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Research Article

Detection and Early Warning of Toxic Gases Based on Semiconductor Wireless Sensors

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This paper studies a semiconductor wireless sensor system, which is composed of a semiconductor wireless sensor sampling circuit, gas-sensitive signal alarm and wireless transmitting circuit, and wireless radio frequency signal receiving circuit. The system is suitable for wireless monitoring of hydrogen fluoride gas in chemical plants. The hydrogen fluoride gas sensor is designed, integrated, and classified according to the polarity and size of the sensor output signal. The signal processing circuit of the sensor output signal is made with an integrated design. This paper developed a simulation experimental system for the wireless monitoring network characteristics of toxic hydrogen fluoride gas and completed the monitoring system's sensor characteristic calibration and accuracy comparison simulation experiment, the communication distance test experiment of the communication system, and the research experiment on the influence of environmental humidity on the sensor characteristics of the monitoring system. In terms of software, the workflow of network nodes has been optimized. Since the structure of the wireless sensor network is not exactly the same in different application fields, the toxic gas monitoring system based on wireless sensor networks must focus on extending the network's life cycle. Without affecting the normal operation of the system, distributed compressed sensing can greatly extend the service life of the system. Therefore, this subject combines the compressed sensing technology developed in recent years with the air monitoring system for the processing of transmission data, in order to achieve the purpose of further reducing the energy consumption of the system. The simulation experiment demonstrated that the lmF neural network combined with gas sensor array technology can realize qualitative identification, quantitative analysis of single gas, and quantitative analysis of mixed combustible gas. The research work in this area also provides a new way to further combine the miniature hydrogen fluoride gas sensor unit with sensor technology, integrate the hydrogen fluoride gas sensor unit and the electronic tag, and expand the wireless application of the gas sensor.

1. Introduction

Toxic chemical leaks caused by chemical plant explosion accidents, forest fires, etc. could result in severe damage to human beings and be disastrous for the environment. With the development of science and technology, gas monitoring technology has been further developed, and various real-time and continuous detection equipment has appeared [1–3]. The increasing attention to hydrogen fluoride leak requires the expansion of the scope of the monitoring environment. It is difficult for a single monitoring point to cover these monitoring environments and monitor the measured environment in real time, so a preliminary environmental monitoring network has emerged [4]. Based on the wired system, data of each monitoring point are transmitted to the central control platform to realize online monitoring. It is very important to monitor the toxic gas dispersion and improve the capabilities of disaster response. And to understand the changing trend of toxic and harmful hydrogen fluoride gas content in the environment, we provide very important data and basis for environmental monitoring such as industrial environment and people's living environment [5–7].

For the measurement of toxic gases, commonly used methods mainly include analytical chemistry methods, semiconductor gas-sensitive detection methods, contact combustion detection methods, spectral analysis methods, electrochemical methods, etc. [8–10]. Among them, the electrochemical measurement method has a fast response speed, can realize online detection, and has good anti-interference to nonmeasured hydrogen fluoride gas, and the produced probe has a small volume and is easy to integrate. Therefore, the system studied in this paper adopts the electrochemical measurement method. Regarding the deficiencies of the above-mentioned equipment, how to realize economic, intelligent, and large-scale layout of monitoring points and realize the networked environmental monitoring has become a hot topic of research [11]. With the development of wireless communication technology, it is possible to solve these problems. At present, the gas detection equipment available on the market is only developed for single gas detection, and they transmit data through wires. If it is necessary to detect a variety of gases, the integration of these gas detection equipment will be very large. Moreover, for the monitoring environment where a large number of monitoring points need to be arranged, the wire transmission data layout is very troublesome and costly [12].

In response to this reality, based on the technology of sensors, wireless communication and wireless sensor networks, and other system-related technologies, this article has carried out a more detailed study on the toxic gas monitoring system and proposed a set of toxic gas monitoring systems based on the wireless sensor network. This paper proposes two design methods of gas sensor signal sampling circuits that individually sample the key points of the hydrogen fluoride gas state. The sampling output signal of the circuit jumps only when the specific hydrogen fluoride gas concentration in the environment to be measured reaches the prewarning concentration value. The control unit alarms by identifying the change in the output signal of the gas sensor sampling circuit. We integrate the design of wireless communication nodes and hydrogen fluoride gas sensors to realize wireless node communication for sensor data transmission and control command transmission and establish a central computer control platform to realize the selection of monitoring points and sensors and the automatic processing of measurement signals. A reasonable gas sensor conditioning circuit is designed in the article. In terms of software, the workflow of network nodes is optimized. The characteristic of the sampling circuit is that it can identify the status information of the hydrogen fluoride gas without continuous data collection and data analysis for the hydrogen fluoride gas sensor, and the detection speed is fast; at the same time, the circuit structure is simple, the components are few, and the cost is low, which is convenient for the hydrogen fluoride gas sensor. The gas sensor sampling circuit is integrated with various wireless sensor systems such as electronic tags.

2. Related Works

When a single sensor cannot make a good selection of hydrogen fluoride gas, it is necessary to use an array of hydrogen fluoride gas sensors to solve the problem of identifying the type of hydrogen fluoride gas. The increase in system power consumption brought about by a considerable number of sensors makes its application conditions very harsh, which greatly limits the application range of sensor arrays. Therefore, reducing power consumption has become one of the important core tasks of hydrogen fluoride gas sensor research [13].

