COMPUTER CONTROLLED SETUP FOR TEMPERATURE MEASUREMENTS FOR THIN FILM DEPOSITION

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Computer controlled module for temperature measurements with thermocouples based on microcontroller PIC18F2620 is developed and tested. It consists of thermocouples, preamplifiyers, microcontroller PIC18F2620 and serial interface unit.

The software configures the microcontroller for temperature measurement, implements a temperature calibration (on a request of the user) and executes a measurement.

Keywords: temperature measurement, processing of sensor signals, data acquisition and control.

1. INTRODUCTION

In the last decades the multifunctional intelligent sensors ("smart noses) [1, 2] have been extensively investigated. Their working principle is based of analyzing gas mixture by means of sensor matrix. Matrix elements are sensitive to separate components of the mixture. Such a measurement requires computer processing of large amount of data. Producing of small sensor computing devices becomes possible after the development of the single chip microcontrollers. Microcontroller measurement modules are low cost, high efficient engineer decision for realizing the present-day sensor device [3].

There are varieties of organic thin films (e. g. polyimides [4], phthalocyanines [5]) that exhibit sensitivity to moisture, oxygen or other gases, acceptors of electrons. Their selectivity could be considerably increased using sensor matrix, controlled by microcontroller.

Polyimide thin films could be obtained by spray deposition or spin-coating. However the deposition from solution leads to a defect formation. To overcome this problem vacuum deposition of the polyimide layers is used.

Polyimide precursors (pyromellitic dianhydride (PMDA) and oxydianiline (ODA)) must be simultaneously deposited in vacuum in stoichiometric ratio. To keep the stoichiometry it is very critical to control the evaporation rate and the temperature of the evaporation sources. This could be achieved by consecutive control of two deposition parameters – the temperature of the evaporation crucibles and the deposition rate.

The polyimide thin film preparation also requires two or three stage thermal treatment for the immidization process to occur [6]. This could be better performed in the vacuum chamber during or after the film deposition. Schematic location of the quartz crystals for the deposition rate measurements and the temperature sensors in the vacuum chamber is presented in Fig 1.

Controlling the temperature of the evaporation sources and the substrate could be easy implemented by multichannel computer controlled setup, based on microcontroller.

This work aimed to accomplish a multi-channel microcontroller based module for temperature measurement during vacuum deposition of polyimide sensor layers.

Beside this aim the experience gathered could be used in future development of intelligent sensors based on polyimides and other organic materials.

