Utilization of Self-Assembled Magnetic Nano-Chains for Bio-engineering Studies

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In past years, magnetic colloidal nano/micrometric beads are of vast interest for a wide range of applications. Particularly, magnetically labeled detection techniques utilizing magnetic beads in vivo and vitro triggered off a great progress not only in resolving technical problems in medical engineering, but also in realizing Lab-on-a-chips. To date, the key works of most of magnetic biosensors is commonly based on the fact that individual magnetic particles functionalized by molecules are immobilized on various magnetic field sensors (Hall sensor, spin-valve sensor, etc) via biochemical events. Those “inhomogeneous” approaches are mostly time-consuming because of multiple steps such as amplifying and washing procedures, and may not be suitable for point of care applications. Recently, enormous attempts to make use of colloidal magnetic particles without any immobilization on substrates have been employed so as to reach real-time detection, which is referred to as “homogeneous” method. Additionally, the introduction of self-assembled nano-structure consisting magnetic beads, which is selectively constructed by incorporation of intermolecular interactions with driven magnetic forces and hydrodynamics on the beads, makes it possible to enhance specificity and sensitivity of biosensor. Moreover, the use of precisely controlled colloidal structure, mostly chain-like structure, actuated by magnetic field highly is diversified into a promising technology for magnetically modulated photonic devices.

Our central research aims to develop an alternative approach for “homogeneous” biomolecular recognition protocol utilizing the change in optical properties associated with rotating self-assembled chain-like structures for enhancing the recognition rate, thereby reducing the detection time, even in assays containing very small concentrations of functionalized magnetic beads.

Firstly, we deal with the structural properties of the self-assembled colloidal chain-like structure in given conditions and its corresponding optical behavior. These studies are focused on transient characteristics of formation, dynamics, and transformation. Furthermore, their rotational motions driven by rotating magnetic field are systematically investigated varying hydrodynamic force.

Secondly, the optical transmittance characteristics of magnetic chain with varying the angle between the orientation of magnetic chains and incident light, and frequency of the rotating chain, and quantified the relationship between the amplitude of optical transmittance and structure of chains.

Lastly, on the basis of study on optical properties of magnetic chains, we deal with structural deformation of bio-functionalized magnetic chain due to inter-molecular interaction and bio-chemical event are successfully evaluated in terms of optical transmittance, and are quantified by simply modeling.

We demonstrate that subnanomolar concentrations of target molecule can be detected by rotating magnetic chains functionalized with magnetic beads functionalized by representative test biomolecules within 30 s. In our protocol, the effect of mixing due to the rotating magnetic chains enhances the probability that the functionalized magnetic beads interact with and capture the target molecules added to the solution. Thus, in our approach, magnetic chain-induced mixing yielded extremely rapid detection times, using extremely small quantities of

nanometer sized magnetic probes.

We also adopt our biosensing platform to more practical medical cases so as to verify the validity. In emergency cases like heart attack, timely prognosis/diagnosis of level of disease and proper interventions are necessary. Cardiovascular disorder has been monitored by measuring B-type Natriuretic Peptide (BNP) which is the most important cardic biomarker on the basis of radioimmunoassay and immunochromatography techniques. To date, these techniques would be inadaptable for real-time hand-held diagnostic device because they have bulky equipment and require multiple procedures by skilled cardiologists. Therefore, we selected congestive heart failure as first practical case. Magnetic bead used in this study (FG-bead) contains ferrite nanoparticles rather than superparamagnetic nanoparticle because of unanticipated technical problems in practical cases. The ferrite is encapsulated with glycidyl methacrylate (GMA) which is further coated with a polymerized GMA. Subsequently, the activated FG beads are coated with two different anti-BNP antibodies: KY-BNP-II antibody against BNP and with the other antibody, BC203. We successfully suggested the possibility for diagnosis of heart failure taking advantage of transforming of self-assembled magnetic chains within a minute.