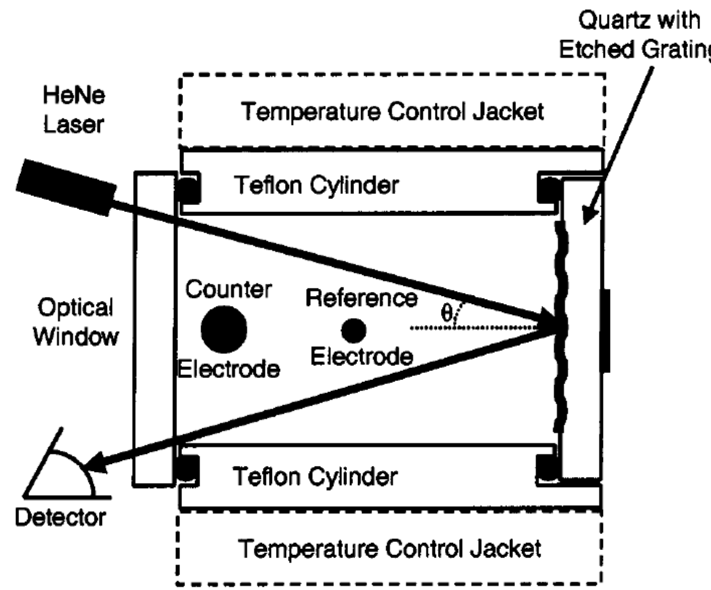
Quartz Crystal Microbalance with Integrated Surface Plasmon Grating Coupler

Yun Zong,[†] Fei Xu,[†] Xiaodi Su,[†] and Wolfgang Knoll*[,†,‡]

*Institute of Materials Research and Engineering, A*STAR (Agency for Science, Technology and Research), 3 Research Link, Singapore 117602, and Max-Planck Institute for Polymer Research, Ackermannweg 10, 55128 Mainz, Germany*

QCM with Grating-Coupled SPR





Langmuir **2002**, *18*, 479–489

Analytical Chemistry, Vol. 80, No. 13, July 1, 2008

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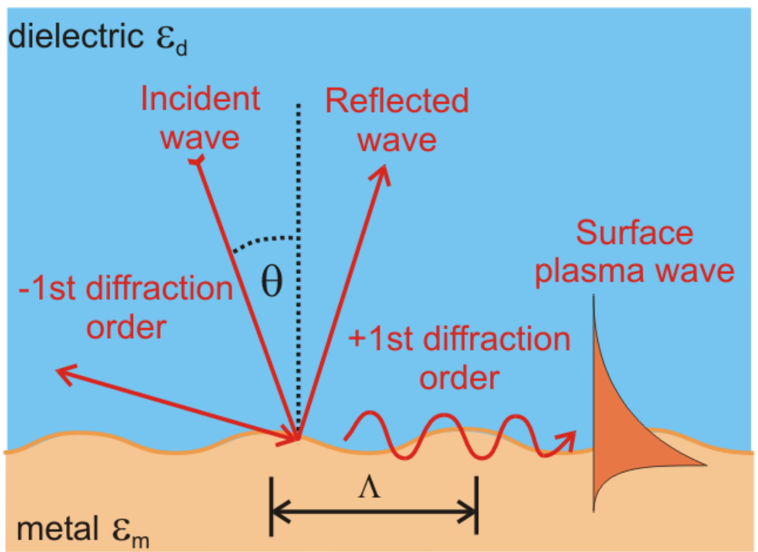
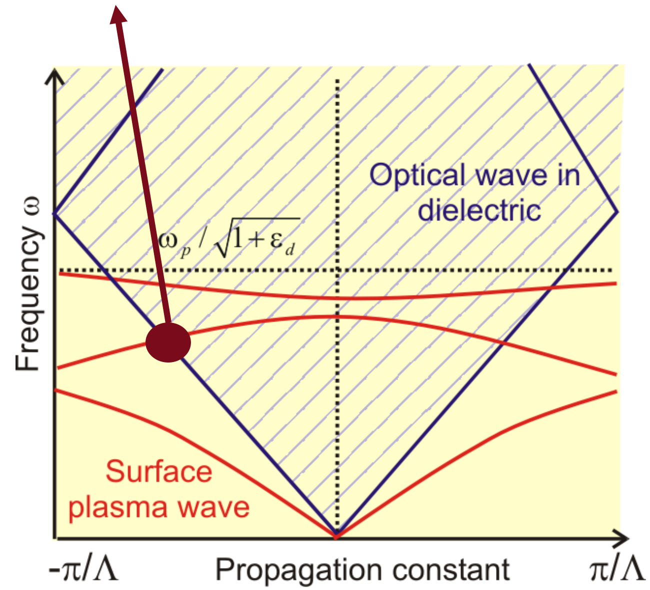
Grating Coupling to PSPs

