Development of a data acquisition system for a vacuum thin film deposition equipment

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Abstract. Digital data acquisition is a must for precise data collection, and monitoring systems should be present on all modern equipment. This article focuses on improving the vacuum deposition systems already present in the SMARTMAT laboratory at the University of Oradea. Previous advancements have been made in installing vacuum chambers and digitally monitoring the vacuum level with the final objective of having a complete and versatile vacuum deposition system: magnetron sputtering, RF sputtering, and resistive heating. This article proposes a complex monitoring system based on modern sensors, data acquisition modules, and a processing and storage unit capable of monitoring all the vacuum deposition steps regarding the resistive heating system. The monitoring system can show real-time charts and store all the data in a database to be further used in modeling. As we already have a digital monitor system for the vacuum level, we have developed a monitoring system for temperature, voltage, and current, thus completing the design and controlling the whole evaporation process.

1. The work so far

The present work described in this article completes the vacuum thermal evaporation deposition system [1-4] and puts it in line with modern systems capable of being monitored electronically. It is clear that in a research environment, the work never stops, but further improvements to the system would be just small increments, and further automatization of the processes will be intensely dependent on the system created so far.

By giving the vacuum deposition system updated features, such as electronic monitoring and control, which has an already sound mechanical and electrical system, we are upcycling old technology and giving it a new life in our SMARTMAT [5] laboratory.

2. Data collection and monitoring system

The schematic of the data collection and monitoring system is presented in Figure 1.

The data collection and monitoring system presented in this paper is part of a complex monitoring system and focuses on measuring and logging data from the two Thermocouples K and R and from the two digital Voltmeters and Amperemeters.

Well-established books [6-8] but also recent articles [9-11] all have in common the same descriptions for data collecting when it comes to vacuum systems: pressure, temperature, and power management (voltage and current intensity).

