AUTONOMOUS TEMPERATURE SENSOR FOR SEMICONDUCTOR PROCESSING

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Memorandum No. UCB/ERL M00/6

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Autonomous Temperature Sensor for Semiconductor Processing

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Introduction

The overall purpose of this project has been to develop autonomous micro-sensor arrays for use in semiconductor processing. With these micro-sensors placed directly on wafers, the information can be used for real-time process control, calibration, and diagnostics. More specifically, this report addresses the testing of an array of temperature sensors to assess their ability to yield repeatable results for an extended period of time.

Apparatus

The temperature sensor wafer, a picture of which is shown in Figure 1, was composed entirely of off-the-shelf components. The sensor array was made up of four thermistors (*National Semiconductor LM61CIM3)* placed around the perimeter. Two button-cell rechargeable batteries (SANYO ML1220) supplied power, and were connected to a voltage regulator (*National Semiconductor LP2985IM5-3.0*). The sensor output was fed through a PIC microprocessor (*Microchip PIC12C67X*) and output via an irfrared LED in a format that was IrDA compliant. Additionally, the circuit included two capacitors to reduce current spikes that occurred each time the PIC output data, and a resistor that was used in turning the voltage regulator off. The circuit design can be credited to Darin Fisher and Michiel Kruger.

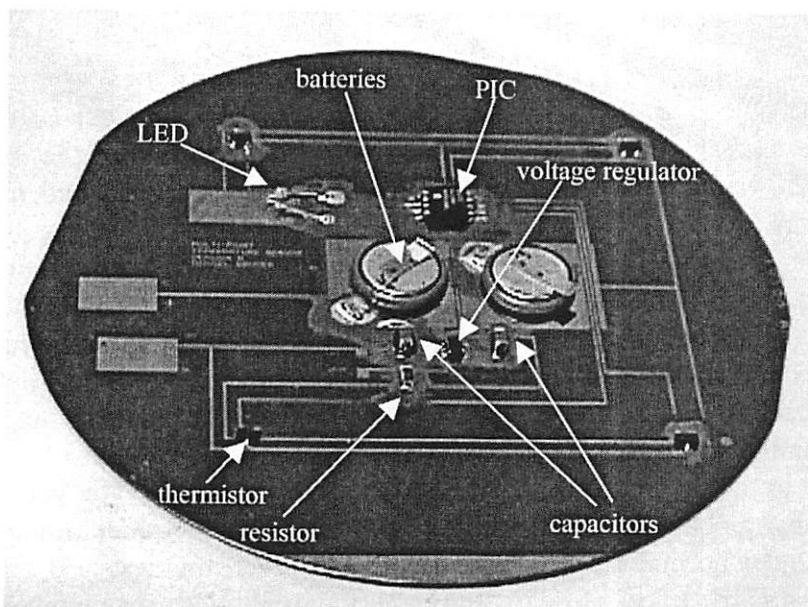

Figure 1. Photograph of the temperature sensor wafer and its components.

The apparatus for testing the wafer included equipment for data acquisition and external temperature control. Data transmitted via the LED was received by an infrared transceiver module (*Hewlett Packard HSDL-1001*) and demodulated by an infrared encode/decode IC (*HP*

HSDL-7001) before being passed on as serial data to a program which saved and formated it. By placing the wafer in a probe station typically used for metrology tests, analog data from the wafer could be measured and stored by a separate program. The metrology probe station also included a controllable bake plate on which the wafer rested. Communication between the computer and the bake plate controller, which was performed with a standard GPIB interface, allowed the bake plate to follow various temperature profiles. A photograph of the probe station is shown in Figure 2.

