Monitoring of Environmental Parameters in Nanoelectronic Fabrication

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***Abstract*—Nanoelectronics are the essential hardware enabler for electronic product and service innovation in key growth markets for global industry, such as telecommunications, transportation and medical technology. dust particles, humidity , temperature parameters have big effect for the fabrication area due to the newest technologies that are usually very complex and very sensitive to the external influences. Dust is one of the major problems of the top-down lithographic approaches is that they require very clean environments because dust and particulates can mask part of the exposed area. For high yields and hence low costs, clean rooms must have particulate densities extremely low and at sizes much smaller than the lithographic minimum feature size. In this context, this paper presents a data acquisition system that is capable to monitor and measure three types of environmental parameters: dust, temperature, and humidity. The remote board containing sensors and processing circuits is connected to the server through wireless network. The analogue to digital conversion is realized by data acquisition card (MDA300). The systems can operate for monitoring and control. The sensors communicate wirelessly with selectable sensors via three wireless smart sensors: temperature, dust sensor and humidity sensor. The software control and the acquired data processing are realized with a MOTEVIEW application that is capable to simultaneously display the measured data. This paper introduces a prototype for an affordable wireless sensors network for monitoring air quality. It can work in two modes: online and offline. In online mode, the sensors periodically send the readings to the base station. In offline mode, the sensors store the readings periodically to the internal memory and these readings can be collected whenever they are needed. With minimal changes, the proposed system can be extended to operate with more types of sensors. Using a wireless transmission method between PC and remote board, the operation distance of the system can be further extended. We obtained encouraging results regarding the accuracy of the optical measurements from dust sensors connected in the wireless network**

Keywords-dust sensors; temperature and humidity sensors; wireless network sensors; Mote-VIEW software

I. INTRODUCTION

In order to monitor and control dust, humidity and temperature in the fabrication processes of electronic components and modules has gained an increasing importance due to the complexity and sensitivity of the new technologies to the influences generated by ambient humidity, dust particles, temperature, radiation levels, pressure, etc.

Due to these facts, when we refer to IC (Integrated Circuits) fabrication technologies for example, where nanotechnologies are currently in use, the control of environmental conditions has become mandatory. Also, in the case of printed circuit boards (PCB) an exposure to humid ambient conditions for example will cause the absorption of moisture that can greatly affect the proper operation of the equipment that contains the respective module. The corrosion on metallic parts of an electronic assembly is another problem generated by the humidity, especially in the fabrication stage This paper presents a data acquisition system with Mote-VIEW software can show the result of measurement parameters and the chart view of the network to monitor the most of important parameters that characterize the environment for PCB fabrication: humidity, dust, temperature. The related work is a data acquisition system that is capable to monitor and measure some environmental parameters like: pressure, temperature and humidity, based on Labview software without using wireless sensor network .The presented system is a scalable industrial quality monitoring system for clean rooms and can be also used as a component of a more complex equipment intended for testing and reliability evaluation of electronic modules in different environmental conditions.

The environmental effects of dust in nanoelectronic fabrication will be described in the 2nd section of this paper, following in the 3rd section with the presentation of a wireless sensor system proposed for the measurement and monitor of the dust, humidity, temperature in a fabrication clean room. In the 4th section we describe the monitoring software designed in Mote-view for the hardware system, followed by the final chapter with the conclusions.

II. ENVIROMENT EFFECTS

Nanoelectronic fabrication technologies originate from the microelectronics industry, and the devices are usually made on silicon wafers even though glass, plastics and many other substrates are in use, microelectronics extension into nanoscale (for example NEMS, for nano electro mechanical systems) have re-used, adapted or extended micro fabrication methods. Micro fabrication is known as "semiconductor manufacturing" or "semiconductor device fabrication is actually a collection of technologies which are utilized in making microdevices [1]. Micro fabrication is carried out in clean rooms, where air has been filtered of particle contamination and temperature, humidity, vibrations and electrical disturbances are under stringent control.

Smoke, dust, bacteria and cells are micrometers in size, and their presence will destroy the functionality of a micro fabricated device. Wafer cleaning and surface preparation work a little bit like the machines in a bowling alley: first they remove all unwanted bits and pieces, and then they reconstruct the desired pattern so that the game can go on [2].

