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SURFACE PLASMON RESONANCE IN APPLICATION TO IMMUNOSENSING

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Aim. To compare two antigen–antibody assay methods and demonstrate the advantages of the more modern surface plasmon resonance (SPR) method over the traditional enzyme-linked immunosorbent assay (ELISA), as well as to highlight the achievements obtained using the SPR method.

Methods. A review of published articles was conducted. The results and achievements reported in studies employing the SPR method in medical and biological research were analyzed.

Results. It has been shown that the SPR method enables real-time, label-free monitoring of molecular interactions at a surface, unlike ELISA. This makes it possible to apply SPR-based immunosensors in immunological studies for the analysis of various biochemical analytes. Proteins, toxins, allergens, and various drugs can be detected using specific antibodies as sensing elements, providing high sensitivity and selectivity. The SPR method also enables more accurate determination of the kinetic characteristics and equilibrium constants of molecular interactions.

Conclusions. Thus, the SPR method offers significant advantages over traditional ELISA in many respects. It provides accurate results and deeper insight into the equilibrium and kinetics of antigen–antibody interactions.

Key words: surface plasmon resonance (SPR), biosensors, biomolecule detection, immunosensors.

The background of the SPR method and its major characteristics

he SPR method is widely used in various scientific and technological applications, particularly in biosensors for studying molecular interactions [1, 2]. SPR is based on the excitation of surface plasmons through the interaction of light with a metal surface. Surface plasmons are collective oscillations of conduction electrons at the interface between a thin metal film and a dielectric medium [3, 4]. These oscillations generate an evanescent electromagnetic field on the opposite side of the thin metal film [5, 6]. Monochromatic laser light is used to excite a surface plasmon wave at the sensing surface, and the angle of the reflected light is measured. These oscillating electromagnetic fields are extremely sensitive to small changes in the refractive index of the dielectric medium near the sensing interface, where various binding events and molecular interactions can be detected. Upon adsorption of the analyte onto the sensing surface, changes in the local refractive index cause a shift in the angle of reflected light and, consequently, in the surface plasmon resonance angle. When the resonance condition is met, a characteristic dip, or minimum, in the intensity of the reflected light is observed as a function of the angle of incidence [7].

Because this phenomenon is particularly sensitive to changes in the refractive index near a thin layer of a noble metal (gold or silver), whose thickness is smaller than the wavelength of light, interactions between molecules—one immobilized on the surface and the other present in solution—can alter the refractive index within the surface layer, thereby changing the characteristics of the surface plasmons, as reflected by a shift in the recorded resonance angle of the reflected light [8]. Changes in the refractive index within the thin layer near the surface provide an effective

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means of detecting molecular binding events in the surrounding solution. The resonance angle (RA) in SPR changes proportionally to the density of biological molecules within the evanescent field (< 500 nm) at the surface of the metal film opposite the incident light beam. Changes in the RA are recorded to provide information on intermolecular interactions at the surface (Fig. 1).

Thus, no labeling is required to detect molecular binding to the surface in real time. Time-dependent changes in the refractive index (RI) within the evanescent field at the metal surface can be used to assess biomolecular interactions and estimate the kinetic and equilibrium constants that characterize these interactions. SPR measurements are commonly performed in a flow-through configuration, with a microfluidic flow cell positioned over the sensor surface to deliver samples and reagents. This configuration provides precise control over mass transport, analyte concentration, and reaction time [10].

The SPR method enables the study of reversible interactions at interfaces based on their affinity [11, 12]. A typical SPR experiment begins by inserting the sensor into the instrument and priming the microfluidic system with a buffer. The ligand (usually a protein) is then injected and immobilized on the sensor surface, either through covalent coupling or using a capture-based method. The sensor type and immobilization conditions (e.g., coating type, ligand concentration, buffer composition, and pH) should be optimized for the specific interaction being studied. Next, the analysis is initiated, and the data are presented as a sensorgram. The sensogramdisplays time on the x-axis and the binding response on the y-axis, as shown in Fig. 2.

During the baseline phase (1), the buffer flows across the sensor surface, conditioning the sensor and allowing any instabilities to be detected. This step is critical for ensuring a stable baseline and obtaining accurate results. The association phase (2) is initiated at $t = 0$, when the flow system introduces the analyte. Analyte binding to the sensor surface increases the signal, from which the association rate constant (k_{on}) can be determined. The steady state is reached when the sensogramreaches a plateau. At this stage (3), the amounts of analyte associating with and dissociating from the ligand are equal, allowing the equilibrium dissociation constant (K_d) to be calculated.

The dissociation phase (4) begins when the analyte solution is replaced with buffer, allowing the dissociation rate constant (k_{off}) to be determined. If the ligand–analyte complex has a long half-life, a regeneration phase may be necessary (5). This involves introducing a solution that disrupts the ligand–analyte interaction, thereby restoring the signal to its original baseline. Solutions with high salt concentrations or low pH are frequently used for sensor regeneration.