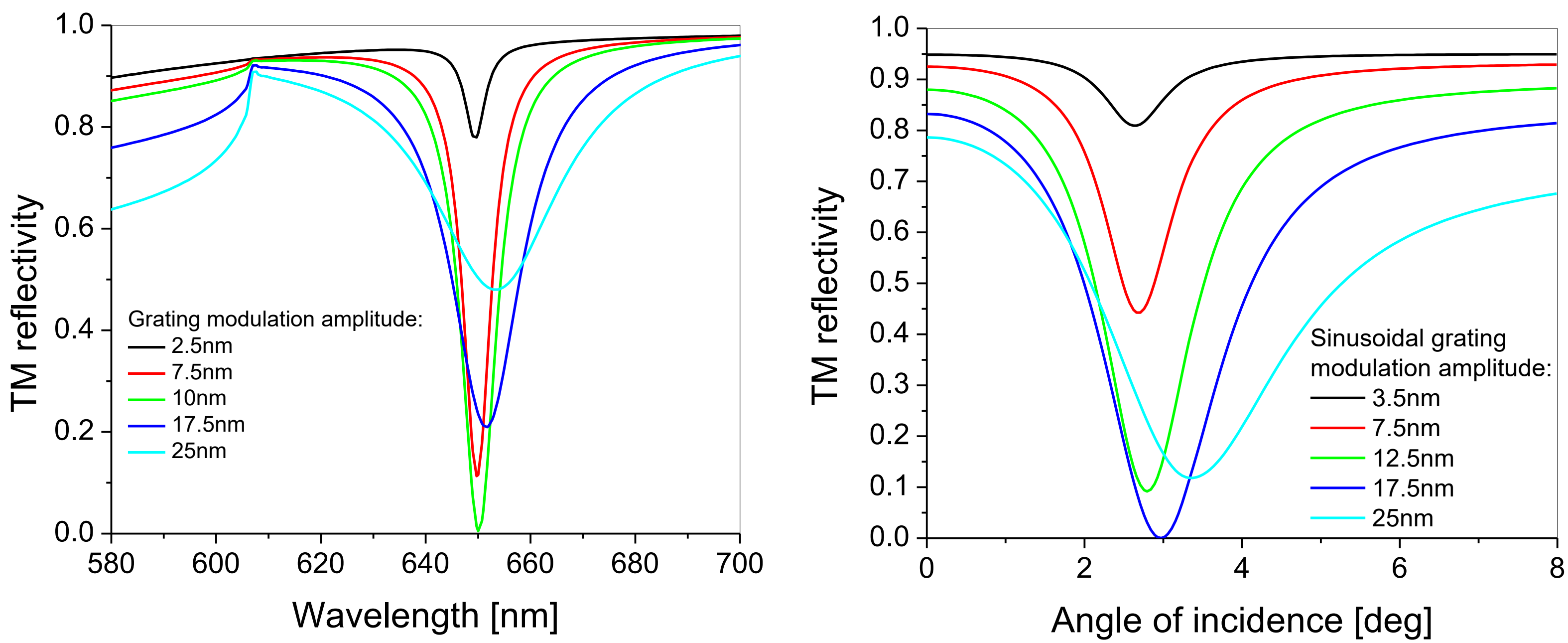
$$\mathrm{Re}\{\beta\} = \frac{2\pi}{\lambda} n_d \sin(\theta) \pm p \frac{2\pi}{\Lambda}$$