Nikolic et al. [14] pioneered a semiconductor hydrogen fluoride gas sensor based on a microhotplate heating structure. The microhotplate of the sensor adopts a "sandwich" structure; that is, the upper and lower layers are made of SiO_2, and the middle layer is made of Si_3N_4. By etching the silicon substrate at the lower part of the microhotplate, the heat dissipation path of the microhotplate is reduced, and the power required to reach the predetermined operating temperature can be reduced. After experimental calculations, a power consumption of about 100 mW can ensure that the microhotplate is heated to 300°C. It can be seen that the application of MEMS technology in the sensor field has greatly reduced the power consumption of the microhotplate hydrogen fluoride gas sensor. Manes et al. [15] designed for the first time a microhotplate hydrogen fluoride gas sensor made of a CMOS compatible process. This initiative has laid a solid foundation for the realization of a highly integrated hydrogen fluoride gas sensor. The microhotplate is mainly composed of a SiO_2 dielectric film for electrical and thermal isolation, a suspended dielectric film supported by four arms, and a polysilicon heater. The microhotplate can be heated to above 300°C in just a few milliseconds, and the power consumption is less than 50 mW, so it has a good practical application prospect. Jo and Khan [16] combined multiplexers and differential readout circuits with integrated gas sensors and successfully developed a 4×4 tin dioxide integrated hydrogen fluoride gas sensor array. The microhotplate adopts a classic bridge structure, and its platinum snake-shaped heating circuit is embedded in a multilayer composite dielectric film. The differential readout circuit in the array can distinguish the resistance value of the gas-sensitive membrane within the range of 20 M. When the operating temperature is 300°C, its power consumption is only 16 mW.

Kim et al. [17] developed a CMOS compatible process microhotplate hydrogen fluoride gas sensor. In this sensor, metal tungsten is used as the heating resistance wire. At the same time, taking into account the reduction of heat dissipation of the microhotplate, the front body silicon corrosion suspension technology is adopted. The sensor can be heated to 300°C within 8 ms, and power consumption is only 19 mW and has a good response to 50 ppm ethanol hydrogen fluoride gas. In order to reduce power consumption, Zhang et al. [18] designed an optimized heating structure for the heating part of the semiconductor gas sensor. The heating structure only needs about 2 mW of power consumption to maintain the temperature at about 300°C. At the same time, the research group designed a pulse heating mode for the optimized heating structure and reduced the power consumption of the sensor heating part to about 350 μW. The system is based on WSN technology. In the event of a fire, we report to relevant personnel in time [19]. Based on WSN and GSM technology, some scholars have designed a set of data based on a solar power supply and wireless sensor network hydrogen fluoride gas monitoring system and home security alarm system. This system could play an important role in antitheft and combustible hydrogen fluoride gas leakage and fire protection monitoring when a dangerous situation occurs. It sends an alarm message to the homeowner's mobile phone to ensure the safety of the family [20]. Some researchers have designed a water quality monitoring system, which is also based on WSN technology. The pH value, pollution level, temperature, and turbidity of water can be monitored, so that the environmental protection department can provide real-time guidance for industries such as industry, plantation, and aquaculture that depend on local water quality conditions [21–23].

3. The Detection and Early Warning Model Construction of Poisonous Gases Based on Semiconductor Wireless Sensors

3.1. Levels of Semiconductor Wireless Sensor Networks. The hydrogen fluoride gas wireless monitoring network is mainly composed of monitoring nodes that can detect hydrogen fluoride gas and a central control platform that can receive data from various monitoring points and send monitoring commands. The monitoring node is an important part of the system, which includes the hydrogen fluoride gas sensor module, sensor working circuit, signal processing circuit, and wireless module. Figure 1 shows the semiconductor wireless sensor network topology.

Its working principle is as follows. The central control platform is initialized, and a wireless network is constructed. After each monitoring point joins the wireless network, the central control platform sends a monitoring command. After the monitoring point receives the command, the hydrogen fluoride gas sensor starts to collect gas concentration information. After the output signal is processed by the signal conditioning circuit, the data is sent to the corresponding wireless module, and the wireless module sends the data to the central control platform. The machine of the central control platform processes the received data and displays the concentration of various hydrogen fluoride gases in real time.

$$\alpha = (i, j, k) = (i(1), i(2)\,; j(1), j(2)\,; k(1), k(2)), \quad i, j, k \in Z. \tag{1}$$

The working circuit of the hydrogen fluoride gas sensor is to make each sensor work normally, which converts the current signal output by the sensor into a voltage signal. The signal conditioning circuit is classified according to the polarity and size of the output signal of the sensor, and the output signal of the sensor of the same type is amplified to prepare it for entering the single-chip microcomputer. The wireless network communication system is to realize the wireless data transmission from the monitoring point to the central control platform. The computer central control platform is to realize the intelligent control of monitoring points and automatic processing of measurement signals.

$$\begin{cases} u(x, y) = \bar{u}(x, y), \\ v(x, y) = \bar{v}(x, y), \end{cases} \quad \bar{x}, \bar{y} \in S(\bar{u}). \tag{2}$$

A semiconductor element made of metal oxide or metal semiconductor oxide material is put into the gas to be measured and interacts with hydrogen fluoride gas to produce surface adsorption or reaction, which causes the characteristic change of the resistive element to measure the concentration of hydrogen fluoride gas. We put the sensor into the measured hydrogen fluoride gas, and the resistance value of the sensor will change with the concentration of hydrogen fluoride gas. It has the advantages of high sensitivity, convenient operation, small size, low cost, and short response time and recovery time.

$$\begin{cases} \phi(i, 1) = \dfrac{[\phi^+(i) + \phi^-(i)]}{2}, \\ \phi(i, 2) = \dfrac{[\phi^+(i) - \phi^-(i)]}{2}. \end{cases} \tag{3}$$

The high molecular hydrogen fluoride gas wireless sensor mainly uses its resistance, material surface acoustic wave propagation speed, frequency, material weight, and other physical properties to change with the specific gas encountered to realize gas detection.

$$\min TV(u) - \text{s.t.}|f - u(i, j)|_t^2 = \sigma^2. \tag{4}$$

According to the different gas-sensing characteristics of the materials used, this type of sensor can be divided into polymer resistance gas sensors, concentration electric gas sensors, surface acoustic wave gas sensors, and quartz vibrator gas sensors. The surface acoustic wave gas sensor is based on the speed or frequency of the sound wave propagating on the surface of the material, which changes as the gas-sensitive material absorbs the gas. The gas concentration can be detected by measuring the speed or frequency of the sound wave.

$$\widehat{s} = \frac{1}{(k(1) \times k(2))} \times \sum_{i=0}^{k1} \sum_{j=0}^{k2} s(i, j) \times p(x, t). \tag{5}$$

The nonresistive semiconductor hydrogen fluoride gas sensor uses some physical benefits and device characteristics to detect hydrogen fluoride gas, for example, the volt-ampere characteristic of the Schottky diode and the change characteristic of threshold voltage of the semiconductor field effect tube, the gas sensor made by using these two characteristics, and its current or voltage changes with the content of hydrogen fluoride gas. This type of sensor is mainly used to detect hydrogen fluoride gas.