Thus, this method enables the measurement of various association and dissociation rates and binding affinities derived from the sensorgram. The sensogramis a real-time plot of the binding signal as a function of time. The association and dissociation rate constants (k_{on} and k_{off}, respectively) are derived from the association and dissociation phases, while the equilibrium dissociation constant is calculated as $K_D = k_{off}/k_{on}$. When molecules bind to a surface, they alter the local refractive index near that surface. SPR detects these

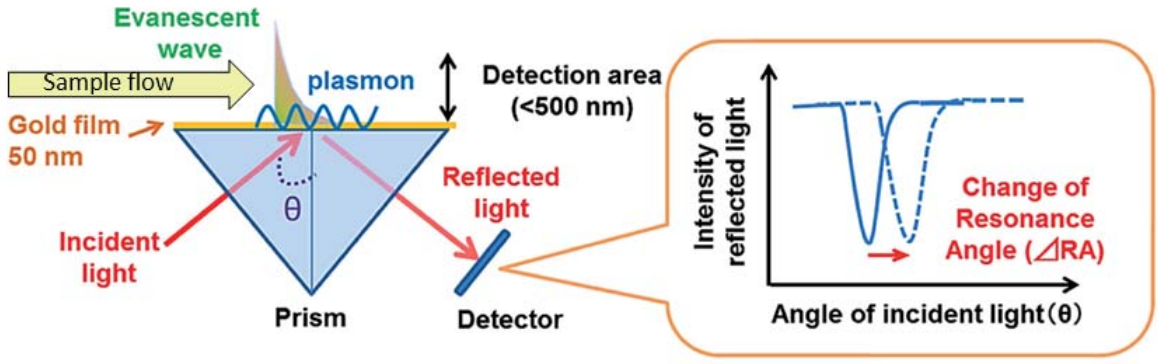

Fig. 1. **Principle of surface plasmon resonance (SPR) sensing [9]**

These sensors detect changes in the refractive index (RI) within the detection region (< 500 nm), which are manifested as changes in the resonance angle (RA) at which the intensity of the reflected light decreases sharply.

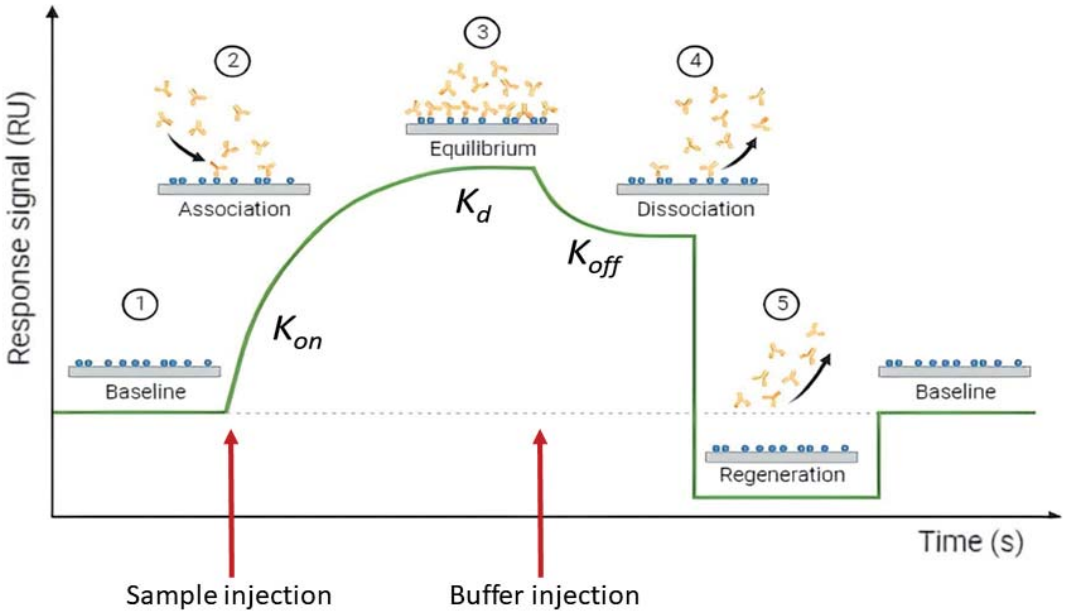

Fig. 2. **A typical kinetic sensogramwith all five phases annotated [10]**

changes optically and reports them as a signal, typically expressed in response units (RU) or millidegrees. Plotting this signal continuously throughout an experiment produces a sensorgram. Several focused publications [8, 13–15] provide practical details on the operation of the SPR method. In some cases, complex kinetics may be observed, which can provide additional information [16].

Comparison of SPR and ELISA in information content and practical applications

Immunosorbent analysis, commonly known as ELISA (Enzyme-Linked Immunosorbent Assay), is a biochemical technique widely used to detect and quantify substances such as proteins, antibodies, and hormones in a sample. It works by using antibodies that "recognize" specific targets and an enzyme that triggers a measurable signal when those targets are present. Usually, this signal is recorded as a change of color in 96-well plates. Binding is detected via a secondary reaction that is produced by the label and measured with microplate readers. The application of ELISA allows choosing different formats of analysis:

– Direct ELISA: The analyte (antigen) is attached to the plate, and an enzyme-linked antibody binds to it directly.

– Indirect ELISA: A primary antibody binds the analyte first, and then a second, enzyme-linked antibody binds to the primary one, which allows detecting antibodies.

– Sandwich ELISA: The analyte is bound between two different antibodies. This is a highly sensitive and widely used method for measuring specific proteins.

– Competitive ELISA: When the analyte is very small, the target competes with a labeled version for binding; a weaker signal actually means a higher concentration in your sample.

