PREFACE

EDITORIAL FOR BIOINTER*PHASES* IN FOCUS: SURFACE PLASMON RESONANCE-PLASMONICS

Bo Liedberg
Division of Molecular Physics, Linköping University, S-58183 Linköping, Sweden

Optical characterization of ultrathin films and interfaces using surface plasmon polariton or surface plasmon resonance (SPR) excitation in "free-electron-like" metals of gold and silver was pioneered by two research groups from Germany in the late 1960s.[1,2] They showed that the SPR phenomenon could be excited optically by the method of attenuated total reflection (ATR) either via a very thin air gap-"the Otto configuration"-or by a route where the thin metal film was deposited directly on the base of a glass prism-"the Kretschmann configuration." Both methods were extensively used to study fundamental optical properties of thin metal films and inorganic/organic coatings deposited on top of the metal film surface. In the following years the SPR-ATR approach became very popular for studies of monomolecular assemblies of Langmuir–Blodgett films on metals[3] and later for the determination of molecular orientation[4] in such assemblies as well as for measurement of refractive index changes occurring during phase transitions in liquid crystals.[5] Many innovative approaches describing the use of SPR-ATR for studies of smooth, roughened, and layered architectures have been summarized in reviews by Boardman[6] and Raether.[7]

The Kretschmann configuration has prevailed as the most attractive mode of operation primarily because of its advantages for applications in complex, opaque, and highly scattering fluids. This opened for real time monitoring of biomolecular recognition events at surfaces, an application of SPR that was demonstrated for the first time in the early 1980s by Liedberg *et al.*[8] The work attracted considerable interest in academia as well as in industry, and in 1990 Pharmacia Biosensor AB (today GE Healthcare-Bioscience) launched the first instrument in a series (BIACORE 1000) for biospecific interaction analysis.[9] The bioanalytical and biosensor applications of SPR have dominated the open literature since then although the technology has been employed in many other areas as well, e.g., for studies of biomaterials, protein adsorption phenomena, and electrochemical reactions at electrodes. A series of excellent reviews and books on SPR for bio- and chemical sensings has been published over the years.[10,11]

In 1987 and 1988 Yeatman and Ash[12] and Rothenhäusler and Knoll[13] published the first papers on SPR microscopy or imaging surface plasmon resonance (iSPR) for the examination of patterned surface architectures with a spatial resolution on the micrometer length scale.[14,15] The research and development of iSPR setups have gained considerable momentum during the past ten years, in part to meet the increasing demands put forward by the proteomics and high throughput screening communities. Even though the technology is available, still many challenges remain to be solved before being able to apply iSPR for large scale label-free protein analysis. For example, the nonspecific effects due to the stickiness of proteins to surfaces and the limited shelf life of protein biochips are examples of very challenging problems that need to be carefully addressed and solved. Nevertheless, several examples of relatively small (<100 spots) and highly specialized microarrays have been successfully developed and employed.[16–18]

SPR also has been successfully combined with other surface analytical techniques for multiparameter characterization of surfaces and sensing. Gordon II and Ernst used a combination of SPR and electrochemistry to study electrode reactions[19] and Zhang *et al.* reported on the progress in this particular field in a recent survey.[20] In 1991 Attridge *et al.* introduced surface plasmon fluorescence spectroscopy (SPFS) for simultaneous label-free monitoring of binding events and enhanced emission of capture fluorophores.[21] In one of the invited contributions of the current Focus Issue of Bio*interphases*, Dostálek *et al.* reviewed the progress in the field of SPFS, and they showed that subfemtomolar concentrations of the target molecules can be detected by taking advantage of the electromagnetic field enhancement and resonant excitation in combination with efficient collection optics.

Evanescent ATR excitation of surface plasmons in planar geometries is today a well established technology. More recently, however, the research focus on SPR has been directed toward studies of so-called localized surface plasmon resonance (LSPR).[22] Both SPR and LSPR are associated with excitation of collective oscillations at the surface of a metal, but LSPR occurs in objects that are much smaller than the wavelength of the radiation used, for example, in nanoparticles, nanoholes, or periodic/aperiodic patterns thereof. The current issue of Biointer*phases* presents two minireviews that compare the sensitivity and figure of merit of LSPR in nanoparticles and nanoholes with traditional SPR. In a third contribution gold nanoparticles are used as a strategy to prepare diffractive grating for DNA detection.

The present volume of Biointer*phases* contains four contributions related to SPR, SPFS, LSPR, and diffractive SPR, and they highlight recent developments and applications of SPR in diverse fields of biosensing and biologically inspired nanoscience and technology. Two more contribution will appear in the next volume and they are related to "ubiquitous affinity biosensing" where SPR is performed with consumer electronic devices as computer screens and web cameras, and "bio-organism sensing via surface enhanced Raman spectros-

copy on controlled metal/polymer nanostructured substrates."

The author would like to express his sincere thanks to Dr. Stefan Löfås and GE Healthcare-Bioscience for the support and generous sponsorship of this Focus issue on surface plasmon resonance.