3.2. Distribution of Early Warning Circuit Nodes. The wireless communication node is mainly composed of a processor module, a wireless communication module, and an energy

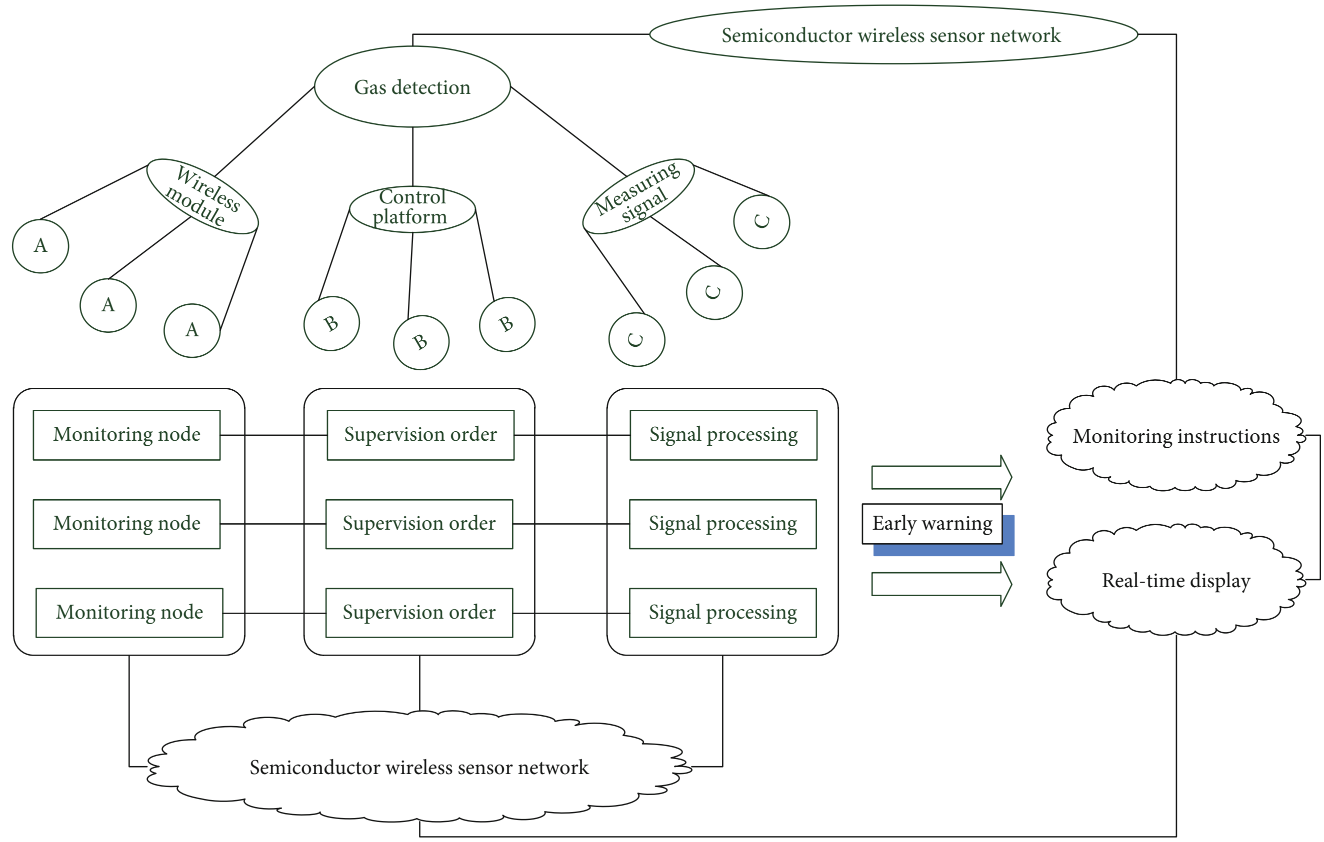

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FIGURE 1: Semiconductor wireless sensor network topology.

supply module. In the entire system, the sensor is the main device that collects the type and concentration of hydrogen fluoride gas. It is one of the cores of the entire system, and its choice directly determines the entire system's recognition ability, recognition range, service life, and so on.

$$E(f(x)) = \frac{\sum_{i=1}^{n} w(t) \times f(x(t))}{\sum_{i=1}^{n} w(t)},$$
$$\frac{f(x)p(x \mid t)dx - 1}{n \times \int f(x)p(t \mid x)p(x)dx} = 0 \quad (6)$$

In our system, a variety of different hydrogen fluoride gas sensors are needed. Choosing a suitable sensor combination plays a vital role in improving the performance of the entire system, and the semiconductor gas-sensing detection method is to put a resistive element made of metal oxide or metal semiconductor oxide material into the hydrogen fluoride gas to be measured and interact with the hydrogen fluoride gas to produce surface adsorption or reaction, causing the conductance of the resistive element rate or surface potential change to measure the hydrogen fluoride gas concentration. Table 1 shows the node description of the early warning circuit. Since it is necessary to amplify the sensor signal, if interference is introduced, it is easy to overwhelm the sensor signal or affect the quality of the sensor signal.

TABLE 1: Node description of the early warning circuit.