In the meantime, the term "immunosorbent analysis" can be equally well applied to SPR when it is operating with antibodies. According to Wikipedia, the name "immunosorbent" comes from its two key features. *Immuno*: It uses components of the immune system (antibodies or antigens) to bind specific molecules. *Sorbent*: The target molecule is "sorbed" (attached) to a solid surface. As we saw above, SPR is an optical technique used to monitor protein adsorption and surface interactions without any labeling. Thus, different assay formats can also be realized with this technique. As a label-free, real-time assay, SPR overcomes many of the limitations of ELISAs while providing greater sensitivity and specificity for challenging applications. Moreover, in contrast to ELISA, which requires antibodies of relatively high affinity so that the complex formed must withstand the incubation and washing steps, the SPR method allows direct, real-time observation of analyte binding, capturing the kinetics towards equilibrium. Below, we provide a side-

A side-by-side comparison of SPR vs ELISA techniques for biomolecular detection

Characteristics	SPR	ELISA
Data measurement	Registration of the kinetics of binding-release of the analyte in real time	The end-point assay can measure and quantify high-affinity proteins and antibodies
Label requirement	The method is essentially label-free	The use of tagged antibodies and substrates to generate a measurable signal
Kinetic analysis	The possibility to measure both the binding affinity and the kinetics of binding-release of the analyte	Does not provide information on the kinetics between the target and the bound biomolecule
Low-affinity interactions	The sensitivity is sufficient to measure low-affinity events	Limited because of applied multiple plate washing procedures
Measuring multiple samples	Possible with special instrumentation (multiplex assays, imaging)	Easily applicable
Measuring low mol. weight samples	Possible in indirect immunoassays (e.g., sandwich format)	Easily applicable
Operating cost	The cost of instrumentation may be high and include the cost of its maintenance	A highly cost-effective and accessible analytical tool for a multitude of assays
Length of experiment	Sensor preparation and washing steps are fast (~1 h) and can be completed in the SPR instrument itself	An experiment includes long coating, incubation, washing, blocking, and signal generation steps that may take ≥ 24 h.

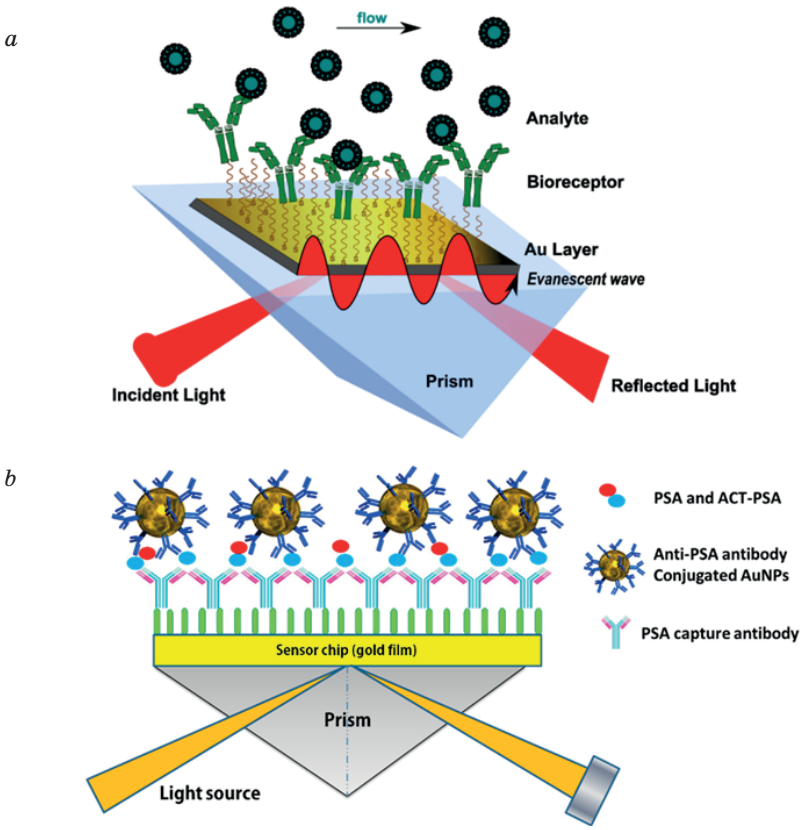

Fig. 3. **Schematic representation of the SPR immunosensors:**
a — Typical configuration with immobilized antibodies [24]; *b* — Sandwich assays performed on SPR sensors with small-sized analytes using secondary antibodies conjugated to gold nanoparticles [12]. An antibody-modified surface is followed by binding of a free antigen, then a secondary antibody-Au conjugate.

by-side comparison of ELISA and SPR to assess the overall usability of each technique based on a literature review [13, 17–20].

Typical application formats for SPR biosensors are presented below (Fig. 3). In one case, the antibodies are immobilized on the sensor surface, and the analyte molecules interact with them in solution, generating the sensor response. In direct SPR biosensors, analyte quantification is achieved by detecting the binding reaction directly. However, the increase in the refractive index produced by the adsorption of small molecules may not be sufficient to be detected directly, so that sandwich [21] or competitive [22] assay methods may be used. Thus, all formats developed for ELISA assays can be realized here, including the application of secondary antibodies [23].

The sensitivity of SPR immunosensors can be greatly enhanced by the application of gold nanoparticles (Au NPs) that immobilize secondary antibodies (see Fig. 3, ***b***). The signal is based on the fact that, upon addition of the linked Au NPs, a pseudo-mass increase of the analyte is induced. This mass change ultimately produces larger changes in the refractive index on the SPR surface [25]. This technique resembles a sandwich immunoassay. Picomolar detection of human immunoglobulin G has been achieved using particle enhancement, with the technique's theoretical limit much lower.

