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Functional Polymer Materials in Environmental Biosensors in the Context of the Internet of Things

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Abstract: The use of functional polymer materials to obtain high-performance biosensors is currently a research hotspot in the field of analysis and materials. Polymer materials have the advantages of good biocompatibility, easy design and controllable preparation of reactive groups, and rich functional types, which are helpful to construct biosensor interfaces with excellent performance. This work aims to study the application of functional polymer materials in environmental biosensors in the context of the Internet of Things, prepare silver nanocubes on Nafion membranes with ATP as a buffer, and establish a new optical detection method. Formaldehyde based color change of the film. In addition, a new method for detecting temperature and spermine using the conformational changes of polythiophene (PT) derivatives under certain conditions was established. According to the color and fluorescence changes of PT induced by iodide ions in the range of 25.5℃-50.5℃, a rapid and sensitive method for temperature detection was established. The establishment of this method shows that polythiophene derivatives can be used as a new type of temperature sensor, thus expanding the application range of PT. In addition, to further validate the method, real beef and chrysanthemum samples were tested, and the detection recoveries ranged from 85.6% to 103%, indicating that the method is feasible for spermine detection.

1. Introduction

Biosensing is an emerging discipline with multi-faceted development in recent years. It integrates biotechnology, information technology, chemistry, materials science, visual science, nanoscience and other fields, and has captured the hearts of many researchers. In biosensors, the detection material used to generate the signal is one of the main factors affecting the detection performance, which determines the sensitivity of the sensor [1]. Therefore, the design and integration of better sensing materials is very important to improve the performance of biosensors. Polymer materials attracted widespread attention due to their good biocompatibility, easy design, controllable preparation of reactive groups, and rich functional types. The intersection of functional polymer materials and biological sciences has become a hotspot of current research [2].

Recently, great progress has been made in the application of functional polymer materials in environmental biosensors. In a simple proof-of-concept experiment by Mazurek P, glycerol-silica membranes containing enzymes were immersed in water to dissolve substrates for biological reactions. The increased osmotic pressure causes the substrate to move to the glycerol reservoir, where it is converted to product and then released from the membrane. This paper evaluates the efficiency of various enzymatic reactions. The glycerol content of the membrane was found to have a significant effect on the reaction rate. We also used this concept to create a soft-skin glucose biosensor [3]. Demirci S showed that the resistance of PIL-based PILs to ionic coordination makes the material resistant to scaling. Poly(1-vinyl-3-butylimidazolium bromide) anion exchangers are used to control host-host interactions. Measurements of film thickness, contact angle, and surface morphology of the resulting particles were used to confirm the mechanical properties of the cyclodextrin-functionalized PIL brushes. PIL brushes with reversible properties protect sterile materials from negative interactions without physical changes during storage and have potential applications in bioseparation and biosensors [4]. Khansili reviews recent advances in label-free optical sensors based on target analytes. This study focuses on a brief classification, principles of optical sensors, optical (surface) analysis techniques (as part of biosensing), and the use of nanostructures in optical sensors. Highlights include the characterization of localized surface plasmons and biosensors based on surface plasmon resonance. In addition, for food and environmental applications, other optical biosensors, such as bioluminescent fiber optic biosensors, transmitted vibrational waves, elliptical polarization, surface Raman scattering, and luminescence potentiometric sensors, have been developed [5]. During the years of research and application of environmental biosensors, many scholars have developed many different methods.

In this paper, combined with the existing laboratory conditions, polymers with different materials, shapes and functions are used as electrode surface modification materials or basic electrode materials to construct electrochemical interfaces and find matching targets. With the continuous advancement of biosensor technology, it is necessary to continuously reduce product costs, improve sensitivity, stability, and prolong service life. Changing these properties will also accelerate the development and commercialization of biosensors. The research and development of new sensors has huge application prospects in many fields such as industry, agriculture, defense, aviation, navigation, medicine, industry, transportation and home services.

2. The Application of Functional Polymer Materials in Environmental Biosensors in the Context of the Internet of Things

2.1. Biosensors

Biosensors are special forms of sensors based on inorganic biological materials or the organism itself (such as organs, bodies, etc.). Bioactive substances are sensitive substances that can selectively identify specific test substances by classifying biochemical reactions, and convert biochemical reactions into metabolic signals, living species and small chemical substances [6-7]. Biosensors have been used in industrial control, food and drug analysis, environmental monitoring and technology due to their advantages of high sensitivity, fast speed, high accuracy, and simplicity. Due to the short development period of biosensors, many aspects have not been researched, and have a series of shortcomings such as low safety and poor practicability. Therefore, it is particularly important to develop new biosensors that are simpler, faster, more sensitive, safer and more applicable [8-9].