Node number	Response power (mW)	Working frequency (kHz)
1	7.15	100
2	9.03	110
3	5.97	105
4	5.62	97
5	7.14	104

Therefore, an operational amplifier with high common-mode rejection ratio, low temperature drift, and low offset voltage must be selected. Considering the power consumption factor, the selected amplifier must also be a low-power amplifier.

The processor module is responsible for controlling the operation of the entire sensor node, such as data storage, data A/D conversion, and processing the data collected by itself and data sent by other nodes; the wireless communication module is used to receive and send wireless signals, and the wireless sensor network terminal node performs wireless communication, which mainly includes two parts: radio frequency and baseband. The former provides the air interface for data communication, and the latter mainly provides the physical channel and data packet of the link. The energy supply module provides the energy required for the operation of the sensor nodes, usually using microbatteries. When there is no toxic hydrogen fluoride gas in the environment or monitoring is not required, the toxic hydrogen fluoride gas wireless monitoring network sends control commands to the monitoring node through the central control platform, so that it turns off the sensor's power supply and stops the sensor from working. The use of multihop transmission here is based on the consideration of communication range or energy saving. The energy value and communication distance of the sink node are slightly stronger than those of the sensor node. It is a bridge between the sensor monitoring area and the external network. Due to the many monitoring points, the intelligent control of the opening and closing of the sensor greatly reduces the power consumption of the entire system. Considering that system monitoring is used not only in large-scale areas but also for some places where the monitoring range is small and does not require wireless data transmission, we consider adding system assistance design. In terms of wired transmission, if the signal is sent in the form of voltage, the signal is transmitted from the sending point to the receiving point through a long transmission line. The voltage signal will form a voltage drop through the output impedance of the sending circuit, the resistance of the transmission line, and other resistances, which is likely to cause the transmission of the signal. If the signal is sent in the form of current, the current provided by the sending circuit is always the desired current regardless of the transmission line resistance and other resistances, and the signal anti-interference ability is greatly improved.

3.3. Hydrogen Fluoride Gas Detection Based on Semiconductor Sensors. Resistive semiconductor gas-sensing materials have a gas-sensing effect. When a special gas is adsorbed on the surface, the resistivity of the gas-sensitive material will change. Gas-sensitive resistors are made of metal oxide semiconductor materials. Through doping, the selectivity of hydrogen fluoride gas can be increased, and the gas sensitivity can be improved by setting the appropriate working temperature and improving the preparation process. Therefore, the gas sensor is designed by using the impedance characteristics of the metal oxide semiconductor gas sensor. To stabilize the output of v_{out}, we propose to control the gas. The sensitive resistance transducer is combined with the CMOS inverter, so that the high and low levels that fluctuate in a certain range can be converted into stable digital output signals 0 and 1. The gas-sensitive recognition analog recognition unit can be converted to a digital circuit. Therefore, the circuit can be effectively integrated into the storage unit and the control unit, and it is possible to realize the identification, storage, and control of the hydrogen fluoride gas signal. Table 2 shows the design of the hydrogen fluoride gas detection parameter.

The resistance R_x can be designed into a microarray structure, and the array resistances $R_1, R_2 \cdots R_x$ can be designed with different reference resistance values. According to actual use requirements, if you need to test the gas state of different hydrogen fluoride gas concentration points, you can choose different requirements through the digital control switch. As the reference point, it can be designed into a gas sensor array structure to realize the monitoring of discrete monitoring points for hydrogen fluoride gas. In the low-level phase of the clock, the master-level transmission gate T_2 is turned on, and the gas-sensitive input signal is directly transmitted to the master-level latch output terminal QM. During this period, the slave-level is in the maintenance state, and the bistable circuit feedback maintains its original state. During the rising edge of the clock, the master stage stops sampling the input and the slave stage starts sampling. In the high state of the clock, the slave stage samples the output (QM) of the master stage, and the master stage is in the maintenance state. Since QM remains unchanged during the high level of the clock, the output Q only samples the input gas-sensing signal per cycle once. After the class A gas sensor amplifier is turned on, due to the power consumption of the tertiary tube being very high, after receiving an effective alarm signal, before processing the alarm information, the input voltage of the tertiary tube can be temporarily turned off through the digital switch. In this way, the tertiary tube is cut off and the alarm stops. This design is more flexible and can detect the return characteristics of the hydrogen fluoride gas sensor. If the requirements are not met, the gas-sensitive resistor can be replaced. The inverter has infinite input impedance and low input loss. Through a multistage inverter cascade, the output state can be amplified step by step. By monitoring the final output voltage change, the change of the gas state can be monitored. In addition, this circuit has lower power consumption than class A gas sensors and is more suitable for the power consumption requirements of wireless gas sensor systems.

Table 2: Parameter design of hydrogen fluoride gas detection.

Gas index	Upper limit of concentration (%)	Lower limit of concentration (%)	Proportion
1	1.17	0.65	0.54
2	2.11	0.88	1.21
3	1.89	1.13	0.87
4	1.76	1.31	1.03

3.4. Model Parameter Weight Optimization. In the star-shaped network topology, all terminal monitoring points communicate directly with the central control platform, and there is no need for a network router in the middle. This kind of network topology is only suitable for the monitoring environment less than the maximum communication distance of two nodes. When the monitoring environment is greater than this distance, the central control platform cannot receive the data of each monitoring point. The mesh topology is different from the star topology. It can act as a router in the mesh topology, forwarding data and various control commands. As long as they are within the communication distance of each node, the central control platform can communicate with network routers. This kind of network is very complex, each node needs to maintain a large amount of information, and there is no fixed path in data transmission; the optimal path must be selected according to the situation, and the construction is very difficult. When the potential is close to and the bias voltage is 0, the bottom current and noise are the smallest. When the sensor detects low-concentration gas, since the response current is small, it is desirable that the bottom current and bias current are as small as possible, so the bias voltage is grounded. The clustered network topology is an upgraded version of the star network topology. This network topology is composed of multiple star topology structures. In the clustered network topology, the data and command transmission paths are clear, and the functions of each wireless communication node in the network are clear. Compared with the mesh topology, the structure is simpler. Compared with the star network topology, it can realize the functions of network routing to forward data and control commands, which greatly increases the coverage area of the network. Figure 2 shows the topology of the semiconductor wireless sensor circuit.