Thus, in many aspects of analytical performance, the SPR technique can compete with ELISA, demonstrating essential advantages [8]. It offers much faster acquisition of results and higher information content on binding equilibrium and kinetics without the need for labeling or label detection. Because the measurement is continuous and label-free, the sensogramcaptures the full kinetics of the interaction — not just an endpoint. This is what makes SPR fundamentally different from techniques like ELISA, which only report whether binding occurred, not how fast it formed or fell apart.

Affinity sensing at interface

The key element of any biosensor, and of the SPR sensor in particular, is its interface that interacts with the analyte and provides a signal from this interaction [11, 27]. A necessary step to achieve both accurate and reliable detection with SPR is to select and apply robust, effective interfaces that enable sensing of a variety of molecular interactions in a highly selective and sensitive manner. An effective recognition layer should be developed to achieve the required sensitivity and maximize the selectivity of the SPR sensor [28, 29]. The self-assembled monolayer on a glass plate covered with a thin layer of gold is commonly used. On the next step, the immobilized interacting partner is commonly attached by a covalent bond. The common practice of using disposable chips imposes stringent requirements on their stability and reproducibility. Integration of the metal substrate, the recognition element, and the linker is required, and there is a broad range of choices for these elements (Fig. 4).

To cover the gold plate, various zwitterionic compounds are used, often involving –SH groups that interact directly with the gold layer. Among these compounds can be proteins, such as peroxidase [30]. As the linkers, thiol derivatives of dextran and its derivatives are commonly used. Aldehyde-dextran sulfonates were developed and applied in research with the participation of the present author [31, 32]. They possess the advantage of the presence of two active functional groups in the matrix, namely, aldehyde and sulfonate, that are responsible for both covalent bonding in the biomaterials and for the electrostatic attraction of the positively charged biomolecules.

Versatile application field of the SPR technique

The first publications on SPR in analysis appeared in the early 1980s, and immunochemistry was the first area in which they were proposed for application [33, 34]. However, the introduction of SPR into research and the practical field at that early time was slow due to the complexity and high cost of instrumentation. Systematic development of SPR biosensor technology by Swedish BIAcore AB (originally Pharmacia Biosensor AB) led to the launch of the first commercial SPR biosensor in 1990. Since then, the BIAcore sensor technology has been further refined in terms of speed, throughput, and accuracy. Important for further exploration of this technique was the development of simple, inexpensive instrumentation that can be built using existing technologies, with a focus on ease of use, robustness, sensitivity, and stability. A description of the available instrumentation can be found in the literature [14]. One of these developments was the