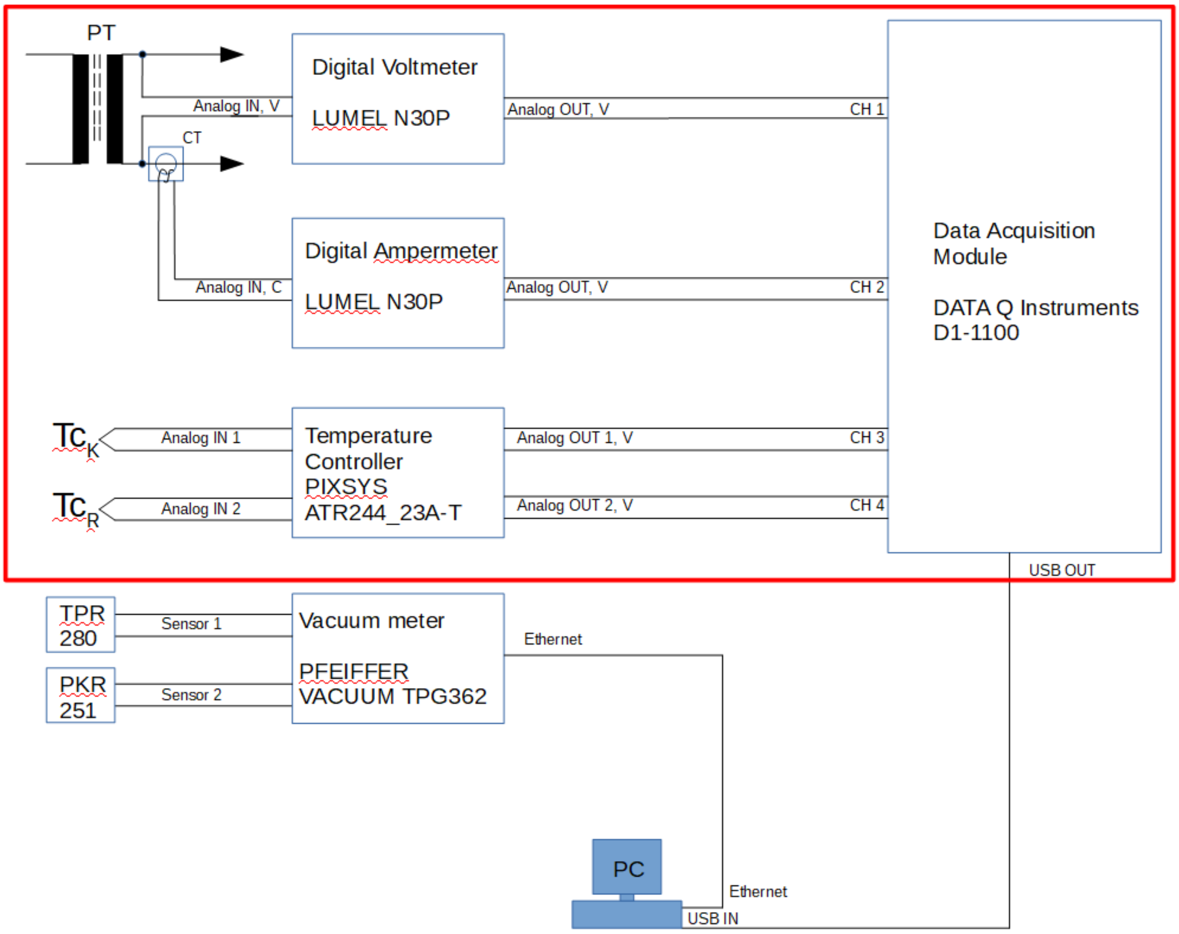

Figure 1. Diagram of the entire data acquisition system. The red rectangle shows the system described in this paper. PT = Power Transformer 3kW; CT=Current Transformer; TC_K = Thermocouple K; TC_R = Thermocouple R; TPR 280, PKR 251 = Vacuum sensors

2.1. Equipment and sensors used.

All the equipment and sensors used are readily available on the market and can be purchased from specialized retailers.

On the baseplate of the vacuum chamber we installed two thermocouple feedthroughs, individually for each sensor. On the outside, the feedthroughs are connected to the temperature controller PIXSYS [12]. On the inside, we connected the temperature sensors. We need two types of sensors because there will be two different ranges of temperatures recorded. The K-type thermocouple [13] has a limit of 1260° Celsius, while the Type R [14] has a maximum temperature range of 1760° Celsius. Because of the two different types of temperature sensors, we had to program the PIXSYS temperature controller with different settings. The calibration of the two thermocouples is made using an already calibrated sensor, as shown in Figure 4. It is essential to have two temperature sensors inside the vacuum chamber, as we need to monitor both the substrate temperature and the evaporation boat temperature. Without the sensors, we cannot accurately replicate different evaporation procedures.

The digital voltmeter was put in parallel on the output lines of the power transformer. The voltage to be measured is the supply voltage for the heating boat. It is an AC voltage with the frequency of 50Hz, adjustable in the range 0…15VAC. The heating current is an AC current, with a frequency of 50Hz, and a value in the range 0…300AAC To measure the heating current intensity, we used a current transformer connected to the digital amperemeter. The current transformer has a primary current nominal value of 300A and a secondary current nominal value of 5A, accuracy class 1.0. Both measuring devices are the same type LUMEL N30P [15], a digital panel meter capable of measuring both voltage and current but with different parameter settings. Unfortunately, one device cannot measure both at the same time. Calibration was needed, and it was done with a pre-calibrated true RMS digital multimeter.

Figure 2. Actual image of the whole setup (above); Previous configuration (below)

For the data acquisition platform, we opted for a DATAQ data acquisition kit with four channels. In retrospect, we should have chosen one with more channels to read the pressure sensors as well, but then again, they are directly connected to our PXI [3].

