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RESEARCH ARTICLE

AUTOMATION OF PRESSURE AND TEMPERATURE MEASUREMENT IN VACUUM DEPOSITION SYSTEMS

*[1]Tuwei A. K., [2]Karimi P. M. and [1]Njogu S. M.

[1]Department of Physical Sciences, Chuka University, P.O. Box 109-60400, Chuka, Kenya
[2]Department of Physics, Kenyatta University, P.O. Box 43844-00100, Nairobi, Kenya

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ABSTRACT

This paper describes a simple automated instrumentation and measurement system that is designed to offer a more reliable and fast method of measuring temperature and pressure, in thin film deposition systems. The designed computer based measuring system was based on thermocouple type K temperature sensor, MP20C-01-F2 pressure sensor, parallel port for interfacing and LabVIEW driver for accessing data. The system was able to measure temperature and pressure simultaneously when implemented in Edward Auto 306 Magnetron Sputtering System and stored these values in a computer memory, hence retrieved at operator's will. It had a temperature and a pressure range of 0 to 3000 °C and 0 to 1.01 x10^3 mbar, respectively and temperature error of ± 0.2 %. However, the designed system recorded varied pressure errors. In higher vacuum, pressure range of 1.0 x10^{-2} to 1.0 mbar, the error was 0.8 % and in the lower range of 1.0 x10^{-5} to 1.0 x10^{-4} mbar, the error of 0.5 % was observed. These errors were within acceptable range and therefore, the system is viable to be used in thin film deposition systems to automate the measurement of process parameters: temperature and pressure to achieve high quality thin films.

INTRODUCTION

In recent years, application of modern digital computers for instrument control [1] and measurement of physical parameters in industries has emerged as a promising area of achieving higher quality products and precise control and measurement of process parameters [3, 4, 5, 6, 7]. Thin film deposition in our research laboratories requires precise physical parameter control and accurate measurement. This ensures that high quality thin films are obtained that corresponds to specified values of process parameters under study. However, cheap and readily available current techniques for measuring temperature and pressure in thin film deposition systems lack back up memory and are manually operated. Therefore, vacuum deposition processes are largely controlled manually despite the fact that modern computers have a high speed of information processing and data storage [1, 9]. This approach is time consuming and prone to human errors while transferring process parameters from one application to another for analysis. Temperature and pressure, for instance, are of great importance in thin film preparation and largely affect their properties [1] hence accurate measurement of these quantities is in evitable [11]. Those that are automated and equipped with memories are quite expensive since they are based on PCI card for data acquisition or wireless transmission of data from the server to the clients [2, 10]. Other systems based on serial port interface are slow [2, 8] compared to parallel port interface. Therefore this paper describes a computer based measuring system that measures and stores the deposition chamber temperature and pressure data in a computer memory in form of a text file. It's based on thermocouple type K temperature sensor, MP20C-01-F2 pressure sensor, parallel port for interfacing and LabVIEW driver for accessing data.

***Corresponding author:** Tuwei A. K., Department of Physical Sciences, Chuka University, P.O. Box 109-60400, Chuka, Kenya.

EXPERIMENTAL PROCEDURES

Hardware designed procedures

The hardware design of the system comprised of the MP20C-01-F2 pressure sensor from Mindman Company, thermocouple type K temperature sensor and digital interface board designed in this project for communication between the computer and the sensors through the parallel port. The designed pressure sensor circuit and its associated 741 amplifier circuit are shown in Figure 1. The sensor had output voltage range of 0 to 100 mV and operated with a V_{cc} of +5 V. The values of the resistors shown were determined using circuit maker 2000 software during the simulation of the circuit. The digital interface board designed as part of the project consisted of the low pass filter and ADC0804 analogue to digital converter, and AD8180 multiplexer which are the standard ICs. The parallel port computer interface was used to transfer pressure and temperature data between the digital interface board and the computer for processing and storage. The designed computer based measuring system was fabricated on printed circuit board to minimize the capacitance observed on the breadboards.

Software designed

The software driver, which was used to access the temperature and pressure data from the parallel port interface, was designed using LabVIEW programming language. This is a graphical programming language and codes appear as icons as opposed to text in text based programming. This minimized syntax errors that are usually encountered in text based programming during coding. The front panel was designed on LabVIEW environment using the numeric and Boolean indicators.