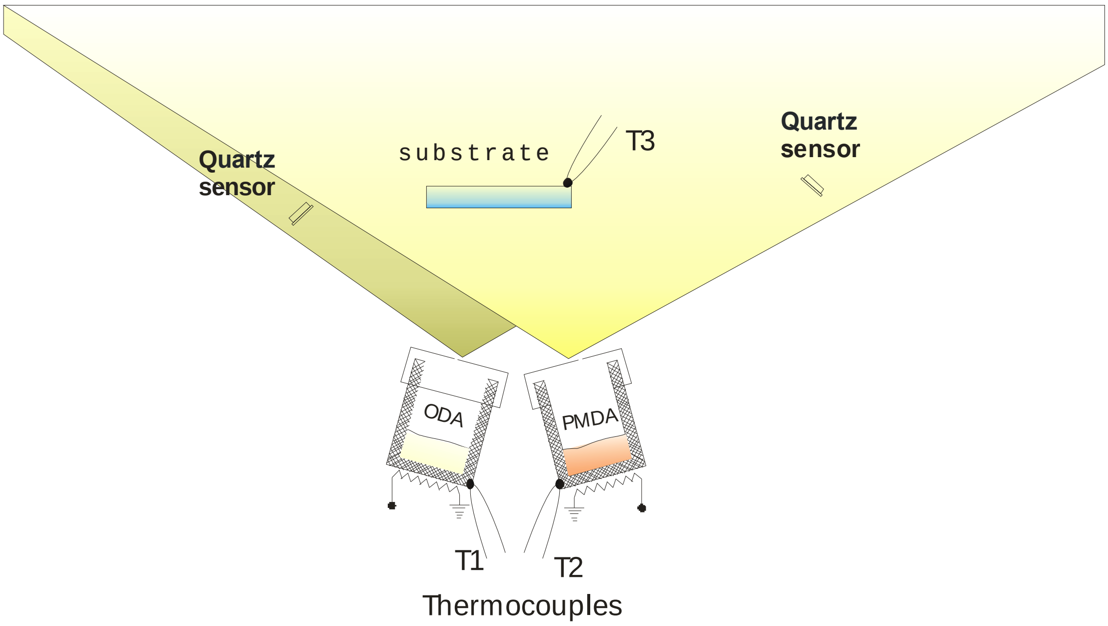

Fig. 1. Schematic location of the quartz crystals for the deposition rate measurements and the temperature sensors T1÷T3 in the vacuum chamber

2. Device Design

2.1. Hardware description

Block diagram of the four-channel microcontroller measurement system is presented on Fig. 2. It consists of thermocouples, four operational preamplifiers OP07, microcontroller PIC18F2620, USART interface and RS232 converter. Analog switches to the input of the ADC converter connect the preamplifiers consequently. Converted temperatures are sent through USART interface to PC. One measurement cycle is made on PC request by activation of the IRQ system on the microcontroller.

Basic oscillator of the microcontroller is configured with an external 4 MHz quartz crystal. This frequency is proper for the peripheral microcontroller devices (USART, ADC) at the chosen working conditions. For the vacuum deposition of polyimmide layers the temperatures vary from room conditions to the temperature of polyimide immidiztion.

In this temperature range platinum resistor or a thermocouple are proper to use. The thermocouple has the advantage of low thermal capacity and more simple electronic circuit for measurement. It is connected to the measuring device by "compensating" wires for cold junction compensation [7].

Generally the dependence of the temperature on the thermocouple output voltage is non-linear and could be interpolated with a polynomial [8]:

$$T = \sum_{n=0}^{N} a_n v^n \quad , \qquad (1)$$

where a_n are given for n from 0 to 5-9. It is very proper task to perform the calculations based on Eq (1) by microcontroller. In this way compact and low-cost temperature sensor could be implemented.

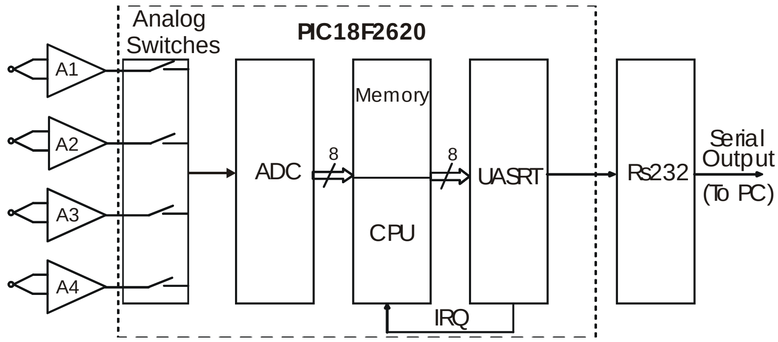

Fig. 2. Block diagram of the microcontroller temperature measurement module

Keeping in mind the calibration requirements for the chromel-alumel thermocouple used working interval 0-300°C is chosen. For the given temperature range the conversion voltage to temperature dependence is given by the equation:

$$Y = A + B.x \, , \qquad (2)$$

where A=0,0459 and B=0,0404.