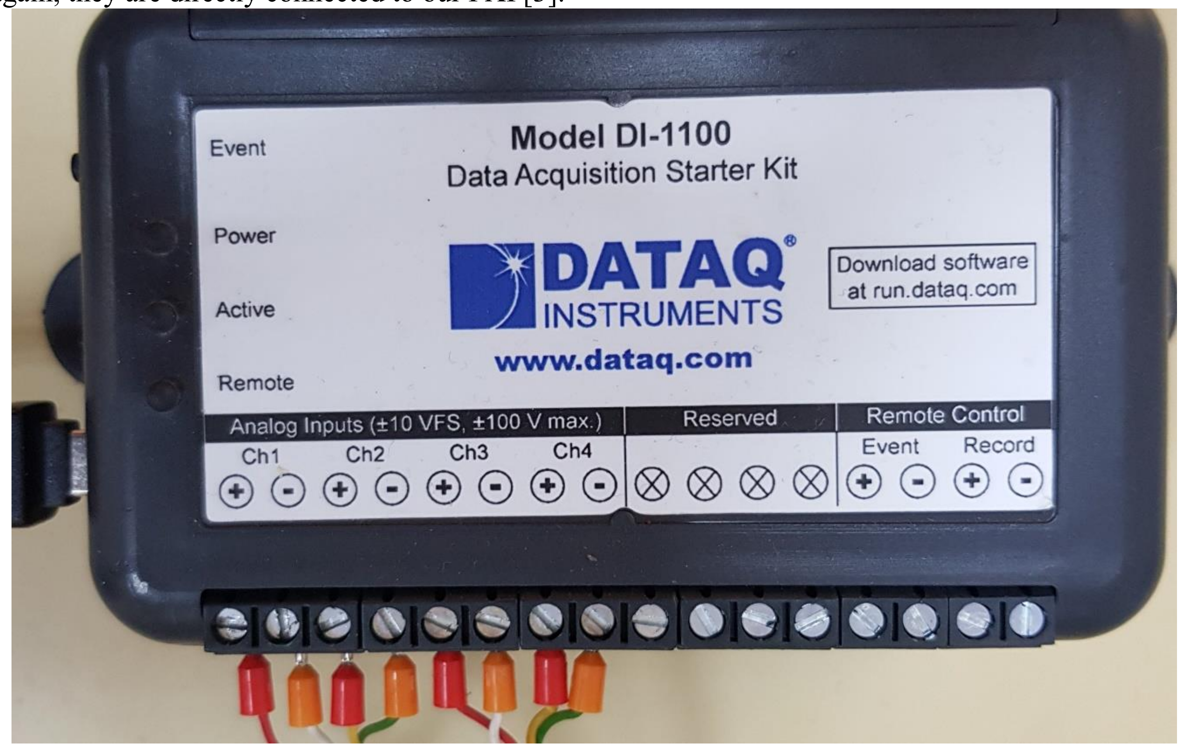

Figure 3. DATAQ DI-1100 data acquisition module

The DATAQ instrument [16] presented in Figure 3 is connected to our PXI via USB, and all the information is stored in a SQL database with timestamps. For each sensor (temperatures, voltage, current intensity), we take a reading each second. There is no need for a greater speed, as the thermocouples do not react instantly to the changes in temperature. Readings in voltage and current are only for reference as the most critical parameter, after the pressure, in a vacuum evaporation deposition system, is the temperature of the boat, but still plays an essential part in replicating the same technique and for validating that the system works correctly.