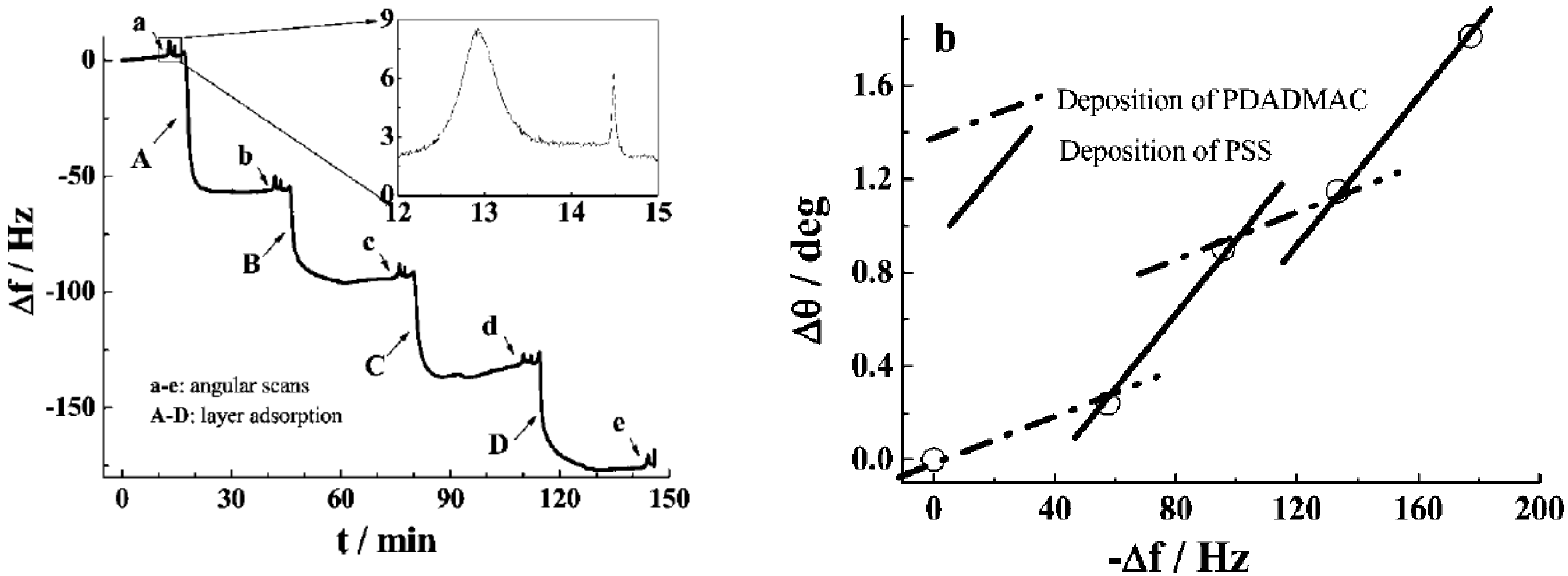
- Phase-matching can be investigated by using dispersion of the modes, manifested as a cross-section for certain diffraction order *p*.

Grating Coupling to PSPs



- On metallic diffraction gratings, the coupling strength to PSPs is controlled by the modulation depth.

QCM with Grating-Coupled SPR



- Demonstrated that upon LbL deposition the ‘optical’ and ‘acoustic’ thickness differs. Information on the viscoelastic properties, bound water molecules, ions….

Analytical Chemistry, Vol. 80, No. 13, July 1, 2008

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Analytica Chimica Acta 558 (2006) 150–157

ANALYTICA CHIMICA ACTA

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In situ electrochemical and surface plasmon resonance (SPR) studies of aniline-carboxylated aniline copolymers