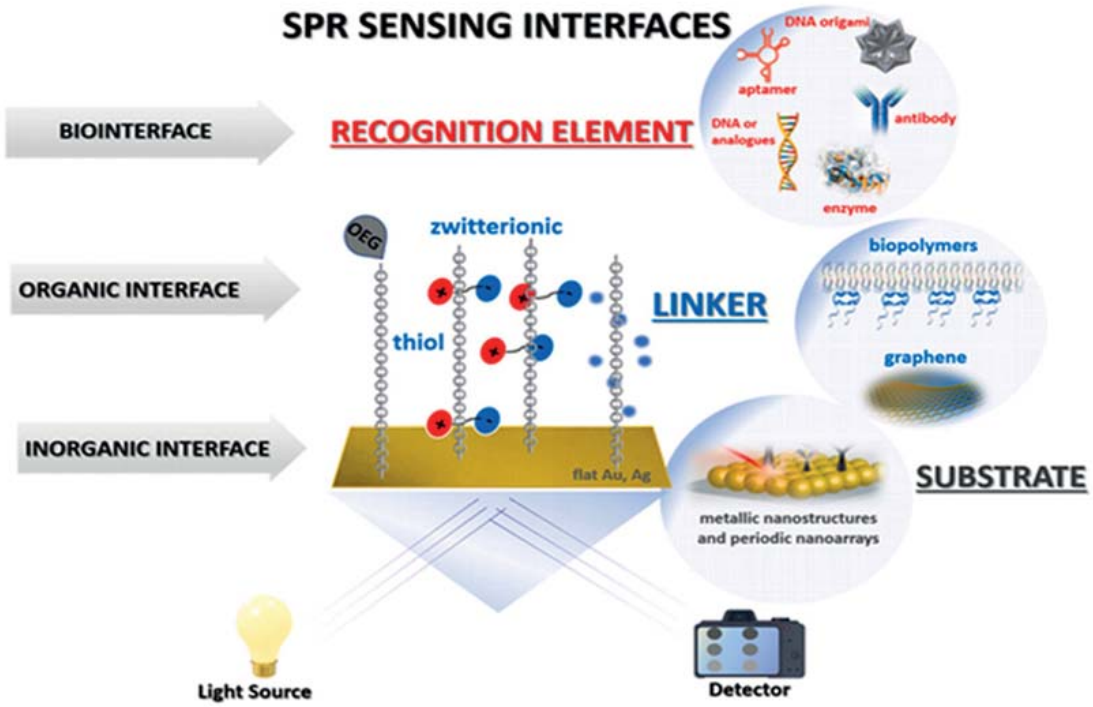

Fig. 4. **The scheme of different elements of an SPR sensing interface [15]**

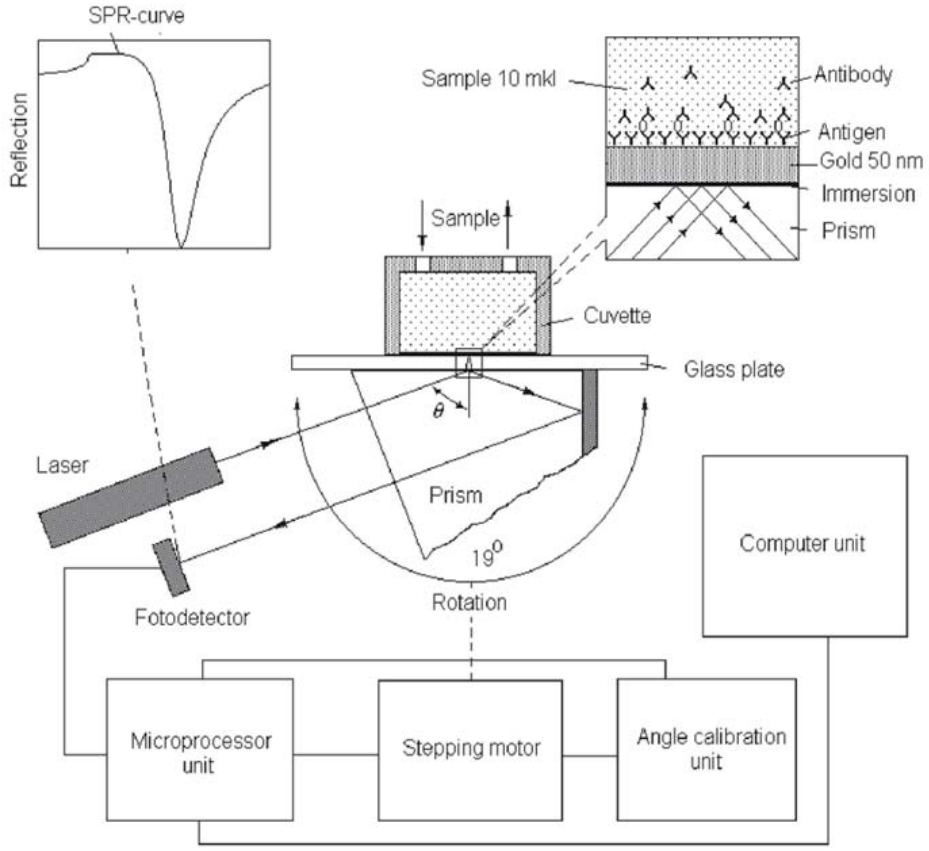

Fig. 5. **Simplified diagram of the sensor PLASMON-4m [35]**

construction of the PLASMON series of instruments at the Institute of Semiconductor Physics of the National Academy of Sciences of Ukraine [35]. Its schematic design is presented in Fig. 5.

Historically, SPR has been predominantly used in pharmaceutical research, where commercial instrumentation has been employed for drug discovery, antibody characterization, and studies of protein/enzyme inhibition. One of the most successful applications was in high-throughput drug screening [12]. Presently, the range of possibilities for designing an appropriate instrument and sensing interface is vast, allowing SPR to be tailored to an extraordinary variety of applications, whether in a research laboratory, a local hospital, or the field for environmental research.

The SPR method has found its road to clinics [36–38]. It proved efficient for diagnostics based on detecting cancer antigens as biomarkers [39–41]. Measurements of serum concentrations of therapeutic antibodies and anti-drug antibodies (ADA) can support clinical decisions for the management of non-responders, optimizing the therapy [42]. It is used to detect viruses [43]. Even whole cancer cells can be selectively detected by the SPR method [44]. Thus, cell-based clinical diagnostics can be enabled by SPR [9]. They became important tools in environment protection [45, 46].

The SPR instrument has become required in research laboratories. Due to the high sensitivity of this method, it is widely used for biochemical analysis of proteins, conjugative complexes, allergens, toxins, drugs, and pesticides across a wide concentration range, providing quantitative binding characteristics [47–49]. A classic example is the work [50], in which the thermodynamic parameters of the interaction between hen egg white lysozyme and Fab D1.3 were determined by measuring the temperature dependence of the ratio of its kinetic association and dissociation rate constants in the range from 5 to 40 °C. It was shown that the binding reaction was driven solely by enthalpy below 23 °C, by both enthalpy and entropy between 23 and 35 °C, and solely by entropy above 35 °C. Whereas calorimetric data pertain to all the components present in the sample, including solvent molecules, SPR measurements monitor only the physical association and dissociation of the two macromolecular species.

The applications of SPR in immunology

Surface plasmon resonance has been successfully incorporated into an immunosensor format for the simple, rapid, and unlabeled assay of various biochemical analytes [51, 52]. Proteins, complex conjugates, toxins, allergens, drugs, and pesticides can be determined directly using either natural antibodies or their fragments as the sensing element with high sensitivity and selectivity. In a classic format, antibodies act as ligands, and the analytical signal results directly from the specific binding of the target antigen. This format enables direct detection in samples, avoiding additional steps during either sample preparation or analysis. However, indirect formats, such as a sandwich or competitive/inhibition SPR assay, are preferable for detecting low-molecular-weight analytes or very low concentrations, thereby increasing sensitivity [37].

The immobilization of an antigen can be chosen, e.g., when this format allows for its convenient attachment. Given the high availability of universal coupling agents and protein conjugation methods, it is easy to adapt the SPR assay format to meet the requirements of the specific analysis. A wide range of molecules can be detected, with lower limits of detection ranging from 10^{-9} to 10^{-13} mol/L. By injecting unlabeled antibody samples onto a biosensor surface where antigen is immobilized at high density, the concentration of active antibodies can be accurately measured [53]. Various strategies for antibody immobilization were described [54]. They include random, covalent, oriented with adsorbed Protein A, followed by antibody binding, and covalent-oriented Protein A, followed by antibody binding. The oriented immobilization of antibodies can be achieved [55].