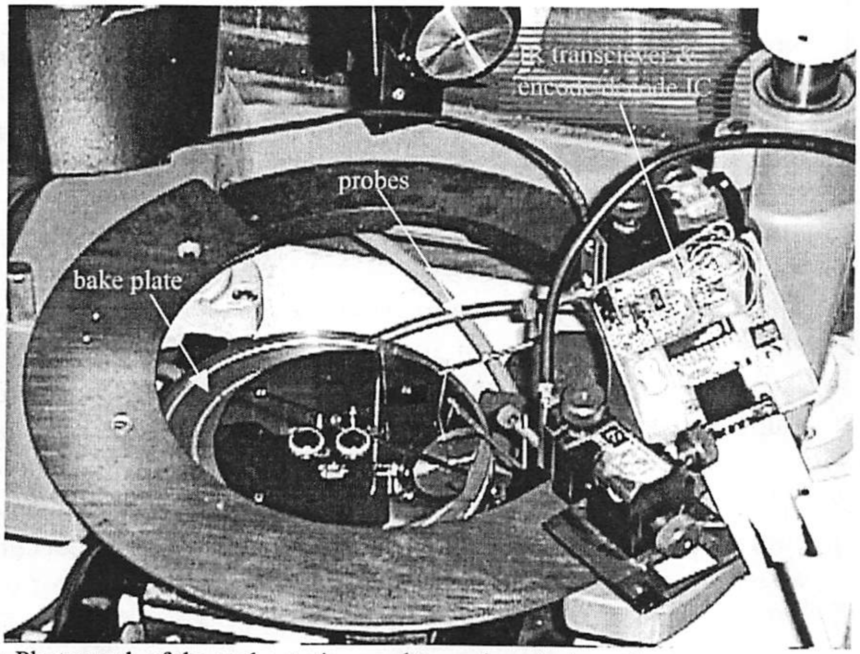

Figure 2. Photograph of the probe station used to perform tests on the temperature sensor wafer.

Methods

As it was the objective of this project to evaluate the performance of the temperature sensor wafer, three types of tests were employed to determine (a) the repeatability of measurements, (b) the operational life of the wafer with battery power, and (c) the transient response of the sensors.

The first type of test was a repeatability test with external power. This involved having the bake plate continuously repeat a simple temperature profile, one that would ramp up to a given temperature and then cool down passively, while the temperature sensor wafer was powered with an external source, such as a computer. Not only did this determine if the measurements were repeatable as the temperature was varied, but it also helped to test the performance of all components, excluding the batteries, at high temperatures.

A test similar to the previous one was also used, except that the wafer was untethered, i.e. power was supplied by the batteries. The main purpose of this test was determine the amount of life in the batteries under normal operating conditions; however, this test also served two other functions: first, to assess the effect of degrading battery power on sensor output, and second, to ascertain the effects high temperatures on the batteries.

The last type of test entailed quickly heating up and cooling down the wafer to evaluate the transient response of the sensors. This test was performed on an SVG Developer Track in the UC Berkeley Microlab, which included a bake plate heated to 120 °C and a separate plate with active cooling. Although this was the simplest of the three tests, it was the closest to the intended use of the wafer.

Results and Discussion

The main results from a repeatability test with external power are shown in Figure 3. The sensor output did not significantly deviate from the bake plate temperature at any time during the test. The sensors each exhibited a resolution of about 0.5 °C and were accurate to within ±2.0 °C. Additionally, all of the components on the wafer (with exception to the batteries) were able to perform adequately at temperatures up to 150 °C.