Front panel for the software driver

The graphical user interface (GUI) depicted in Figure 2 was designed using numeric and Boolean indicators. It displayed chamber

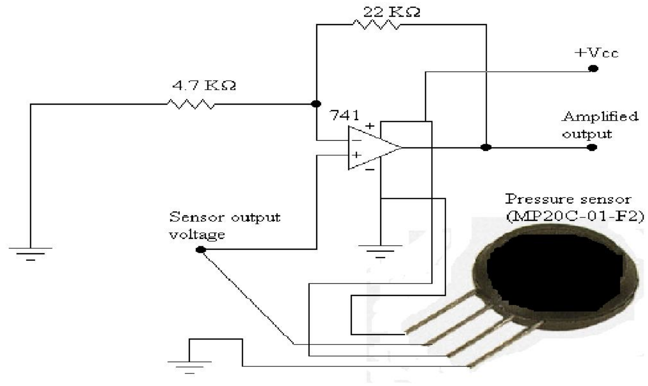

Fig. 1. The designed circuit of the pressure sensor MP20C-01-F2

temperature and pressure to the user during deposition of thin films in Edward auto 306 magnetron sputtering system. The on/off button on the front panel was used to activate and deactivate the software driver when data was to be accessed from the parallel port.

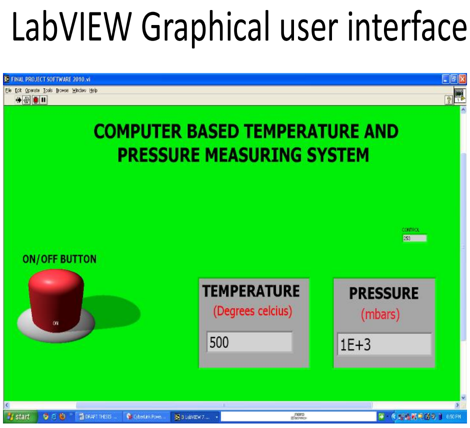

Fig. 2. The GUI of the software driver for the designed electronic system

The chamber temperature data was displayed in degrees celsius while chamber pressure was displayed in mbars to the user.

Block diagram for the software driver

The LabVIEW codes that were used to access temperature and pressure data from the parallel port interface are shown in Figure 3. The codes processed the values of these parameters and stored them in a computer memory for retrieval by the user after the deposition process. The codes appeared as icons on the block diagram as opposed to text based codes that are composed of several lines of text in text based programming. In frame A, bidirectional property of the parallel port is enabled by writing decimal number 32 to the data port to be able to input temperature and pressure data from peripheral sensors used to the computer memory for processing. The SELECT signal of the multiplexer AD8180 used is also enabled for 20 ms to allow only temperature data to be read by the computer. In frame B, temperature data is read from thermocouple type K temperature sensor used, processed, stored in computer memory in form of a text file and displayed to the user. In frame C, the SELECT signal of the multiplexer AD8180 is enabled for also 20 ms to allow only pressure data to be read by the computer. In the last frame D, pressure data is read from the sensor through the parallel port, processed, stored in computer memory in form of a text file and displayed to the user as indicated in figure 2. All the codes from frame A to frame D were executed in 80 ms and repeated again. Therefore, this time is so short that the user’s eyes could not notice the delay in reading the temperature and pressure data separately. It appeared on the GUI simultaneously to the user.

Testing the interface designed concept

The functionality of the designed computer based measuring system was tested in Edward auto 306 magnetron sputtering system as indicated in Figure 4. The MP20C-01-F2 pressure sensor was fixed to the vacuum chamber through a vacuum pipe and so to thermocouple type K temperature sensor. Their signal outputs were fed into the digital interfacing board designed and transmitted to the computer via the parallel port. The chamber pressure was measured by the designed system when Edward auto306 magnetron sputtering system was pumping up (venting) and when it was pumping down (evacuating). The chamber temperature was measured when samples of SnSe were deposited in the chamber through evaporation process. These measurements were also done with pirani gauge for pressure and uninterfaced thermocouple type K already fitted in the vacuum chamber. The measured values are discussed in the result and discussion section.