Yanju Wang, Wolfgang Knoll *

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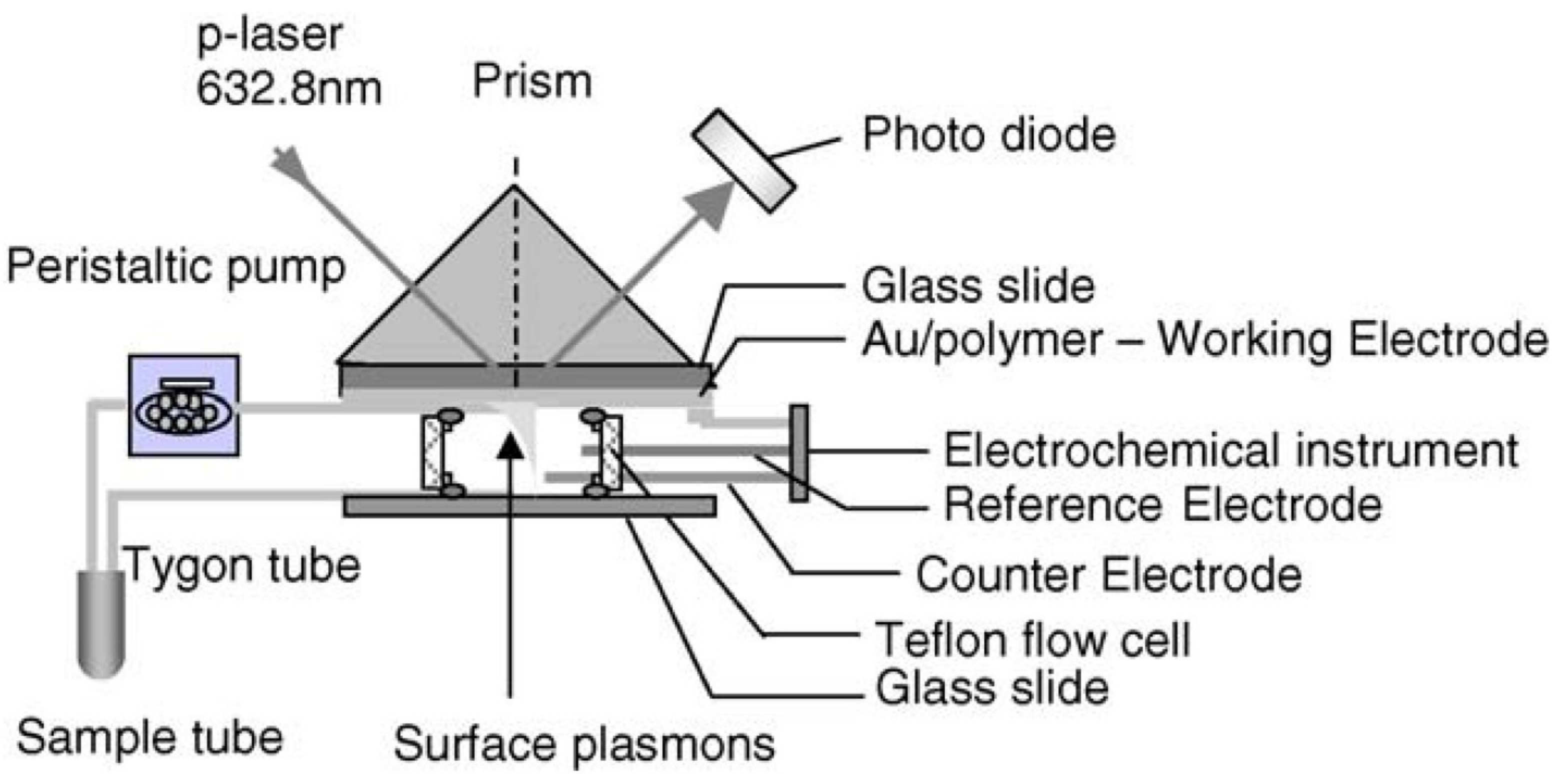
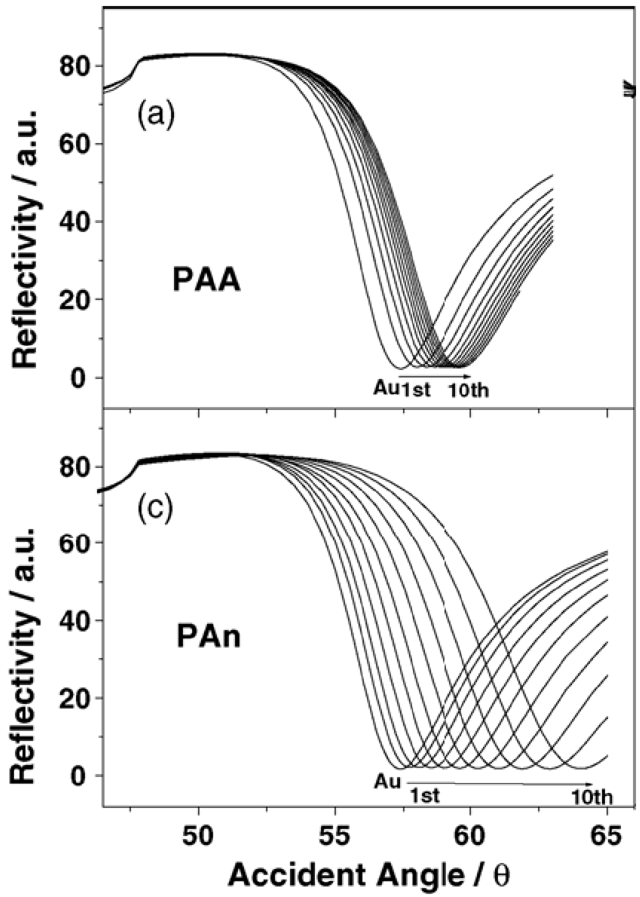
Received 23 August 2005; received in revised form 30 October 2005; accepted 1 November 2005
Available online 20 December 2005