First, the sensor nodes are deployed in the monitoring area (sensor field), usually by manual deployment or aircraft dissemination or even by means of rockets. Obviously, this kind of deployment has strong randomness, and the number of sensor nodes deployed each time is relatively large. Secondly, when the sensor nodes deployed in the monitoring area are successfully awakened, they form a network in a self-organizing manner and transfer data to the nodes through multihop relays. Finally, the data in the entire area is transmitted to the remote-control center for centralized processing by means of the convergence node link. At the same time, the user's query request can be sent to the sensor network. The sensitive element and the conversion element constitute the basic part of the sensor, and they, respectively, complete the two basic functions of detection and conversion. It is worth noting that not all sensors can be clearly divided into two parts: sensitive components and conversion components, such as semiconductor gas or temperature sensors, thermocouples, piezoelectric crystals, and optoelectronic devices.

4. Application and Analysis of the Detection and Early Warning Model of Toxic Gases Based on Semiconductor Wireless Sensors

4.1. Wireless Sensor Data Processing. The working process of the poisonous gas monitoring system based on the wireless sensor network is as follows: the sensor nodes arranged in the monitoring area will collect the data about the poisonous gas to the gateway node through the multihop ad hoc network, and the gateway node will collect the data to the gateway node. The data is transmitted to the Internet network through the GPRS network, and then, the monitoring center realizes real-time monitoring through the Internet network. Figure 3 shows the fan-shaped distribution of wireless sensor modules. The model of the GPRS module selected by this system is ZHD121AX GPRS DTU, which is the most important product of the ZZHD1X series of DTUs. It can enable non-IP system equipment to easily connect to the GPRS network and the Internet through the serial port. The GPRS module is embedded with a TCP/IP protocol stack and adopts a general RS232/RS485/TTL interface. At the same time, the interactive interface of the GPRS module is easy to operate.

The node needs to be connected to the router when it is working, and the router is connected to the computer. At this time, the node and the computer are in the same local area network, and the data can be uploaded to the LabVIEW platform. The NB-IoT node introduces the Internet of thi5ngs card provided by National Telecom. This is connected to a radio frequency antenna to upload data to the developer platform through the NB-IoT network. Before each communication is completed, the gateway node will send a message requesting sleep to the data relay. After the data relay communicates with the upper computer, it will set up the entire network according to the requirements of the upper computer. The response of the sensor will still increase after it is removed from the test chamber. Under normal circumstances, when the sensor is removed from the gas to be measured, the response of the sensor will immediately begin to decrease because the reactant that produces the response does not exist. In the wireless data transmission part of the transformer online monitoring system, the coordinator node is connected to many terminal nodes, and the parameter data information collected by the terminal nodes is transmitted to the monitoring terminal, so that the coordinator node plays the role of the center, and many terminal nodes are connected to it, so the matrix use of the keyboard is necessary.

4.2. The Hardware Simulation Design of the Detection System. This section will simulate the actual sensing data in the WSN-based toxic gas monitoring system. The simulation data uses the buffer voltage data in the environmental monitoring data project. 100 nodes simultaneously detect the buffer voltage, and the buffer voltage changes over time. The amplitude changes slowly, and the geographical locations of the nodes are relatively close, so there is a correlation between these perception data. Now, we suppose that there are multiple signal groups, the number of signals contained in each signal group is $J = (1, 5, 10, 40)$, the length of each signal is $N = 50$, and the sparsity is $K = 5$. Since the difference between the data perceived by 100 nodes at the same time is small, it can be assumed that it is sparse in the Fourier domain. The connection method of the microhotplate hydrogen fluoride gas sensor in the two nodes is as described in the text. The series resistance R is 510 k. To prevent the wireless signal from being shielded, the node is placed in a paper box, and 40 ppm hydrogen fluoride gas and 60 ppm hydrogen fluoride gas are, respectively, introduced. We set an alarm when the hydrogen fluoride gas concentration is greater than 55 ppm. Figure 4 shows the line graph of the hydrogen fluoride concentration detected by wireless sensing. The test data was extracted on the LabVIEW platform and the National Internet of Things development platform, and the results are as follows.

As the concentration of hydrogen fluoride gas increases, the gas-sensitive resistance decreases, which will cause the gas-sensitive voltage signal to rise. It can be seen that the