The determination of binding constants and stoichiometry for antibody-antigen interactions is well described in the literature [53]. It was interesting to compare the data from the SPR technique for the affinity of monoclonal antibody complexes with the results from the advanced ELISA procedure developed by Bobrovnik and Stevens [56, 57]. Bobrovnik showed that it is possible, by plotting a well-chosen graph, to obtain more precise and detailed information on the affinity constants and to detect the coexistence of several populations of complexes in solution. A simple non-linear fit of the same data to an

appropriate formula gives even better results. This method offers all the advantages of the conventional ELISA techniques discussed above and can also be applied to protein–protein or protein–nucleic acid interactions. The comparison with the SPR technique on the same system (fibronectin from human plasma as the antigen and the mouse anti-human fibronectin antibody) yielded interesting results [20]. The standard SPR procedure could not resolve the heterogeneity in antigen binding observed by Bobrovnik's method. However, recent developments allow the complex behavior of binding kinetics to be determined [16]. It was shown that this method allows for the resolution of the discrete-component kinetic parameters (association and dissociation rate constants) of the affinity interaction. Using surface plasmon resonance technology, it was found that the real-time association kinetics of Fabs specific for hen egg-white lysozyme did not conform to a 1:1 Langmuir association model. It was suggested to use the association-dissociation rate ratio as the characteristics of each antibody–antigen complex.

The application of the SPR technique contributed significantly to understanding the functional role of antibodies and their structural elements [58] in realizing the antigen-antibody recognition [59]. Both specific and nonspecific antibody binding play a role in the immune response, and this subject is better characterized by the SPR method [60].

With these tools, the scientists identified many possibilities for SPR applications in immunodiagnostics, with broad-scale clinical use [37, 61]. Modern medical diagnostics, ranging from screening tests for the rapid detection of disease biomarkers to the detection of viral and bacterial infections, are largely based on detecting specific, rare proteins [36, 62, 63]. A common feature of these analytes is their relatively large mass and the wide availability of high-affinity antibodies for their detection. Both features make protein biomarkers attractive SPR targets, enabling their direct determination. Many examples for monitoring antibodies, proteins, enzymes, drugs, small molecules, peptides, and nucleic acids in biofluids collected from patients afflicted with a series of medical conditions (Alzheimer's, hepatitis, diabetes, leukemia, and cancers such as prostate and breast cancers, among others) can be found in the literature. This demonstrates the rapid progress of SPR sensing in clinical chemistry.

Future directions

The parent SPR techniques give rise to many new technological solutions that provide instrumentation for various practical needs in immunochemistry [2, 13, 64]. Using disposable chips with immobilized antigen or antibody dramatically reduced the length and complexity of analysis. However, it raised the problem of reducing variability between chips. Hopefully, that finds successful solution [65, 66]. The operational challenges encountered with antibodies have led to the development of aptamers—oligonucleotide biomolecules rationally designed to adopt tertiary structures that enable high-affinity, specific binding to a wide range of analytes [67]. Aptamers have been extensively adopted in SPR biosensor setups with promising clinical and industrial prospects.

One of the difficulties inherent to conventional SPR, compared with ELISA, is its limited applicability to high-throughput applications, and we observe numerous efforts to overcome this limitation. The development of multiplex assays allows for the simultaneous detection of multiple antibodies in a single test, thereby enhancing work efficiency [68]. Various mechanisms and materials were identified that enable multiplexing across SPR platforms, including traditional prism-based SPR, localized surface plasmon resonance (LSPR), and SPR imaging (SPRi). By concurrently measuring multiple analytes, these techniques overcome the limitations of single-analyte assays, providing a more comprehensive disease profile [69]. Key applications of multiplex SPR systems are seen in medical diagnostics, employing immunosensor, aptasensor, and protein-based assays. The technical solutions include dividing flow cells into multiple channels, enabling simultaneous examination of various ligands or substances on distinct regions of the sensor surface.

The successfully realized possibility is the development of the SPR imaging (SPRi) systems [12, 69]. They can visualize a whole biochip using a CCD camera. See Fig. 6. Being the modified versions of the SPR design, they can simultaneously process hundreds or thousands of samples. Rapid optical arrays have found applications in the high-throughput screening of drugs and biomarkers, as well as in clinical diagnosis.

In addition to flat metal surfaces, SPR can be realized on metal nanoparticles, where plasmons are localized within their

