Design of pH Measuring in Wireless Therapy Capsule Against *Helicobacter Pylori* Infections

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Abstract: A wireless blue light therapy capsule against *Helicobacter Pylori* infections based on a pH sensor was addressed. A pH measuring circuit module and wireless communication module were designed to pre-process and transmit the pH signal. By measuring the pH value changes, the capsule can identify the locations and trace the pH of the gastrointestinal tract. A micro controller was designed to sample the pH signal and regulate the therapy parameters according the feedback information. Vitro experiments were conducted to show the performances of the pH sensing module.

Introduction

Helicobacter Pylori (*H. pylori*) colonizes the mucus layer of the human stomach which causes peptic ulcers and adenocarcinoma [1]. Recently, blue light is widely used in clinic to kill bacteria. It is reported that blue light exhibits bactericidal effects against cultured *Helicobacter pylori (H. pylori)* and many other microbial bacteria around the wavelength of 405nm [2-3]. Additional tests indicated that the largest reduction in bacterial load was in the antrum (>97%), followed by body (>95%) and fundus (>86%), with treatments by blue light at wavelength of 408nm [4, 5]. These results proved that blue light could be used to kill the *H. pylori* in clinic to against the *H. pylori* infections.

Advancement in sensor technology and semiconductor technology has prompted highly integrated applications. Endoscopy capsule and physiological parameters detection capsule are just some representatives. As a typical micro medical device, the first endoscopy capsule named M2A provided a noninvasive detection method for digestive tract [6]. Different capsule devices have been designed to suit different purposes in clinical treatments such as non-invasive capsule for targeted drug delivery, capsule robot for local surgery, or monitoring capsule for physiological information collection [7-11]. Combined blue light killing *H. pylori* with capsule designing, we proposed a blue light therapy capsule based on a pH sensor to against *Helicobacter Pylori* infections in this study. And pH measurement is the key issue in this paper will be discussed. By measuring the pH value of gastrointestinal tract, it indicates the approximate location of the capsule when it moved along in the digestive tract. For further, the device can mark the places with abnormal pH value and adjust work parameters with feedback information.

System Design

System architecture. The inner architecture of the proposed capsule, shown in Figure 1. The pH measuring unit consists of a pH sensor and a measuring circuit to detect the pH value. The pH sensor measures the changes of voltage that reflects the changes of pH values. The measuring circuit amplifies the voltage signal from the pH sensor so that the MCU can acquire the analog voltage signal accurately.

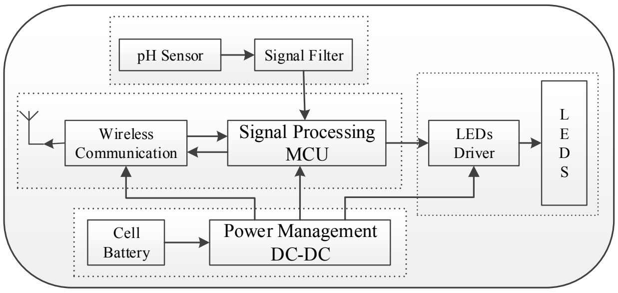

Figure 1. Architecture inside the capsule

pH Sensor. The pH values range from 1 to 7.5 for the whole digestive tract with a pH value about 7 in the esophagus, 1~4 for the gastric juice, and 6.6~7.5 for the intestinal juice [12]. Clearly, the sensor needs to cover the entire pH range with a resolution less than 2.6. For above considerations, antimony electrode is selected as the pH sensor whose detection range is from 1 to 9. The antimony electrode belongs to the class of oxidation-reduction solid electrode which has two electrodes, one for pH measurement and the other for reference. The change of voltage between the two electrodes is measured, and it scales linearly with the change in pH value at a fixed ambient temperature. The out voltage formula as follow:

$$V = V_0 + \frac{2.303RT}{F} pH \qquad (1)$$

where V is measuring voltage, R for gas constant 8.314, T as target temperature (K), F for faraday constant 96500. According to the formula, measuring voltage increases with the increase of pH value when the temperature is stable.

