Replacement-Free Electrodeless Quartz Crystal Microbalance Biosensor Using Nonspecific Adsorption of Streptavidin on Quartz

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All biosensor chips in the existing biosensor systems need to be replaced. The same sensor chip cannot be used for many times because washing with strong acid or strong alkali deteriorates the sensor surfaces. Biosensor chips must have been replaced, consuming cost and time and deteriorating the reproducibility. Therefore, a replacement-free biosensor has been desired. We have succeeded in developing a replacement-free and surface-modification-free quartz crystal microbalance (QCM) biosensor for the first time, which uses the high nonspecific adsorption binding behavior of streptavidin on quartz.

Pure shear-wave vibrations are excited and detected in the solution by the line antennas contactlessly in a 30 μm-thick naked quartz crystal plate, whose fundamental resonance frequency is 55 MHz. The target proteins adsorbed on the quartz surfaces can be detected through the decrease in the resonance frequency due to the increase in the mass of the resonator. Using this homebuilt biosensor system, we discover that streptavidin shows significantly high affinity for the quartz surfaces with the equilibrium dissociation constant K_D=0.13 nM (Fig. 1). Thus, using the streptavidin base adsorbed on the quartz surfaces nonspecifically, we can detect target proteins through biotin-conjugated receptor proteins. (The avidin and biotin bind with extremely high affinity.) Figure 2 shows an example of the multi-injection sequence, where the target protein hIgG is detected through biotin-conjugated anti-hIgG antibody immobilized on the base streptavidin. All the proteins on the surfaces can be removed by washing the quartz crystals with a strong acid such as a piranha solution, making the replacement-free biosensor chip possible.

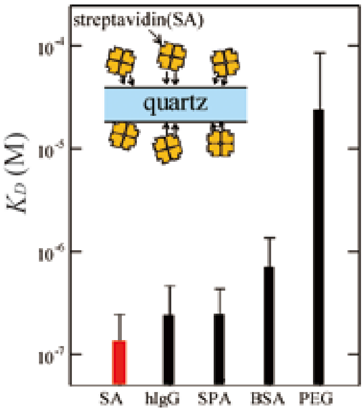

Fig. 1 Equilibrium dissociation constants K_D for nonspecific adsorption of streptavidin (SA), human immunoglobulin G (hIgG), staphylococcus protein A (SPA), bovine serum albumin (BSA), and polyethylene glycol (PEG) on quartz.

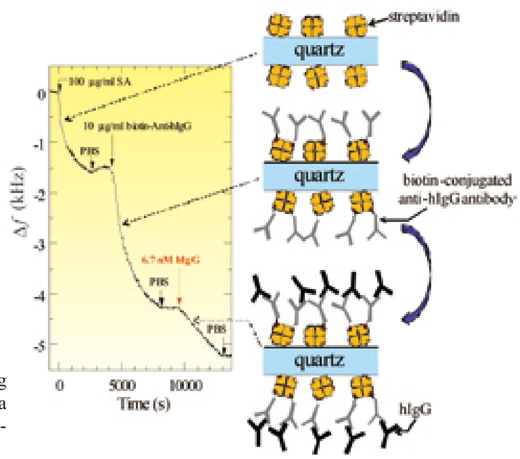

Fig. 2 Resonance frequency change observed during the multi-injection sequence. The hIgG is detected via the anti-hIgG antibody immobilized on the streptavidin base.

Two-Laser-Guided Three-Dimensional Microfabrication and Processing in a Flexible Polymer Matrix

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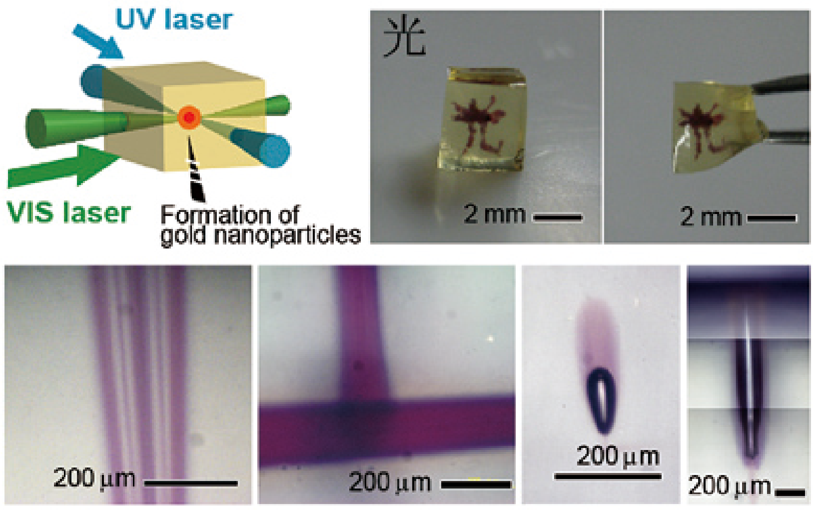
With the increase in demand for high-performance, compact and portable devices, flexible materials are attracting considerable attention because they provide low-profile and light-weight products and often good performance. Three-dimensional (3-D) processing causes a steady and effective improvement in the capabilities of flexible materials.

The development of a novel 3-D processing technique for flexible materials is viewed as the key to advance several emerging technologies such as flexible dense microelectronics, photonics, and microelectromechanical systems (MEMS). In the present study, we have developed an MCLP (MCLP; processing using two or more laser beams with different wavelengths) system with high applicability and versatility and used it to demonstrate the 3-D microprocessing inside the flexible polymer matrices. Multicolour laser processing is a powerful strategy for the direct 3-D laser processing where the multicolour laser induced reactive species such as excited radicals and molecules in the higher excited states can be selectively generated in the overlapping area of the laser beams. Because the multicolour laser induced reactions, which proceed by stepwise multiphoton absorption, can be achieved by low-density photon, MCLP enables the internal processing of laser ablative material without surface damages. The other advantages of using multi-laser beams are the significant increase in the processing area due to an adjustable processing area (the area is equivalent to the overlapping area of the laser beams) and the processing diversity.



We synthesized the gold nanoparticles (AuNP) directly within a polymer matrix containing carbazole (Cz) and $HAuCl_4$. Two laser beams of different wavelength successively excited Cz into higher excited states to form a Cz radical and hydrogen atom. The hydrogen atom then triggered the generation of AuNP from the $HAuCl_4$. We have fabricated 3-D Chinese character denoting 'light' on the AuNP array written in polymer matrix. It is noteworthy that the irradiation of two laser beams causes new photo-induced phenomena (laser-guided formation of AuNP array in a fluid like manner and formation of microcavity (tunnel)). The advantageous optical and electrical features of a noble-metal NP/polymer composite promise that the MLCP can be applicable for 3-D wiring in flexible microelectronics and optical devices. In addition, the space-selective fabrication of microcavities (tunnels) would find potential applications in the MEMS, microfluidics, 3-D optical memory, and others.