The parameters of the measuring unit were determined in the following way. According to the ADC catalogue minimum reference voltage must be 3 V. In our case it is sufficient to use supply voltage V_{CC}=5V. At 10 bits conversion (2^{10}=1024 steps) the maximum resolution is U_{LSB} = 5V/1024=4.882 mV. This is not sufficient for measuring temperature with a thermocouple. Therefore an additional amplification of the signal is necessary. For this purpose the low cost, precise amplifier OP07C with low temperature coefficient of the input drift voltage (0,7 - 1,8 µV/°C) is chosen. Setting a gain of 1000 maximum resolution of 4.882 µV (0.24°C for Cr-Al thermocouple) is obtained. Due to the high value of the voltage gain it is necessary to compensate the input offset voltage. This is done by the input offset nulling circuit according to the OP07 requirements. The preamplifier is connected to the circuit as a classical inverted amplifier.

The amplified voltage is set to the ADC capacitor C_{HOLD} for a time higher than time constant of the ADC converter (min. 2.4 µs). After that the 10 bits ADC converts the measured value using successive approximation principle [9]. Finally the measuring number D is contained in the DAC registers. The dependence between D and the input ADC voltage is given by the equation

$$\frac{1024}{D} = \frac{U_{REF}}{U_X} \, , \qquad (3)$$

where U_{REF} is the reference voltage, U_X is the voltage measured by the thermocouple. The measured value is sent to the PC computer via USART interface and RS232 signal converter.

The temperature measuring module has four identical channels connected consequently to the ADC converter. One of them measuring room temperature is used as reference. Its “cool” ends are placed in melting ice or connected to a temperature compensation electronic unit. The “cool” ends of the last three thermocouples are kept at room temperature, correcting the “zero” point by the reference channel.

2.2. Software description

The software configures the microcontroller for temperature measurements, implements a temperature calibration (on a request of the user) and finally gets into an endless loop, expecting IRQ call from the PC computer to execute a measurement.

The algorithm of the software is presented in Fig. 3. Microcontroller configuration consists of setting the oscillator mode and other vitally important parameters. The configuration of the USART interface includes setting of the transmitter/receiver parameters. Baud rate (*BR*) is calculated according to the formula:

$$BR = \frac{F_{OSC}}{16(N+1)}, \qquad (4)$$

where F_{OSC} is oscillator frequency and *N* is a number set to the baud rate generator. At F_{OSC} = 4MHz and *N*=25 *BR* = 9600 bps is obtained.

Conversion frequency of ADC module is set to $F_{OSC}/4$ (time for conversion of one bit T_{AD}=1µs). Acquisition time $6T_{AD}$ = 6 µs is chosen to be large enough than the minimum acquisition time T_{ACQ}, ensuring a stable conversion. Finally the corresponding pins are configured to setreference voltage of 5 V.

After the configuration is complete, a relative or absolute temperature calibration procedure could be activated on user request. Both procedures must be implemented when all thermocouples are set to the room temperature long enough time to reach equilibrium with the ambient. Fourth channel, which measures room temperature, is used as reference. The values of the three working channels are compared with the fourth reference cannel. After recalculation of the “cool” end compensation voltage the differences of measuring channels with respect to the reference one are consider as amplifier input voltage drifts. This error is corrected by writing compensating coefficients in the ROM memory.

For an absolute temperature calibration the user imports a room temperature value measured with external device. It is compared with the measured data from the fourth reference channel. The difference is also considered as amplifier input voltage drifts and corrected with compensation coefficient. Then relative temperature compensation is implemented.

After the temperature calibration the microcontroller get into an endless loop expecting IRQ signal from the PC computer. When IRQ event is committed the measurement starts. The microcontroller reads the sting from the PC computer and activates the corresponding channel. The ADC module digitizes the measured value. The number obtained by the ADC is converted to a temperature by equations 2 and 3, transformed to string and sent through USART.