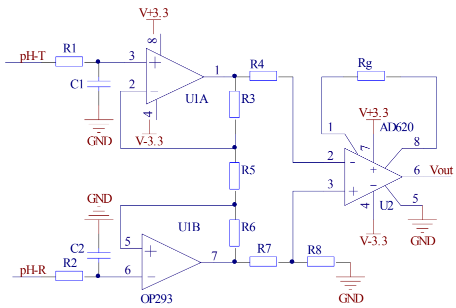
Figure 2. pH Measuring Circuit

pH Measuring Circuit. The voltage between pH measuring electrode and reference electrode is the target signal. The voltage changes with the changing of pH value. Measuring circuit amplifies the voltage and removes noising signal. Impedance circuit filters the signal to a compatible value for micro controller. As shown in Figure 2, voltage follower and subtraction with functions such as isolation, buffering, filtering were constituted by OP293. An amplifier AD620 was employed to amplify the signal with high input resistance and common mode rejection ratio.

System operation. The wireless communication chip nRF24L01 was applied in this system which is a single chip radio transceiver for the worldwide band. The InGaN LED with a wavelength of 408±2nm was employed in it as light source for therapy. MSP430G2553, a low-power-cost and mixed-signal controller with analog-to-digital converter embedded chip was selected as the core component of the MCU module. Firstly, the capsule is turned on when taken out of the magnetic cover and the MCU enters wake-up mode. Then the micro controller samples the pH value measured by pH sensor and processes the pH data to pinpoint the capsule location and turn on LEDs when the capsule moves into the stomach. The micro controller also regulate the light source based on the feedback pH information and transmit the data outside. When the capsule is out of stomach, the system will turn off.

Experiment Results

pH Sensor Time Response. The pH sensor has a cylinder shape with 3.5mm in diameter and 5.5mm in length. A series of control experiments are conducted to test the performance of the pH measuring unit. Liquid of different acidity with pH value ranging from 1 to 8 is prepared with HCl and NaOH, and then placed in eight vessels labeled as number1 to 8. The controlled measuring experiments were also conducted by the standard pH meter PB-10 (Sartorius Corporation). Buffer solution with pH value of 7.2 was prepared to calibrate PB-10 and sensor before each measurement.

Table 1 Time response of pH sensor (ambient temperature: 27℃)

pH	1.1	2.3	3.2	4.3	5.1	6.2	7.4	8.6
time/s	Measuring voltage/mV							
0	160	213	255	309	331	381	428	469
90	162	211	256	309	332	378	428	471
180	161	212	255	308	332	379	427	470

pH Measuring Calibration. Five group comparing experiments were carried out to calibrate the performance of pH sensor. For each labeled pH liquid, five experiments were conducted to measure the pH value and the voltage. To ensure each result was stable, each experiment took about 5 minutes. The average voltage and pH value over the five replicates were calculated and depicted in Figure 3.

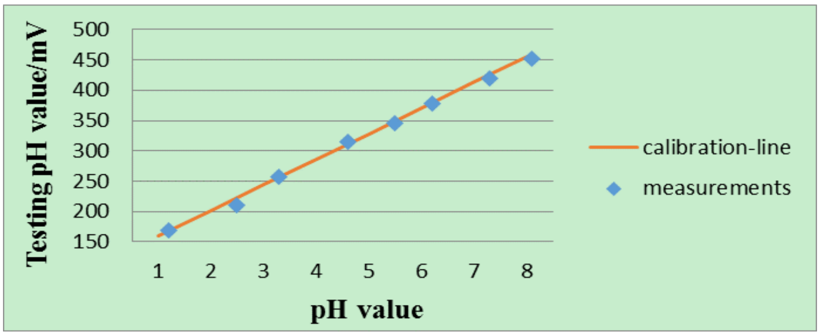

Figure 3. The calibration for the average voltage of pH measured

According to the vitro experiments, the pH sensor sensitivity is about 42±2mV/pH, and resolution better than 0.2 in pH value. The pH value difference between the esophagus and the stomach is about 3, which corresponds to 126mV in voltage. Similarly, the pH value difference between the stomach and the intestinal tract is about 2.6 or 110mV in voltage. The above two voltage thresholds are the significant parameters for the system to detect the capsule location intelligently. It should be noted that the pH testing precision is influenced by temperature. The temperature in the stomach of human is 36.7±0.5℃,and in the intestinal tract is about 36.9℃~37.9℃. Both of them are relatively constant [13-14]. The change in temperature is small, so the temperature influence can be approximately ignored.

Conclusion

A pH measuring application was designed in blue light therapy capsule. The sensor has a cylinder shape with 3.5mm in diameter and 5.5mm in length, and was integrated in the therapy capsule. It can detect the pH value of esophagus, gastric and intestinal tract, and automatically turn on or off the therapy module. By tracing the pH feedback information the capsule smartly adjust the system parameters. With the advancement in technology, increasing noninvasive and smart therapy capsules will be developed and becoming easier to use.

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