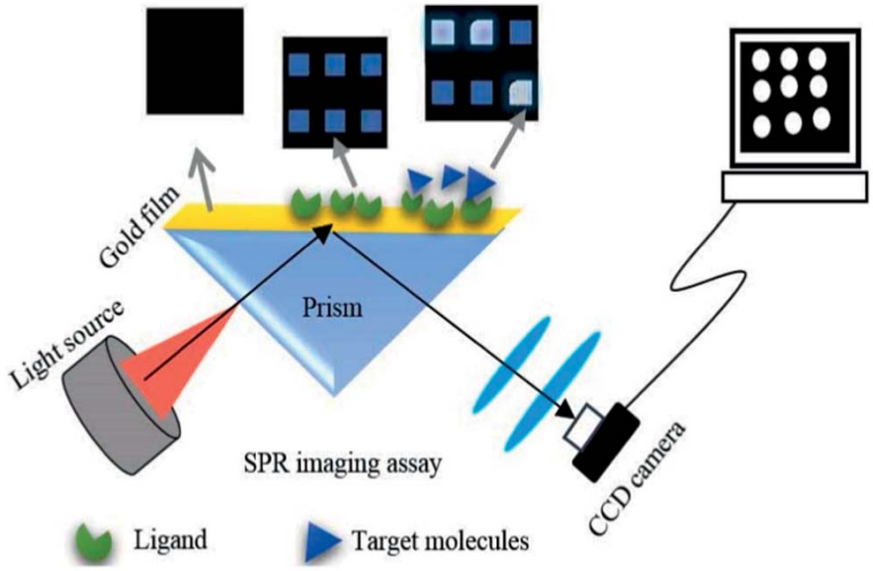

Fig. 6. **The instrumentation of a SPR imaging (SPRi) system [69]**
A monochromatic CCD camera captures reflected light from the gold surface, and the lenses are positioned in front of the camera to produce higher-quality images. Finally, images can be digitally stored using a frame grabber and further analyzed using photography software.

volumes, giving rise to the localized SPR (LSPR) technique [70]. LSPR excitation generates intense local electromagnetic fields that amplify spectroscopic signals and enable highly sensitive detection modalities. The confinement of plasmonic resonances at the nanoparticle scale enables higher sensitivity in LSPR-based sensors than in traditional SPR systems. LSPR sensors offer remarkable miniaturization potential, making them suitable for integration into compact diagnostic tools [71, 72].

Miniaturization of SPR instruments reached the portable, pocket-sized level. The development of portable SPR systems for *on-site* detection enabled the adaptation of commonly available instruments for use as detectors. Thus, the integration of SPR platforms with smartphones has been reported [73, 74]. Optical fibers connect the lightweight optical components and sensing elements on a phone case. By developing portable, cost-effective, and robust SPR systems, the technology could be adapted for use in areas with limited access to advanced healthcare infrastructure [75]. Such systems could facilitate rapid diagnostics for infectious diseases, water quality monitoring, and agricultural pathogen detection, addressing critical challenges in global health and sustainability. Innovations in device portability, affordability, and ease of use will be essential to realizing this vision, ensuring that the benefits of SPR reach underserved populations worldwide.

The SPR technique has progressed rapidly (Fig. 7). One of the latest developments is the application of artificial intelligence (AI) and machine learning (ML) to plasmonic and surface-enhanced sensing [76]. The advent of a new generation of AI and ML tools provides an opportunity to advance further the design, synthesis, and characterization of plasmonic materials, improve signal processing and image analysis in plasmonic sensing experiments, and design sensors with better sensitivity, selectivity, and robustness.

Conclusions

Surface Plasmon Resonance (SPR)-based biological detection systems have emerged as powerful tools for real-time, label-free biomolecular interaction analysis, revolutionizing fields such as diagnostics, drug discovery, and environmental monitoring (Fig. 8).

The center circle shows the engineering choices for the plasmonic nanostructures (geometry and composition) and the irradiation light (wavelength, pulse width, energy, etc.). The second inner circle represents the main phenomena: absorption, scattering, and the near field. The outer circle shows examples of various applications that exploit specific phenomena, based on the engineering choices.

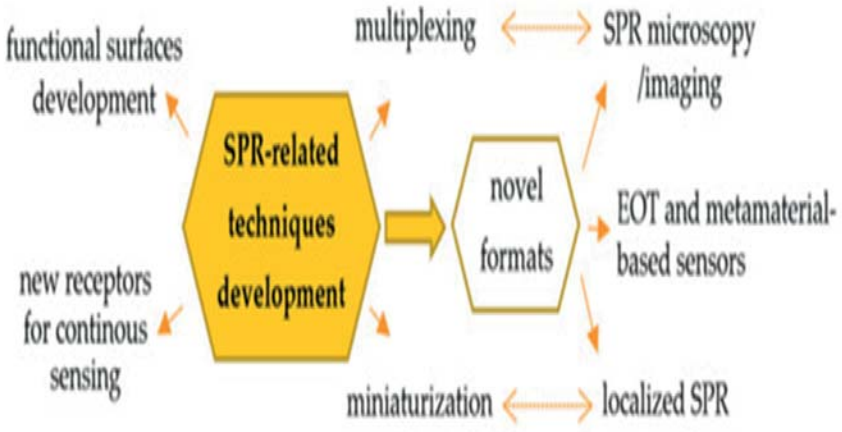

Fig. 7. **Current major trends in the development of plasmon-based immunosensors [61]**