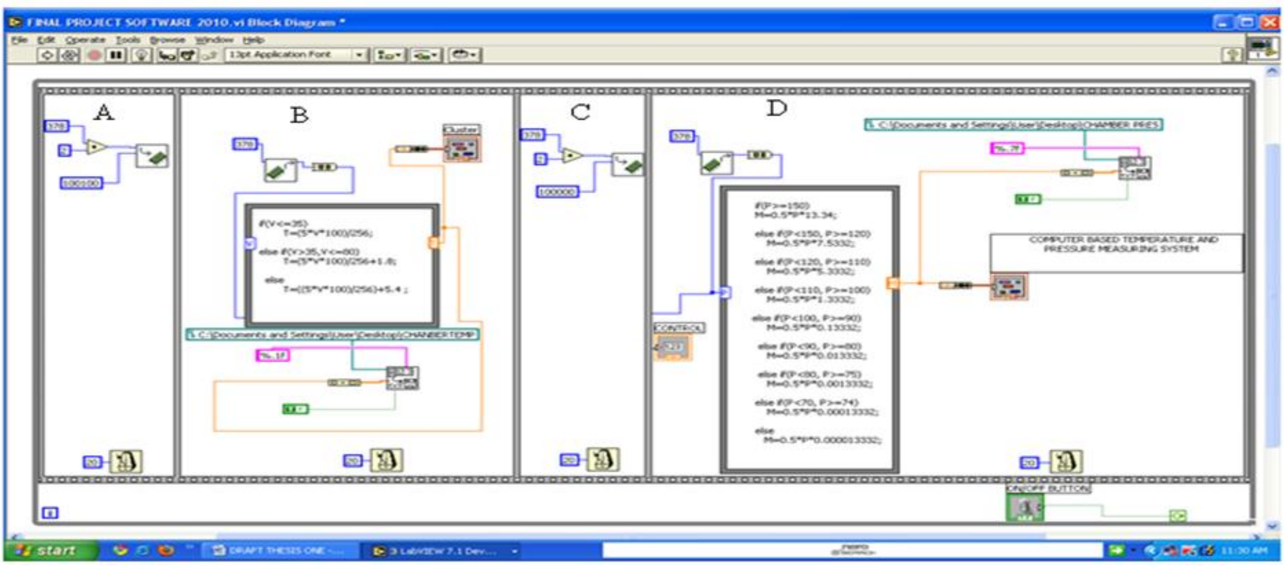

Fig. 3. LabVIEW codes that controlled the designed computer based measuring system

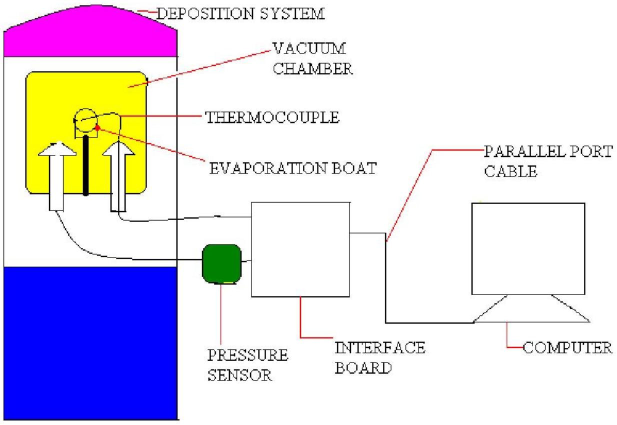

Fig. 4. Schematic diagram of the designed computer based temperature and pressure measuring system tested in Edward auto 306 magnetron sputtering system

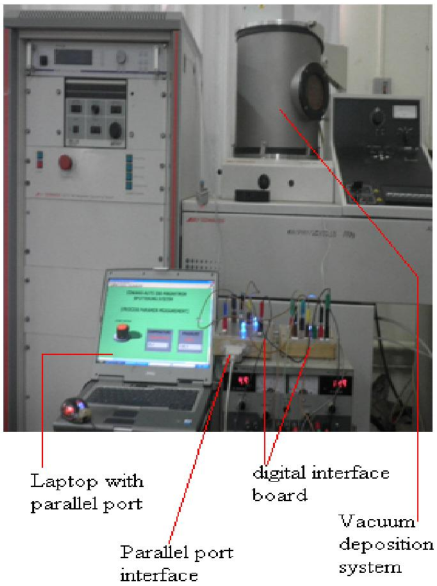

Figure 5. Photograph of the designed computer based measuring system when interfaced to the Edward auto 306 magnetron sputtering system and a Laptop with a parallel port interface.