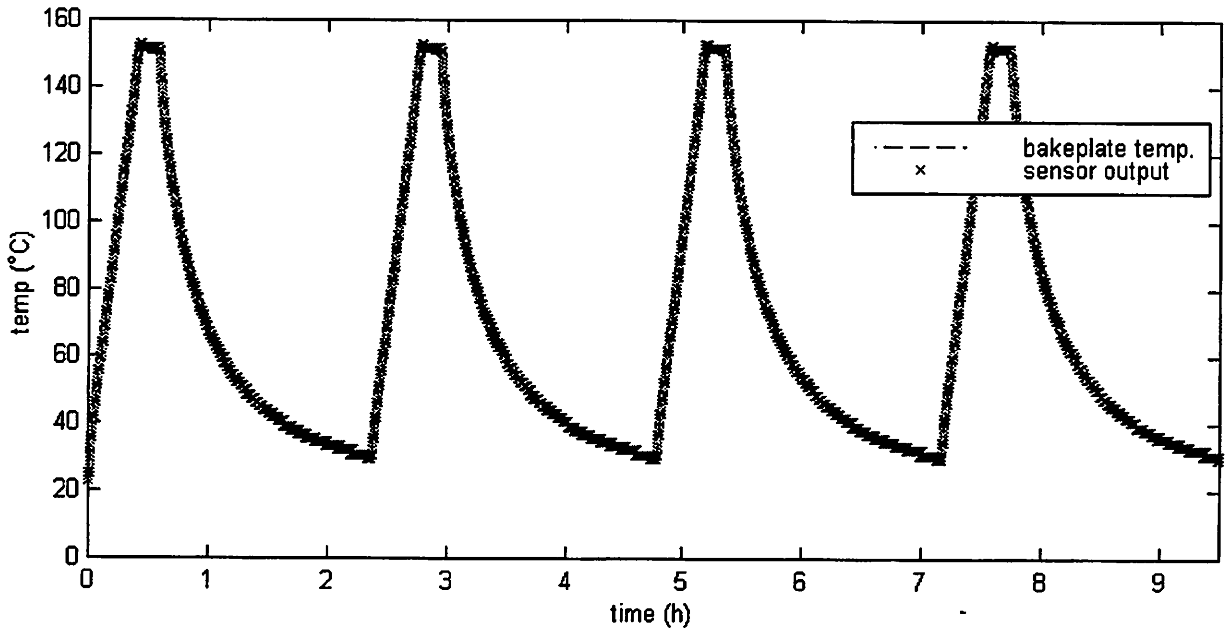

Figure 3. Output of a temperature sensor during a tethered repeatability test.

The operational life of the wafer using battery power was determined with an untethered repeatability test up to 120 °C. With the batteries fully charged to 6.0-V before starting the test, they were able to last just over 11 hours, as shown in the plot of battery voltage versus time in Figure 4. The only noticeable effect that high temperatures had on the batteries was to increase their voltage, which can be also be seen Figure 4. Furthermore, as the battery voltage degraded, there was no significant change in sensor output, which can be seen in the plot of sensor output (Figure 5) from the same test.