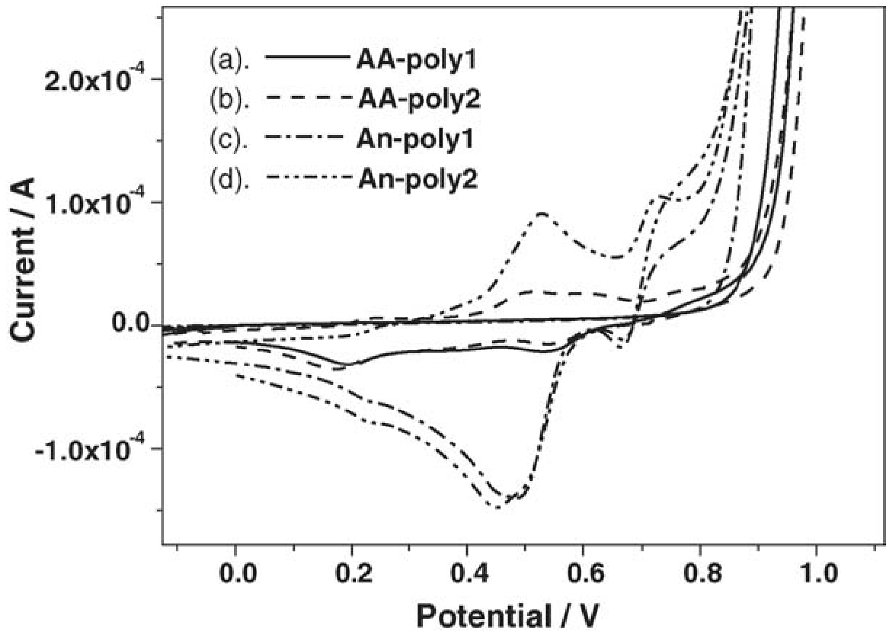
EC-SPR Setup



- SPR-active gold surface used as a working electrode.

EC-SPR Setup





- Cyclic voltammetry combined with SPR was used for the monitoring of polymerization and conductive polymer film stability.

Analytica Chimica Acta 558 (2006) 150–157

SPR Sensitivity to Ions on the Metallic Surface

Biosensors and Bioelectronics 126 (2019) 365–372

Contents lists available at ScienceDirect

Biosensors and Bioelectronics

journal homepage: www.elsevier.com/locate/bios

ELSEVIER

Biomolecular charges influence the response of surface plasmon resonance biosensors through electronic and ionic mechanisms

Hana Šípová-Jungová*,[1], Ludmila Jurgová, Kateřina Mrkvová, Nicholas Scott Lynn, Barbora Špačková[1], Jiří Homola*

Institute of Photonics and Electronics, Czech Academy of Sciences, Chaberská 57, 182 51 Prague, Czech Republic

- 1) the formation of an electrical double layer (**ionic mechanism**), and 2) changes in the electron density at the surface of a metal (**electronic mechanism**).

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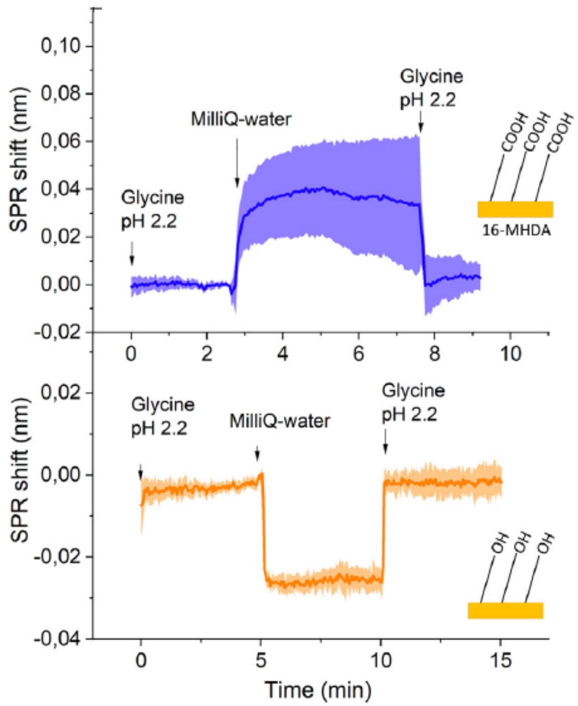
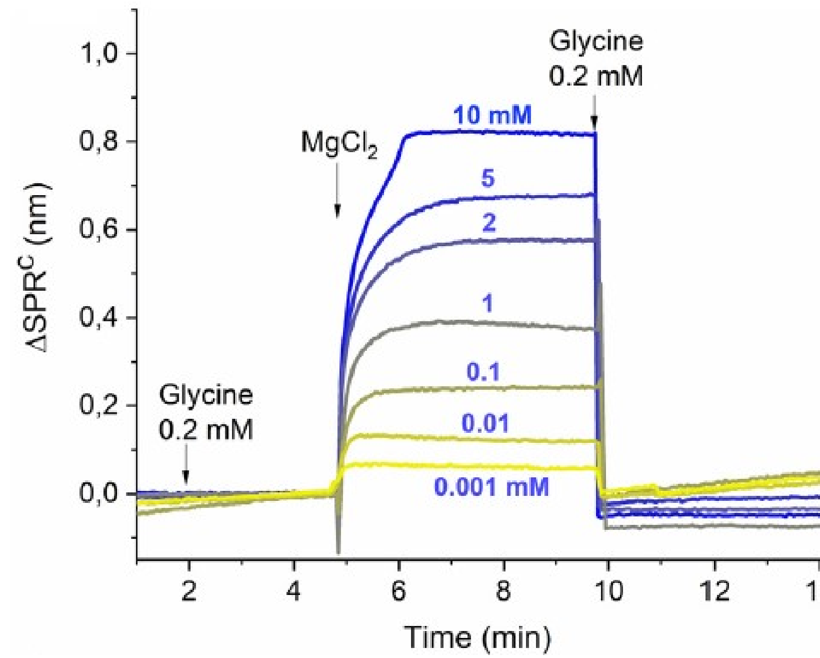
SPR Crosstalk With Ions on the Metallic Surface