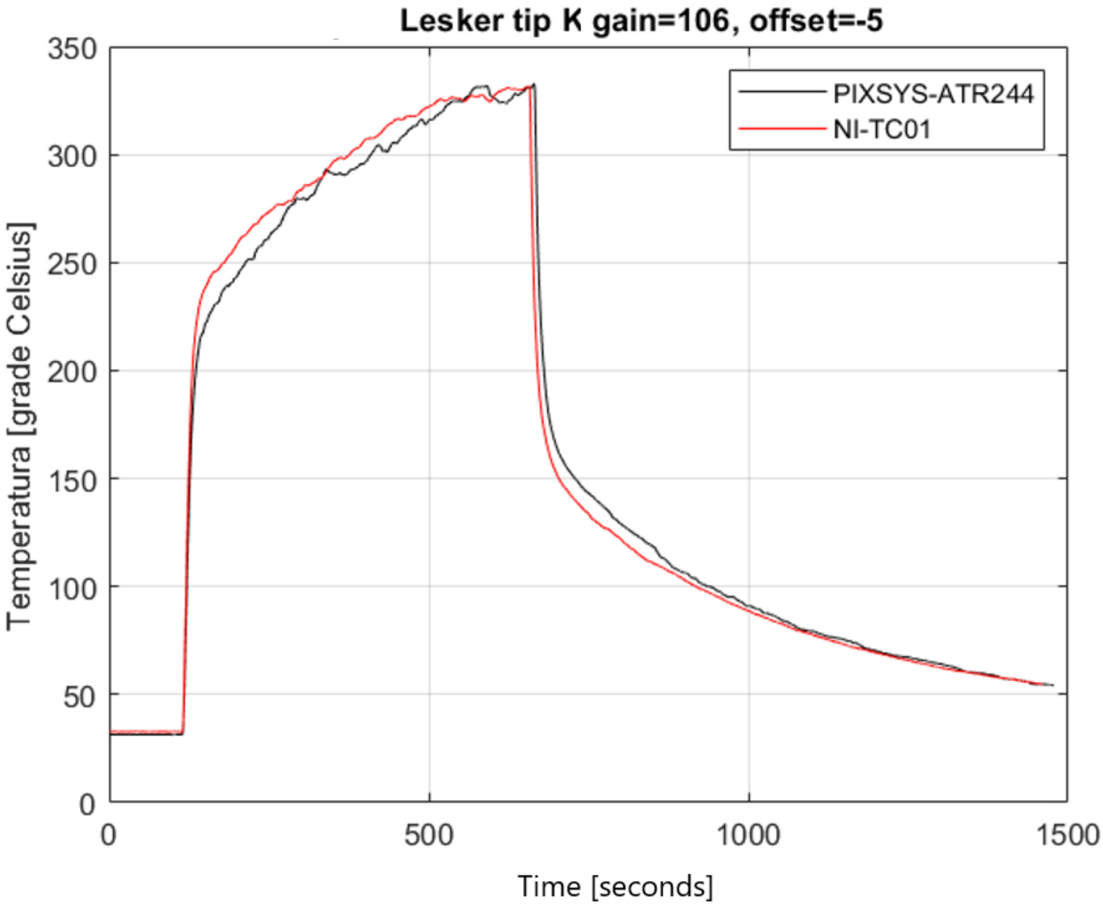

Figure 4. Calibration of type K thermocouple. Black (PIXSIS) – our device; Red (NI) – control device

3. Results and interpretation

Figure 5 presents a test made with both thermocouples R and K in a vacuum environment. The boat was not heated to the operating temperature, but a clear result was obtained. The sensors are working correctly, and as was expected, the R thermocouple is more dynamic in registering temperatures, as its wires are thinner and connection junction is smaller.

Of course, slight differences also appear because the sensors were placed on opposite ends of the boat, and the connection was not perfect.

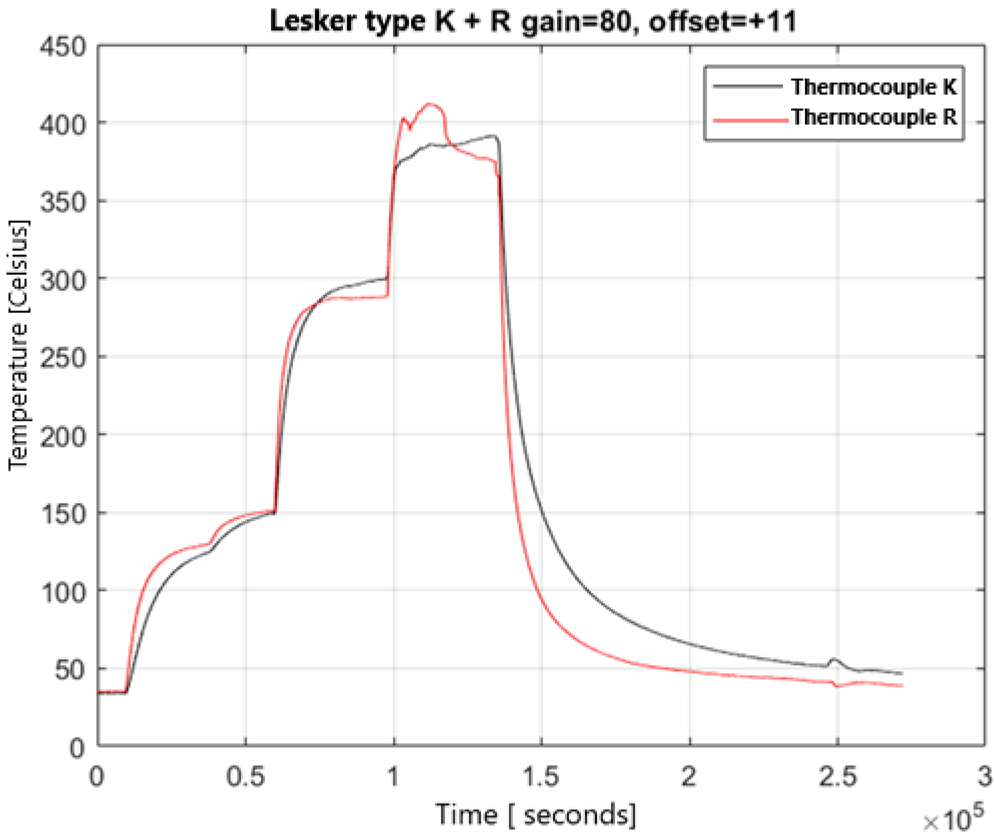

Figure 5. Testing both thermocouples K and R on the boat

4. Conclusions and further work

Given that this is an experimental setup, and optimizations are needed, the results are encouraging, and the data collection system is now complete. Furthermore, it can be translated or replicated in other systems. Since this is a developed system, we now have the know-how and skill-sets to implement such a complex data collection system in similar environments.

A correlation between all parameters will be made to better understand the interdependency between pressure, temperature, voltage and current, but that will be the subject of future work. Optimizations will be made on the system based on these measurements. Also, an electronic adjustment system for the current that is supplied to the boat will be installed in order to have more precise adjustments and, in the end, to have a system that auto-corrects itself and keeps either the temperature constant, either the voltage or current.

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