[1]E. Kretschmann and H. Raether, Z. Naturforsch. B **23A**, 2135 (1968).
[2]A. Otto, Z. Phys. **216**, 398 (1968).
[3]I. Pockrand, J. D. Swalen, J. G. Gordon II, and M. R. Philpott, Surf. Sci. **74**, 237 (1978).
[4]G. J. Sprokel, R. Santo, and J. D. Swalen, Mol. Cryst. Liq. Cryst. **68**, 29 (1981).
[5]K. C. Chu, C. K. Chen, and V. R. Shen, Mol. Cryst. Liq. Cryst. **59**, 97 (1980).
[6]*Electromagnetic Surface Modes*, edited by A. D. Boardman (Wiley, New York, 1982).
[7]H. Raether, *Surface Plasmons on Smooth and Rough Surfaces and On Gratings* (Springer-Verlag, Berlin, 1988).
[8]B. Liedberg, C. Nylander, and I. Lundström, Sens. Actuators **4**, 299 (1983).
[9]M. Malmqvist, Nature (London) **361**, 186 (1993).
[10]J. Homola, *Surface Plasmon Resonance Besed Sensors*, Springer Series on Chemical Sensors and Biosensors, Methods and Applications Vol. 4, edited by O. Wolfbeis (Springer, Heidelberg, 2006).
[11]J. Homola, Chem. Rev. (Washington, D.C.) **108**, 462 (2008).
[12]E. M. Yeatman and E. A. Ash, Electron. Lett. **23**, 1091 (1987).
[13]B. Rothenhäusler and W. Knoll, Nature (London) **332**, 615 (1988).
[14]E. M. Yeatman, Biosens. Bioelectron. **11**, 635 (1996).
[15]J. M. Brockman, B. P. Nelson, and R. M. Corn, Annu. Rev. Phys. Chem. **51**, 41 (2000).
[16]H. J. Lee, D. Nedelkov, and R. M. Corn, Anal. Chem. **78**, 6504 (2006).
[17]G. Klenkar, R. Valiokas, I. Lundström, A. Tinazli, R. Tampé, J. Piehler, and B. Liedberg, Anal. Chem. **78**, 3643 (2006).
[18]G. Klenkar and B. Liedberg, Anal. Bioanal. Chem. **391**, 1679 (2008).
[19]J. G. Gordon II and S. Ernst, Surf. Sci. **101**, 499 (1980).
[20]N. Zhang, R. Schweiss, Y. Zong, and W. Knoll, Electrochim. Acta **52**, 2869 (2007).
[21]J. W. Attridge, P. B. Daniels, J. K. Deacon, G. A. Robinson, and G. P. Davidson, Biosens. Bioelectron. **6**, 201 (1991).
[22]M. E. Stewart C. R. Anderton, L. B. Thompson, J. Maria, S. K. Gray, J. A. Rogers, and R. G. Nuzzo, Chem. Rev. (Washington, D.C.) **108**, 494 (2008).

PREFACE

BIACORE SYSTEMS: LEADING THE REVOLUTION IN LABEL-FREE INTERACTION ANALYSIS

Stefan Löfås
GE Healthcare Bio-Sciences AB, Rapsgatan 23, SE-751 84 Uppsala, Sweden

Over the past two decades, label-free interaction analysis has developed into a widely accepted tool for a range of different applications within life science research and drug discovery. The main driver in this revolution has been the Swedish company Biacore AB (part of GE Healthcare since 2006). In 1990 it commercialized an analytical biosensor instrument system based on surface plasmon resonance (SPR) detection, thereby opening up a completely new way to monitor and quantify interactions between proteins and other biomolecules. In particular, this real-time detection method enabled high-quality affinity and kinetics data to be conveniently obtained, opening up a new era for the detailed characterization of biomolecule binding properties.

SPR-based analysis is now widely accepted, as demonstrated by the thousands of Biacore™ instruments sold and the ever-increasing stream of peer reviewed articles based on their use. For example, in 2008, the number of published articles quoting the use of Biacore systems is expected to reach over 10 000.

The selection of the optical phenomenon SPR as the detection principle in Biacore instruments for biomolecular interaction studies was based on its high sensitivity relative to other label-free detection principles. The ability to combine the detection method with advanced microfluidics handling and a range of surface chemistries for different applications into a fully integrated system was also a major advantage.

SPR can be conveniently miniaturized to provide multiple detection areas on one sensor chip, which improves the analysis throughput and referencing capabilities. Indeed, the first Biacore instrument had four detection areas on each sen-

sor chip and these were individually addressable via the microfluidics system. Later systems have increased these numbers (e.g., 20 detection areas in Biacore A100 or 400 in Biacore Flexchip), facilitating their use in different types of screening applications. The gold-coated sensor surfaces are also ideal for developing a variety of chemistries to enable the attachment of different types of biomolecules and for minimizing nonspecific binding.

The technology and applications for SPR-based label-free analysis have developed tremendously since the first Biacore instrument was launched. For example, direct analysis of the binding of small-molecule drug candidates to their immobilized protein targets are now standard applications for systems such as Biacore T100. As evidenced by this special edition of Biointer*phases*, the research focus on SPR continues with high intensity and helps drive the development of new instruments and applications. GE Healthcare is dedicated to continue this lead in the future.