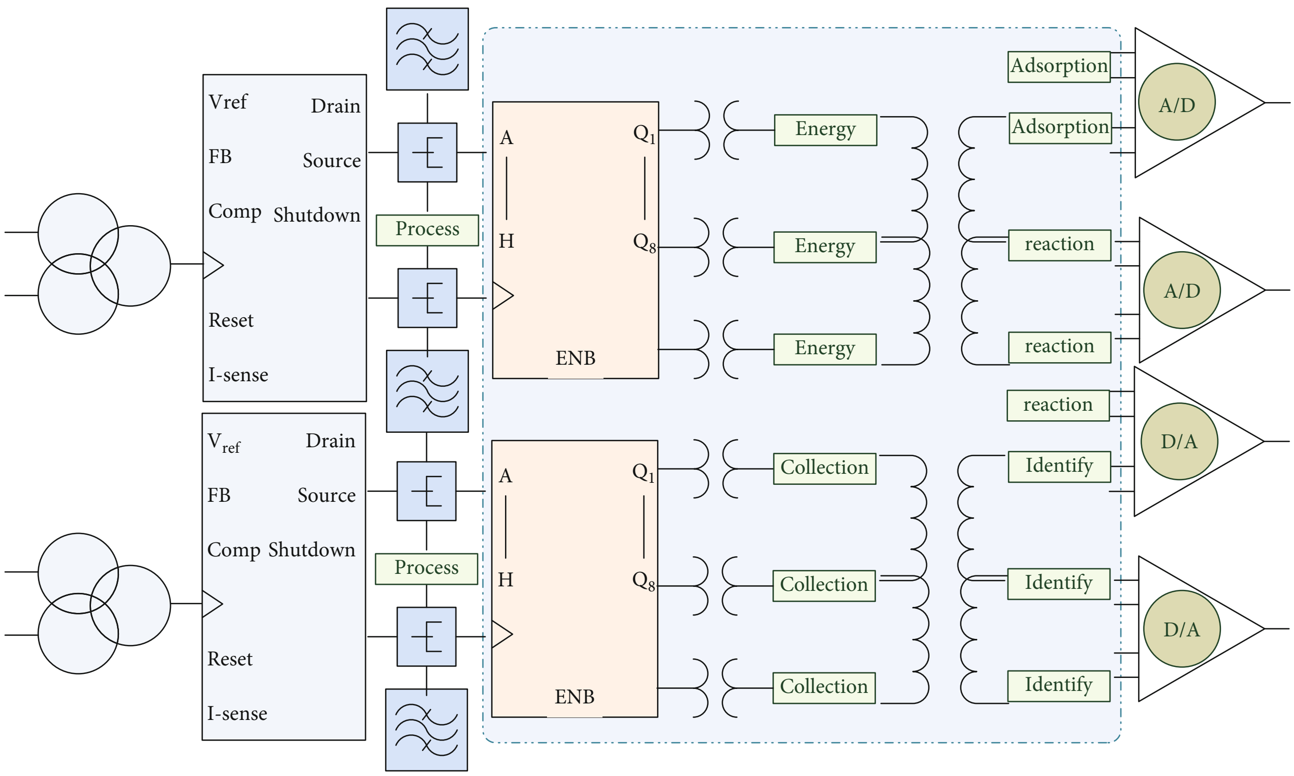

Figure 2: Semiconductor wireless sensor circuit topology.

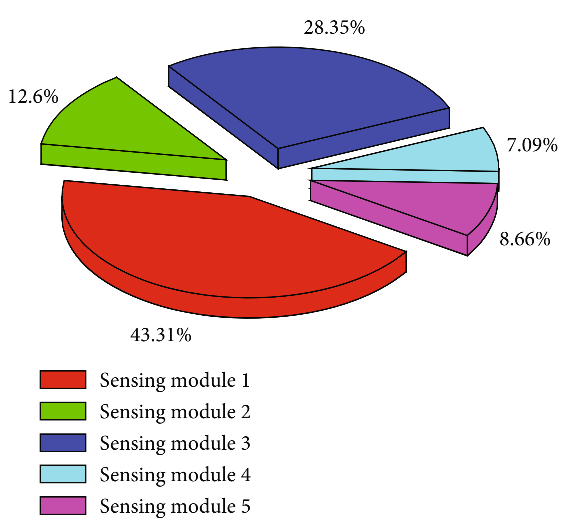

Figure 3: Fan-shaped distribution diagram of the proportion of wireless sensor modules.

gas-sensitive voltage signals collected by the two nodes are close to the same, increasing with the increase in the hydrogen fluoride gas concentration. At the same time, when the hydrogen fluoride gas concentration is greater than 55 ppm, the node immediately reports data and changes the reporting frequency to 1 min. When the hydrogen fluoride gas concentration is less than 55 ppm, the frequency of the node reporting data is changed to reporting data once every 10 minutes. Since TLC27C2L uses 5 V power supply and the power supply of the system is 12 V, it is necessary to perform power conversion to obtain a 5 V voltage. The stability and accuracy of the op amp voltage directly affect the stability of the op amp and the stability of the output signal, so we must choose a high-precision power conversion chip and we must do a good job of anti-interference processing. According to these principles, we choose LM336. It is a precision 5 V shunt regulator diode integrated circuit. Since the high-speed reference has a short start-up time and remains in a low-power state when ADC conversion is not in progress, the use of a high-speed reference will result in lower overall power consumption. Based on the above points, the voltage reference selects the internal 1.65 V high-speed reference voltage. These IC voltage references can work like 5 V Zener diodes with a low temperature coefficient, with a dynamic impedance of 0.6, and the third terminal provided on the chip can easily fine-tune the reference voltage and temperature coefficient. The devices of this series are suitable for precision 5 V power supply and low voltage reference for a digital voltmeter, power supply, or operational amplifier.

From the above comparison, we can see that the power consumption of the processor and sensor module is lower and the power consumption of the communication module (sending, receiving, and idle) is higher. On the premise of not affecting the performance of the system, reducing the data transmission volume of the communication module can naturally reduce the time for the communication module to send and receive data, thereby achieving the goal of reducing the energy consumption of the communication module. Figure 5 shows the linear fit of the average energy consumption of the wireless sensor network. When the

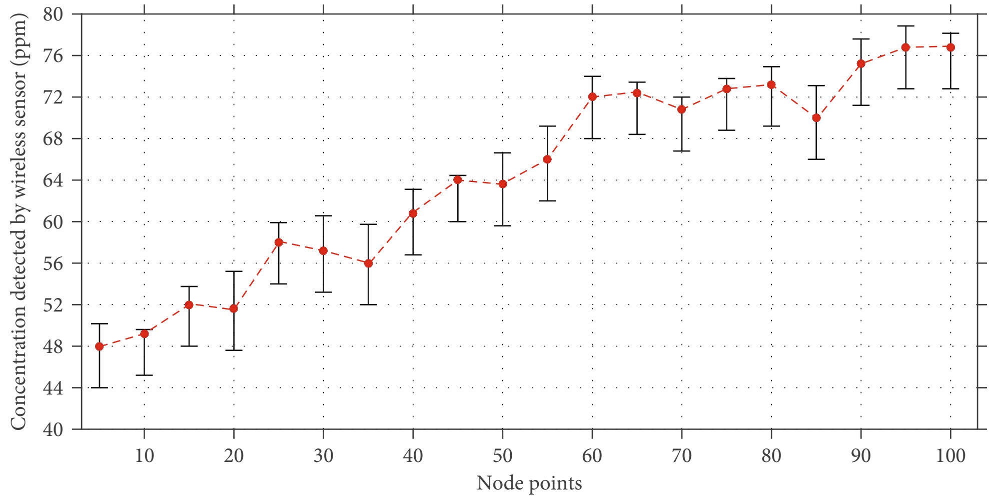

FIGURE 4: Line graph of hydrogen fluoride concentration detected by a wireless sensor.