Moisture can accelerate various failure mechanisms in printed circuit board assemblies. Moisture can be initially present in the epoxy glass prepare , absorbed during the wet processes in printed circuit board manufacturing, or diffuse into the printed circuit board during storage. Moisture can reside in the resin, resin/glass interfaces, and micro-cracks or voids due to defects [3].

Higher reflow temperatures associated with lead-free processing increase the vapor pressure, which can lead to higher amounts of moisture uptake compared to eutectic tin-lead reflow processes. The processing of silicon wafers to produce integrated circuits (IC) involves specific chemistry and physics to build up a succession of layers of materials and geometries to produce thousands of electronic devices at very small dimensions. The conditions under which these processes can work to successfully to transform the silicon into ICs require the absence of contaminants (dust, humidity, unwanted chemical elements etc.). Thus, the process chambers normally operate under vacuum, with elemental, molecular, and other particulate contaminants rigorously controlled. The ideas presented in the above sections support the necessity of measurement and monitoring systems for environmental conditions in fabrication areas [5].

III. SYSTEM ARCHITECTURE

To measure and monitor the dust, humidity, temperature values in a fabrication clean room, we propose the distribution of several nodes, from N_1 to N_n. Each node is a smart sensor operating in a Plug-and-Play mode and each node communicates to a server, over a wireless network by using the IEEE 1451.5-802.11 standard [4].

This standard will enable sensors and devices to communicate wirelessly, eliminating the monetary and time costs of installing cables at acquisition points. IEEE is currently working on three different standards, IEEE 802.15.4, Bluetooth and Zigbee.

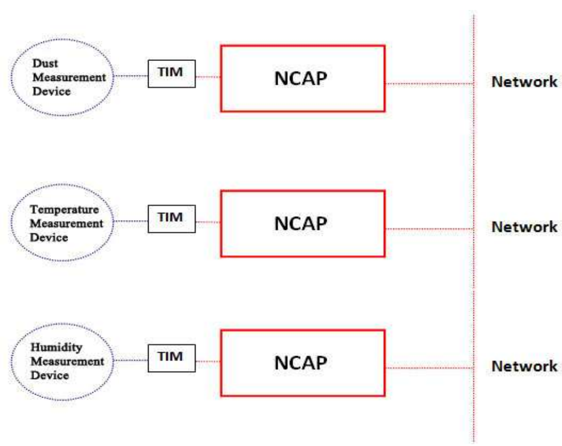

Figure 1. Dust, temperature, humidity smart sensors.

In the proposed implementation, 3 sensors are: Sharp GP2Y1010AU0F dust sensor that is based on the optical principle [6] and LM35 for temperature [11] and HIH 3605 for humidity level measurements [10] connected with MDA 300 data acquisition [12] from crossbow and these sensors communicate wirelessly to NI wireless sensor network (WSN) from National Instruments devices provide the same quality and accuracy as traditional wired measurement systems [14], but with increased flexibility, lower costs, and the ability to create smart WSN systems based on Mote-VIEW software [7].

Mote-VIEW is designed to be an interface ("client layer") between a user and a deployed network of wireless sensors. *Mote-VIEW* provides users the tools to simplify deployment and monitoring. It also makes it easy to connect to a database, to analyze, and to graph sensor. The humidity sensor (HIH 3605) consists of a polymer capacitive sensing element with on-chip integrated signal conditioning and a second polymer layer to protect against dirt. The humidity sensor has a linear voltage output with an accuracy of ±2% RH (relative humidity) and ±0.5% RH linearity. If the measurement is realized in slowly moving air at 25°C the response time of this sensor is of maximum 15s. The LM35 is calibrated directly in Celsius degrees and has an sensitivity of a 10.0 mV/°C and an 0.5°C accuracy over -55°C to +150°C range. This sensor was chosen because does not require any external calibration or trimming to provide its typical accuracy.

