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Opinion Article

Rapid Blood Typing with a Localized Surface Plasmon Resonance Biosensor

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DESCRIPTION

Blood typing remains a fundamental step in transfusion medicine, emergency care and surgical procedures. Accurate identification of blood groups is essential to prevent hemolytic reactions and other complications resulting from incompatible transfusions. Traditional serological approaches, including tube agglutination and gel-based methods, have been used successfully for decades but require trained personnel, laboratory infrastructure and time for processing. Advances in biosensing technologies have introduced alternative methods capable of providing rapid, accurate and portable blood typing. One such technology, Localized Surface Plasmon Resonance (LSPR), offers a sensitive platform for detecting molecular interactions in a label-free and real-time manner.

Localized surface plasmon resonance is an optical phenomenon that occurs when conduction electrons in metallic nanoparticles resonate with incident light. This resonance is highly sensitive to changes in the refractive index near the nanoparticle surface, which occurs when molecules bind to functionalized surfaces. The shift in resonance wavelength or intensity can be measured and correlated with the presence of specific analytes. In the context of blood typing, LSPR biosensors can detect interactions between blood antigens and immobilized antibodies, providing a direct and rapid readout of blood group.

Designing an LSPR-based biosensor for blood typing involves careful consideration of surface chemistry, nanostructure design and detection methods. Sensor surfaces are functionalized with antibodies that specifically recognize ABO and Rh antigens. Functionalization strategies include covalent bonding, self-assembled monolayers and affinity-based immobilization. Ensuring proper orientation and stability of antibodies on the sensor surface is critical to maintain high binding efficiency and reproducibility. Gold nanoparticles are commonly employed due to their stability, biocompatibility and favorable plasmonic properties. Nanoparticle size, shape and spacing influence sensitivity, detection range, and signal-to-noise ratio.

The point-of-care nature of LSPR biosensors offers multiple advantages. The assay requires minimal sample volume, which is beneficial in pediatric or emergency settings. Label-free detection reduces assay complexity and time, eliminating the need for secondary reagents or washing steps. Integration into portable platforms, such as handheld devices or microfluidic chips, enables rapid blood typing outside centralized laboratories. This is particularly useful in emergency response, field hospitals and remote locations where conventional laboratory infrastructure is unavailable.

Sensitivity and specificity of LSPR biosensors depend on antibody quality, immobilization method, and optical setup. Optimized sensor surfaces enable detection of weakly expressed antigens and differentiation of subgroups within the ABO and Rh systems. Multiplexing can be achieved by functionalizing distinct regions of the sensor surface with different antibodies, allowing simultaneous detection of multiple blood group antigens in a single assay. This reduces testing time and provides comprehensive blood typing information efficiently.

Microfluidic integration enhances the performance of LSPR biosensors by controlling sample flow, cell-surface interaction and mixing. Microchannels can guide erythrocytes over nanoparticle-coated surfaces, ensuring uniform contact and reproducible signal generation. Reduced sample and reagent consumption, combined with precise control over assay conditions, improves overall efficiency. Automated sample handling in microfluidic LSPR devices minimizes user intervention and allows faster processing.

Clinical validation involves testing with diverse human blood samples, including rare and weak antigen expressions. Comparative studies with conventional serological methods confirm accuracy, sensitivity and specificity. LSPR biosensors can provide results in minutes, whereas traditional assays may require longer processing times. Rapid results are particularly advantageous in transfusion emergencies, surgical procedures and mass casualty scenarios, where immediate blood typing is necessary to ensure patient safety.

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In conclusion, the development of a point-of-care LSPR biosensor represents a significant step forward in rapid blood typing. The combination of nanostructured surfaces, antibody functionalization, optical detection and potential microfluidic integration provides a platform that is highly sensitive, specific and portable. The technology reduces sample volume and assay time, offers real-time monitoring, and enables deployment outside centralized laboratories. Continued research in nanotechnology, biosensing and device integration will enhance performance, making LSPR-based platforms a valuable tool in transfusion medicine, emergency care and immunohematology.