2.2. Features of Functional Polymer Materials

Functional polymers are new materials that emerged after polymer materials entered the fields of biology, energy, and electronics. The so-called "functional" means that such polymers have chemical reactivity, electrical conductivity, catalysis, biocompatibility, selective separation, energy conversion and magnetic properties in addition to their mechanical properties [10-11]. Functional polymers are widely used in medicine, environmental protection and other fields due to their advantages of light weight, high strength, corrosion resistance, diverse varieties, abundant raw materials, and simple molecular structure [12-13].

2.3. Application of Functional Polymers in Electrochemical Biosensors

Currently, the applications of materials based on carbon, inorganic or metallic materials in electrochemical analysis are limitless. Compared with ordinary materials, functional polymers are more suitable as bioactive materials. Functional polymers are mainly used as biosensor interface modification materials, substrate electrode materials and biomolecule immobilization substrates [14-15]. Bioactive molecules can be effectively immobilized on functional polymer surfaces by various immobilization methods, and functional polymer surfaces with good biocompatibility can provide a suitable microenvironment for the compatibility of bioactive materials with substrate solutions. Molecules can communicate efficiently and selectively [16-17].

In order to improve the ability to immobilize biomolecules, increase electron transport, and increase current signals, many researchers have used functional polymer nanomaterials to immobilize enzymes, antibodies, DNA and other biologically active substances, and prepared many new biosensors [18].

3. Experiment on the Application of Functional Polymer Materials In Environmental Biosensors in the Context of Internet of Things

3.1. Preparation of the Sensor

Dissolve the chitosan powder in a 2.5 wt% acetic acid solution. Dilute it into a 2.5 wt% chitosan solution with the second water. A colloidal suspension of LDH [Zn3-Al-Cl] (2 mgml) was obtained by dissolving LDH in decarbonated secondary water overnight. Dissolve an equal amount of PPO in decarbonated secondary water and store the dry electrode in a refrigerator at 5 ℃.

3.2. Experimental Process

(1) Feasibility analysis of HP/PF sensor

Firstly, the feasibility of the sensor to detect DNA was analyzed. The steps are as follows: (1) Take 15μL of LP2 probe solution, add it to 85μL of buffer solution, and then add 15μL of target sequence T1 solution. At the same time, 12μL illiQ water was used as a blank control instead of P1 solution. (2) The above mixed solution was heated to 90℃ for 10min denaturation, and then slowly renatured at room temperature; heated to 25℃ for 20min reaction. (3) Add 25μLPF solution

(10-5M) to the above samples, mix well, add MilliQ water to make up 5mL, and perform fluorescence detection and analysis.

(2) Sensitivity detection of HP/PF sensor

Add 15 μL of T1 solution with concentrations of 0, 50pM, 5nM, 100nM, 200nM, 20 μM, 400nM, and 2 μM to the P2 probe solution, respectively, and add PF according to the above operation steps for fluorescence detection and analysis, and draw the concentration curve.

(3) SNP detection and condition optimization by HP/PF sensor

SNPs were detected with this fluorescent sensor. The above detection steps were repeated with the target DNA sequence T2 with a single base mismatch instead of T1 in the above detection, and after adding PF, the fluorescence detection analysis was carried out to see whether the fluorescence sensor could distinguish between the perfectly complementary strand T1 and the single base mismatched strand. T2.

3.3. Thermogravimetric (TGA) Characterization

Thermogravimetric analysis of the material was carried out using SDT-Q600 from TA Company. The measurement conditions are that under the air atmosphere of 200 mL/min, the temperature rises from room temperature to 90 ℃ at a heating rate of 15 ℃/min. Through thermogravimetric analysis, the content of the graft polymer can be calculated. The specific calculation formula is as follows.

$$\frac{W_{IO\,SiO_2-Br,800}}{100-W_{IO\,SiO_2-Br,800}}=\frac{W_{IO\,SiO_2-g-PtBA,800}-X}{100-W_{IO\,SiO_2-g-PtBA,800}} \quad (1)$$

$$\Delta m(\%)=\frac{X}{1-X}\times 100\% \quad (2)$$

Among them, $W_{IOSiO2\text{-}Br,\,800}$ is the weight loss percentage of organic small molecules at 800 ℃, △m(%) is Grafting amount.