Figure 1 shows the implementation of a Wireless Sensor Network (WSN) based on IEEE 802.15.4, Zigbee and communicate wirelessly with the sensor NI WSN-3202 for the 3 sensors through MDA300 data acquisition system. These wireless sensors communicate with the memsic wireless base station from Crossbow, which is programmable with the Mote-VIEW Software, can communicate with NI wireless sensor network (WSN) devices. The network is scalable up to many WSN nodes (in a mesh topology); having also the features of dual Ethernet ports to provide flexible connectivity to other devices in your measurement system, such as enterprise-level networks or wired I/O systems. With this flexibility, we can configure this network according our application to monitoring and measurement of environmental parameters which effected in the fabrication of semiconductor industries to prevent and malfunction and to increase the yield of the production.

Each node connects with a smart sensor, namely: a dust detection device or temperature or humidity, transducer interface model (TIM) and Network Capable Application processor (NCAP), as shown in Figure 1.

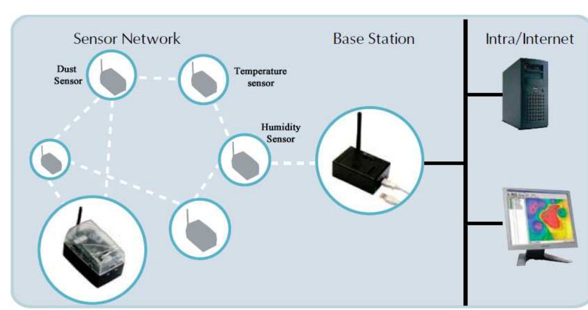

Figure 2. Environmental monitoring network.

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The server acquires the monitoring information from the distributed network of smart sensors and processes this data via specialized software. Based on the user configured thresholds, the server will either take no action, but to record the data for statistic purposes, or send a signal to other devices for specific tasks, such as air trap shutdown or activating air recirculation systems, in case the configured thresholds have been surpassed to a critical level. This depends on the specific application for which the dust detection sensor or humidity or temperature network is used.

The network consists from 3 nodes via data acquisition MDA300 with NI WSN-3202 for dust, temperature and humidity. Figure 3, depicts the practical picture of the NI WSN 3202 and MDA 300.

Figure 3. Real-life pictures of used equipment.

The NI WSN-3202 measurement node is a wireless device that provides four ±10 V analog input channels and four bidirectional digital channels that we configured on a per-channel basis for input, sinking output, or sourcing output. The 18-position screw-terminal connector delivers direct connectivity to sensors and offers a 12 V, 20 mA sensor power output that use to drive sensors that require external power. The power for the measurement node is similar to NI WSN - 3226 (four 1.5 V, AA alkaline battery cell).

A 2.4 GHz radio wirelessly transmits data to the WSN gateway, where you can connect through Ethernet to other network devices. NI-WSN software delivers easy network configuration in NI Measurement & Automation Explorer (MAX) and data extraction with NI Mote-VIEW software. The nonprogrammable WSN-3202 does not include a license to target and program the node with the Mote-VIEW Wireless Sensor Network (WSN) Module Pioneer.

IV. Monitoring Application of the Wireless Sensor Network

The network of wireless sensors in Figure 2 is made out of wireless sensors network (WSN) based on IEEE 802.15.4. Zigbee and the acquired of data from the sensors are periodically read with a selectable multiplexing according NI Mote-VIEW software. The performance of the proposed measurement and monitoring systems depends mainly on the sensors that are used to acquire the environmental data. The resolution and conversion time of the (MDA300 data acquisition board) analog to digital converter that was used in the application is sufficient for the proposed application and can be expendable for using with many sensors. The Topology view shows a map of the network of Motes, including placement and parenting information. This allows the user to define and view a topology of their Mote deployment.

The front panel of the application used for monitoring and measurement of environmental parameters is presented in Figure 4. As it can be observed, each signal from the sensor is displayed. The application allows the user to set the variation limits for every channel.