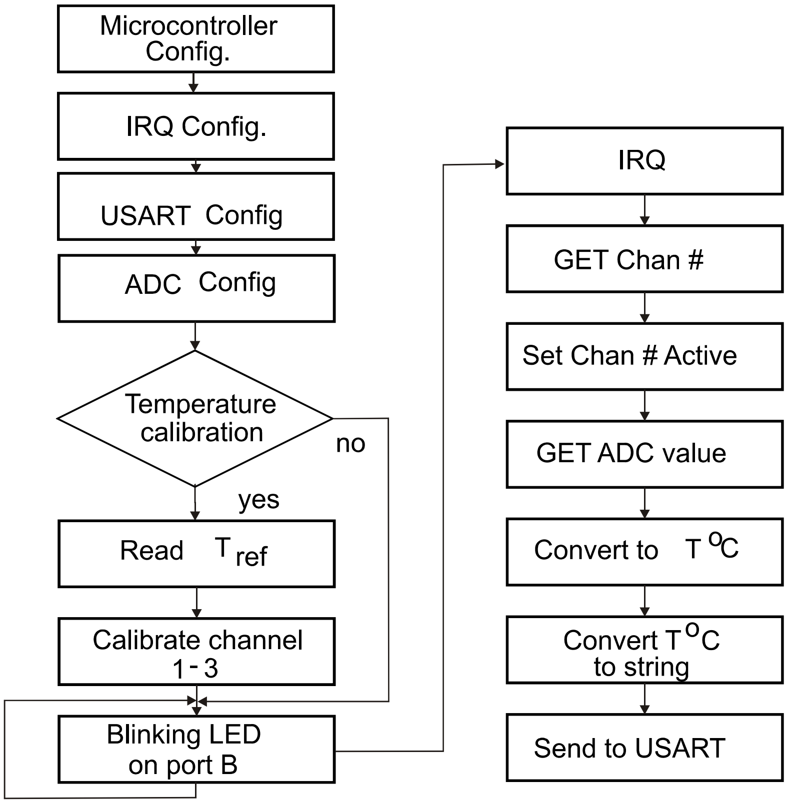

Fig. 3. Program flow chart

3. Testing and Measurements

The device stability of the temperature measuring module is tested applying a constant value of 1.03±0.01 V on the preamplifier's input for about 30 minutes. The values measured are recorded in file and plotted in Fig. 4. For seek of clarification 10 points are omitted and every eleventh is plotted. The measured data (points) are averaged (full line) and an average value of 1.095V with a standard deviation of ± 0.002V is obtained. This value corresponds to preamplifier's gain of 1063. The noise in the whole measuring system is about ±10%.

4. Conclusion

Module for temperature measurement during thin film vacuum deposition is accomplished and tested. It consists of thermocouple, microcontroller PIC18F2620 and serial interface for connection with PC computer.

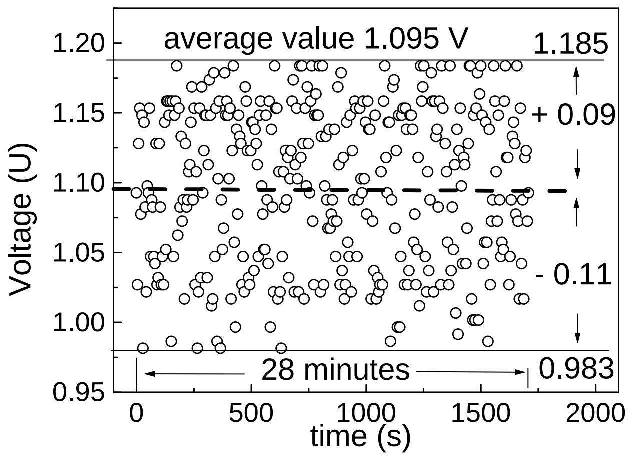

Fig. 4. Module test applying 1.03±0.1 V on the preamplifier output for about 30 minutes: (points) – measured data, (dash line) – the average value

The software configures the microcontroller for temperature measurements, implements a temperature calibration (on a request of the user) and finally gets into an endless loop, expecting IRQ call from the PC computer to execute a measurement.

The module is tested applying reference voltage to the preamplifier's input. The test shows standard deviation of ±0.18% and noise in the whole measuring about ±10%.

5. ACKNOWLEDGMENTS

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