4. Analysis on the Application of Functional Polymer Materials in Environmental Biosensors in the Context of the Internet of Things

4.1. Detection of Spermine by Fluorescence Spectroscopy

The amino groups at both ends of spermine can interact with the phosphate groups in the two strands of DNA to form complex precipitates. Therefore, adding spermine to the ctDNA solution can produce ctDNA-spermine precipitation complex. However, once this precipitate is formed, ctDNA cannot form a stable triple-stranded structure with PT. At this time, the addition of iodide ions will induce aggregation of PT and quench its fluorescence. Quantitative detection of spermine.

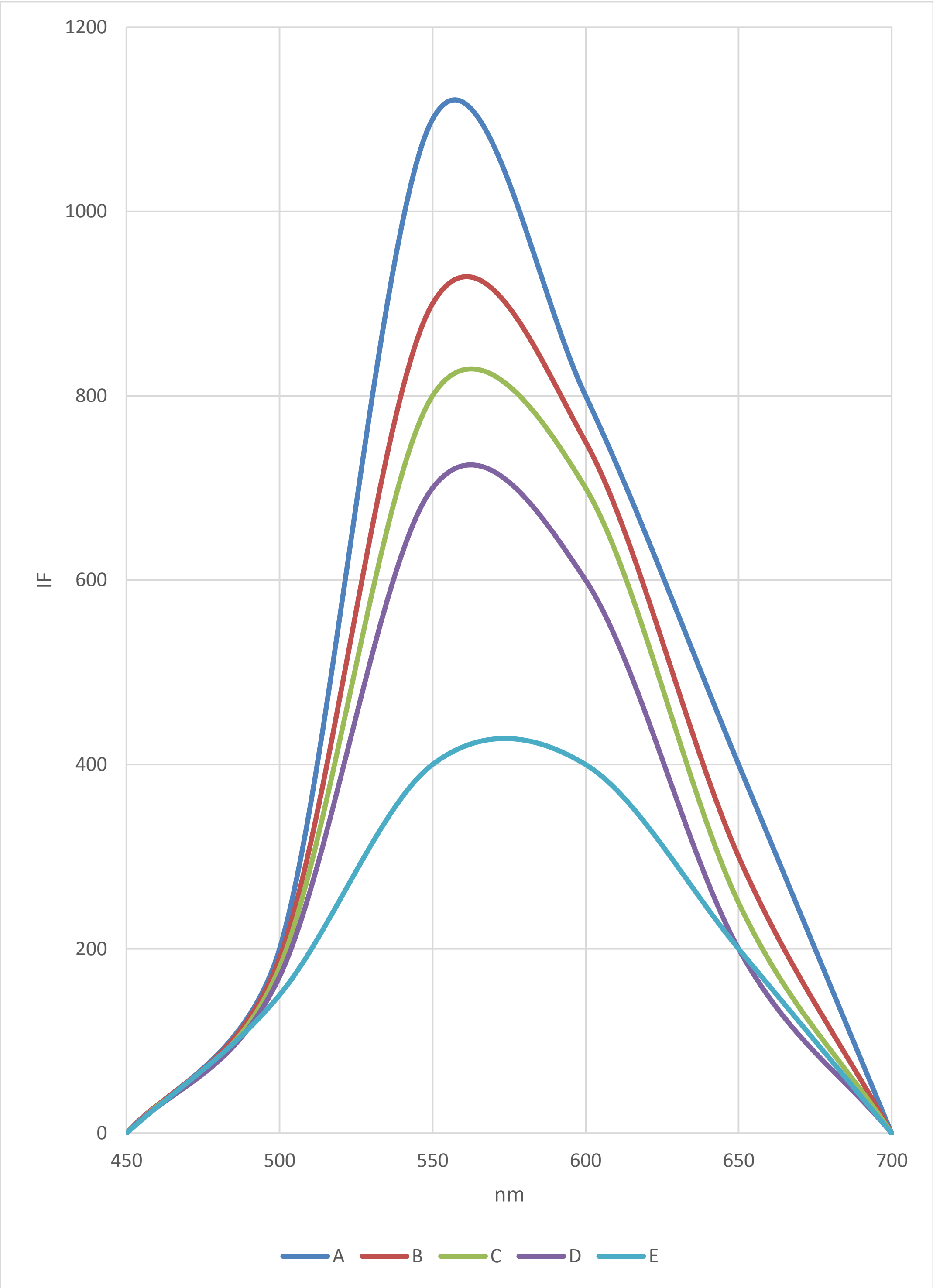

Figure 1. Fluorescence spectra of spermine detection based on PT

As shown in Figure 1, PT bound to ctDNA has strong fluorescence in the presence of iodide ions. When spermine is added, the interaction between ctDNA and spermine produces precipitation, and the fluorescence of PT is quenched by iodide ions.