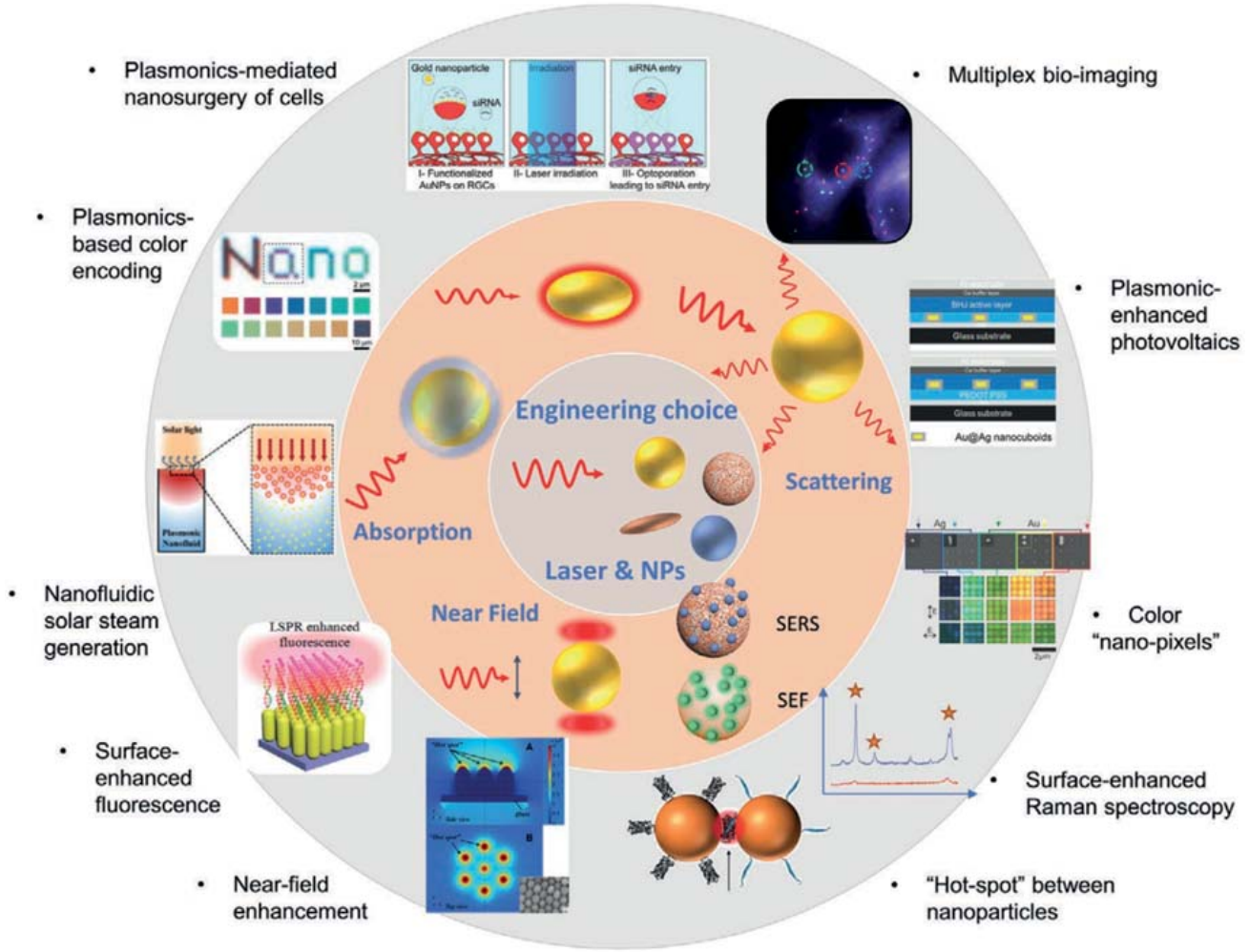

Fig. 8. **Schematic representation from plasmonic nanostructure design to applications [77]**

Regarding immunosorbent analysis, the past few decades have seen the emergence of surface plasmon resonance (SPR) as a preferred method for studying antibody detection over more traditional techniques such as ELISA. Modern SPR systems are distinguished by their capacity for real-time, label-free detection with extraordinary sensitivity, achieving picomolar and even femtomolar range and enabling comprehensive applications in biomolecular interaction analysis, clinical diagnostics, environmental surveillance, and pharmaceutical development. The progress in surface functionalization methodologies is evident. It includes the deployment of aptamers and molecularly imprinted polymers, which have greatly enhanced the specificity of molecular recognition. Integration with complementary technologies such as microfluidics and artificial intelligence has enabled high-throughput capabilities and optimized analytical performance, further broadening the potential applications of SPR biosensors.

The ongoing development of SPR technology is expected to drive groundbreaking advancements in multidisciplinary research and industrial practices. Innovations in plasmonic materials, advanced signal processing, and sensor miniaturization are likely further to expand the versatility and efficiency of SPR-based systems, solidifying their role as a cornerstone of modern science and technology. All these achievements are equally applicable to the detection of antigens and antibodies, which are widely needed in biochemistry and cell biology, as well as in medicine, agriculture, and other areas.

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ПОВЕРХНЕВИЙ ПЛАЗМОННИЙ РЕЗОНАНС В ІМУНОСЕНСОРИЦІ

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Мета. Проаналізувати два методи дослідження антиген-антитіло і показати перевагу більш сучасного метода поверхнево плазмонного резонансу (SPR) над традиційним ELISA методом. Продемонструвати досягнення з використанням цього методу.

Матеріали й методи. Проведено огляд опублікованих статей. Аналізовано описані результати і досягнення з використанням методу SPR в медичних і біологічних дослідженнях.

Результати. Показано, що завдяки методу SPR можна вістежити зв'язування молекул з поверхнею в режимі реального часу без використання міток, яких потребує ELISA метод. Це дає можливість застосовувати його в імунології в форматі імуносенсора для аналізу різних біохімічних аналітів. Протеїни, токсини, алергени та різні лікарські препарати можна визначати як чутливий елемент, природні антитіла, що забезпечує високу чутливість та селективність. А також дає можливість більш точно визначити кінетичні характеристики і константи рівноваги.

Висновки. Таким чином, за багатьма показниками метод SPR демонструє суттєві переваги над традиційним ELISA методом. Він забезпечує точність результатів і більшу інформативність щодо рівноваги і кінетики зв'язування в імунологічних реакціях без використання мітки, що потребує ELISA метод.

Ключові слова: поверхневий плазмонний резонанс (SPR), біосенсори, виявлення біомолекул, імуносенсори.

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