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Microfluidic Plasmonic Device for the Sensitive Dual LSPR-Thermal Detection of the Cardiac Troponin Biomarker in Laminal Flow

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Abstract : Acute myocardial infarction (AMI) is the most severe cardiovascular disease, which has threatened human lives for decades, thus a continuous interest is directed towards the detection of cardiac biomarkers such as cardiac troponin I (cTnI) in order to predict risk and, implicitly, fulfill the early diagnosis requirements in AMI settings. Microfluidics is a major technology involved in the development of efficient sensing devices with real-time fast responses and on-site applicability. Microfluidic devices have gathered a lot of attention recently due to their advantageous features such as high sensitivity and specificity, miniaturization and portability, ease-of-use, low-cost, facile fabrication, and reduced sample manipulation. The integration of gold nanoparticles into the structure of microfluidic sensors has led to the development of highly effective detection systems, considering the unique properties of the metallic nanostructures, specifically the Localized Surface Plasmon Resonance (LSPR), which makes them highly sensitive to their microenvironment. In this scientific context, herein, we propose the implementation of a novel detection device, which successfully combines the efficiency of gold bipyramids (AuBPs) as signal transducers and thermal generators with the sample-driven advantages of the microfluidic channels into a miniaturized, portable, low-cost, specific, and sensitive test for the dual LSPR-thermographic cTnI detection. Specifically, AuBPs with longitudinal LSPR response at 830 nm were chemically synthesized using the seed-mediated growth approach and characterized in terms of optical and morphological properties. Further, the colloidal AuBPs were deposited onto pre-treated silanized glass substrates thus, a uniform nanoparticle coverage of the substrate was obtained and confirmed by extinction measurements showing a 43 nm blue-shift of the LSPR response as a consequence of the refractive index change. The as-obtained plasmonic substrate was then integrated into a microfluidic “Y”-shaped polydimethylsiloxane (PDMS) channel, fabricated using a Laser Cutter system. Both plasmonic and microfluidic elements were plasma treated in order to achieve a permanent bond. The as-developed microfluidic plasmonic chip was further coupled to an automated syringe pump system. The proposed biosensing protocol implicates the successive injection inside the microfluidic channel as follows: p-aminothiophenol and glutaraldehyde, to achieve a covalent bond between the metallic surface and cTnI antibody, anti-cTnI, as a recognition element, and target cTnI biomarker. The successful functionalization and capture of cTnI was monitored by LSPR detection thus, after each step, a red-shift of the optical response was recorded. Furthermore, as an innovative detection technique, thermal determinations were made after each injection by exposing the microfluidic plasmonic chip to 785 nm laser excitation, considering that the AuBPs exhibit high light-to-heat conversion performances. By the analysis of the thermographic images, thermal curves were obtained, showing a decrease in the thermal efficiency after the anti-cTnI-cTnI reaction was realized. Thus, we developed a microfluidic plasmonic chip able to operate as both LSPR and thermal sensor for the detection of the cardiac troponin I biomarker, leading thus to the progress of diagnostic devices.

Keywords : gold nanobipyramids, microfluidic device, localized surface plasmon resonance detection, thermographic detection
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