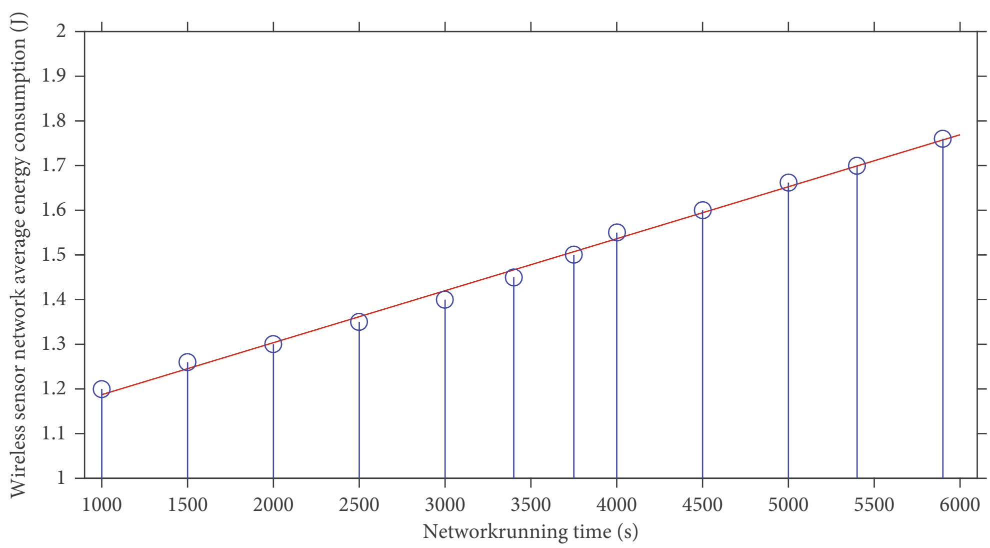

FIGURE 5: Linear fitting of average energy consumption of the wireless sensor network.

network runs for 1000 s, the average energy consumption of the nodes of the original algorithm is about 1.8 J, while the average energy consumption of the nodes of the algorithm in this paper is less than 1.6 J. At the same time, when the original algorithm runs for 1250 s, the nodes are almost exhausted, and the algorithm in this paper runs for about 2000 s before using up all the energy. Therefore, during the entire running time of the network, the average energy consumption of the algorithm nodes in this paper is significantly less than that of the original algorithm; that is, the algorithm in this paper has a better energy-saving effect than the original algorithm. Through simulation verification, in the data transmission of the toxic gas monitoring system based on the wireless sensor network, the superiority of compressed sensing and distributed compressed sensing is given. Without affecting the normal operation of the system, distributed compressed sensing can greatly extend the service life of the system.

4.3. Example Application and Analysis. The concentration of the hydrogen fluoride gas sample used in the simulation experiment in this section is limited to 40-4000 ppm, and the concentration interval is 20 ppm. Among them, 1200 samples are selected as the training samples of the wireless sensor network, and the remaining 131 samples are used as the test samples. Due to the large number of test samples, only 20 of the test result data are displayed here. Because the wireless module sends data at an interval of about 10 minutes, the length of the sent data is about 11 kbps and the wireless transmission rate is 16 Mbps. It only takes about milliseconds for the wireless module to send data once, so the average power consumption of the wireless module is approximately equal to its sleep power consumption. Figure 6 shows the data transmission rate comparison of the wireless sensor network. The sampling module only samples 5 times in the cycle, so the working time of the sampling module and impedance matching circuit cycle is about 50 μs. The pulse heating module is always working

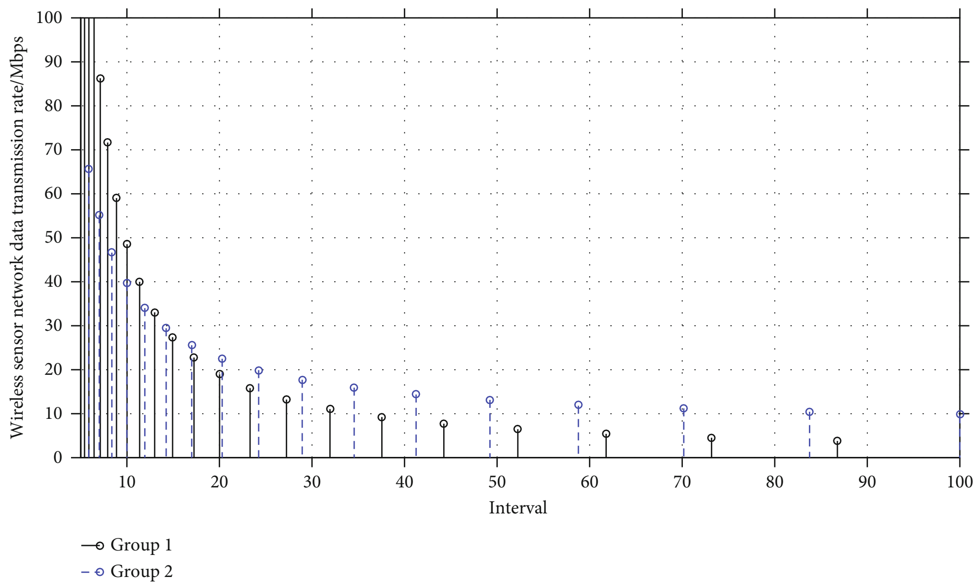

Figure 6: Comparison of the data transmission rate of the wireless sensor network.