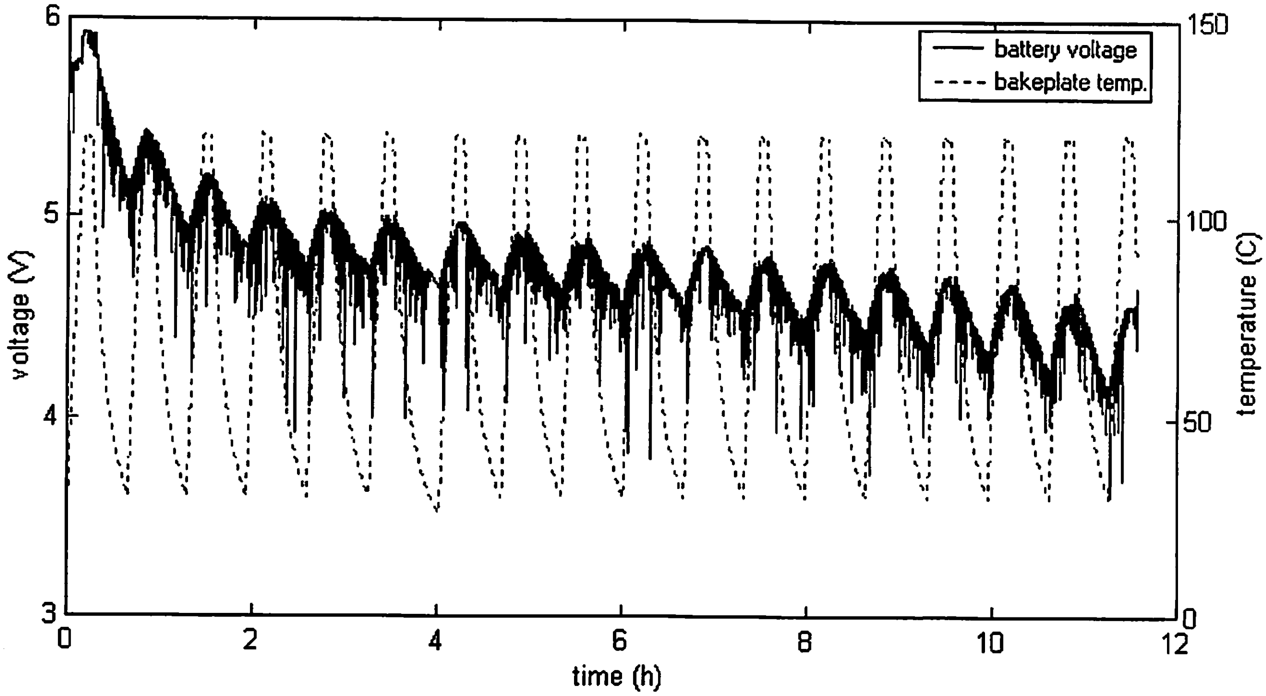

Figure 4. The battery voltage and bake plate temperature plotted versus time during an untethered repeatability test.

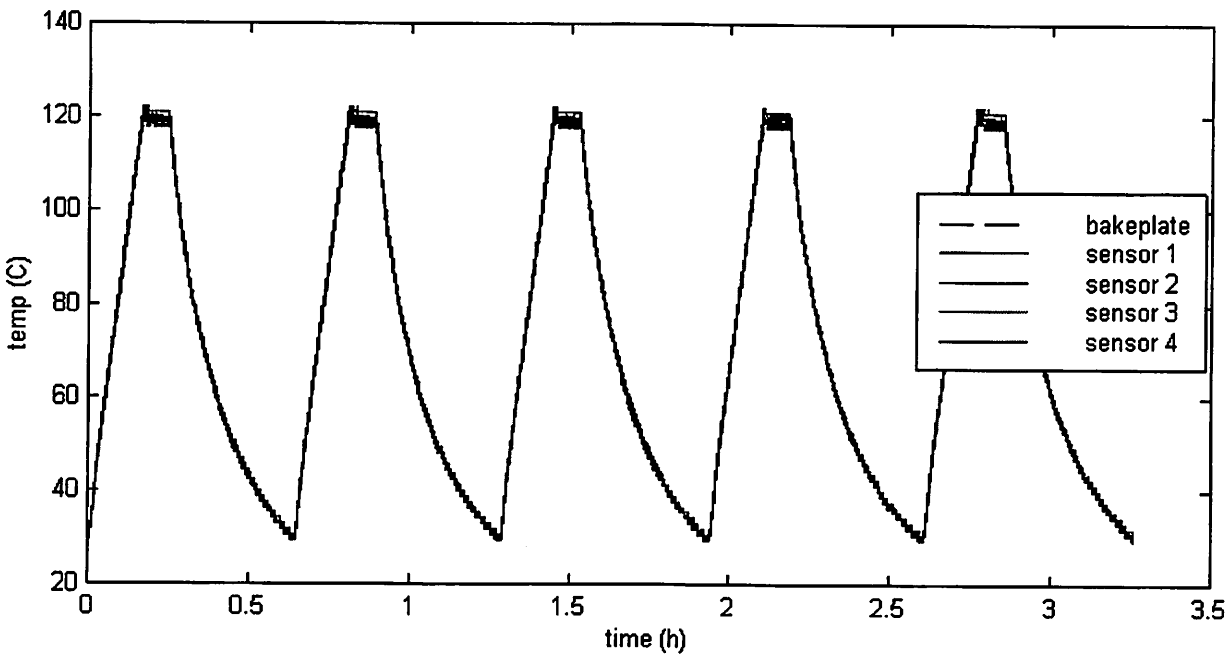

Figure 5. Output of each of the four temperature sensors during an untethered repeatability test.