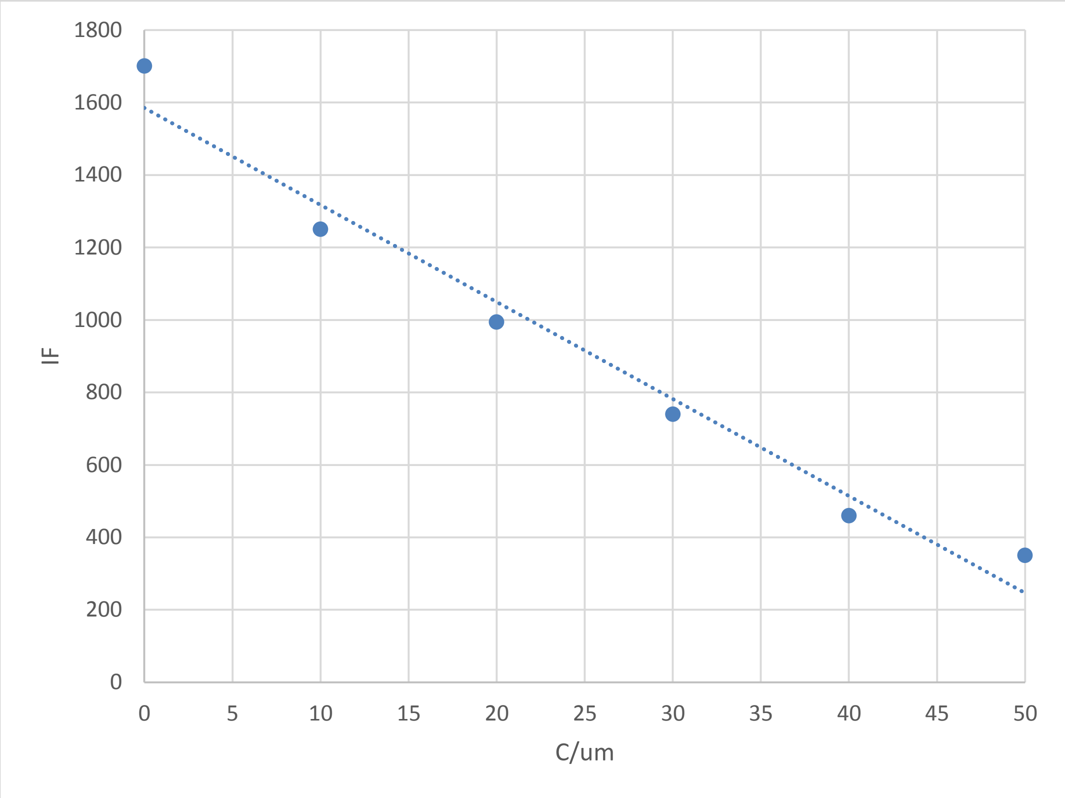

Figure 2. Linear equation for spermine detection based on PT

The experiment showed (Fig. 2), when the spermine concentration was in the range of 5~50μM, the fluorescence intensity of PT was linearly related to the spermine concentration. The linear equation was IF=1530.14-22.4c(μM), and the detection limit was 1.5μM.

Experiments found that when the concentration of spermine analogues putrescine and spermidine was 15 times higher than that of spermine, they had no effect on the analysis of spermine, and foreign substances such as metal ions, amino acids, and glucose did not affect the analysis of spermine. In addition, in order to further verify this method, we tested the actual samples of beef and chrysanthemum. The test results are shown in Table 1. The recovery rate is in the range of 85.6%~103%, indicating that the method is feasible for spermine detection.