RESULTS AND DISCUSSIONS

Pressure measurement

The measured pressure data are tabulated in Tables I and II when Edward auto 306 magnetron sputtering system was venting and pumping down respectively.

Table I. Chamber pressure measured in Edward auto 306 sputtering system when it was venting (pumping up)

Pressure measured by the designed electronic system (mbar)	Pressure measured by Pirani gauge (mbar)
1.0×10^{-4}	1.2×10^{-4}
1.2×10^{-3}	1.3×10^{-3}
1.0×10^{-2}	1.2×10^{-2}
2.6×10^{-2}	2.5×10^{-2}
3.6×10^{-1}	3.4×10^{-1}
8.5×10^{-1}	8.1×10^{-1}
1.3×10^{0}	1.3×10^{0}
6.0×10^{1}	6.0×10^{1}
2.0×10^{2}	2.0×10^{2}
7.0×10^{2}	7.0×10^{2}
1.0×10^{3}	1.0×10^{3}

Table II. Chamber pressure measured in Edward auto 306 sputtering system when it was evacuating

Pressure measured by designed electronic system (mbar)	Pressure measured by Pirani gauge (mbar)
1.0×10^{3}	1.0×10^{3}
2.2×10^{2}	2.2×10^{2}
6.0×10^{1}	6.0×10^{1}
4.4×10^{1}	4.4×10^{1}
1.2×10^{1}	1.2×10^{1}
8.5×10^{0}	8.5×10^{0}
7.5×10^{0}	7.5×10^{0}
1.2×10^{0}	1.2×10^{0}
9.0×10^{-1}	9.2×10^{-1}
3.4×10^{-1}	3.6×10^{-1}
1.5×10^{-2}	1.4×10^{-2}
2.0×10^{-2}	2.3×10^{-2}
1.5×10^{-3}	1.6×10^{-3}
1.1×10^{-3}	1.2×10^{-3}
1.3×10^{-4}	1.4×10^{-4}

The pressure sensor MP20C-01-F2 works on piezoelectric principle. When a mechanical force is applied on the sensor, a voltage is induced across the positive and negative terminals of the sensor. When Edward auto 306 magnetron sputtering system was pumping up (venting), the number of air molecules was increasing in the vacuum chamber. Therefore collision of air molecules increased within the chamber hence pressure increased as observed in table I when the air continued to be pumped in. When Edward auto 306 magnetron sputtering system was pumping down, the number of air molecules reduced in the vacuum chamber. Therefore collision of air molecules decreased within the chamber hence pressure reduced as observed in table II when the air continued to be pumped out of the chamber.

Temperature measurement

SnSe thin films were deposited on glass substrate in the ratio 1:1 in Edward auto 306 magnetron sputtering system using evaporation technique. During deposition process, the evaporation temperature of the samples was measured. Two thermocouple type K sensors, fixed in the chamber were used simultaneously to measure the evaporation temperature of the samples. One of the sensors was interfaced to the computer and the other to the standard thermocouple display. The measurements were repeated three times and their averages calculated. The evaporation temperatures measured by the designed electronic pressure and temperature measuring system and those from the standard thermocouple displays are shown in Table III.

Table III. Evaporation temperature of SnSe thin films prepared by evaporation technique in Edward auto 306 sputtering system.

Sample (Thin films of SnSe)	Temperature measured by designed electronic system (°C)	Temperature measured by standard thermocouple (°C)
A	426	425
B	427	428
C	428	429
D	431	430
E	424	423
F	425	425

Conclusions

The automated designed electronic measuring system described in this paper was tested in Edward auto 306 magnetron sputtering system and work quite well. It had a temperature and a pressure range of 0 to 3000 °C and 0 to 1.01 $\times 10^{3}$ mbar, respectively and temperature error of ± 0.2 %. However, the designed system recorded varied pressure errors. In higher vacuum, pressure range of 1.0 $\times 10^{-2}$ to 1.0 mbar, the error was 0.8 % and in the lower range of 1.0 $\times 10^{-5}$ to

1.0 x10^{-4} mbar, the error of 0.5% was observed. Therefore, the system is viable to be used in thin film deposition systems to automate the measurement of deposition pressure. It can be applied to other thin film deposition equipments.

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