Development of Novel Signal Amplified-Virus Sensing Platform using Tunable Localized Surface Plasmon Resonance and Electrochemically Active Liposome

（課程博士・様式７）（Doctoral qualification by coursework, Form 7）

学 位 論 文 要 旨

Abstract of Doctoral Thesis

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（調節可能な局在表面プラズモン共鳴及び電気化学的機能性リポソームを用いた新規シグナル増幅型ウイルス検出プラットフォームの開発）

論文要旨：

The ongoing research in nanotechnology is emerging in the most challenging field of virus sensing as life undergoes to threatened due to the rapid spread of several viral infections recently. Precise and sensitive methods for virus detection are in high demand for the diagnosis and control of diseases. The key to highly sensitive detection methods should be reliable in the early stage of infection, which may improve the probability of survival. To improve sensitivity, proper signal amplification of target needs where the system can generate strong indication for easy detection even in the presence of a few virus particles.

The main aim of this thesis is to develop various biosensing platforms by using different nanocomposites along with their application in the sensing field, which further leads to virus detection. The study includes the synthesis, characterization of nanocomposites, and applications in developing biosensors for virus detection. Different sensing mechanisms are adequately explained and shown by schematic illustrations. The presented work in this thesis can give some new ideas for the development of biosensors for virus detection.

In this work, the limitations of the sensing process have overcome without compromising its advantages. Here, the work has focused on the optical and electrochemical sensing process by incorporating different nanoparticles like quantum dots (QDs), gold nanoparticles (AuNPs), etc. and established various techniques for sensing target analytes with high specificity, sensitivity, and low detection limit. Therefore, to find out the simplicity and reliable method of biosensing was the first and foremost goal of this work.

The whole work about this thesis describes five chapters (**Chapter 2, 3, 4, 5,** and **6)** along with the introduction (**Chapter 1**) and Conclusion (**Chapter 7**).

Chapter 2 describes the detail about the chemicals, materials, virus samples, different antibodies used in this whole work. Used instruments in this study for the characterization and analysis of the nanoparticles and nanocomposites, along with the sensing procedures, were introduced.

Chapter 3 describes the concepts, principles, and detection mechanisms for virus sensing using plasmonic and electrochemical methods.

Chapter 4 describes the construction and application of a new method of the virus sensing system. In this work, the CdSeTeS QDs/AuNPs nanocomposite was employed to induce localized surface plasmon resonance (LSPR) of gold nanoparticles (AuNPs) and fluorescent quantum dots (QDs). While adding the target virus into the solution, the steric hindrance between AuNPs and QDs induced LSPR signal for the virus detection. This method applied to norovirus-like particles (NoV-LPs) and a clinical sample of norovirus (NoV) detection, which exhibited a 100-fold higher sensitivity than the commercially available ELISA kit. Therefore, the developed biosensor showed ultrasensitive detectability at a femtogram level of the target virus.

Chapter 5 described the preparation and application of a tunable biosensor for virus detection based on the designed LSPR and optimized the distance between fluorescent CdZnSeS/ZnSeS QDs and AuNPs in a controlled way. Different lengths of peptide chains were designed and employed for creating the distance between these two nanoparticles that is the crucial point to generate surface plasmon effect towards virus detection. In this case, binding of target virus on the nanocomposite initiates steric hindrance on the LSPR, and therefore, amplified the signal. A highly sensitive biosensor has been developed for entrapping different concentrations of the influenza virus with a very low limit of detection.

Chapter 6 describes the advancement of a new model of dual-functional signal amplification method to detect viruses by using the combination of a fluorescent and a redox indicator dye encapsulated liposome. Amine functionalized liposomes have been constructed containing hydrophobic fluorescent QDs in the lipid bilayer and centrally filled with methylene blue (MB) as a redox indicator. In the presence of the target, the dual functional liposome can form a sandwich structure with the virus and APTES-coated Fe_3O_4 magnetic nanoparticles (MNP) and magnetically separate the target virus from its analyte medium. After the external burst out of the liposome, the released QDs and MB generate the fluorescence and electrochemical signal, respectively. This amplified signal can give the indirect quantification of the target virus.

Chapter 7 summarizes all the results found in the presented work and includes a discussion about further research scope in this field.

Overall, the scope of the thesis encompasses the development of different nanocomposites and applicability of the proposed sensors for the detection of several viruses in a wide range of sensing platforms, which can give some new ideas. Based on the obtained results, these proposed biosensors can be a good alternative in the large potential window of the application on monitoring disease and point-of-care of infectious viral diseases.