Metal RI change

$\omega = \ldots m_e c$

Dielectric RI change



- Under low ionic strength conditions, the electronic mechanism is dominant and the SPR wavelength shift is linearly proportional to the surface concentration of biomolecular charges. At high ionic strength conditions, both electric and ionic mechanisms contribute to the SPR shift.

Field Effect Transistor (FET)

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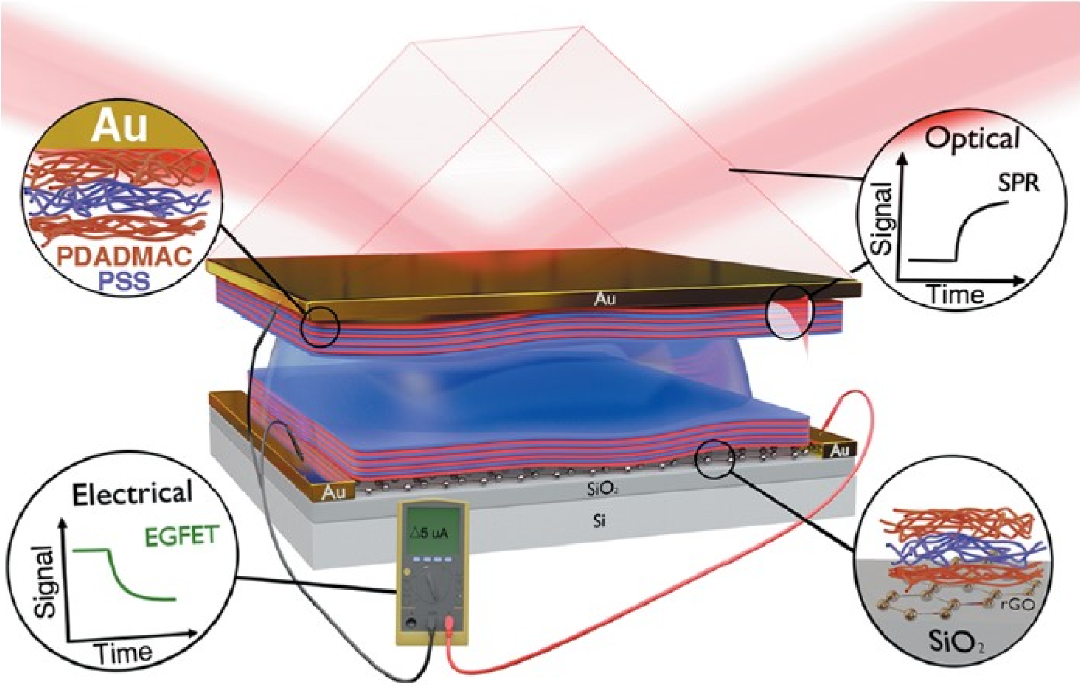
Article

Dual Monitoring of Surface Reactions in Real Time by Combined Surface-Plasmon Resonance and Field-Effect Transistor Interrogation

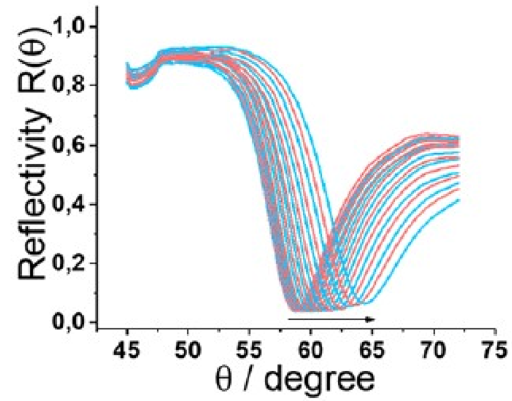
Patrik Aspermair,[⊥] Ulrich Ramach,[⊥] Ciril Reiner-Rozman, Stefan Fossati, Bernadette Lechner, Sergio E. Moya, Omar Azzaroni, Jakub Dostalek, Sabine Szunerits, Wolfgang Knoll, and Johannes Bintinger*