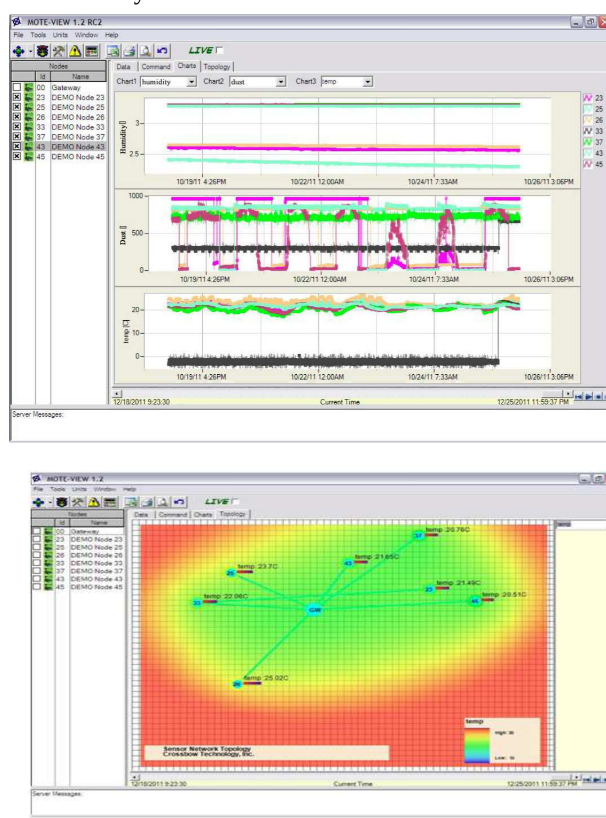

Figure. 4 The interface of the application used to display the acquired data from sensors

The experimental results were obtained by using several types of dust: sand dust with high granularity, plaster dust and smoking ash. Another dust detector has been used as a reference, based on the gravimetric principle “D-RC80 Automatic sampling device for Gravimetric Dust measurements”, used as reference measuring system. The output of the sensor is sent through the MDA300 based on Mote_view software to the server.

For the smoking ash, we obtained a fluctuation in the results, as shown in Figure 5, with a solid average, which was within the values obtained by using the dust detector with the gravimetric principle.

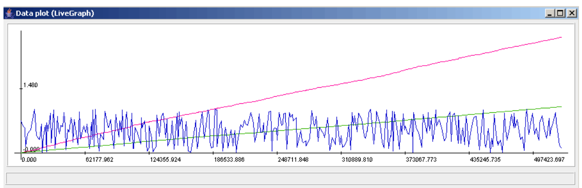

Figure.5 Graph of smoking ash measurements.

The experimental results depicted in Table I are encouraging regarding the accuracy of the optical measurement, compared to the ones made with a gravimetric device. The mean values were calculated based on 20 measurements.

TABLE I. MEAN EXPERIMENT RESULTS

Type of dust	Mean measurement with our setup	Gravimetric measurement
Sand	3.0 mg/s	3.4 mg/s
Plaster	2.9 mg/s	3.9 mg/s
Smoking Ash	1.43 mg/s	1 mg/s

We also conducted tests with other two sensors for humidity and temperature, that were sending data simultaneously to the server and we obtained satisfactory average results, having the humidity around point 27% and the temperature around 22Cº.

Based on the user configured thresholds, the server will either take no action, but to record the data for statistic purposes, or send a signal to other devices for specific tasks, such as air trap shutdown or activating air recirculation systems, in case the configured thresholds have been surpassed to a critical level. This depends on the specific application for which sensor network is used.

V. CONCLUSIONS AND FUTURE WORKS

Environmental parameters (humidity, dust, temperature, etc.) have significant effects on electronic fabrication and especially nanoelectronic industries modules and circuits, those been necessary to be continuous monitored and measured, especially in industrial areas. Each parameter sensing device can focus on a specific area and by managed as a single entity or in turn it can be used as only one point of presence in an area, contributing to the overall accuracy of the measurement. The human interaction will be greatly reduced by using such a network. Also, compared to human observation, the introduction of a smart sensor network is more flexible when it comes to dangerous and hostile environments where humans can’t penetrate, allowing access to information previously unavailable from such close proximity. Future work aims at improving the performance and durability of smart sensors networks and to prove them as a versatile application. We also aim to increase the ability of the dust sensors to make discrimination regarding the type of dust and based on this to configure the system’s threshold value in order to make a decision according to the settings and applications.

Sensor scheduling can be obtained by enabling the sensor nodes to modify communication requirements in response to network conditions and events detected.

From the experience of already existing devices, we can expect that in the coming decade a large number of monitoring systems for all physical phenomena will emerge, with great application in the human health sector, industrial sector and the environment. The monitoring system gives excellent opportunities to design and configure many types of sensors to monitor and control all physical phenomena for many applications based on people demands.

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