Table 1. Detection of spermine in beef and chrysanthemum

Sample	Measured amount (x10^{-6} M)	Adding amount (x10^{-6} M)	Determination of the total amount(x10^{-6} M)	Recovery rate (%,n=4)	RSD (%,n=4)
Beef	1.8,2.5	30	22.4,23.1	95.1-103	6.5
Chrysanthemum	25.4,26.7	30	45.6,46.7	85.6-87	1.5

4.2. Application of Polythiophene Derivatives in Temperature Sensors

Figure 1 shows the fluorescence spectra of iodide ion-induced PT in the range of 25 ℃ to 55 ℃. The fluorescence of PT induced by iodide ions gradually increased with the increase of temperature, and the maximum emission wavelength was blue-shifted from 600 nm to 550 nm. In order to further probe the sensitivity of the sensor, we kept the excitation wavelength constant and performed time scanning to obtain the fluorescence intensity-time scanning graph of iodide ion-induced PT when it was naturally cooled from 60 ℃ to room temperature.

Table 2. Iodide ion-induced fluorescence of PT at different temperatures

	A	B	C	D	E
450	0	0	0	0	0
500	190	180	170	180	140
550	1090	910	790	710	420
600	790	740	690	610	410
650	410	310	240	210	210
700	0	0	0	0	0

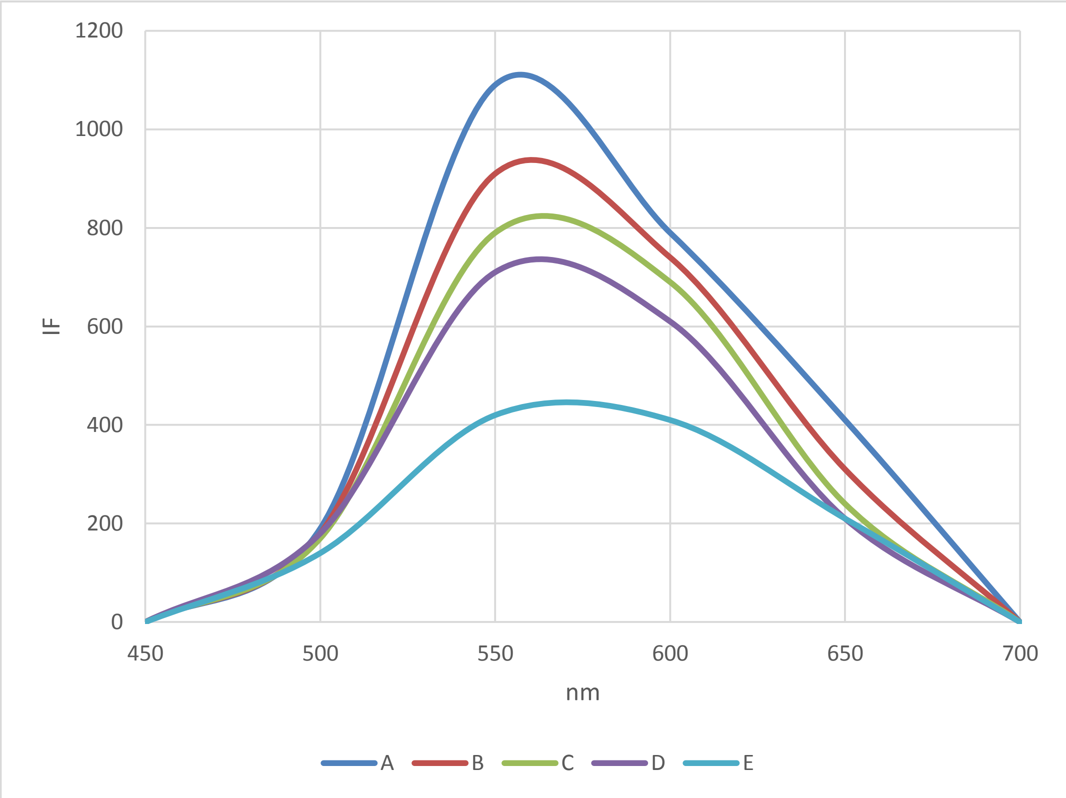

Figure 3. Fluorescence spectra of iodide-induced PT at different temperatures

Figure 3 shows that the iodide ion-induced PT has thermochromic properties. Based on the color and fluorescence changes of PT induced by iodide ions in the range of 25.5℃-50.5℃, a fast and sensitive method for temperature detection was established.

5. Conclusion

Functional polymer materials have the characteristics of high mechanical strength, stable physical and chemical properties, and good biological affinity, which can provide more reactive sites for the sensing interface, and at the same time build a good microenvironment for biologically sensitive components its biological activity. Some functional polymers have excellent electrical conductivity. Therefore, in this work, biosensors are based on polymers with different materials, different shapes and different functions, such as electrode surface modification materials or electrode materials, which are applied in biomedical analysis and detection.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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