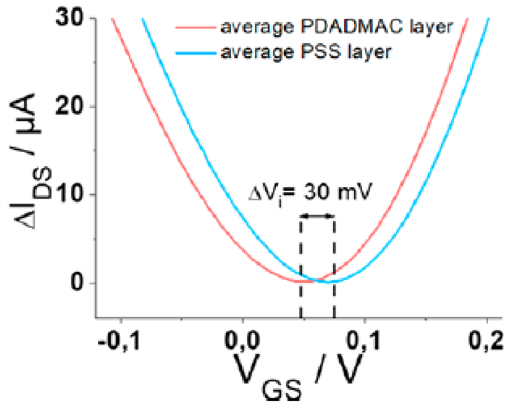
SPR Crosstalk With Ions on the Metallic Surface

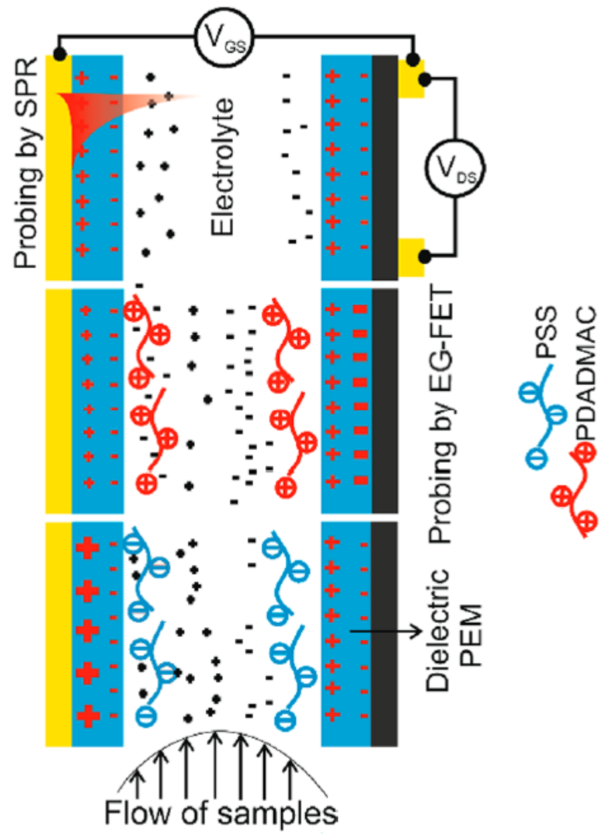


- SPR-active gold film used as a gate electrode in electrolyte-gated field-effect transistor.