Lastly, the temperature sensor wafer was tested on the SVG Developer Track in the Microlab to examine the transient response of the sensors. From the results shown below in Figure 6, the sensors had a uniform settling time of approximately 2 seconds for heating; however, upon cooling there was variation among the settling times of the four sensors. This was most likely due to the arrangement of the sensors and the fact that the sensors did not make contact with the cooling plate at the same time, as they did with the bake plate. Furthermore, the thermal mass of the wafer was not evenly distributed, which might have caused such nonuniform cooling.

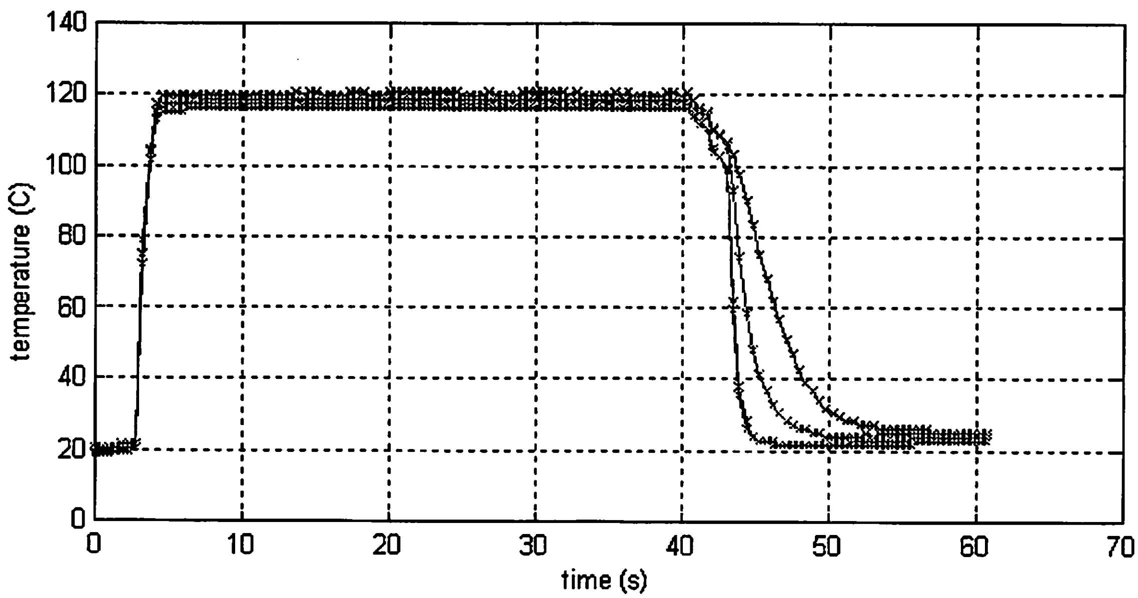

Figure 6. Output of each of the four temperature sensors during an untethered test on an SVG Developer Track.

Conclusions and Recommendations

From the results of these tests, the temperature sensor wafer has met the following objectives:

1. The measurements with the sensors are repeatable.
2. The wafer can operate autonomously for an extended period of time, without change in the quality of the results at temperatures up to 120 °C.
3. The transient response of the sensors is relatively fast, on the order of a few seconds.

As this is an on-going project, future tests should focus on the integration of new components, such as thin-film batteries and flip-chip components, and the adequacy of isolation for use in plasma.