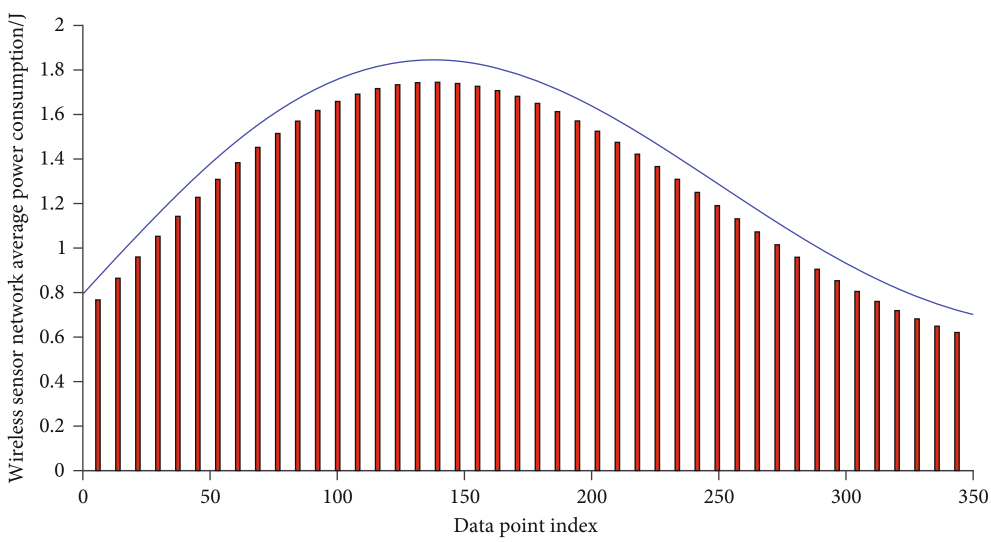

Figure 7: Bar graph of average power consumption of the wireless sensor network.

during the heating phase, so the working time in the cycle is 2 s. Each node is allocated to 5 subzones according to the set area number. In each zone, the nodes are randomly deployed, and the position will not be adjusted after deployment. The simulation time is 2500 s. Throughout the simulation process, the capacity consumed by each sensor node and the number of surviving nodes are recorded.

Compared with others, the CC3200 module, heating module, and sensor module consume the most power, because the CC3200 integrates a wireless module and consumes a lot of power. However, because the module has a very short working time in the node, the average power consumption is still relatively small. The total power consumption of the node is the sum of the average power consumption of each module, about 1.01 mW. Compared with ordinary Wi-Fi nodes (power consumption is about tens of milliwatts), it is reduced to about 1/20 of the original. It can be seen that the power consumption of each module of the node designed with NB-IoT is very low, especially the wireless and processor modules. Relatively speaking, the average power consumption of the hydrogen fluoride gas sensor is the largest, followed by the heating module, and that of the power supply and wireless module is the lowest. Since multihop routing and forwarding are common methods of internal communication in wireless sensor networks, the connectivity of the network will affect the information exchange between sensor nodes, so it needs to be considered in the process of considering some coverage issues. Therefore, the power consumption of the hydrogen fluoride gas sensor and the heating module can be further reduced in the follow-up. Therefore, the wireless node developed in conjunction with NB-IoT is about 1/40 of the ordinary node. Figure 7 shows the histogram of the average power consumption of the wireless sensor network.

The experiment selected transformer partial discharge and hydrogen fluoride gas as monitoring parameters to construct an online monitoring model of a wireless sensor network. The normalized power spectrum content of the three frequency bands was selected as the first three variables of the input vector, and a tin dioxide semiconductor was also selected. The gas sensor measures the relative percentages of the seven faulty hydrogen fluoride gases of the transformer as the remaining seven variables of the input vector, so that there are ten input nodes in the network, and the output vector is selected as the fault code corresponding to the four fault types. Then, the trial-and-error method is used to determine that the number of nodes in the 30 hidden layers is reasonable, and the learning and training of the network are realized through learning samples. We can see that in the same running time, the number of surviving nodes using this algorithm is more than using the original algorithm. In the original algorithm, when the network runs for more than 1500 s, most of the nodes are dead, but with the algorithm in this paper, most of the nodes die when it runs for about 2250 s. Therefore, the survival rate of nodes using the algorithm in this paper is significantly higher than that in the original algorithm. The results show that both nodes can complete the functions of timed heating of sensors and data collection, wireless uploading, and network access. At the same time, when encountering hydrogen fluoride gas that exceeds the set threshold concentration, it can report data in time and light up the alarm.

5. Conclusion

For the monitoring of hydrogen fluoride gas in a large environment, monitoring points must be arranged at different locations to form a monitoring network. If we use wired data to transmit data, the cost is higher and the wiring is very troublesome. In some places, wired monitoring points may be difficult to achieve. In view of these shortcomings and the characteristics of wireless sensor networks, this paper needs to design a wireless monitoring network. This article realized the design of the wireless alarm module circuit composed of the gas sensor monitoring circuit and the wireless transmitting circuit, which completed the communication mode of the microcontroller and the radio frequency chip, as well as the design of the interface circuit and the power supply circuit. The key radio frequency parameters such as the working frequency band and transmit power of the radio frequency chip were selected. On the basis of compressed sensing theory, the distributed compressed sensing theory which has great advantages in signal group processing is further introduced. At the same time, this topic analyzes the energy consumption model of the node to prepare for the software energy consumption simulation. We use MATLAB software to verify the feasibility of these two algorithms in data transmission based on the wireless sensor network for the toxic gas monitoring system from the perspective of simulation. Using SILICON's WDS simulation software and IDE software, the RF parameters in the system and the microcontroller's register initialization parameters were set, and the program code was generated. In the end, this paper designs the overall system of the semiconductor wireless sensor based on the above two gas sensor sampling circuits, the microcontroller, and the UHF radio frequency chip. The key parameters of the radio frequency circuit are tested on the demo board, and the radio frequency signal transmission distance can be greater than 10 m.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

We declare that there is no conflict of interest.

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