SPR Crosstalk With Ions on the Metallic Surface

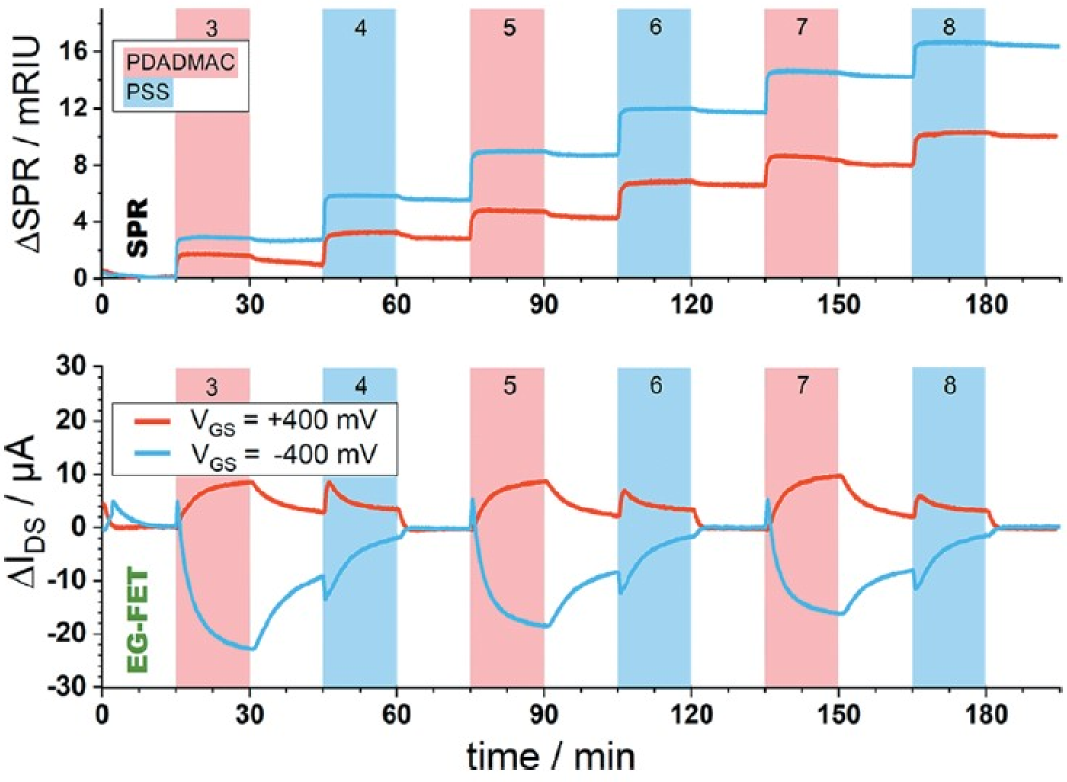






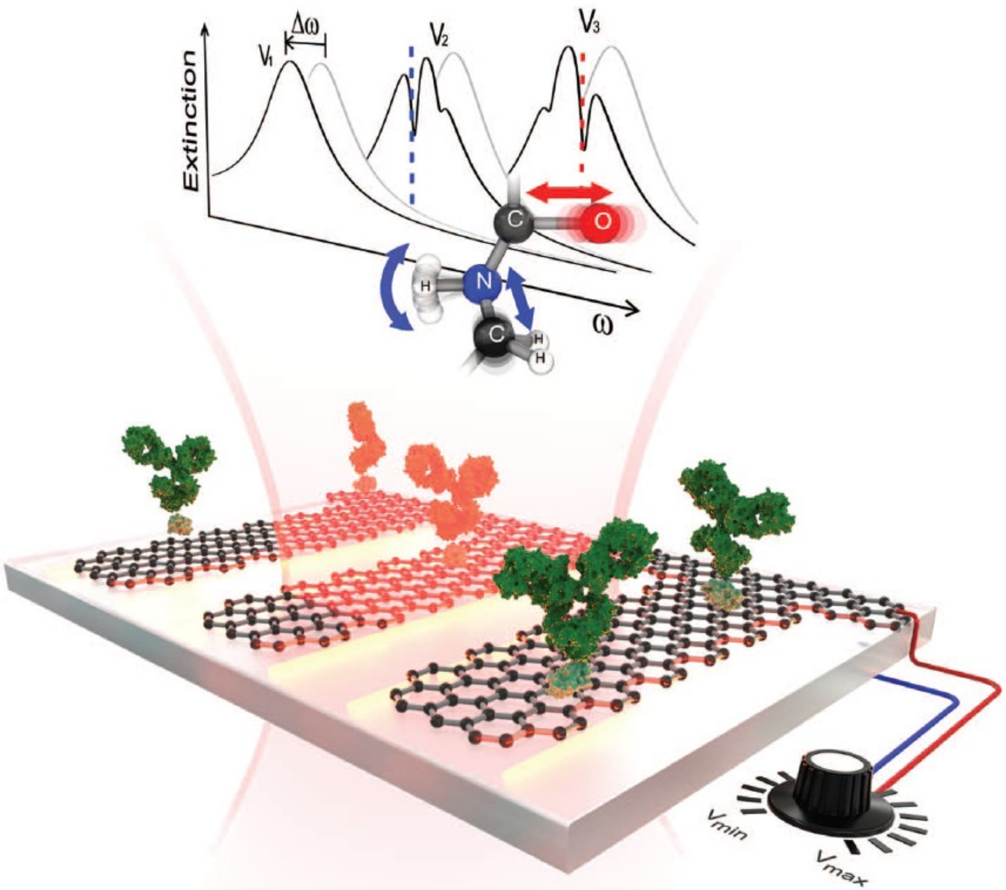
- Dual readout of the interfacial processes manifested by changes in the refractive index (SPR) and charge density (FET).

SPR Crosstalk With Ions on the Metallic Surface



- SPR and FET response kinetics are different and peeks on different aspects of the process of LbL formation.

Graphene Plasmonics



- Graphene is semiconductive material and exhibits surface plasmons in the NIR spectral range (lower plasma frequency)
- Its properties can be electronically tuned and thus enable for active tuning of its plasmonic properties.

10.1126/science.aab2051